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Textbook of ORTHODONTICS

SECOND EDITION

Editor
Gurkeerat Singh



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Textbook of Orthodontics

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Second Edition

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Published by

Jitendar P Vij
Jaypee Brothers Medical Publishers (P) Ltd
B-3 EMCA House, 23/23B Ansari Road, Daryaganj
New Delhi 110 002, India
Phones: +91-11-23272143, +91-11-23272703, +91-11-23282021, +91-11-23245672,
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Textbook of Orthodontics

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First Edition: 2004
Second Edition: **2007**

ISBN 81-8448-080-6

Typeset at JPBMP typesetting unit
Printed at Ajanta Offset & Packagings Ltd., New Delhi

To

My Parents

and

My Teacher

Dr V Surendra Shetty

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Preface to the Second Edition

The *Textbook of Orthodontics* was written with the purpose— "to let the dentist be able to diagnose an orthodontic problem as and when a patient presents himself/herself and to be able to guide the patient if and when orthodontic intervention is required". The resounding sale of the textbook and the response from our readers was not only encouraging but also a motivation by itself. Hence, the second edition.

We are grateful to the senior faculty in the field of orthodontics who took time to go through the contents of the book in detail and guide us further in our endeavor to make orthodontic education comprehensive at the undergraduate level. The lacunae were highlighted and all attempts have been made to overcome these.

There have been considerable advances in computerized diagnostics and orthodontic implants in the past couple of years. The concerned chapters have been revised and suitably illustrated to make the comprehension of the contents easy. Each chapter now has a list of books and/or articles which are recommended for further reading and shall be able to provide more information to the students. The quality of the figures and photographs has been improved and some more photograph have been added to illustrate the contents further.

The textbook has been provided with a code which will enable its readers to access the photographs and related multiple choice questions on the web. Also, this password would enable the students to get updates on certain topics before they are incorporated in the forthcoming editions. This is of course a first for any Indian textbook.

I am again grateful to the contributors who have taken the time out from their busy schedules to update the concerned chapters. My heartfelt thanks to my colleagues and friends who have read and reread the chapters and contributed by way of suggestions and corrections to make this textbook as error free as humanly possible. Last but not the least, the family at Jaypee Brothers Medical Publishers deserves full marks for their tireless efforts to make the book take its present form.

We look forward to suggestions and positive criticism for the further improvement in the contents of the textbook.

Gurkeerat Singh
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Preface to the First Edition

The science and art of orthodontics has undergone a huge transformation in the past ten years; and unfortunately for the students of this wonderful field, we, the teachers, have not managed to provide them with any single book which imparts to them the complete curriculum for their knowledge and comprehension. Also, with the mushrooming of dental colleges in our country, there has been a degradation in the information provided on this already neglected subject. At times, we find that dental students who graduate consider the subject only from a theoretical standpoint and not with the prospect of using their knowledge clinically.

The book has been written with only one motive, and that is, to let a dentist be able to diagnose an orthodontic problem as and when a patient presents himself/herself. By studying this textbook, the dentist will not become an orthodontist but will definitely be able to guide the patient if and when orthodontic intervention is required. He will also be able to communicate with an orthodontist in the technical terms that we are so used to hearing.

Emphasis has been given to understanding orthodontic problems and not being just able to answer questions in an exam. The answers to the most frequently asked questions are all there, but it is expected that the student will first understand the concepts and then reproduce these answers in his or her own words. Keeping that in mind, the book has been extensively illustrated with more than 2500 photographs and diagrams. The text has been kept simple and alongwith the illustrations will help the student to grasp the meaning better. For the first time, orthodontic materials and their uses including their sterilization have been discussed.

The book is the cumulative effort of the extensive work done over the past seven years. Compiling and condensing the data and producing the matter in a book form has taken nearly two years. I wish to acknowledge the help provided by the contributors, without whom this textbook would never have materialized. Special thanks to Dr Akhtar Hussain, who has designed the front cover at an extremely short notice.

I sincerely hope that the book fills the lacuna that was being felt at the undergraduate level of education and would also help the postgraduate students to use it as a quick reference guide.

Gurkeerat Singh

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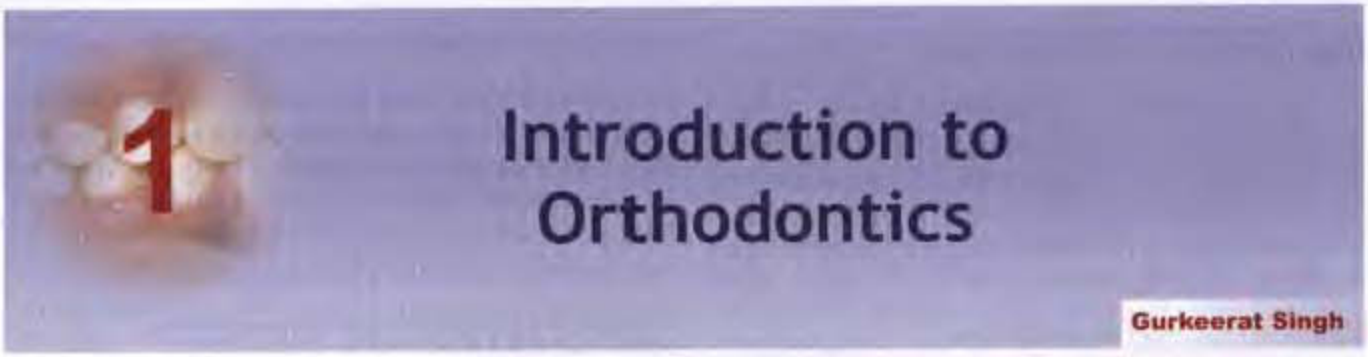
Section One

NORMAL GROWTH

1. Introduction to Orthodontics
2. Basic Principles of Growth
3. Prenatal Growth of Cranium, Facial and Oral Structures
4. Postnatal Growth of the Craniofacial Complex
5. Development of Dentition
6. Occlusion in Orthodontics

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1 Introduction to Orthodontics

Gurkeerat Singh

- What is orthodontics?
- Branches of orthodontics
- Aims of orthodontic treatment
- Scope of orthodontics
- History of orthodontics

WHAT IS ORTHODONTICS?

What does the common man associate with the term orthodontics? It is a special branch of dentistry which deals with the alignment of teeth. What people perceive of this branch of dentistry is what we as dentists project of the capabilities of an orthodontist.

Orthodontics has been defined by Salzmann (1943) as *'a branch of science and art of dentistry which deals with the developmental and positional anomalies of the teeth and the jaws as they affect oral health and the physical, esthetic and mental well being of the person.'* This definition may be over fifty years old yet even at that time the potential of orthodontics was not lost. The emphasis is on maintenance of oral, physical and mental health of the patient and also his/her esthetics.

Yet, this was not the first definition proposed. Definitions proposed earlier had also recognized the importance of the knowledge of growth and the essentiality of correcting aberrations as early as possible. In 1911, Noyes defined orthodontics as *"the study of the relation of the teeth to the development of the face, and the correction of arrested and perverted development."*

This definition was further modified when in 1922 the British Society of Orthodontists proposed that *"Orthodontics includes the study of growth and development of the jaws and face particularly, and the body generally, as influencing the position of the teeth; the study of action and reaction of internal and external influences on the development, and the prevention and correction of arrested and perverted development."*

The definitions now recognise the importance of growth but also associate it with etiology and the purpose of orthodontics—to create and maintain a normal environment and proper physiologic activity of the teeth, the soft oral tissues, the facial and masticatory musculature, in order to ensure as far as possible optimum dentofacial development and function. The use of the word prevention before correction symbolizes the need to diagnose a problem as soon as possible.

The definition of orthodontics proposed by the American Board of Orthodontics (ABO) and later adopted by the American Association of Orthodontists states:

*"**Orthodontics** is that specific area of the dental profession that has as its responsibility the study and supervision of the growth and dev elopment of the dentition and its related anatomical structures from birth to dental maturity, including all preventive and corrective procedures of dental irregularities requiring the repositioning of teeth by functional and mechanical means to establish normal occlusion and pleasing facial contours."*

The American Board of Orthodontics' definition recognizes the capability of the orthodontists in being able to change the profile by not only moving teeth but also by redirecting growth using functional appliances. Hence, we see that the science has evolved over the years and its scope has been increasing along with our increased knowledge of the underlying biological principles of growth and development.

BRANCHES OF ORTHODONTICS

The art and science of orthodontics can be divided into three categories based on the nature and time of intervention.

- Preventive orthodontics
- Interceptive orthodontics
- Corrective orthodontics.

PREVENTIVE ORTHODONTICS

Preventive orthodontics, as the name implies, is action taken to preserve the integrity of what appears to be the normal occlusion at a specific time. Preventive orthodontics requires the ability to appraise normal dentofacial and general development and growth and the recognition of deviations from the normal. It entails the elimination of deleterious local habits involving dentofacial structures; the correction of general contributory causes, such as incorrect posture and malnutrition; the maintenance of tooth form by proper restoration of individual teeth; timely removal of retained deciduous teeth; use of space maintainers after premature loss of deciduous teeth, if indicated, and reference for treatment of related affections and abnormalities to other specialists.

INTERCEPTIVE ORTHODONTICS

According to the definition given in the brochure on orthodontics by the American Association of Orthodontists, Council of Orthodontic Education, is *"that phase of the science and art of orthodontics, employed to recognize and eliminate potential irregularities and malpositions in the developing dentofacial complex"*. This phase specifically concentrates on its efforts towards improving environmental conditions to permit future normal development. The preventive measures envisaged may include caries control, anatomical dental restorations, space maintenance, transitory oral habit correction, genetic and congenital anomalies, and supervising the exfoliation of deciduous teeth.

Certain procedures under the preventive and interceptive orthodontic fields may overlap. Hence, at times it may not be possible to segregate the two, however, interception always recognizes the existence of a malocclusion or malformation whereas the prevention is aimed at preventing the malocclusion or malformation from occurring.

CORRECTIVE ORTHODONTICS

Corrective orthodontics, like interceptive orthodontics, recognizes the existence of a malocclusion and the need for employing certain technical procedures to reduce or eliminate the problem and the attendant sequelae. The procedures employed in correction may be mechanical, functional or surgical in nature.

AIMS OF ORTHODONTIC TREATMENT

The treatment provided should not only satisfy the patient's esthetic desires but also satisfy certain functional and physiologic requirements. Jackson had summarized the aims of orthodontic treatment as:

- Functional efficiency
- Structural balance
- Esthetic harmony

These three are now famous as the **Jackson's triad**.

FUNCTIONAL EFFICIENCY

The teeth along with their surrounding structures are required to perform certain important functions. The orthodontic treatment should increase the efficiency of the functions performed by the stomatognathic system.

STRUCTURAL BALANCE

The structures affected by the orthodontic treatment include, not only the teeth but also the surrounding soft tissue envelop and the associated skeletal structures. The treatment should maintain a balance between these structures, and the correction of one should not be detrimental to the health of another.

ESTHETIC HARMONY

The orthodontic treatment should increase the overall esthetic appeal of the individual. This might just require the alignment of certain teeth or the forward movement of the complete jaw including its basal bone. The aim is to get results which gel with the patient's personality and make him/her to look more esthetic.

SCOPE OF ORTHODONTICS

Orthodontic treatment is aimed at moving teeth, orthopedic change and altering the soft tissue envelop.

MOVING TEETH

The main reason for the existence of this specialty was it's capability of moving teeth. Moving teeth without any deleterious effects into more ideal locations is what everyone always associates this field with. How efficiently this can be undertaken and to what extent, depends upon the nature of the malocclusion and the capability of each individual clinician.

ORTHOPEDIC CHANGE

Using functional appliances and the latest orthognathic techniques, it is possible to move entire jaws into more favorable positions. It is very much within the capabilities of an orthodontist to use appliances at times in conjunction with other specialists to move the entire jaws along with its basal bone and the soft tissue envelop to achieve the objectives of treatment.

ALTERING THE SOFT TISSUE ENVELOP

The functions performed by the soft tissue envelop of the teeth and the oral cavity have a definite impact on the growth and development of the oral and facial structures. The orthodontist can help retain or restrain the soft tissues and or bring about a change in them by altering the position of the teeth or the jaws. The various functional appliances and at times habit breaking appliances may be used along with other treatment procedures.

HISTORY OF ORTHODONTICS

Hippocrates (460-377 BC) was the first to draw attention towards the association of teeth to jaw structures. In his writings are the lines "Among those individuals whose heads are long shaped, some have thick necks, strong members and bones, others have strongly arched palates, thus teeth are disposed to irregularity, crowding one on the other and they are molested by headaches and otorrhea."

The first recorded method of treatment was that of Celsius (125 BC-AD 50). He recommended that—"If a second tooth should happen to grow in children before the first has fallen out, that which ought to be shed is to be drawn out."

The first mechanical treatment for correcting irregularities was suggested by Gaius Plinius Secundus (Pliny) (AD 23-79). He advocated the filing of elongated teeth to produce proper alignment.

Paul of Aegina (AD 625-690) was the first to mention supernumerary teeth.

Piette Dionis (1658-1718) was the first to mention "separators for the teeth,—to open or widen the teeth when they are set too close together." He also, commented on the etiology of dental irregularity.

Matthacus Gottfried Purmana, in 1692 was the first to mention casts in dentistry. He used wax, as the impression material.

Plaster of paris for impressions were first reported in 1756, by Phillip Pfall.

Kneisel, in 1836, published the first book (in German) on malocclusion of the teeth. It was entitled, Der Schiefstand der Zahne. Kneisel attempted the first classification of malocclusion and was the first to advocate the use of removable appliances. He also introduced the modern impression tray.

Pierre Fauchard was the first to use the title "surgeon-dentist."

Fauchard (1728) gave to the orthodontics the "bandelete" later known as the "expansion arch."

In 1743 Bunon first used the term orthopedics in connection with the correction of malocclusion.

John Hunter (1728-1793) wrote at length about irregularities of teeth and their correction in his book—natural history of human teeth (1771 and 1778).

Joseph Fox wrote two books (1803 and 1806) in which he gave explicit directions for the correction of malocclusions.

In 1825, Joseph Sigmond recognized habit as a factor in malocclusion.

Thumbsucking as a cause of dental abnormalities was first mentioned by William Imrie in 1834.

Term *orthodontia* was used originally by Lefoulon in 1839. According to Lischer, the term orthodontics was first used by Sir James Murray. The term orthodontics was formally defined by Schelling in 1909.

In 1841, JMA Sehange of France contributed articles on orthodontics. He described a clamp band in which a screw was employed for tightening the band to the tooth.

In 1859, Norman William Kingsley presented the first obturator to a cleft palate patient.

The first outstanding work devoted exclusively to orthodontics was written by John Nutting Farrar (1839-1913) aptly titled—*'Treatise on Irregularities of the Teeth*

and their Correction.'

In 1887 EH Angle presented his classification of malocclusion.

In 1900, Edward H Angle started his first school of orthodontics in St. Luise. He developed the "E" arch, the pin and tube appliance, the ribbon arch appliance and the edge-wise appliance. He was a proponent of the non-extraction school of thought.

Calvin S Case in 1892 stressed the importance of root movement and was one of the first to use elastics for treatment. In 1917 he advocated the use of light resilient wires. He opposed the Angle school of universal applicability of the normal occlusion theory and advocated extractions as part of orthodontic treatment.

Martin Dewey (1914) wrote the book—'Practical Orthodontics'. He founded the International Journal of Orthodontics (now the American Journal of Orthodontics and Orthopedics).

In the 1930s Raymond Begg presented the Begg appliance (light wire differential force technique). It was a modification of the ribbon arch appliance, but used extremely light forces for treatment.

There were many more contributors to the field of orthodontics. And as the vast possibilities of this science are unfolding, they are still emerging. The basic difference is that the American school is continuing with the improvement in fixed appliances whereas the European school concentrated more on the removable and functional appliances. Now the world has become so small that contributors to this science are not restricted to regions and techniques. Although it is better to work within one's limit, one also learns from the experience of others.

FURTHER READING

1. Enlow DH, Hans MG. Essentials of Facial Growth, Philadelphia, 1996, Saunders.
2. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
3. Moyers RE. Handbook of Orthodontics, ed. 3, Chicago, 1973, Year Book.
4. Salzmann JA. Practice of Orthodontics, J B Lippincott Company, 1996.
5. White TC, Gardiner JH, Leighton BC. Orthodontics for Dental Students, 3rd ed., Macmillan Press Ltd, 1976.
6. White TC, Gardiner JH, Leighton BC, Valiathan A. Orthodontics for Dental Students, 4th ed., Oxford University Press, Delhi, 1998.

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2 Basic Principles of Growth

Navjot Singh, Tapasya Juneja

- Introduction and definition
- Methods of studying physical growth
- Methods of collecting growth data
- Basic tenets of growth
- Rhythm and growth spurts
- Factors affecting physical growth
- Terminology related to growth
- Growth control
- Theories of skull growth control
- Architectural analysis of the skull

INTRODUCTION AND DEFINITION

The study of head form in man has always been of considerable interest to anthropologists, anatomists and other students of human growth. In fact, the wide array of students involved in solving the complex phenomenon of growth have been aptly described by Krogman as early as 1943 in these golden words; *"Growth was conceived by an anatomist, born to a biologist, delivered by a physician, left on a chemist's doorstep, and adopted by a physiologist. At an early age—she eloped with a statistician, divorced him for a psychologist, and is now being wooed, alternately and concurrently, by an endocrinologist, a pediatrician, a physical anthropologist, an educationalist, a biochemist, a physicist, a mathematician, an orthodontist, an eugenicist and the children's bureau!"*

As orthodontists we are interested in understanding how the face changes from its embryologic form through childhood, adolescence and adulthood. Of particular interests is an understanding of how and where the growth occurs, how much growth is remaining and in which direction and when the growth will express itself, what role the genetic and environmental factors play in influencing facial growth and in turn how we can influence these factors with our treatment to achieve the optimum results in each individual.

According to **Todd**: *'growth is an increase in size; development is progress towards maturity'*. But each process relies on the other and under the influence of morphogenetic pattern; the threefold process works its miracles; self-multiplication, differentiation, organization—each according to its own kind! A fourth dimension is time.

SOME DEFINITIONS RELATED TO GROWTH

As is the nature of growth, wherein the concepts keep changing with new research findings, there has been no single definition associated with it. Different researchers have defined growth in various ways—

- The self multiplication of living substance—**JX Huxley**.
- Increase in size, change in proportion and progressive complexity—**Krogman**.
- Entire series of sequential anatomic and physiological changes taking place from the beginning of prenatal life to senility—**Meredith**.
- Quantitative aspect of biologic development per unit of time—**Moyers**.
- Change in any morphological parameter which is measurable—**Moss**.

SOME DEFINITIONS RELATED TO DEVELOPMENT

Development means progress towards maturity—**Todd** .

All the naturally occurring unidirectional changes in the life of an individual from its existence as a single cell to its elaboration as a multifunctional unit terminating in death—**Moyers**.

METHODS OF STUDYING PHYSICAL GROWTH

The data collection for the evaluation of physical growth is done in two ways:

1. *Measurement approach* It is based on the techniques for measuring living animals (including humans), with the implication that measurement itself will do no harm and that the animal will be available for additional measurements at another time.
2. *Experimental approach* This approach uses experiments in which growth is manipulated in some way. This implies that the subject will be available for some detailed study that may be destructive. For this reason, such experimental studies are restricted to non-human species.

MEASUREMENT APPROACHES

1. Craniometry
2. Anthropometry
3. Cephalometric radiography

Craniometry

Craniometry involves measurement of skulls found among human skeletal remains. It has the advantage that rather precise measurements can be made on dry skulls whereas the big disadvantage is that such a growth study can only be cross sectional.

Anthropometry

Anthropometry is a technique, which involves measuring skeletal dimensions on living individuals. Various landmarks established in the studies of dry skull are measured in living individuals by using soft tissue points overlying these bony landmarks. These measurements can be made on both dry skull as well as living individuals, although in the latter case the thickness of soft tissue will also need to be considered. Despite this shortcoming the most important advantage is that the study can be longitudinal, wherein the growth of an individual can be followed directly over a period of time with repeated measurement without damaging the subject.

Cephalometric Radiography

Cephalometric radiography is a technique that depends on precise placement of the individual in a cephalostat so that the head can be precisely oriented vis a vis the radiograph and precisely controlled magnification can be made. This technique combines the advantages of both craniometry and anthropometry in that direct bony measurements as seen on the radiograph can be made over a period of time for the same individual. However the disadvantage is that it produces a two dimensional representation of a three-dimensional structure making it impossible to make all the measurements.

EXPERIMENTAL APPROACHES

These include the following:

- Vital staining
- Autoradiography
- Radioisotopes
- Implant radiography

Vital Staining

Vital staining, introduced first by John Hunter in the eighteenth century. Here growth is studied by observing the pattern of stained mineralized tissues after the injection of dyes into the animal. These dyes remain in the bones and the teeth, and can be detected later after sacrificing the animal. Alizarin was found to be the active agent and is still used for vital staining studies. Such studies are however not possible in the humans. With the development of radio isotropic tracers, it is now possible to replace alizarin. The gamma emitting isotope ^{99m}Tc can be used to detect areas of rapid bone growth in humans but these images are more useful in diagnosis of localized growth problems than for studying growth patterns.

Autoradiography

Autoradiography is a technique in which a film emulsion is placed over a thin section of tissue containing radioactive isotope and then is exposed in the dark by radiation. After the film is developed, the location of radiation indicates where growth is occurring.

Radioisotopes

These elements when injected into tissues get incorporated in the developing bone and act as *in vivo* markers and can then be located by means of a Geiger counter, e.g. ^{99m}Tc, Ca-45 labeled component of protein, e.g. proline.

Implant Radiography

Implant radiography, used extensively by Bjork and co-workers, is one of the techniques that can also be used in human subjects. Herein, inert metal pins (generally made of titanium) are inserted anywhere in the bony skeleton including face and jaws. These pins are biocompatible. Superimposing radiographs (cephalograms in case of face) on the implants allow precise observation of both changes in the position of one bone relative to another and changes in external contour of the individual bone.

Other methods of studying growth include:

- *Natural markers*—nutrient canals, trabeculae, etc.
- *Comparative Anatomy*
- *Genetic Studies*

METHODS OF COLLECTING GROWTH DATA

The data gathered as by above means is then subjected to statistical analysis to arrive at a conclusion. The studies conducted thereof are of two types;

1. Longitudinal studies
2. Cross-sectional studies.

LONGITUDINAL STUDIES

Longitudinal studies involve gathering data of a given individual or subject over varying periods of time at regular intervals. This represents an example of a study on long-term basis. Although it has an advantage of studying the developmental pattern of the subject over a period of time giving a good insight into the variations involved, yet the major draw back is that it is very time consuming and runs the risk of loss of subject(s) due to that. Furthermore, it requires elaborate maintenance of records over time, making it an expensive proposition.

CROSS-SECTIONAL STUDIES

Cross-sectional studies on the other hand involve gathering data from different samples and are therefore faster. Also, it is less expensive with a possibility of studying larger samples, and can be repeated if required. However, it may not provide conclusive evidence because not all individuals grow in the same way. Also, such a study would obscure individual variations.

Types of Growth Data

1. Opinion
2. Observation
3. Ratings and rankings

Quantitative measurements: includes direct, indirect and derived data.

BASIC TENETS OF GROWTH—PATTERN, VARIABILITY, TIMING

The first important feature of growth corresponds to pattern.

Pattern in general terms indicates the proportionality of the given object in relation to its various sizes. However, in the concept of growth, it refers not only to the proportionality at a point of time but also to changes in this proportionality over a period of time. The fourth dimension "time" is of immense importance here. This can be clearly understood in the following illustration (Fig. 2.1), which depicts the change in overall body proportions over a period of time-from fetus to adulthood.

The figure illustrates the changes in overall body proportions that occurs during normal growth and development. In fetal life, at about the third month of intrauterine development, the head takes up almost 50 percent of the total body length. At this stage, the cranium is large relative to the face and represents more than half the total head. In contrast, the limbs are still rudimentary and the trunk is underdeveloped. By the time of birth, the trunk and limbs have grown faster than the head and face, so that the proportion of the entire body devoted to the head has decreased to about 30 percent. The overall pattern of growth thereafter follows this course, with a progressive reduction of the relative size of the head to about 12 percent in the adult.

All of these changes, which are a part of the normal growth pattern, reflect the *cephalocaudal gradient of growth* (Table 2.1). This simply means that "there is an axis of increased growth extending from the head toward the feet."

Another aspect of the normal growth pattern is that not all the tissue systems of the body grow at the same

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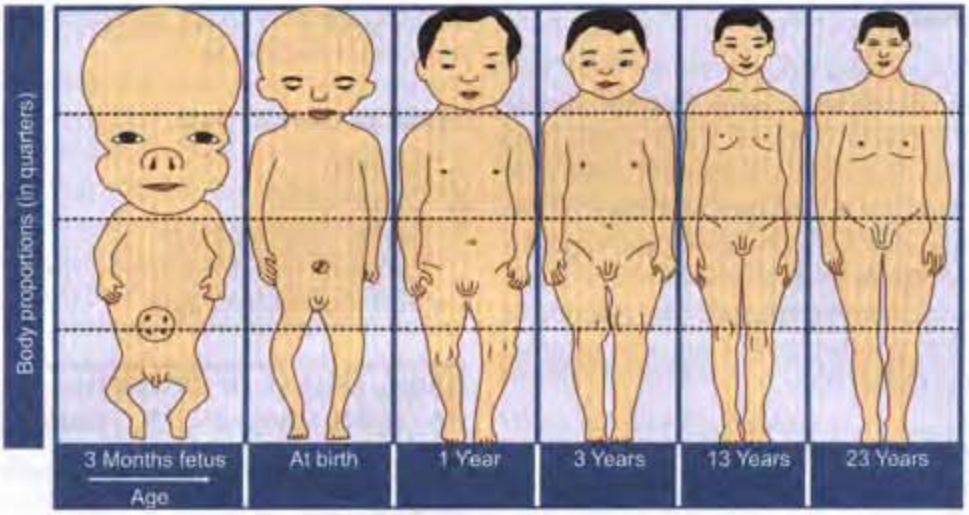


Fig. 2.1: Diagrammatic representation of the cephalocaudal gradient of growth

Table 2.1: Cephalocaudal gradient of growth

Cephalocaudal gradient of growth-Scammons: There is an axis of increased growth extending from head towards the feet
• In fetal life, about the third month of intrauterine development (IUD), head occupies 50 percent of the total body length and within the head the cranium is large relative to the face. The trunk and limbs are rudimentary
• *At birth:* head—39 percent of total body length Legs—1/3rd of total body length
• *In adults:* head—12 percent of total body length Legs— ½ of the total body length Therefore, with growth, trunk and limbs grow faster than the head and face

Table 2.2: Differential Growth (Scammon's Growth Curve)

Different tissues in the body grow at different times and different rates. Therefore, the amount of growth accomplished at a particular age is variable. Scammon divided the tissues in the body into:
a. Neural tissues b. Lymphoid tissues c. Somatic/general tissues (muscles, bone, viscera). d. Genital tissues
• Neural tissues complete 90 percent of their growth by 6 years and 96 percent by 10 years of age
• Lymphoid tissues reach 100 percent adult size by 7 years: proliferate far beyond the adult size in late childhood (200% by 14 years) and involute around the onset of puberty
• Somatic tissues show an S-shape curve with definite slowing of growth rate during childhood and acceleration at puberty going on till age 20
• Growth of the genital tissues accelerate rapidly around the onset of puberty

rate. After birth, the muscular and skeletal elements grow faster than the brain and central nervous system, as reflected in the relative decrease of head size.

The overall pattern of growth is a reflection of the growth of the various tissues making up the whole organism. Scammon has classically described the growth of various tissues (Table 2.2) in the following diagram (Fig. 2.2).

Patterns are repeated in skeletal proportions over time. A change in growth pattern would indicate an alteration in the expected and predictable sequence of changes in proportions expected for that individual.

The second important concept in the study of growth and development is *variability*. It indicates the degree of difference between two growing individuals in all four planes of space including the all-important time. Since every one is not alike in the way they grow, it is clinically very difficult to decide and decipher the deviation of growth pattern of an individual from the normal. One way to do this is to compare the growth of a given child relative to person on a standard growth chart (Fig. 2.3).

Although charts of such nature are commonly used for height and weight, the growth of any part of the body can also be plotted this way. Such charts help us in two ways.

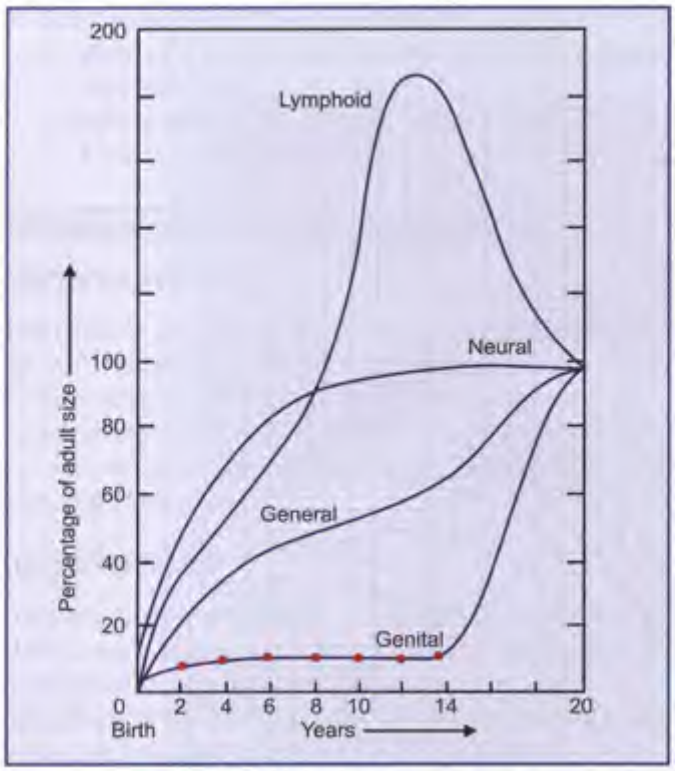


Fig. 2.2: Scammon's growth curve

1. To evaluate the present growth status of the individual, and
2. To follow the child's growth over a period of time using such charts.

Probably, the most important concept in the study of growth and development is that of timing. All the individuals do not grow at the same time or in other words possess a biologic clock that is set differently for all individuals. This can be most aptly demonstrated by the variation in timing of menarche (onset of menstruation) in girls. This also indicates the arrival of sexual maturity. Similarly, some children grow rapidly and mature early completing their growth quickly, thereby appearing on the high side of the developmental charts until their growth ceases and their peer group begins to catch up. Others grow and develop slowly and so appear to be behind even though in due course of time they might catch up or even overtake others.

RHYTHM AND GROWTH SPURTS

Human growth is not a steady and uniform process of accretion in which all body parts enlarge at the same rate and same increment per year. The rate of growth is most rapid at the beginning of cellular differentiation, increases until birth and decreases thereafter, e.g. in the prenatal period height increases 5000 times from stage of ovum to birth whereas in the postnatal period increase is only 3 fold. Similarly weight increases 6.5 billion fold from stage of ovum to birth whereas in the postnatal period increase is only 20 fold.

Postnatally growth does not occur in a steady manner. There are periods of sudden rapid increases, which are termed as growth spurts. Mainly 3 spurts are seen:

Name of spurt	*Female*	*Male*
1. Infantile/childhood growth spurt	3 yrs	3 yrs
2. Mixed dentition/ Juvenile growth spurt	6-7 yrs	7-9 yrs
3. Prepubertal/ adolescent growth spurt	11-12 yrs	14-15 yrs

CLINICAL SIGNIFICANCE OF THE GROWTH SPURTS

- To differentiate whether growth changes are normal or abnormal.
- Treatment of skeletal discrepancies (e.g. Class II) is more advantageous if carried out in the mixed dentition period, especially during the growth spurt.
- Pubertal growth spurt offers the best time for majority of cases in terms of predictability, treatment direction, management and treatment time.
- Orthognathic surgery should be carried out after growth ceases.
- Arch expansion is carried out during the maximum growth period.

FACTORS AFFECTING PHYSICAL GROWTH

The developmental ontogeny of the dentofacial complex is dependent primarily upon the following three elements:

1. *Genetic endowment* These include:
   a. Inherited genotype, like heredity
   b. Operation of genetic mechanisms, like race
2. *Environmental factors* These include
   a. Nutrition and biochemical interactions
   b. Physical phenomena like temperature, pressures, hydration, etc.

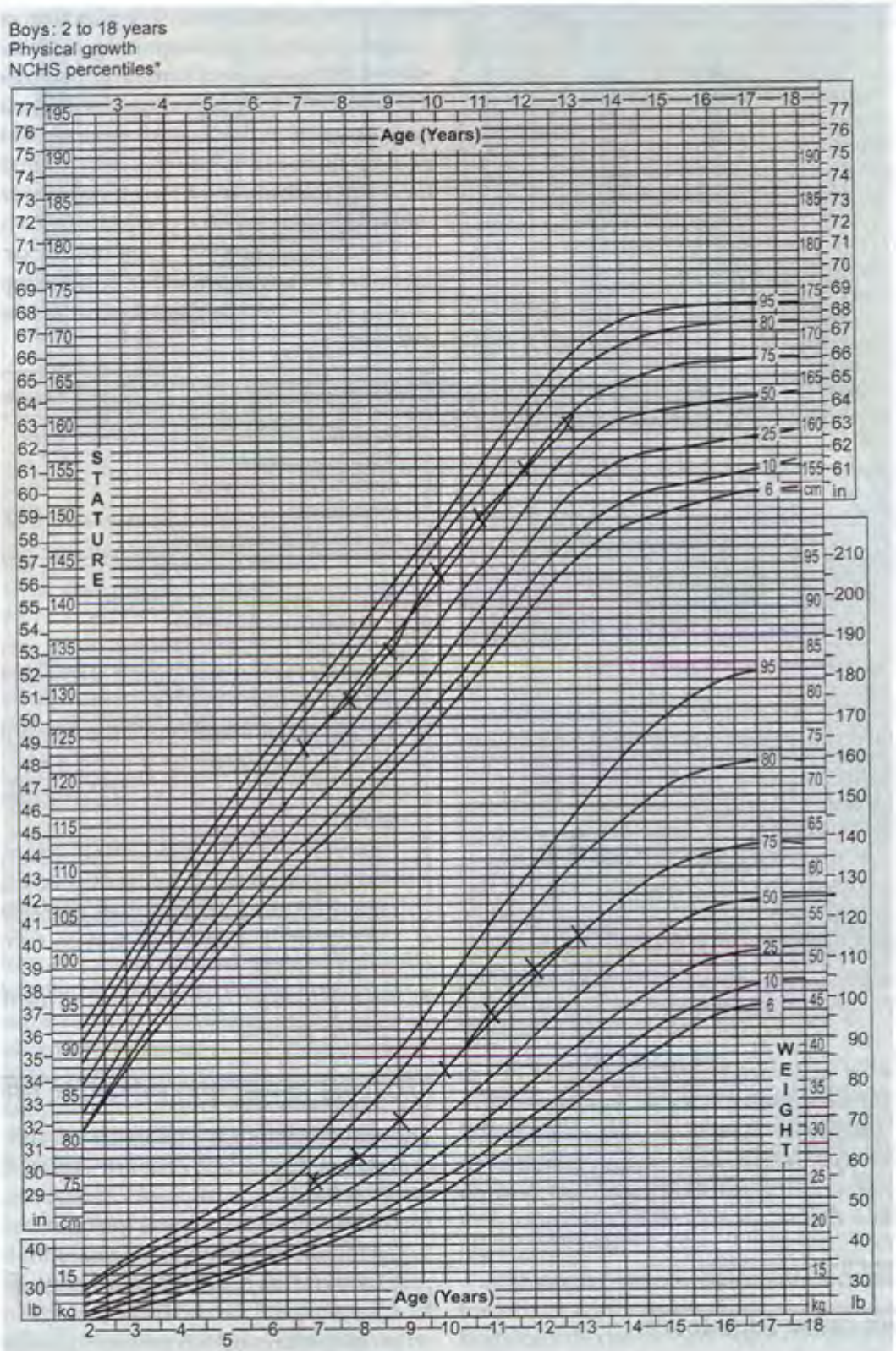


Fig. 2.3: Growth chart

3. *Functional forces* These include:
   a. Extrinsic and intrinsic forces of muscle actions, like exercise
   b. Space occupying organs and cavities
   c. Growth expansion

TERMINOLOGY RELATED TO GROWTH

GROWTH FIELDS

The outside and inside surfaces of bone are blanketed by soft tissues, cartilage or osteogenic membranes. Within this, blanket areas known as growth fields, which are spread all along the bone in a mosaic pattern, are responsible for producing an alteration in the growing bone.

GROWTH SITES

Growth sites are growth fields that have a special significance in the growth of a particular bone, e.g. mandibular condyle in the mandible, maxillary tuberosity in the maxilla. The growth sites may possess some intrinsic potential to grow (debatable).

GROWTH CENTERS

Growth centers are special growth sites, which control the overall growth of the bone, e.g. epiphyseal plates of long bones. These are supposed to have an intrinsic growth potential (unlike growth sites).

REMODELING

It is the differential growth activity involving deposition and resorption on the inner and outer surfaces of the bone, e.g. ramus moves posteriorly by a combination of resorption and deposition.

GROWTH MOVEMENTS

Growth movements are primarily of 2 types:

Cortical Drift

Cortical drift is a type of growth movement occurring towards the depository surface by a combination of resorption and deposition on the opposing surfaces simultaneously.

Displacement

Displacement is the movement of the whole bone as a unit. Two types are seen.

- *Primary displacement* Displacement of bone in conjunction with its own growth. It produces space within which the bones continue to grow.
- *Secondary displacement* Displacement of bone as a result of growth and enlargement of adjacent bone/bones.

CHARACTERISTICS OF BONE GROWTH

Bone formation occurs by two methods of differentiation of mesenchymal tissue that may be of mesodermal or ectomesenchymal (neural crest) origin. Accordingly two types of bone growth ossification are normally seen.

Intramembranous Ossification

Intramembranous ossification is the transformation of mesenchymal connective tissue, usually in membranous sheets, into osseous tissues.

Endochondral Ossification

Endochondral ossification is the conversion of hyaline cartilage prototype models into bone.

Endochondral bone is three dimensional in its growth pattern, ossifying from one or more deeply seated and slowly expanding centers. The interstitial growth or expansion capability of cartilage, even under pressure leading to its avascularity, precluding ischemia, (cartilage nutrition is provided by perfusing tissue fluids that are not easily obstructed by load pressures), allows for directed prototype cartilage growth. The cartilage ' template' is then replaced by endochondral bone, accounting for indirect bone growth.

Intramembranous bone growth, by contrast, is by direct apposition of osseous tissue in osteogenic (periosteal) membranes creating accretional growth, often with great speed, especially over rapidly growing areas, such as the frontal lobes of the brain, or at fracture sites.

Ossification commences at definable points in either membranes or cartilages, and from these centers of ossification the ossifying process radiates into the precursor membrane or cartilage. Secondary cartilages, not part of the cartilaginous primordium of the embryo, appear in certain membranous bone (mandible, clavicle) after intramembranous ossification begins. Endochondral ossification occurs later in these secondary cartilages of intramembranous

bone. The distinction between intramembranous and endochondral bone, while useful at the embryological level of osteogenesis, tends to become insignificant in the postnatal life.

MODES OF BONE GROWTH (Figs 2.4A to D)

At the cellular level, there are only three possibilities for growth.

Hypertrophy

This refers to the increase in size of individual cells.

Hyperplasia

This refers to increase in the number of cells.

Extracellular Material

This refers to the cells which secrete extracellular material, thus contributing to an increase in size independent of the number or size of the cells themselves.

In fact, all three processes occur in skeletal growth. Hyperplasia is a prominent feature of all forms of growth. Hypertrophy occurs in a number of special circumstances, but is relatively a less important mechanism. Although tissues throughout the body secrete extracellular material, this phenomenon is particularly important in the growth of the skeletal system where extracellular material later mineralizes.

Growth of the soft tissues occurs by a combination of hyperplasia and hypertrophy. These processes go on everywhere within the tissues, and the end result is what is called interstitial growth, which simply means that it occurs at all points within the tissue.

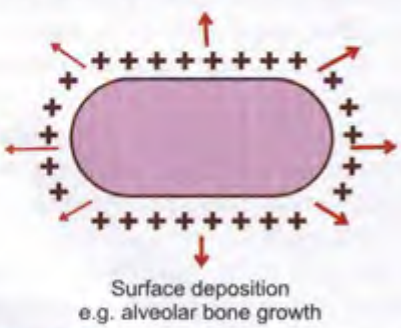


Fig. 2.4A: Endochondral bone growth

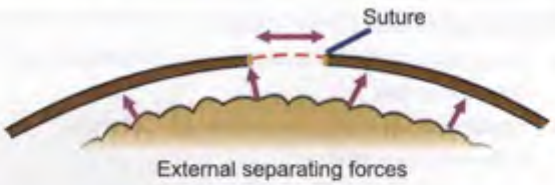


Fig. 2.4B: Intramembranous bone growth

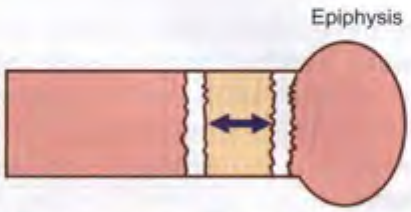


Fig. 2.4C: Internal expansion of growth cartilage

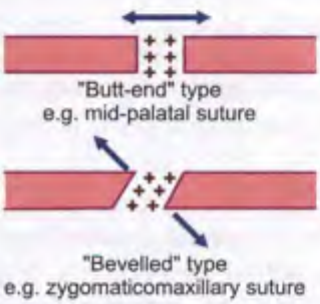


Fig. 2.4D: Sutural growth

GROWTH CONTROL

From its earliest days the orthodontic literature has contained reports of investigations into the nature and mechanisms of craniofacial growth.

Mills (1982) notes that orthodontic textbooks invariably commence with a chapter describing the normal development of the face, jaws and dentition. He considers that it is important before understanding the abnormal to have a clear idea of the way the face and its component parts develop. He goes on to say *'although we appear to have a fairly clear idea of how the face grows, and of where it grows, we have little idea of why it grows...we do not fully understand the factors which control the amount and direction of growth.'*

The human growth has a complex growth pattern. Growth of the brain case or calvarium is tied to the

growth of the brain itself, while growth of the facial and masticatory bones is relatively independent of the brain growth even though these bones are in actual contact with the cranial super-structure. Obviously in natures' plan, growth of any part of the skull is coordinated with that of other parts. The original pattern of the skeleton is maintained with the stationary biologic center lying in the body of the sphenoid bone.

Limborgh poses three main questions concerning the control of morphogenesis of the skull—

1. Are there, in the embryonic phase, any causal relationships between the development of the skull on one hand and the presence of primordium on the other?
2. How is the coordination between the endochondral and intramembranous bone growth brought about within the skull once it is formed?
3. In which way is the coordination between the skull growth and that of the other structures realized?

To answer these questions analysis must be made of the more obvious controlling and modifying factors. These are:

a. The **intrinsic genetic factors** or those inherent in the skull tissues themselves.
b. **Epigenetic factors**, are genetically determined but manifest their influence in an indirect way by means of intermediary actions or structures (i.e. eyes, brain, and so forth)
c. **Local and general environmental factors** are also controlling entities and require a value judgment in the overall picture.

To elicit an acceptable answer to these queries, researchers, over a period of time, have postulated various solutions that are collectively termed as theories of growth control.

THEORIES OF SKULL GROWTH CONTROL

GENETIC THEORY

The **classic approach** attributed control of skull growth largely to intrinsic genetic factors. This approach was questioned by researchers like Scott, Sicher, and Moss. It was van Limborgh in 1970, who analysed the controlling and modifying factors in the growth of the skull.

SUTURAL DOMINANCE THEORY

Sicher considered that, apart from minor remodeling which could be caused by local environmental factors such as muscular forces; bone growth was independent and immutable. The apparent correlation between the growth of the skull and its associated soft tissues was said to be a consequence of genetic harmony and not due to any interdependence. All osteogenic tissues, that is, cartilage sutures and periosteum, were thought to play an equally significant role in the control of the growth of the skull. However, his theory is generally referred to as the **sutural dominance theory**, with proliferation of connective tissue and its replacement by bone in the sutures being a primary consideration.

Sicher's proposition, in which growth of the skull was considered to be highly independent, was soon questioned. There was no reason to believe that the guiding genetic factors were contained in the bones. They may equally well operate indirectly through epigenetic factors. Experimental studies which demonstrated this were:

- That extirpation of facial sutures has no appreciable effect on the dimensional growth of the facial skeleton.
- That the shape of the sutures is dependent on functional stimuli
- That the closure of sutures is likewise extrinsically determined
- That sutural growth can be halted by mechanical forces, were to provide evidence that the suture does not have an independent growth potential (Koski, 1968).

Furthermore, the findings in spontaneous malformations such as hydrocephaly and microcephaly and the results of experiments carried out on normal embryos, gave strong support to the notion that a close relationship existed between skull growth and the morphology and activity of the associated structures.

CARTILAGINOUS THEORY

Scott proposed an alternative view, which is regarded as the second major hypothesis, on the nature of craniofacial growth, in the early 1950's.

He assumed that intrinsic, growth-controlling factors were present only in the cartilage and in the periosteum. He claimed that growth in the sutures was secondary and entirely dependent on the growth of the cartilage and adjacent soft tissues. Scott's hypothesis could explain the coordinated growth that had been observed within the skull, and between the

skull and the soft tissues. He introduced the concept of cartilaginous 'growth centers'. The role of these growth centers was explained in a contemporary summary of craniofacial skeletal growth (Scott 1955).

Several of Scott's basic tenets still hold credibility for researchers in the field of growth. Van Limborgh supported the view that synchondroses of cranial base have some degree of intrinsic control. However, he felt that the periosteum should also be considered as a secondary growth site because of its similarity to the suture.

FUNCTIONAL MATRIX HYPOTHESIS

Melvin Moss introduced the functional matrix hypothesis to the orthodontic world in 1962. His so called 'method of functional cranial analysis' was a conceptual framework designed to unify the existing concepts and to emphasize the contention that the bones do not 'just grow'.

He was inspired by the ideas of Van der Klaauw (1952) that 'bones' were in reality, composed of several 'functional cranial components' the size, shape and position of which were relatively independent of each other. He experimentally verified and expanded on these concepts and incorporated them with his own.

The original version of the functional matrix hypothesis held that,' the head is a composite structure, operationally consisting of a number of relatively independent functions; digestion, respiration, vision, olfaction, audition, equilibrium, speech, neural integration, etc. Each function is carried out by a group of soft tissues which are supported and/or protected by related skeletal elements. Taken together, the soft tissues and skeletal elements related to a single function are termed a *functional cranial component*. The totality of all the skeletal elements associated with a single function is termed a *skeletal unit*. The totality of the soft tissues associated with a single function is termed as the *functional matrix*. It may be further demonstrated that the origin, growth and maintenance of the skeletal unit depend almost exclusively upon its functional matrix.

In 1964, Moss presented a unified view of the role of all craniofacial 'growth cartilages'; 'the growth observed both at facial sutures and at cartilaginous areas (nasal cartilages, mandibular condyles, sphenooccipital synchondroses,) are all secondary , compensatory events whose net effect is to retain structural and functional continuity between skeletal parts'. An active mechanical role for spaces was suggested explicitly. For example, when considering the nasopharyngeal space, he stated 'this physically empty but physiologically necessary space is the primary biologic object that grows. The growth of nasal septal cartilage is, then, a secondary, mechanically obligatory growth which is totally compensatory in nature.'

In 1968, Moss presented an updated version of his hypothesis. The tissues, organs, spaces, and skeletal parts necessary to carry out a given function were termed collectively, a *'functional cranial component'*. On the basis of their relation to transformative and translative growth, the soft tissues of a functional component were classified as either *'periosteal'* or *'capsular' functional matrices;* on the basis of their relation to functional matrices, skeletal units were classified as either *'microskeletal'* or *'macroskeletal'* units. All translative growth was seen as occurring secondarily to the expansion of central, encapsulated volumes (brains, eyeball, spaces, etc.), while transformative growth was due to the presumably direct action of periosteal functional matrices (muscles, teeth, fat, glands, etc.).

Later, in his quest for the underlying control mechanism for craniofacial growth, Moss (1971) focused his attentions on the phenomenon of neurotrophism. *Neurotrophism is defined as a ' non- impulse transmitting neural function that involves axoplasmic transport and provides for long-term interactions between neurons and innervated tissues that homeostatically regulate the morphologic, compositional, and functional integrity of soft tissues.'* Moss concluded that the nerve influences the gene expression of the cell, and suggested that the genetic control lies not in the functional matrix alone, but reflects constant neurotrophic regulation stemming from a higher neural source.

Taken as a group, these schemes are commonly referred to as the functional matrix hypothesis. It is scientifically parsimonious, emphasizing the need to consider only the form and function in order to understand the basis of growth. It has been applied to explain the observations as diverse as:

- The diminution in size of the coronoid process subsequent to experimental denervation of the temporalis muscle,
- The growth of the calvarium in response to the expanding brain,

- The shrinkage of the alveolar process subsequent to tooth removal, and even
- The spatial maintenance of the appropriate foramina along a logarithmic spiral path during growth in response to the demand for an unloaded trigeminal neurovascular bundle.

These and many other examples were presented by Moss as evidence to support the functional matrix hypothesis.

SERVOSYSTEM THEORY

A further step in understanding the mechanisms of craniofacial growth was made when Charlier and Petrovic (1967) and Stutzmann and Petrovic (1970) detected in organ culture, in both transplantation and *in situ* investigations, the basic dissimilarities relative to different growth cartilages.

This led to the servosystem theory of the processes controlling postnatal craniofacial growth (Petrovic and Stutzmann, 1980).

According to this concept, the influence of the STH—somatomedin complex on growth of the ***primary cartilages*** (epiphyseal cartilages of the long bones, cartilages of the nasal septum and spheno-occipital synchondrosis, lateral cartilaginous masses of ethmoid, cartilage between the body and the greater wings of the sphenoid, etc.) has the cybernetic form of a 'command' (i.e., does not include any so far detected local feedback loops) (Figs 2.5A and B).

Quite the contrary, the influence of the STH-somatomedin complex on the growth of the ***secondary cartilages*** (condylar, coronoid, and angular cartilages of the mandible, cartilages of the mid palatal suture, some other craniofacial sutures, and the provisional callus during bone fracture repair, and (to some extent) rib growth cartilages) comprise not only direct but also some indirect effects on the cell multiplication. With condylar, coronoid and angular cartilages these indirect effects correspond to *regional* and *local* factors involving primarily neuromuscular mechanisms relative to postural adjustment.

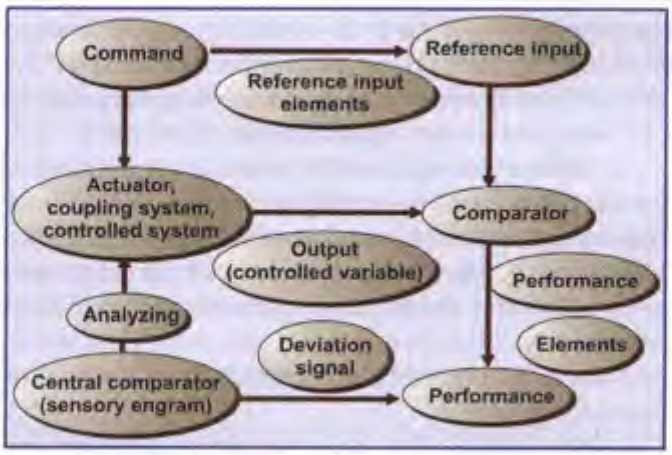


Fig. 2.5A: Components of a servosystem

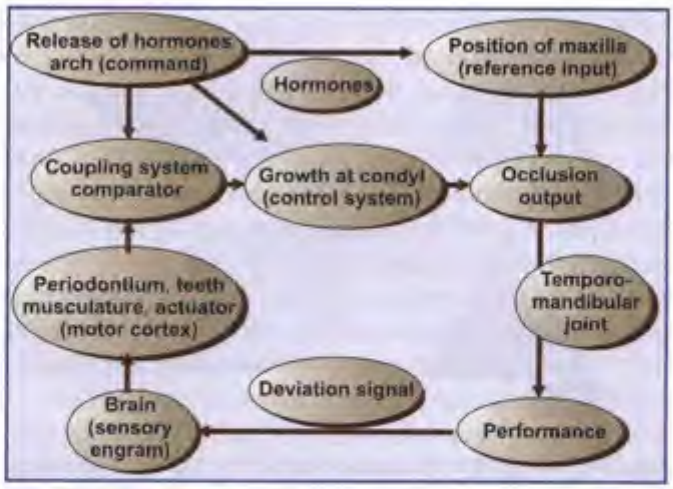


Fig. 2.5B: The face as a servosystem

ARCHITECTURAL ANALYSIS OF THE SKULL

GENERAL PLAN

The skull is a stress-bearing structure and has to withstand significant and complicated forces when an individual punctures, shears, or chews its food.

The common engineering solution to the resistance of force is manifest in the design of, "frames and trusses." The basic frame is a triangle, a form in two dimensions. Three members (bars) with joints at their angles resist distortion of the triangle from forces applied in any direction in the same two-dimensional plane. Increase in the number of members weakens the frame, e.g. say a rectangle so jointed collapses when similar angular force is applied (Fig. 2.6).

The basic truss is a tetrahedron (three-sided pyramid), which is simply four triangles (base included), a form in three dimensions. It resists distortion from forces applied in any direction in three planes of space. Increase in number

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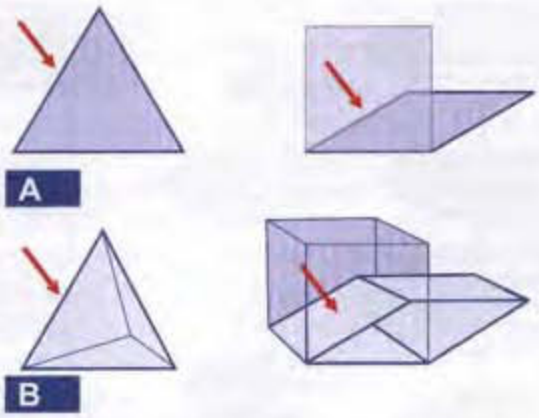


Fig. 2.6: Frames and trusses (A) Frame: triangular frame resists distortion from external force, rectangular frame collapses, (B) Thruss: tetrahedral truss resists distortion from external force; cubic truss collapses



Fig. 2.7: Frames and trusses of skull, frontal view



Fig. 2.8: Frames and trusses of skull; lateral view

of members weakens the truss, e.g. a cube collapses when similar angular force is applied.

The structural strategy of the skull is a biologic compromise that accommodates multiple competing functional demands. Most evident are the protective housings for the brain and each of the functionally oriented special sense organs, the separate corridors for the airway and food, and the variety of entrances and exits for arteries, veins, and nerves. In addition, the masticatory system is deeply rooted within this assemblage. Though its force-resisting triangles and tetrahedrons may be somewhat wrapped to bypass obstructing organs, the truss-work can be readily traced throughout the skull as pillars of reinforced bone (Fig. 2.7).

In frontal view several frames can be clearly outlined (Fig. 2.8). A central triangle dominates the facial skeleton. Its sides are formed by canine buttresses, which begin at the anterior corners of the dentition and run up between nasal and orbital spaces to meet at the glabella, bulging in the midline of the frontal bone. This, in turn, is backed by the vertical temporal squama. The base of the central triangle is formed by the thickened anterior strip across the palate between the canines. A large inverted triangle can be traced on each side of this central frame. Its medial side is the canine buttress in common with the central frame. Its lateral side diverges as the zygomatic process of the maxilla, which is continuous upward through the reinforced middle strip of the zygomatic bone to meet the frontal bone at its zygomatic process. The base of this inverted triangle is the bulky superciliary bar, which forms the upper margin of the orbit.

A shorter triangle can be seen fitted within the greater frame. Its sides are the same below, but its base cuts it short at the thickened lower margin of the orbit. Now it can be seen that this truss work already meets several of the essential requirements specified previously. It frames nasal, sinus spaces while providing an optimal force-resisting framework for masticatory stress.

In the lateral view this functional plan can be followed in depth (Figs 2.8 and 2.9). Canine and

zygomatic buttresses can be seen diverging from the dentition. Posteriorly the bulbous maxillary tuberosity can be seen, strongly braced by the pterygoid process, which takes up the force on the posterior dentition like a flying buttress diverging upward to the cranial base.

The plan of this three-dimensional truss work is convincingly demonstrated in a horizontal section of the maxilla. A three-sided pyramid (tetrahedron) cut in half, yields a triangular plane which, in the maxilla, is reinforced as a bony pillar at each angle; these are the canine buttress, the zygomatic buttress, and the maxillary tuberosity, which butts against the pterygoid buttress. Between these buttresses the bone is thin and forms the walls of the various cavities.

The mandible completes the framework of the skull. It contributes the movable part of a complicated lever system. To meet this function it is designed as a strong central bar, like the shaft of a long bone, running forward in a continuous curve from condyle to condyle (Fig. 2.10). The bar is reinforced at its midline symphysis by the bulging chin, which resists the squeezing action of the lateral pterygoids at the condylar ends of the horseshoe-shaped curve. This central bar supports three processes. Thus two thinner plates are pinched off above and below for the attachment of masticatory muscles. The temporalis inserts on the coronoid process, which is reinforced by the narrow temporal crest; the masseter and the medial pterygoids insert on the mandibular angle, which is a slightly thicker plate since it must resist the pull of two muscles. The alveolar process for the attachment of the dental arch is a continuous process pulled up from the bar with the eruption of teeth.

This basic framework of the mandible is unmistakably demonstrated in the senile jaw. With the loss of teeth the alveolar process disappears. Since masticatory function is thus severely reduced, the masticatory muscles atrophy from disuse. This is accompanied by extensive resorption of their mandibular insertions. Coronoid and angular plates recede, and little but the central bar of bone remains.

INTERNAL CONSTRUCTION OF BONE

Bone tissue is both resistant and resilient. It is thus well adapted to withstand all the kinds of stress-that is, pressure, tension, and shear-generated by the living, vigorous animal. But bone is also remarkably plastic. It grows and is continuously remodeled during life by—the sculpturing activity of deposition and resorption along the bone surfaces. In the direction and control of growth, the bony surfaces are augmented by precisely placed cartilaginous (epiphyseal) plates, such as those near the ends of long bones and between the bones at the base of the skull. Sutures between bones further increase the workable surfaces in the cranium. They join bones by fibrous connective tissue and are therefore tension bearing.

Individual bones provide the mechanical units of the skeleton. They have evolved by the natural selection of adaptive engineering. Thus most bones are designed with a dense outer casing of compact or cortical bone housing an inner meshwork of trabecular, spongy, or cancellous bone. Exceptions are found where bones are so thin that only a compact plate is possible, as in certain bones of the skull.

Compact bone is rigorously organized. It is composed of bony lamellae (layers) lying parallel on the surface. They overlie deeper tubular constructs of concentric lamellae surrounding longitudinal central canals like alternating plywood layers. These structures, called Haversian systems or osteones, run side by side and are oriented along lines of force transmission. Such a cylinder resists bending in any direction and, since it is hollow in its central axis where pressure and tension from bending are neutralized, it is also provided with a protected channel for its vascularization. Even in areas where distinct osteones cannot be traced because of local remodeling or filling in of interstices between incongruent osteone surfaces, or where bone is too thin, etc. the pattern of bony strips adhere to lines of force transmission called *trajectories*.

Spongy bone protects this stress-bearing organization interior of the bone. Here it dissipates the stress transferred to it by the osteones, or carries loads to the osteones, from stresses at the joints. Its trabeculae (little beams) springs from the inner cortical layers like the flying buttresses of Gothic cathedrals to span the medullary spaces to opposite sides. These struts and braces are continuous with the osteones, and the pattern of their trajectories traces the dispersion of the stresses.

In the maxilla struts and braces converge from local areas of masticatory stress to concentrate in the pillars

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that form the trusses that characterize the facial skeleton (Fig. 2.9).

The head of the mandible faces upward and forward, offset on the bent mandibular neck. Its trabeculae can be seen to cross in arches springing from the cortical bone. A transverse section of the mandibular condyle is supported by parallel vertical struts and cross ties.

The mandible resists bending forces with its strong, compact layer. The compact shell is filled with cancellous bone, forming and surrounding the sockets of the teeth. The masticatory pressure exerted on the teeth is transmitted as tension on the alveolar bone proper, or cribriform plate, through the bundles of the periodontal ligament. The alveolar bone proper tends to sink into the mandible if the tooth is under pressure; this tendency is counteracted by the spongy bone around the alveolar bone proper. These trabeculae arise on the outer surface of the alveolar bone proper. Some connect the sockets of two adjacent teeth and may be horizontal and regular or irregular. Others end mainly on the compact alveolar plates. Because of their specific function, the spongy trabeculae and the compact alveolar plates are designated as supporting bone of the alveolar process.

Some of the spongy trabeculae surrounding the apical part of the sockets unite as a trajectory that runs backward below the sockets and then diagonally upward and backward through the ramus to end in the condyle (Fig. 2.10). In this way the masticatory pressure is finally transmitted to the base of the skull over the craniomandibular articulation.

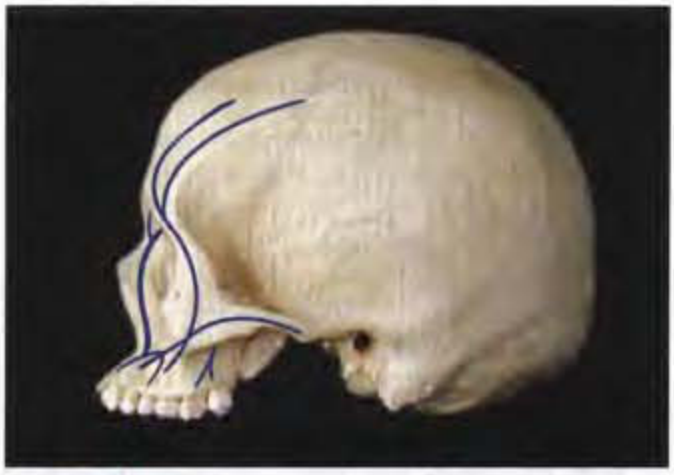


Fig. 2.9: Supporting pillars of the maxillary skeleton



Fig. 2.10A: Trajectories of the mandible (buccal aspect)



Fig. 2.10B: Trajectories of the mandible (lingual aspect)

This most important trajectory of the mandible, the dental trajectory, bulges on the inner surface of the ramus as a blunt crest, the crest or ridge of the mandibular neck continuous with the mylohyoid ridge.

Other trajectories of the mandible are formed in response to the forces exerted by the muscles of mastication. One is found in the region of the mandibular angle; another begins at the tip of the coronoid process and fans out into the mandibular body. Between these trajectories there is a region of the mandible, above and in front of the angle, where the cancellous bone is relatively free of stresses. In this region the trabeculae of the spongy bone are thin and the marrow spaces wide, a fact that can also be verified by studying roentgenograms.

The region of the chin is especially endangered if bending forces act on the mandibular body. Forceful forward thrust of the mandible causes a measurable deformation, namely, a contraction of the mandible by the inward pulling component of the two lateral pterygoid muscles. In response to these forces, the region of the chin is strengthened not only by the rather massive yet compact mental protuberance, but also by trajectories of the spongiosa. These tracts of trabeculae cross each other at right angles, running from the right lower border of the chin upward to the left into the alveolar process and vice versa.

The upper jaw and the skeleton of the upper face form, biologically and mechanically, a unit anchored to the base of the skull. On each side of the skull are three vertical pillars that have already been described. All of them arise in the basal part of the alveolar process, and all of them abut to the base of the cranium (Fig. 2.9).

Seen in basal view, the connection between the posterior end of the horizontal arm of the zygomatic pillar and upper end of the pterygoid pillar is a thickened reinforcement of the bone in front of the foramen ovale connecting the articular eminence with the root of the pterygoid process. The hard palate connects the system of pillars of one to that of the other side and thereby forms a vaulted supporting arch between the bases of the right and left alveolar processes.

FURTHER READING

1. Bjork A. Facial Growth in man, studied with the aid of metallic implants, Acta Odont Scand 1955;13:9-34.
2. Bjork A. Prediction of Mandibular Growth Rotation, Angle Ortho 1969;55:585-99.
3. Dixon AD. The development of the jaws. Dent. Pract 1958;9:10-18.
4. Dixon AD. The early development of maxilla. Dent. Pract 1953;3:331-56.
5. Enlow DH, Hans MG. Essentials of Facial Growth, Philadelphia, 1996, W.B. Saunders.
6. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
7. Houston WJB. Mandibular growth rotations- their mechanisms and importance, Eur J Ortho 1988;10:369-73.
8. Jansen HW, Duterloo HS. Growth and growth pressure of mandibular condylar and some primary cartilages of the rat in vitro, Am J Orthod Dentofacial Orthop 1986;90:19-28.
9. Klaauw CJ van der. Cerebral skull and facial skull. A contribution to the knowledge of skull structure. Arch. Neerl. Zool. 1946;9:16-36.
10. Klaauw CJ van der. Size and position of the functional components ofthe skull. A contribution to the knowledge of the architecture of the skull based on data in the literature. Arch Neerl. Zool. 1948;9:1-176.
11. Klaauw CJ van der. Size and position of the functional components of the skull (continuation). ARch Neerl. Zool 1951;9:177-368.
12. Klaauw CJ van der. Size and position of the functional components of the skull (conclusion). Arch Neerl Zool 1952;9:369-560.
13. Koski K. Some aspects of growth of the cranial base and the upper face, Odont Trans 1960;68:344-58.
14. Koski. Cranial growth centers: Facts or Fallacies? Am J Orthod 1968;566-83.
15. Krogman WM. Principles of human growth. Ciba Sympos, 1943;5:1458-66.
16. Latham RA. The septo-premaxillary ligament and maxillary development, J Anat 1969;104:584-6.
17. Latham RA. The septo-premaxillary ligament and maxillary development, J Anat 1969;104:584-6.
18. Limborgh J van. A new view on the control of the morphogenesis of the skull. Acta Morph Neerl Scand, 1970;8:143-60.
19. Limborgh JV. A new view on the control of the morphogenesis of the skull. Acta Morph Neer-Scand,, 1970;8:143-60.
20. Moss M, Salentijn L. The Primary role of functional matrices in facial growth, Am J Ortho 1969;5:566-77.
21. Moss ML. Functional cranial analysis and the functional matrix, ASHA reports no. 1971;5-18.
22. Moss ML. The functional Matrix Hypothesis Revisited, Am J Orthod Dentofacial Orthop 1997;112:8-11,221-6, 338-42, 410-7.
23. Moyers RE. Handbook of Orthodontics, ed. 3, Chicago, 1973, Year Book.
24. Nolla CM. The development of the permanent teeth, J Dent Child 1960;27:254.
25. Scott JH. Dento-facial development and growth, London, Pergamon Press, 1967;65-137.
26. Scott JH. The doctrine of functional matrices, Am J Orthod, 1969;56:38-44.
27. Solow B, Houston WJB. Mandibular rotations: concepts and terminology, Eur J Ortho 1988;10:177-9.
28. Storey E. Growth and remodeling of boe and bones, Am J Orthod, 1972;62:142-65.
29. Todd TW. Differential skeletal maturation in relation to sex, race variability and disease, Child Develop, 1931;2:49-65.

3 Prenatal Growth of Cranium, Facial and Oral Structures

Navjot Singh

- Prenatal growth phases
- Prenatal growth proper
- Development of the skull
- The calvaria
- The cranial base
- The facial skeleton

PRENATAL GROWTH PHASES

The prenatal life of an individual can be broadly classified into the following three phases:

1. Period of ovum (from fertilization to the 14th day)
2. Period of embryo (from 14th to 56th day)
3. Period of foetus (56th day to birth)

PRENATAL GROWTH PROPER

The growth of the cranial, facial and oral structures begins around the 21st day (period of embryo) after conception. At this stage the embryo is about 3 mm in size and the head begins to take shape. Figure 3.1 explains clearly the sequence of events.

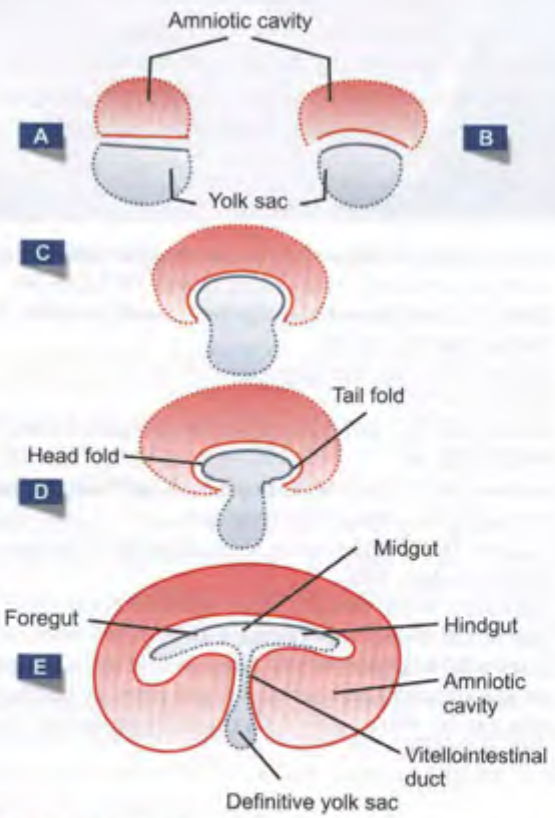
Although there is progressive increase in the size of the embryonic disc, yet, the head and tail ends of the disc (x, y) remain relatively close together. This results in the disc to bulge upwards into the amniotic cavity. As the disc enlarges further, the embryonic disc becomes folded on itself at the head and tail ends. These are called the head and tail folds.

After the formation of head fold, the developing brain and the pericardium forms two prominent bulgings in the ventral aspect of the embryo (Fig. 3. 2).

In between them, there is a depression called the stomodaeum, the floor of which is formed by the buccopharyngeal membrane. This membrane separates the stomodaeum from the foregut (Fig 3.3).

Soon the mesoderm covering the developing brain proliferates and forms a downward projection that overlaps the upper part of the stomodaeum. This downward projection is called the frontonasal process (Fig. 3.4.).

As is evident till now, the neck is not yet present. The neck is formed by the elongation of the region between stomodaeum and the pericardium. This is



Figs 3.1A to E: Formation of the head and tail folds

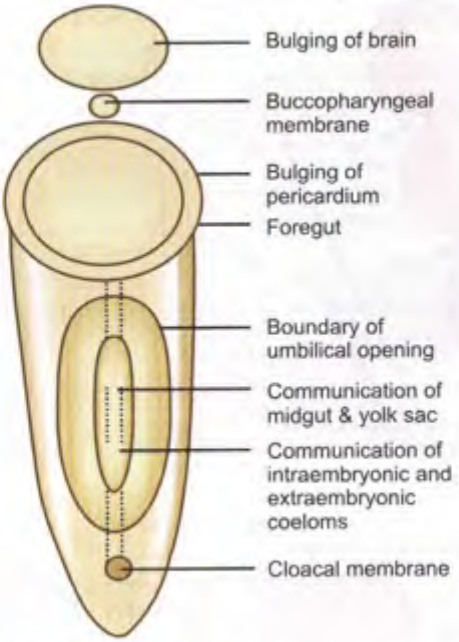


Fig 3.2: Prominent brain and pericardium bulge

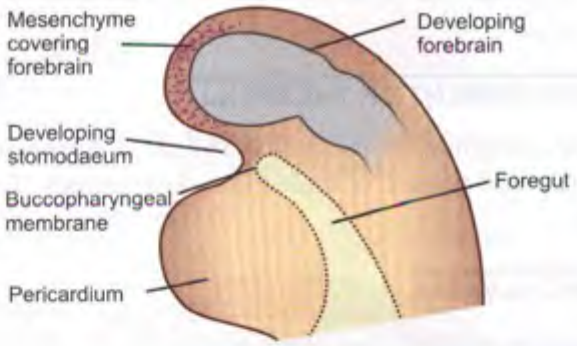


Fig. 3.3: Appearance of stomodaeum

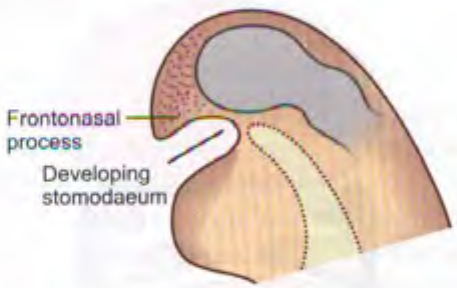


Fig. 3.4: Formation of frontonasal process

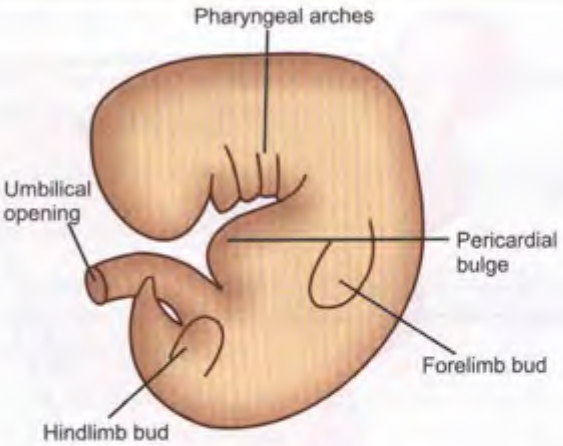


Fig. 3.5: Pharyngeal arches

achieved partly by a descent of the developing heart and mainly due to the appearance of a series of mesodermal thickenings in the wall of the cranial most part of the foregut. These are called the pharyngeal or the branchial arch (Fig. 3.5).

These are 4 in number. Although there is a 5th arch, it disappears soon after formation (Fig. 3.6). Only the first two arches are named; the mandibular arch and the hyoid arch respectively. Each of these arches is separated by a groove and is supplied by a nerve that innervates the striated muscle of the arch along with the overlying ectoderm and endoderm.

At this stage, the mid-sagittal section of the embryo looks like Figure 3.7.

At this stage each mandibular arch forms the lateral wall of the stomodaeum (Fig. 3.8A).

This arch gives off a bud from its dorsal end and is called the maxillary process (Fig. 3.8B). It grows ventromedially cranial to the main part of the arch which is now called the mandibular process.

The ectoderm overlying the frontonasal process soon shows bilateral localized thickenings that are situated a little above the stomodaeum.

These are called nasal placodes and they soon sink below the surface to form nasal pits (Fig. 3.9). The pits are continuous below with the stomodaeum. The edges of each pit are raised above the surface; the medial raised edge is called the medial nasal process and the lateral edge is called the lateral nasal process.

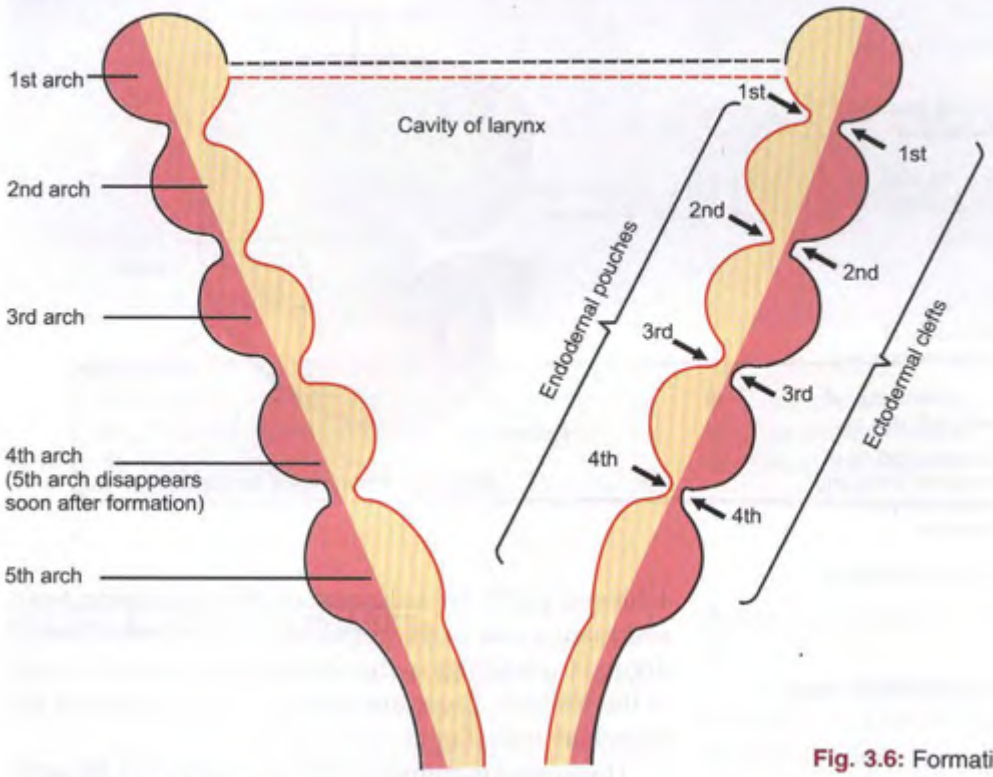


Fig. 3.6: Formation of pharyngeal arches

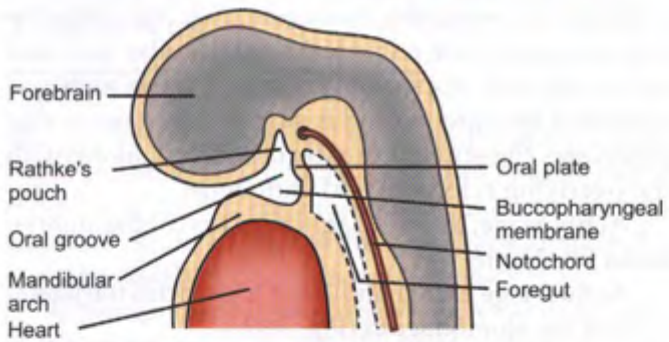


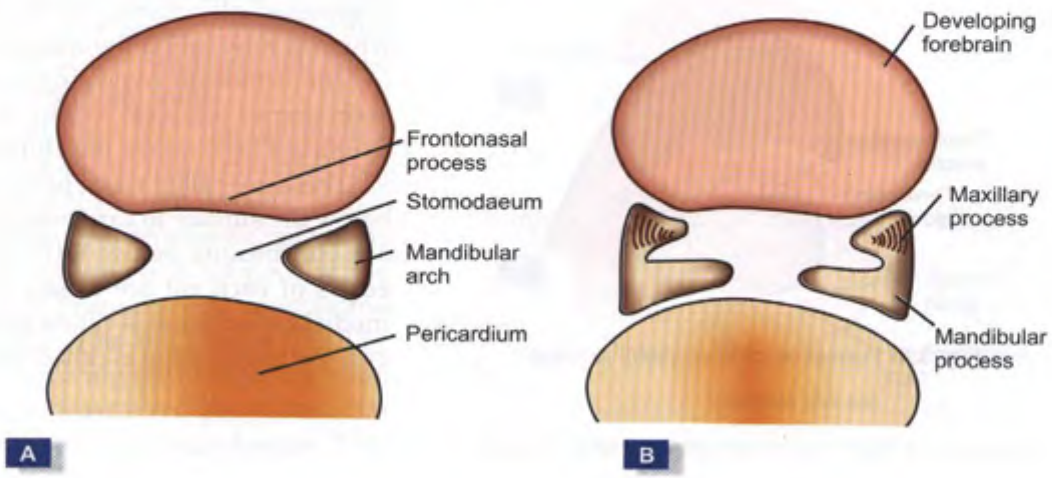
Fig. 3.7: Mid-sagittal section of embryo(21 days)

DEVELOPMENT OF THE SKULL

The development of the skull is a blend of the morphogenesis and growth of three main skull entities (Table 3.1).

THE CALVARIA

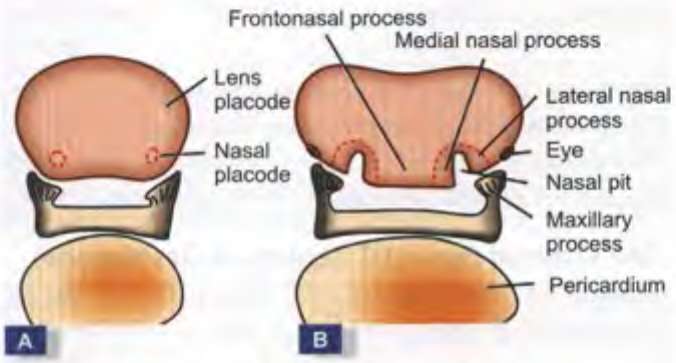
The mesenchyme that gives rise to the vault of the neurocranium is first arranged as a capsular



Figs 3.8A and B: Formation of maxillary process

Table 3.1: Development of the skull

The Neurocranium	The vault of the skull or calvaria is of recent origin to cover the expanded brain and is formed from intramembranous bone, also called the desmocranium.
The Face	The cranial base is derived from the phylogenetically ancient cranial floor with which are associated the capsular investments of the nasal and auditory sense organs; formed from endochondral bone, its cartilaginous precursor is called chondrocranium.
The Masticatory Apparatus	The orognathofacial complex is derived from the modifications of the phylogenetically ancient branchial arch structures; formed from the intramembranous bone; also called the splanchnocranium; forms the oromasticatory apparatus.
	The dentition; derived phylogenetically from ectodermal placoid scales which is reflected in the embryological development of the teeth from oral ectodermal dental lamina).



Figs 3.9: Formation of nasal placodes and nasal processes



Fig. 3.10: Component parts of the calvarium

membrane around the developing brain. The membrane is composed of two layers, an inner endomeninx, of neural crest origin and an outer ectomeninx, of mesodermal origin (Fig. 3.10).

The endomeninx forms the two leptomeningeal coverings of the brain—pia mater and the arachnoid. The ectomeninx differentiates into the inner dura mater covering the brain, which remains unossified, and an outer superficial membrane with chondrogenic and osteogenic properties. Osteogenesis of the ectomeninx occurs as intramembranous bone formation over the dome of the brain, forming the skull vault or calvaria, while the ectomeninx forming the floor of the brain chondrifies as the chondrocranium that later ossifies endochondrally.

Ossification of the intramembranous calvarial bones depends upon the presence of the brain, for in its absence (ancephaly) no bony calvaria develops. Several primary and secondary ossification centers develop in the outer layer of the ectomeninx to form individual bones (Fig 3.11). A pair of frontal bones appears from single primary ossification centers forming in the region of each superciliary arch at the 8th week IU.

Three pairs of secondary centers appear later—in the zygomatic processes, nasal spine, and trochlear fossae. Fusion between all these centers is complete at 6-7 months IU.

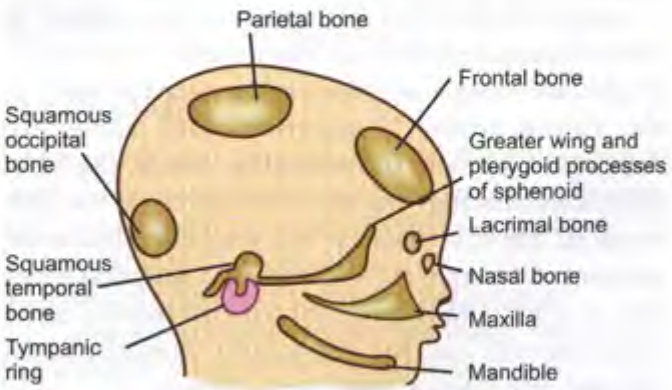


Fig. 3.11: Ossification sites of the bones of the skull

The two parietal bones arise from two primary ossification centers for each bone that appear at the parietal eminence in the 8th week IU and fuse soon after. Delayed ossification in the region of the parietal foramina may result in the presence of a sagittal fontanelle at birth.

The squamous portion of the occipital bone (above the superior nuchal line) ossifies intramembranously from one center appearing in the 8th week IU.

Should any unusual ossification centers develop between individual calvarial bones, their independent existence is recognized by small sutural bones called wormian bones. The earliest centers of ossification appear during the 7th to 8th weeks IU, but ossification is not completed well after birth (Fig. 3.11). The mesenchyme between the bones develops fibers to form articulations. The membranous mesenchyme covering the bones forms the periosteum.

THE CRANIAL BASE

Although during the 4th week, mesenchyme derived from the primitive streak and neural crest condenses between the developing brain and foregut to form the basal portion of the ectomeningeal capsule, yet the development of the skull starts comparatively late, after the primordia of many of the other cranial structures, such as the brain, cranial nerves, the eyes, and the blood vessels have already developed. Conversion of the ectomeninx mesenchyme into cartilage constitutes the beginning of the chondrocranium that commences from the 40th day IU onwards.

Approximately 110 ossification centers appear in the embryonic human skull. Many of these centers fuse to produce 45 separate bones in the neonatal skull. In the young adult, 32 separate skull bones are recognized. Centers of ossification within the basal plate, commencing with the basioccipital in the 10th week IU lay the basis for the endochondral bone portions of the occipital, sphenoid, and temporal bones (all of which also have intramembranous bone components) and for the wholly endochondral ethmoid and inferior nasal concha bones.

The above can be summarily tabled as follows:

The Occipital Bone (7 Ossification Centers)

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Supranuchal squamous part	Intramembranous	8th week	02
Below superior nuchal line	Endochondral	10th week	02
Basilar part	Endochondral	11th week	01
Condylar part	Endochondral	12th week	02

The Temporal Bone (11 Centers of Ossification)

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Squamous	Intramembranous	8th week	01
Tympanic ring	Intramembranous	12th week	04
Premastoid	Endochondral	20th week	04
Styloid	Endochondral	36- 38th week	02

The Ethmoid Bone (03 Centers of Ossification)

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Entire bone	Endochondral	16th week and 36th week	01 +02

The Sphenoid Bone (up to 15 Centers of Ossification)

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Greater wing of sphenoid and lateral pterygoid plate	Intramembranous	8th week	02
Medial pterygoid plate*	Endochondral		01
Presphenoid	Endochondral	20th week	05
Postsphenoid	Endochondral	16th week	04

The ossification center for the medial pterygoid plate first appears in a nodule of secondary cartilage that forms the pterygoid hamulus, but subsequent ossification of the pterygoid plate is intramembranous.

The Inferior Nasal Concha

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Entire bone	Endochondral	20th week	01

THE FACIAL SKELETON

For the sake of convenience, the face may be divided into following thirds:

1. The upper face (corresponding to frontonasal process, embryologically).
2. The middle face (corresponding to maxillary process, embryologically).
3. The lower face (corresponding to mandibular process, embryologically).

Their boundaries being approximately the horizontal planes passing through the pupils of the eyes and the rima oris.

The upper third of the face, which is primarily of neurocranial composition, initially grows most rapidly in keeping with its neurocranial association and the growth of the frontal lobes of the brain. In contrast, the growth of middle and lower third is slow and fairly prolonged.

The facial bones develop intramembranously from ossification centers in the neural crest mesenchyme of the embryonic facial processes. The above can be tabulated as follows:

The Upper Face

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
The frontal bone	Intramembranous		01

The Frontonasal Process

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Nasal bone	Intramembranous	12th week	02 (right and left)
Lacrimal bone	Intramembranous	12th week	02 (right and left)

The Maxillary Processes

Part of the bone	*Ossification type*	*Timing (IU)*	*No. of ossification centers*
Sphenoid bone (medial pterygoid plates*)	Intramembranous	8th week	02
Vomer	Intramembranous	8th week	02
Greater wing of sphenoid and lateral pterygoid plate	Intramembranous	8th week	02
Palatine bones	Intramembranous	8th week	02
Maxilla	Intramembranous	8th week	02
Zygomatic bones	Intramembranous	8th week	02
Temporal bone (squamous portion)	Intramembranous	8th week	02

THE MAXILLA

A primary intramembranous ossification center appears for each maxilla in the 8th week IU at the termination of the infraorbital nerve just above the canine tooth dental lamina. Secondary cartilages appear at the end of the 8th week IU in the regions of the zygomatic and alveolar processes that rapidly ossify and fuse with the primary intramembranous center. Two further intramembranous ' premaxillary centers' appear anteriorly on each side in the 8th week IU and rapidly fuse with the primary maxillary center.

Single ossification centers appear for each of the zygomatic bones and the squamous portions of the temporal bones in the 8th week IU.

THE PALATE

The growth and development of the palate holds special interest for the orthodontist. The three elements that make up the secondary definitive palate are:

1. Lateral maxillary processes
2. Primary palate of the frontonasal process.

These are initially widely separated due to the vertical orientation of the lateral shelves on either side of the tongue. Later in the 7th week IU (between the

47th and 54th day) a remarkable transformation in position of the lateral shelves takes place, when they alter from vertical to horizontal, as a prelude to their fusion and partitioning the oronasal chamber.

Ossification of the palate proceeds during the 8th week IU from the spread of the bone into the mesenchyme of the fused lateral palatal shelves and from trabeculae appearing in the primary palate as' premaxillary centers', all derived from the single primary ossification centers of the maxillae.

Posteriorly hard palate is ossified from the trabeculae spreading from the single primary ossification centers of each of the palatine bones. Mid-palatal sutural structure is first evident at around 10th week IU when an upper layer of fiber bundles develops across the midline.

In the most posterior part of the palate, ossification does not occur, giving rise to the region of soft palate.

A cleft of the palate occurs if the palatal shelves fail to fuse together as may happen if the tongue fails to descent due to underdevelopment of the mandible. Incomplete penetration of the mesoderm into the palatal shelves can give rise to a submucous cleft palate. Thus the formation of a cleft lip and alveolus (primary palate) occurs between the 4th and 8th week after conception and clefts of the hard and soft palate (secondary palate) occurs between the 8th and 12th week. A complete cleft of the lip, alveolus and palate would therefore, suggest a continuation of the effects of the etiological factors over all these weeks while clefts of the primary or secondary palate alone would imply its restriction to the appropriate weeks.

It is now well understood that any one of the following reasons can result in cleft palate.

- Defective growth of the palatine shelves
- Failure of elevation of the shelves
- Failure of fusion of the shelves
- Postfusion rupture of the shelves
- Micrognathia as in Robin Complex

THE MANDIBULAR PROCESSES

Part of the bone	*Ossification type*	*Timing (IU)*	*No of ossification centers*
Mandible	Intramembranous	6th week	02 (right and left)
Temporal bone (tympanic ring)	Intramembranous		02 (right and left)

The Mandible

The first structure to develop in the primordium of the lower jaw is the mandibular division of the trigeminal nerve that preceded the mesenchymal condensation forming the first (mandibular) arch (Fig. 3.12). The prior presence of the nerve has been postulated as being necessary to induce osteogenesis by the production of neurotrophic factors.

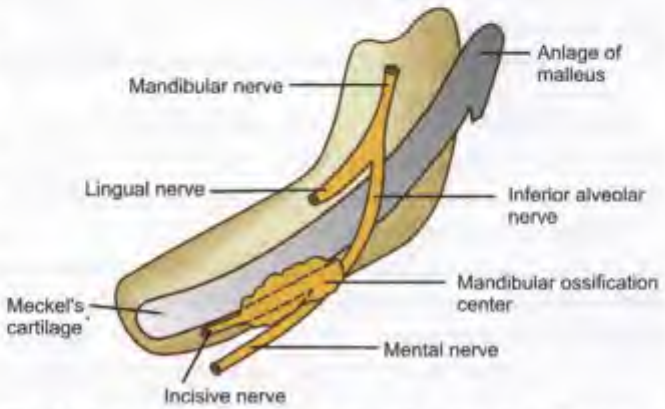


Fig. 3.12: Schematic representation of center of ossification of the mandible lateral to Meckel's cartilage at the bifurcation of the inferior alveolar nerve

The mandible is derived from the ossification of an osteogenic membrane formed from ectomesenchymal condensation at around 36 to 38 days IU. The resulting intramembranous bone lies lateral to Meckel's cartilage of the first (mandibular) arch.

A single ossification center for each half of the mandible arises in the 6th week IU, in the region of the bifurcation of the inferior alveolar nerve and artery into the mental and incisive branches. There is marked acceleration of mandibular growth between the 8th and 12th weeks IU. As a result of mandibular length increase, the external auditory meatus appears to move posteriorly.

Bone begins to develop lateral to Meckel's cartilage during the 7th week and continues until the posterior aspect is covered with bone. Ossification stops at the point, which will later become the mandibular lingula, and the remaining part of the Meckel's cartilage continues on its own to form the sphenomandibular ligament and the spinous process of the sphenoid (Meckel's cartilage lacks the enzyme phosphatase found in the ossifying cartilages, thus precluding its

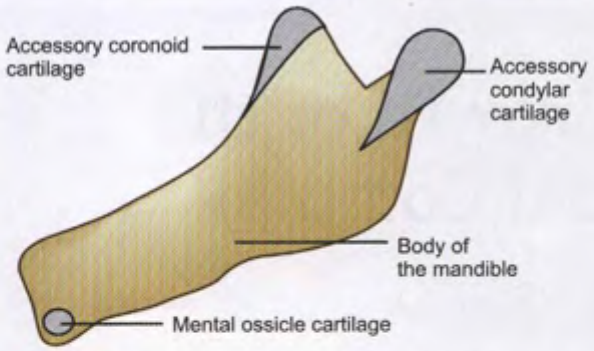


Fig. 3.13: Accessory cartilages of the fetal mandible

ossification. Meckel's cartilage does, however, persists until as long as the 24th week IU, before it disappears).

Secondary accessory cartilages appear between the10th and 14th weeks IU to form the head of the condyle, part of the coronoid process, and the mental protuberance (Fig. 3.13).

FURTHER READING

1. Enlow DH, Bang S. Growth and remodeling of the human maxilla, Am J Orthod, 1965;51:446-64.
2. Enlow DH, Harris DB. A study of the postnatal growth of the human mandible, Am J Orthod, 1964;50:25050.
3. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
4. Johnston MC. Developmental Biology of mouth, palate, and pharynx. In Tewfik TL, Derkaloussian VM (editors): Congenital anomalies of ear, nose and throat, New York, 1997, Oxford University Press.
5. Koski. Cranial growth centres: Facts or Fallcies? Am J Orthod 1968;566-83.
6. Limborgh JV. A new view on the control of the morphogenesis of the skull. Acta Morph Neer-Scand, 1970;8:143-60.
7. Moyers RE. Handbook of Orthodontics, ed. 3, Chicago, 1973, Year Book.
8. Orban B. Oral Histology and Embroyology, 7th ed., Philadelphia, WB Saunders, 1965.
9. Salzmann JA. Practice of Orthodontics, J B Lippincott Company, 1996.
10. Sperber GH. Craniofacial Embryology. In dental Practitioner Handbook, 4th edn. London: Wright, 1996.
11. Ten cate AR. Oral Histology: Development Structure and Function, CV. Mosby, St Louis, 1980.
12. Thompson DT. On Growth and Form, Cambridge, Mass., 1971, Cambridge University Press.

4 Postnatal Growth of the Craniofacial Complex

Navjot Singh

- Introduction
- The cranial vault
- The cranial base
- The nasomaxillary complex
- The mandible

INTRODUCTION

For the basis of simplicity, the growth of the craniofacial complex can be divided into four areas that grow rather differently:

a. *The cranial vault* the bone that covers the upper and outer surface of the brain.
b. *The cranial base* the bony floor under the brain, which is also a dividing line between the cranium and the face.
c. *The nasomaxillary complex* made up of the nose, maxilla, and the associated structures.
d. *The mandible.*

THE CRANIAL VAULT

The growth in the cranial vault is because of the enlarging brain (Fig. 4.1).

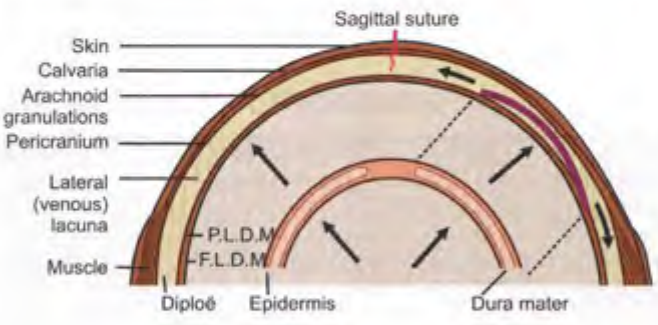


Fig. 4.1: The cut section of the developing skull

The rate of bone growth is more during infancy and by the fifth year of life more than 90 percent of the growth of cranial vault is achieved (Table 4.1). It is made up of a number of flat bones that are formed directly by *intramembranous ossification*, without cartilaginous precursors. From the time that ossification begins at a number of centers that foreshadow the eventual anatomic bony units, the growth process is entirely the result of periosteal activity at the surfaces of the bones. Some selective resorption occurs early in postnatal life on the inner surfaces of the cranial bones to help flatten them out as they expand. Apposition can be seen on both the internal and external tables of the cranial bones as they become thicker. This increase in thickness which permits the development of the diploë is not uniform. Sicher attributes this to the fact that the inner cranial table is primarily under the influence of the growth of the brain—the brain capsule while the outer plate has certain mechanical influences operating upon it. These mechanical influences contribute to the growth of cranial superstructures. Of particular significance are the supraorbital, otic, and mastoid regions. These structures are usually more marked in the males than females.

Remodeling and growth occur primarily at the periosteum lined contact areas between adjacent skull bone, called the skeletal sutures. At birth, the flat bones of the skull are rather widely separated by relatively loose connective tissues. These open spaces, the fontanelles (Figs 4.2 A to C), allow a considerable

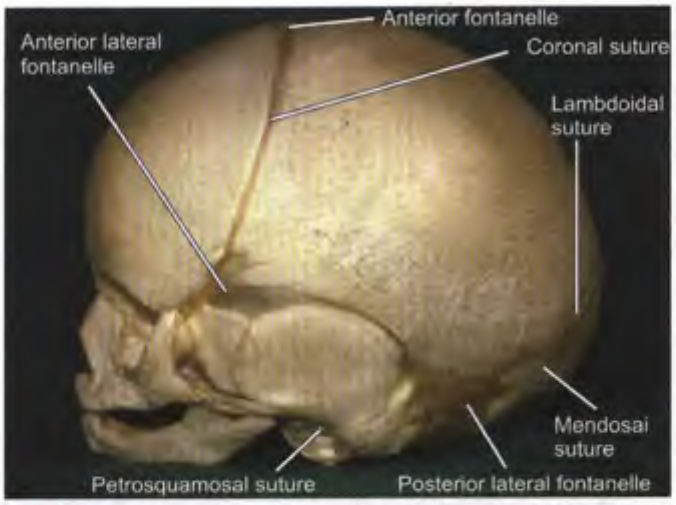


Fig. 4.2A: The location of the various fontanelles (lateral view)

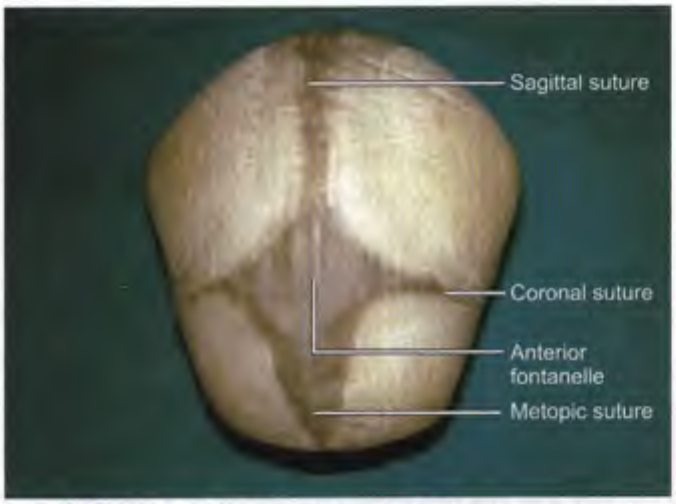


Fig. 4.2B: Location of the various fontanelles (superior view)

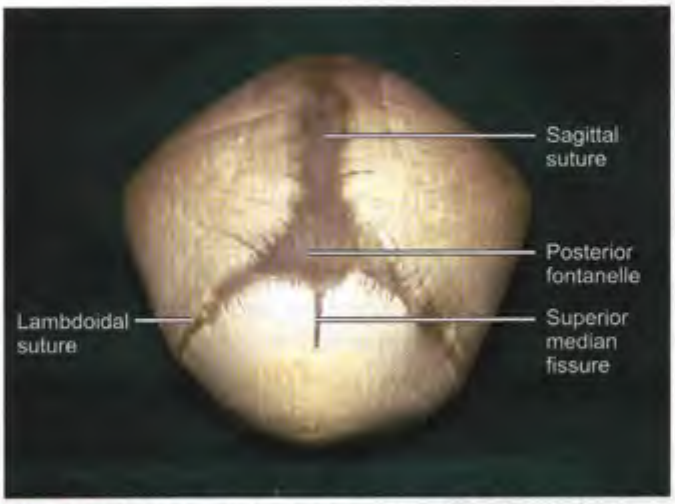


Fig. 4.2C: Location of the various fontanelles (posterior view)

amount of deformation of the skull at birth—a fact which is important in allowing the relatively large head to pass through the birth canal.

After birth, apposition of bone along the edges of the fontanelles eliminates these open spaces fairly quickly, but the bones remain separated by a thin periosteum lined suture for many years, eventually fusing in adult life.

The newborn not only has his frontal bone separated by the soon to close metopic suture, but also has no frontal sinuses. Both the inner and outer surfaces are quite parallel and quite close to each other. With the general growth and thickening of the cranial vault there is an increase in the distance between the internal and external plates in the supraorbital region. This may be seen on the external surface as a ridge. The spongy bone between the external plates is gradually replaced by the developing frontal sinus.

The cranial vault increases in width primarily through 'fill in' ossification of the proliferating connective tissue in the coronal, lambdoidal, interparietal, parietosphenoidal and parietotemporal sutures. It should be realized that there is actual translation as well as remodeling of the individual bones, with the structures being moved outward by the growing brain. Despite early accomplishment of the pattern, the parietal bones do not close until the middle of third decade of life.

Increase in length of the brain case may be primarily due to the growth of the cranial base with active response at the coronal suture.

Height of the brain case is due to the activity of the parietal sutures along with the occipital, temporal, and sphenoidal contiguous osseous structures.

Table 4.1: Percentage for growth in length of the cranial vault at various ages (Davenport)

Birth	63 percent
06 months	76 percent
1 year	82 percent
2 years	87 percent
3 years	89 percent
5 years	91 percent
10 years	95 percent
15 years	98 percent

THE CRANIAL BASE

The cranial base, unlike cranial vault, is not completely dependent on brain growth and may have some intrinsic genetic guidance and a pattern that is, similar in some dimensions, to that of the facial skeleton.

In contrast to the cranial vault, the bones of the cranial base are formed initially in the cartilage and are later transformed by endochondral ossification into bone. This is particularly true of the midline structures. As one moves laterally, growth at sutures becomes more important, but the cranial base is essentially a midline structure.

Centers of ossification appear early in embryonic life in the chondrocranium, indicating the eventual location of the basioccipital, sphenoid and ethmoid bones that form the cranial base (Fig. 4.3).

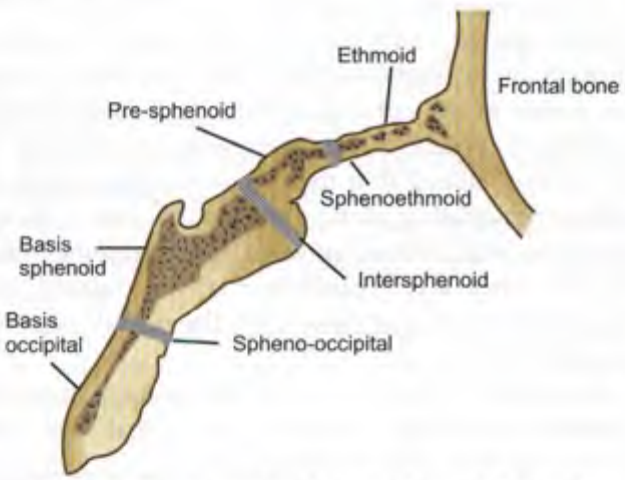


Fig. 4.3: The bones that form the base of the skull

The cranial base grows primarily by cartilage growth in the sphenoethmoidal, intersphenoidal, spheno-occipital and intraoccipital synchondroses, mostly following the neural growth curve (Fig. 4.4).

Activity at the intersphenoidal synchondrosis disappears at birth. The intraoccipital synchondrosis closes in the 3rd to 5th years of life. The spheno-occipital synchondrosis is a major contributor as the ossification here extends till the 20th year of life.

THE NASOMAXILLARY COMPLEX

The growth of the cranium and facial skeleton progress at different rates (Scammon). By differential growth,



Fig. 4.4: Growth at the inter-sphenoidal synchondrosis



Fig. 4.5: The nasomaxillary complex as it emerges from beneath the cranium

the face literally emerges from beneath the cranium (Fig. 4.5). The upper face, under the influence of cranial base inclination, moves upwards and forwards; the lower face moves downwards and forwards on an 'expanding V".

Since the maxillary complex is attached to the cranial base, there is a strong influence of the latter on the former. Although, there is no sharp line of demarcation between cranium and maxillary growth gradients, yet the position of the maxilla is dependent upon the growth at spheno-occipital and spheno-ethmoidal synchondroses. Hence, while discussing the growth of nasomaxillary complex, we have to look into two aspects.

1. The shift in the position of the maxillary complex, and
2. The enlargement of the complex itself.

Needless to say that both these issues are interrelated and concomitant. Enlow and Bang apply the principle of "area relocation" to the complex and multidirectional growth movements. As the dynamic process continues, " specific local areas come to occupy new actual positions in succession, as the entire bone enlarges. These growth shifts and changes involve corresponding and sequential remodeling adjustments in order to maintain the same shape, relative positions and constant proportions of each individual area in the maxilla as a whole". Moss described these as translocation and transposition respectively.

The maxilla develops entirely by intramembranous ossification. Sutural connective tissue proliferations, ossification, surface apposition, resorption and translation are the mechanisms for maxillary growth. The maxilla is related to the cranium at least partially by the frontomaxillary suture, the zygomaticomaxillary suture, zygomaticotemporal suture and pterygopalatine suture. Weinmann and Sicher have pointed out that these sutures are all oblique and more or less parallel with each other (Fig. 4.6). Thus, growth in these areas would serve to move the maxilla downward and forward (or the cranium upward and backward) (Fig. 4.6).

Moss and Greenberg point out that the basic maxillary skeletal unit is the infraorbital neurovascular triad, where the maxillary basal bone largely serves as a protection mechanism for the trigeminal nerve. It is this neurotrophic influence, which maintains the spatial constancy for the infraorbital canal with respect to the anterior cranial base. Thus, indirectly it produces a similar constancy of the basal maxillary skeletal unit relative to the same base.

Moss cites three types of bone growth changes to be observed in the maxilla.

1. Those changes that are associated with compensations for the passive motions of the bone brought about by the primary expansion of the orofacial capsule.
2. There are changes in bone morphology associated with alterations in the absolute volume, size shape or spatial position of any or all of the several relatively independent maxillary functional matrices, such as orbital mass.
3. There are bone changes associated with the maintenance of the form of the bone itself.

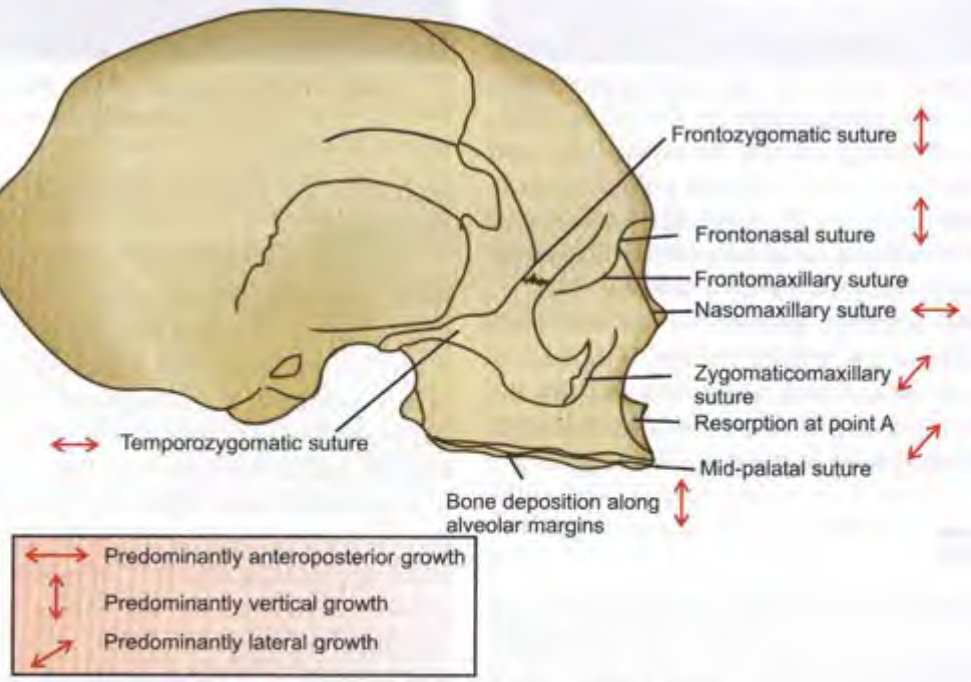


Fig. 4.6: The placement of the various sutures

All these changes do not occur simultaneously but rather differentially or sequentially.

To analyze the growth of the maxilla better , we must shift our focus to the functional matrices. It has been noted that the growth of the eyeball is essential for the development of the orbital cavity. Experimental evidence suggests that if there is no primordium for the eye, there is no orbit. It is clear that this functional matrix has a direct effect on the contiguous osseous structures. Also, just as the neurocranial bones are enclosed within a neurocranial capsule, the facial bones are enclosed within the orofacial capsule. Resultantly the facial bones are passively carried outward (downward, forward, and laterally) by the primary expansion of the enclosed orofacial matrices (orbital, nasal, oral matrices). In addition there is an essential growth of the sinuses and spaces themselves, which perform important functions. The resultant maxillary changes would thus be secondary, compensatory and mechanically obligatory. In anteroposterior direction vector, the forward, passive motion of the maxilla is constantly being compensated for by the accretions at the maxillary tuberosity and at the palatal processes of both the maxillary and the palatine bones.

Specifically mentioning, the vertical growth of the maxillary complex is due to the continued apposition of alveolar bone on the free borders of the alveolar process as the teeth erupt. As the maxilla descends, continued bony apposition occurs on the orbital floor, with concomitant resorption on the nasal floor and apposition of the bone on the inferior palatal surface. By the alternate process of bone deposition and resorption, the orbital and nasal floors and the palatine vault move downward in a parallel fashion.

Transversely, additive growth on the free ends increases the distance between them. The buccal segments move downward and outward, as the maxilla itself is moving downward and forward, following the principle of expanding "V" (Fig. 4.7).

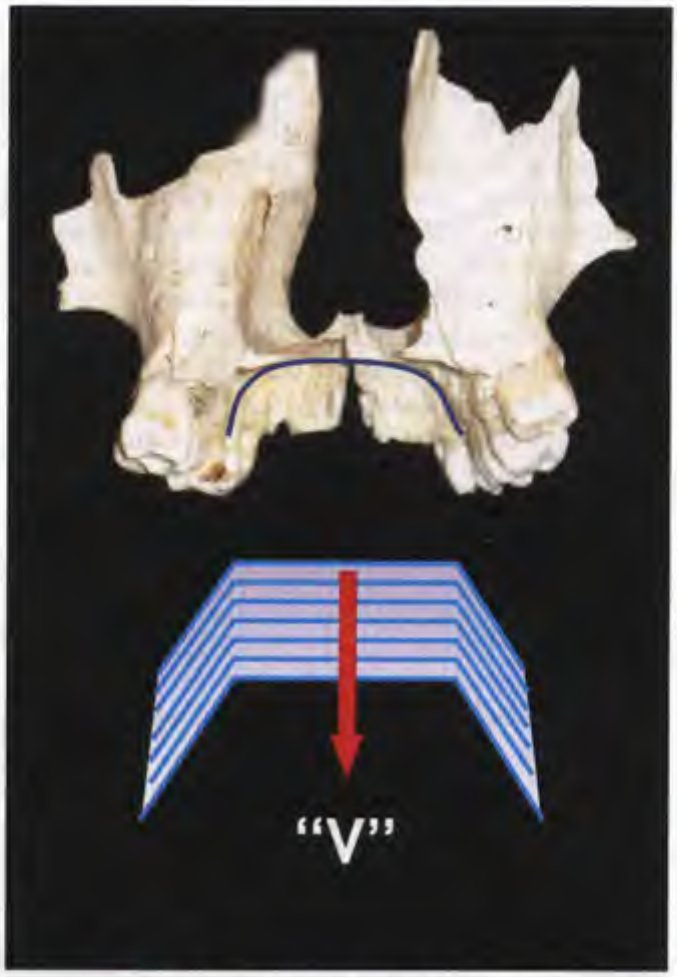


Fig. 4.7: The expanding 'V' in the downward and forward growth of the maxilla

THE MANDIBLE

In contrast to maxilla, *both endochondral and periosteal activities* are important in growth of the mandible. Cartilage covers the surface of the mandibular condyle at the temporomandibular joint. All other areas of the mandible are formed and grow by direct surface apposition.

At birth the two rami of the mandible are quite short. Condylar development is minimal and there is practically no articular eminence in the glenoid fossa. A thin line of fibrocartilage and connective tissue exists at the midline of the symphysis to separate right and left mandibular bodies. Between four months of age and the end of the first year, the symphyseal cartilage is replaced by bone. Although growth is quite general during the first year of life, with all surfaces showing bone apposition, there is apparently no significant growth between the two halves before they unite. During the first year of life, appositional growth is specially active at the alveolar border, at the distal and superior surfaces of the ramus, at the condyle, along

the lower border of the mandible and on its lateral surfaces (Fig. 4.8).

After the first year of life the mandibular growth becomes more selective. The condyle does show considerable activity as the mandible moves and grows downward and forwards. Heavy appositional growth occurs on the posterior border of the ramus and on the alveolar process. Significant increments of growth are still observed at the tip of coronoid process.

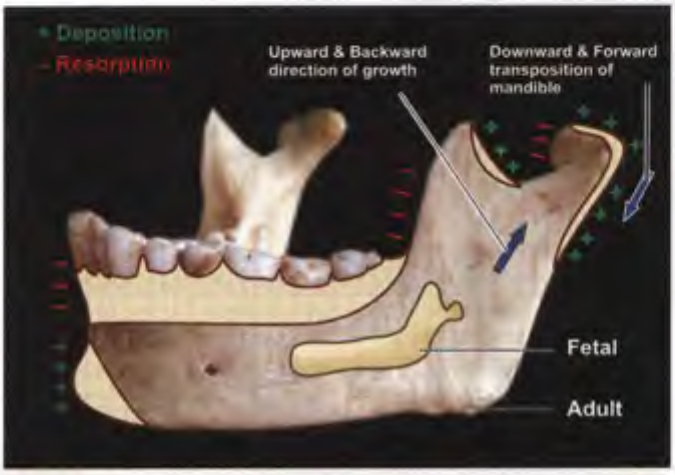


Fig. 4.8: Bone deposition and resorption sites at the mandible



Fig. 4.9: The expanding 'V' principle in the development of the mandible

Resorption occurs along the anterior border of the ramus lengthening the alveolar border and maintaining the antero-posterior dimension of the ramus. Cephalometric studies indicate that the body of the mandible maintains a relatively constant angular relationship to the ramus throughout life. The gonial angle changes little after the muscle activity is established. Transverse dimensions, after the first year of life are mainly due to the growth at the posterior border in an expanding "V" pattern (Fig. 4.9). The two rami also diverge outward from below to above so that additive growth at the coronoid notch, coronoid process and condyle also increases the superior inter-ramus dimension.

Alveolar processes of the mandible grows upward and outward on an expanding arc. This permits the dental arch to accommodate the larger permanent teeth. Relatively little increase in mandibular body width is noted after the cessation of lateral surface appositional growth. Modeling deposition at the canine eminence and along the lateral border is seen.

Scott divides the mandible into three basic types of bone: basal, muscular and alveolar. The basal portion is a tube like central foundation running from the condyle to the symphysis. The muscular portion (gonial angle and the coronoid process) is under the influence of the masseter, internal pterygoid and temporalis muscle. Alveolar bone exists to hold the teeth and it is gradually resorbed in the event of tooth loss.

Moss speaks of the mandible as a group of micro-skeletal units (Fig. 4.10).

The coronoid process is one skeletal unit under the influence of temporalis. The gonial angle is another

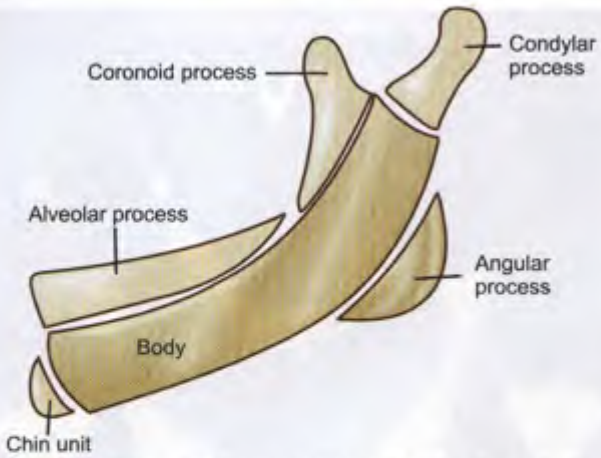


Fig. 4.10: The microskeletal units in the mandible as proposed by Moss

skeletal unit under the influence of masseter and internal pterygoid muscles. The alveolar process is under the influence of the dentition. The basal tubular portion of the mandible serves as protection for the mandibular canal and apparently follows a logarithmic spiral in its downward and forward movement from beneath the cranium.

THE CHIN: Enlow and Harris feel that chin is associated with a generalized cortical recession in the flattened regions positioned between the canine teeth. The process involves a mechanism of endosteal cortical growth.

On the lingual surface behind the chin, heavy periosteal growth occurs, with the dense lamellar bone merging and overlapping on the labial side of the chin. Particularly in the male, the apposition of the bone at the symphysis seems to be about the last change in shape during the growing period. This means that some time between 16 and 25 years of age, appositional changes give a new shape to the symphysis in males. This change is much less apparent in females.

FURTHER READING

1. Copay JC. Growth of the nasal septal cartilage of the rat invitro, J Anat 1986;144:99-111.
2. DuBrul EL, Sicher H. Te Adaptive Chin. Springfield Ill., Charles C Thomas, 1954.
3. Enlow DH, Bang S. Growth and remodeling of the human maxilla, Am J Orthod, 1965;51:446-64.
4. Enlow DH, Hans MG. Essentials of Facial Growth, Philadelphia, 1996, W. B Saunders
5. Enlow DH, Harris DB. A study of the postnatal growth of the human mandible, Am J Orthod, 1964;50:25050.
6. Ferguson MWJ. Development of face and palate, CPCJ, 1988;32;522-4.
7. Ferguson MWJ. Palate development, Developoment, 1988;103 suppl:41-60.
8. Ghafari J, Degroote C. Condylar cartilage response to continuous mandibular displacement in the rat. Angle Orthod 1986;56:49-57.
9. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
10. Koski K. Cranial growth centers: fact or fallacies? Am J Orthod 1968;54:566-83.
11. Moss ML, Rankow RM. The role of the functional matrix in mandibular growth. Angle Orthod, 1968;38:95-103.
12. Moss ML. The primary role of functional matrices in facial growth, Am J Orthod 1969;55:566-77.
13. Proffit WR (Ed). Concepts of growth and development. In Contemporary Orthodontics. 2nd edn. Pp. 24-62. St Louis: Mosby Yearbook, 1999.
14. Sicher H. The growth of the mandible, Am J Orthod, 1947;33:30-35.
15. Sperber GH. Craniofacial Embryology. In dental Practitioner Handbook, 4th edn. London: Wright, 1996.
16. Ten cate AR. Oral Histology: Development Structure and Function, CV. Mosby, St Louis, 1980

5 Development of Dentition

Tapasya Juneja, Gurkeerat Singh

- Introduction
- Evolution
- Theories of origin of mammalian teeth
- Characteristics of human dentition
- Prenatal development of dentition
- Development of dentition from birth to complete deciduous dentition
- The mixed dentition stage
- The permanent dentition
- Eruption
- Dimensional changes in the dental arches
- Developmental disturbances affecting the teeth
- Conclusion

INTRODUCTION

Dentition is defined as type, number and arrangement of teeth or it refers to all upper and lower teeth collectively. The upper and lower arches are a functional unit made up of specific components, i.e. the teeth. The mammalian dentition goes back 75 million years. The dental formula of early primates consisted of 2 incisors, 1 canine, 4 premolars and 3 molars.

EVOLUTION

The jaws and teeth in the humans have undergone evolutionary changes over several years to reach their present form. Reptilian dentition was polyphyodont (many sets of teeth) which evolved to diphyodont (only 2 sets of teeth) in mammals. Also the dentition evolved from homodont (all teeth same) to heterodont (different types of teeth) in the present day humans.

To develop a functional occlusion it became necessary for the teeth and bones to develop synchronously. Over a period of time there was loss or fusion of cranial and facial bones, the number of bones have reduced and dental formula has also undergone changes.

THEORIES OF ORIGIN OF MAMMALIAN TEETH

THEORY OF CONCRESCENCE

Mammalian dentition was produced by the fusion of two or more primitive conical teeth and each tubercle with its root originated as simple reptilian tooth.

THEORY OF TRITUBERCULY

Each of the mammalian tooth was derived from a single reptilian tooth by secondary differentiation of tubercles and roots.

THEORY OF MULTI-TUBERCULY

Mammalian dentition is a result of reduction and condensation of primitive multi-tuberculate teeth.

In terms of evolution, teeth are said to have developed from lobes or primary centrals. Incisors, premolars and maxillary molars developed from 4 lobes whereas mandibular molars developed from 5 lobes.

CHARACTERISTICS OF HUMAN DENTITION

MODE OF ATTACHMENT

Teeth may be attached to the jaws in the following ways:

- *Acrodont* Teeth attached to the jaw by a connective tissue.
- *Pleurodont* Teeth are set inside the jaws.
- *Thecodont* Teeth inserted in a bony socket.

NUMBER OF SUCCESSIVE TEETH

- *Polyphyodont* Teeth replaced throughout life, e.g. shark
- *Diphyodont* Two sets of teeth, e.g. humans
- *Monophyodont* Single set of teeth, e.g. sheep.

SHAPE OF TEETH

- *Homodont* Single type of teeth.
- *Heterodont* Teeth of different shapes, e.g. incisors, molars, etc. as in humans.

Dental Formula in Humans

Deciduous: I 2/2 C 1/1 M 2/2 =10
Permanent: I 2/2 C1/1 P 2/2 M 3/3= 16

PRENATAL DEVELOPMENT OF DENTITION

The embryonic oral cavity is lined by stratified squamous epithelium called the *oral ectoderm*, which is visible around 28-30 days of intrauterine life.

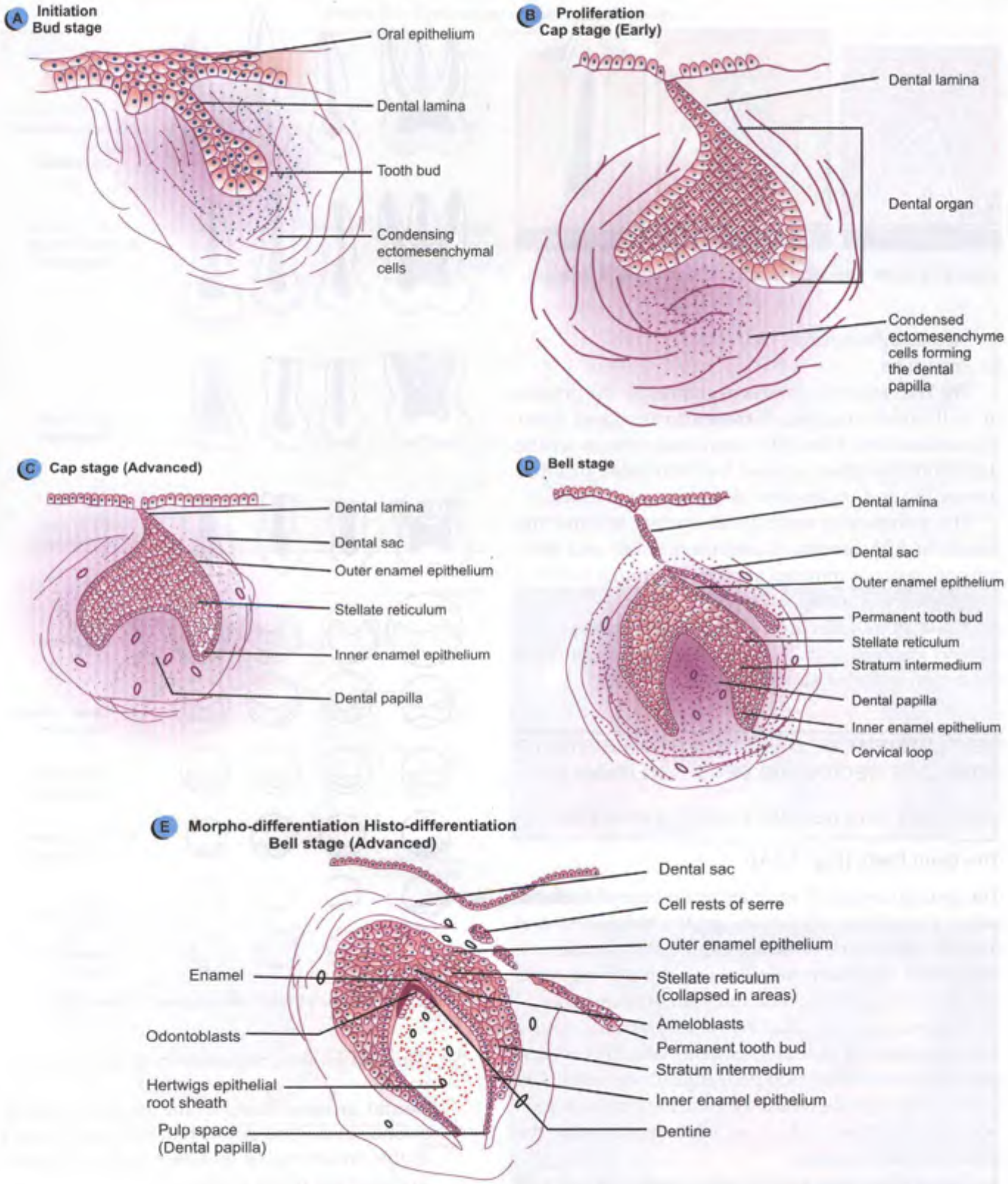
The first sign of tooth development appears late in the 3rd embryonic week when the epithelial lining begins to thicken on the inferior border of the maxillary process and the superior border of the mandibular process which join to form the lateral margins of the oral cavity.

At 6 weeks, four maxillary odontogenic zones coalesce to form the dental lamina and the two mandibular zones fuse at the midline. The dental lamina is the foundation for the future dental arches. Tooth formation begins with invagination of the dental lamina epithelium into the underlying mesenchyme at specific locations.

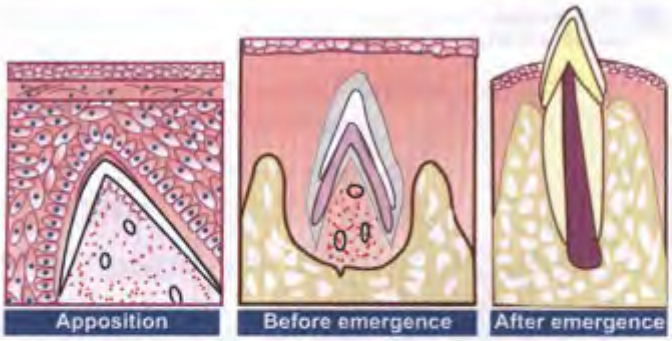
The dental lamina gets demarcated into ten knob-like structures namely the tooth bud/germ. A tooth bud (Fig. 5.1) consists of an enamel organ, which is derived from the oral ectoderm, a dental papilla and a dental sac, both of which are derived from the mesenchyme. Each of these swellings of the lamina proliferate and differentiate, passing through various histological and morphological differentiation stages namely bud, cap and bell stages.

STAGES OF TOOTH BUD DEVELOPMENT (Fig. 5.1)

1. *Initiation* This is the first epithelial incursion into the ectomesenchyme of the jaw. The tooth bud is the primordium of the enamel organ. Histologically it consists of peripheral low columnar cells and centrally located polygonal cells. The area of ectomesenchymal condensation subjacent to the bud is the dental papilla. The dental sac surrounds the tooth bud and the dental papilla. The dental papilla later on forms the dentin and pulp whereas the dental sac forms cementum and the periodontal ligament. Initiation takes place as follows:
   - Deciduous dentition: 2nd month *in utero*.
   - Permanent dentition: Growth of the free distal end of dental lamina gives rise to the successional lamina, which initiates the permanent dentition; starts from 5th month *in utero*.
   - Dental lamina elongates distal to the second deciduous molar and gives rise to the permanent molar tooth germs.
2. *Proliferation* Unequal growth in different parts of the bud produces a shallow invagination on the deep surface of the bud to produce a cap shaped structure. Histologically it is made up of the outer enamel epithelium (cuboidal cells) at the convexity of the cap and the inner enamel epithelium (tall, columnar cells) at the concavity of the cap. Between the above 2 layers polygonal cells are located which is known as the stellate reticulum. These cells assume a branched reticular network as more intercellular fluid is produced.
3. *Histo-differentiation* The enamel organ now assumes a bell shape as the invagination of the cap continues and the margins grow longer. Four different layers are seen. The inner enamel epithelium (IEE) cells remain tall columnar cells. The outer enamel epithelium flatten to low cuboidal cells. The stellate reticulum expands further and the cells become star shaped. A new layer of cells known as Stratum Intermedium whose function is to provide nutrition to IEE cells appears between inner enamel epithelium and stellate reticulum.



Figs 5.1A to E: Life cycle of a tooth (growth phase)



Figs 5.1A to H: Life cycle of tooth (Calcification to eruption)

4. *Morpho-differentiation (bell stage)*
5. *Apposition*

The enamel organ produces enamel by the process of cell proliferation, differentiation and later mineralization. Mineralization commences in the deciduous dentition around the 14th week of intrauterine life and occurs first in the central incisors.

The permanent tooth buds appear around the fourth to fifth month of intrauterine life and their mineralization is initiated at birth, beginning with the first permanent molar.

Nolla (1960) divided tooth development into various stages (Fig. 5.2). He took the calcification of the crown and root structures into account.

DEVELOPMENT OF DENTITION FROM BIRTH TO COMPLETE DECIDUOUS DENTITION (Table 5.1)

MOUTH OF THE NEONATE—0 TO 6 MONTHS

The Gum Pads (Fig. 5.3A)

The alveolar arches of an infant at the time of birth are called Gum Pads. These are greatly thickened oral mucous membrane of the gums, which soon become segmented, and each segment is a developing tooth site. They are pink in color and firm in consistency.

The pads get divided into a labio/buccal and a lingual portion which differentiates later. Transverse grooves separate the gum pads into 10 segments. The groove between the canine and the first molar region is called the lateral sulcus, which helps to judge the inter-arch relationship.

- The upper gum pad is horse shoe shaped and shows:

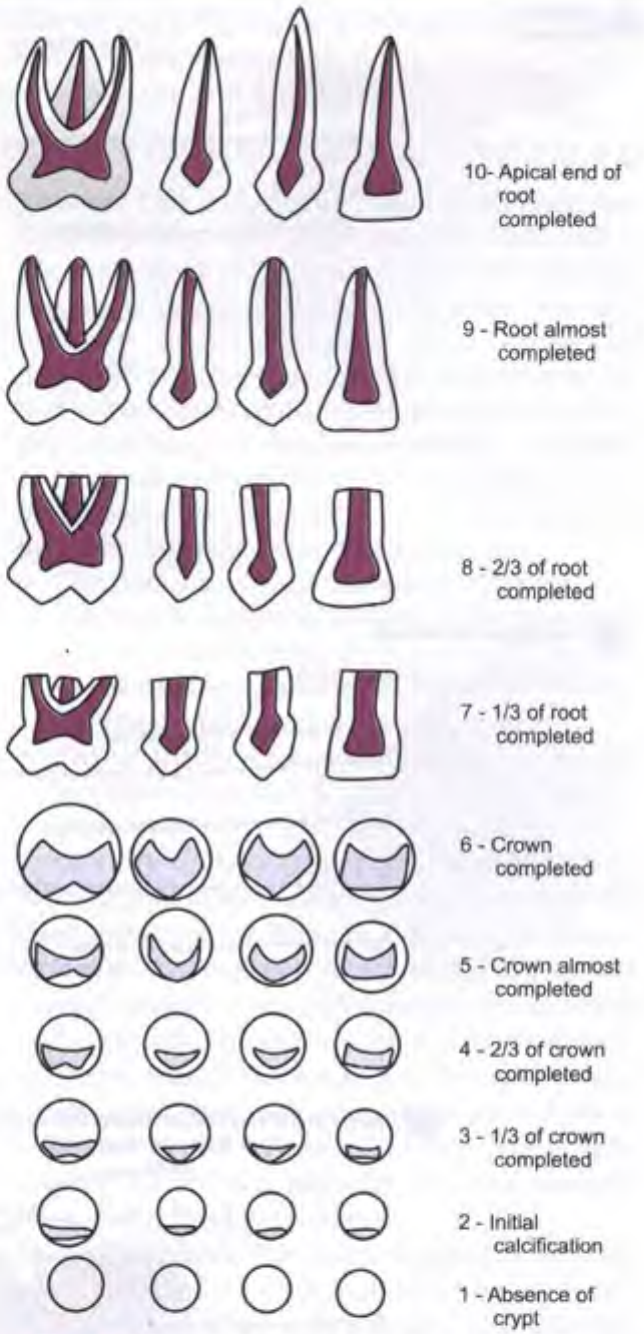


Fig. 5.2: Stages of tooth development (Nolla 1960)

— Gingival groove: Separates gum pad from the palate.
— Dental groove: Starts at the incisive papilla, extends backward to touch the gingival groove in the canine region and then moves laterally to end in the molar region.
— Lateral sulcus.

Table 5.1: Chronology of tooth development

Tooth		Tooth germ fully developed	Dentine formation begins	Calcification begins	Crown formation complete	Appearance in oral cavity	Root complete
Deciduous	Incisors	3-4 mths	4-6 mths i.u.l.		2-3 mths	6-9 mths	1-1.5 yrs after
	Canines	i.u.l.			9 mths	16-18 mths	appearance in
	1st Molars				6 mths	12-14 mths	the mouth
	2nd Molars				12 mths	20-30 mths	
Permanent	Maxillary centrals	30th week i.u.l.	3-4 mths	3-4 mths	4-5 yrs	7-9 yrs	2-3 yrs after
	Mandibular centrals			3-4 mths		6-8 yrs	appearance in
	Maxillary laterals		10-12 mths	10-12 mths		7-9 yrs	the mouth
	Mandibular laterals		3-4 mths	3-4 mths		6-8 yrs	
	Maxillary canines	30th week i.u.l.	4-5 mths	4-5 mths	6-7 yrs	11-12 yrs	2-3 yrs after
	Mandibular canines					9-10 yrs	appearance in the mouth
	Maxillary 1st premolar	30th week i.u.l.	1.5-2.5 yrs	1.5-1.75 yrs	5-6 yrs	10-11 yrs	2-3 yrs after
	Mandibular 1st premolar			1.75-2 yrs		10-12 yrs	appearance in
	Maxillary 2nd premolar			2-2.25 yrs	6-7 yrs	10-12 yrs	the mouth
	Mandibular 2nd premolar			2.25-2.5 yrs		11-12 yrs	
	1st molar	24th week i.u.l.	Before birth	At or shortly after birth	2.5-3 yrs	6-7 yrs	2-3 yrs after appearance in
	2nd molars	6th mth	2.5-3 yrs	2.5-3 yrs	7-8 yrs	11-13 yrs	the mouth
	3rd molars	6th yr	7-10 yrs	7-9 yrs	12-16 yrs	17-21 yrs	

i.u.l. = intra-uterine life

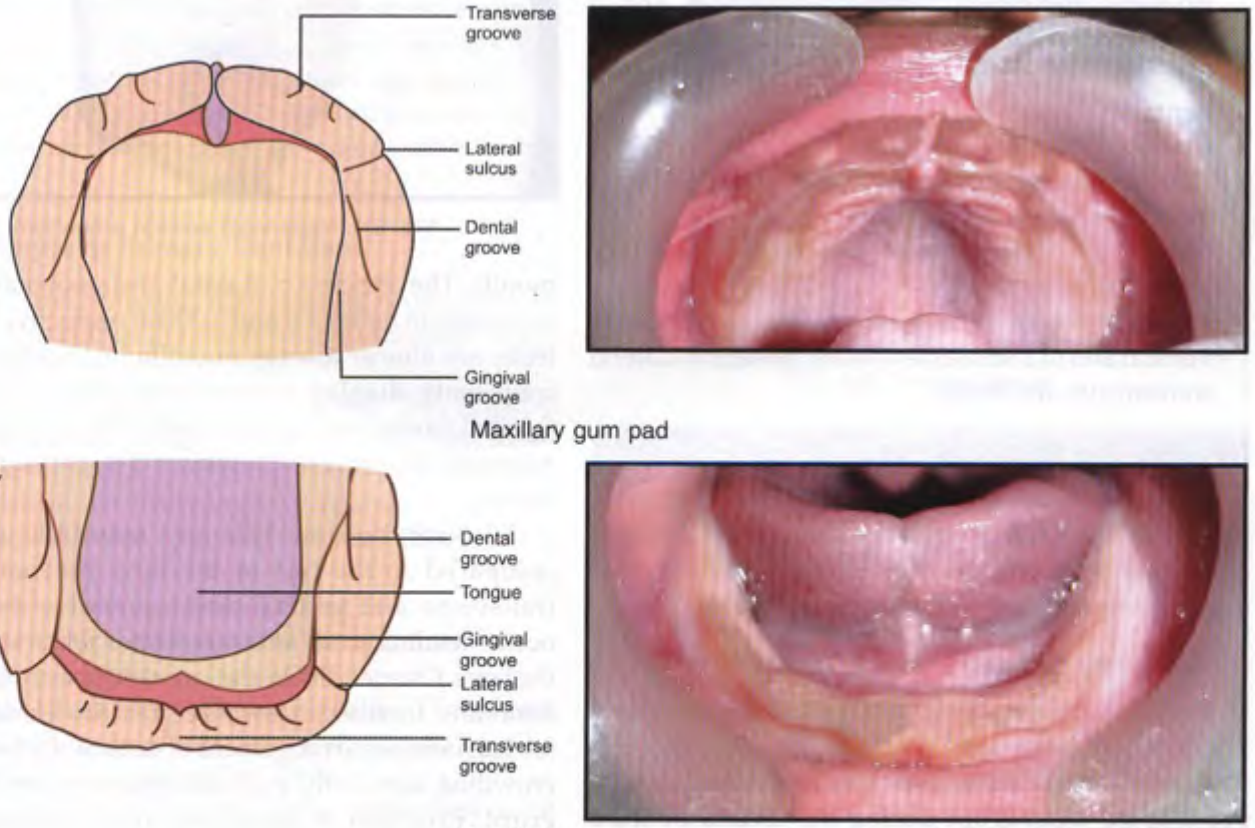


Fig. 5.3A: Gum pads (a) Maxillary (b) Mandibular



Fig. 5.3B: Relation between upper and lower gum pads at birth

- The lower gum pad is U-shaped and rectangular, characterized by:
  - — Gingival groove: Lingual extension of the gum pads.
  - — Dental groove: Joins gingival groove in the canine region.
  - — Lateral sulcus.

Relationship of gum pads (Fig. 5.3B)

- Anterior open bite is seen at rest with contact only in the molar region. Tongue protrudes anteriorly through this space. The intermaxillary space closure, occurs with eruption of primary teeth, thus it is a self-correcting anomaly of the developing dentition.
- Complete overjet
- Class II pattern with the maxillary gum pad being more prominent.
- Mandibular lateral sulci posterior to maxillary lateral sulci.
- Mandibular functional movements are mainly vertical and to a little extent anteroposterior. Lateral movements are absent.

Neonatal Jaw Relationships

A precise "bite" or jaw relationship is not yet seen. Therefore, neonatal jaw relationship cannot be used as a diagnostic criterion for reliable prediction of subsequent occlusion in the primary dentition.

Precociously Erupted Primary Teeth

Occasionally a child is born with teeth already present in the mouth. Natal teeth (Fig. 5.4) are present at birth whereas neonatal teeth erupt during the first month. Pre-erupted teeth erupt during the second or third



Fig. 5.4: Natal tooth seen in a newborn

month. The incidence of natal and neonatal teeth is estimated to be 1:1000 and 1:30000 respectively. These teeth are almost always mandibular incisors, which frequently display enamel hypoplasia. There are familial tendencies for such teeth. They should not be removed if normal but removed if supernumerary or mobile.

At birth, both maxilla and mandible are small compared to the rest of the face. Extensive early transverse and ventral development of both jaws occurs leading to an anteroposterior relation between the jaws. Overjet diminishes markedly during the first 6 months. Increase in jaw size provides enough space for harmonious arrangement of deciduous teeth. Thus crowding seen in the pads disappears when the teeth erupt. Eruption of deciduous teeth commences at



Fig. 5.5: Spacing in deciduous dentition

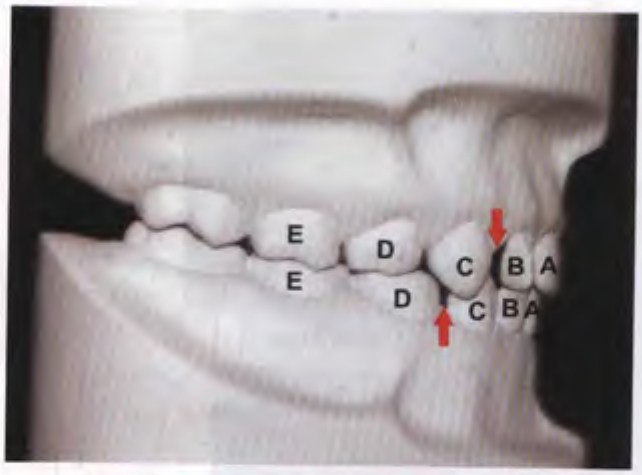
about 6 months of age. Occlusion starts developing posteriorly when deciduous first molars attain contact. By the time the first molars have settled, occlusion in the posterior region is established.

THE DECIDUOUS DENTITION STAGE

The deciduous dentition stage starts from the eruption of the first deciduous tooth, usually the deciduous mandibular central incisors and ends with the eruption of the first permanent molar, i.e. from 6 months to 6 years of postnatal life. By 2½ years of age, deciduous dentition is usually complete and in full function. Root formation of all deciduous teeth is complete by 3 years of age.

Normal Signs of Primary Dentition

a. Spaced anteriors (Fig. 5.5): Spacing is usually seen in the deciduous dentition to accommodate larger permanent teeth in the jaws.
b. Primate/simian/anthropoid space: This space is present mesial to the maxillary canine and distal to the mandibular canine (Fig. 5.6). Most subhuman primates have it throughout life and use it for interdigitation of opposing canines. This space is used for early mesial shift.
c. Shallow overjet and overbite (Fig. 5.7).
d. Almost vertical inclination of the anteriors.
e. Ovoid arch form.
f. Straight/flush terminal plane relation: The molar relationship in the primary dentition can be classified into 3 types (Fig. 5.8A).
   - *Flush terminal plane* When the distal surfaces of maxillary and mandibular deciduous second



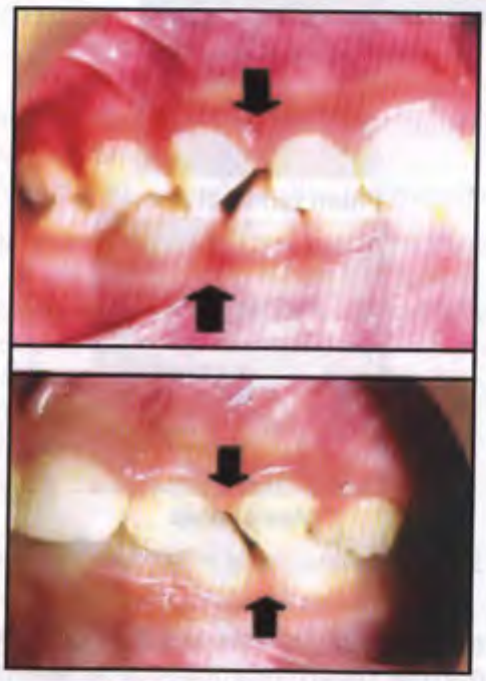


Fig. 5.6: Primate spaces



Fig. 5.7: Decreased overjet and overbite, even with the congenital absence of the deciduous mandibular lateral incisors



Distal step



Flush terminal plane



Mesial step

Fig. 5.8A: Molar relationship in the deciduous dentition

molars are in the same vertical plane; this is the normal molar relationship in the primary dentition because the mesiodistal width of the mandibular molar is greater than the mesiodistal width of the maxillary molar.

- *Mesial step* Distal surface of mandibular deciduous second molar is mesial to the distal surface of maxillary deciduous second molar.
- *Distal step* Distal surface of mandibular deciduous second molar is more distal than the distal surface of maxillary deciduous second molar, i.e. the upper second molar occludes with two opposite teeth.

Between 5 and 6 years, just before shedding of the deciduous incisors, there are more teeth in the jaws than at any other time.

THE MIXED DENTITION STAGE

This is the period where teeth of both deciduous and permanent dentition are seen. It extends from 6-12 years of age. Most malocclusions make their appearance during this stage. This stage can be divided into two transitional periods—first and second.

FIRST TRANSITIONAL PERIOD

Emergence of the first permanent molars and transition of incisors The following events take place during this period.

Eruption of Permanent First Molars

The first permanent molars erupt at 6 years. They play an important role in the establishing and in the functioning of occlusion, in the permanent dentition.

Anteroposterior positioning of the permanent molars is influenced by:

1. Terminal plane relationship (Fig. 5.8B)
   - When the deciduous second molars are in a flush terminal plane, the permanent first molar erupts initially into a cusp-to-cusp relationship, which later transforms into a Class I molar relation using the primate spaces (Fig. 5.8C). Later, cusp-to-cusp relationship of the permanent first molar can be converted to a

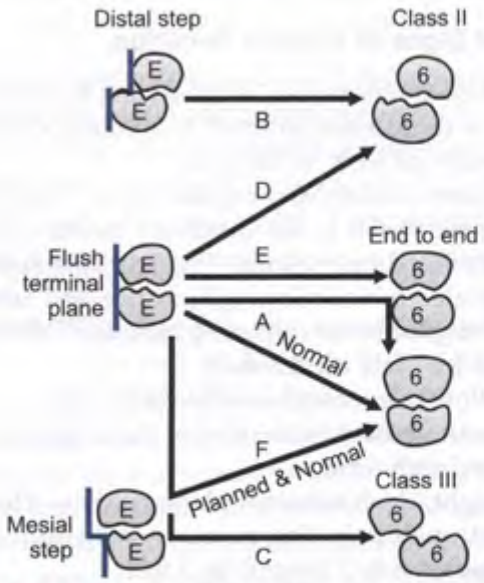


Fig. 5.8B: Occlusal relationships of primary and permanent molars

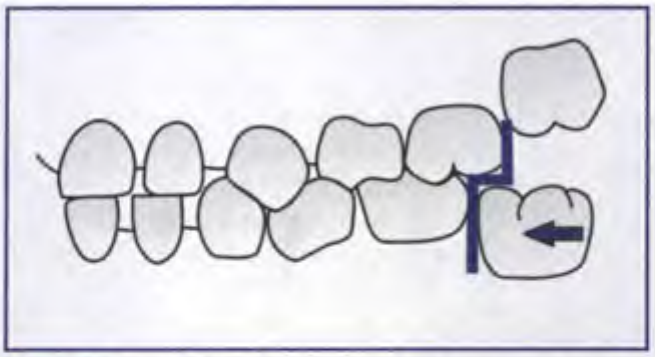


Fig. 5.8C: Early shift of the erupting first permanent molars moving utilizing the primate spaces

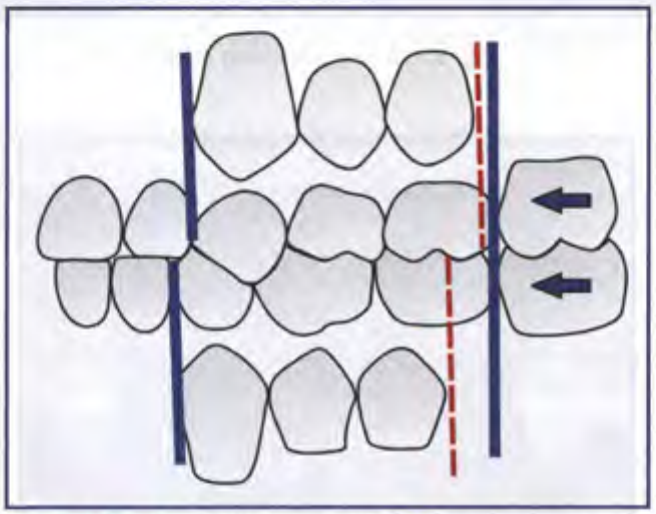


Fig. 5.8D: Late shift by utilization of the Leeway space

Class I relationship by the mesial shift of the permanent first molar following exfoliation of the primary molar and thus making use of the Leeway space (late mesial shift, Fig. 5.8D).

- When the deciduous second molars are in a distal step, the permanent first molar will erupt into a Class II relation. This molar configuration is not self-correcting and will cause a Class II malocclusion despite Leeway space and differential growth.
- Primary second molars in mesial step relationship lead to a Class I molar relation in mixed dentition. This may remain or progress to a half or full cusp Class III with continued mandibular growth.

2. Early mesial shift in arch with physiologic spacing: In a spaced arch, eruptive force of the permanent molars causes closing of any spaces between the primary molars or primate spaces, thus allowing molars to shift mesially (Fig. 5.8C).
3. Differential growth of maxilla and mandible.

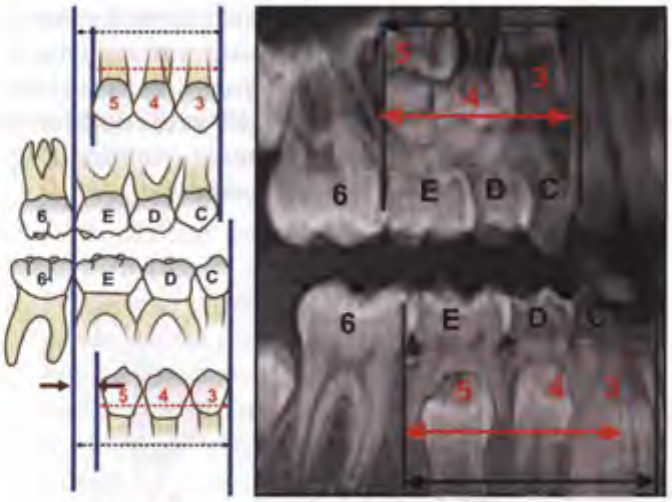


Fig. 5.9: Leeway space of Nance

Leeway space of Nance The combined mesiodistal widths of deciduous canine, first and second molars is more than that of the combined mesiodistal width of permanent canine, first and second premolar (Figs 5.8D and 5.9). The difference between the two is called the Leeway space.

Maxilla 0.9 mm/segment = 1.8 mm total
Mandible 1.7 mm/segment = 3.4 mm total.

Incisor Eruption

Permanent incisors develop lingual to the primary incisors. For incisors to erupt in normal alignment, there is an obligate space requirement in the anterior part of both the arches which is termed as *incisor liability*, i.e. the total sum of the mesiodistal width of four permanent incisors is larger than that of primary incisors by 7.6 mm in maxilla and 6 mm in mandible (*Wayne*). This obligate space is provided by:

- Interdental physiologic spacing in the primary incisor region: 4 mm in maxillary arch; 3 mm in mandibular arch.
- Increase in the inter-canine arch width: Significant amount of growth occurs with the eruption of incisors and canines.
- Increase in the anterior length of the dental arches: Permanent incisors erupt labial to the primary incisors to obtain an added space of 2-3 mm.

- Change in inclination of permanent incisors: Primary teeth are upright but permanent teeth incline to the labial surface thus decreasing the inter-incisal angle from about 150° in the deciduous dentition to 123° in the permanent dentition (Fig. 5.10). This increases the arch perimeter.

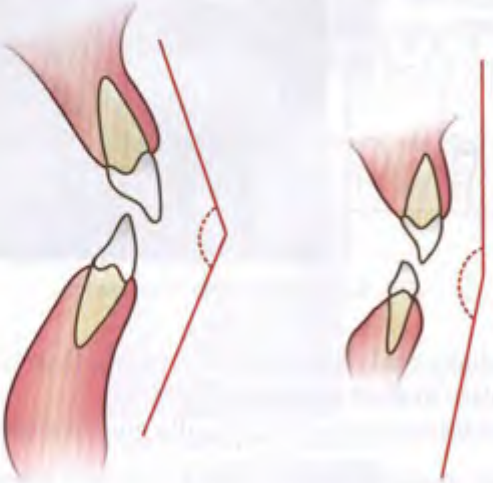


Fig. 5.10: Comparison of the angulation of the permanent and primary teeth

The Broadbent's Phenomenon—Ugly Duckling Stage (7-14 years)

Around the age of 8 years, a midline diastema is commonly seen in the upper arch, which is usually misinterpreted by the parents as a malocclusion. Crowns of canines in young jaws impinge on developing lateral incisor roots, thus driving the roots medially and causing the crowns to flare laterally. The roots of the central incisors are also forced together thus causing a maxillary midline diastema. The period from the eruption of lateral incisor to canine is termed as the Ugly Duckling stage (Fig. 5.11A). It is an unaesthetic metamorphosis, which eventually leads to an aesthetic result.

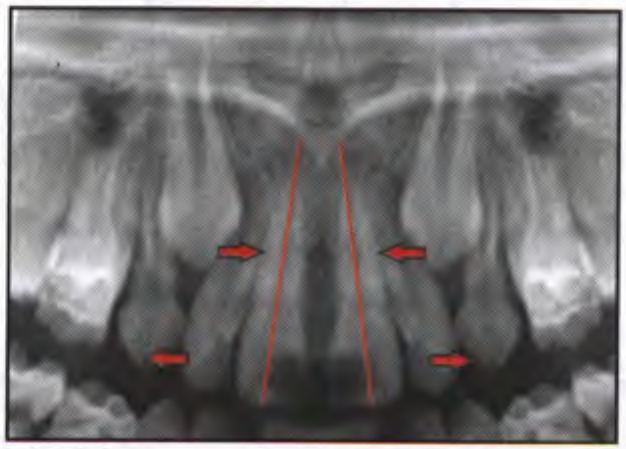
With eruption of canines, the impingement from the roots shifts incisally thus driving the incisor crowns medially, resulting in closure of the diastema (Fig. 5.11B).

THE INTER-TRANSITIONAL PERIOD (1.5 YEARS)

This is a stable phase where little changes take place in the dentition. The teeth present are the permanent



Fig. 5.11A: Ugly duckling stage



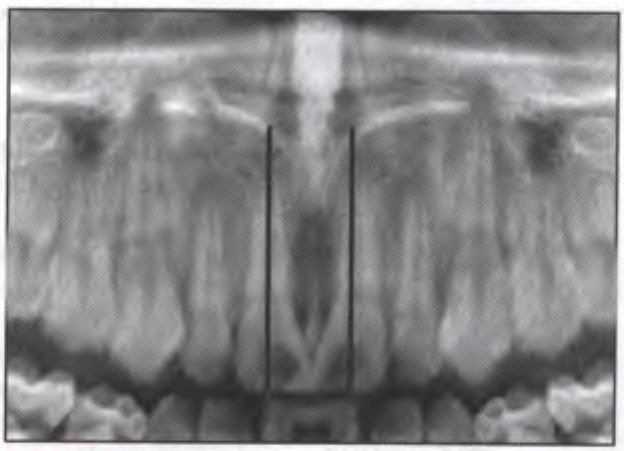


Fig. 5.11B: Ugly duckling stage (a) Canine crowns impinging on roots of lateral incisors with resultant distal flaring of incisor crowns (b) Continued eruption of canines results in closure of midline space

incisors and first molar along with the deciduous canines and molars. Some of the features of this stage are:

1. Any asymmetry in emergence and corresponding differences in height levels or crown lengths between the right and left side teeth are made up.
2. Occlusal and interproximal wear of deciduous teeth causes occlusal morphology to approach that of a plane.
3. Ugly duckling stage.
4. Root formation of emerged incisors, canines and molars continues, along with concomitant increase in alveolar process height.
5. Resorption of roots of deciduous molars.

This phase prepares for the second transitional phase.

THE SECOND TRANSITIONAL PERIOD

The following events take place:

1. *Exfoliation of primary molars and canines* At around 10 years of age, the first deciduous tooth in the posterior region, usually the mandibular canine sheds and marks the beginning of the second transitional period. Usually no crowding is seen before emergence except maybe between the maxillary first premolar and canine.
2. *Eruption of permanent canines and premolars* (Fig. 5.12) These teeth erupt after a pause of 1-2 years following incisor eruption. The first posterior teeth to erupt are the mandibular canine and first premolar (9-10 years) followed by maxillary premolars and canine around 11-12 years. Most common eruption sequence is 4-5-3 in the maxilla and 3-4-5 in the mandible. Favorable occlusion in this region is largely dependent on:
   - Favorable eruption sequence.
   - Satisfactory tooth size- available space ratio.
   - Attainment of normal molar relation with minimum diminution of space available for bicuspids.
3. *Eruption of permanent second molars* Before emergence second molars are oriented in a mesial and lingual direction. These teeth are formed palatally and are guided into occlusion by the Cone Funnel mechanism (the upper palatal cusp/cone slides into the lower occlusal fossa/funnel). The arch length is reduced prior to second molar eruption by the mesial eruptive forces. Therefore, crowding if present is accentuated.
4. *Establishment of occlusion*



Fig. 5.12: Eruption of the pre-molars

THE PERMANENT DENTITION

The permanent dentition forms within the jaws soon after birth. Calcification begins at birth with the calcification of the cusps of the first permanent molar and extends as late as the 25th year of life. Complete calcification of incisor crowns takes place by 4 to 5 years and of the other permanent teeth by 6 to 8 years except for the third molars. Therefore the total calcification period is about 10 years. The permanent incisors develop lingual to the deciduous incisors and move labially as they erupt. The premolars develop below the diverging roots of the deciduous molars.

Nolla (1960) gave stages of tooth development to make a meaningful assessment of eruption from panoramic/posteroanterior radiographs which is given in Figure 5.2 and elaborated in Table 5.1.

At approximately 13 years of age all permanent teeth except third molars are fully erupted. Before the deciduous incisors are shed, there are 48 teeth / parts of teeth present in the jaws.

Features of the permanent dentition:

- Coinciding midline.
- Class I molar relationship of the permanent first molar.
- Vertical overbite of about one-third the clinical crown height of the mandibular central incisors.

- *Overjet:* Overjet and over bite decreases throughout the second decade of life due to greater forward growth of the mandible.
- *Curve of Spee:* Develops during transition and stabilizes in adulthood.

ERUPTION

Eruption is the developmental process that moves a tooth from its crypt position through the alveolar process into the oral cavity and to occlusion with its antagonist. During eruption of succedaneous teeth:

- Primary tooth resorbs
- Roots of the permanent teeth lengthen
- Increase in the alveolar process height
- Permanent teeth move through the bone.

Teeth do not begin to move occlusally until crown formation is complete. It takes 2-5 years for posterior teeth to reach the alveolar crest following crown completion and 12-20 months to reach occlusion after reaching alveolar margin.

PROCESS OF TOOTH ERUPTION

Tencate divided tooth eruption into the following 3 stages:

1. Pre-eruptive tooth movement: Movement of tooth germs within the jaws before they begin to erupt.
2. Eruptive tooth movement: Tooth movement from its position within the jaws to its functional position.
3. Post-eruptive tooth movement: Maintaining the position of erupted tooth in occlusion while the jaws continue to grow.

Tooth eruption can also be divided into:

1. *Pre-emergent eruption* During the stage of crown formation, there is very slow labial or buccal drift of the tooth follicle within the bone. However, there is no eruptive movement.

   Two processes are necessary for a tooth to erupt intra-osseously:
   - Resorption of bone and primary tooth roots overlying the crown of the erupting tooth.
   - Eruption mechanism itself must move the tooth in the direction where the path has been cleared.

   Resorption is the rate-limiting factor in pre-emergent eruption.
2. *Post-emergent eruption* Once a tooth emerges into the mouth, it erupts rapidly (about 4 mm in 14 weeks) until it approaches the occlusal level and is subjected to the forces of mastication. This stage of relatively rapid eruption is called as the post-emergent spurt. This is followed by a phase of Juvenile Occlusal Equilibrium, i.e. after teeth reach the occlusal level; eruption becomes almost imperceptibly slow although it definitely continues. After the teeth are in function, they erupt at the same rate as the vertical growth of the mandibular ramus unless there is occlusal wear or the antagonist tooth is lost at any age, in which case additional eruption occurs. When the pubertal growth ends, a final phase of tooth eruption takes place known as Adult Occlusal Equilibrium.

FACTORS DETERMINING TOOTH POSITION DURING ERUPTION

Tooth passes through four distinct stages of development:

1. *Pre-eruptive* Initially position of tooth germ is dependent on heredity.
2. *Intra-alveolar* Tooth position is affected by-
   - Presence or absence of adjacent teeth
   - Rate of resorption of primary teeth
   - Early loss of primary teeth
   - Localized pathologic conditions.
3. *Intraoral stage* Tooth can be moved by lip, cheek, tongue muscles or external objects and drift into spaces.
4. *Occlusal stage* Muscles of mastication exert influence through interdigitation of cusps. The periodontal ligament disseminates the strong forces of chewing to the alveolar bone.

SEQUENCE OF ERUPTION

There is wide variability in the sequence of arrival of teeth in the mouth.

Maxilla 6-1-2-4-3-5-7 or 6-1-2-4-5-3-7 (most common)
Mandible 6-1-2-4-5-3-7 or 6-1-2-3-4-5-7 (most common)

Dental age 6: First stage of eruption

- Eruption of mandibular central incisor and permanent first molar (Fig. 5.13).

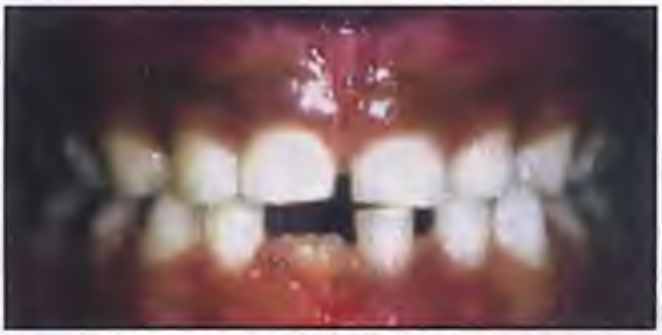


Fig. 5.13: First stage of eruption at dental age 6 years

- Mandibular molar eruption precedes maxillary molar.

Dental age 7

- Eruption of maxillary central and mandibular lateral incisor.
- Root formation of maxillary lateral incisor well advanced.
- Crown completion of canines and premolars.

Dental age 8

- Eruption of maxillary lateral incisor.
- Delay of 2-3 years before any further teeth erupt.

Dental age 9

- One-third root formation of mandibular canine and first premolar is complete.
- Root development of mandibular second premolar begins.

Dental age 10

- One-half root formation of mandibular canine and first premolar is complete.
- Significant root development of maxillary and mandibular second premolar as well as maxillary canine.
- Root completion of mandibular incisors and near completion of maxillary laterals.
- According to Moyers, mandibular canine erupts between 9 and 10 years.

Dental age 11

- Eruption of mandibular canine (according to Proffit), mandibular first premolar and maxillary first premolar.
- Maxillary first premolar erupts ahead of canine and second premolar.

Dental age 12

- Remaining succedaneous teeth erupt.
- Second permanent molars nearing eruption
- Early beginnings of third molar

Dental age 13,14,15

- Completion of roots of permanent teeth
- Third molars apparent on the radiograph

Change in eruption sequence is a reliable sign of disturbance in normal development of the dentition.

Certain normal variations with important clinical significance:

- Eruption of second molars ahead of premolars in the mandibular arch. This decreases the space for second premolars, which get partially blocked out.
- Eruption of maxillary canines ahead of premolars will cause the canines to be forced out labially.
- Asymmetries in eruption between the right and left sides occurs when there is lack of space to accommodate erupting teeth due to different pattern of mechanical obstruction, decreased space on one side compared to the other.

DIMENSIONAL CHANGES IN THE DENTAL ARCHES

The usual arch dimensions measured are:

1. Widths of the canines, primary molars (premolars) and first permanent molars:
   a. Dimensional increase in width involves alveolar process growth almost totally, since there is little skeletal width increase at this time.
   b. Clinically significant differences exist in the manner and magnitude of width changes in the maxilla and mandible. Width increase correlates highly with vertical alveolar process growth. Maxillary alveolar processes diverge while mandibular alveolar processes are more parallel. Thus, maxillary width increases more and can be easily altered in treatment.
   c. The only significant increase in mandibular inter-canine width occurs during eruption of incisors when primary cuspids are moved distally into primate spaces and does not increase significantly thereafter.

d. Maxillary arch width increase is timed with periods of active eruption of teeth. Eruption of maxillary permanent canines is an important factor in widening of the arch.
e. Maxillary premolar width increase is coincidental with vertical growth whereas mandibular premolar width increase occurs because of further buccal placement of premolar crowns.

2. Length or depth: Arch length or depth is measured at the midline from a point midway between central incisors to a tangent touching distal surfaces of second primary molars or premolars. Any changes in arch length are coarse reflections of changes in perimeter.
3. Arch circumference or perimeter: Measured from distal surface of second primary molar or mesial surface of first permanent molar around the arch over contact points and incisal edges in a smoothened curve to the distal of second primary molar or mesial surface of first permanent molar of the opposite side. The reduction in mandibular arch circumference during transitional and early adolescent dentition is a result of:
   a. Late mesial shift of first permanent molar as "Leeway space" is pre-empted (Figs 5.8D and 5.9).
   b. Mesial drifting tendency of posterior teeth throughout life.
   c. Slight interproximal wear of teeth.
   d. Lingual positioning of incisors.
   e. Original tipped position of incisors and molars.

DEVELOPMENTAL DISTURBANCES AFFECTING THE TEETH

DISTURBANCES DURING INITIATION OF TOOTH GERMS

1. *Ectodermal dysplasia* Complete or partial anodontia of both the dentitions along with the presence of malformed teeth (Fig. 5.14).
2. *Anodontia* Absence of 1 or more teeth due to failure of tooth bud initiation. Most commonly missing teeth are third molars (16%) followed by mandibular second premolars (4.4%), maxillary lateral incisor (1.7%) and maxillary second premolars (1.6%).



Fig. 5.14: Orthopantomogram of a case with ectodermal dysplasia

3. *Supernumerary and supplemental teeth* Teeth in excess of the normal complement of teeth. The difference between the two is that supplemental teeth resemble normal teeth whereas supernumerary teeth do not, e.g. of supernumerary teeth:
   - *Mesiodens* between maxillary central incisors.
   - *Peridens* located buccal to the arch
   - *Distomolar* distal to the third molar.
   - *Paramolar* located buccal or lingual to molars.
4. *Natal and neonatal teeth* These may be either supernumerary or deciduous teeth.
5. *Predeciduous dentition* Aborted structures with caps of enamel and dentine.
6. *Post permanent dentition* Teeth erupt after the loss of the permanent dentition, usually impacted accessory teeth.

DISTURBANCES DURING MORPHO-DIFFERENTIATION OF TOOTH GERMS

1. *Hutchinson's incisors* Screwdriver shaped notched incisors, e.g. in congenital syphilis.
2. *Mulberry molars* Occlusal surface is narrower than the cervical margin and is made up of agglomerate mass of globules; seen in congenital syphilis.
3. *Peg shaped laterals* Proximal surfaces of the crown converge giving the tooth a conical shape.
4. *Macrodontia* Teeth larger than normal. It may be true or relative generalized.
5. *Microdontia* Teeth smaller than normal. It may be true or relative generalized; most commonly the lateral incisor and third molars.
6. *Dens in dente* Tooth invaginates before calcification, e.g. permanent maxillary lateral incisor.
7. *Dens evaginatus* A tubercle or protruberance from the involved surface of the affected tooth; occurs

due to proliferation or evagination of part of the inner enamel epithelium into the stellate reticulum. Seen in premolars.

8. *Gemination* Single tooth germ splits into partially or fully separated crowns but with a common root and root canal.
9. *Fusion* Two tooth germs unite to form a single large crown with two root canals; seen in incisors.
10. *Dilaceration* Twisting, bending or distortion of a root.
11. *Taurodontism* Enlargement of the body and pulp chamber of a multi-rooted tooth with apical displacement of the pulpal floor and bifurcation of the roots.

DISTURBANCES DURING APPOSITION OF HARD TISSUES

1. *Enamel hypoplasia* Reduction in the amount of enamel formed.
   - *Local enamel hypoplasia* Periapical infection or trauma (Turner's tooth)
   - *Systemic enamel hypoplasia* Rickets, German measles, fluoride ingestion.
   - *Hereditary enamel hypoplasia* Tooth appears yellow due to reduced enamel thickness.
2. *Amelogenesis imperfecta* Hereditary disorder wherein the quality and quantity of enamel formed is altered. Three types:
   - *Hypoplastic* Defective matrix formation
   - *Hypocalcification* Defective mineralization of matrix.
   - *Hypomaturation* Immature enamel crystals.
3. *Dentinogenesis imperfecta* Hereditary developmental disorder of the dentine. The dentine appears grey to brownish violet, enamel frequently separates from the defective dentine, roots become short, canals get obliterated, rapid attrition is seen.
4. *Dentinal dysplasia* Premature loss of teeth, short roots.
5. *Shell teeth* Roots fail to form, pulp chambers are wide.
6. *Odontodysplasia (Ghost teeth)* Enamel and dentine is defective and very thin.
7. *Pigmentation of enamel and dentine*
   - Erythroblastosis fetalis: enamel is green/blue.
   - Porphyria: red to brownish
   - Tetracyclines: brownish
8. *Cemental hypoplasia* Reduced rate of cementum formation, e.g. hypophosphatasia.
9. *Enamel pearls* Attached to the furcation area of maxillary molars.

DISTURBANCES DURING CALCIFICATION OF HARD TISSUE

1. *Enamel hypocalcification* Calcification is subnormal. It may be local, systemic or hereditary.
2. *Interglobular dentine* Areas of partially calcified dentine.

DISTURBANCES DURING ERUPTION OF TEETH

1. *Concrescence* Cemental union of two teeth.
2. *Retarded eruption* Due to endocrine disturbances, vitamin deficiencies, local causes.
3. *Ankylosed teeth* Teeth fail to erupt to the occlusal level as they are fused to the bone.

CONCLUSION

Development of dentition in humans is complex and depends on many variables. Development of dentition deviates markedly from that of other parts and structures of the body. Crowns of teeth are formed directly to adult size and housed within the jaws years before they emerge.

To determine an abnormal course of development, it is the responsibility of an orthodontist to have adequate knowledge on the subject to differentiate abnormal from normal before initiating therapy.

FURTHER READING

1. Bishara SE, Hoppens BJ, Jakobsen JR, Kohout FJ. Changes in molar relationships between the deciduous and permanent dentitions: a longitudinal study, Am J Orthod Dentofac Orthoped 1988;93:19.
2. Bjork A, Skeiller V. Facial development and tooth eruption. An implant study at the age of puberty, Am J Orthod 1972;62:339-83.
3. British Standards Institute. Glossary of Dental terms (BS 4492). London: BSI, 1983.
4. Broadbent BH. Ontogenetic development of occlusion, Angle Orthod, 1941;11:223-41.
5. Clements EMB, et al. Age at which deciduous teeth are shed, Brit Med J 1957;1:1508.
6. Friel S. The development of ideal occlusion of the gum pads and teeth, Am J Orthodint 1954;40:1963.

7. Hellman M. Factors influencing occlusion, In Gregory WK, Broadbent BH, Hellman M, editors: Development of Occlusion, Philadelphia, 1941, University of Pennsylvania Press.
8. Inuzuka K. Changes in molar relationships between the deciduous and permanent dentitions: a longitudinal study, Am J Orthod Dentofac Orthoped 1990;93:19.
9. Marks SC Jr, Schroeder HE. Tooth eruption: theories and facts, Anat Rec 1996;245:374-93.
10. Marks SC Jr. The basic and applied biology of tooth eruption, Connective Tissue Res 1995;32:149-57.
11. Moorrees C. The dentition of the growing child: a longitudinal study of dental development between 3 and 18 years of age, Cambridge, Mass, 1959, Harvard University Press.
12. Moorrees CF, Chadha JM. Available space for the incisors during dental development, Angle Orthod, 1965;35:12-22.
13. Sillman JH. Dimensional changes of dental arches: longitudinal studies from birth to 25 years, Am J Orthod 1964;50:824-42.
14. Van der Linden, Dutterloo HS. Development of Human Dentition: an atlas: Harper and Row, 1976.

6 Occlusion in Orthodontics

Manoj Varma, Gurkeerat Singh

- Introduction
- Understanding frequently used terms
- Concepts of occlusion
- Classifications of occlusion
- Relating centric relation to centric occlusion
- Importance of centric relation in orthodontics
- Compensatory curvatures
- Andrews six keys to normal occlusion

INTRODUCTION

Occlusion has been rightly defined as "the medium that brings all branches of dentistry together" by Ramford and Ash. Ricketts Dorlands Medical Dictionary defined occlusion as, 'the act of closure or process of being closed.' In dentistry, occlusion, refers to the "relationship of the maxillary and mandibular teeth when they are in functional contact during activity of mandible."

The study of occlusion involves the entire stomatognathic system, the understanding of the interrelationship between the teeth, periodontal tissues, bones, joints, muscles and nervous system during the full range of mandibular movements as well as the normal functional movements. The study of occlusion is essential for the proper understanding, and for achieving the objectives of orthodontic treatment.

The purpose of this chapter is to present orthodontically oriented concepts of occlusion that require certain acceptable static cusp-fossa relationships to be present for an occlusion to be considered normal, as well as help in achieving a functional occlusion. The establishment of a functional occlusion is one of the primary goals of the orthodontics.

UNDERSTANDING FREQUENTLY USED TERMS

GNATHOLOGY

It is the science of mandibular movement and resultant occlusal contacts.

DENTAL OCCLUSION

Shaw defined dental occlusion, "as the static, closed contacting position of the upper teeth to lower teeth".

DISOCCLUSION OF TEETH

Harvey Stallard defined disocclusion, "as a separation of the teeth from occlusion; the opposite of occlusion".

STAMP CUSPS

The cusps that stamp into a fossa of an opposing tooth are known as stamp cusps. The lingual cusps of the upper teeth and the buccal cusps of the lower teeth are the posterior stamp cusps.

SHEARING CUSPS

The upper buccal cusps and the lower lingual cusps are used to shear or cut food and are called shearing cusps.

NORMAL OCCLUSION

What is referred to as normal occlusion orthodontically, is an Angle's Class I occlusion. The key teeth for this classification are the permanent first molars. The mesiobuccal cusp of the maxillary first molar should occlude in mesiobuccal groove of the mandibular first permanent molar (Fig. 6.1). However, even with this relationship, when the teeth are in full closure there may be a significant discrepancy between the relationships of mandibular or temporomandibular joints (TMJ) and the maxilla.



Fig. 6.1: Normal occlusion

Normal occlusion usually involves occlusal contact, alignment of teeth, overjet, overbite, arrangement and relationship of teeth between the arches and relationship of teeth to osseous structures.

"Normal" simply implies a situation commonly found in the absence of disease. It should include not only a range of anatomically acceptable values but also physiological adaptability.

IDEAL OCCLUSION

This concept refers both to an aesthetic and a physiologic ideal (Fig. 6.2). In recent times, emphasis has moved from aesthetic and anatomic standards to the current concern with function, health and comfort. This has primarily occurred due to our increased knowledge of the underlying physiology of jaw movements and the TMJ.



Fig. 6.2: Ideal occlusion, aesthetic, and satisfying the idealized structural and functional characteristics

Hence now the important aspect of ideal occlusion includes functional harmony and stability of masticatory system and the neuromuscular harmony in the masticatory system.

BALANCED OCCLUSION

Balanced occlusion is said to exist when there exist a simultaneous contact of maxillary and mandibular teeth, on the right and left, in the anterior and posterior occlusal areas when the jaws are either in centric or eccentric occlusion.

PHYSIOLOGIC OCCLUSION

The occlusion that exists in an individual, who has no signs of occlusion related pathosis, is a physiologic occlusion. Physiologic occlusion may not be an ideal occlusion but it is devoid of any pathological manifestation in the surrounding tissue due to these deviations from the ideal. Here there is a controlled adaptive response characterized by minimal muscle hyperactivity, and limited stress to the system.

TRAUMATIC OCCLUSION

It is an occlusion which is judged to be a causative factor in the formation of traumatic lesions or



Fig. 6.3: Examples of traumatic occlusion

disturbances in the supporting structures of the teeth, muscles and TMJ (Fig. 6.3).

Almost every dentition has supra contacts that have traumatic potential to alter the status of muscle tones and induce stress. However, the criterion which determines if an occlusion is traumatic or not is not how teeth occlude but whether it produces any injury.

THERAPEUTIC OCCLUSION

It is a treated occlusion employed to counteract structural interrelationship related to traumatic occlusion.

CONCEPTS OF OCCLUSION

Numerous concepts of occlusion have been suggested. Some of the important ones are listed below.

1. Angle 1887
2. Hellman 1921
3. Lucia 1962
4. Stallard and Stuart 1963
5. Ramford and Ash 1983

These concepts stress to a varying degree, state and/or functional characteristic of occlusion. None are completely applicable to natural dentition. Since a few concepts provide specific occlusal relations to joint positions, some provide ways in which muscles and the neuromusculature functions.

CLASSIFICATIONS OF OCCLUSION

Many different classifications have been suggested, but the important ones are:

1. Based on mandibular position
2. Based on relationship of 1st permanent molar
3. Based on organization of occlusion
4. Based on pattern of occlusion.

BASED ON MANDIBULAR POSITION

Centric Occlusion

It is the occlusion of the teeth when the mandible is in centric relation.

Centric relation has been defined as the maxillo-mandibular relationship in which condyles articulate with the thinnest avascular position of their respective discs with the complex in the anterosuperior position against the shape of the articular eminence.

This position is independent of tooth contact and is clinically discernable when the mandible is directed anteriorly and superiorly. It is restricted to a purely rotary movement about the transverse horizontal axis.

Eccentric Occlusion

It is defined as the occlusion, other than centric occlusion. It includes:

1. *Lateral occlusion* It can be right or left lateral occlusion. It is defined as the contact between opposing teeth when the mandible is moved either right or left of the midsagittal plane.
2. *Protruded occlusion* Defined as the occlusion of the teeth when the mandible is protruded, i.e. the position of mandible is anterior to centric relation.
3. *Retrusive occlusion* Occlusion of the teeth when the mandible is retruded, i.e. position of mandible is posterior to centric relation.

BASED ON RELATIONSHIP OF 1ST PERMANENT MOLAR

Depending on the anteroposterior jaw relationship, Edward H Angle classified occlusion into 3 types.

a. *Class I* (also known as neutro-occlusion) (Fig. 6.4A): Dental relationship in which there is normal anteroposterior relationship, as indicated by the correct interdigitation of maxillary and mandibular molars (crowding, rotation or other individual tooth malrelations may be present elsewhere in the arch).
b. *Class II* (also known as disto-occlusion) (Fig. 6.4B): Dental relationship, in which the mandibular dental arch is posterior to the maxillary dental arch in one or both lateral segments as determined by the relationship of the permanent first molars. Mandibular 1st molar is distal to the maxillary 1st molar.

   Further subdivided into 2 divisions:

   Division I Bilateral distal retrusion with a narrow maxillary arch and protruding maxillary incisors, increased overjet.

   Division II Bilateral distal retrusion with a normal or square-shaped maxillary arch, retruded maxillary central incisors, labially malposed maxillary lateral incisors, an excessive overbite (deepbite).

   Subdivision Unilateral, right or left, distal retrusive position of the mandible.



Fig. 6.4A: Molar relation angle's class I



Fig. 6.4B: Molar relation angle's class II



Fig. 6.4C: Molar relation angle's class III

c. *Class III* (or mesio-occlusion—Fig. 6.4C): Dental relationship, in which mandibular arch is anterior to maxillary arch in one or both the lateral segments. The mandibular first molar is mesial to the maxillary first molars and mandibular incisors are in anterior crossbite.
Subdivision Right or left, i.e the molar relation exists unilaterally, with other characters remaining same.
d. *Class IV*: Dental relationship in which occlusal relations of the dental arches present the peculiar condition of being in distal occlusion in one lateral half and in mesial occlusion in the other half. This term is obsolete now.

BASED ON THE ORGANIZATION OF OCCLUSION

a. *Canine guided or protected occlusion* During lateral movements, only working side canine comes into contact with the other. This results in disocclusion of all posterior teeth, i.e. on both the working and balancing side. This is because the mandible moves away from the centric occlusion.

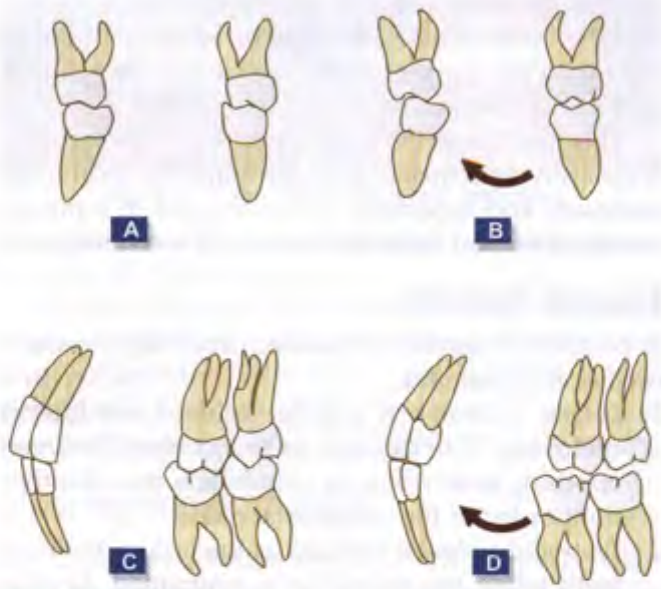
Here the tip or the buccal incline of the lower canine is seen to slide along with palatal surface of the upper canine.

b. *Mutually protected occlusion* Occlusal scheme in which the posterior teeth prevent excessive contact of the anterior teeth in maximum intercuspation. Also, the anterior teeth disengage the posterior teeth in all mandibular excursive movements (Figs 6.5A to D).
c. *Group function occlusion* It is defined as the multiple contact relationship between the maxillary and mandibular teeth, in lateral movements of the working side; where by simultaneous contacts of several teeth is achieved and they act as a group to distribute occlusal forces.

BASED ON PATTERN OF OCCLUSION

There are two types:

a. *Cusp to embrasure/marginal ridge occlusion* (Fig. 6.6A) Development of occlusion can result in fitting of



Figs 6.5A to D: The mutual protection concept of occlusion. Frontal view with molars in centric occlusion (A), In lateral excursion, there is buccal-to-buccal contact on the working side and disocclusion on the nonworking side (B), Centric occlusion viewed laterally (C), and In protrusion, only maxillary and mandibular incisors are in contact (D)

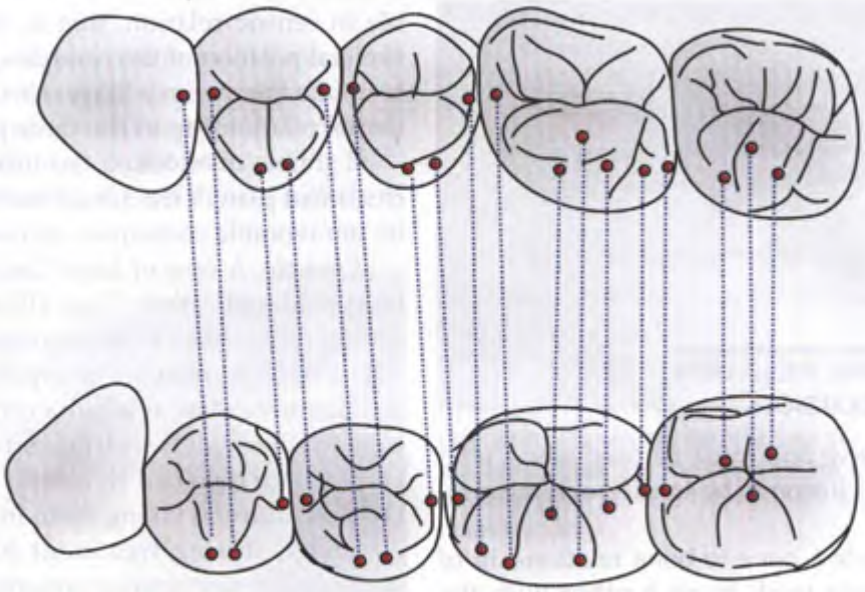


Fig. 6.6A: The cusp-embrasure or tooth-to-two-teeth arrangement

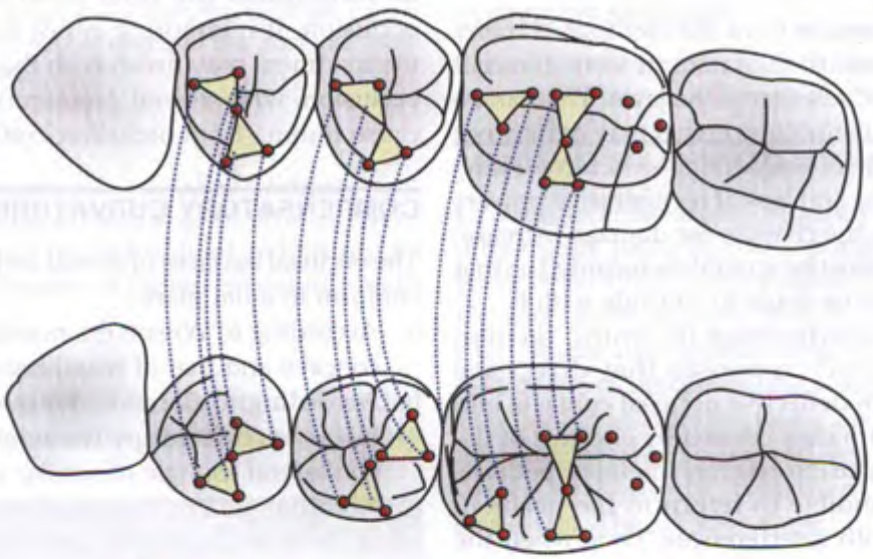


Fig. 6.6B: The cusp-fossa or tooth-to-tooth arrangement

one stamp cusp into a fossa and the fitting of another cusp of the same tooth into the embrasure area of two opposing teeth. This is a tooth-to- two-teeth relation occlusion.

b. *Cusp to fossa occlusion* (Fig. 6.6B) Development and growth of the masticatory apparatus results in most or all of the stamp cusps fitting into fossa. This cusp-fossa relationship normally produces an interdigitations of the cusps and fossa of one tooth with the fossa only on opposing tooth. This is a tooth-to-one-tooth relation.

The cusp-fossa, tooth-to-tooth arrangement has some distinct advantages over the cusp-embrasure arrangement (Table 6.1).

Table 6.1: Advantages of cusp-fossa arrangement over cusp-embrasure arrangement

i. Forces are directed more towards the long axis of the teeth
ii. The arrangement leads to greater stability of the arch, decreasing the tendency towards tooth movement
iii. The chance of food impacting in the embrasures is less

RELATING CENTRIC RELATION TO CENTRIC OCCLUSION

Centric is an adjective and must be used along with either relation or occlusion to be specific and meaningful.

Centric relation is a bone-to-bone relationship of the upper and lower teeth to each other with the mandibular condyle in the glenoid fossa. Once centric relation is established, centric occlusion can be built to coincide with it.

Confusion also results from the fact that in many people the centric occlusion of natural teeth does not coincide with centric relation of the jaws. This can be considered a minor malocclusion that may or may not contribute to damage of periodontal structures. However, as age advances and loss of recuperative powers by the body tissues, the chances for damage increase.

Centric relation must be accurately recorded so that centric occlusion can be made to coincide with it.

Natural tooth interferences in centric relation initiate impulses and responses that direct the mandible away from deflective occlusal contacts into centric occlusion. Impulses created by closures of the teeth into centric occlusion establish memory patterns that permit the mandible to return to the position, usually without tooth interferences. Thus when the natural teeth are removed or lost the receptors that initiate impulses resulting in positioning of the mandible are lost or destroyed. Therefore, the edentulous patient cannot control mandibular movements or avoid defective occlusal contact in centric relation, in the same manner as dentulous patients.

IMPORTANCE OF CENTRIC RELATION IN ORTHODONTICS

Diagnosis and treatment planning should be performed by an evaluation of the occlusion with mandible in centric relation, that is, the natural musculoskeletal position of the condyles in the fossa, in order to obtain the true maxillary—mandibular skeletal and dental relationship in the three plane of space.

If this is overlooked, an incorrect diagnosis and treatment plan of the actual malocclusion, along with its unfavorable consequences may result.

Example: A case of false Class III, may incorrectly be considered a true Class III, with a consequently poorer prognosis, or the cusp crossbite, in centric relation. Therefore, bilateral manipulation of the mandible into centric relation is imperative at the first visit. Usually, the models are trimmed and the lateral cephalograms are obtained in centric occlusion because of the difficulties in taking them in centric relation.

Hence, during treatment planning we have to consider any discrepancy presented. Moreover, during every appointment the patient has to be monitored in centric relation so that the mechanotherapy is guided to accomplish the final ideal state of functional occlusion. If monitoring is not done in this manner, the treatment may finish with the mandible in centric occlusion, with several prematurities. This may later cause trauma from occlusion and TMJ disorder.

COMPENSATORY CURVATURES

The occlusal surfaces of dental arches do not generally conform to a flat plane.

a. According to Wilson the mandibular arch appears concave and that of maxillary arch convex.
b. According to Bonwill, the maxillary and mandibular arches adapt themselves in part to an equilateral triangle of similar sides.
c. According to Von Spee, cusps and the incisal ridges of the teeth display a curved alignment when the arches are observed from a point opposite the 1st molar. The curve of Spee, as it is frequently called, is seen from the sagittal plane.
d. Monson connected the curvature in the sagittal plane with compensatory curvatures in the vertical plane and suggested that the mandibular arch adapts itself to the curved segment of a sphere of similar radius.

Here, the maxillary canine guides the mandible, so that the posterior teeth come into occlusion with a minimum of horizontal forces.

CURVE OF SPEE

It refers to the anteroposterior curvature of the occlusal surfaces, beginning at the tip of the lower cuspid and following cusp tip of the bicuspids and molars continuing as an arc through to the condyle (Fig. 6.7). If the curve were extended, it would form a circle of about 4 inches diameter.



Fig. 6.7: The curve of Spee: A line from the tip of the canine touching the tips of the buccal cusps of the posterior teeth (drawn on jaws of a skull)

CURVE OF WILSON

It is a curve that contacts the buccal and lingual cusp tips of the mandibular posterior teeth. The curve of Wilson is mediolateral on each side of arch. It results from the inward inclination of the lower posterior teeth (Figs 6.8A and B).

The curve helps in two ways

1. Teeth aligned parallel to the direction of medial pterygoid for optimum resistance to masticatory forces.



Fig. 6.8A: A curve drawn on the third molars (of a skull)



Fig. 6.8B: Curves on the first and the second molars of the mandible. Note the flattening of the curve as it progresses distally (the curves have been exaggerated for easy understanding)

2. The elevated buccal cusps prevent food from going past the occlusal table.

CURVE OF MONSON

It is obtained by extension of the curve of Spee and curve of Wilson to all cusps and incisal edges.

ANDREWS SIX KEYS TO NORMAL OCCLUSION

Lawrence F Andrews studied 120 casts of non-orthodontic patients with normal occlusion for four years (1960-1964). He identified 6 key characteristics. He was of the opinion, that for normal occlusion to exist these six characteristics had to be present. According to Andrews, the 6 keys to normal occlusion contributed individually and collectively to the total scheme of occlusion and, were therefore essential for an orthodontic treatment to be considered successful. The six keys were:

KEY I

Molar relationship (Fig. 6.9A) The molar relationship should be such that the distal surface of the distal marginal ridge of the upper first permanent molar contacts and occludes with the mesial surface of the mesial marginal ridge of the lower second molar. Secondly, the mesiobuccal cusp of the upper first permanent molar falls within the groove between the mesial and middle cusps of the lower first permanent molar. Also, the mesiolingual cusp of the upper first molar seats in the central fossa of the lower first molar.



Fig. 6.9A: The Andrews first key—molar relationship



Fig. 6.9C: Andrews key III—Crown inclination, the labiolingual or buccolingual torque



Fig. 6.9B: Andrews key II—Crown angulation, the mesiodistal 'tip'



Fig. 6.9D: Andrews key IV—No rotations

KEY II

Crown angulation (Fig. 6.9B), the mesiodistal "tip".

In normally occluded teeth, the gingival portion of the long axis (the line bisecting the clinical crown mesiodistally or the line passing through the most prominent part of the labial or buccal surface of a tooth) of each crown is distal to the occlusal portion of that axis. The degree of tip varies with each tooth type.

KEY III

Crown inclination (Fig. 6.9C), the labiolingual or buccolingual, "torque". Crown inclination is the angle between a line 90 degrees to the occlusal plane, and a line tangent to the middle of the labial or buccal surface of the clinical crown.

The crowns of the maxillary incisors are so placed that the incisal portion of the labial surface is labial to the gingival portion of the clinical crown. In all other crowns, the occlusal portion of the labial or buccal surface is lingual to the gingival portion. In the maxillary molars the lingual crown inclination is slightly more pronounced as compared to the cuspids and bicuspids. In the mandibular posterior teeth the lingual inclination progressively increases.

KEY IV

Absence of Rotations (Fig. 6.9D). Teeth should be free of undesirable rotations. If rotated, a molar or bicuspid occupies more space than it would normally. A rotated incisor can occupy less space than normal.

KEY V

Tight contacts (Fig. 6.9E). In the absence of such abnormalities as genuine tooth-size discrepancies, contact points should be tight.



Fig. 6.9E: Andrews key V—Tight contacts



Fig. 6.9F: Andrews key VI—A flat curve of Spee

KEY VI

Flat curve of Spee (Fig. 6.9F). A flat occlusal plane is a must for stability of occlusion. It is measured from the most prominent cusp of the lower second molar to the lower central incisor, no curve deeper than 1.5 mm is acceptable from a stand point of stability.

FURTHER READING

1. Andrews LF. The six keys to normal occlusion, Am J Orthod 1972;63:296-302.
2. Angle EH. Classification of occlusion, D Cosmos 1899;41:248.
3. Baker C. Development of the occlusion of the teeth, J Am Dent Assoc, 1944;31:1470.
4. Beyron HL. Optimal occlusion, Dent Clin North Am 1969;13:537.
5. Bonwill WGA. The geometrical and mechanical laws of the articulation of human teeth- the anatomical articulator. In Litch WF, (Ed): The American system of dentistry in treatises by various authors: operative and prosthetic dentistry, vol. 2, Philadelphia, 1886-87, Lea and Febiger, pp 486-498.
6. British Standards Institute. Glossary of Dental terms (BS 4492). London: BSI, 1983.
7. Celenza FB. The centric position: replacement and character, J Prosthet Dent 1973;30:591.
8. Friel S. Occlusion: observations on its development from infancy to old age, Int J Orthod Surg 1927;13:322.
9. Friel S. The development of ideal occlusion of the gum pads and teeth, Am J Orthodont 1954;40:1963.
10. Monson GS. Occlusion as applied to crown and bridgework, J Nat Dent Assoc 1920;7:399.
11. Ramfjord SP, Ash MM. Occlusion, Philadelphia, 1966, WB Saunders Company.
12. Sanin C, Savara BS. The development of an excellent occlusion, Am J Orthod, 1971;1:345-52.
13. Spee FG. Die Verschiebungsbahn des Unterkiefers am Schädel, Arch Anat Physiol Anat Ab 1890;285-94.
14. Stallard H, Stuart C. Concepts of occlusion, Dent Clin North Am November, 1963.
15. Wheeler RC. Textbook of Dental Anatomy and Physiology. 4th ed., WB Saunders Co. 1965.

Section Two

DIAGNOSIS

7. Diagnostic Aids—Case History and Clinical Examination
8. Orthodontic Study Models
9. Cephalometrics—Landmarks and Analyses
10. Diagnostic Radiographs and Photographs
11. Maturity Indicators
12. Computerized Diagnostic Systems
13. Classification of Malocclusion
14. Etiology of Malocclusion—Classifications
15. Etiology of Malocclusion—General Factors
16. Etiology of Malocclusion—Local Factors
17. Dental Public Health Aspects of Orthodontics

7 Diagnostic Aids—Case History and Clinical Examination

- Introduction
- Essential diagnostic aids
- Nonessential or supplemental diagnostic aids
- Case history
- Clinical examination
- Functional examination

INTRODUCTION

Treatment is secondary, the primary task for the clinician is to identify the problem and find its etiology. Once this is done, and only then can a treatment plan be formulated. Diagnosis involves the development of a comprehensive and concise database of pertinent information, sufficient to understand the patient's problem as well as answer questions arising in the treating clinicians mind. The data is derived from essential and nonessential diagnostic aids or supplemental diagnostic aids.

ESSENTIAL DIAGNOSTIC AIDS

Essential diagnostic aids, as the name suggests are considered essential for the diagnosis of an orthodontic case. Ideally before starting a case, a treating clinician must possess these aids. These include the following.

1. Case history
2. Clinical examination
3. Study models
4. Certain radiographs:
   a. Periapical radiographs
   b. Lateral radiographs
   c. Orthopantomograms
   d. Bite wing radiographs.
5. Facial photographs.

These diagnostic aids are simple and easy to obtain, except for specialized radiographs like orthopantomograms and lateral cephalograms where a specialized radiographic setup might be required.

NONESSENTIAL OR SUPPLEMENTAL DIAGNOSTIC AIDS

These diagnostic aids may be required only in certain cases and may require specialized equipment, which might not be available in every dental clinic. The supplemental diagnostic aids include:

1. Specialized radiographs; like
   a. Occlusal views of maxilla and/or mandible.
   b. Selected lateral jaw views, etc.
2. Electromyographic examination of muscle activity
3. Hand-wrist radiographs
4. Computed axial tomography (CT scan)
5. Magnetic Resonance Imaging (MRI)
6. Endocrine tests and/or other blood tests
7. Estimation of the basal metabolic rate
8. Sensitivity (vitality) tests
9. Biopsy.

CASE HISTORY

Case history is the information gathered from the patient and/or parent and/or guardian to aid in the overall diagnosis of the case. It includes certain personal details, the chief complaint, past and present dental and medical history and any associated family history. The aim is to establish a rapport with the patient and to obtain an accurate account of the individual's complaints, which, following examination will enable, a diagnosis to be made.

PERSONAL DETAILS

These include very basic data, for communication and access. It includes:

Name

The patients name should be recorded not only for the purpose of communication and identification but because it gives a personal touch to the following conversation. It makes the patients more comfortable when he is addressed by his first name and arouses a feeling of familiarity, which has a positive psychological effect on the patient.

Age and Date of Birth

The chronologic age of the patient helps in diagnosis, treatment planning and growth prediction. Certain transient conditions, which might be perceived as malocclusion by the patient and parents, can be identified and the concerned are counseled accordingly.

The age of the patient also dictates the use of certain treatment protocols—for example, surgical correction might be advocated following cessation of growth whereas the same malocclusion might be treated using functional appliances if the patient has a potential to grow.

Sex

Sex of the patient also helps in treatment planning. Girls mature earlier than boys, i.e. the timing of growth related events including growth spurts, eruption of teeth and onset of puberty are different in males and females.

Psychologically also the reaction of males and females may be different to similar malocclusion. Females are generally more concerned about facial aesthetics.

Address and Occupation

These are important for communication, assessing the socioeconomic status as well as for records. The socioeconomic status might dictate the kind of appliance required. Also, patients coming from far may require a different appliance therapy as they might not be able to visit the clinician more frequently.

CHIEF COMPLAINT

The patient's chief complaint should be recorded in his or her own words. It should mention the conditions the patient feels he /she is suffering from. This helps in identifying the priorities and desires of the patients. The parents' perception of the malocclusion should also be noted. This will help in setting the treatment objectives and satisfying the family in general.

MEDICAL HISTORY

Knowledge of a patient's general health is essential and should be obtained prior to examination. It is best obtained by a questionnaire.

In most cases orthodontic treatment can be undertaken but precautions may be required prior to extractions. Antibiotic coverage may be required in patients with rheumatic fever or cardiac anomalies even for molar band placement/removal, if the adjacent gums are inflamed or bleeding is anticipated. Mentally or physically challenged patients may require special management.

DENTAL HISTORY

The patient's dental history should include information on the age of eruption and exfoliation of deciduous and permanent teeth. Reason for exfoliation will also hint at the oral hygiene maintenance capabilities of the patient. The past dental history will also help in assessing the patients and parents attitude towards dental health.

PRENATAL HISTORY

Prenatal history should concentrate on the condition of the mother during pregnancy and the type of delivery. Her nutritional state and any infections that she might have will affect the developing teeth of the child. The use of certain drugs or even excess use of certain vitamins can result in congenital deformities of the child.

Forcep deliveries have been associated with injuries to the temporomandibular joint (TMJ). Excess forcep pressure in the TMJ region can cause ankylosis of the joint and associated mandibular growth retardation.

POSTNATAL HISTORY

The postnatal history should concentrate on the type of feeding, presence of habits especially digit/thumb sucking and the milestones of normal development.

Tongue thrust and digit sucking habits are associated with malocclusions. These will be discussed later in detail.

FAMILY HISTORY

Skeletal malocclusions especially skeletal Class III malocclusions and congenital conditions such as cleft lip and palate are inherited. Detailed records of such malocclusions might aid in any future studies on the subject.

CLINICAL EXAMINATION

GENERAL EXAMINATION

General examination should begin as soon as the patient first comes to the clinic. A general appraisal of the patient is done. The clinician should observe the gait, posture and physique of the patient. Height and weight are recorded to assess for the physical growth and development of the patient. Abnormal gait may be present due to an underlying neuromuscular disorder. Abnormal posture also may lead to malocclusions.

Body Build

Sheldon classified body build into:

a. Ectomorphic: Tall and thin physique
b. Mesomorphic: Average physique
c. Endomorphic: Short and obese physique.

Cephalic and Facial Examination

The shape of the head can be evaluated based on the cephalic index of the head which was formulated by Martin and Saller (1957) as:

$$I = \frac{\text{Maximum skull width}}{\text{Maximum skull length}}$$

Index values

- Mesocephalic (Fig. 7.1A) (average) 76.0-80.9
- Brachycephalic (Fig. 7.1B) (short, broad skull) 81.0-85.4
- Dolicocephalic (Fig. 7.1C) (long, narrow skull) < – 75.9
- Hyperbrachycephalic –> 85.5



A



B



C

Figs 7.1A to C: Classification of head types: (A) Mesocephalic head, (B) Brachycephalic head, and (C) Dolicocephalic head

The index is based on the anthropometrics determination of the maximum width of the head and the maximum length.

The shape of the face is assessed by the morphologic facial index which was given by Martin and Saller (1957) as:

$$I = \frac{\text{Morphologic facial height (distance between nasion and gnathion)}}{\text{Bizygomatic width (distance between the zygoma points)}}$$

Index values

- Hypereuryprosopic} low facial skeleton × – 78.9
- Euryprosopic (Fig. 7.2A)} low facial skeleton 79.0 – 83.
- Mesoprosopic (Fig. 7.2B)} average facial skeleton 84.0 – 87.9
- Leptoprosopic (Fig. 7.2C)} high facial 88.0 – 92.9
- Hyperleptoprosopic } skeleton 93.0 – ×

The type of facial morphology has a certain relationship to the shape of the dental arch, e.g. euryprosopic face types have broad, square arches; border line crowding in such cases should be treated by expansion. On the other hand, leptoprosopic face types often have narrow apical base/arches. Therefore, extraction is preferred over expansion.

Assessment of Facial Symmetry

A certain degree of asymmetry between the right and left sides of the face is seen in most individuals. The face should be examined in the transverse and vertical planes to determine a greater degree of asymmetry than is considered normal. Gross facial asymmetries (Fig. 7.3) may be seen in patients with:



Fig. 7.2A: Euryprosopic face



Fig. 7.2B: Mesoprosopic face



Fig. 7.2C: Leptoprosopic face



Fig. 7.3: Facial asymmetry

i. Hemifacial hypertrophy/atrophy
ii. Congenital defects.
iii. Unilateral condylar hyperplasia
iv. Unilateral Ankylosis, etc.

Facial Profile

The profile is examined from the side by making the patient view at a distant object, with the FH plane parallel to the floor. Clinically or in extraoral photographs, the profile can be obtained by joining two reference lines:

a. Line joining forehead and soft tissue point A
b. Line joining point A and soft tissue pogonion.

Three types of profiles are seen:

a. *Straight/ orthognathic profile* The two lines form an almost straight line (Fig. 7.4A).



Fig. 7.4A: Straight / orthognathic profile



Fig. 7.4B: Convex profile



Fig. 7.4C: Concave profile

b. *Convex profile* The two lines form an acute angle with the concavity facing the tissues. This type of profile is seen in Class II div 1 patients due to either a protruded maxilla or a retruded mandible (Fig. 7.4B).
c. *Concave profile* The two lines form an obtuse angle with the convexity facing the tissues. This type of profile is seen in Class III patients due to either a protruded mandible or a retruded maxilla (Fig. 7.4C).

Facial Divergence

The lower face may be straight or inclined anteriorly/posteriorly relative to the forehead. This inclination is also termed as the facial divergence, which may be influenced by the patient's ethnic or racial background. A line is drawn from the forehead to the chin to determine whether the face is:

a. *Anterior divergent* (Fig. 7.5A), line inclined anteriorly.
b. *Posterior divergent* (Fig. 7.5B), line inclined posteriorly.
c. *Straight/orthognathic* (Fig. 7.5C), straight line, no slant seen.

ASSESSMENT OF ANTEROPOSTERIOR JAW RELATIONSHIP

A fair picture of the sagittal skeletal relationship can be obtained clinically by placing the index and middle fingers at the approximate A and B points after lip retraction (Fig. 7.6). Ideally, the maxilla is 2 to 3 mm anterior to the mandible in centric occlusion. In skeletal Class II cases, the index finger is much ahead of



Fig. 7.5A: Anterior divergent profile



Fig. 7.5B: Posteriorly divergent profile



Fig. 7.5C: Straight/orthognathic profile



Fig. 7.6: Assessment of anteroposterior jaw relationship

the middle finger whereas in Class III the middle finger is ahead of the index finger.

ASSESSMENT OF VERTICAL SKELETAL RELATIONSHIP

A normal vertical relationship is one where the distance between the glabella and subnasale is equal to the distance from the subnasale to the under side of the chin (Fig. 7.7). Reduced lower facial height is associated with deep bites while increased lower facial height is seen in anterior open bites.



Fig. 7.7: Evaluation of facial proportions

Examination of the Soft Tissues

Extraoral

1. *Forehead* The esthetic prognosis of an orthodontic case is determined by its profile, which in turn is influenced by the shape of the forehead and the nose. For a face to be harmonious, the height of the forehead (distance from hairline to glabella) should be as long as the mid-third (glabella-to-subnasale) and the lower third (subnasale-to-menton), i.e. each of these is one-third the total face height (Fig. 7.7). Dental bases are more prognathic in cases with a steep forehead, than with a flat forehead.
2. *Nose* Size, shape and position of the nose determines the esthetic appearance of the face and is therefore important in the prognosis of a case.
3. *Lips* Lip length, width and curvature should be assessed. In a balanced face, the length of the upper lip measures one-third, the lower lip and chin two-thirds of the lower face height. The upper incisal edge exposure with the upper lip at rest should be normally 2 mm.

   Lips can be classified into:
   a. Competent lips: Slight contact of lips when musculature is relaxed (Fig. 7.8A).
   b. Incompetent lips: Anatomically short lips, which do not contact when musculature is relaxed. Lip seal is achieved only by active contraction of the orbicularis oris and mentalis muscles (Fig. 7.8B).
   c. Potentially competent lips: Lip seal is prevented due to the protruding maxillary incisors despite normally developed lips (Fig. 7.8C)
   d. Everted lips: These are hypertrophied lips with redundant tissue but weak muscular tonicity (Fig. 7.8D).



Fig. 7.8A: Competent lips



Fig. 7.8C: Potentially competent lips



Fig. 7.8B: Incompetent lips



Fig. 7.8D: Everted lips

NASOLABIAL ANGLE

This is the angle formed between a tangent to the lower border of the nose and a line joining the subnasale with the tip of the upper lip (labrale superius) (Fig. 7.9). Normal value is 110 degrees.

In patients with maxillary prognathism and proclined upper anteriors this angle reduces whereas it becomes more obtuse in cases with a retrognathic maxilla or retroclined maxillary anteriors.



Fig. 7.9: Nasolabial angle

Chin

The configuration of the chin is determined not only by the bone structure, but also by the thickness and tone of the mentalis muscle.

- *Mentalis activity* A normal mentalis muscle becomes hyperactive (Fig. 7.10) in certain malocclusions like Class II div 1 cases, wherein puckering of the chin may be seen.



Fig. 7.10: Hyperactive mentalis

- *Mentolabial sulcus* It is the concavity present below the lower lip (Fig. 7.11A). Deep sulcus (Fig. 7.11B) is seen in Class II cases whereas a shallow sulcus (Fig. 7.11C) is seen usually in bimaxillary protrusion cases.



Fig. 7.11A: Mentolabial sulcus



Fig. 7.11B: Deep mentolabial sulcus



Fig. 7.11C: Shallow mentolabial sulcus

Along with the chin width, development of chin height is important. Chin height is the distance from the

- *Mentolabial sulcus to menton* Over development of chin height alters the lower lip position and interferes with lip closure.
- *Chin position and prominence* Prominent chin is usually associated with Class III malocclusions (Fig. 7.4C) whereas recessive chin is seen in Class II malocclusion (Fig. 7.4B).

INTRAORAL EXAMINATION

Tongue

Tongue is examined for shape, color and configuration. It may be small, long on broad. Tongue size can be roughly estimated with the help of a lateral cephalogram. An excessively large tongue (macroglossia) usually shows imprints on its lateral margins, which gives the tongue a scalloped appearance. However diagnosis of macroglossia requires a detailed diagnostic investigation (e.g. cineradiography). The lingual frenum should be examined for tongue tie. Tongue tie (Fig. 7.12) can lead to impaired tongue movements. Abnormalities of the tongue can upset muscle balance and equilibrium leading to malocclusion.

Lip and Cheek Frena

Among the different frena, the maxillary labial frenum is most commonly the cause of a malocclusion. A thick, fibrous, low labial frenum (Fig. 7.13i) prevents upper central incisors from approximating each other leading to a midline diastema. A frenectomy is indicated when the frenum is inserted deeply with fiber extensions into the interdental papilla. An IOPA of the area may show a bony fissure between the roots of the upper central incisors (Fig. 7.13ii).

Blanch test can be done to confirm diagnosis wherein the upper lip is stretched upward and outwards. Presence of blanching in the papilla region indicates an abnormal attachment. The mandibular labial frenum is less often associated with a diastema. However, it can exert a strong pull on the free and attached gingiva leading to recession in the lower anterior region. The presence of buccal attachments must also be examined carefully especially in adolescents and adults (Fig. 7.13iii).



Fig. 7.12: Tongue tie, restricted movement of the tongue



Fig. 7.13i: Fleshy labial frenum

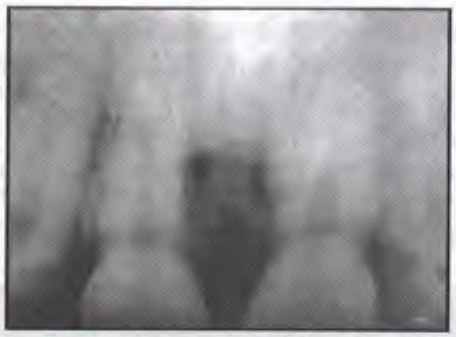


Fig. 7.13ii: 'V' shaped notching seen in the interdental region on an IOPA



Fig. 7.13iii: Blanching seen in the inter-dental region



Fig. 7.14: Trauma from occlusion causing gingival recession in relation to 41



Fig. 7.15: Scaring following cleft palate repair

Gingiva

The gingiva should be examined for the type (thick fibrous or thin fragile), inflammation and mucogingival lesions. In children, most commonly generalized marginal gingivitis occurs due to plaque accumulation and can be resolved by improving the oral hygiene. In adults, scaling followed by curettage and sometimes mucogingival surgery is usually required.

Local gingival lesions may occur due to occlusal trauma (Fig. 7.14), abnormal functional loadings or medication (e.g. Dilantin). In mouth breathers, open lip posture causes dryness of the mouth leading to anterior marginal gingivitis.

Gingivitis is a contraindication for orthodontic treatment. Treatment should be started only when the gingival condition improves.

Palate

The palatal mucosa is examined for:

a. Pathologic palatal swelling: Indicative of displaced/ impacted tooth germ, cysts, etc.
b. A traumatic deep bite can lead to mucosal ulcerations and indentations.
c. Palatal depth and shape varies in accordance with the facial form, e.g. Brachyfacial patients have broad and shallower palates as compared to dolicofacial patients.
d. Presence of clefts of varying degree may be seen. Scar tissue following palatal surgery prevents normal development of the maxillary arch (Fig. 7.15).
e. Rugae can be used as a diagnostic criterion for anterior proclination. Third rugae is normally in line with the canines.

Tonsils and Adenoids

The size and presence of inflammation in the tonsils, if present, should be examined. Prolonged inflammation of the tonsils causes alteration of the tongue and jaw posture, upsets the orofacial balance and can result in "Adenoid facies".

Clinical Examination of the Dentition

The dentition is examined for:

1. The dental status, i.e. number of teeth present, unerupted or missing.
2. Dental and occlusal anomalies should be recorded in detail. Carious teeth should be treated before beginning orthodontic treatment. Dentition should be examined for other malformation, hypoplasia, restorations, wear and discoloration.
3. Assessment of the apical bases.
   - *Sagittal plane* Check whether molar relation is Class I, II or III.
   - *Vertical plane* Overjet and overbite are recorded and variations like deep bite, open bite should be recorded.
   - *Transverse plane* Should be examined for lateral shift and cross-bite.
4. Midline of the face and its coincidence with the dental midline should be examined.

5. Individual tooth irregularities, e.g. rotations, displacements, fractured tooth
6. Shape and symmetry of upper and lower arches.

FUNCTIONAL EXAMINATION

Orthodontic diagnosis should not be restricted to static evaluation of teeth and their supporting structures but should also include examination of the functional units of the stomatognathic system. A functional analysis is important not only to determine the etiology of the malocclusion but also to plan the orthodontic treatment required. A functional analysis includes:

1. Assessment of postural rest position and maximum intercuspation.
2. Examination of the temporomandibular joint.
3. Examination of orofacial dysfunctions.

ASSESSMENT OF POSTURAL REST POSITION

Determination of postural rest position: The postural rest position is the position of the mandible at which the synergists and antagonists of the orofacial system are in their basic tonus and balanced dynamically. The space which exists between the upper and lower jaws at the postural rest position is the *interocclusal clearance or freeway space* which is normally 3 mm in the canine region.

The rest position should be determined with the patient relaxed and seated upright with the back unsupported. The head is oriented by making the patient look straight ahead. The head can also be positioned with the Frankfurt horizontal parallel to the floor.

Various methods to record the postural rest position:

a. *Phonetic method* The patient is told to pronounce some consonants like "M" or words like "Mississippi" repeatedly. The mandible returns to the postural rest position 1-2 seconds after the exercise.
b. *Command method* The patient is asked to perform selected functions like swallowing, at the end of which the mandible returns spontaneously to the rest position. Phonetic exercise is also a type of command method.
c. *Non command method* The clinician talks to the patient on unrelated topics and observes the patient as he speaks and swallows while he remains distracted. Patient is not aware that any examination is being carried out. While talking, the patients musculature is relaxed and the mandible reverts to the postural rest position.
d. *Combined methods* A combination of the above methods is most suitable for functional analysis in children. The patient is observed during swallowing and speaking. The "Tapping test" can also be carried out to relax the musculature. Here, the clinician holds the chin with his index finger and thumb and then opens and closes the mandible passively with constantly increasing frequency until the musculature is relaxed. This can be confirmed by palpating the submental muscles. The rest position can then be determined.

Regardless of the method, mandible position is checked extraorally and the patient is told not to change the jaw, lip or tongue position. The lips are then parted and the maxillomandibular relation as well as the freeway space is determined.

Registration of the Rest Position

1. **Intraoral methods**
   a. *Direct method* Vernier calipers can be used directly to measure the interocclusal clearance in the canine region.
   b. *Indirect method* Impression material is used to register the freeway space.
2. **Extraoral methods**
   a. *Direct method* Reference points are made on the skin with plaster, one on the nose and the other on the chin in the midsagittal plane. The distance between these two points is measured at rest position and centric occlusion. The difference between the two is the freeway space.
   b. *Indirect method* Includes
      - Cephalometric registration: 2 cephalogram one at postural rest position and other in centric occlusion are taken to determine the freeway space.
      - Kinesiographic registration: a magnet is fixed on the lower anterior teeth and the mandibular movements are recorded by sensors which is then processed in the Kinesiograph.

Evaluation of the Path of Closure

The path of closure is the movement of the mandible from rest position to full articulation which should be analyzed in all 3 planes of space, i.e. sagittal, vertical and frontal planes. The amount of rotation and sliding during mandibular closure is analyzed.

Sagittal Plane

In Class II malocclusions, 3 types of movements can be seen.

a. Pure rotational movement without a sliding component—seen in functional true Class II malocclusion.
b. Forward path of closure—i.e. rotational movement with anterior sliding movement. The mandible slides into a more forward position, therefore, Class II malocclusion is more pronounced than can be seen in habitual occlusion.
c. Backward path of closure, i.e. rotational movement with posterior sliding movement. In Class II div 2 cases, the mandible slides backward into a posterior occlusal position because of premature contact with retroclined maxillary incisors.

Vertical Plane

It is important to differentiate between two types of overbites.

The true deep overbite is caused by infraocclusion of the molars and can be diagnosed by the presence of a large freeway space. The prognosis with functional therapy is favorable. Pseudo-deep bite is caused due to over-eruption of the incisors and is characterized by a small freeway space. Prognosis with functional therapy is unfavorable.

Transverse Plane

During mandibular closure, the midline of the mandible is observed. In case of unilateral crossbite, this analysis is relevant to differentiate between laterognathy and laterocclusion. Laterognathy or true crossbite-the centre of the mandible and the facial midline do not coincide in rest and in occlusion. Laterocclusion—the centre of the mandible and facial midline coincide in rest position but in occlusion the mandible deviates due to tooth interference leading to non-coinciding midlines.

EXAMINATION OF THE TEMPOROMANDIBULAR JOINT (TMJ)

The clinical examination of the TMJ should include auscultation and palpation of the temporomandibular joint and the musculature associated with mandibular movements as well as the functional analysis of the mandibular movements. The main objective of this examination is to look for symptoms of TMJ dysfunction such as crepitus, clicking, pain, hypermobility, deviation, dislocation, limitation of jaw movements and other morphological abnormalities.

Specific TMJ radiographs may be indicated as part of orthodontic diagnosis in exceptional cases, Tomograms of the TMJ in habitual occlusion and maximum mouth opening may be analyzed from condyle position in relation to the fossa, width of the joint space, etc.

Adolescents with Class II div 1 malocclusions and lip dysfunction are most frequently affected by TMJ disorders. Therefore, orofacial dysfunctions must also be assessed as they may lead to unbalanced joint loading which can then trigger off TMJ disturbances.

EXAMINATION OF OROFACIAL DYSFUNCTIONS

Includes evaluation of:

- Swallowing
- Tongue
- Speech
- Lips
- Respiration

Swallowing

At birth the tongue protrudes anteriorly between the gum pads to establish lip seal. Therefore the infant swallows viscerally for the first 1 ½ to 2 years of age. This infantile swallow is gradually replaced by the mature swallow as the deciduous dentition is completed. If infantile swallow persists beyond the fourth year, it is considered as an orofacial dysfunction. The difference between infantile and mature swallow has been discussed in the chapter on oral habits.

Tongue

Tongue thrust is one of the most common dysfunction of the tongue. Tongue dysfunction can be assessed

clinically by electromyographic examination, cephalometric analysis, cine radiographic, palatographic and neurophysiologic examinations.

Cephalograms can help to evaluate the position and size of the tongue in relation to the available space. However, in orthodontics diagnostic registration of tongue position is usually more important than its size. Palatography involved applying a thin layer of contrasting impression material to the patients tongue.

Diagnosis of habits has been also covered in the chapter on habits. The students are request to refer to the same.

The findings should be recorded in a systematic manner. Conclusions drawn should be compared to the results obtained from cephalometric analysis. No decision should be taken arbitrarily, and all possible safeguards should be taken to prevent diagnosing a case wrongly.

FURTHER READING

1. Anderson GM. Practical Orthodontics, 9th ed., CV Mosby Co., 1960.
2. Case CS. A Practical Treatise on the Techniques and Principles of Dental Orthopedia, Reprinted Leo Bruder. New York, 1963.
3. Graber TM. Diagnosis and panoramic radiography, Am J Orthod, 1967;53:799-821.
4. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders 1988.
5. Moorrees CFA, Grøn AM. Principles of orthodontic diagnosis, Angle Orthod, 1966;36:258-62.
6. Moyers RE. Handbook of Orthodontics, ed. 3, Chicago, 1973, Year Book.
7. Proffit WR, Fields HW (Eds). Contemporary Orthodontics, 3rd ed, Mosby, 2000.
8. Salzmann JA. Practice of Orthodontics. J.B.lipincott Co., 1966.
9. Simon P. Fundamental Principles of a Systematic Diagnosis of Dental Anomalies. Translated by B.E.Lisher, Boston, Stratford Co. 1926.

8 Orthodontic Study Models

Tapasya Juneja, Gurkeerat Singh

- Introduction
- Objectives of ideal orthodontic study models
- Why we make study models?
- Uses of study models
- Parts of the study model
- Study model fabrication and trimming
- Model analysis
  - Pont's analysis
  - Linder Harth index
  - Korkhaus analysis
  - Ashley Howe's analysis
  - Wayne A. Bolton analysis
  - Carey's analysis
  - Moyer's mixed dentition analysis
  - Tanaka and Johnson analysis
- Kesling diagnostic set-up

INTRODUCTION

Orthodontic study models are essential diagnostic records, which help to study the occlusion and dentition from all three dimensions. They are accurate plaster reproductions of the teeth and their surrounding soft tissues.

IDEAL REQUIREMENTS OF ORTHODONTIC STUDY MODELS

1. Models should accurately reproduce the teeth and their surrounding soft tissues.
2. Models are to be trimmed so that they are symmetrical and pleasing to the eye and so that an asymmetrical arch form can be readily recognized.
3. Models are to be trimmed in such a way that the dental occlusion shows by setting the models on their backs.
4. Models are to be trimmed such that they replicate the measurements and angles proposed for trimming them.
5. Models are to have clean, smooth, bubble-free surfaces with sharp angles where the cuts meet.
6. The finished models should have a glossy mar-proof finish.

WHY WE MAKE STUDY MODELS?

1. They are invaluable in planning treatment, as they are the only three dimensional records of the patient's dentition.
2. Occlusion can be visualized from the lingual aspect.
3. They provide a permanent record of the intermaxillary relationships and the occlusion at the start of therapy; this is necessary for medicolegal considerations.
4. They are a visual aid for the dentist as he monitors changes taking place during tooth movement.
5. Help motivate the patient, as the patient can visualize the treatment progress.
6. They are needed for comparison at the end of treatment and act as a reference for posttreatment changes.
7. They serve as a reminder for the parent and the patient of the condition present at the start of treatment.
8. In case the patient has to be transferred to another clinician, study models are an important record.

USES OF STUDY MODELS

1. Assess and record dental anatomy
2. Assess and record intercuspation

3. Assess and record arch form
4. Assess and record the curves of occlusion
5. Evaluate occlusion with the aid of articulators
6. Measure progress during treatment
7. Detect abnormality, e.g. localized enlargements, distortion of arch form, etc.
8. Calculate total space requirements/discrepancies
9. Provide record before, immediately, after and several years following treatment for the purpose of studying treatment procedures and stability.

PARTS OF THE STUDY MODELS

The study models can be divided into two parts for the purpose of description:

- The anatomic portion
- The artistic portion
- The anatomic portion is that part which is the actual impression of the dental arch and its surrounding soft tissue structures. This is the part, which must be preserved when trimming the model
- The artistic portion is the stone base supporting the anatomic portion. This portion is trimmed in a manner, which depicts, in a general way, the dental arch form and is pleasing to the eye.

STUDY MODEL FABRICATION AND TRIMMING

Preliminary procedures in the fabrication of study models are:

1. Remove any excess flash or obviously excessive bulk on the periphery of the models
2. Remove any nodules that may be present on the occluding surfaces of the teeth
3. Remove any extensions in the posterior areas that prevent occluding of the models
4. Using the wax bite, occlude the models.

STEPS IN ART PORTION FABRICATION

1. Determine the occlusal plane of the dentition. Once this has been determined, the base of the lower model is trimmed parallel to the occlusal plane (Fig. 8.1A). The occlusal plane is considered to be the highest three points of the erupted teeth.
2. Trim the back of the lower model perpendicular to the base (Fig. 8.1B). This is done on a near symmetrical model by measuring the distance from the distal of the first molars or second bicuspids to the back of the model on both the left and right sides. On a model that is not symmetrical, compensation must be made to keep the back as near perpendicular to the midline as possible. The midline of the lower model should normally correspond favorably with the upper mid-palatal raphae. It is generally easier to locate the midline in the maxillary cast. The back is trimmed so that it is 90° to the base of the model.



Fig. 8.1A: Trim lower base parallel to occlusal plane



Fig. 8.1B: Trim lower back perpendicular to base

The posterior surface should not be trimmed too close to the posterior aspect of the mandibular teeth, as the hamular notch of the upper model

governs the distance, this surface should be from the teeth.

3. To trim the back of the upper model, occlude the models utilizing the wax bite. The wax bite not only maintains the correct interrelationship but will also help to prevent fracturing of the teeth. Carefully trim the posterior surface of the occluded models so that the upper model matches that of the lower model (Fig. 8.1C). The back of the upper and lower models should now be 90° to the base of the lower model. Trim the posterior surfaces of both models until you are just posterior to the hamular notch which should be several millimeters posterior to the last tooth.
4. Trim the base of the upper model so that it is parallel to the base of the lower model (Fig. 8.1D). Trim until the top base is flat, but leave several millimeters of extra height so the occlusal plane of the models can be centered and the models finished to the specified dimension.

   The occlusal plane should be centered between the top of the maxillary model and the base of the mandibular model, when the models are occluded without the wax bite, the models being viewed from the buccal.
5. Now we have two bases parallel to each other and to the occlusal plane (Fig. 8.1E). The backs of both the upper and lower bases are at right angles to the bases, the occlusal plane and to the mid-palatal aponeurosis.

From here onwards, the upper and lower models shall be trimmed independently of each other.

The Lower Model

1. Make the buccal cuts on the edge of the vestibule at 60° angle to balk (Fig. 8.1F). The edge of the vestibule is taken as a point approximately 5 to 6 mm away from the most prominent point of the lower canine or first bicuspid tooth (whichever is more prominent). The model is trimmed to this point provided that this does not cut beyond the deepest point of the vestibule in the region of the first or second molar. If this guideline would place the cut beyond the depth of the vestibule, then it is advisable to use the depth of the vestibule to determine the depth of the buccal cuts.
2. The anterior segment of the lower arch is trimmed into a curve, which should follow the arc of a circle



Fig. 8.1C: With models in occlusion, trim upper back so it is flush with the lower back



Fig. 8.1D: Place upper model (on its back) on the model trimmer. Trim until the top base is flat



Fig. 8.1E: Occlude models. Check bases for parallelism, backs for flush plane

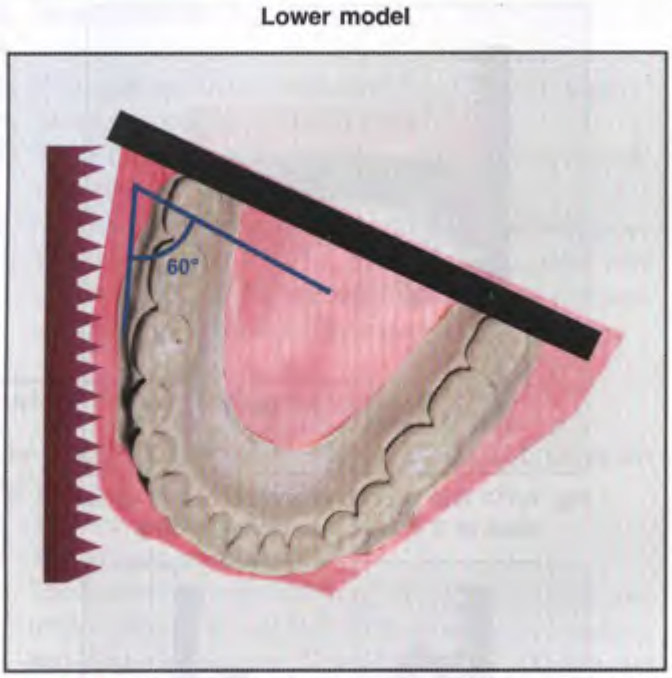


Fig. 8.1F: Make buccal cuts, at the edge of the vestibule 60° to the baite of the model

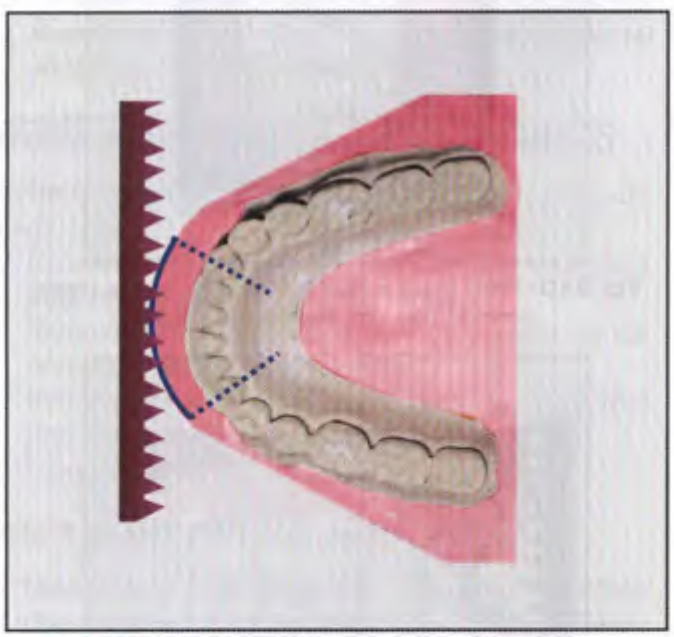


Fig. 8.1G: Make a smooth curve from canine to canine

(Fig. 8.1G). The radius of this segment of the circle should represent the general curvature of the lower anterior teeth. The finished model should have this curve trimmed to within 5 to 6 mm of the anterior teeth.

3. The heels of the lower model are cut at approximately 115° to the back of the model (Fig. 8.1H). The floor of the mouth should be leveled and smoothed to form a flat surface.

The ideal set of models will have the art portion representing approximately 1/3rd of the total height and the anatomic portion approximately 2/3rd of the height.

The Upper Model

1. Make the buccal cuts to the edge of the vestibule at an angle of 60° (Fig. 8.1I) to the back of the model.
2. Make the anterior cuts so that the ends are at the midline and approximately in the canine area (Fig. 8.1J). This cut should be approximately 5 to 6 mm from the labial surface of the anterior teeth, with both sides of equal length and their intersection on the midline.
3. The heels of the upper model are formed by occluding both the models and finishing them such that they are flush with the heels of the lower models at 115° (Fig. 8.1K). The heels of the upper model may not be the same length as those of the lower model.
4. The finished height of the occluded models should be 7 cm (Fig. 8.1L).

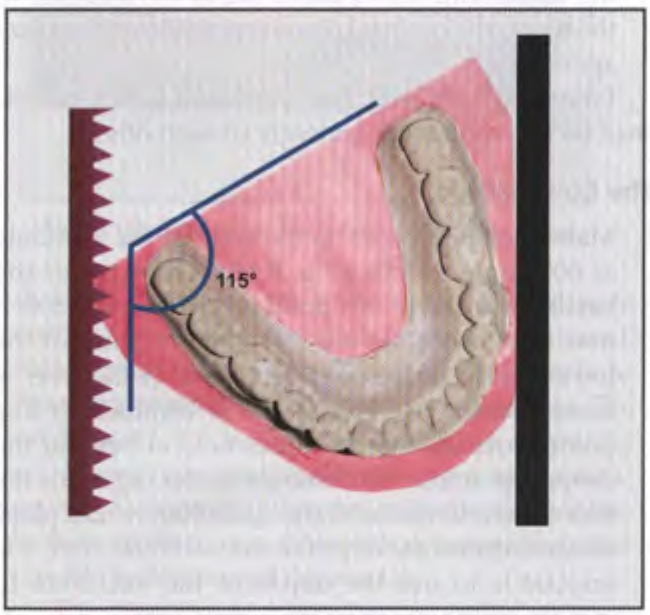


Fig. 8.1H: Move model trimmer guide to its extreme position to make the heel

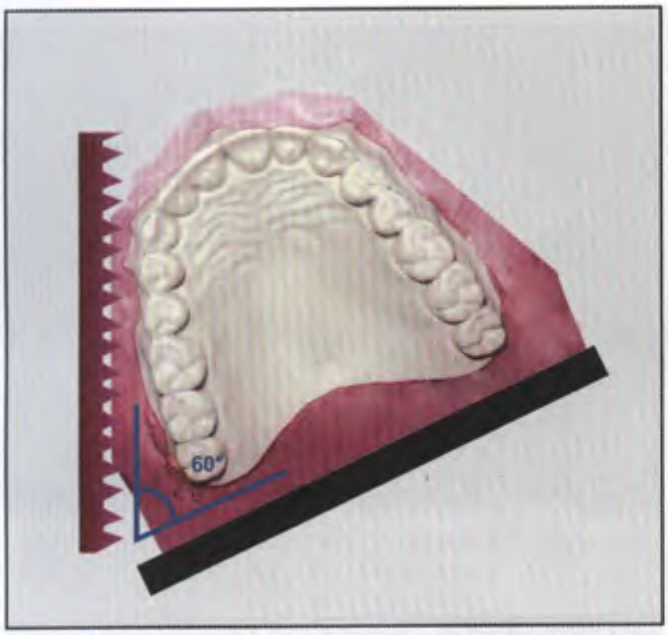


Fig. 8.1I: Make buccal cuts, at the edge of the vestibule 60° to back of the model

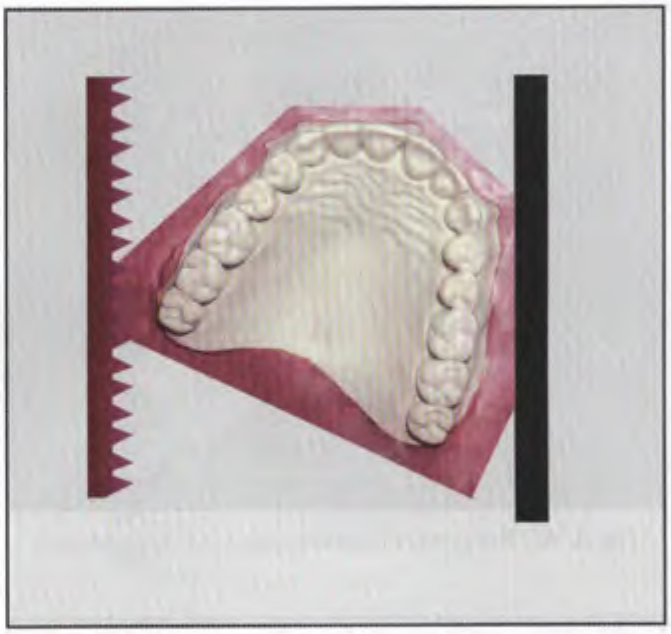


Fig. 8.1K Occlude models. Trim upper heels so they are flush with lower heels

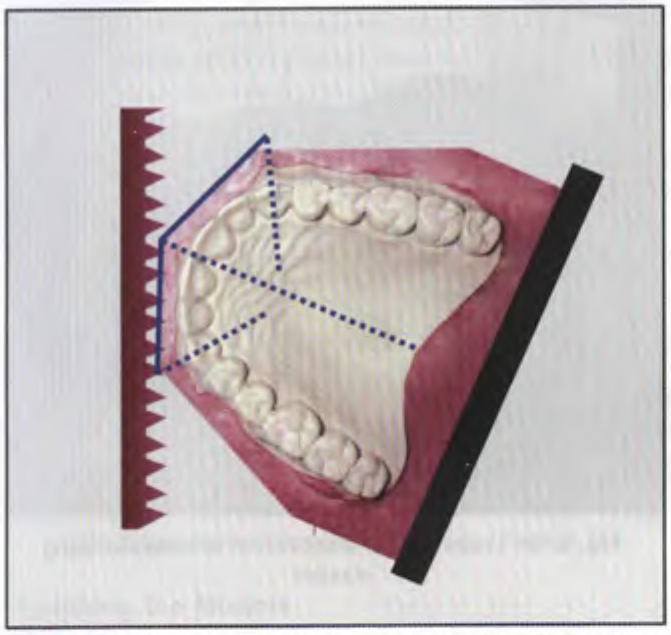


Fig. 8.1J: Make anterior cuts, the ends of which should be at the midline and the middle of each canine

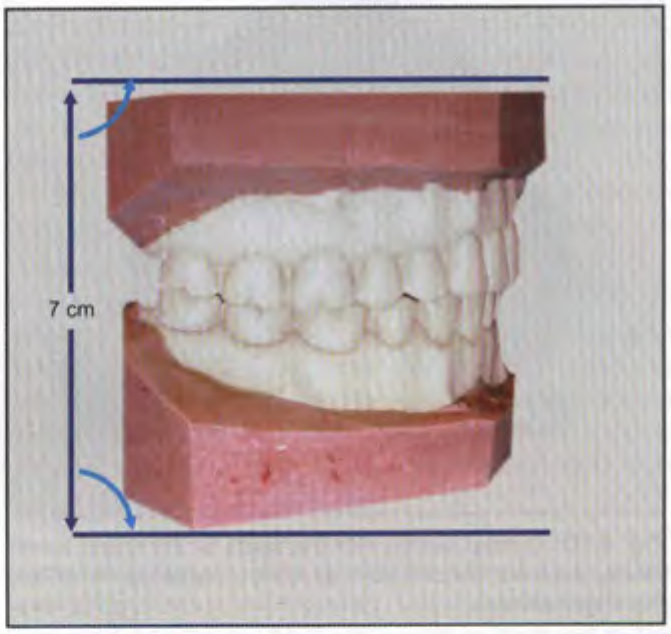


Fig. 8.1L: Occluded models should have a sharp 90° angle between their base and back

Commercially available plastic bases are now available which can be used to base the upper and lower model in articulation. These bases offer the advantage that they have a standard size, made of plastic and hence are easy to store. The procedure involved for using pre formed plastic bases for basing of models is as follows:

1. Using a pencil and the mid-palatal raphe as a reference, mark the midline of the maxillary cast. Match the mid palatal plane to the symmetric scribe line on the positioning plate. Secure the model in this position against the specially provided hooks using elastics (Fig.8.1M).

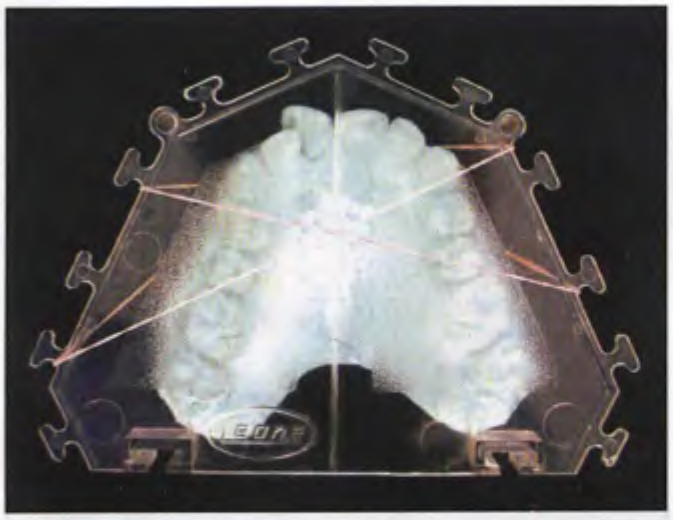


Fig. 8.1M: The positioning plate stabilized using elastics

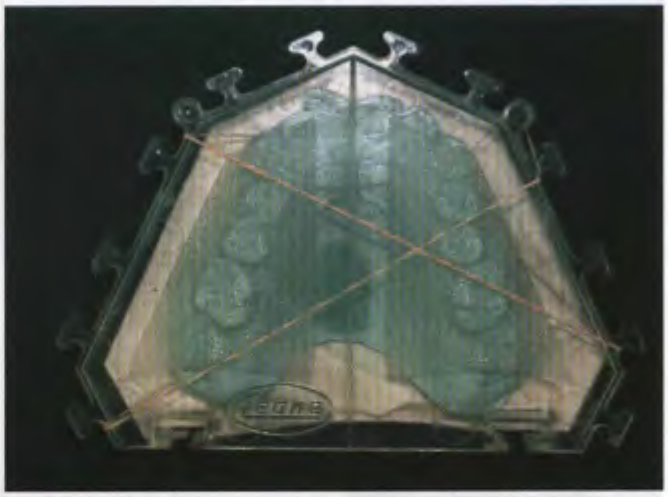


Fig. 8.1N: The stabilized upper model placed in the upper model base loaded with plaster



Fig. 8.1O: Guides seated into the seats of the upper model plaster base with the rest point directed towards the model and the edge upwards



Fig. 8.1P: Lower model stabilized in articulation using elastics

2. Now take the upper plastic model base and place the dove tails into the rear guide rails with the rest point outwards and the beveled edge upwards. The upper model base is easily recognizable by the anterior intercanine square shape. Pour sufficient quantity of well spatulated plaster into the upper model base and insert the position plate along with the stabilized upper model into the guide rails until the foot of the positioning plate touches the table top (Fig.8.1N). The excess plaster should be removed and the surface smoothened. The elastics can be cut and removed after the initial setting of the plaster has taken place. Once the plaster is completely set, the position plate and the guide rails can be taken off.



Fig. 8.1Q: The based models in occlusion



Fig. 8.1R: The based models with hinges act as joints for demonstration

3. The guides must be seated again into the seats of the upper model plaster base with the rest point directed towards the model and the edge upwards (Fig.8.1O).
4. Place the lower model into articulation with the upper model and stabilize it with elastics (Fig.8.1 P). The lower base is now loaded with a suitable quantity of well spatulated plaster and seated over the lower model with the guide rails into the seats of the lower plastic model base, until they are in contact with the rest point.
5. The excess plaster can be removed and the models finished (Fig.8.1Q).
6. The rails can be replaced with the hinges which keep the models in occlusion and act as hinge joints for demonstration purpose (Fig.8.1 R).

Finishing the Models

The surface must be made smooth, remaining at the same time absolutely flat and at right angles to the bases of the models. The finishing process should not change the dimensions or any of the angulations of the models. In the carborandum stone technique, the model is rubbed over the stone with an even pressure under a stream of water until a smooth surface results. The method is to rub the model on a frosted glass surface. After the surfaces have been finished, and the exact dimensions achieved, the model is set aside to dry for 48 hours or dried overnight in an orthodontic oven. At this point the model should be labeled with the patient's name and date on the backs of both the upper and lower models.

The final glazing is put on the models by immersing them in a commercial gloss. The models are allowed to remain in this solution for one-half hour. Holding each arch under cold water, the models are polished and soap solution removed by buffing with cotton. The models are set on their occlusal surfaces to dry for another twelve hours, then buffed with a very light but rapid motion using cotton. The models should assume a high, even luster which will then resist soiling while handling.

The models should be placed on a flat surface with their backs down. They should be picked up together and always returned together. Individual handling of the models is more likely to result in damage to the models.

Cast Trimming to Indicate Occlusal Plane Relationships

The gnathostatic technique, was introduced by Simon in 1962. It reproduces the inclination of the occlusal plane with reference to the eye-ear (Frankfort horizontal) plane. Trimmed in this fashion, the casts

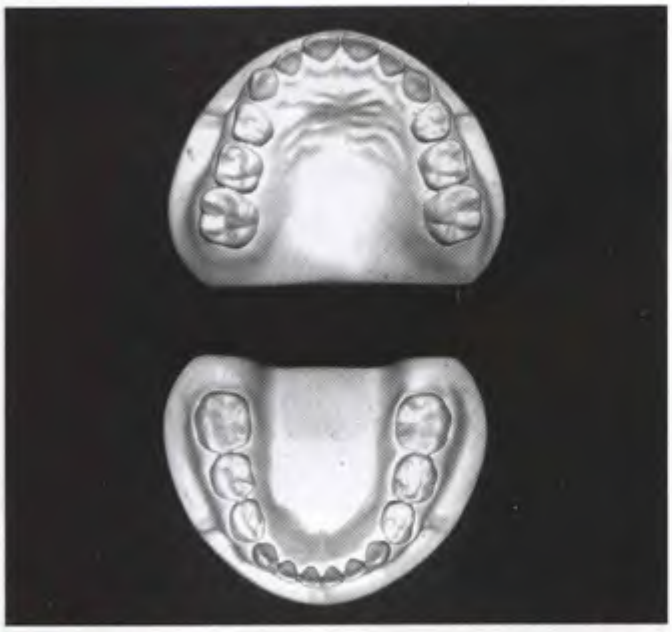


Fig. 8.2A: Sum of the mesiodistal widths of individual incisor teeth is added to calculate the arch width in the posterior region

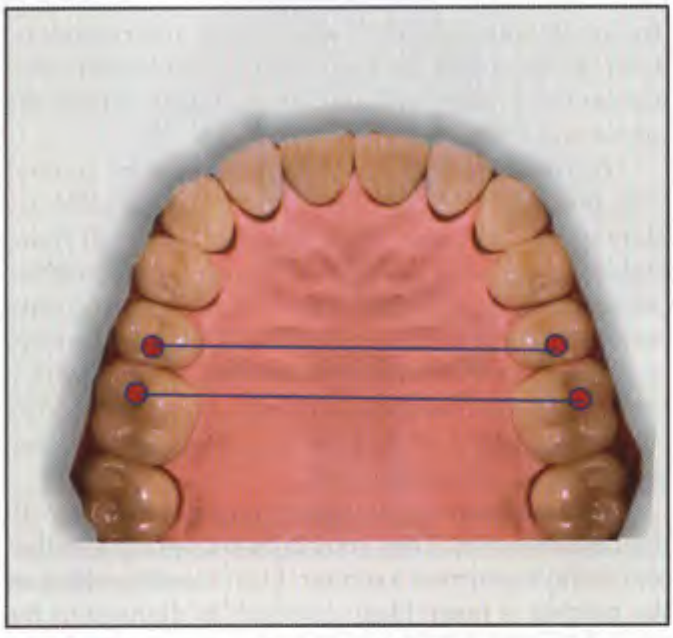


Fig. 8.2B: Measured molar value (MMV) in the maxillary arch

show the approximate inclination of the occlusal plane in the face of the patient. This information is valuable, but can be gained more accurately with the use of cephalogram. Also the casts so produced are not esthetically pleasing as they lack symmetry.

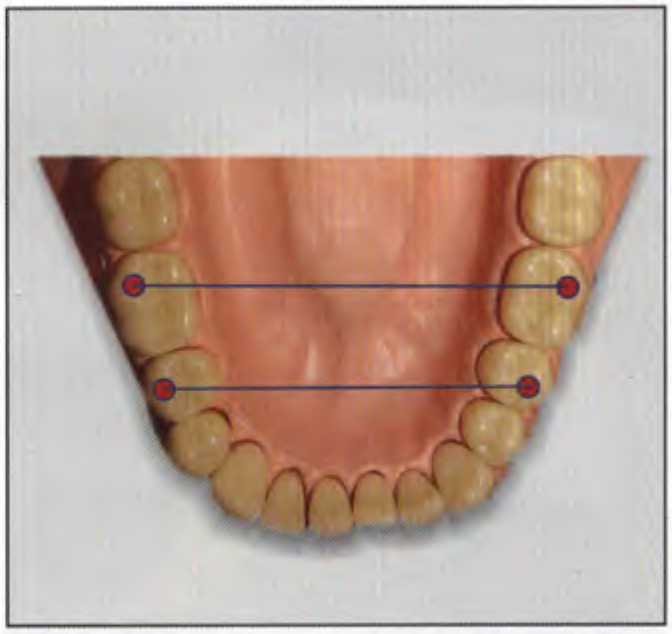


Fig. 8.2C: Measured molar value (MMV) in the mandibular arch

MODEL ANALYSIS

PONT'S ANALYSIS

In 1909 Pont presented to the profession a system whereby the mere measurement of 4 maxillary incisors automatically established the width of the arch in the premolar and molar region.

The greatest width of the incisors is measured with calipers recorded on a line, and their sums then recorded in millimeters. This is termed as *Sum of Incisors* (SI) (Fig. 8.2A).

The distance between the upper right first premolar and upper left first premolar (i.e. the distal end of the occlusal groove) is recorded and called as *Measured Premolar Value* (MPV) (Fig. 8.2B).

The distance between the upper right first molar and upper left first molar (i.e. the mesial pits on the occlusal surface) is recorded and is termed as *Measured Molar Value* (MMV) (Fig. 8.2B) whereas on the mandibular teeth the points used are the distobuccal cusps of the first permanent molar (Fig. 8.2C).

Calculated premolar value (CPV) The expected arch width in the premolar region is calculated by the formula:

$$\frac{SI \times 100}{80}$$

Calculated molar value (CMV) The expected arch width in the molar region is calculated by the formula:

$$\frac{SI \times 100}{64}$$

The difference between the measured and calculated values determines the need for expansion. If measured value is less, expansion is required.

Pont's index gives an approximate indication of the degree of narrowness of the dental arches in a case of malocclusion and also the amount of lateral expansion required for the arch to be of sufficient size to accommodate the teeth in perfect alignment.

Drawback of Pont's Analysis

1. Maxillary laterals are the teeth most commonly missing from the oral cavity.
2. Maxillary laterals may undergo morphogenetic alteration like 'peg' shaped lateral.
3. This analysis is derived solely from the casts of the French population.
4. It does not take skeletal malrelationships into consideration.
5. It may be useful to know the desired maxillary dimension for a case, but it is more difficult to achieve the corresponding mandibular dimensions that are necessary to maintain a balanced occlusal relationship.
6. Pont's index does not account for the relationship of the teeth to the supporting bone, or the difficulties in increasing the mandibular dimensions.

It should always be remembered that the patient's original mandibular and maxillary arch form should be considered as the ultimate guide for arch width rather than the values arrived at by using the Pont's index.

LINDER HARTH INDEX

Linder Harth proposed an analysis, which is very similar to Pont's analysis. However he made a variation in the formula to determine the calculated premolar and molar value.

The calculated premolar value is determined using the formula:

$$\frac{SI \times 100}{85}$$

The calculated molar value is determined using the formula:

$$\frac{SI \times 100}{64}$$

where SI = sum of mesiodistal width of incisors.

KORKHAUS ANALYSIS

This analysis makes use of the Linder Harth's formula to determine the ideal arch width in the premolar and molar region. An additional measurement is made from the midpoint of the inter-premolar line to a point in between the two maxillary incisors. According to Korkhaus, for a given width of upper incisors a specific value of the distance between the midpoint of inter-premolar line to the point between the two maxillary incisors should exist (Fig. 8.3A). In case of proclined

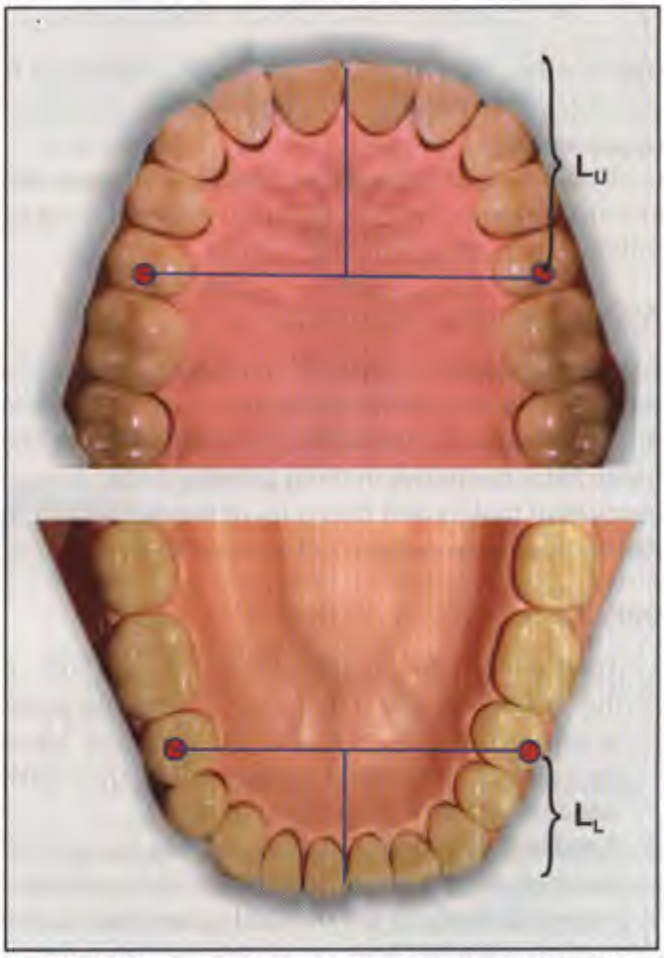


Fig. 8.3A: Measurement of anterior arch length (occlusal view)

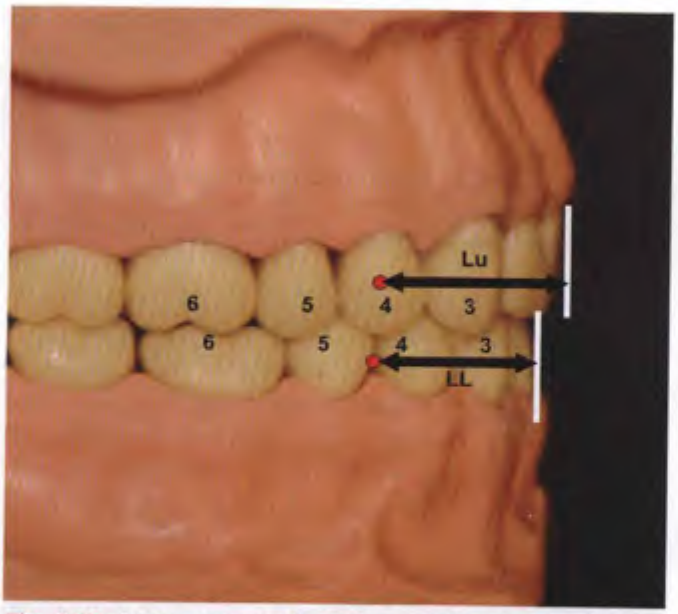


Fig. 8.3B: Measurement of anterior arch length (lateral view)

upper anteriors, an increase in this measurement is seen while a decrease in this value denotes retroclined upper anteriors.

For the values noted the mandibular value (Ll) should be equal to the maxillary value (Lu) in millimeters minus 2 mm (Fig. 8.3B).

ASHLEY HOWE'S ANALYSIS

Ashley Howe considered tooth crowding to be due to deficiency in arch width rather than arch length. He found a relationship between the total width of the mesiodistal diameters of teeth anterior to the second permanent molars and the width of the dental arch in the first premolar region.

Definitions

1. **Total tooth material (TTM)** Refers to the sum of the mesiodistal width of the teeth from first molar to first molar (inclusive of the first molars), taken on casts of the dental arches, measured with dividers or a Boley's gauge (Fig. 8.4A).
2. **Basal arch length (BAL)** In the maxilla the median line measurement from Downs A point is projected perpendicularly to the occlusal plane, then to the median point on a line connecting the distal surface of first molars (Fig. 8.4B).

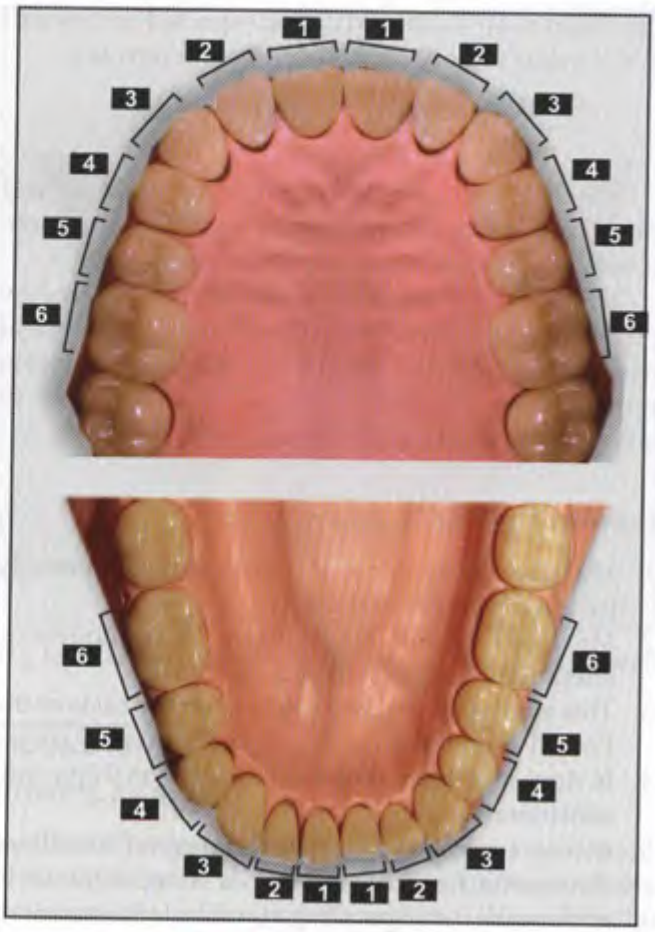


Fig. 8.4A: Total tooth material

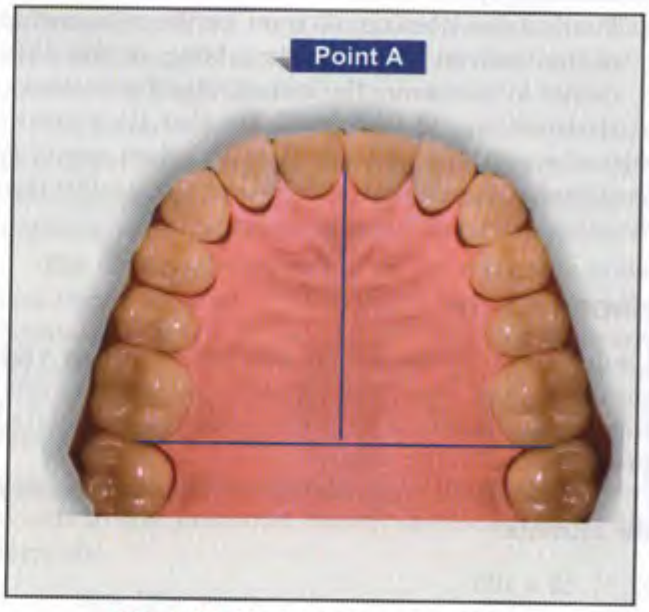


Fig. 8.4B: Maxillary basal arch length

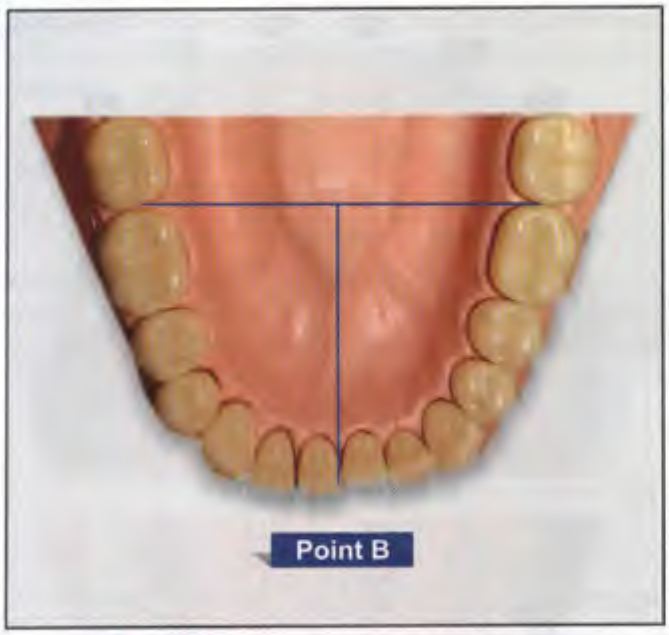


Fig. 8.4C: Mandibular basal arch length

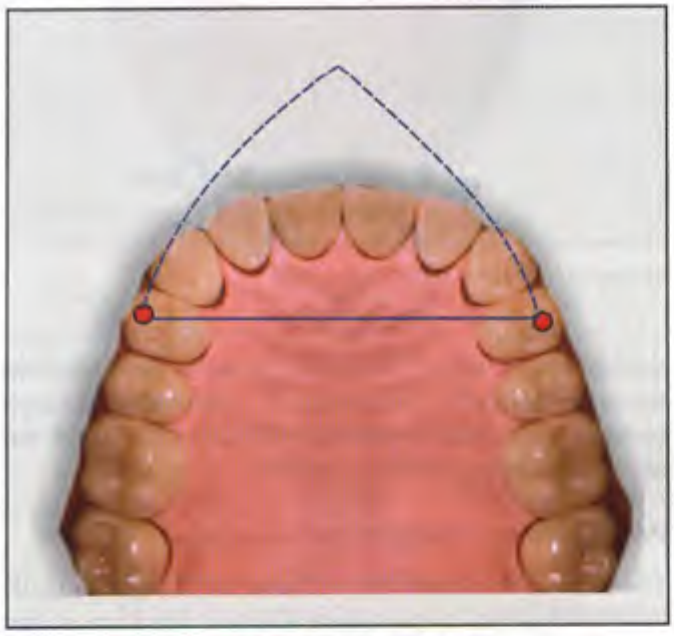


Fig. 8.4D: Premolar diameter

In the mandibular arch the measurement is made from Downs B point to a mark on the lingual surface of the cast in the same manner as in the maxilla (Fig. 8.4C).

3. **Premolar diameter (PMD)** Is the arch width measured at the top of the buccal cusp of the first premolar (Fig. 8.4D).
4. **Premolar basal arch width (PMBAW)** Is obtained by measuring the diameter of the apical base from canine fossa on one side to the canine fossa on the other side or else 8mm below the chest of interdental papilla between IOP below the canine and first premolar with the lower end of the Boley's gauge.

According to Ashley Howe, to determine whether the apical bases of the patient could accommodate the patients' teeth, the following measurements have to be obtained:

1. Percentage of premolar diameter to tooth material is obtained by dividing the PMD by the total tooth material.

$$\frac{\text{PMD}}{\text{TTM}} \times 100$$

2. Percentage of premolar basal arch width to tooth material is obtained by dividing the premolar basal arch width by the total tooth material.

$$= \frac{\text{PMBAW} \times 100}{\text{TTM}}$$

Percentage of basal arch length to tooth material is obtained by dividing the basal arch length by total tooth material.

$$\frac{\text{BAL} \times 100}{\text{TTM}}$$

Comparison between PMBAW and PMD gives an idea of the need and the amount of expansion required and PMBAW% gives an indication towards an extraction or non-extraction treatment plan.

Inference

a. If the width between the canine fossa is greater than the width of the premolars (PMBAW > PMD), it is an indication that basal arch is sufficient to allow expansion of the premolars.

   If the canine fossa width or PMBAW is less than PMD there can be 3 possibilities:
   - Don't treat.
   - Move teeth distally to wider part of the arch.
   - Extract some teeth.

b. According to Howe, to achieve a normal occlusion with a full complement of teeth the canine fossa measurement (PMBAW) should be 44 percent of the sum of the maxillary tooth diameter. When this ratio is between 37 percent and 44 percent, extraction of first premolars is doubtful, and the case is

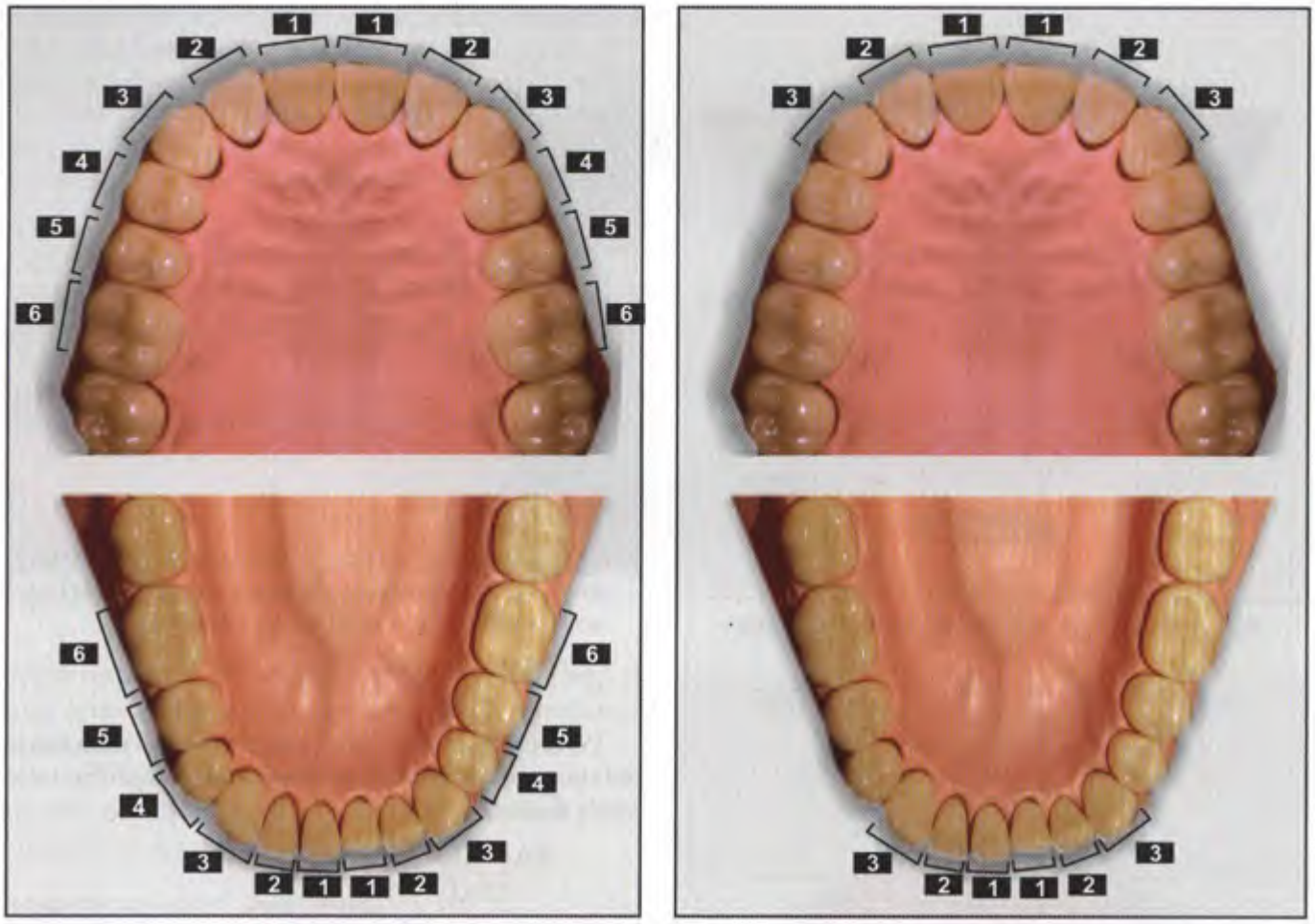


Fig. 8.5: Sum of the mesiodistal widths of the maxillary and mandibular teeth

considered to be in the borderline category. When it is less than 37 percent, then it is considered to be definitely a case for first premolar extraction as it is a basal arch deficiency. Any value, 44 percent or above indicates a non-extraction case.

Therefore, this analysis is a useful treatment planning tool and helps to determine whether to extract or expand.

WAYNE A. BOLTON ANALYSIS

Bolton pointed out that the extraction of one tooth or several teeth should be done according to the ratio of tooth material between the maxillary and mandibular arch, to get ideal interdigitation, overjet, overbite and alignment of teeth. To attain an optimum inter-arch dental relationship, the maxillary tooth material should approximate desirable ratios, as compared to the mandibular tooth material. Bolton's analysis helps to determine the disproportion between the size of the maxillary and mandibular teeth.

Procedure for doing Bolton Analysis

The sum of the mesiodistal diameter of the 12 maxillary teeth (sum of maxillary 12) and the sum of the mesiodistal diameter of the 12 mandibular teeth (sum of mandibular 12) including the first molars are determined. In the same manner, the sum of 6 maxillary anterior teeth (sum of maxillary 6) and the sum of 6 mandibular anterior teeth from canine to canine (sum of mandibular 6) is determined (Fig. 8.5).

Overall ratio The sum of the mesiodistal widths of the 12 mandibular teeth should be 91.3 percent the

mesiodistal widths of the 12 maxillary teeth, according to Bolton. This ratio is calculated using the following formula:

$$\text{Overall ratio} = \frac{\text{sum of mand. } 12 \times 100}{\text{sum of max. } 12}$$

The sum of the 12 maxillary and 12 mandibular teeth for a given patient is inserted into the formula and the overall ratio is determined. If the overall ratio is greater than 91.3 percent, then the mandibular tooth material is excessive. The amount of mandibular tooth material excess is calculated by using the formula:

$$\text{Mandibular overall excess} = \text{sum of mand. } 12 - \left\{\frac{\text{sum of max. } 12 \times 91.3}{100}\right\}$$

If the overall ratio is less than 91.3 percent, then the maxillary tooth material is excessive. The amount of maxillary tooth material excess is calculated by using the formula:

$$\text{Overall maxillary excess} = \text{sum of max. } 12 - \left\{\frac{\text{sum of mand. } 12 \times 100}{19.3}\right\}$$

Anterior ratio This ratio can be found out using the formula:

$$\text{Anterior ratio} = \frac{\text{sum of mand. } 6 \times 100}{\text{sum of max. } 6}$$

The sum of the mesiodistal diameter of the 6 mandibular anterior teeth should be 77.2 percent the mesiodistal widths of the 6 maxillary anterior teeth.

If the anterior ratio is greater than 77.2 percent, then the mandibular anterior tooth material is excessive. The amount of mandibular tooth material excess is calculated by using the formula:

$$\text{Mandibular anterior tooth material excess} = \text{sum of mandibular } 6 - \left\{\frac{\text{sum of max. } 6 \times 77.2}{100}\right\}$$

If the anterior ratio is less than 77.2 percent, then the maxillary anterior tooth material is excessive. The amount of maxillary tooth material excess is calculated by using the formula:

$$\text{Maxillary anterior tooth material excess} = \text{sum of max } 6 - \left\{\frac{\text{sum of max. } 6 \times 100}{77.2}\right\}$$

Drawbacks of the Analysis

1. This study was done on a specific population and the ratios obtained need not be applicable to other population groups.
2. Bolton analysis doesn't take into account the sexual dimorphism in the maxillary canine widths.

Bolton advocated the reduction of tooth material in the anterior region if the anterior ratio shows an excess of tooth material. He prefers to do proximal stripping on the upper arch if the upper anterior tooth material is excess and extraction of a lower incisor, if necessary, to reduce tooth material in the lower arch.

CAREY'S ANALYSIS

The arch length- tooth material discrepancy is the main cause for most malocclusions. This discrepancy can be calculated with the help of Carey's analysis. This analysis is usually done in the lower arch. The same analysis when carried out in the upper arch is called as *arch perimeter analysis.*

Methodology

Determination of arch length The arch length is measured anterior to the first permanent molar using

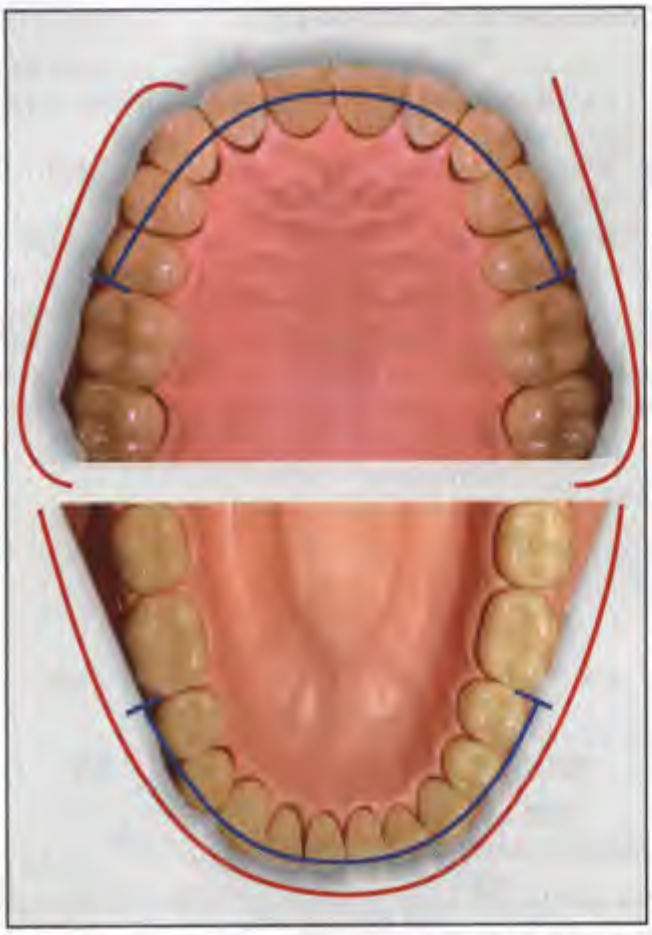


Fig. 8.6: Brass wire measurement and actual mesiodistal widths of the teeth mesial to the first permanent molars

a soft brass wire. The wire is placed touching the mesial aspect of lower first permanent molar, then passed along the buccal cusps of premolars, incisal edges of the anteriors and finally continued the same way up to the mesial of the first molar of the contralateral side (Fig. 8.6). The brass wire should be passed along the cingulum of anterior teeth if anteriors are proclined and along the labial surface if anteriors are retroclined. The mesiodistal width of teeth anterior to the first molars are measured and summed up as the Total tooth material.

The difference between the arch length and the actual measured tooth material gives the discrepancy.

Interpretation

The amount of discrepancy between arch length and tooth material is calculated.

If the arch length discrepancy is

- 0 to 2.5 mm—Proximal stripping can be carried out to reduce the minimal tooth material excess.
- 2.5 to 5 mm—Extraction of 2nd premolar is indicated
- Greater than 5 mm—Extraction of first premolar is usually required.

MOYER'S MIXED DENTITION ANALYSIS

The purpose of a mixed dentition analysis is to evaluate the amount of space available in the arch for succeeding permanent teeth and necessary occlusal adjustments. Many methods of mixed dentitions analysis have been suggested; however, all fall into two strategic categories:

1. Those in which the sizes of the unerupted cuspids and premolars are estimated from measurements of the radiographic image, and
2. Those in which the sizes of the cuspids and premolars are derived from knowledge of the sizes of permanent teeth already erupted in the mouth.

The correlation between the sizes of the mandibular incisors and the combined sizes of cuspids and bicuspids in either arch is high enough to predict the amount of space required for the unerupted teeth during space management procedures. The mandibular incisors have been chosen for measuring, since they erupt into the mouth early in the mixed dentition. The maxillary incisors are not used in any of the predictive procedures, since they show too much variability in size, and their correlations with other groups of teeth are of lower predictive value.

Procedure

a. **Procedure in the mandibular arch**

1. Measure with the tooth–measuring gauge or a pointed Boley's gauge, the greatest mesiodistal width of each of the four mandibular incisors.
2. Determine the amount of space needed for alignment of the incisors. Set the Boley's gauge to a value equal to the sum of the widths of the left central incisor and left lateral incisor. Place one point of the gauge at the midline of the alveolar crest between the central incisors and let the other part lie along the line of the dental arch on the left side. Mark on the tooth or the cast the precise point where the distal surface

of the lateral incisor will be when it has been aligned. Repeat this process for the right side of the arch.

3. Compute the amount of space available after incisor alignment. To do this, measure the distance from a point marked in the line of the arch to the mesial surface of the first permanent molar. This distance is the space available for the cuspid and two bicuspids and for any necessary molar adjustment after the incisors have been aligned. Record the data for both sides on the mixed dentition analysis form.
4. Predict the size of the combined widths of the mandibular cuspid and bicuspids. Prediction of the combined widths of cuspid, first bicuspid, and second bicuspid is done by use of probability charts. Locate in the left column of the mandibular chart the value that most nearly corresponds to the sum of the widths of the four mandibular incisors. To the right is a row of figures indicating the range of values for all the cuspid and bicuspids sizes that will be found for incisors of the indicated size. The value at the 75 percent level of probability is chosen as the estimate, since it has been found to be the most practical from a clinical standpoint.

b. **Procedure in the maxillary arch. The procedure is similar to that for the lower arch, with two exceptions**
   1. A different probability chart is used for predicting the upper cuspid and bicuspid sum.
   2. Allowance must be made for overjet correction when measuring the space to be occupied by the aligned incisors. Remember that the width of the lower incisors is used to predict upper cuspid and bicuspid widths.

TANAKA AND JOHNSON ANALYSIS

The prediction of the size of unerupted canines and premolars in contemporary orthodontic population can also be done with the Tanaka and Johnson analysis.

Tanaka and Johnson did a study to repeat Moyer's observation to validate its equation on a new sample. The possibility of secular changes within the past 20 years was to be examined and they found Moyer's prediction table to be equally appropriate for contemporary population.

However they have simplified Moyers 75 percent level of the prediction table into a formula

Predicted width of maxillary canine and premolar

$$\left\{\frac{\text{Mesiodistal width of four lower incisors}}{2}\right\} + 11$$

= estimated width of maxillary canine and premolar in one quadrant

Predicted width of mandibular canine and premolar

$$\left\{\frac{\text{Mesiodistal width of four lower incisors}}{2}\right\} + 10.5$$

= estimated width of canine and premolar in one quadrant

KESLING DIAGNOSTIC SET-UP

HD Kesling introduced the diagnostic set-up which is made from an extra set of trimmed study models (Fig. 8.7A). The diagnostic helps the clinician in treatment planning as it simulates various tooth movements, which are to be carried out in the patient. The individual teeth along with their alveolar process are sectioned off from the model using a saw (Figs 8.7B to 8.7E) and replaced back in the desired final position.

The procedure is as follows (Fig. 8.7):

- Dental cast is related to FMIA
- Constant FMIA = 65° and find ideal position of mandibular incisors mesiodistally.
- Align both the lower central and lateral incisors on the lower cast at FMIA = 65°
- Mandibular incisors are placed at right angles to mandibular plane.
- Canines are the next teeth to be positioned (Fig. 8.7F).
- First and second premolars are then set on the model.
- If the remaining space on each side is adequate to receive the permanent first molars, then extraction is not required.
- If space is inadequate and amounts to more than can be gained by uprighting the permanent second molars, then some teeth must be removed usually the first premolar (Fig. 8.7G).



Fig. 8.7A: Base the models to be used for Kesling setup

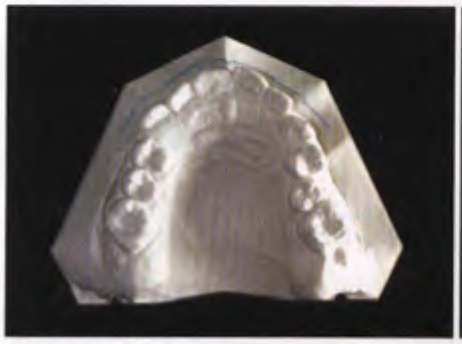


Fig. 8.7B: Mark the labial position of the anterior teeth and the canine width on the artistic portion of the model



Fig. 8.7C: Section individual teeth using a saw-starting with a vertical cut



Fig. 8.7D: Section individual teeth using a saw



Fig. 8.7E: Section the teeth molar to molar



Fig. 8.7F: Mandibular incisors are placed with an ideal inclination and position



Fig. 8.7G: According to the lower incisors the posterior teeth are set with or without extracting certain teeth depending on space requirements



Fig. 8.7H: The maxillary teeth are set according to the mandibular teeth



Fig. 8.7I: The finished set-up with ideal/proposed changes visible

Figs 8.7A to I: Steps in the fabrication of the Kesling set-up

- When the mandibular set-up is completed, the maxillary teeth are cut from their base and repositioned, then articulated to the mandibular set-up (Figs 8.7H and 8.7I).

Uses of Diagnostic Set-up

1. Aids in treatment planning as it helps to visualize tooth size-arch length discrepancies and determine whether extraction is required or not.
2. The effect of extraction and tooth movement following it, on occlusion can be visualized.
3. It also acts as a motivational tool as the improvements in tooth positions can be shown to the patient.

FURTHER READING

1. Ballard, Wylie. Mixed dentition case analysis: estimating size of unerupted teeth, Am J Orthod 1947;33:177-223.
2. Bolton WA. Disharmony in tooth size and its relationship to the analysis and treatment of malocclusion, Angle Orthod, 1958;28:113.
3. Bolton WA. The clinical application of a tooth-size analysis, Am J Orthod 1962;48:504-29.
4. Carey CW. Linear arch dimension and tooth size, Am J Orthod 35:1949.
5. Graber TM. Current Orthodontic Concepts and Techniques, WB Saunders Co. 1969.
6. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
7. Hixon EH, Oldfather RE. Estimation of the sizes of unerupted cuspid and bi-cuspid teeth, Angle Orthod, 1958;28:236.
8. Howe AE. Case analysis based on tooth material to base, Am J Orthod, 1947;33:353.
9. Huckaba GW. Arch size analysis and tooth size prediction. Dent Clin North Am July 1964;431.
10. Joondeph DR, Riedel RA, Moore AW. Pont's index: Clinical evaluation, Angle Orthod, 1970;40:112.
11. Kesling HD. The diagnostic setup with consideration of the third dimension, Am J Orthod, 1956;42:740-8.
12. Mills. Arch width, arch length and tooth size, Angle Orthod 1964.
13. Moyers RE. Handbook of Orthodontics, ed 3, Chicago, 1973, Year Book.
14. Nolla CM. The development of the permanent teeth, J Dent Child 1960;27:254.
15. Pont A. Der Zahn Index in der orthodontia, Z.Zahnaerztl, 1909.
16. Sanin C, Savara BS. Analysis of permanent mesiodistal crown size. Am J Orthod 1971;59:488.
17. Simon P. Fundamental Principles of a Systematic Diagnosis of Dental Anomalies. Stratford Co., 1926.
18. Tanaka, Johnston. The prediction of size of unerupted canines and premolars, Jam Dent Asso 1974;88:798.

9 Cephalometrics—Landmarks and Analyses

Gurkeerat Singh

- Introduction
- History of cephalometrics
- Uses of Cephalometrics
- Obtaining the cephalogram
- Tracing technique
- Anatomic structures in the cephalogram
- Points and landmarks—definition and requisites
- Points and landmarks—classified
- Points and landmarks—described in the lateral projection
- Down's analysis
- Steiner analysis
- Tweed analysis
- The WITS appraisal of jaw disharmony

INTRODUCTION

Cephalometric radiography is a standardized method of production of skull radiographs, which are useful in making measurements of the cranium and the orofacial complex. The radiograph thus obtained is called a cephalogram.

Cephalometrics had its beginning in craniometry. For many years anatomists and anthropologists were confined to measuring the craniofacial dimensions of skulls of dead individuals. This was not possible in case of living individuals, where the varying thickness of soft tissues interfered with the accuracy of these measurements. With the advent of radiography, an alternative method was provided which enabled the researchers to obtain indirectly but with sufficient accuracy, and convenience the skeletal measurements of the human skull. The reproducibility of these radiographs allowed for a longitudinal serial study of growth of living individuals.

Cephalometrics can be a useful diagnostic and evaluative tool for the Pedodontist, the Prosthodontist, the Oral Surgeon and the General Practitioner of Dentistry. Yet, it has primarily remained within the province of the Orthodontist and still remains a mystery to clinicians in other areas of dentistry. There is a general lack of knowledge of cephalometrics at the undergraduate level. This chapter will try to clear the basic fundamentals of cephalometrics and present in brief the commonly used analysis.

HISTORY OF CEPHALOMETRICS

In the 16th century artists Durer and DaVinci sketched a series of human faces with straight lines joining homologous anatomic structures. Variations in these lines highlighted the structural differences among the faces. These facial proportions were basically an artist's attempt, with beauty and harmony as the guiding principles, to quantify the basic structure of the human face.

Much later the anthropologists invented an instrument—the Craniostat, which helped in orienting dry skulls and facilitating standardized measurements. This improved the art of comparisons as the instrument improved reproducibility. But this also did not allow the study of skulls of living humans. The discovery of the X-rays in 1895 by Sir William Conrad Roentgen proved to be a boon in this direction.

The first paper on what we would today call cephalometrics was probably of that by Pacini in 1922. He presented the concept of standardized radiographic head images where subjects were positioned

to the cassette with gauze bandages at a distance of 2 meters from the X-ray tube.

In 1931, Hofrath in Germany and Broadbent in the United States simultaneously published articles in which they had refined the technique and applied these principles to orthodontics. Around this time, Simon's system of gnathostatics, a method for orienting orthodontic casts to the Frankfort horizontal plane, was in use. These ideas from anthropometrics and gnathostatics naturally evolved and fused into the new technology and evolved as the science of radiographic cephalometrics.

USES OF CEPHALOMETRICS

1. *Study of craniofacial growth* Serial cephalogram studies have helped in providing information regarding
   - The various growth patterns.
   - The formation of standards, against which other cephalograms can be compared.
   - Prediction of future growth.
   - Predicting the consequences of a particular treatment plan.
2. *Diagnosis of craniofacial deformity* Cephalograms help in identifying, locating and quantifying the nature of the problem, the most important result being a differentiation between skeletal and dental malrelationships.
3. *Treatment planning* By helping in diagnosis and prediction of craniofacial morphology and future growth, cephalometrics help in developing a clear treatment plan. Even prior to starting orthodontic treatment an orthodontist can predict the final position of each tooth within a given patient's craniofacial skeleton to achieve aesthetic and more stable results. It helps in distinguishing cases which can be treated with growth modification appliances or which may require orthognathic surgery in future.
4. *Evaluation of treated cases* Serial cephalograms permit the orthodontist to evaluate and assess the progress of treatment and also helps in guiding any desired change.
5. *Study of relapse in orthodontics* Cephalometrics also helps in identifying causes of orthodontic relapse and stability of treated malocclusions. It helps in establishing positions of individual teeth within the maxilla or the mandible, which can be considered to be relatively stable.

By convention, the distance from the X-ray source to the subjects' midsagittal plane is kept at five feet. The distance from the midsagittal plane to the cassette can vary in different machines, but must be the same for each patient everytime.



Fig. 9.1: Diagrammatic representation of the American standard cephalometric arrangement

OBTAINING THE CEPHALOGRAM

1. *Cephalometric equipment (Fig. 9.1)* A cephalometric apparatus consists of a cephalostat or head holder, an X-ray source, and a cassette holder. Cephalostats are of two types.
   A. *The Broadbent-Bolton method* utilizes two sources and two film holders so that the subject need not be moved between the lateral and postero-anterior exposures. It makes more precise three-dimensional studies possible but precludes oblique projections.

B. *The Higley method* used in most modern cephalostats uses one X-ray source and film holder with a cephalostat capable of being rotated. The patient is repositioned in the course of the various projections.

2. *The lateral projection* (Figs 9.2 and 9.3)
   A. *The midsagittal plane* of the subject's head is conventionally placed at 60 inches (152.4 cm) from the target of the X-ray tube with the left side (European convention is the right side) of the subject towards the film. The central beam of the X-ray coincides with the transmeatal axis, i.e. with the ear rods of the cephalostat. Under most circumstances, the distance from the midsagittal plane to the film is held constant, usually at 7 inches (18 cm). This distance can vary from machine to machine, but should remain the same for each patient every time his/her radiograph is taken. In the Brodbent-Bolton cephalometer, this distance is varied according to the subject. The patient's head is placed with the Frankfort plane parallel to the floor and the subjects teeth together in their usual occlusal position and the lips are left loose.
   B. *The posteroanterior projection* (Fig. 9.4) The head is rotated by 90 degrees so that the central ray perpendicularly bisects the transmeatal axis. It is crucial that the Frankfort plane be accurately horizontal, because when the head is tilted, all vertical displacements measured are altered.
   C. *Oblique projections* The right and left oblique cephalograms are taken at 45° to the lateral projection, the central ray entering behind one ramus to obviate superimposition of the halves of the mandible. The Frankfort plane must stay horizontal; any tipping will alter measurements. The oblique cephalogram is particularly useful for patients in the mixed dentition. But has been rarely prescribed by the clinicians.



Fig. 9.2: Lateral cephalogram



Fig. 9.3: Lateral cephalogram



Fig. 9.4: P-A cephalogram

TRACING TECHNIQUE

Tracing should be systematic. One should begin with a general inspection of the cephalogram and then locate and identify standard landmarks. This is followed by tracing the anatomic structures in a logical sequence, and finally constructing derived landmarks and lines.

STEPWISE TRACING TECHNIQUE

Step 1

Draw at least two plus shaped crosses on the top right and left corners of the radiograph. These are drawn away from any landmarks and are used to orient the tracing over the radiograph.

Step 2

Trace the soft tissue profile, external cranium, and the cervical vertebrae.

Step 3

These are followed by the tracing of the cranial base, internal border of cranium, frontal sinus, and ear rods (Moorrees recommends abandoning porion and instead using the superior border of the head of condyle to define FH).

Step 4

Maxilla and related structures including the *key ridges* (which represent the zygomatic processes of the maxillary bone) and pterygomaxillary fissures are then traced. The nasal floor is also traced along with the anterior and posterior nasal spines. The first molar and the most anteriorly placed maxillary incisor (including its root) are also traced.

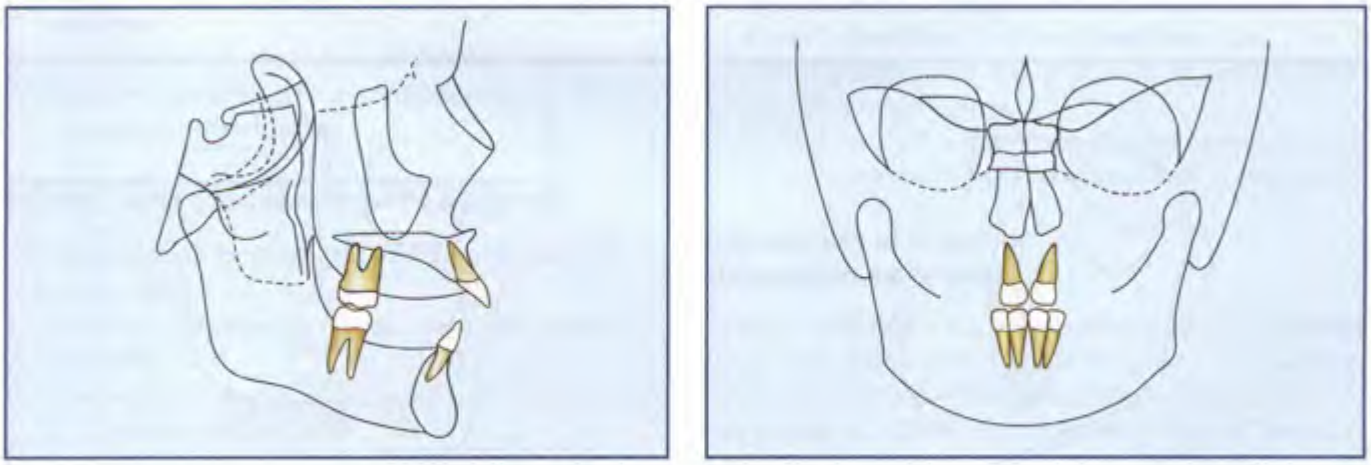
Step 5

Finally the mandible, including the symphysis, the lower border of the mandible, the condyles and the coronoid processes is traced. The first molars and the most anteriorly placed incisor tooth including its root are to be traced. The mandibular canal may be traced and is at times used for superpositioning serial radiographs.

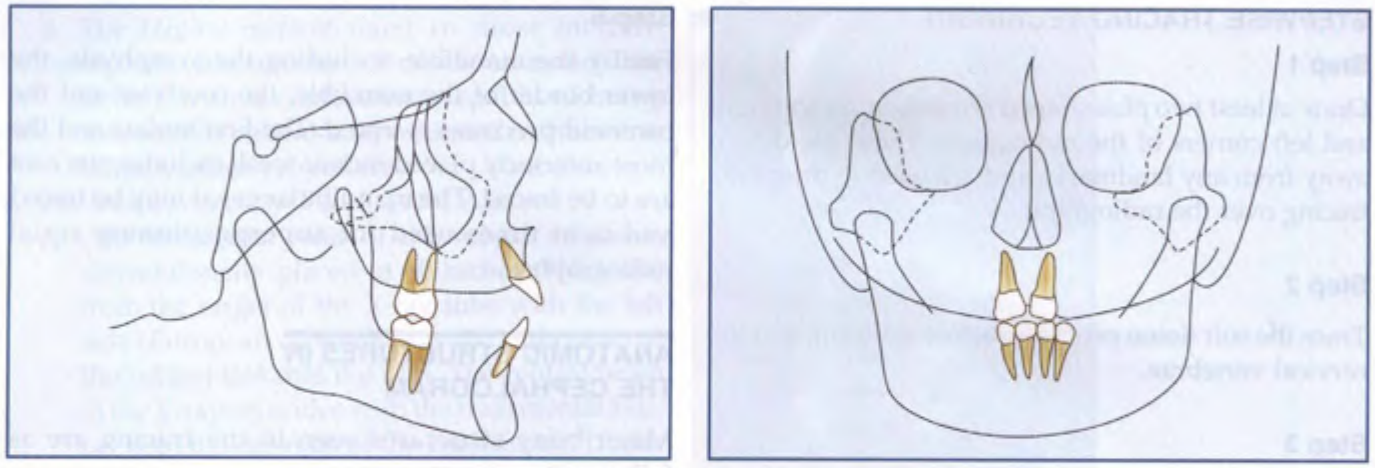
ANATOMIC STRUCTURES IN THE CEPHALOGRAM

Major bony structures seen in the tracing are as follows:

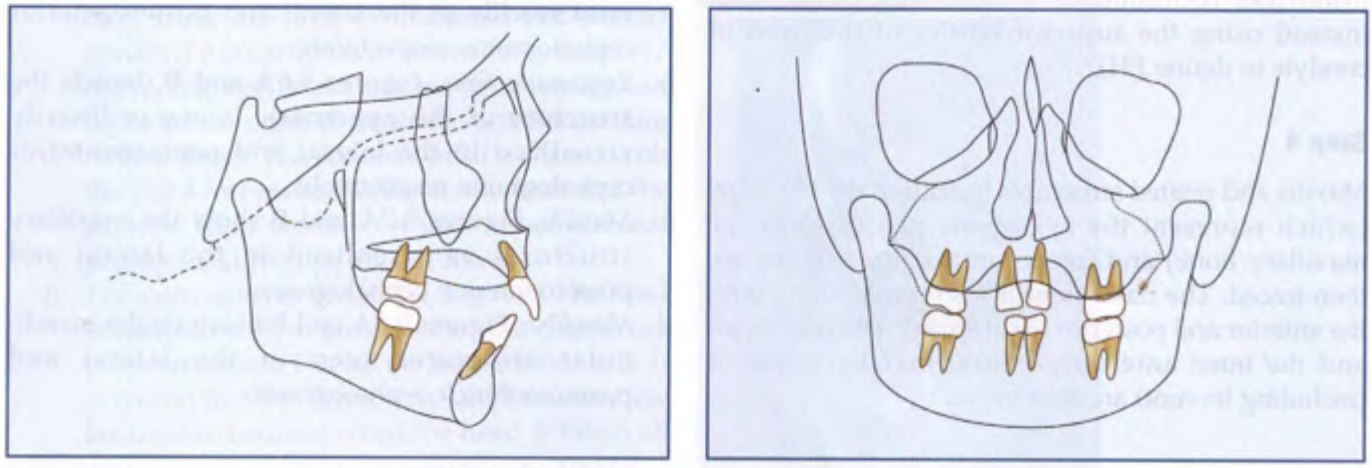
a. *Sphenoid bone,* Figures 9.5A and B show in heavy outline those structures of the sphenoid bone seen most readily in the lateral and posteroanterior cephalograms respectively.
b. *Zygomatic bone,* Figures 9.6A and B depicts the structure of the zygomatic bones ordinarily visualized in the lateral and posteroanterior cephalograms respectively.
c. *Maxilla,* Figures 9.7A and B show the maxillary structures as visualized in the lateral and posteroanterior cephalograms.
d. *Mandible,* Figures 9.8A and B illustrate the mandibular structures seen in the lateral and posteroanterior cephalograms.



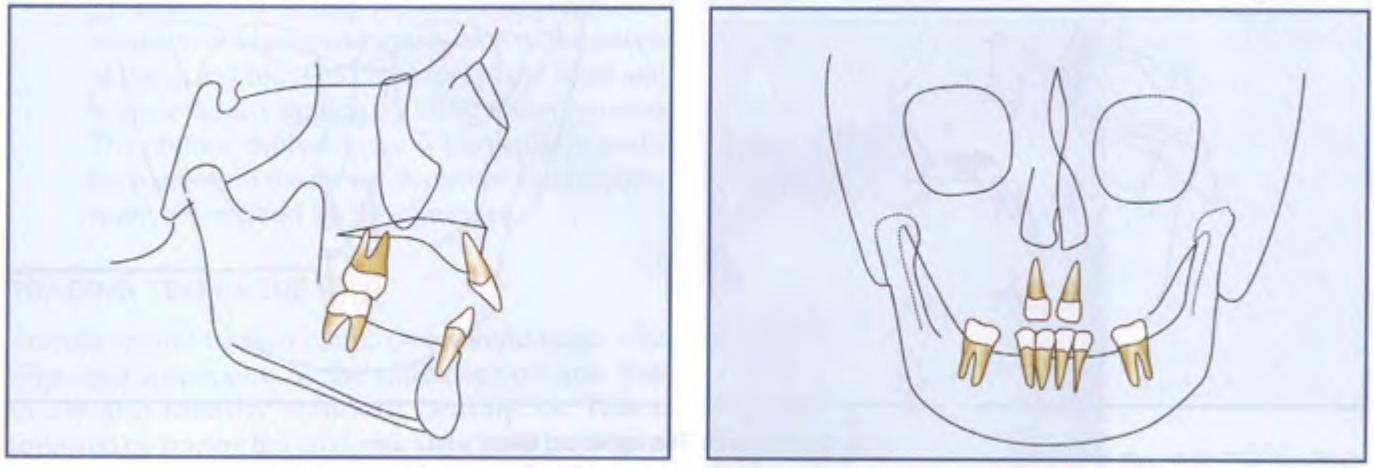
Figs 9.5A and B: The sphenoid bone



Figs 9.6A and B: The zygomatic bone



Figs 9.7A and B: The maxilla



Figs 9.8A and B: The mandible

POINTS AND LANDMARKS—DEFINITION AND REQUISITES

A landmark is a point serving as a guide for measurement. An ideal landmark is located reliably on the skull and behaves consistently during growth. It should not be assumed that all landmarks are equally reliable and valid.

The reliability (reproducibility, dependability) of a landmark is affected by

- The quality of the cephalogram (Figs 9.2 and 9.3)
- The experience of the tracer, and
- Confusion with other anatomic shadows.

The validity (correctness or use as proof) of the landmark is determined largely by the way the landmark is used.

Cephalometric landmarks and points should have the following attributes (according to the Research Workshop on Cephalometrics Organized by The American Association of Orthodontics in Washington DC in 1960):

1. Landmarks should be easily seen on the radiograph, they should be uniform in outline, and should be easily reproducible.
2. Lines and planes should have significant relationship to the vectors of growth of specific areas of the skull.
3. Landmark should permit valid quantitative and qualitative measurements of lines and angles projected from them.
4. Measurements should be amenable to statistical analyses.
5. Cephalometric analysis preferably should not require extensive specialized training on the part of clinical orthodontist.

POINTS AND LANDMARKS—CLASSIFIED

Cephalometric points and landmarks are of the following kinds:

1. Anatomic landmarks or true anatomic points.
2. Implants
3. Derived landmarks. These can be of three types:
   a. External points
   b. Intersections of edges of regression, and
   c. Intersections of constructed lines

TRUE ANATOMIC POINTS

Anatomic "points" are really small regions, which might be located on the solid skull even better than in the cephalogram. Each point has its own scale and its own uncertainty in one or two dimensions. Examples include the anterior nasal spine (ANS). Infradentale (ID), cusp tips or incisal edges (Is), and Nasion (Na).

IMPLANTS

Implants are artificially inserted radiopaque markers, usually made of an inert metal. They are "private points" and their position can vary from subject to subject, making cross-sectional studies very difficult. They may be located more precisely than traditional points and provide precise super positioning, and are ideal for longitudinal studies on the same subject.

DERIVED POINTS

As the name suggests the derived points are derived to or created for the purpose of comparison or calculations of the cephalograms. These are of the following three types.

External Points

External points are points characterized by their properties relative to the entire outline:

a. These points are extremes of curvature, e.g. incision superius (Is)
b. Points whose coordinates are largest or smallest of all points on a specific outline, (e.g. "A point", "B Point". Gnathion (Gn), or Condylion (Co)
   These points have less precision of location than true anatomic points.
c. Points defined in pairs: e.g. the two gonions used to measure mandibular width in the PA projection.

Intersection of Edges of Regression as "Points"

"Points" defined as the intersection of images are really lines looked at down their length. For instance, articulare (Ar) and Pterygomaxillary fissure (Ptm) are not points at all and are in no way part of the solid skull. Such "points" exist only in projections and are dependent on subject positioning.

Intersection of Constructed Lines

Intersections of constructed lines are used as "Points", e.g. "Gonion" sometimes is defined as the intersection of the ramal and mandibular lines.

POINTS AND LANDMARKS—DESCRIBED IN THE LATERAL PROJECTION (Fig. 9.9)

Precise definitions of the points and measures used in current cephalometrics is important for improved use in practice. The universal acceptance of definitions will enable clinicians from different orthodontic schools to communicate and understand each other more accurately. All definitions are for easy understanding and may at times vary for a particular analysis.

UNILATERAL LANDMARKS

Nasion (Na) (Fig. 9.10)

The frontonasal suture at its most superior point on the curve at the bridge of the nose.

Anterior Nasal Spine (ANS) (Fig. 9.11)

The most anterior point on the maxilla at the level of the palate.

Superior Prosthion (SPr or PR) (Fig. 9.12)

Also termed supradentale. The most anterior inferior point on the maxillary alveolar process, usually found near the cementoenamel junction of the maxillary central incisor.

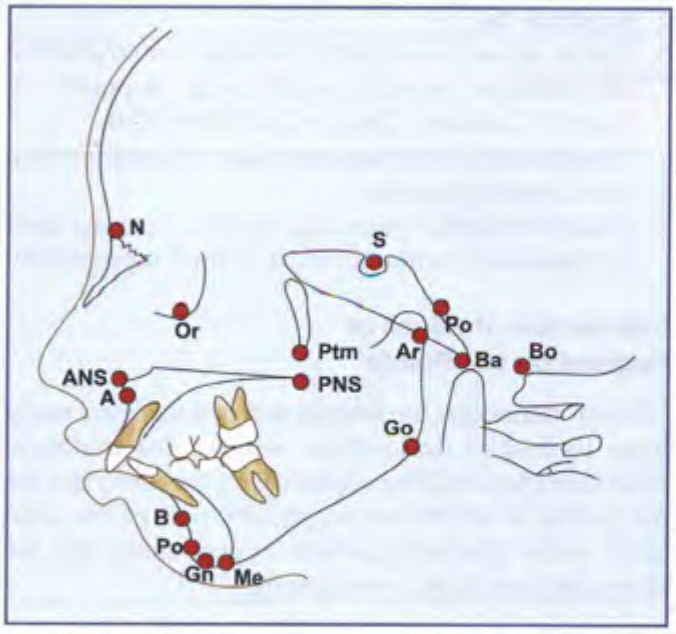


Fig. 9.9: Commonly used landmarks in cephalometrics

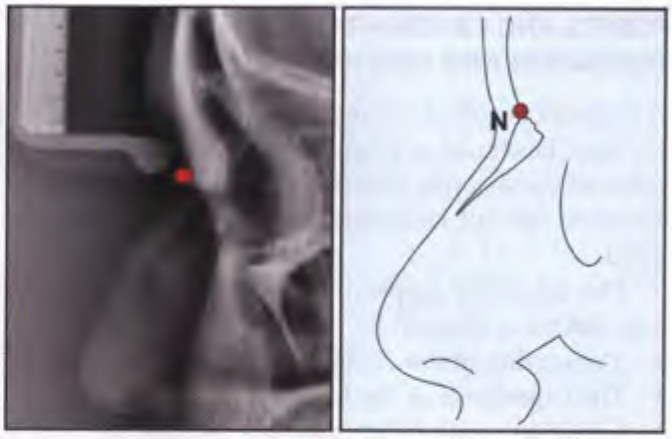


Fig. 9.10: Nasion

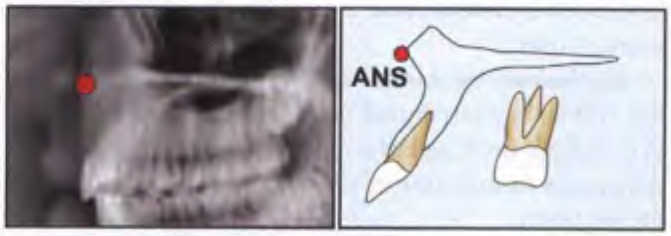


Fig. 9.11: Anterior nasal spine or ANS (red dot)

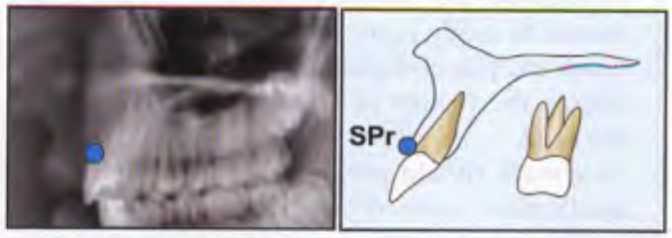


Fig. 9.12: Superior prosthion or supradentale or point SPr (blue dot)

Subspinale ("A" Point) (Fig. 9.13)

The most posterior point on the curve between ANS and PR (SPr). "A" point is usually found 2 mm anterior to the apices of the maxillary central incisor root.

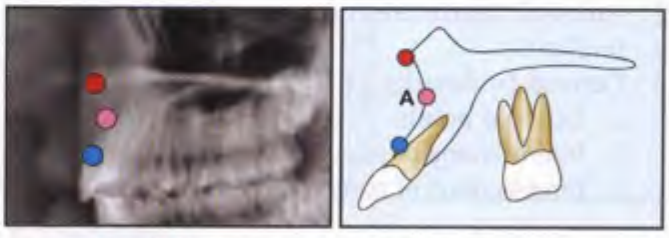


Fig. 9.13: Subspinale or Point "A" (pink dot)

Incision Superius (Is) (Fig. 9.14)

The incisal tip of the most anterior maxillary central incisor.

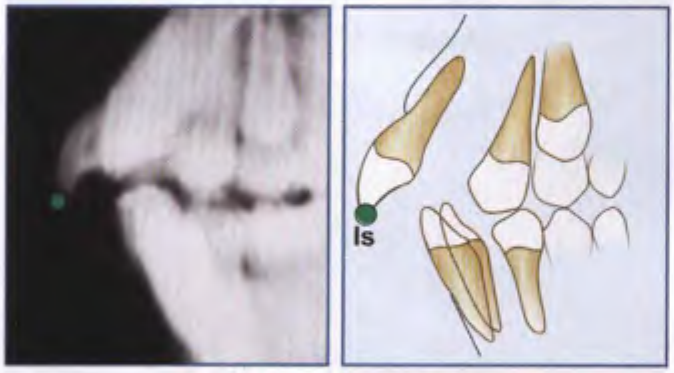


Fig. 9.14: Incision superius

Incision Inferius (Ii) (Fig. 9.15)

The incisal tip of the most labial mandibular central incisor.

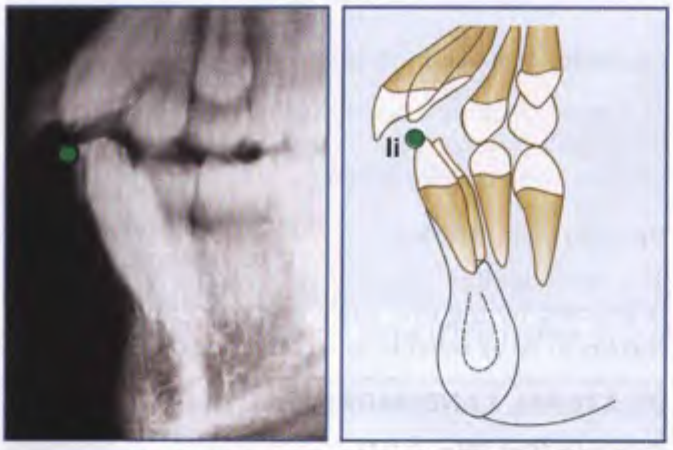


Fig. 9.15: Incision inferius (green dot)

Infradentale (Id) (Fig. 9.16)

The most anterosuperior point on the mandibular alveolar process usually found near the cemento-enamel junction of the mandibular central incisor. Also termed inferior prosthion.

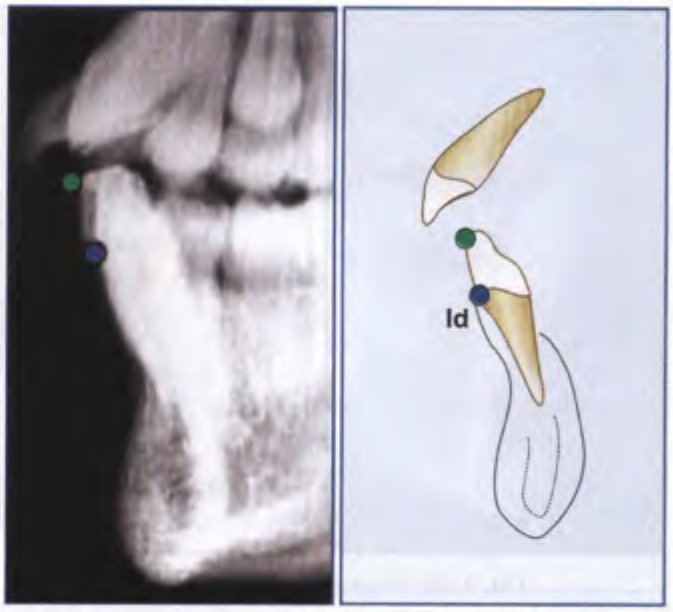


Fig. 9.16: Infradentale (Id) or inferior prosthion (blue dot)

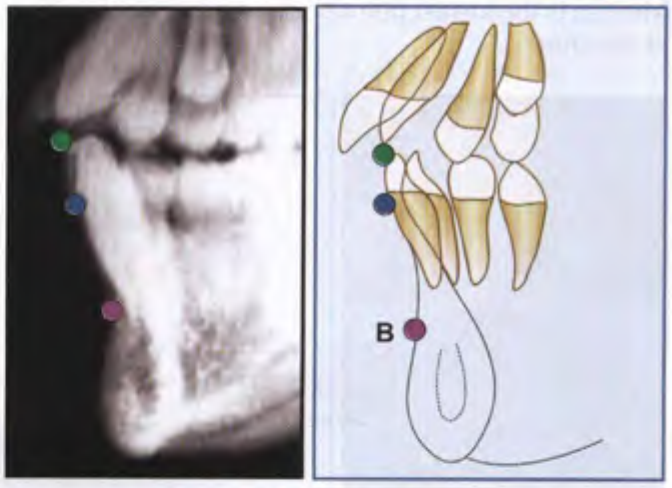


Fig. 9.17: Point "B" (pink dot)

Supramentale ("B" point) (Fig. 9.17)

The most posterior point of the bony curvature of the mandible below infradentale and above Pogonion. "B" point is usually found near the apical third of the roots of the mandibular incisors and may be obscured during the eruption of these teeth. When the profile of the chin is not concave, "B" point cannot be determined.

Pogonion (Pog) (Fig. 9.18)

Pogonion is the most anterior point on the contour of the chin. Pogonion usually is located by a tangent perpendicular to the mandibular line or a tangent dropped to the chin from nasion.

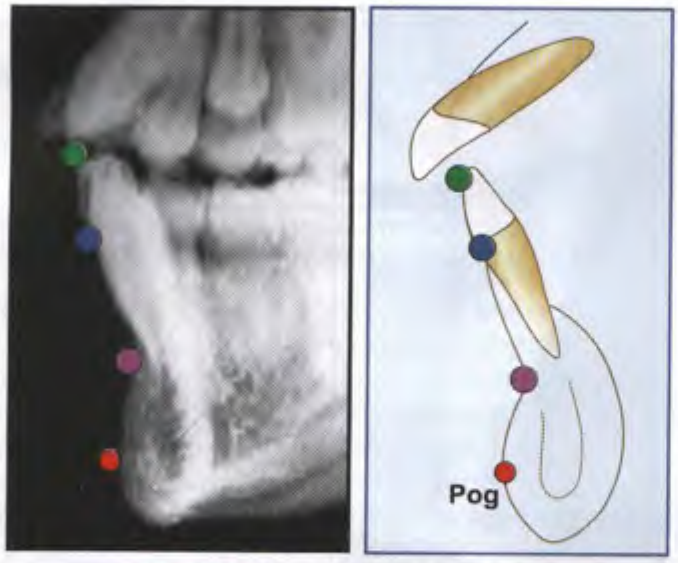


Fig. 9.18: Pogonion (Pog) (red dot)

Menton (Me) (Fig. 9.19)

Menton is the lowest point on the symphyseal outline of the chin.

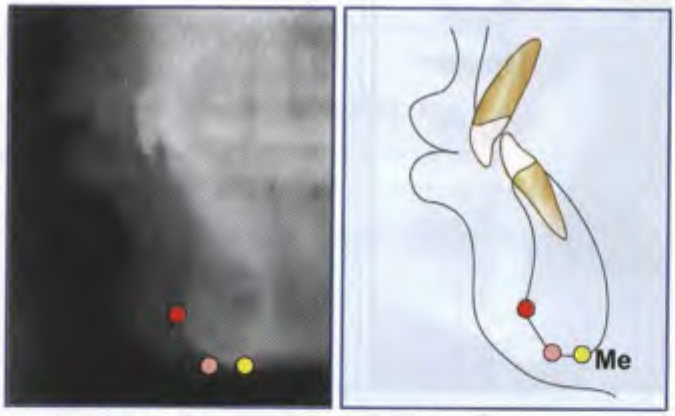


Fig. 9.19: **Menton (yellow dot);** Gnathion (orange dot); Pogonion (red dot)

Gnathion (Gn) (Fig. 9.20)

The most anteroinferior point on the lateral shadow of the chin. Gnathion may be approximated by the midpoint between pogonion and menton on the contour of the chin.

Basion (Ba) (Fig. 9. 21)

The most inferoposterior point in the sagittal plane on the anterior rim of the foramen magnum—the tip of the posterior cranial base.

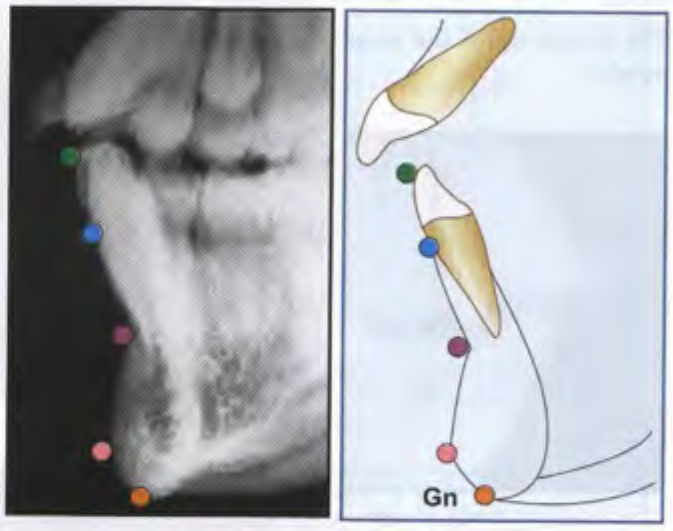


Fig. 9.20: Gnathion (orange dot)

Bolton Point (BO)

The highest point in the upward curvature of the retrocondylar fossa (according to broadbend).

Posterior Nasal Spine (PNS) (Fig. 9.22)

The most posterior point on the bony hard plate in the sagittal plane: usually the meeting point of the inferior and superior surfaces of the hard plate.

Sella(S) (Fig. 9.23)

The center of the hypophyseal fossa (sella turcica). It is selected by the eye, since that procedure has been shown to be as reliable as a constructed center.

BILATERAL LANDMARKS

Orbitale (Or) (Fig. 9.24)

Orbitale has been defined as the lowest point of the bony orbit. In the PA cephalogram, each may be identified but in the lateral cephalograms, the outlines of the orbital rims overlap. Usually, the lowest point on the average outline is used to construct the Frankfort plane.

Gonion (Go) (Fig. 9.25)

Gonion is the most posteroinferior point at the angle of the mandible. It may be determined by inspection or by bisecting the angle formed by the junction of the ramal and mandibular lines, and extending this bisector through the mandibular border.

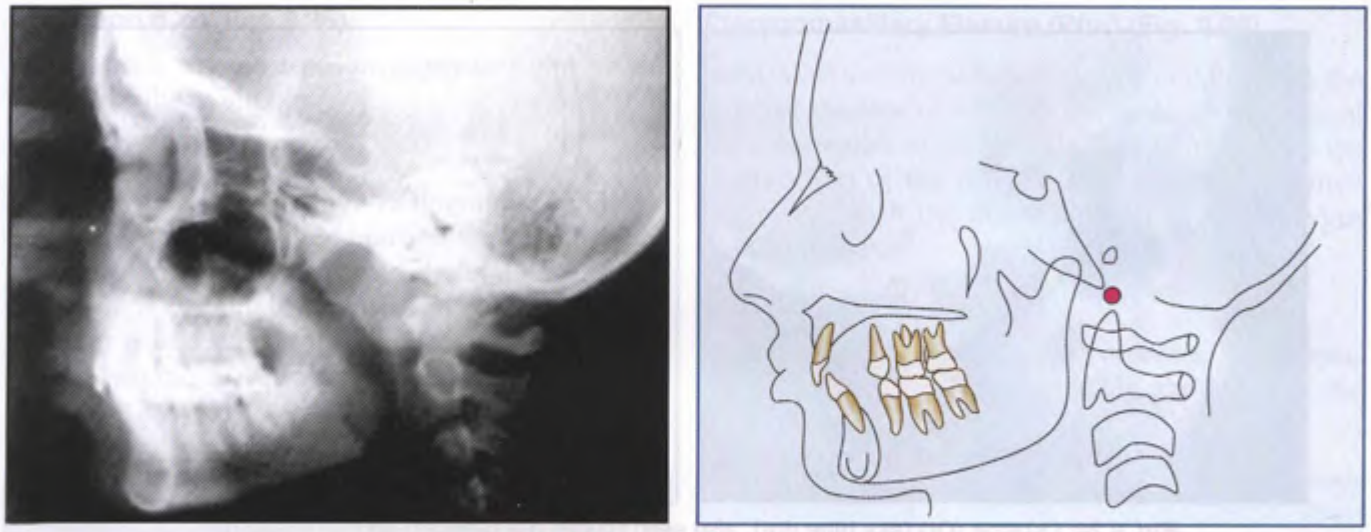


Fig. 9.21: Basion (Ba) (pink dot)

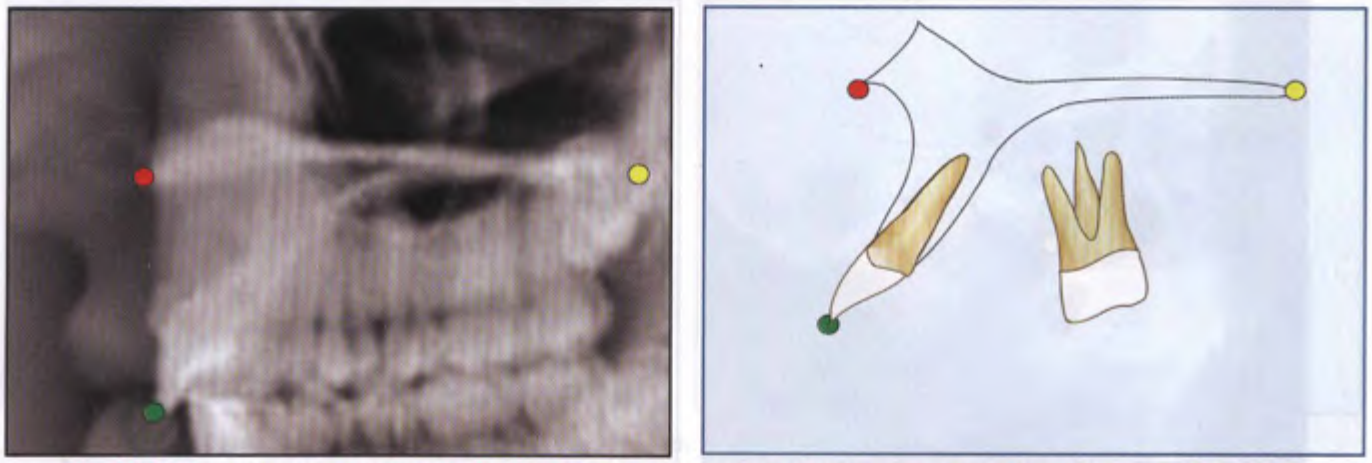


Fig. 9.22: **Posterior nasal spine (PNS) (yellow dot);** also seen is Incision superius (green dot) and ANS (red dot)

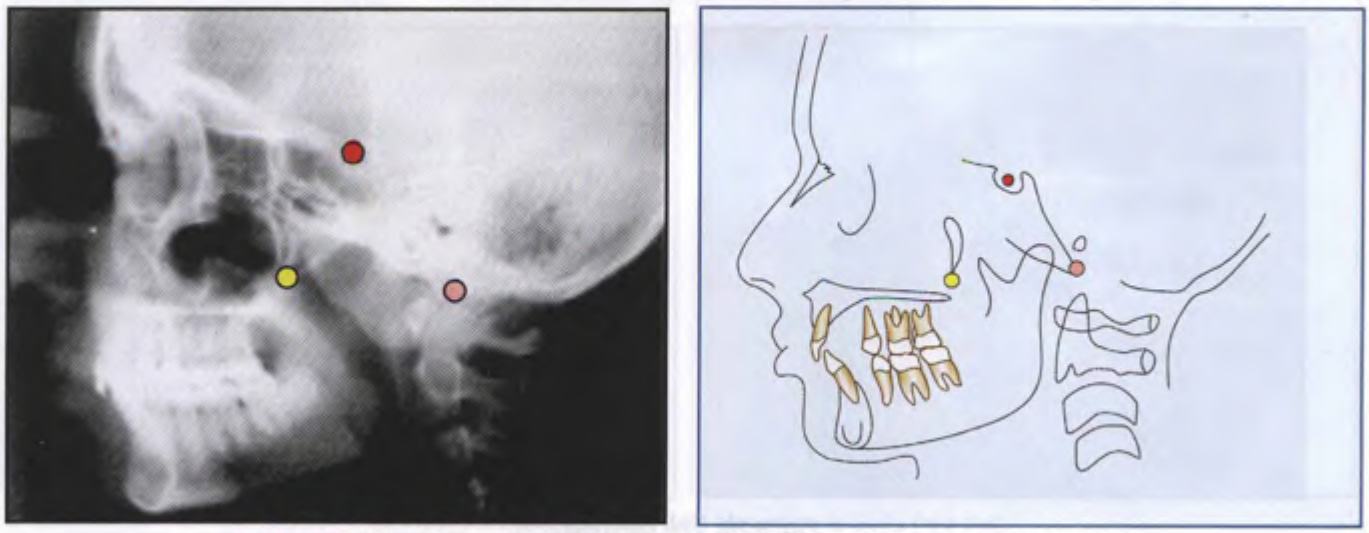


Fig. 9.23: **Sella (S) (red dot);** also seen are Basion (Ba pink dot), Ptm (yellow dot)

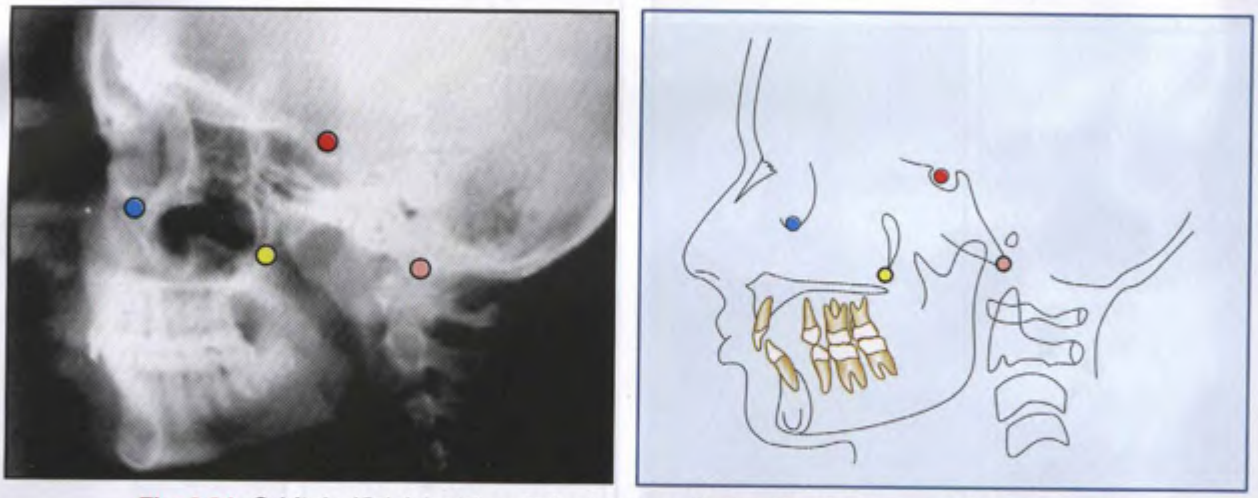


Fig. 9.24: **Orbitale (Or) (sky blue dot);** also seen Basion (Ba pink dot) and Sella (red dot)

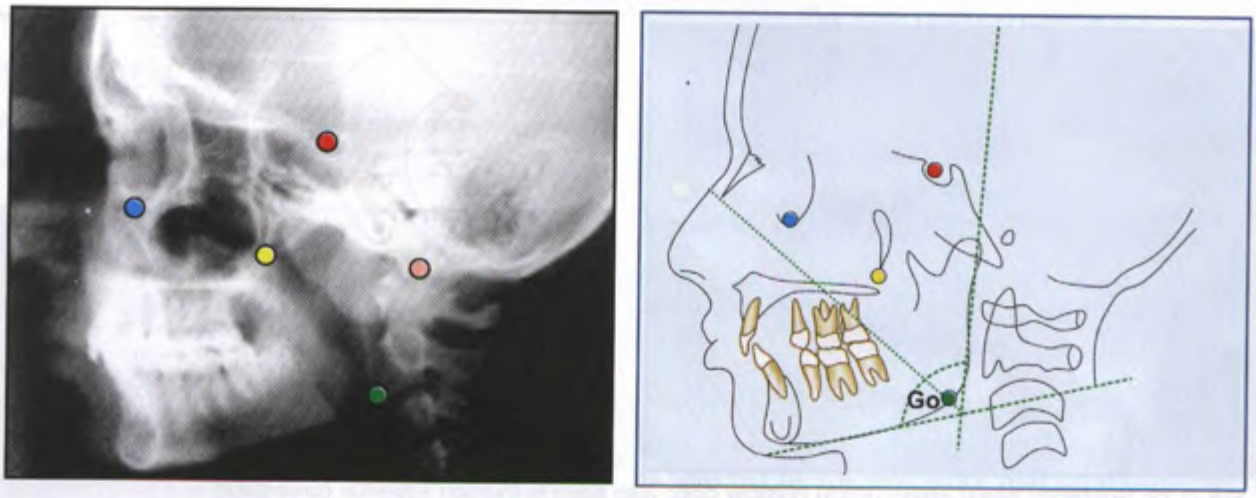


Fig. 9.25: Gonion (Go) (green dot)

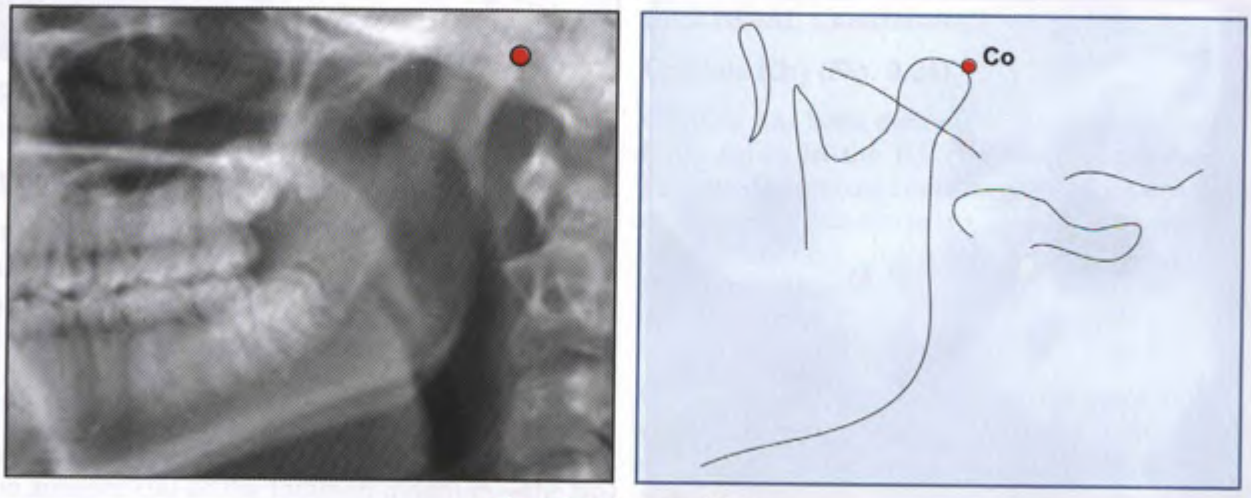


Fig. 9.26: The condylion

Condylion (Co) (Fig. 9.26)

Condylion is the most posterosuperior point on the condyle of the mandible.

Articulare (Ar) (Fig. 9.27)

The intersection of the three radiographic shadows: the inferior surface of the cranial base and the posterior surfaces of the necks of the condyles of the mandible. Articulare is systematically used for condylion when the latter is not reliably discernible. Displacement of the condyle moves the articulare.

Pterygomaxillary Fissure (Ptm) (Fig. 9.28)

A bilateral teardrop-shaped area of radiolucency, the anterior shadow of which is the posterior surfaces of the tuberosities of the maxilla. The PTM point is the intersection of the inferior border of the foramen rotundum with the posterior wall of the pterygomaxillary fissure.

Porion (Po) (Fig. 9.29)

The "top" of the external auditory meatus. Sometimes, because porion is quite unreliable, the "top" of the

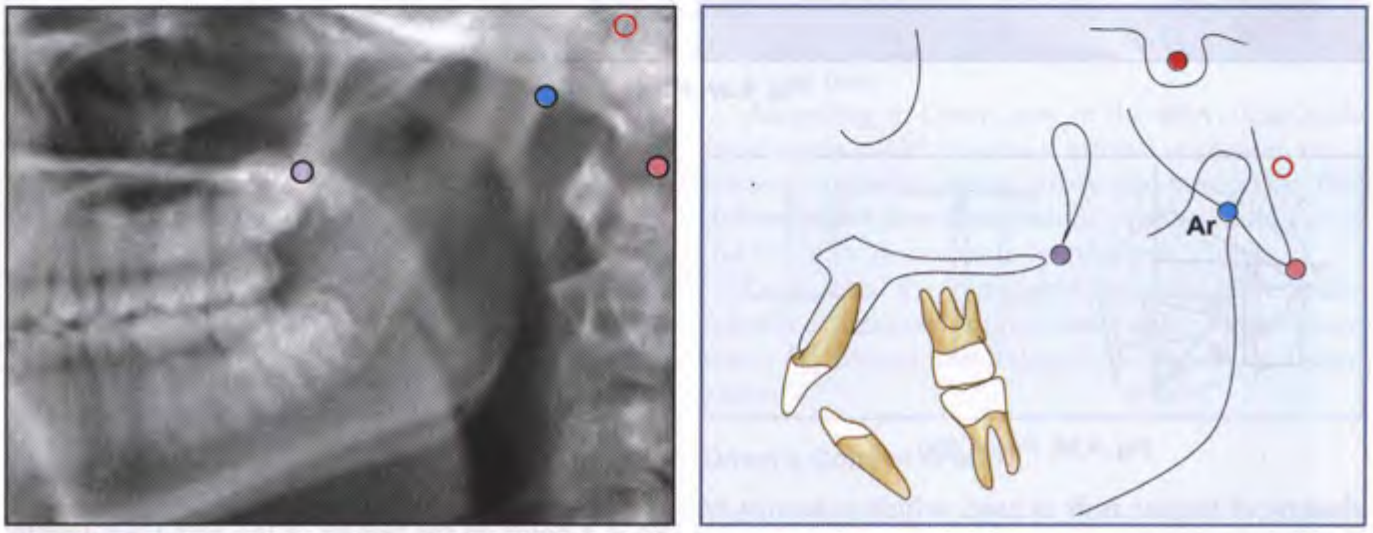


Fig. 9.27: Articulare (Ar, blue dot), Basion (Ba pink dot), Sella (red dot), Ptm point (violet dot), Porion (red circle)

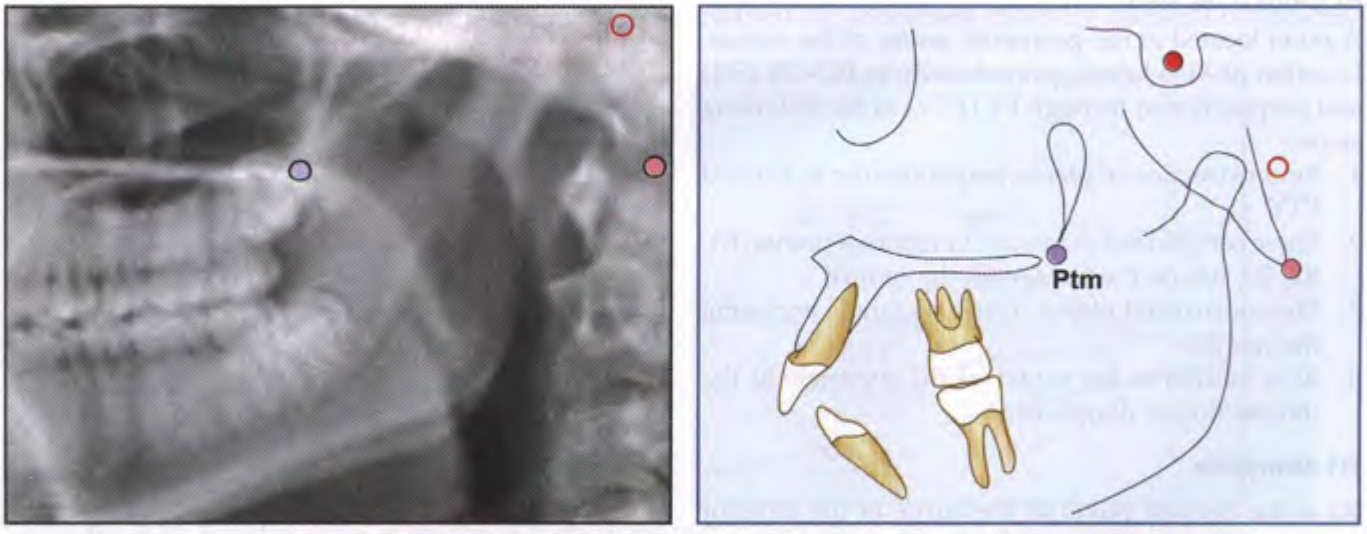


Fig. 9.28: Ptm point (violet dot) also seen is Sella (red dot)

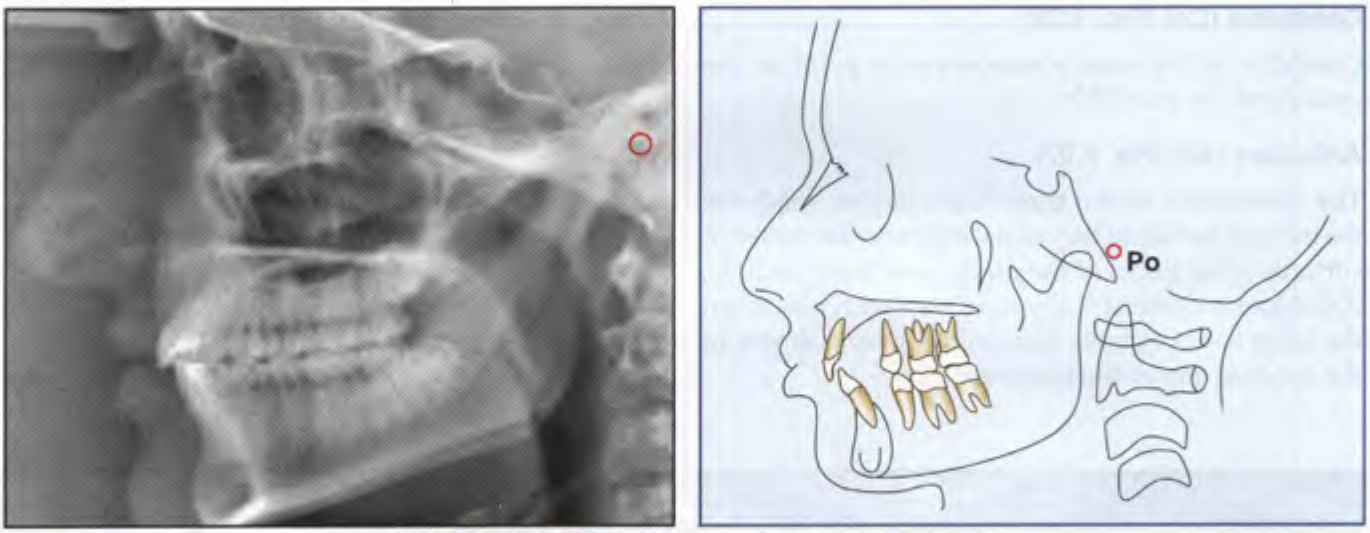


Fig. 9.29: Porion (Po)

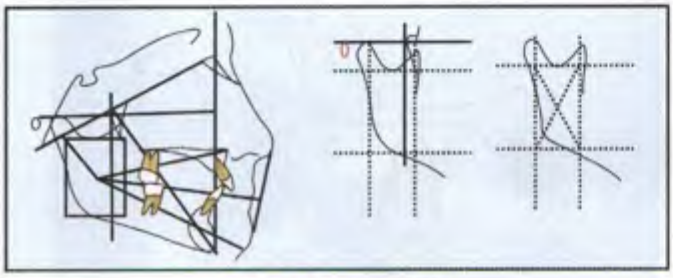


Fig. 9.30: Porion (Po)

shadow of the ear rods is used, which is known as "machine porion".

Xi-Point (Fig. 9.30)

A point located at the geometric center of the ramus. Location of Xi is keyed geometrically to PO-OR (FH) and perpendicular through PT (PTV) in the following steps:

1. By construction of planes perpendicular to FH and PTV
2. These constructed planes are tangents of points (R1, R2, R3, R4) on the borders of the ramus.
3. The constructed planes form a rectangle enclosing the ramus.
4. Xi is located in the center of the rectangle at the intersection of diagonals.

R1-Mandible

R1 is the deepest point on the curve of the anterior border of the ramus, one-half the distance between the inferior and superior curves.

R2-Mandible

R2 is located on the posterior border of the ramus of the mandible.

R3-Mandible

R3 is located at the center and most inferior aspect of the sigmoid notch of the ramus of the mandible.

R4-Mandible

R4 is a point on the border of the mandible directly inferior to the center of the sigmoid notch of the ramus.

COMMONLY USED LINES AND PLANES DESCRIBED IN THE LATERAL PROJECTION

Frankfort Horizontal Plane

Used first by Down, it is drawn from the point orbitale to the superiormost point on the external auditory meatus (Porion). (Fig. 9. 31, yellow line).

S-N Line

The S-N line represents the anterior cranial base. It is constructed by connecting the points sella turcica and the Nasion (Fig. 9.31, red line).

Bolton's Plane

This plane is constructed by extending a line from the Bolton's point to Nasion (Fig. 9.31, pink line).

Palatal Plane

The palatal plane is drawn by extending a line from the anterior nasal spine (ANS) to posterior nasal spine (PNS) (Fig. 9.31, sky blue line).

Occlusal Plane (Functional OP, Anatomic OP)

It was originally described by Down as the line connecting the molars in occlusion to the bisector of the overbite (vertical overlap of the incisors anteriorly), also know as the **anatomic occlusal plane**. It was later modified to be represented by the line passing through the occlusion of the premolars and the molars (Fig. 9.31, orange line), also known as the **functional occlusal plane**.

Mandibular Plane

Mandibular planes have been defined by various authors based upon their clinical experience and use in their cephalometric analyses.

Tweed described the mandibular plane as a line that is a tangent to the inferior border of the mandible.

Down considered the mandibular plane to represent a line connecting the points gonion and menton.

Steiner drew the mandibular plane by joining the points Gonion and Gnathion.

DOWN'S ANALYSIS

INTRODUCTION

For us to be able to derive any meaningful conclusions from the study of cephalograms, it is essential to have certain standards against which to compare the data obtained after analyzing the patient's cephalogram. One of the first and also one of the most commonly used data / analysis was provided by Down.

Down divided his analysis into two components. The skeletal component helped in defining the underlying facial type and the dental component is used to establish if the dentition is placed normally in relation to the underlying bony structures.

Down classified the face into four basic types –

- *Retrognathic*- a regressive or retruded lower jaw.
- *Mesognathic*- an "ideal" or average position of the lower jaw.
- *Prognathic*- a protrusive lower jaw.
- *True prognathism*- a pronounced protrusion of the lower face.

According to Down, any of the above four basic facial types could possess a normal occlusion and a harmonious facial profile, in form and proportion. This did not mean that ideal skeletal profiles could not or did not have dental malrelationships.

Down used the Frankfort-Horizontal plane as the reference plane; as it approximates a near level position when the patient is standing in a posture of distant vision.

Down's Control Group

The control group studied by Down was derived from 20 Caucasian subjects, who ranged in age from 12 to 17 years and were equally divided as to sex. All individuals possessed clinically excellent occlusions.

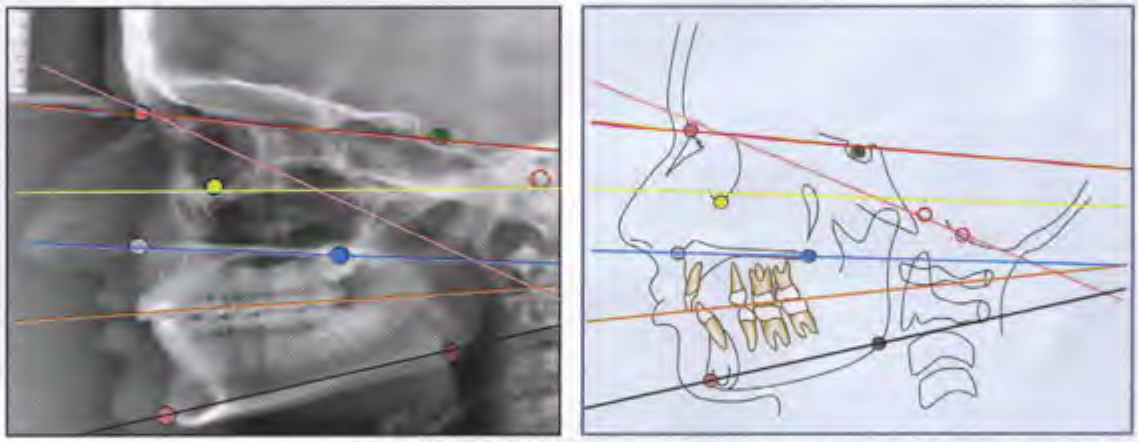


Fig. 9.31: Frankfort plane- yellow line, S-N plane- red line, Bolton's plane- pink line, palatal plane- blue line, occlusal plane- orange line, mandibular plane (Go- Gn)-black line

SKELETAL PARAMETERS

Facial Angle

The facial angle is used to measure the degree of retrusion or protrusion of the lower jaw. The facial angle provides an indication of the degree of recession or protrusion of the mandible in relation to the upper face. Facial angle is the inferior inside angle formed by the intersection of the facial line (Nasion-Pogonion) to the Frankfort Horizontal (FH) Plane (Fig. 9.32A)

The mean reading for this angle is 87.8° (± 3.6°) with a range of 82° to 95°.

A prominent chin increases this angle, whereas a smaller than average angular reading suggests a retrusive or retropositioned chin.

Angle of Convexity

The angle of convexity is formed by the intersection of line N-point A to point A-Pogonion (Fig. 9.32B).

This angle measures the placement of the maxillary basal arch at its anterior limit (point A) relative to the total facial profile (Nasion-Pogonion).

This angle is read in plus or minus degrees starting from zero. If the line Pogonion-point A is extended and located anterior to the N-A line, the angle is read as positive. A positive angle suggests prominence of the maxillary denture base relative to the mandible. A negative angle of convexity is associated with prognathic profile or in other words a Class III profile.

The range extends from –8.5° to +10°, with a mean of 0°.

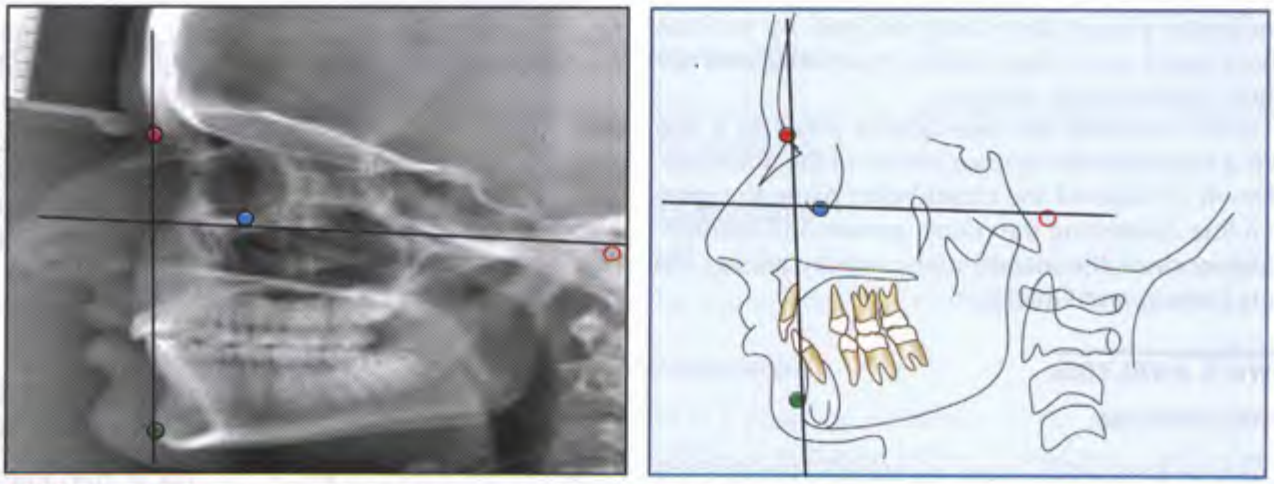


Fig. 9.32A: Facial angle—an average of 87.8° + 3.6° (Nasion-red dot, Pogonion-green dot, Porion-red circle, orbitale-blue dot)

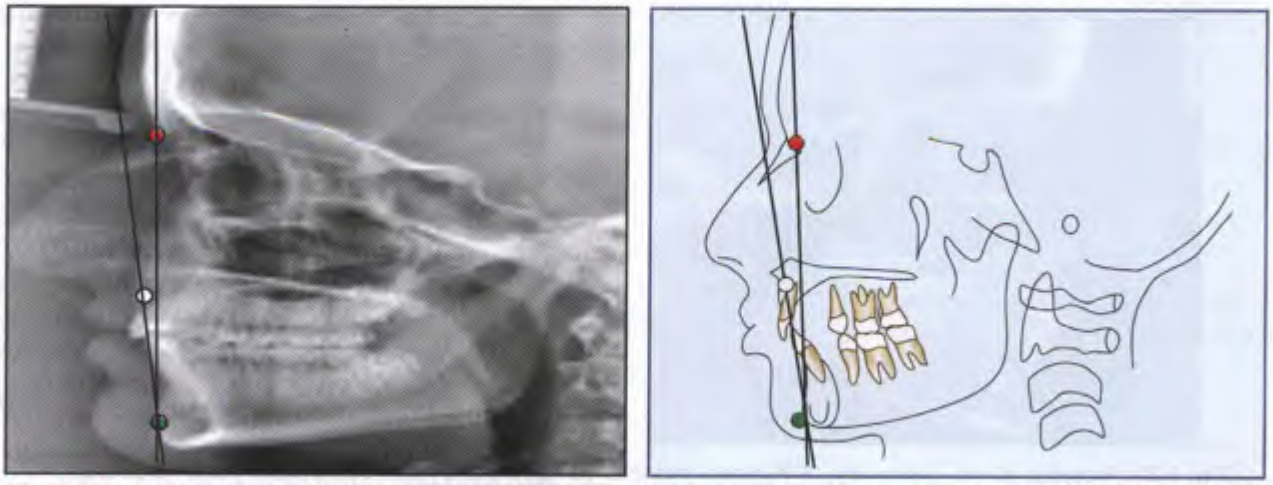


Fig. 9.32B: Angle of convexity—the average value is 0° ± (Nasion- red dot, Pogonion- green dot, 'A' point- white dot)

A-B Plane Angle

Points A and B are joined by a line which when extended forms an angle with the line Nasion-Pogonion, this is called the A-B plane angle (Fig. 9.32C).

The A-B plane is a measure of the relation of the anterior limit of the apical bases to each jaw relative to the facial line. Generally point B is positioned behind point A thus this angle is usually negative in value, except in Class III malocclusions or Class I occlusions with prominence of the mandible.

A large negative value suggests a Class II facial pattern, which can be due to the retro-positioned chin or mandible or underdeveloped chin point or a prominent maxilla, i.e. point B located behind point A.

The range extends from a maximum of 0° to a minimum of –9° with a mean reading of –4.6°.

Mandibular Plane Angle

The mandibular plane according to Down, is a "tangent to the gonial angle and the lowest point of the symphysis". (Some authors describe the mandibular plane as the line joining the gonion and the gnathion). The mandibular plane angle is established by relating the mandibular plane to the Frankfort Horizontal plane (Fig. 9.32D).

High mandibular plane angles occur in both retrusive and protrusive faces and are suggestive of unfavorable hyperdivergent facial patterns or 'long face cases'.

The range extends from a minimum of 17° to a maximum of 28° with a mean of 21.9°.

Y-(Growth) Axis

The growth axis is measured as an acute angle formed by the intersection of a line from sella turcica to Gnathion with the Frankfort horizontal plane (Fig.9.32E).

This angle is larger in Class II facial patterns than in those with Class III tendencies. It indicates the degree of downward, rear ward or forward position of the chin in relation to the upper face.

A decrease of the Y-axis in serial radiographs may be interpreted as a greater horizontal than vertical growth of the face or a deepening of the bite in orthodontic cases. An increase in the Y-axis is suggestive of vertical growth exceeding horizontal growth of the mandible or an opening of the bite during orthodontic treatment. The Y-axis reading also increases with the extrusion of the molars (this is generally desirable when correcting malocclusions in horizontal growers.

The range extends from a minimum of 53° to a maximum of 66° with a mean reading of 59.4°.

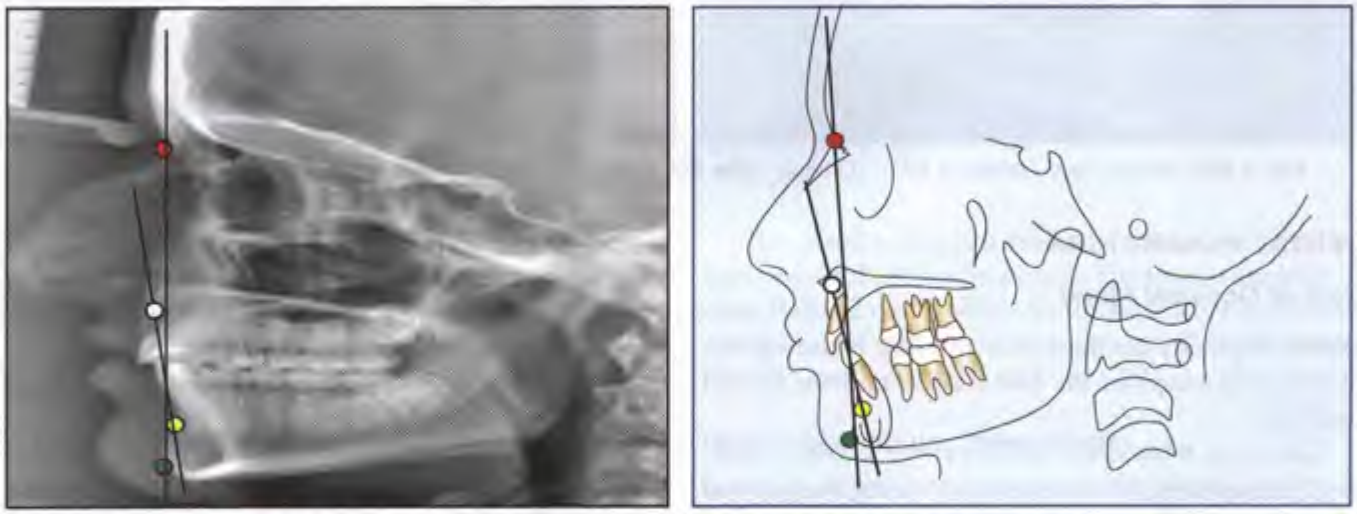


Fig. 9.32C: A-B Plane Angle—has a mean value of –4.6° (Nasion- red dot, Pogonion-green dot, 'A' point- white dot 'B' Point- yellow point)

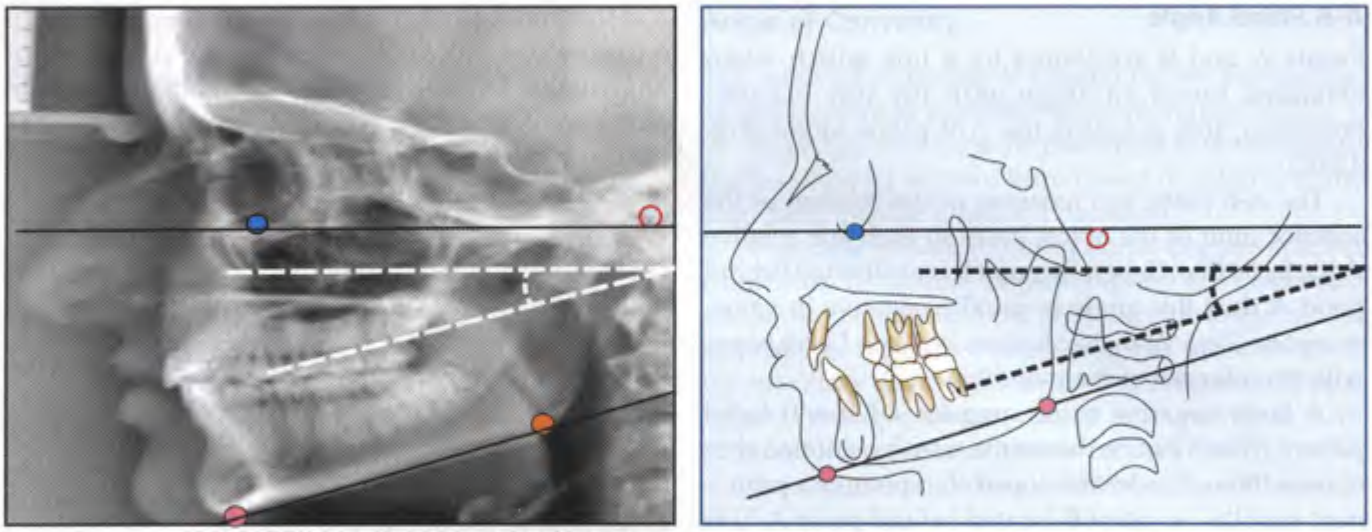


Fig. 9.32D: Mandibular plane angle—mean value of 21.9° (Porion- red circle, Orbitale- blue dot , Gonial angle—orange dot, Pink point is the lowest point of the symphysis)

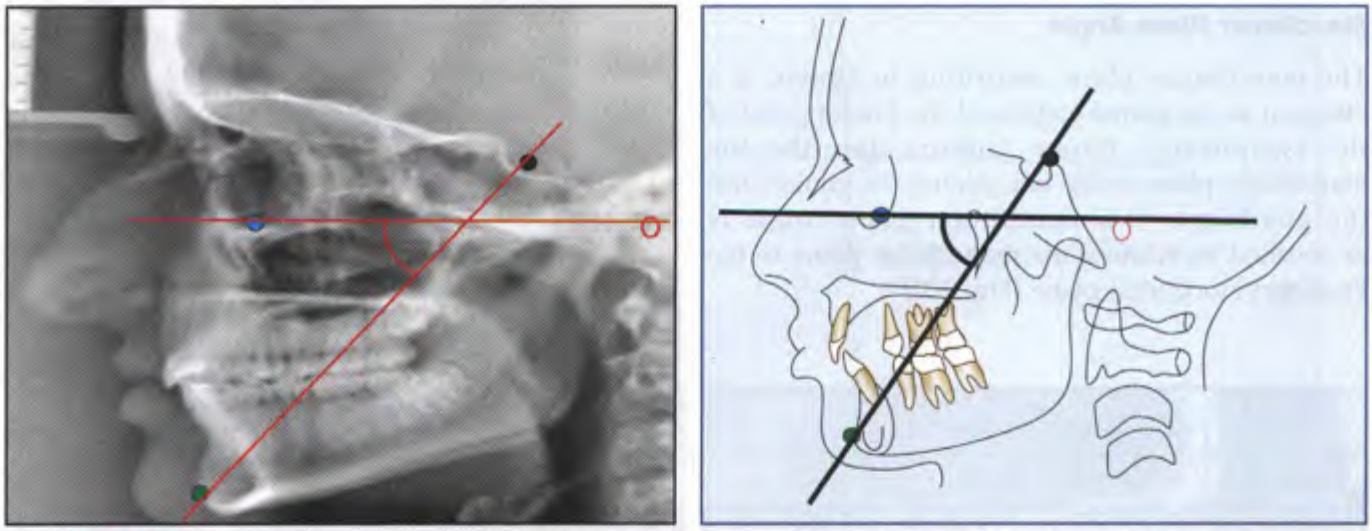


Fig. 9.32E: Growth axis—mean of 59.4° (Orbitale- blue dot, Porion-red circle, Sella-black dot, Gnathion- green dot)

DENTAL PARAMETERS

Cant of Occlusal Plane

Down originally defined it as the line bisecting the overlapping cusps of the first molars and the incisal overbite.

Cases in which the incisors are grossly malpositioned, Down recommended drawing the occlusal plane through the region of the overlapping cusps of the first premolar and first molars (Fig. 9.32F).

The Cant measures the slope of the occlusal plane to the Frankfort Horizontal plane. When the anterior part of the plane is lower than the posterior, the angle would be positive. Large positive angles are found in Class II facial patterns. A long mandibular ramus also tends to decrease this angle.

The mean value is +9.3° with a range of +1.5° to +9.3°.

Inter-incisal Angle

The inter-incisal angle is established by passing a line through the incisal edge and the apex of the root of the maxillary and mandibular central incisors (Fig. 9.32G).

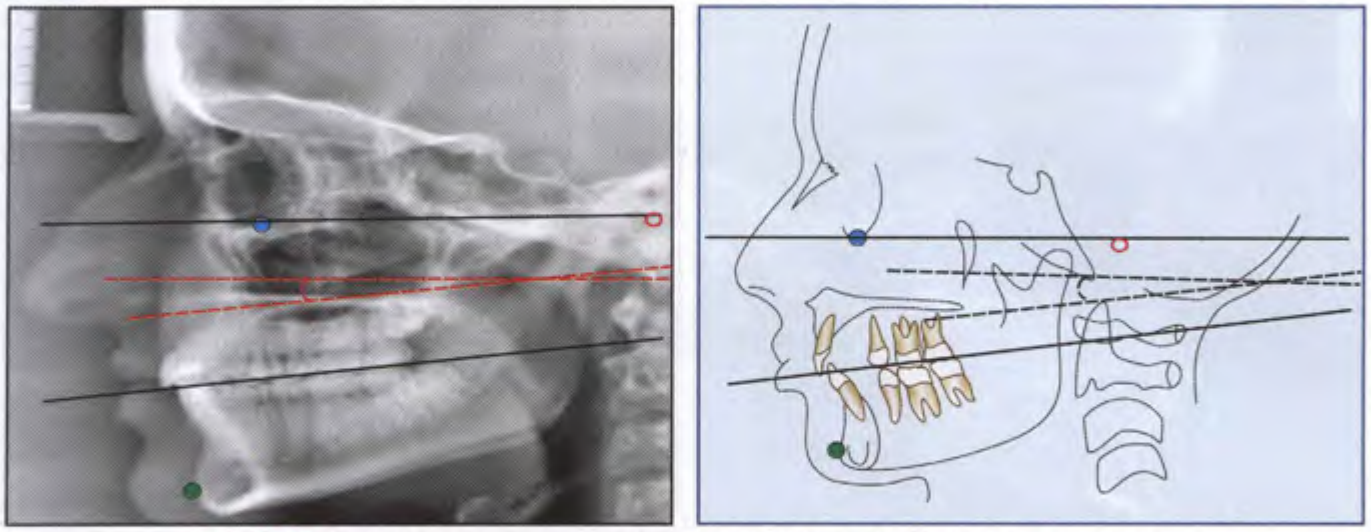


Fig. 9.32F: Cant of occlusion—mean value of +9.3° (Orbitale- blue dot, porion- red circle)

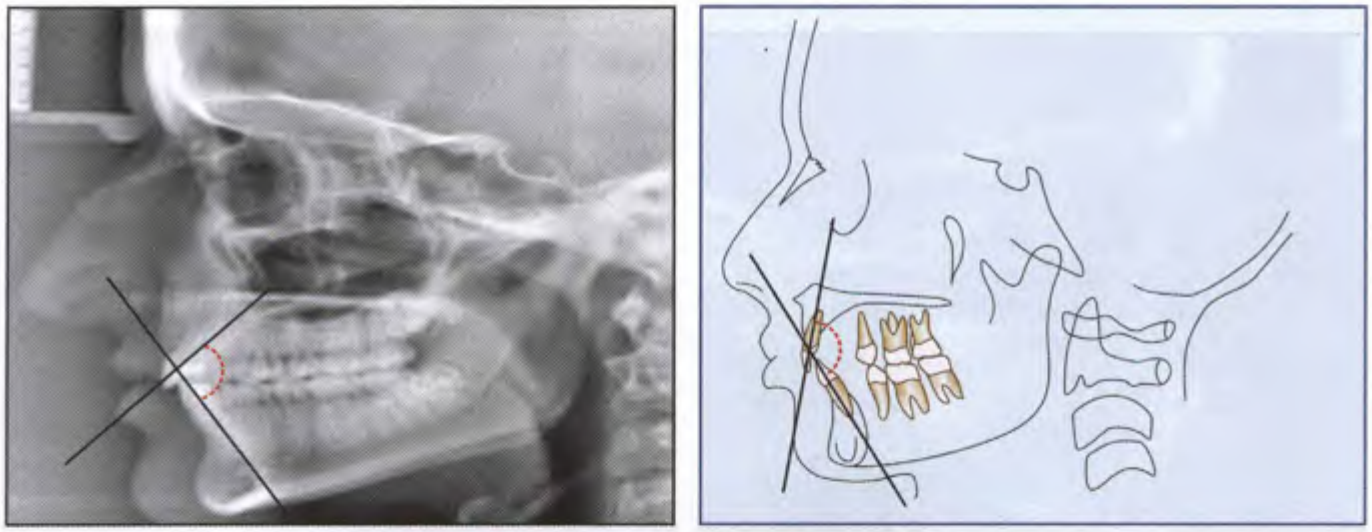


Fig. 9.32G: Inter-incisal angle—a mean of 135.4°

The inter-incisal angle is relatively small in individuals whose incisors are tipped forward on the denture base, i.e. they are proclined.

The mean value is 135.4°, with a range of 130° to 150°.

Incisor Occlusal Plane Angle

This angle relates the lower incisors to their functioning surface at the occlusal plane. The inferior inside angle is read as a plus or minus deviation from the right angle (Fig. 9.32H).

The positive angle increases as these teeth incline forward, i.e. become proclined. The values are least in class II div. 2 cases where the incisors are retroclined.

The mean value is 14.5° with a standard deviation of ±3.5° and a range of +3.5° to +20°.

Incisor Mandibular Plane Angle

It is formed by the intersection of the mandibular plane with a line passing through the incisal edge and apex of the root of the mandibular central incisor (Fig. 9.32 I).

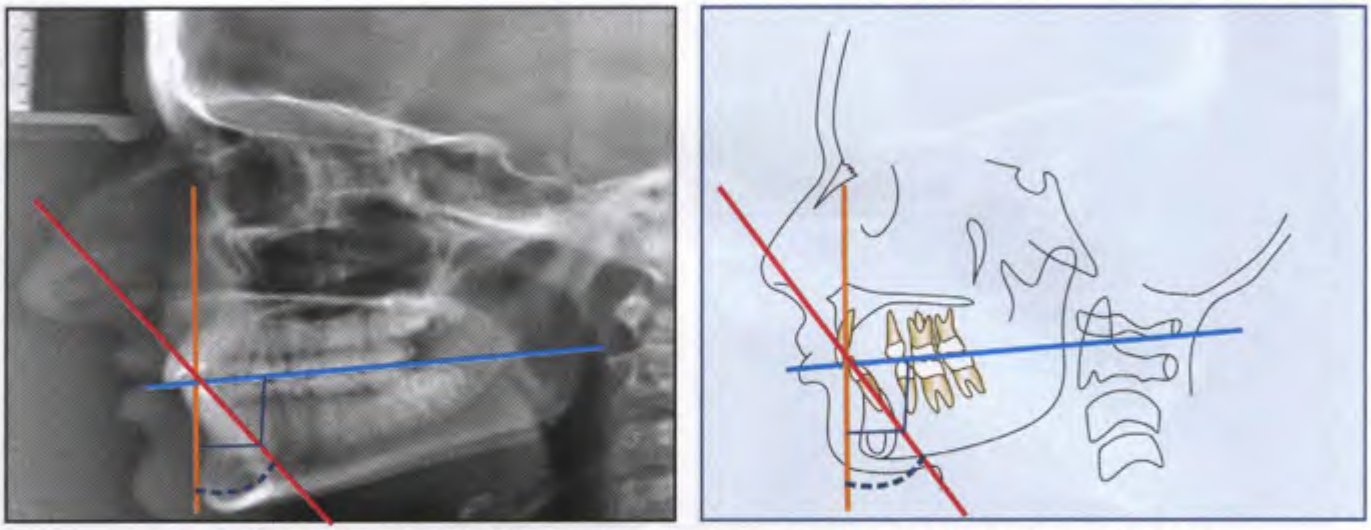


Fig. 9.32H: Mandibular incisor to occlusal plane—mean value of +14.5° (Occlusal plane- blue line, Long axis of the mandibular incisor- orange line)

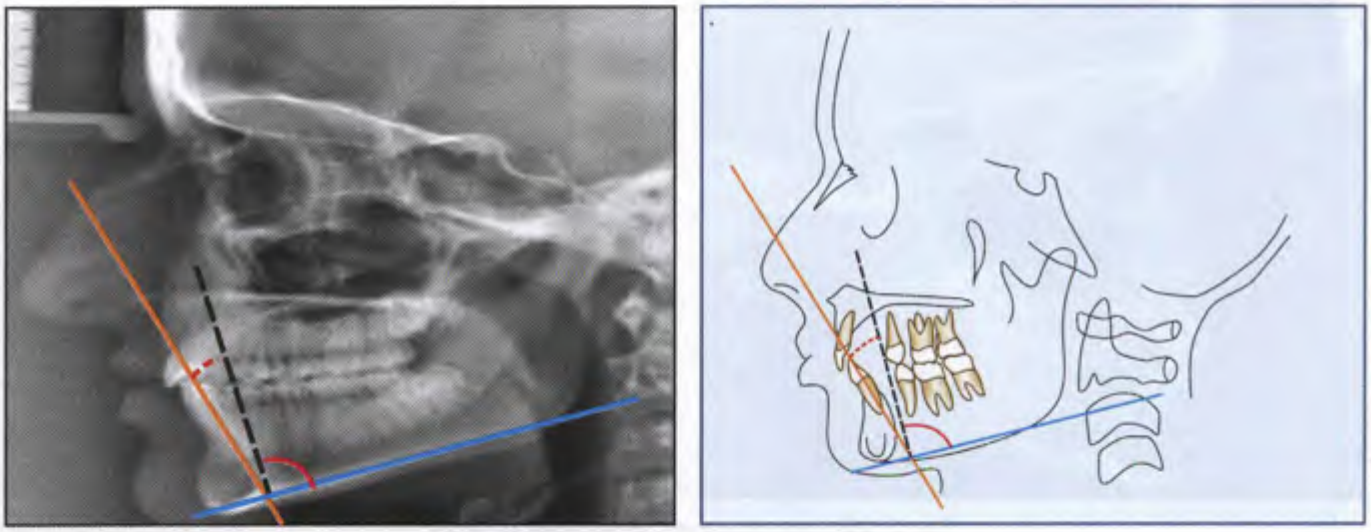


Fig. 9.32I: Incisor mandibular plane angle 1.4° (Mandibular plane angle-blue line, long axis of the mandibular incisor-orange line)

The angle is positive when the incisors are tipped forward on the denture base, i.e. they are proclined forward. The value increases as the proclination increases.

The mean value is 1.4°with a range of -8.5° to +5°.

Protrusion of Maxillary Incisors

It is measured as the distance between the incisal edge of the maxillary central incisor to the line from Point A to Pogonion (Fig. 9.32 J). This distance is positive if the incisal edge is ahead of the point A-Pogonion line and negative if the incisal edge lies behind this line. It indicates the amount of maxillary dental protrusion.

The mean value is +2.7 mm with a range of –1.0 to +5 mm.

STEINER ANALYSIS

Cecil C. Steiner went a step further when he evolved an analysis that took into account not only the relation of the teeth to each other and to their respective dental

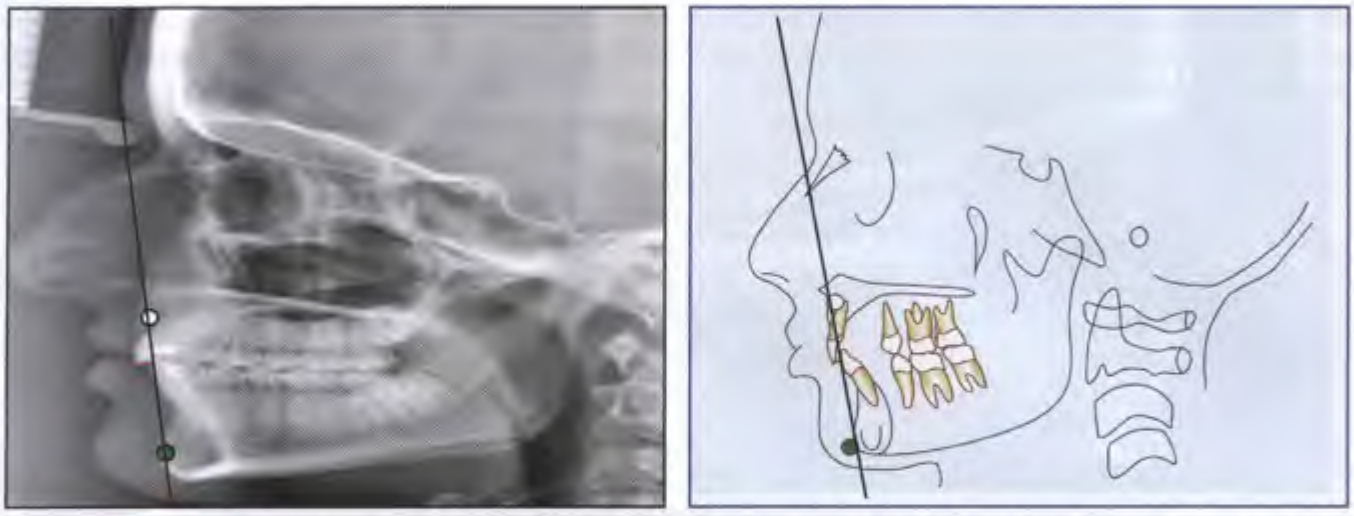


Fig. 9.32J: Protrusion of the maxillary incisor is measured as the horizontal distance of the maxillary incisal tip to the A-Pog line (shown as bold red line in illustration). Mean value of +2.7mm

bases but also recognized the importance of the soft tissue cover and included data to analyze the same. He selected what he considered to be the most meaningful parameters and evolved a composite analysis, which he believed would provide the maximum clinical information with the least number of measurements. By comparing measurements of patients with malocclusions with those of "normal" occlusions, the degree of deviation from the normal could be determined.

THE ANALYSIS

Steiner divided his analysis into three parts—skeletal, dental and soft tissues. Skeletal analysis entails relating the upper and lower jaws to the skull and to each other. The dental analysis entails relating the upper and lower incisor teeth to their respective jaws and to each other. And the soft tissue analysis provides a means of assessing the balance and harmony of the lower facial profile.

Steiner noted that landmarks such as Porion and Orbitale are not always easily identified on lateral cephalometric head films, hence, he elected to use the anterior cranial base (Sella to Nasion) as the line of reference for his analysis. The advantage of using these two midline points is that they are moved only a minimal amount whenever the head deviates from the true profile position. This remains true even if the head is rotated in the cephalostat.

Relating the Maxilla to the Skull

The angle SNA is formed by joining the lines S-N and N-A (Fig. 9.33A).

The mean reading for this angle is 82°.

If the angular reading is more than 82°, it would indicate a relative forward positioning or protrusion of the maxilla. Conversely, should the reading be less than 82°, it would indicate a relative backward or recessive location of the maxilla.

Relating the Mandible to the Skull

To assess whether the mandible is protrusive or recessive relative to the cranial base, the SNB angle is read (Fig. 9.33B). The mean for this angle is 80°.

If the angle is less than 80°, it is indicative of a retruded mandible. An angle greater than 80° degrees suggests a prognathic or forwardly positioned mandible.

Relating the Maxilla to the Mandible

The angle ANB (Fig. 9.33C), provides information on the relative positions of the jaws to each other. The ANB angle provides a general idea of the anteroposterior discrepancy of the maxillary to the mandibular apical bases.

The mean reading for this angle is 2°. A reading greater than 2° indicates a Class II skeletal tendency. As a rule, the larger the figure, the greater the

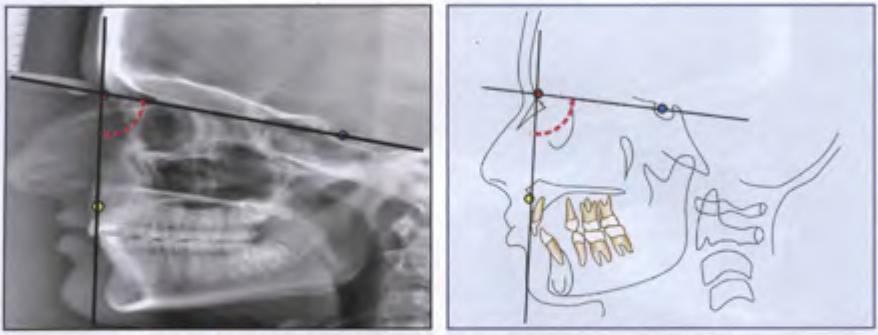


Fig. 9.33A: Angle SNA (Sella turcica-blue dot, Nasion- red dot, A point- yellow dot)

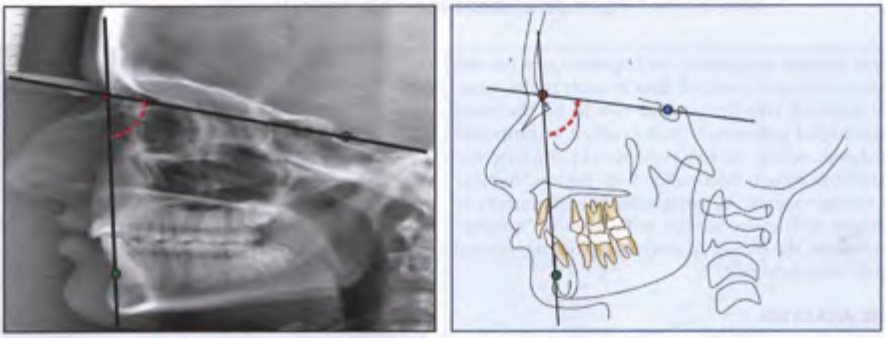


Fig. 9.33B: Angle SNB (Sella turcica-blue dot, Nasion- red dot, B point-green dot)

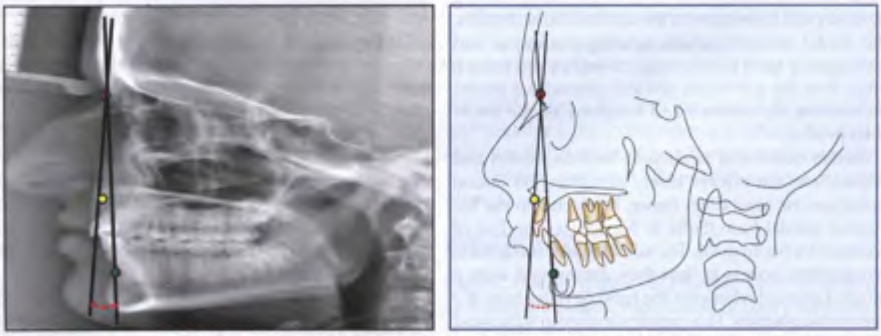


Fig. 9.33C: Angle ANB (Nasion- red dot, A point- yellow dot, B point-green dot)

anteroposterior jaw discrepancy, and hence the greater the difficulty in correcting a malocclusion.

Angles less than 2° and readings of below zero (e.g. -1°, -2°, etc.) indicate that the mandible is located ahead of the maxilla, suggesting a Class III skeletal relationship.

Occlusal Plane Angle

The occlusal plane is drawn through the region of the overlapping cusps of the first premolars and first molars. The angle of the occlusal plane to S-N plane is measured (Fig. 9.33D).

The mean reading for normal occlusions is 14°. The angle is increased in long face or vertically growing individuals and also skeletal open bite cases. It may be decreased in horizontally growing individuals or cases with a skeletal deep bite.

Mandibular Plane Angle

The mandibular plane is drawn between Gonion (Go) and Gnathion (Gn). The mandibular plane angle is formed by joining the mandibular plane to the anterior cranial base (S-N plane) (Fig. 9.33E).

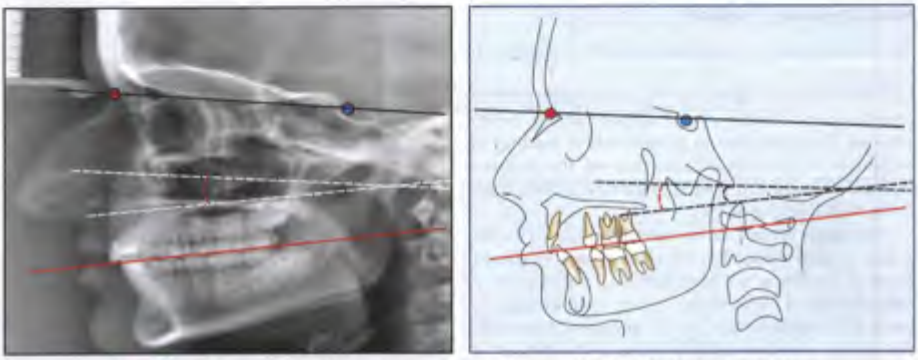


Fig. 9.33D: Occlusal plane angle (Nasion- red dot, Sella turcica- blue dot, Occlusal plane- red line)

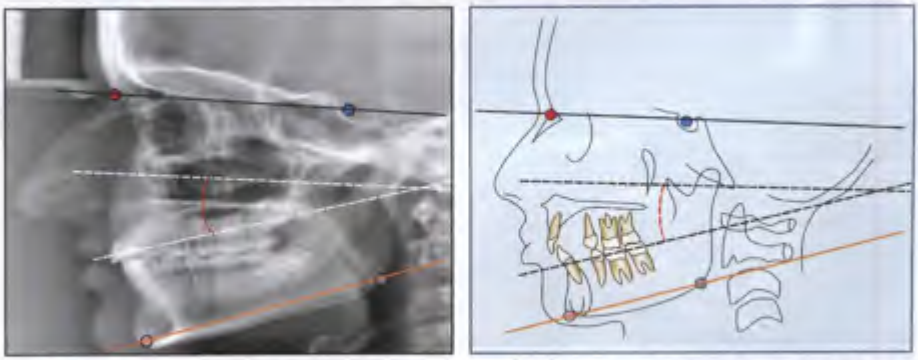


Fig. 9.33E: Mandibular plane angle (Nasion-red dot, Sella turcica-blue dot, Gnathion-pink dot, Gonion- lavender dot, mandibular plane- orange line)

The mean reading for this angle is 32°.

Excessively high (vertical growers) or low (horizontal growers) mandibular plane angles are suggestive of unfavorable growth patterns and these may complicate treatment results.

The Dental Analysis

This part of the analysis is designed to confirm the clinical observations already made and to determine the position of the dentition with respect to their respective bony bases and to each other.

Maxillary Incisor Position

The maxillary incisor is related to the N-A plane both by angular as well as linear measurements. The upper incisor to N-A reading in degrees indicates the relative angular relationship of the upper incisor teeth, whereas the upper central incisor to N-A reading in millimeters provides information on the relative forward or backward positioning of the incisor teeth to the N-A line (Fig. 9.33F).

The upper central incisors should relate to the N-A line in such a way that the most anteriorly placed point of its crown is 4 mm (but may range up to 7 mm) in front of the N-A line and its axial inclination bears a 22° angle to the line. To precisely determine the relative anteroposterior position of the incisors, it is necessary to measure the distance of the most labial surface of the incisor to the N-A line.

Mandibular Incisor Position

The relative anteroposterior linear position and angulation of the lower incisor teeth is determined by relating the most protruding incisor tooth to the N-B line (Fig. 9.33G). The lower incisor to N-B line measurement in millimeters shows the relative forward or backward positioning of these teeth to the N-B line. The lower central incisor to N-B reading in degrees indicates the relative axial inclination of these teeth.

The most labial portion of the crown of the lower incisor teeth should be located 4 mm ahead of the N-B line, and the axial inclination of this tooth to the N-B line should be 25°.

Inter-incisal Angle

The inter-incisal angle relates the relative position of the upper incisor to that of the lower incisor (Fig. 9.33H). If the angulation is more acute or less than the mean of 130°, then the anteriors are considered to be proclined. Hence, the upper and or lower teeth may require up-righting or need to be retracted. Conversely, if the angle is greater than 130° or more obtuse, the upper and/or lower incisors may require

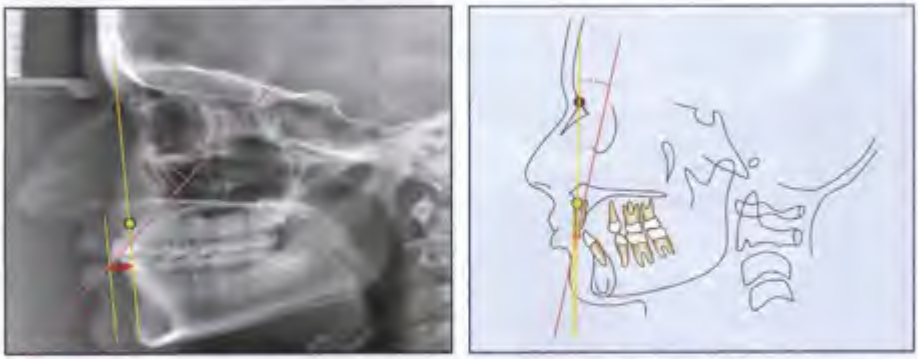


Fig. 9.33F: Maxillary incisor position—the red line denotes the linear measurement from the N-A line (yellow line) and the angular measurement between the N-A line and the long axis of the maxillary incisor (pink line)

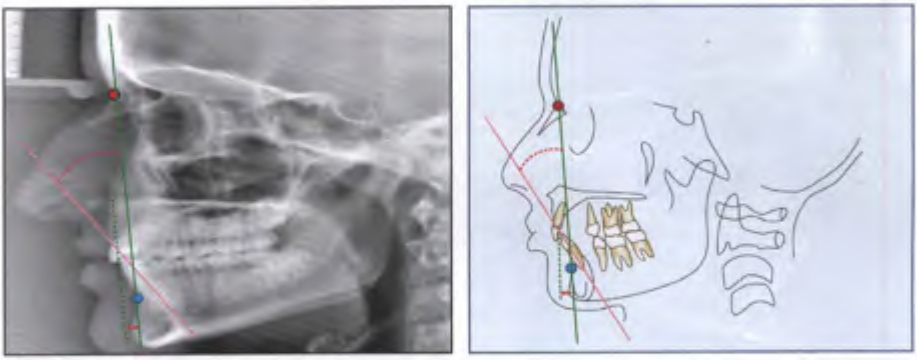


Fig. 9.33G: Mandibular incisor position—the red line denotes the linear measurement from the N-B line (green line) and the angular measurement between the N-B line and the long axis of the mandibular incisor (pink line)

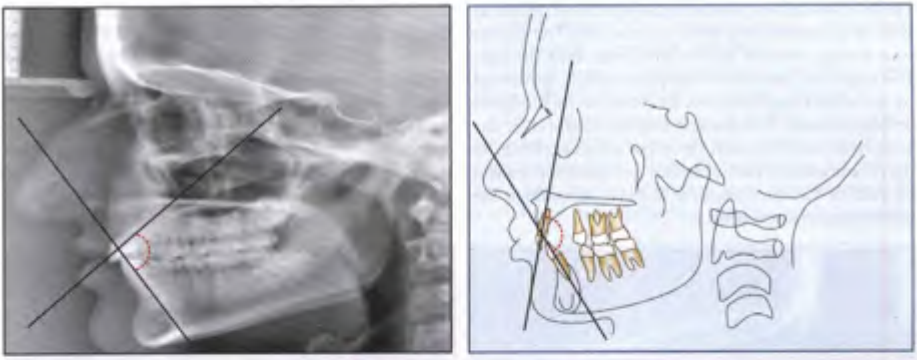


Fig. 9.33H: The inter-incisal angle

advancing anteriorly or correction of their axial inclinations.

Lower Incisor to Chin

The chin forms one of the most important landmarks on the profile. According to studies conducted by Holdaway, the distance between the labial surface of the lower incisor to the N-B line and the distance from Pogonion to the N-B line should be equal (i.e., 4 mm) (Fig. 9.33I). A 2 mm discrepancy between these measurements is acceptable; a 3 mm is less desirable, but tolerable. If the difference between these dimensions exceeds 4 mm, however, corrective measures are generally indicated.

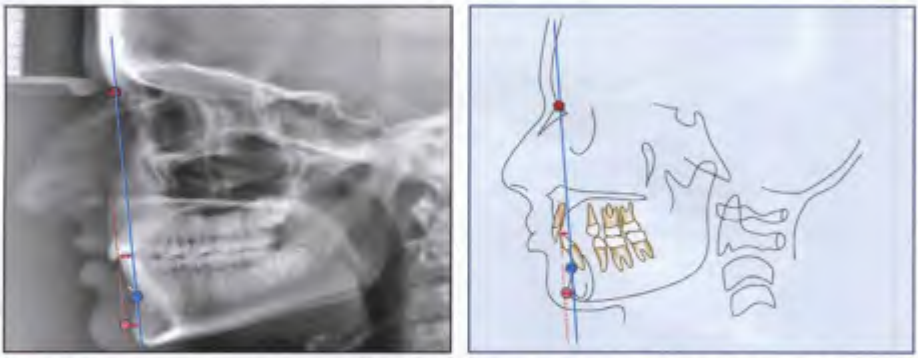


Fig. 9.33I: The distance of pogonion (pink dot) to the N-B line (denoted here by the pink line) should be equal to the linear measurement from the most labial surface of the most prominent mandibular incisor to the N-B line (denoted here by the red line)

THE SOFT TISSUE ANALYSIS

The analysis laid emphasis on the soft tissue profile as well as the underlying skeletal structure. The profile was mainly affected by the chin, nose and the lips. The shape and posture of the lips is partially governed by the underlying dentition and thus can be modified orthodontically. The thickness of the tissue over the symphysis and the nasal structure also contributes to the prominence of the lower face and attention should be paid to the same when as it may camouflage the underlying malocclusion.

Steiner's S-line

According to Steiner, the lips in well balanced faces, should touch a line extending from the soft tissue contour of the chin to the middle of an "S" formed by the lower border of the nose. This line is referred to as the "S-line" (Fig.9.33J).

Lips located beyond this line tend to be protrusive in which case the teeth and/or the jaws usually require orthodontic treatment to reduce their prominence. If the lips are positioned behind this line, it is generally interpreted that the patient possesses a "concave"

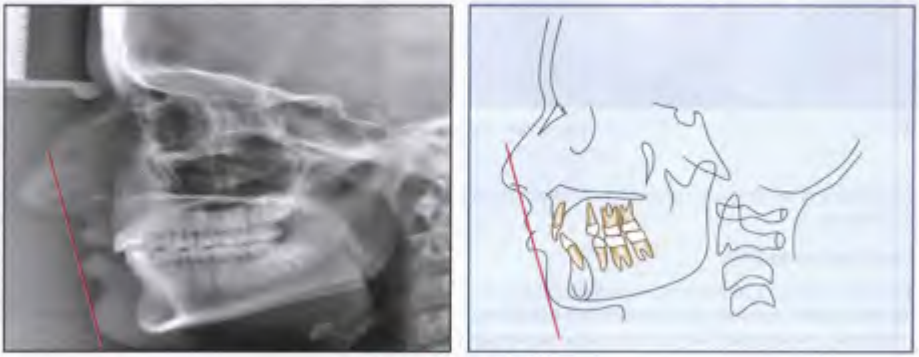


Fig. 9.33J: The 'S' line

profile. Orthodontic correction usually entails advancing the teeth in the dental arches to protrude the lips to approximate the S-line.

TWEED ANALYSIS

Tweed developed this analysis as an aid to treatment planning, anchorage preparation and determining the prognosis of orthodontic cases. At that time great emphasis was laid on the placement of the mandibular incisors for the preservation of the orthodontically achieved results.

This analysis is based primarily on the deflection of the mandible as measured by the Frankfort mandibular plane angle (FMA) and the posture of the lower incisor. The analysis is done to determine the final position, the lower incisors should occupy at the end of treatment. Once the final position of these teeth has been determined, the space requirements could be calculated and decision regarding the extractions could be made. Dr. Tweed established that prognosis could be predicted relatively accurately based on the configuration of the triangle.

DESCRIPTION

The analysis consists of the Tweed's triangle formed by (Fig.9.34):

1. Frankfort horizontal plane.
2. The mandibular plane.
3. The long axis of lower incisor.

The three angels thus formed are:

1. Frankfort-Mandibular plane (FMA)
2. Lower incisor to mandibular plane (IMPA)
3. Lower incisor to Frankfort horizontal (FMIA)

The normal values for

FMA = 25°
IMPA = 90°
FMIA = 65°
ANB = 2° with a range of 5 to -2°.

The basis is the FMA angle, and the following can be derived from the change in its value as:

1. FMA 16° to 28°: prognosis good
   at 16°, IMPA should be 90° + 5°= 95°
   at 22°, IMPA should be 90°
   at 28°, IMPA should be 90°-5° = 85°
   Approximately 60 percent malocclusions have FMA between 16° and 28°
2. FMA from 28° to 35°, prognosis fair at 28°, IMPA should be 90°-5° = 85° extractions necessary in majority of cases at 35°, IMPA should be 80 to 85°
3. FMA above 35°, Prognosis bad, extractions frequently complicate problems.

Tweed stressed the importance of the FMIA angle, recommending that it be maintained at 65 to 70°.

The Tweed analysis is primarily for clinical treatment planning and should not be considered a complete analysis by itself. By establishing the position lower incisors should occupy, provisions are made for variations in mandibular position and the upper

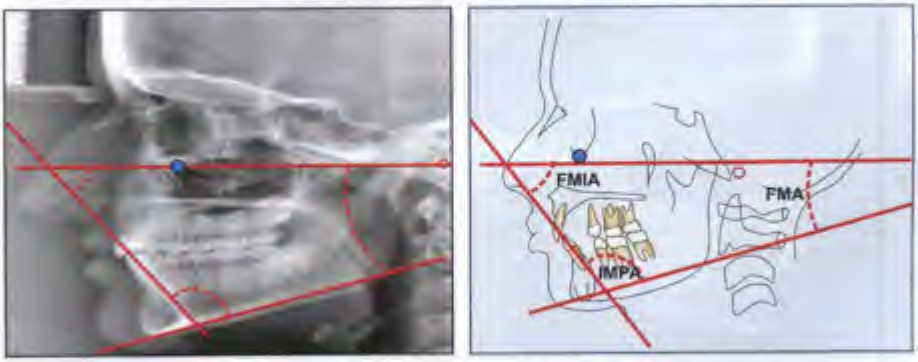


Fig. 9.34: The Tweed diagnostic facial triangle

incisors are placed according to the lower incisors. The ideal positioning of the lower incisors helps in the stability of the results achieved, thereby, indicating the prognosis of the case.

THE WITS APPRAISAL OF JAW DISHARMONY

The "Wits" appraisal of jaw disharmony employes just one measurement and is intended as a diagnostic aid whereby the severity or degree of anteroposterior jaw disharmony can be measured on a lateral cephalometric head film. It is to be used as an adjuvant along with other analysis, mainly to reconfirm their results.

The ANB angle is the most commonly used reading for the appraisal of the horizontal disharmony of the face. The SNA reading merely shows whether the face protrudes or retrudes below the skull. The ANB angle in normal occlusions is generally 2°. Angles greater than this indicate tendencies toward Class II jaw disharmonies; smaller angles (extending to negative readings) reflect Class III anteroposterior jaw discrepancies. The Wits appraisal is useful in identifying cases in which ANB reading does not accurately reflect the extent of underlying anteroposterior jaw dysplasia.

Relating jaws to cranial reference planes presents inherent inconsistencies because of variations in craniofacial skeletal structure and also because the field of interest , i.e. jaws are away from the reference points / planes. Included among the craniofacial skeletal variations are (1) the anteroposterior spatial relationship of nasion relative to the jaws and (2) the rotational effect of the jaws relative to cranial reference planes.

Any change in the relative forward or backward positioning of nasion by virtue of an excessively long or short anterior cranial base (represented by the S-N line) or a relative posterior or anterior positioning of both jaws within the skeletal craniofacial complex will directly influence the ANB reading.

Clockwise or counterclockwise rotation of the S-N line (due to nasion or sella turcica being positioned relatively superiorly or inferiorly to each other) either increases or decreases the SNA reading. Conventional analysis would suggest that the maxilla is positioned either forward or backward to the craniofacial complex. Similarly, the rotational effect of the jaws relative to the cranial reference plane would also affect the ANB angle reading directly.

Reliability of ANB angle is suspected in cases where the mandibular plane angle (Go-Gn to S-N) reading is considerably higher or lower than the mean of 32° ± 5°.

The Wits appraisal entails drawing perpendiculars on a lateral cephalometric head film tracing from points A and point B onto the occlusal plane (which is drawn through the region of maximum cuspal interdigitation). The points of contact on the occlusal plane from points A and B are labeled AO and BO respectively (Fig. 9.35A).

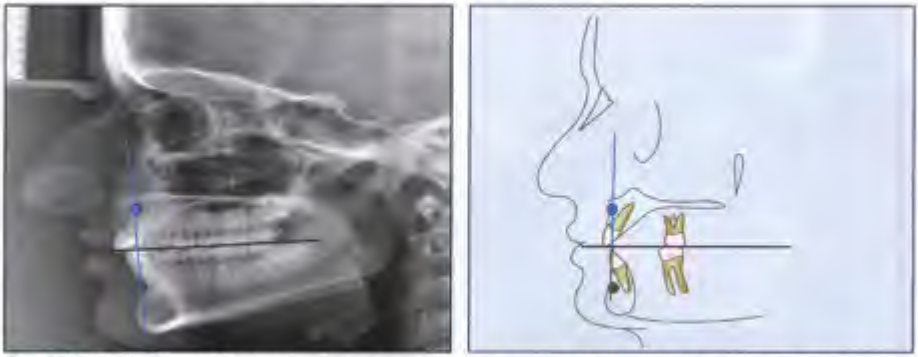


Fig. 9.35A: Points AO and BO coinciding (Occlusal plane- blue line, perpendicular from Point A- red line, perpendicular from point B- green line)

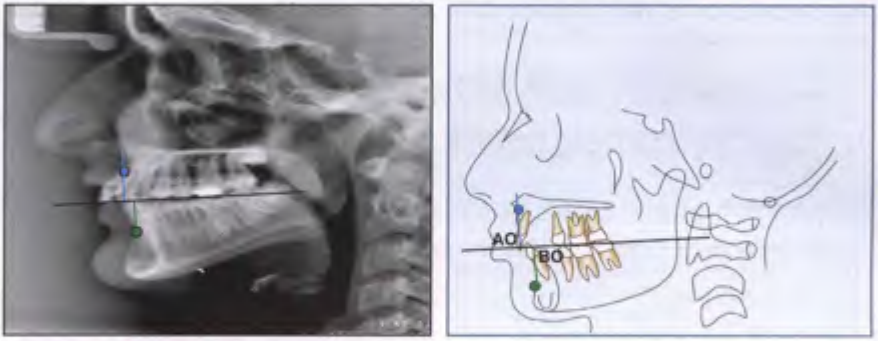


Fig. 9.35B: Skeletal Class II with point BO placed more than 4 mm posterior to point AO

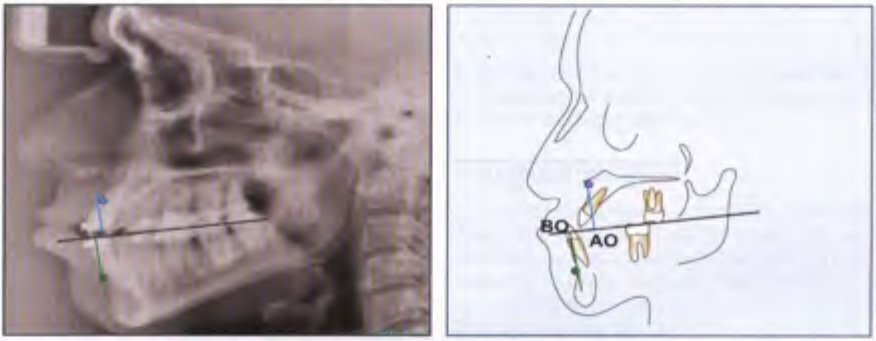


Fig. 9.35C: Skeletal Class III, where point BO is ahead of point AO

In skeletal Class II jaw dysplasias (Fig. 9.35B), point BO would be located well behind point AO (A positive reading) whereas in skeletal Class III jaw disharmonies (Fig. 9.35C) the "Wits" reading would be negative with point BO being in front of point AO.

The more the "Wits" readings deviate from 1 mm in males and 0 mm in females, the greater the horizontal jaw disharmony.

FURTHER READING

1. Athanasiou AE. Orthodontic Cephalometry, Chicago, 1995, Mosby.
2. Broadbent BH. A new X-ray technique and its application to orthodontics, Angle Orthod 1931;1:45-66.
3. Broadbent BH. The face of the normal child: Bolton standards and technique. Angle Orthod 1937;7:183-233.
4. Downs WB. Variations in facial relationships: Their significance in treatment and prognosis, Am J Orthod 1948;34:812.
5. Houston WJB. The analysis of errors in orthodontic measurements. Am J Orthod 1983;83:382-90.
6. Jacobson A. Application of the 'Wits' appraisal, Am J Orthod 1976;70:179-89.
7. Jacobson A. Radiographic Cephalometry: From Basics to Videoimaging, Chicago, 1995, Quintessence.
8. Jacobson A. The "Wits" appraisal of jaw disharmony, Am J Orthod 1975;67:125-38.

9. Moyers RE, Bookstein FL. The inappropriateness of con-ventional cephalometrics. Am J Orthod 1979;75:599-617.
10. Steiner CC. The use of cephalometrics as an aid to planning and assessing orthodontic treatment, Am J Orthod 1960;46:721-35.
11. Tweed CH. The diagnostic facial triangle in the control of treatment objectives, Am J Orthod 1969;55:651.
12. Tweed CH. The Frankfort-mandibular incisor angle (FMIA) in orthodontic diagnosis, treatment planning and prognosis, Angle Orthod 1954;24:121-9.
13. Tweed CH. Treatment planning and therapy in the mixed dentition, Am J Orthod 1963;49:900.
14. Yen P. Identification of landmarks in cephalometric radiographs, Angle Orthod 1960;30-35.

10 Diagnostic Radiographs and Photographs

Gurkeerat Singh

- Introduction
- Why radiographs?
- Orthopantomogram
- Intraoral radiographs
  - Intraoral periapical radiographs
  - Bitewing radiographs
  - Occlusal radiographs
- Facial photographs

INTRODUCTION

Among the essential diagnostic aids, radiographs and photographs play an important role in the diagnosis of a particular case. In the previous chapter, we have already understood the importance and uses of cephalograms. The other important radiographs that are encountered for everyday use in a dental clinic include the orthopantomogram, the intraoral periapical views (IOPA's) and the bitewing radiographs.

In this chapter, we will discuss the orthopantomogram, the intraoral periapical radiographs, occlusal views, as well as the facial photographs.

WHY RADIOGRAPHS?

This question is very pertinent to answer. Radiographs give the true picture regarding the underlying structure of the bone and associated structures. Radiographs are recommended for the following reasons:

1. Detection of pathologies associated with the teeth in particular and the jaws in general. These may include caries, periapical pathologies, odontomas, etc.
2. To determine the number, size and shape of the teeth.
3. To determine the exact eruption status, including placement and path of eruption, of the succedaneous teeth.
4. For the calculation of total tooth material, i.e. the mesiodistal dimensions of the permanent teeth.
5. For medicolegal purposes.

ORTHOPANTOMOGRAM

The orthopantomogram is considered an essential diagnostic aid and should be examined prior to undertaking any orthodontic treatment. It is not available routinely in dental clinics and the patient may require to be referred to special X-ray centers. The biggest advantage (Table 10.1) of this radiograph is that it provides visualization of a large area of interest to an orthodontist using a single radiograph. With its few drawbacks (Table 10.2), these are probably the most frequently preserved records of any orthodontic case in areas where this facility is available.

The orthopantomogram has an inherent disadvantage that it requires extra space and the equipment, which by itself is expensive, but the radiograph covers the complete dentition and the underlying skeletal structure with amazing clarity at a fraction of the radiation dose of a full-mouth IOPA protocol.

For any student of orthodontics it is essential to be able to correctly read and interpret an orthopantomogram. It is advised that while reading an orthopantomogram a correct protocol must be followed so as not miss out any important diagnostic detail. The most convenient and simple method is presented.

Table 10.1: Advantages of an orthopantomogram

1. A large anatomic area is visualized
2. The radiation exposure is low, less than that for four IOPAs
3. Patient cooperation is rarely a problem
4. Inter-operator variation is minimal

Table 10.2: Disadvantages of an orthopantomogram

1. Specialized equipment is required
2. Distortions, magnifications and overlapping of structures are a problem
3. Definition of structures is not as good as in IOPAs
4. It is not standardized
5. IOPAs may still be required

Step 1

Orient the radiograph as when looking at the patient, i.e. with the patient's left side positioned on the clinician's right. The radiograph is then placed on a view box, which is uniformly lit (Fig. 10.1A). Prefer to dim the remaining lights in the room.



Fig. 10.1A: OPG viewer

Step 2

Start examining from the right condylar head and follow the outline along the neck and the posterior border of the ramus. Continue following the outline of the mandibular body to the symphyseal region anteriorly along the lower border of the mandible to the left condyle. Compare the outline for discontinuities, radiopacities or radiolucencies and most importantly from an orthodontic perspective for symmetry. Asymmetry may result from faulty positioning of the patient or that of the cassette in its holder. Note the thickness and density of the mandibular cortex and the other structures including the mandibular canals, mental foramina, and the coronoid process (Fig. 10.1B).

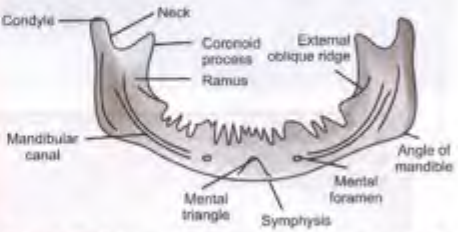


Fig. 10.1B: Outline of the structures seen—including the condyles, coronoid processes, mandibular cortex, mandibular canals, mental triangle, and the mental foramina

Step 3

Examine the medullary bone of the mandible for the usual anatomic landmarks and note anything suggestive of pathology, especially in the periapical regions of the teeth (Fig. 10.1C). The third molar development and position should definitely be noted as it may play an important role in determining the type of retention planned and/or their enucleation if required.

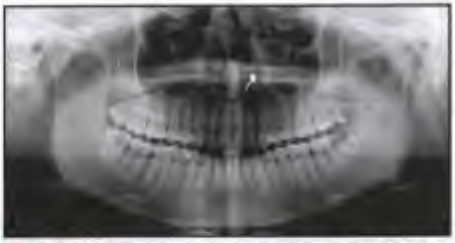


Fig. 10.1C: Orthopantomogram with all teeth clearly visible

Step 4

Next, examine the cortical outline of the maxilla starting on the right side. Trace the pterygo-maxillary fissure, hard palate with the anterior nasal spine. Examine the nasal cavities and the nasal septum followed by the maxillary sinuses. It is advisable to

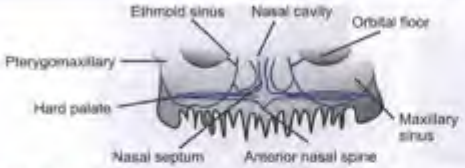


Fig. 10.1D: Outline of nasal cavities and the maxillary sinuses



Fig. 10.1E: Radiopacities in the maxillary anterior region

compare the right and left sides especially of the nasal cavities and the maxillary sinuses (Fig. 10.1D). Radiopacities in these regions could be suggestive of pathology (Fig. 10.1E) or sometimes the presence of foreign body. These might reflect upon the breathing pattern of the patient.

Step 5

Margins of a number of soft tissue structures may be seen on the orthopantomogram. These include the—tongue, soft palate, nose and earlobes (Figs 10.1F and G). Also, sometimes seen, though not as clearly, are the lip lines and the nasolabial folds.

Step 6

Radiopaque shadows, which superimpose on normal anatomic structures are called "ghosts" and are actually artifacts. These can sometimes pose a problem in radiographic interpretation. These are created when the X-ray beam projects through a dense object, e.g. the spinal cord and the opaque shadow of the object projects onto the opposite side of the radiograph.

Step 7

Finally evaluate the teeth for—presence, stage of development, state of eruption unerupted or impacted

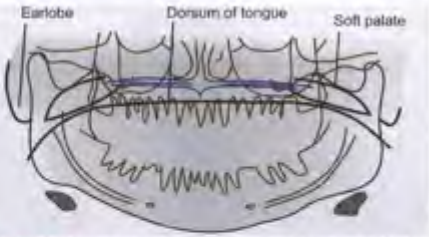


Fig. 10.1F: Outline of soft tissue structures seen in an OPG



Fig. 10.1G: Shadows of the soft tissues are more prominent is OPGs of edentulous patients

teeth, placement, root morphology and position, cavities, fractures, contacts, and/or any pathology (Fig. 10.1H). These findings have to be clinically correlated and/or with IOPA's or bitewing radiographs. Teeth may appear to be magnified or minimized in the horizontal dimension depending on their position. The maxillary and mandibular cusp tips should be generally separate (unless there is a change in the cant of occlusion Fig. 10.1I) and there should be gentle curve to the occlusal plane.

The orthopantomogram may not be sufficient by itself. If any doubt arises it is recommended that an IOPA of the concerned region be taken (Fig. 10.1J).



Fig. 10.1H(i): Outline of an OPG highlighting maxillary and mandibular teeth



Fig. 10.1H(ii): Orthopantomogram showing mixed dentition



Fig. 10.1I: Orthopantomogram showing decreased space between the maxillary and the mandibular cusp tips due to the change in the cant of occlusion

Earlier, before the advent of the OPGs, the IOPAs along with the bitewing radiographs were the main stay for an orthodontist.

INTRAORAL RADIOGRAPHS

The intraoral radiographs are the easiest to take for most orthodontic patients. They formed the mainstay for all orthodontists till the advent of the orthopantomogram. Still they are the most frequently used as all centers may not possess the orthopantomogram. They are also recommended for specific regions in all cases where a doubt remains regarding the clarity of the orthopantomogram (Fig. 10.1J).



Fig. 10.1J(i): Orthopantomogram fails to show the mesiodence, which was evident on the IOPA of the region



Fig. 10.1J(ii): IOPA of the region

The most frequently used views include:

- Intraoral periapical radiographs (IOPA)
- Bitewing radiographs
- Occlusal radiographs.

INTRAORAL PERIAPICAL RADIOGRAPHS

A full set of ten IOPAs (Fig. 10.2) was recommended before the advent of the orthopantomogram. They covered all the present teeth and the adjacent teeth. They are still ideal for the detection of anomalies related to changes in the size, shape and content of the tooth structure and/or the laminadura and/or the periapical region (Table 10.3).

The main disadvantages of the IOPAs includes the increased radiation that a person has to undergo to cover the full complement of his/her teeth. Also at times the patient is not cooperative, and may not allow the repeated placement of films in the desired manner in his/her mouth.

With the increased use of OPGs, the use of IOPAs has reduced considerably. Yet, they are ideal for localized views in relatively small areas of interest because of the excellent clarity that they allow.

BITEWING RADIOGRAPHS

Bitewing radiographs (Fig. 10.3) are used primarily to record the coronal portion of the maxillary and the mandibular posterior dentition. They are seldom used but are ideal for the detection of proximal caries and the study of interdental bone height in these areas. They may also help in the detection of the secondary caries under restorations or overhanging margins of proximal restorations.

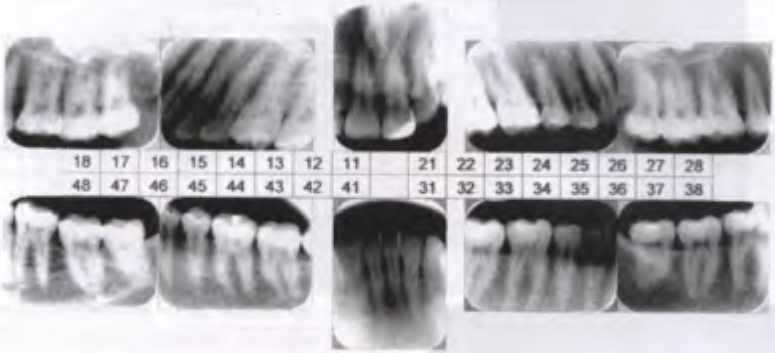


Fig. 10.2: Full mouth IOPAs

Table 10.3: IOPAs are recommended for

1. Adult cases with periodontal disease
2. Medicolegal cases
3. Detection of congenital absence of teem or supernumerary teeth
4. Evaluation of the dental health of the deciduous and/or permanent teeth periapically
5. Detection of pathologic conditions in the early stage especially dental caries
6. Assessment of traumatized teeth after an injury (espically root fractures)
7. Determination of the size, shape and relative position of unerupted permanent teeth
8. Determination of dental age of the patient by assessing the length of the roots of permanent unerupted teeth and the amount of resorption of primary teeth as in dental age analysis
9. Calculation of the total space analysis
10. Detection of root resorption, before during and after treatment.
11. Evaluation of third molars before, during and after treatment
12. Final appraisal of the dental health after orthodontic treatment



Fig. 10.3: Bitewing radiograph

OCCLUSAL RADIOGRAPHS

Intraoral occlusal radiographs are of special interest to an orthodontist when dealing with impacted teeth (Figs 10.4A to D) or for the study of the labio-lingual position of the root apices in the anterior segments of the maxillary and the mandibular dentition.



Fig. 10.4A: Occlusal view of the maxilla to localize the ectopic canine



Fig. 10.4B: Occlusal view of the maxilla to check the labio-lingual position of the incisor roots (note the superimposed radiopaque nose-pin



Fig. 10.4C: Occlusal view of the maxillary arch to access the extent of the periapical pathology



Fig. 10.4D: Occlusal view of the mandibular arch to localize the impacted canines

FACIAL PHOTOGRAPHS

Facial photographs are the easiest to store, occupy the least amount of space and provide immense information to the clinician as well as the patient. Photographs can be,

- Extraoral photographs
- Intraoral photographs

EXTRAORAL PHOTOGRAPHS

Extraoral photographs are considered essential records and should be taken before starting treatment and after completion of treatment. The information provided by these photographs (Table 10.4) is invaluable and this is one record that the patient can really relate to. American Board of Orthodontics has laid down guidelines for these photographs as far back as 1993 (Table 10.5).

Table 10.4: Uses of extraoral photographs

1. Evaluation of craniofacial relationships and proportions before and after treatment
2. Assessment of soft tissue profile
3. Proportional facial analysis and/or photographic analysis of AM Schwarz
4. Important for conducting the Total space analysis
5. Monitoring of treatment progress (if standardized)
7. Invaluable for longitudinal study of treatment and post retention follow-up
8. Detection and recording muscle imbalances
9. Detecting and recording facial asymmetry
10. Identifying patients

Table 10.5: American board of orthodontist's requirements for extraoral photographs

• Quality, standardized facial photographs either black and white or color prints
• Patients head oriented accurately in all three planes of space and in FH plane
• One lateral view, facing right, serious expression, lips closed lightly to reveal muscle imbalance and disharmony
• One frontal view, serious expression
• Optional—one frontal view, serious expression
• Optional—one lateral/profile view and/or frontal view with lips apart
• Optional—one frontal view, smiling
• Background free of distractions
• Quality lightening revealing facial contours with no shadows in the background
• Ears exposed for purpose of orientation
• Eyes open and looking straight ahead glasses removed

It is recommended that at least three extraoral photographs be taken for all patients (Figs 10.5A and B). This includes:

- Frontal facial with lips relaxed
- Facial profile with lips relaxed
- Three-quarter view, smiling or
- Frontal facial, smiling.



Fig. 10.5A: Extraoral photographs—frontal, profile and frontal smiling



Fig. 10.5B: Extraoral photographs—frontal, profile and three-fourth smiling

For facial deformity cases or cases likely to undergo orthognathic correction it is recommended that all the four photographs mentioned above should be complemented with the following:

- Frontal facial in maximum intercuspal position, lips sealed
- Left and right, facial profile in maximum intercuspation, lips sealed
- Left and right, facial profile, lips relaxed
- Left and right three-quarter view, smiling or frontal facial, smiling.

All extraoral photographs should be taken in the natural head position, preferably without any shadows appearing in the background. The ears should be exposed (for the purpose of orientation) and the patient should not be wearing eye ware. It would be ideal if the distance and magnification could be standardized.

INTRAORAL PHOTOGRAPHS

Intraoral photographs (Fig. 10.6) are considered non-essential diagnostic records yet they are simple to take, maintain and store and of course useful (Table 10.6). This is because they are neither standardized nor three-dimensional.

These are helpful in explaining and motivating the patient. They are also used to monitor treatment progress and results. They are also helpful in medico-legal cases involving the texture and color of teeth.

The American board of orthodontics guidelines (Table 10.7) are practically universally followed. It would be pertinent to mention here that if these photographs are taken prior to oral hygiene procedures also, they would enable us to judge the patient's attitude towards his oral hygiene!



Fig. 10.6: Intraoral photographs

Table 10.6: Uses of intraoral photographs

1. Record the structure and color of enamel
2. Patient motivation
3. Assessing and recording health or disease of the teeth and soft tissue structures
4. Monitoring of treatment progress
5. Study of relationships before, immediately following and several years after treatment, to improve treatment planning

Table 10.7: The American board of orthodontist's guidelines for intraoral photographs

1. Quality, standardized intraoral color prints
2. Photographs should be oriented accurately in all three planes of the space
3. One frontal photograph in maximum intercuspation
4. Two lateral views—right and left
5. Optional—two occlusal views—maxillary and mandibular
6. Free of distractions—retractors, labels etc.
7. Quality lightening revealing anatomical contours and free of shadows
8. Tongue should be retracted posteriorly
9. Free of saliva and/or bubbles
10. Clean dentition

FURTHER READING

1. British Orthodontic Society (1994, 2000). Orthodontic Radiography Guidelines. London: BOS.
2. Graber TM. Current Orthodontic Concepts and Techniques, WB Saunders Co. 1969.
3. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
4. Graber TM. Panoramic radiography in dentistry, J Canad Dent Asso, 1965;32:158-73.
5. Hutchinson I, et al. Digital cameras and orthodontics: An overview, Dent Update, 1999;26:144-9.
6. Papika S, et al. Orthodontic application of color image addition to visualize differences between sequential radiographs, Am J Orthod 1999;115:488-93.
7. Quintero JC, et al. Craniofacial imaging in orthodontics: Historical perspective, current status and future developments, Angle Orthod, 1999;69:491-506.
8. Whaites E. Essentials of Dental Radiography and Radiology, ed. 2, London: Churchill Livingston, 1996.

11 Maturity Indicators

Sudhanshu Kansal, Gurkeerat Singh

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INTRODUCTION

Rickets stated that to take advantage of growth we must have an idea of- first, its magnitude, second, its direction and third the element of timing. By using the element of timing of maximum growth in conjunction with ones knowledge of magnitude and direction, one can readily transform orthodontics to a profession of "face forming, as well as tooth positioning".

Various authors have suggested a number of growth assessment methods. Chronological age, appearance of secondary sexual characteristics, growth charts, dental development and skeletal maturation are often used for growth prediction in clinical orthodontic practice. With such wide number of growth assessment methods available, the key question is reliability.

REQUIREMENTS FOR AN IDEAL MATURITY INDICATOR

Ideal requirements for maturity indicators include:

1. Should be safe
2. Non-invasive
3. Require minimum radiation
4. Should be accurate
5. Stages of maturity should be well defined and easily identifiable
6. Cost-effective
7. Minimum armamentarium and personnel requirements
8. Method should be simple to conduct
9. Should be valid over time and across age-groups.

CLINICAL IMPORTANCE

Why study maturity indicators? Why use a particular method for assessing the age of an individual? Which method is ideal for the purpose of studying the maturity of an orthodontic patient? The key to successful treatment in growing patients is the harnessing of growth, and unless we know the exact status of growth, both in magnitude as well as in direction, treatment planning would be futile. Hence, the knowledge of maturity indicators is important.

They help us:

1. To determine the potential vector of facial development
2. To determine the amount of significant cranio-facial growth potential left
3. To evaluate the rate (velocity) of growth
4. To decide the onset of treatment timing
5. To decide the type of treatment:
   a. Orthopaedic
      - Removable
      - Fixed
   b. Orthodontic
   c. Orthognathic surgical procedure
   d. Combination of any of the above
6. To evaluate the treatment prognosis.
7. To understand the role of genetics and environment on the skeletal maturation pattern.

LATE AND EARLY DEVELOPMENT

Six types of skeletal development have been recognized.

1st Group	Average Children.
2nd Group	Children who are tall in their childhood only because they have matured faster than average; they will not be particularly tall adults.
3rd Group	Children who not only mature early, but are also genetically tall. The children are taller than average from early childhood and will be tall adults.
4th Group	Children who are small because they mature late, but who will eventually be of average stature.
5th Group	Children who are both late in developing and genetically short in stature.
6th Group	Indefinite group who start puberty either much earlier or much later than usual.

MATURITY INDICATORS

The key to successful treatment is to start at the right age. The age can be expressed in number of ways:-

1. Neural age
2. Mental age
3. Physiological age and biochemical age
4. Chronological age
5. Sexual/pubertal age
6. Dental age
7. Age determination using growth charts
8. Skeletal/anatomical/radiological age.

NEURAL AGE

In spite of the large size of the central nervous system at birth, it is not completely functional and requires a considerable time to develop to the stage at which it can be utilized to the fullest. The maturation of psychological awareness involves progression from completely self centered absorption to the recognition of the existence of others and finally to the development of an adult appreciation of the individuals place in society.

Gesell and his colleagues in America have done a great deal of work on the neural development in humans. Certain landmarks of development were accounted and now form an important index of maturity. These can be correlated to chronological age, growth and weight.

The neural age helps us to understand that the patient is mentally developed to understand the need for treatment and to what extent would he/she be able to cooperate and follow proper instructions.

Development Landmarks

Years	Age (Months)	
—	2	Follows moving objects with eyes
—	4	Can sit propped up for a short time; Moves head to inspect surroundings
—	6	Grasps objects, begins to bang and shake them
—	8	May sit unaided
—	10	Creeps, picks up small objects between fingers and thumb; one/two words; tries to help with feeding
1	—	"Cruises along holding on to rail of cot; walks with one hand held; throws objects on floor;

Years	Age (Months)	
		cooperates in dressing , waves good-bye; puts toys in and out of container
1.5	—	Walks; runs awkwardly and stiffly; builds towers of 3-4 blocks; can turn pages of a book; vocabulary of about 30 words
2	—	Runs without falling; uses three-word sentences; can turn doorknob; obeys simple instructions; builds towers of 6-7 blocks; bowel and bladder control sometimes good.
3	—	Walks erect. Stand on one foot; climbs; can put on shoes and unbutton some buttons; bowel and bladder control usually established; eats reasonably well by himself; counting begins
4	—	Draws; copies, writes alphabets, cleans teeth, washes and dries face and hands.
5	—	Can tie shoe laces and begins to use tools; some read quite well and most can write their own names; questions about meaning of words
6	—	Reads; Plays; balls are bounced and sometimes caught

MENTAL AGE

There have been attempts to devise performance tests, which measure the elusive quantity conveniently described as "intelligence" by the Stanford-Binet test/ the Wechsler scale.

Tests of this kind take cognizance of arithmetical, verbal and logical ability and also other capacities such as the recognition of form. They correspond to the mental side of development, as compared to the radiological indicators, which measure the physical side. These are of importance as they help in determining the outlook of the patient towards treatment. They also help in assessing the expected level of cooperation that can be expected from a patient.

The mental age is thus an index of maturation of the mind, and like the radiological age, increases at a rate that depends on many intrinsic and environmental factors.

a. A convenient way of classifying intelligence test performance is by the use of the concept of the Intelligence Quotient (IQ) which is the mental age expressed as a percentage of the chronological age. Thus, a child with a mental age of 12 years and a chronological age of 10 would have an IQ of 120.
b. The ability to draw a human figure is often used to assess development and the items the child includes in the drawing can be scored and rated in terms of mental age. There is good correlation between assessments made between 5 and 11 years of age.
c. Another method of estimating mental development is simply to use as the standard capacity of the child to read.

PHYSIOLOGICAL AND BIOCHEMICAL AGE

A series of physiological and biochemical changes occur during growth which can be correlated to skeletal and chronological age.

a. Many physiological and biochemical changes during growth show a sex difference in timing, for they are more closely related to other indices of maturation than to chronological age. Thus girls show a spurt in systolic blood pressure which occurs earlier than the corresponding spurt in the male and the resting mouth temperature which falls by 0.5 to 1°C from infancy to maturity, reaches its adult value earlier in girls. The erythrocyte count and blood value of boys diverge away from the figures for girls at the time of the adolescent spurt.
b. In the plasma, inorganic phosphate shows a steady fall from the high levels of childhood to reach adult figures by the ages of 15 in girls and 17 in boys.
c. The alkaline phosphatase rises significantly in parallel with the growth velocity between the ages of 8-12 in girls and 10-14 in boys and thereafter it falls rapidly to adult levels.
d. More promising index of maturity is the ratio of creatine to creatinine in the urine, this ratio is thought to fall progressively with age after about the age of 14½ years, probably under hormonal influences. Girls maturing early have a lower ratio than those of the same chronological age maturing late and a measurement of this ratio might be made to afford information regarding maturity if considered along with skeletal and other data obtained at the same time.

CHRONOLOGICAL AGE

It is defined as age measured by years lived since birth.

It is considered as a poor indicator of maturity as it provides little validity for identifying the stages of development progression through adolescence to adulthood. It may help to categorize the individual as early, average or late maturer.

This enables an orthodontist to determine and predict the rate and magnitude of facial growth and help decide the time, duration and method of treatment.

SEXUAL/PUBERTAL AGE

There is a great deal of individual variation but puberty and the adolescent growth spurt occurs on an average in early second decade of life. It is generally seen 2 years earlier in girls than in boys. The stage of development of secondary sexual characteristics provides a physiologic calendar of adolescence that correlates with the individual's physical growth status.

The stages of sexual development in boys are more difficult to specifically define than in girls (Table 11.1). Puberty begins later and extends over a longer period of about 5 years in boys as, compared to 3 ½ years in girls.

HAGG and TARANGER (1980) made the following findings concerning the relationship in time between the various pubertal events:

- ***Girls*** If the menarche has occurred, peak height velocity (PHV) has been attained and the growth rate is decelerating.
- If the menarche has not occurred the growth rate may be decreasing but has certainly not yet reached the level of the end of the pubertal growth spurt (20 mm per year)
- ***Boys*** If a boy has a prepubertal voice, it is most probable that the peak height velocity has not yet been reached
- If the voice change has begun the boy is in the pubertal spurt.
- If a boy has a male voice, the growth rate has begun to decelerate
- No boy will reach the end of the pubertal spurt without having a male voice.

DENTAL AGE

Dental age can be correlated to skeletal and chronological age but there is some controversy as eruption timetable can be altered due to general and local factors.

Spier (1918) was the first to associate tooth eruption to growth stature.

Table 11.1: Time table of sexual maturation

	Boys	*Girls*
Onset	Testicular enlargement begins Seminiferous tubules canalize Primary spermatocytes appear Fine downy straight pubic hair appears	Ovarian enlargement begins Breasts develop to 'bud' stage Fine downy straight pubic hair appears
A year	Secondary spermatocytes present, penile enlargement	Pigmentation of areolar pubic hair now coarser and curling
A year or more later	Relative enlargement of larynx beginning First ejaculation	Relative increase of pelvic diameter beginning Menarche; first cycles may not produce ova
A further year or more later	Mature spermatozoa present. Axillary hair Sweat and sebaceous glands very active	Full reproductivity Axillary hair Sweat and sebaceous glands very active

Methods to Determine Dental Age

Eruption time table (Fig. 11.1): Chronological age can be correlated to the eruption time table of primary and secondary teeth. Radiographic appearances of developing jaws and teeth are taken into account. Factors such as completion of crowns, cusps and roots are studied. Radiological development of root of lower canine is considered to be an accurate method to correlate dental age to skeletal age, e.g. second permanent molar, which erupts at age 12 years, was once considered the indication for British child to allow him to work in the factory under the terms of British factory Act and hence was known as the 'Factory tooth'.

Age Determination Using Growth Chart

- Growth charts involve the height, weight and chronological age of the child. There is variation seen in boys and girls.
- It is used to understand growth pattern in terms of deviations from the usual pattern and to express variability quantitatively. It can be done on individual basis or growth can be compared using



Fig. 11.1: For girls—6 months: Mean times of eruption of the permanent teeth eruption of third molars too variable to be considered

standard growth charts. The importance is to determine whether growth is normal/abnormal or the child is in early/late development phase.

- Growth charts can be used to follow the child over a time to evaluate, whether there is unexpected change in growth pattern hence the pattern, timing, variability, velocity and predictability of growth can be determined.
- It can determine the peak height velocity which is the circum-pubertal, (the apex of the pubertal growth spurt) i.e. maximum period at which rate of increase in height is the highest.
- Height and weight measurements are one of the powerful tools in growth assessment but become impractical in clinical orthodontics, as it requires longitudinal data, which is seldom available and needs time and repeated observations. This method can be accurately correlated with pubertal and skeletal age.

SKELETAL AGE

Skeletal/radiological/anatomical age is considered to be the most reliable age for assessment of growth for orthodontic purposes. It is closely related to the growth of an individual. The stages of growth can be accurately determined using methods based on the skeletal maturation indicators and these can be used by the orthodontist to decide the type of treatment and determine the prognosis of a particular case.

Anatomical Regions

Anatomical regions suitable for skeletal maturational assessment should have ideally:

- Region should be small to restrict radiation exposure and expense.
- Should have many ossification centers which ossify at separate times and which can be standardized.
- Region should be easily accessible.

Regions normally used for age assessment

Head and neck	:	Skull
		Cervical vertebrae
Upper limb	:	Shoulder joint-scapula
		Elbow
		Hand wrist and fingers
Lower limb	:	Femur
		Hip joint
		Knee
		Ankle
		Foot-tarsals
		Metatarsals
		Phalanges

Hand wrist radiographs The hand-wrist region is made up of numerous small bones. These bones show a predictable and scheduled pattern of appearance, ossification and union from birth to maturity. Hence, this region is one of the most suited to study growth. The only disadvantage of using this region is that this is a bit further away from the sight, i.e. the oral cavity, which the clinician might be exposing to radiation.

Anatomy of Hand-Wrist

The hand-wrist region is made up of the following four groups of bones (Fig. 11.2A).

1. Distal ends of long bones of forearm
2. Carpals
3. Metacarpals
4. Phalanges

Distal ends of long bones of forearm The distal ends of radius and ulna, which are the long bones of the forearm, were initially used for the purpose of skeletal age determination. The method is rarely used nowadays and is of more interest for theoretical purpose than for its clinical applicability.

The carpals They consist of eight small, irregularly shaped bones arranged in two rows—a proximal row and a distal row. The bones of the proximal row are scaphoid, lunate, triquetral and pisiform (Fig. 11.2A).

The distal row of bones include trapezium, trapezoid, capitate and hamate (Fig. 11.2A).

The metacarpals These are the 5 miniature long bones forming the skeletal framework of the palm of the human hand. They are numbered 1 to 5 from the thumb to the little finger. All the metatarsals ossify from one primary ossifying center located in their shafts and a secondary center on their distal end; except the first metacarpal where it appears at the proximal end.



Fig. 11.2A: Anatomy of hand and wrist (1) radius, (2) ulna, (3) distal epiphysis of radius, (4) distal epiphysis of ulna, (5) trapezium, (6) trapezoid, (7) capitate, (8) hamular process of hamate, (9) hamate, (10) triquetral, (11) pisiform, (12) lunate, (13) scaphoid, (14) sesamoid, m = metacarpal, P = phalanx

The phalanges They are small bones that form the fingers. There are three phalanges in each finger. The thumb has only two phalanges.

The bones of the phalanges are referred to as the proximal, middle (absent in thumb) and the distal phalanges (Fig. 11.2A). The phalanges have been considered to ossify in three stages (Figs 11.2B to D).



Figs 11.2B to D: Stages in ossification of phalanges (B) the epiphysis and diaphysis are equal(C) the epiphysis caps the diaphysis (D) fusion of the epiphysis and the diaphysis

The sesamoid bone The sesamoid bone is a small nodular bone most often present embedded in tendons in the region of the thumb (Fig. 11.2A).

RADIOLOGICAL METHODS OF ASSESSMENT AND PREDICTION OF SKELETAL GROWTH

GREULICH AND PYLE METHOD

Greulich and Pyle published an atlas containing ideal photographs of hand-wrist radiographs of children of various different chronological ages. Separate sets of photographs exist for male and female patients. The patient's radiograph is matched on an overall basis with one of the photographs in the atlas.

SINGER'S METHOD OF ASSESSMENT

Julian Singer in 1980 proposed a system of age assessment which was far quicker and easier to perform under routine clinical circumstances than any previously described. It involved six stages of hand-wrist development characterized as early, prepubertal, pubertal onset, pubertal, pubertal deceleration and growth completion (Table 11.2).

FISHMAN'S SKELETAL MATURITY INDICATORS

Keonord S Fishman proposed a system for evaluation for skeletal maturation in 1982. Fishman made use of four anatomical sites located on the thumb, third

Table 11.2: Characteristics of Singer's method of skeletal maturation

Stage	*Characteristic*
One (early):	This stage is characterized by absence of the pisiform , absence of hook of the hamate and epiphysis of proximal phalanx of second finger being narrower than its diaphysis
Two (prepubertal)	This stage is characterized by initial ossification of hook of the hamate, initial ossification of pisiform and proximal phalanx of second finger being equal to its epiphysis
Three (pubertal onset)	This stage is characterized by beginning of calcification of ulnar sesamoid, increased width of epiphysis of proximal phalanx of the second finger and increased calcification of hook of hamate and pisiform.
Four (pubertal)	This stage is characterized by calcified ulnar sesamoid and capping of the diaphysis of the middle phalanx of the third finger by its epiphysis.
Five (pubertal deceleration):	This stage is characterized by calcified ulnar sesamoid, fusion of epiphysis of distal phalanx of third finger with its shafts, and epiphysis of radius and ulna not fully fused with respective shafts
Six (growth completion)	No remaining sites seen

finger, fifth finger and radius. Eleven discrete adolescent skeletal maturity indicators (SMI's) (Fig. 11.3A) were proposed which covered the entire period of adolescent development. The Fisherman's system of interpretation uses four stages of bone maturation (Fig. 11.3B), which include:

1. Epiphysis equal in width to diaphysis
2. Appearance of adductor sesamoid of the thumb
3. Capping of epiphysis
4. Fusion of epiphysis



Fig. 11.3A(i): Sites of skeletal maturity indicators in Fishman's method (diagramatic representation)



Fig. 11.3A(ii): Sites of skeletal maturity indicators in Fishman's method (radiographic representation)



Fig. 11.3B: Fishman's method for radiographic identification of skeletal maturity indicators (1) Epiphysis equal in width to diaphysis, (2) appearance of adductor sesamoid of the thumb, (3) capping of epiphysis, (4) fusion of epiphysis

The eleven skeletal maturity indicators (Fig. 11.3C) are as follows:

SMI 1: The third finger proximal phalanx shows equal width of epiphysis and diaphysis.

SMI 2: Width of epiphysis equal to that of diaphysis in the middle phalanx of third finger.

SMI 3: Width of epiphysis equal to that of diaphysis in the middle phalanx of fifth finger.

SMI 4: Appearance of adductor sesamoid of the thumb.

SMI 5: Capping of epiphysis seen in distal phalanx of third finger.

SMI 6: Capping of epiphysis seen in middle phalanx of third finger.

SMI 7: Capping of epiphysis seen in middle phalanx of fifth finger.

SMI 8: Fusion of epiphysis and diaphysis in the distal phalanx of third finger.

SMI 9: Fusion of epiphysis and diaphysis in proximal phalanx of third finger.

SMI 10: Fusion of epiphysis and diaphysis in the middle phalanx of third finger.

SMI 11: Fusion of epiphysis and diaphysis seen in the radius.

SKELETAL MATURATION EVALUATION USING CERVICAL VERTEBRAE OR CERVICAL VERTEBRAE MATURITY INDICATORS (CVMI)

Hassel and Farman developed a system of skeletal maturation determination using cervical vertebrae. The shapes of the cervical vertebrae were found to be different at different levels of skeletal development.

The shapes of the vertebral bodies of C3 and C4 vertebrae changed from a relatively wedged shape to a rectangular shape and further to a square shape. The increase in vertical height was associated with increasing skeletal maturity. Also, it was observed that the inferior vertebral borders were flat initially and became concave with increased skeletal maturity. The curvature of the inferior vertebral borders were seen to appear sequentially from C2 to C3 to C4 as the skeleton matured. Based on this finding Hassel and Farman have put forward the following six stages in vertebral development using the C2, C3 and C4 cervical vertebrae (Fig. 11.5).

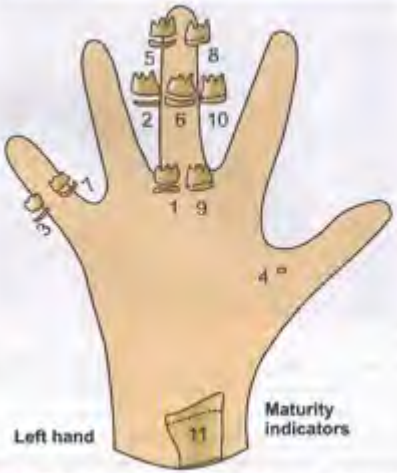


Fig. 11.3C: Skeletal maturity indicators Fishman method (SMI). *Width of epiphysis wide as diaphysis:* (1) Third finger—proximal phalanx, (2) Third finger—middle phalanx, (3) Fifth finger—middle phalanx. ***Ossification*** (4) Adductor sesamoid of thumb. *Capping of epiphysis:* (5) Third finger—distal phalanx, (6) Third finger—middle phalanx, (7) Fifth finger—middle phalanx, *Fusion of epiphysis and diaphysis* (8) Third finger—distal phalanx, (9) Third finger—proximal phalanx, (10) Third finger—middle phalanx, (11) Radius

MATURATION ASSESSMENT BY HAGG AND TARANGER AND THE KR (KANSAL AND RAJAGOPAL) MODIFIED MP3 METHOD

Hagg and Taranger analyzed yearly hand wrist radiographs of individuals from age 6 to 18 years and studied the ossification of the sesamoid (S), the middle and distal phalanges of the third finger (MP3 and DP3) and the distal epiphysis of the radius. Kansal and Rajagopal modified the MP3 indicators further and compared it to the cervical vertebrae maturation indices (CVMI) as described by Hassel and Farman.

Evaluation

For the purpose of easy understanding the parameters studied by Hagg and Taranger are mentioned in blue, additional features observed by Kansal and Rajagopal in pink and Hassel and Farmen in red.

Comparative evaluation of the modified MP3 stages and CVMI produced the following findings.

MP3-F stage: Start of the curve of pubertal growth spurt (Fig. 11.6)

Features observed

1. Epiphysis is as wide as metaphysis.
2. Ends of epiphysis are tapered and rounded.
3. Metaphysis shows no undulation.
4. Radiolucent gap (representing cartilaginous epiphyseal growth plate) between epiphysis and metaphysis is wide.

BJORK, GRAVE AND BROWN

They divided skeletal development into 9 stages (Table 11.3 and Fig. 11.4). Schoph in 1978 associated each of these stage with a particular chronological age.

CVMI-1: Initiation stage of cervical vertebrae (Fig. 11.5).

1. C2, C3 and C4 inferior vertebral body borders are flat.
2. Superior vertebral borders are tapered from posterior to anterior (wedge shape).
3. 80-100 percent of pubertal growth remains.

MP3-FG stage: Acceleration of the curve of pubertal growth spurt.

Features observed

1. Epiphysis is as wide as metaphysis.
2. Distinct medical and/or lateral border of epiphysis forms line of demarcation at right angle to distal border.
3. Metaphysis begins to show slight undulation.
4. Radiolucent gap between metaphysis and epiphysis is wide.

Table 11.3: Nine stages of skeletal development according to Bjork, Grace and Brown

Stage	*Males aged (years)*	*Females aged (years)*	*Characteristic*
One	10.6	8.1	The epiphysis and diaphysis of the proximal phalanx of index finger are equal
Two	12.0	8.1	The epiphysis and diaphysis of middle phalanx of the middle finger are equal
Three	12.6	9.6	This stage is characterized by presence of 3 areas of ossification a. The hamular process of the hamate exhibits ossification b. Ossification of pisiform c. The epiphysis and diaphysis of radius are equal
Four	13.0	10.6	This stage marks the beginning of the pubertal growth spurt an is characterized by: a. Initial mineralization of the ulnar sesamoid of the thumb b. Increased ossification of the hamular process of the hamate bone
Five	14.0	11.0	This stage marks the peak of the pubertal growth spurt. Capping of diaphysis by the epiphysis is seen in: a. Middle phalanx of the third finger b. Proximal phalanx of thumb c. Radius
Six	15.0	13.0	This stage signifies the end of the pubertal growth spurt and is characterized by the union between epiphysis and diaphysis of the distal phalanx of the middle finger
Seven	15.9	13.3	This stage is represented by the union of epiphysis and diaphysis of the proximal phalanx of the little fingers occurs
Eight	15.9	13.9	This stage is represented by the fusion between the epiphysis and diaphysis of the middle phalanx of the middle finger
Nine	18.5	16.0	This is the last stage and it signifies the end of skeletal growth. It is characterized by fusion of epiphysis and diaphysis of the radius



A

Fig. 11.4A: Stage one—Epiphysial width equal to diaphysial width of the proximal phalanx finger are equal



B

Fig. 11.4B: Stage two—The epiphysis and diaphysis of the middle phalanx of the middle finger are equal



C



D



E

Figs 11.4C to E: Stage three (C) The Hamular process of the hamate exhibits ossification, (D) Ossification of pisiform, (E) The epiphysis and diaphysis of radius are equal



F



G

Figs 11.4F and G: Stage four—Initial mineralization of the ulnar sesamoid of the thumb (G) Increased ossification of the hamular process of the hamate bone





Figs 11.4H to J: Stage five—Capping of diaphysis by the epiphysis is seen in middle phalanx of the third finger (I) Proximal phalanx of the thumb (J) Radius



Fig. 11.4K: Stage six—Union between epiphysis and diaphysis of the distal phalanx of the middle finger



Fig. 11.4L: Stage seven—Union of epiphysis and diaphysis of the proximal phalanx of the little finger



Fig. 11.4M: Stage eight—Fusion between the epiphysis and diaphysis of the middle phalanx of the middle finger



Fig. 11.4N: Stage nine—Fusion of epiphysis and diaphysis of the radius

Figs 11.4A to N: Nine stages of development according to Bjork, Grace and Brown

CVMI-2: Acceleration stage of cervical vertebrae (Fig. 11.5).

1. Concavities are developing in lower borders of C2 and C3.
2. Lower border of C4 vertebral body is flat.
3. C3 and C4 are more rectangular in shape.
4. 65-85 percent of pubertal growth remains.

MP3-G stage: Maximum point of pubertal growth spurt (Fig. 11.6).

Features Observed

1. Sides of epiphysis have thickened and cap its metaphysis, forming sharp distal edge on one or both sides.
2. Marked undulations in metaphysis give it "Cupid's bow" appearance.
3. Radiolucent gap between epiphysis and metaphysis is moderate.



Fig. 11.5: Six stages of cervical vertebrae maturation indices

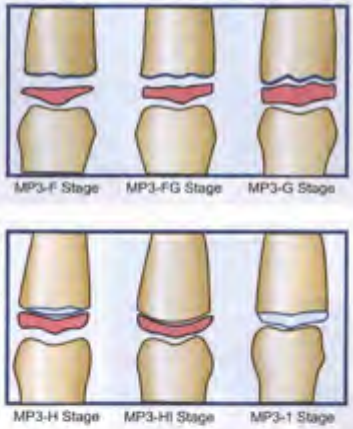


Fig. 11.6: Six modified stages of MP3 development

CVMI-3: Transition stage of cervical vertebrae (Fig. 11.5).

1. Distinct concavities are seen in lower borders of C2 and C3.
2. Concavity is developing in lower border of C4.
3. C3 and C4 are rectangular in shape.
4. 25-65 percent of pubertal growth remains.

MP3-H Stage: Deceleration of the curve of pubertal growth spurt.

Features observed

1. Fusion of epiphysis and metaphysis begins.
2. One or both sides of epiphysis form obtuse angle to distal border.
3. Epiphysis is beginning to narrow.
4. Slight convexity is seen under central part of metaphysis.
5. Typical "Cupid's bow" appearance of metaphysis is absent, but slight undulation is distinctly present.
6. Radiolucent gap between epiphysis and metaphysis is narrower.

CVMI-4: Deceleration stage of cervical vertebrae (Fig. 11.5).

1. Distinct concavities are seen in lower borders of C2, C3 and C4.
2. C3 and C4 are nearly square in shape.
3. 10 = 25 percent of pubertal growth remains.

MP3-HI stage: Maturation of the curve of pubertal growth spurt .

Features of this "new" stage observed in the KR study.

1. Superior surface of epiphysis shows smooth concavity.
2. Metaphysis shows smooth, convex surface, almost fitting into reciprocal concavity of epiphysis.
3. No undulation is present in metaphysis.
4. Radiolucent gap between epiphysis and metaphysis is insignificant.

CVMI-5: Maturation stage of cervical vertebrae (Fig. 11.5)

1. Accentuated concavities of C2, C3 and C4 inferior vertebral body borders are observed.
2. C3 and C4 are square in shape.
3. 5-10 percent of pubertal growth remains.

MP-I Stage: End of pubertal growth spurt.

Features observed

1. Fusion of epiphysis and metaphysis complete.
2. No radiolucent gap exists between metaphysis and epiphysis.
3. Dense, radiopaque epiphyseal line forms integral part of proximal portion of middle phalanx.

CVMI-6: Completion stage of cervical vertebrae.

1. Deep concavities are present in C2, C3 and C4 inferior vertebral body borders.
2. C3 and C4 are greater in height than in width.
3. Pubertal growth in complete.

This study correlated the finding of three studies and proved that recording modified MP3 stages using periapical X-ray film can be an accurate, simple, practical, and economical growth indicator for making decisions on treatment timing. It also led to a significantly lower radiation exposure compared to lateral cephalograms or hand-wrist X-rays. The periapical film used gave clear distortion free image of the MP3 region. The changes recorded were distinct and easily identifiable, unlike the more subtle changes in CVMI stages. And yet they bore a close correlation to the six stages of CVMI.

To undertake growth modification and to be able to take maximum benefit of the remaining growth potential of the patient, it is mandatory to assess the skeletal maturation status of each individual patient. The methods discussed above are not complete or conclusive in all respects but reflect the changing trends with our increasing knowledge of the growth and development of the human skeletal system with emphasis on the face and jaws.

FURTHER READING

1. Anderson DL, Thompson GW, Popovich F. Interrelationship of dental maturity, skeletal maturity, height and weight from age 4 to 14 years. Growth 1975;39:453-62.
2. Bowden BD. Epiphyseal changes in the hand/wrist area as a indicators of adolescent. Aust Orthod J. 1976;4:87-104.
3. Fishman LS. Radiographic evaluation of skeletal maturity. Angle Orthod 1982;8-112.
4. Grave KC, Brown T. Skeletal ossification and the adolescent growth spurt. Am J Orthod 1976;69:611-9.
5. Gruelich WW, Pyle SI. Radiographic atlas of skeletal development of the hand and wrist, Palo Alto, Calif., 1959, Stanford University Press.
6. Hagg U, Taranger J. Maturation indicators and the pubescent growth spurt. Am J Orthod 1982;82:299-309.
7. Houston W. Relationships between skeletal maturity estimated from hand-wrist radiographs and the timing of the adolescent growth spurt. Eur J Orthod 1980;2:81-93.
8. Houston WJB, Miller JC, Tanner JM. Prediction of the timing of the adolescent growth spurt from ossification events in hand-wrist films. Brit J Ortho. 1979;6:145-52.
9. Kansal S, Rajagopal R. A comparison of modified MP3 stages and the cervical vertebrae as growth indicators. J Clin Orthod 2002;36:398.
10. Moore, Moyer, DuBois. Skeletal maturation and craniofacial growth. Am J Orthod 1990;33-40.
11. Singer J. Physiologic timing of orthodontic treatment. Angle Orthod 1980;50:322-33.

12 Computerized Diagnostic Systems

Siddarth Shetty, Gurkeerat Singh

- Introduction
- The digital image
- Various methods of digital radiography
- Digital cephalometrics
- Video-Cephalometry
- Digital photography
- Three-dimensional imaging
- Digital study models

INTRODUCTION

When the word "technology" is mentioned, most people think about computers. Virtually every facet of our lives has some computerized component. A few years ago, it was considered a specialized component, which has now been converted to an everyday appliance. *The computer is basically an automatic electronic machine that performs calculations or derives results based on the data fed into it and the software/program it is designed for.* A computer is capable of accepting data, performing operations according to instructions and providing the results of these operations in comparatively shorter duration of time and with greater accuracy as compared to manual labour. It is built to perform routine calculations with speed, reliability and ease.

Most appliances in our homes have microprocessors built into them, e.g. our televisions. Even our cars have a computer. But the computer that everyone thinks of first is typically the personal computer, or PC. A PC is a general-purpose tool built around a microprocessor. It has lots of different parts—memory, a hard disk, a modem, etc.—that work together. "General purpose" means that you can do many different things with a PC. You can use it to type documents, send e-mail, browse the web and play games.

Today the computers is no longer the domain of a few. Conservative estimates of computer literate individuals would be close to 550 million! Of these about, 320 million have access to the internet.

Orthodontists with their love for technology and miniaturization have not remained untouched. Computers are practically used in all the facets of any dental practice today (Table 12.1). Computers have become especially useful to orthodontists for:

Table 12.1: Uses of computers in dental practice

Administrative applications
- Patient case records
- Recall appointments
- Patient scheduling
- Accounts
- Patient correspondence
- Billing
- Inventory lists
- Prescription formats
- Post-treatment instructions
- Insurance claims
- Referral information

Clinical applications
- Patient photographs—analysis and storage
- Patient radiographs—analysis and storage
- Inter- specialty referral and opinion
- Patient motivation
- Appliance design using CAD CAMs
- Growth predictions
- Visual treatment objectives
- Generation of pre- and post-treatment photographs
- Patient interaction and information on the internet

Miscellaneous applications
- Survey information/epidemiological data
- Presentations
- Continuing dental/medical education
- Literature reviews
- Entertainment

- Digital photography
- Digital radiography
- Digital cephalometrics
- Video cephalometrics
- 3-D imaging
- Digital study models

Computers are especially useful as diagnostic aids due to their capability for storing large amount of data, objective approach and ability to perform complex calculation relatively easily in a short span of time. Their advantages (Table 12.2) out-weigh their only disadvantage of lacking the flexibility and insight of the human brain.

Table 12.2: Advantages of a computer

1. Capable of storing a large amount of data
2. Various analyses are possible of the stored data
3. Multiple tasks can be performed at the same time
4. It is logical
5. Results are obtained fast hence, it results in time saving

This chapter will provide an overview of the uses of computers in the diagnosis of various ailments while highlighting the orthodontic perspective.

THE DIGITAL IMAGE

A digital image is a matrix of square pieces or picture elements referred to as **pixels** that are displayed upon a flat panel display or a CRT and constitute the image space. The image space on a monitor is made up of pixels arranged in a series of horizontal lines called "raster lines".

The significance of the pixels and their accumulation is seen in the resolution of an image. The pixels are arranged in a matrix. 512 × 512. Matrix will contain 262,144 pixels. If a large number of pixels are used to represent an image their discrete nature becomes less apparent.

A digital image is stored in a matrix of rows and columns of pixels values known as a bitmap image. Resolution basically refers to the density of pixels in a bitmapped image. Pixels/inch or pixels/mm, i.e. the spatial resolution of an image increases as the number of pixels increase. A digital image when enlarged exhibits graininess (Fig. 12.1)—pixelization. The value of each pixel is stored in one or more 'bits' of data.

Sample depth: Number of bits used to represent each pixel, i.e. each pixel has a digital value that represents the intensity of the information recorded for its detection. Information in computers is stored as 1's and 0's, basically in a binary state. Each pixel of n bits/pixel is capable of 2n different colors and intensities.



Fig. 12.1: Enlarged digital image exhibiting graininess

In a 6-bit image, each pixel has 64 different values and in a 8 bit image each pixel has 256 different intensities or colors.

Grayscale images such as a radiograph, needs to possess 8 bits of data/pixel to be perceived as a continuous tonal range. Presently 12 bits (4096 shades of gray) is considered optimal.

Color images are usually represented by 24 bits of data/pixel (16.7 million possible color), i.e. 8 bits of data of each in RGB. Therefore in each RG and B channel 256 colors exist. If the colors chosen from the palette match the tones of image, image quality can be remarkably good.

IMAGE ARCHIVING / STORAGE

The storage of cephalometric radiographs and/or other radiographs is expensive and this cost could be reduced by image archiving. Such archiving of radiographs could prove extremely useful in long-term growth studies or treatment analysis studies utilizing radiographs. The problem of image storage increases with an increase in the number of pixels or sample depth.

However an aid in the storage and transmission of images is the system of image compression. It is possible to compress data with no significant loss of image quality at compression ratios of up to 3:1. This is termed *lossless compression.*

For greater compression some loss of information would occur but clinically acceptable pictures would be obtained at compression ratios up to 20:1—*lossy compression*.

JPEG (joint photographic experts group) is the most commonly used compression method where 95 percent of storage space reduction is achieved. The JPEG works on 8 × 8 blocks of pixels and creates artifacts at the corner of blocks as data is encoded.

IMAGE DISPLAY

A normal monitor exhibits 625 lines. To be able to optimally view images 2,048 lines are considered necessary.

TOTAL DIGITAL RADIOGRAPHY

The concept of total digital radiography is today a reality, i.e. an entire radiology department would utilize solely digital imaging facilities. Here there is a central storage and retrieval system which would facilitate the distribution of images to many locations within the hospital.

The immense volume of data, which is considered difficult to manage (12.81 terabytes/year), could be viewed at various locations-"*multimodality viewing*". This would permit the display of not just the patients history, but also conventional radiographs, CT scans, photographs and other information. Patient's history and all other information integrated with the radiographs would definitely be more informative to any clinician irrespective of his/her field of specialization.

TELERADIOLOGY

Transmission of radiographs to various sites via telephone lines/satellite link (Fig. 12.2). This is dependent upon the

- System used.
- Size of the pixel matrix.
- Time required.

It is being done, but requires higher configuration systems and relatively lesser picture size (pixel mass).

VARIOUS METHODS OF DIGITAL RADIOGRAPHY

Three methods are available for acquiring digital grayscale images of radiographs.

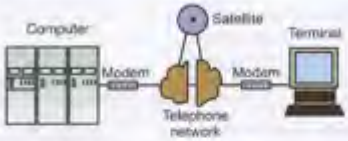


Fig. 12.2: Teleradiology

i. Phosphor plate technique.
ii. Direct receptor technique.
iii. Transparency scanner technique.

PHOTO STIMULABLE PHOSPHOR PLATES

Step 1: Conventional X-ray tube end is used to expose the plate.

Step 2: Activating its phosphor coating and formation of a latent image.

Step 3: Sensitivity of the plate causes decrease of X-ray exposure by about 90 percent.

Step 4: The plate is passed over a laser scanner.

Step 5: The laser scanner stimulates the phosphor coating to emit visible light proportional to the X-ray exposure.

Step 6: The light is detected and converted to grayscale intensities creating a digital image which is transferred to a computer and saved on a local or network storage.

Step 7: The latent image is then removed by placing the plate over a bright light for a few minutes; plates are reusable and can be used for several thousand exposures.

The image is obtained at 12 bits/pixel but can be down sampled to 8 bits/pixel.

DIRECT RECEPTORS

These use a photosensitive sensor such as a:

- Charged couple device.
- Complementary MO semiconductor.

Conventional X-ray tube is used to expose the sensor and activate thousands of tiny light-sensitive fields.

As with the phosphor plate method, exposure decreases by about 90 percent.

The phosphor plate systems require 2 steps-exposure and scanning; direct receptors display images immediately on the monitor.

Intraoral sensors are suitable for periapical and bitewing radiography. A small and large sensor for cephalometry is also available.

FLATBED TRANSPARENCY SCANNER

Many orthodontists contemplating digital cephalometry find this method to be simplest and least expensive method of digital image acquisition.

A conventional X-ray film is planned on the scanners flat transparent surface and is scanned by a light source.

The transmitted light in detected by a CCD and is converted into grayscale intensities.

A new class of flatbed scanners that can obtain images at 12 bits/pixel and a resolution of 600 pixels/inch are now available.

However the images obtained by this method require a lot of memory space.

AUTOMATIC IDENTIFICATION OF LANDMARKS

The cephalometric radiograph is scanned into the computer. The computer automatically loads the landmarks and performs the analysis. This overcomes the errors usually encountered in the manual identification of land marks (Table 12.3).

Table 12.3: The various manual errors in the analysis of cephalograms

- Reproducibility errors
- Variation in image acquisition
- Landmark identification
  - Interobserver variation
  - Intraobserver variation
- Measurement errors

The procedure of computerized automatic identification has the potential to increase accuracy, and improve our ability to correctly diagnose orthodontic problems. Also the very use of computerization might make the application of alternative methods of form description, other than lines and analysis possible. Techniques such as FEM, allometric models, Mesh diagram, etc. have the potential of becoming more clinically applicable.

The common approach to identify landmarks have a similar approach in that—

- Image pixels in the regions of high intensity gradient or edges are identified.
- These edges are assumed to be object boundaries.
- Landmarks are then found in relation to these labeled boundaries.

This approach involves four steps:

1. Remove noise.
2. Label pixels according their edginess.
3. Count pixels and label edge.
4. Find landmark band on position or relationship to labelled edge.

DIGITAL CEPHALOMETRICS

Cephalograms are two dimensional representation of 3-D anatomy. Our ability to derive meaningful information from head films depends on the reliability with which the anatomic relations can be evaluated.

Fortunately, orthodontists around the world have agreed on a reasonably high level of standardization in the methods used to acquire a cephalogram. The head position and orientation, source object distance and radiographic enlargement have been standardized to a degree that permits a common descriptive language of dentofacial morphology and the development of consistent methods of anthropometric landmark identification.

The information inherent in the large data collections that cephalometric studies entail is of fundamental importance to orthodontic diagnosis and understanding craniofacial changes due to growth or orthodontic therapy.

The analysis and acquiring of cephalometric data can be streamlined and made more efficient by using a new approach or a new analytic tool. This technology must be able to store, score, retrieve and analyze vast collections of information.

This new approach has two important features. First, it applies powerful mathematical technologies to describe and analyze morphologic structures and secondly, this from can be analyzed by the computer.

In the past two decades we have witnessed the development of number of systems for the computer aided encoding of data from lateral cephalograms for use in craniofacial research and clinical treatment planning.

The cephalometric application workflow is as follows:

DIGITIZATION

Digitization is the form by which analog information is converted to digital form. The methods involved can be either direct or indirect.

During digitization X-Y coordinates of cephalometric landmarks are recorded and stored in a data set. This data set is the starting point for the formulation of various computer generated VTO's and STO's.

Direct Computer Digitization

A digitizing tablet or digitizer is used for this purpose.

Digitizers may be opaque, translucent or transparent.

Translucent or transparent digitizers can be backlit, allowing direct digitization of cephalo-grams without any intermediate acetate tracing.

Resolution and Accuracy

Resolution is the smallest distance that can be resolved by the digitizer in the order of 1000 lines/inch.

Accuracy is the precision with which a digitizer can record reported movements over various regions on its surface. It should be in the order of ± 0.25 mm for cephalometric application.

The anatomical points are entered using on electronic pen or instrument. The digitizing tablet is made up of a fine electric grid that includes registration points as fine as 0.009 mm apart. This electronic instrument emits an electronic signal either on command or continuously. Various varieties of instruments are available for this purpose. The two most commonly used are:

- Electronic pen
- Cross hair cursor.

Electronic pen An electronic pen is activated to emit a signal when the tip of the pen is pressed against the film or a button on the pen is pressed. Electronic signals are emitted directly from the pen to the grid completing the circuit.

Cross hair cursor This potentiometer consists of two wires arranged in a cross hair pattern which are embedded into a glass window. The electronic registration signal is emitted from the junction of the wires. The operator presses a button to activate the potentiometer.

The cross hair cursor is less popular now because:

i. The digitizer is bulky and not very easy to use.
ii. Glow from the glass in which the wires are embedded prevents optimum mapping of the various landmarks.

Indirect Digitization

For indirect digitization, a video camera or mapper captures an image of the cephalometric radiograph and stores it in the computer. The video camera must be calibrated with the cephalometric film being plowed into the computer. The digital radiography is another method of data input into the computer.

The image is then displayed on a monitor and the landmarks are identified using a mouse. The only disadvantage of this method is that the digitizing resolution obtained is lesser than that obtained with a digitizer.

Mode of digitization

- Point mode
- Stream mode

Point mode (Fig. 12.3A) The user sequentially locates landmarks in a pre-determined order recording one coordinate pair for each landmark. It basically involves the direct location of individual landmarks.

A visual representation of a cephalogram is generated by connecting discretely located points due to their proximity and sequence, making a visual representation of a cephalogram possible.



Fig. 12.3A: Point mode

Stream mode (Fig. 12.3B) Here the operator 'traces' a cephalogram using the digitizing device and the tracing thus obtained in the form of a stream of points controlled by a programmable option. The points are recorded as a specific number of coordinate points per second or after the cursor has moved a certain distance.

The points when joined form audible contour and this analogy is easily accepted by the computer.



Fig. 12.3B: Stream mode

Advantage and disadvantage

- Point mode digitization is more time consuming but more accurate.
- Stream mode digitization is less accurate due to the manner in which the data is acquired.
- The location of hard and soft tissue landmarks must be provided to the predictive software. Point mode reliably provides location of the landmarks whereas the stream mode does not.
- A coordinate pair may not be transmitted as the cursor passes over a landmark such as the subnasale. Thus, the accuracy of landmark location suffers here.
- Also, to locate a point and determine a change in its position over time it is helpful to know the precise position of the landmarks relative to its origin. The accuracy of such information can be obtained only by way of point digitization.

Direct Digitization

Computer softwares that allow direct digitization of cephalometric radiographs are currently available. These software programs perform various orthodontic and surgical movements based upon parameters entered by the user into the program.

'Dentofacial planner' program has a digitization regimen for the lateral-cephalogram consisting of 68 landmarks of which 43 are soft tissue landmarks and the remainder are hard tissue landmarks.

'Quick ceph', another commercially available program uses a 28 landmarks regimen with all points representing hard tissue landmarks.

Both programs can perform a variety of functions with the digital cephalometric radiograph including:

- Cephalometric analysis (Fig. 12.4A)
- Superimposition (Fig. 12.4B)
- Growth estimation
- Orthodontic treatment planning
- Surgical prediction.

The hard tissue positions as predicted in the expected surgical procedure are fed into the program and the expected soft tissue changes are then calculated.

The soft tissue profile prediction is made possible by the application of ratios of soft tissue and hard tissue changes to the surgical movements that are within the program.



Fig. 12.4A: Cephalometric analysis using computers



Fig. 12.4B: Superimposition of profile photograph over lateral cephalogram and cephalometric plotting

These ratios are based upon retrospective studies of stability and soft tissue changes.

CEPHALOMETRIC ANALYSIS AND TREATMENT PLANNING

The various tasks that make up cephalometrics can be broadly divided into static and dynamic function.

Static Function

Information derived from the radiograph contours on a current film or collection of films.

Dynamic Function

Dynamic functions include elements of cephalometric representation that are transformed or manipulated.

- Growth prediction.
- Orthodontic/surgical text planning.

Static cephalometric function Cephalometric applications use the digitized coordinates for a sequence of landmarks for the anatomic structures they represent. Vector mathematics is used to compute a variety of commonly used cephalometric movements, such as the linear distance between 2 landmarks, the angle between 2 lines and the perpendicular from a point to a line, etc.

Movements derived from a patient's digital cephalogram are reported in comparison to a data base of age and sex specific values.

To accommodate cephalometric enlargement the coordinates of all digital landmarks are scaled by a factor that reduces the dimension of the overall representation to a corrected size. Digitized cranial base or regionally stable land marks are used for imposition of digitized landmarks. Spatial changes in landmark location are reported as vectors incorporating magnitudes and dimension of change. Analyses can be conducted for all superimposed coordinate sets.

The basic problem with using software programs for superimposition is that unlike in manual superimposition where stable landmarks are super imposed on one another or the best fit contours are matched in cephalometric computer applications, superimpositions are done using landmarks already stored in their data sets, this can potentially result in errors due to poor landmark location.

Dynamic cephalometric function The concept of cephalometric prediction rapidly for planning combined surgical and orthodontic treatment is well established. These are basically growth and treatment visualization systems.

Treatment decisions are entered into the system and immediately evaluated. Landmarks sufficient to render an adequate distribution of the structures involved must be digitized.

Cephalometric growth forecasting is still a region of some controversy. However it is well documented that it is possible to estimate growth to a certain degree using cephalometry.

The Rickets growth prediction methodology is widely used and is easily implemented in various softwares. It applies increments of growth to a series of landmarks along reference lines determined by the subjects existing anatomy. These can be refined by the use of growth increments sensitive to the subject's skeletal age.

Cephalometric applications allow the user to manipulate the position and inclination of skeletal and dental structures to create orthodontic and surgical treatment plans. Software "HANDLES" are available that allow the manipulation of the position and orientation of a specific structure.

The profile changes in an individual in response to manipulation can be visualized and algorithms exist

that can predict the patients soft tissue profile following such alterations. Soft tissue profile changes are a combination of a number of factors (growth + orthopedic changes + orthodontics).

Profile changes in an adult are relatively easier to evaluate especially if the only manipulation is surgical in nature. Hence it is easier to study the effect of surgery or orthodontic treatment in adults rather than growing individuals especially upon soft tissue profile.

Studies have shown that software predictive models to be at least as effective as manual prediction.

Advantages of using computers for cephalometry include:

1. Speed—1 min for digitization.
2. Luxury of exploring many treatment options simultaneously and weighing the results vs variables.
   a. Extraction vs non-extraction.
   b. Surgery vs pure orthodontic approach.
3. Can share the information with colleagues/referral sources.
4. Collaborate with the surgeon on treatment plan.
5. The laborious measurement of angles and distances by the manual use of a protractor is eliminated as measurements are made virtually instantaneously by the computer.
6. All the various cephalometric data can be converted to digital data and any number of analyzes can be performed.
7. Data bases can be created for various ethnic communities, gender/sex, even in private practices.
8. Speeds up the process of constructing a visual treatment objective (VTO).

VIDEO-CEPHALOMETRY

Prior to the advent of the present graphic capabilities of the computer video imaging technique, the profile that predicted the result of orthognathic surgery was communicated via profile tracings and verbal descriptions. Photo modification, as it was called, involved the sectioning of photographs using a pen-like device and the lines were then rearranged to provided visualization of treatment results.

PROFILE VIDEO IMAGE MODIFICATION

The evolution of relatively inexpensive and accessible computer technology has made it possible to incorporate graphics into the planning and communication phases of orthodontic treatment. Computer assisted "cut and paste" movements are used to modify the image in an effort to describe the anticipated profile or facial result from dental or surgical movements.

The need for video cephalometry stems from the fact that unlike for plastic surgery when just the soft tissue result of a particular procedure is required, in orthodontics a knowledge of the effect of the treatment upon the underlying skeletal and soft tissue structures too is essential. The composite results required, because of the manipulation of both the hard and soft tissues dictates the need for the superimposition of the cephalometric radiograph over the face.

QUANTIFIED PROFILE MODIFICATION THROUGH EXTRAPOLATION

As the development of imaging software progressed, an effort was made to quantify the movement's produced on a computer screen to allow for planning to correlate the required changes to the facial changes for correction of malocclusion.

The company 'Orthographic' was the first to introduce treatment visualization using video images. A video image was made and the software in the computer was capable of measuring the image in real life size.

A lead rod was stuck to the image and since the size of the marker was known, the computer software could then be calibrated to the size of the rod based on its size on the computer image.

PHOTO-CEPHALOMETRY

Photo cephalometry consisted of taking radiograph and photographs from a similar distance. The photograph negative could then be enlarged and accurately superimposed onto the photograph to visualize profile changes due to orthognathic surgical procedures.

TECHNIQUES OF IMAGE SUPERIMPOSITION UPON CEPHALOGRAM

There are four basic ways in which a cephalometric image can be superimposed over a video image of the patient. They are:

1. Digitization of the cephalogram then sizing the profile video image to the cephalogram.
2. Digitization followed by sizing of the cephalogram to an existing video image.
3. Gathering a video image of the cephalogram and matching it to an existing video image, with the cephalogram being digitized on screen.
4. Simultaneous cephalometric and video image gathering.

To achieve consistently matching profiles it is recommended that the video camera be exactly correlated to the cephalometric source. Yet, since this is not possible always, certain errors are bound to get incorporated in the process (Table 12.4). The two ways that are most frequently used for the correlation of the video and the cephalometric images are:

Direct Digitization

Two or more points digitized (on the cephalograms) and the distance between them is noted and these act as a reference for all other points on the video image.

Indirect Digitization

A grid is placed on the radiograph/image and the digitization in the computer is done on a preset grid that matches the grid on the image.

Table 12.4: Common clinical errors in video imaging

- If facial images and cephalograms are not taken simultaneously, it may result in significant differences in head position and image magnification discrepancies
- A minor alteration of either cephalogram or video image is at times required to obtain best fit between the alteration, this in turn raises questions regarding the validity of the video-cephalometric study
- Errors in head position during image capture might have a deleterious effect upon perception planning of profile.
- The video image and cephalometry both might show a different soft tissue position
- Differences exist in soft tissue response in differently gathered subjects and corrections might have to be built in the softwares used for such alterations
- Distortion of image might originate from the use of a particular camera
- Distortion could be due to distortion on the computer monitor (this can be avoided or at least minimized by using flat screen monitors)

DIGITAL PHOTOGRAPHY

Digital photography has revolutionized the way photographs are now taken and stored. The technology available to us now allows all but the most demanding of photographic application to be executed with consummate ease. Orthodontic photographic needs though essential, are basic and easily accomplished using digital cameras.

The procedure involved is practically the same as conventional photography, except that it stores images in digital form on a storage media. Also, it provides many advantages over conventional photography (Table 12.5). The most important being that it is simple to transfer and manipulate such data.

PIXELS AND RESOLUTION

800 × 600 and 1800 × 1600 pixels are believed to be adequate for orthodontic purpose.

INPUT DEVICES

The big difference between traditional film camera and digital camera is that unlike traditional cameras that capture the image on film, here there is a solid state device called an image sensor.

EXPOSURE

When shutter release is pressed a metering cell measures the amount of light coming through the lens and accordingly sets the aperture and shutter speeds for the correct exposure when the shutter opens briefly.

Each pixel on the image sensor records the brightness of the light that falls on it as an electrical

Table 12.5: Advantages of digital photography over conventional photography

- Versatility—incredibly easy to
  - Alter photographs
  - Store and distribute
  - E-mail
  - Post on website
- Less chance of poor shots due to the back screen
- Saves money in the long run
  - No rolls
  - Development
- Instant knowledge regarding the appearance of pictures
- Pictures can be identified before printing
- Eco-friendly
- No waiting for film to be processed
- Sound and video possible

charge. The more light that hits a pixel the higher the charge, i.e.

Lights from brightly lit areas→ high charges

Light from shadows → low charges

Pixels only capture brightness and not color! Colors are recorded on the image sensor as red, green or blue. Each pixel on the sensor has a filter so that it can record only that light that forms though the filter and other colors are blocked. Only that particular colors brightness can be evaluated. But when a color other than that of the 3 types of pixels is transmitted onto the sensor a process known as interpolation is used to calculate the third color.

By combining the color registered with the color directly, detected by the pixel the actual color can be arrived at. All these calculations are performed by a microprocessor.

Types of image sensors frequently used:

- Charged couple device (CCD).
- Complementary metal oxide semiconductor (CMOS).

Both these image sensors capture light on a grid of small pixels on their surfaces. How they process the image, is what differentiates them from each other.

A charge couple device (CCD) gets its name from the way the charges on its pixels are read after exposure. After exposure the charges are transferred on to a plane on the register called the read out register, then to an amplifier, and then onto an analog to digital converter. Once the row has been read out, and registered its charges on the read out row are deleted.

The charges on each row are compiled onto the one above so that when one moves down the one above can move down to the read out register.

Complementary metal oxide semiconductor (CMOS) is a technology used to make millions of chips for computer processors and memory. With CMOS the costs are greatly reduced. CMOS have processing circuits on the same unit. Here the only problem is the noise associated with pictures.

IMAGE RESOLUTION

The optical resolution of a camera or scanner is an absolute number because the image sensor pixels are photo elements, i.e. physical devices that can be counted.

Interpolated resolution is the enhancement of a picture by adding software pixels. This is not acceptable because it is just a make believe enhancement and a burden on the memory, yet it is frequently used to enhance photograph quality.

IMAGE STORAGE FORMAT

The size of an image file is huge when compared to other file formats. With increased resolution the requirement of memory also increases.

Image storage can be done in two forms depending upon their attachment to the digital cameras. The storage facility may be *removable* and *fixed*.

Older cameras have fixed storage, that limits the number of photos that can be taken. All the present day cameras have some form of removable storage enabling the photographer to take any number of photos as he wishes and is limited only by the amount of media he possesses.

Advantage of removable storage

i. Erasable and reusable
ii. Usually removable
iii. Easy transfer to computer.

Removable storage devices include

- Flash cards
- Smart media
- Floppy drive
- Micro drive

PHOTOGRAPHY SOFTWARE

i. Download software
ii. Photo-editing software
iii. Album software
iv. Photo-printing software

The softwares basically allow for the manipulation of the digital photographs for various purposes. They permit the required detail to get highlighted and depending upon the function required for the image can be stored or printed. They are extremely important for patient motivation as the pretreatment photographs can be modified to show approximate or expected post-treatment changes (Fig. 12.5).

THREE-DIMENSIONAL IMAGING

Orthodontics and dentofacial orthopedics deals primarily with physical relationships among the various parts of the human head. Even though we tend



Fig. 12.5: Post-treatment smile generated from the pre-treatment photograph

to visualize and plan treatment using two dimensional aids such a cephalograms and facial photographs the current paradigm shift in orthodontics and the keen interest in esthetics has resulted in an interest in three dimensional visualization and diagnosis to plan treatment for what is a three dimensional structure.

Except for a few structures of interest which lie in the midsagittal plane it is difficult to make accurate measurements using cephalograms. Conventional facial photos too lose depth information by projecting images of structures at different heights upon a single plane. Also the one true three dimensional representation of oral tissues, the dental cast must be integrated into facial images.

In the late 1970's computerized axial tomography initially referred to as CAT and later CT become available. CT measures X-ray attenuation coefficients as they spatially vary across a section of the anatomy. They are ideal for the visualization of hard osseous structures as these structures attenuate X-rays more than the surrounding soft tissues. Magnetic resonance imaging (MRI), which followed the development of the CT, recorded the density of mobile hydrogen nuclei in tissues. The concentration of mobile hydrogen nuclei is maximum in the soft tissues and hence MRIs provide excellent resolution and contrast between soft tissues.

Upon introduction it was heralded that the CT and the MRI would replace conventional radiography. However their use in conventional orthodontic treatment has been limited due to the following reasons:

1. The dose of ionizing radiation has been high.
2. Economic costs are prohibitive.
3. Slices of relatively thick tissue detail in vertically oriented teeth is quite poor.
4. Distortions are produced if CT scans are done with orthodontic appliances in place (Fig. 12.6A).

All 3-D imaging systems try to capture the Z-axis and this they achieve by counting the number of slices into which the images are divided. Calibration is particularly important when one tries to integrate 3-D images and the cephalogram. The problem with 3-D imaging of face is that the face inherently contains little detail and it is difficult to obtain a set of discrete points which can then be used to superimpose and to construct a useful map (Figs 12.6B and C). CT scans are most useful to exactly localize impacted or erupting



Fig. 12.6A: Distortion produced by beam reflecting off an orthodontic molar band



Fig. 12.6B: Tomogram generated following a CT scan

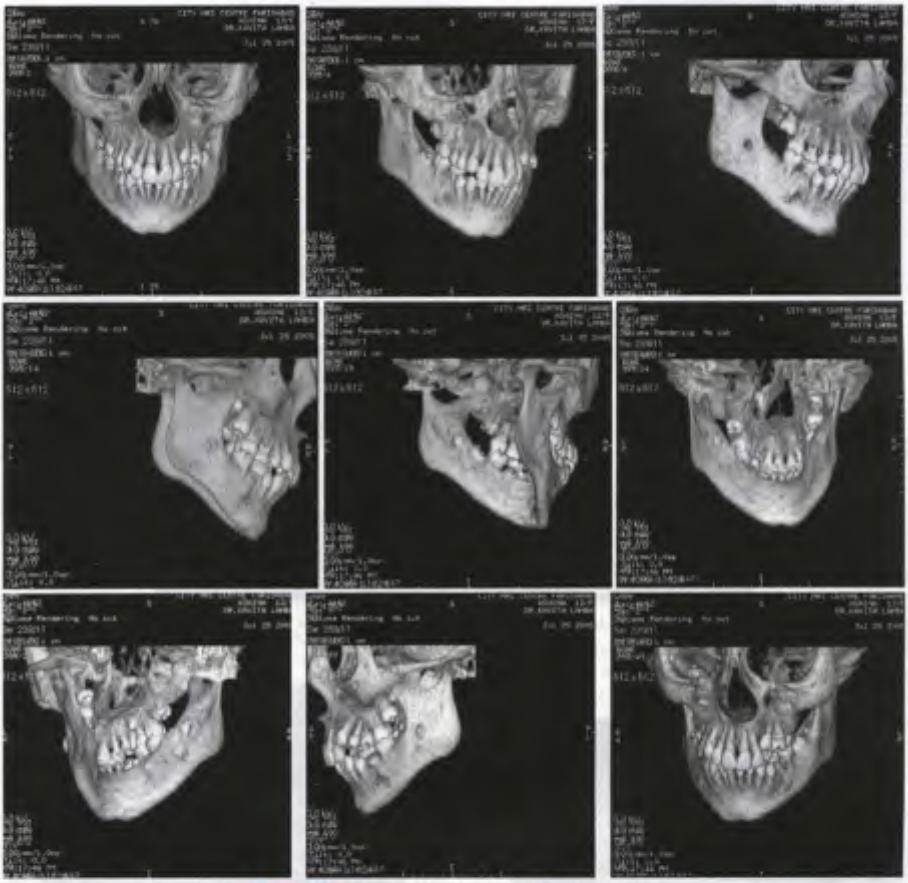


Fig. 12.6C: Series of 3D images created by a CT scan

teeth (Fig. 12.7) or study the placement of microimplants (used to provide anchorage) (Fig. 12.8).

A method of overcoming this is to project pseudo points onto the face. This is done by using laser ranging techniques. At each rotational step the laser projects a thin vertical line upon the face and ranges the distance to that line.

CRANIOFACIAL IMAGING AND ANIMATION WITH THE LASER SCANNER

This is a significant technology breakthrough in facial 3-D image reconstruction.

Vivid 700 was the first commercially viable laser scanner introduced by Minolta.

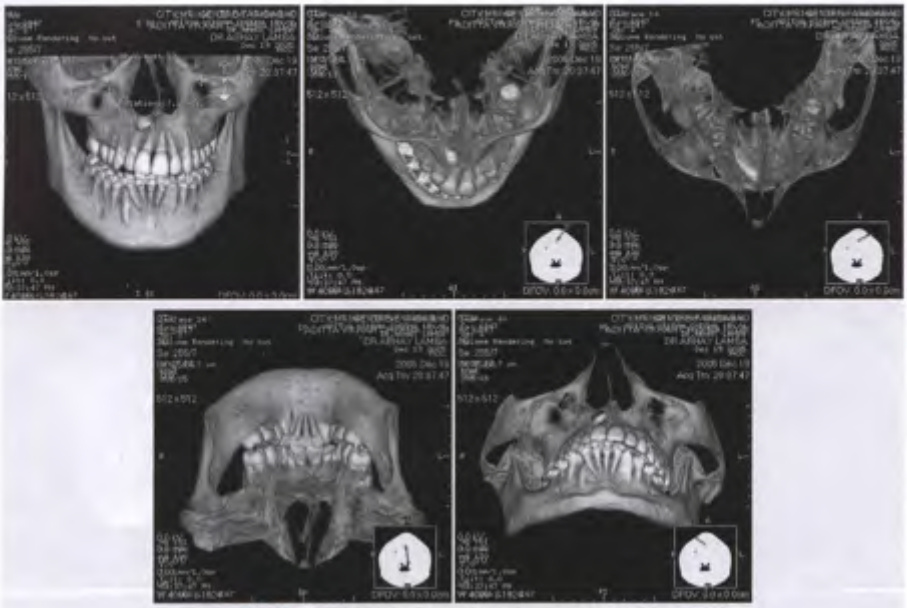


Fig. 12.7: Localization of an impacted canine using a CT scan



Fig. 12.8A: Micro anchorage implants as visible on a generated 3D image CT scan

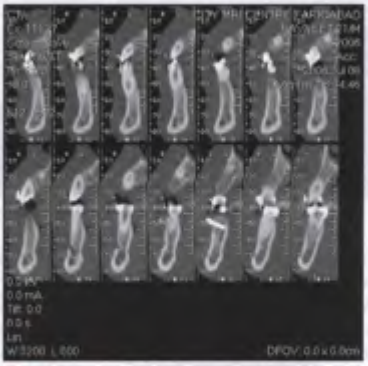


Fig. 12.8B: Cut section showing the micro anchorage implant

A Class II laser is used to scan the face. Facial photographs are taken using a CCD camera, that is present adjacent to the scanning outlet. A beam splitter facilitates the capture of the laser scan simultaneously with color texture map.

The skeletal images were generated using lateral and PA view cephalogram films. Using a technique for land mark identification in 3-D a skeletal structure is obtained.

Laser scanners record the distortion of lasers when passed over a face and infer their distortions to provide a surface map. Color/texture map is recorded simultaneously using a digital camera and this is superimposed over the surface map to obtain a composite image.

The problem with laser scanning is an inability to scan transparent, bright white and black objects. If the face is scanned when the patient is smiling the laser light is reflected and spikes are emitted. The problem caused by shadows can be overcome by using makeup. Safety concerns regarding the effect of lasers on the eyes exist.

METHODS OF 3-D CRANIOFACIAL SKELETAL IMAGING

Within the next one or 2 years the orthodontist will have available to them 3 or 4 methods to obtain 3-D radiographic images of patients, namely:

- Tomosynthesis
- Tuned aperture CT (TACT)
- Anatomic reconstructions
- Cone beam CT.

METHODS OF 3-D INTRAORAL DENTAL IMAGING

The technology of laser scanning and SL can be miniaturized to image the dentition. A system that incorporates SL has been introduced ORAMATRIX SURE SMILE-ORASCANNER.

A video camera records SL distortions on dental crowns as it passes over the dentition over a time period of approximately 1 minute.

A stream of images is fed back to a computer and proceeds are used to stitch together a complete dental arch.

METHODS OF CAPTURING MANDIBULAR MOTION IN 3-D

Three systems allow for the recording of mandibular movements in real time, recording and display of the 3-D movements in digital form.

- Hinge axis
- Condylar inclination
- Side shifts.

Ultrasound emitters are bonded to the labial surface of the lower arch using a jig customized with cold cure acrylic. These are of importance in the study of TMJ problems as well as functional shifts and centric relation and centric occlusion studies.

DIGITAL STUDY MODELS

Now computerized softwares are commercially available which are capable of scanning study models and storing the scanned data as 3-dimensional images. The scanned data is calibrated to the actual size of the study models. Hence, certain softwares are now capable of using these digital study models to do certain model analyses directly on the computer.

The biggest advantage of this system is to allow storage of invaluable information contained in these three-dimensional records, which would otherwise be lost on a moment's carelessness due to the plaster study model breaking. Also, certain model analysis results are now available at the click of a 'mouse'.

With the development of the computer and associated advancement in technology it is now possible to gain more information about the patient than ever before. It is in the hands of the clinician how he/she uses this information for the benefit of the patient.

FURTHER READING

1. Adams GL, Gansky SA, Miller AJ, et al. Comparison between traditional two-dimensional cephalometry and a three-dimensional approach Am J Orthod Dentofacial Orthop, 2002;122(1):117-20.
2. Carlson CA. Imaging modalities in X-ray computerized tomography and in selected volume tomography. Phy Med Biol 1989;44:R23-R55.
3. Cutting C, Grayson B, Bookstein FL, et al. Computer-aided planning and evaluation of facial Orthognathic surgery. Clin Plast Surg 1986;13:449-62.

4. Elefteriadis JN, Athanasiou AE. Evaluation of impacted canines by means of computerized tomography, Int J Adult Orthod Orthognath Surg 1996;11:257-64.
5. Grayson B, Bookstein F, Kim H, et al. The three-dimensional cephalogram: theory, technique and clinical applications, Am J Otrthod Dentofacial Orthop, 1988;94:327-37.
6. Harrell WE Jr, Hatcher DC, Bolt RL. In search of anatomical truth:3-dimentional modeling and the future of orthodontics, Am J Orthod Dentofacial Orthop, 2003;122(3):325-30.
7. Hutchinson I, et al. Digital cameras and orthodontics: An overview, Dent Update, 1999;26:144-9.
8. Jackson PH, Dickson GC, Birnie DJ. Digital imaging processing of cephalometric radiographs: a preliminary report, Br J Orthod 1985;12:122-32.
9. Kamazawa T, Hashiguchi K, Ishizaki R. Statistical Analysis by Quantification Theory using Personal Computer, Tokyo: Asakura, 1998:89-103.
10. Mah J, Danforth RA, Bumann A, et al. Radiation absorbed in maxillofacial imaging with a new dental computed tomography device, Oral Surg Oral Med Oral Pathol Oral Radiol Endol 2003;96(4):508-13.
11. Mason C, Papadakou P, Roberts GJ. The radiographic localization of impacted maxillary canines: A comparison of methods, Eur J Orthod 2001;23:25-34.
12. Mozzo P, et al. A new volumetric CT machinefor dental imaging based on the cone-beam technique: preliminary results, Eur radil 1998;8:1558-64.
13. Quintero JC, Trosien A, Hatcher D, et al. Craniofacial imaging in orthodontics: historical perspective, current status, and future developments. Angle Orthod 1999;69(6):491-506.

13 Classification of Malocclusion

Gurkeerat Singh

- Introduction
- Individual tooth malpositions
- Malrelation of dental arches
- Skeletal malocclusions
- Angle's classification of malocclusion
- Dewey's modification
- Lischer's modification
- Bennette's classification
- Simon's classification
- Skeletal classification
- Ackerman-Profitt system of classification
- Incisor classification

INTRODUCTION

To understand a group of identities it is advisable to divide them into groups and subgroups based on certain similarities. *Classification of malocclusion is the description of dentofacial deviations according to a common characteristic, or norm.* Various classifications are proposed by different researchers based on their experiences and depending upon what they found to be clinically relevant. The understanding of these classifications is essential for the student of orthodontics as they would be frequently referred to during communications between consultants and sometimes, certain identities within a subgroup will require the same treatment protocols.

Depending upon which part of the oral and maxillofacial unit is at fault, malocclusions can be broadly divided into three types-

- Individual tooth malpositions.
- Malrelation of the dental arches or dentoalveolar segments.
- Skeletal malrelationships.

These three can exist individually in a patient or in combination involving each other, depending upon where the fault lies—in the individual dental arch or the dentoalveolar segments or the underlying skeletal structure.

INDIVIDUAL TOOTH MALPOSITIONS

These are malpositions of individual teeth in respect to adjacent teeth within the same dental arch. Hence, they are also called intra-arch malocclusions.

These can be of the following types:

MESIAL INCLINATION OR TIPPING

The tooth is tilted mesially, i.e. the crown is mesial to the root (Fig. 13.1A).

DISTAL INCLINATION OR TIPPING

The tooth is tilted distally, i.e. the crown is distal to the root (Fig. 13.1B).



Fig. 13.1A: Mesially inclined/tipped central incisors. The long axis of the teeth is depicted in black, with the midline in white dots



Fig. 13.1B: Distally inclined maxillary right lateral incisor. The long axis is depicted in black, with the ideal inclination of the tooth depicted by white dots

LINGUAL INCLINATION OR TIPPING

The tooth is abnormally tilted towards the tongue (or the palate in the maxillary arch) (Fig. 13.1C).

LABIAL/BUCCAL INCLINATION OR TIPPING

The tooth is abnormally inclined towards the lips/cheeks (Fig.13.1D).



Fig. 13.1Ci: Palatally inclined maxillary left incisor



Fig. 13.1Cii: Lingually inclined mandibular second molars





Fig. 13.1D: Labially inclined maxillary right central incisor

INFRA-OCCLUSION

The tooth is below the occlusal plane as compared to other teeth in the arch (Fig. 13.1E).

SUPRAOCCLUSION

The tooth is above the occlusal plane as compared to other teeth in the arch (Fig. 13.1F).

ROTATIONS

This term refers to tooth movements around the long axis of the tooth. Rotations are of the following two types:

Mesiolingual or Distolabial

The mesial aspect of the tooth is inclined lingually or in other words, the distal aspect of the crown is labially placed as compared to its mesial aspect (Fig. 13.1G)

Distolingual or Mesiolabial

The distal aspect of the tooth is inclined lingually or in other words, the mesial aspect of the crown is labially placed as compared to its distal aspect (Fig. 13.1H)



Fig. 13.1E: Right mandibular Ist premolar in infra-occlusion



Fig. 13.1F I: Supraerupted maxillary anteriors



Fig. 13.1F II: Maxillary central and mandibular incisors are supraerupted



Fig. 13.1G: Maxillary central incisors are rotated mesio-palatally



Fig. 13.1H: Maxillary left central incisor is rotated mesio-buccally



Fig. 13.1 I: Transposition of the mandibular right canine with the mandibular right lateral incisor

Transposition

This term is used in case where two teeth exchange places, e.g. a canine in place of the lateral incisor (Fig. 13.1I).

MALRELATION OF DENTAL ARCHES

These malocclusions are characterized by an abnormal relationship between teeth or groups of teeth of one

dental arch to that of the other arch. These inter-arch malrelations can occur in all the three planes of space, namely—sagittal, vertical or transverse.

SAGITTAL PLANE MALOCCLUSIONS

They can be of two types:

Pre-normal Occlusion

Where the mandibular dental arch is placed more anteriorly when the teeth meet in centric occlusion (Fig. 13.2A).

Post-normal Occlusion

Where the mandibular dental arch is placed more posteriorly when the teeth meet in centric occlusion (Fig. 13.2B).

VERTICAL PLANE MALOCCLUSIONS

They can be of two types depending on the vertical overlap of the teeth between the two jaws.

Deep Bite

Here the vertical overlap between the maxillary and mandibular teeth is in excess of the normal (Fig. 13.3A).

Open Bite

Here there is no overlap or a gap exists between the maxillary and mandibular teeth when the patient bites in centric occlusion. An open bite can exist in the anterior (Fig. 13.3B) or the posterior (Fig. 13.3C) region.



Fig. 13.2A: The mandible is placed more anteriorly as compared to normal



Fig. 13.2B: The mandibular arch is located more posteriorly as compared to normal



Fig. 13.3A: Anterior deep bite



Fig. 13.3B: Anterior open bite



Fig. 13.3C: Posterior open bite due to the presence of a lateral tongue thrust habit





Figs 13.4A i and ii: The posterior segment is in cross bite



Fig. 13.4B: Single maxillary lateral incisor in cross bite

TRANSVERSE PLANE MALOCCLUSIONS

These include the various types of cross bites. Generally the maxillary teeth are placed labial/buccal to the mandibular teeth. But sometimes due to the constriction of the dental arches or some other reason this relationship is disturbed, i.e. one or more maxillary teeth are placed palatal/lingual to the mandibular teeth (Figs 13.4A and B). These differ in intensity, position and the number of teeth that may be involved.

SKELETAL MALOCCLUSIONS

These malocclusions are caused due to the defect in the underlying skeletal structure itself. The defect can be in size, position or relationship between the jaw bones.

ANGLE'S CLASSIFICATION OF MALOCCLUSION

In 1899, Edward Angle classified malocclusion based on the mesial-distal relation of the teeth, dental arches and jaws. He considered the maxillary first permanent molar as a fixed anatomical point in the jaws and the key to occlusion. He based his classification on the relationship of this tooth to other teeth in the mandibular jaw. More than 100 years have passed since Angle proposed his system of classification yet, it remains the most frequently used classification system. It is simple, easy to use and conveys precisely what it was conceived for, i.e. the relationship of the mandibular teeth with respect to the maxillary first permanent molar.

Angle classified malocclusion into three broad categories. It is presented in a form that is most accepted in the present times.

The three categories are designated as "Classes" and are represented by Roman numerals—I, II and III.

CLASS I—MALOCCLUSION (Fig. 13.5)

The mandibular dental arch is in normal mesiodistal relation to the maxillary arch, with the mesiobuccal cusp of the maxillary first molar occluding in the buccal groove of the mandibular first permanent molar and the mesiolingual cusp of the maxillary first permanent molar occludes with the occlusal fossa of the mandibular first permanent molar when the jaws are at rest and the teeth approximated in centric occlusion.

CLASS II—MALOCCLUSION

Mandibular dental arch and body are in distal relation to the maxillary arch. The mesiobuccal cusp of the maxillary first permanent molar occludes in the space between the mesiobuccal cusp of the mandibular first permanent molar and the distal aspect of the mandibular second pre-molar. Also, the mesiolingual cusp of the maxillary first permanent molar occludes mesial to the mesio-lingual cusp of the mandibular first permanent molar.

Angle divided the Class-II malocclusions into two divisions based on the labiolingual angulation of the maxillary incisors as:

Class II—Division 1 (Fig. 13.6)

Along with the molar relation which is typical of class II malocclusions the maxillary incisor teeth are in labioversion.

Class II—Division 2 (Fig. 13.7)

Along with the typical Class II molar relationship, the maxillary incisors are near normal anteroposteriorly or slightly in linguoversion whereas the maxillary lateral incisors are tipped labially and/or mesially.

Class II—Subdivision (Fig. 13.8)

When the Class II molar relationship occurs on one side of the dental arch only, the malocclusion is referred to as a subdivision of its division.



Fig. 13.5: Angle's Class I malocclusion



Fig. 13.6: Angle' Class II division 1



Fig. 13.7: Angle's Class II division 2



Fig. 13.8: Angle's Class II subdivision (Class I molars on the left side)



Fig. 13.9: Angle's Class III malocclusion



Fig. 13.10: Pseudo Class III malocclusion

CLASS III—MALOCCLUSION (Fig. 13.9)

The mandibular dental arch and body is in mesial relationship to the maxillary arch; with the mesiobuccal cusp of the maxillary first molar occluding in the interdental space between the distal aspect of the distal cusps of the mandibular first molar and the mesial aspect of the mesial cusps of the mandibular second molar.

Pseudo Class III—Malocclusion (Fig. 13.10)

This is not a true Class III malocclusion but the presentation is similar. Here the mandible shifts anteriorly in the glenoid fossa due to a premature contact of the teeth or some other reason when the jaws are brought together in centric occlusion.

Class III—Subdivision

It is said to exist when the malocclusion exists unilaterally.

Angle's classification was the first comprehensive classification of malocclusion. It is still the most widely accepted classification and is used routinely for day to day communication between clinicians. With its simplicity, it also had its inherent drawbacks (Table 13.1).

DEWEY'S MODIFICATION OF ANGLE'S CLASSIFICATION OF MALOCCLUSION

Dewey in 1915 modified Angle's Class I and Class III by segregating malpositions of anterior and posterior segments as:

MODIFICATIONS OF ANGLES CLASS I

Type 1

Angles Class I with crowded maxillary anterior teeth (Fig. 13.11).

Type 2

Angles Class I with maxillary incisors in labio-version (proclined) (Fig. 13.12).

Type 3

Angle's Class I with maxillary incisor teeth in linguoversion to mandibular incisor teeth (anteriors in cross bite) (Fig. 13.13).



Fig. 13.11: Angle's Class I molars with anterior crowding or Dewey's Class I Type 1



Fig. 13.12: Angle's Class I with anteriors proclined or Dewey's Class I Type 2



Fig. 13.13: Dewey's Class I Type 3 malocclusion, molars in Angle's Class I with maxillary anteriors in cross bite



Fig. 13.14: Dewey's Class I Type 4 malocclusion, Angle's Class I with posterior cross bite

Table 13.1: Drawback of Angle's classification

1. Angle presumed the first permanent molars as fixed points within the jaws, which definitely is not so
2. Angle depended exclusively on the first molars. Hence, the classification is not possible if the first molars are missing or if applied in the deciduous dentition
3. Malocclusions are considered only in the anteroposterior plane. Malocclusion in the transverse and vertical planes are not considered
4. Individual tooth malocclusions have not been considered
5. There is no differentiation between skeletal and dental malocclusions
6. Etiology of the malocclusions has not been elaborated upon

Type 4

Molars and/or premolars are in bucco or linguoversion, but incisors and canines are in normal alignment (posteriors in cross bite) (Fig. 13.14).

Type 5

Molars are in mesio-version due to early loss of teeth mesial to them (early loss of deciduous molars or second premolar) (Fig. 13.15).

DEWEY'S MODIFICATION OF ANGLE'S CLASS III

Type 1

Individual arches when viewed individually are in normal alignment, but when in occlusion the anteriors are in edge to edge bite (Fig. 13.16).



Fig. 13.15: Dewey's Class I Type 5, permanent molar has drifted mesially due to the early loss of the deciduous 2nd molar



Fig. 13.16: Dewey's Class III Type 1, individual arches when viewed individually are in normal alignment, but when in occlusion the anteriors are in edge to edge bite



Fig. 13.17: Dewey's Class III Type 2, molars in Angle's Class III with mandibular retroclined and/or crowded with maxillary anteriors in labio-version

Type 2

The mandibular incisors are crowded and lingual to the maxillary incisors (Fig. 13.17).

Type 3

Maxillary arch is underdeveloped, in cross bite with maxillary incisors crowded and the mandibular arch is well developed and well aligned (Fig. 13.18).



Fig. 13.18: Dewey's Class III Type 3, maxillary arch is underdeveloped, in cross bite with maxillary incisors crowded and the mandibular arch is well developed and well aligned

LISCHER'S MODIFICATION OF THE ANGLE'S CLASSIFICATION OF MALOCCLUSION

Lischer in 1933 further modified Angle's classification by giving substitute names for Angle's Class I, II and

III malocclusions. He also proposed terms to designate individual tooth malocclusions.

NEUTRO-OCCLUSION

Neutro-occlusion is the term synonymous the Angle's Class I malocclusion.

DISTO-OCCLUSION

Disto-occlusion is synonymous with Angle's Class II malocclusion.

MESIO-OCCLUSION

Mesio-occlusion is synonymous with Angle's Class III malocclusion.

Lischer's nomenclature for individual tooth malpositions involved adding the suffix "version" to a word to indicate the deviation from the normal position.

1. Mesioversion—mesial to the normal position (Fig. 13.19A)
2. Distoversion—distal to the normal position (Fig. 13.19B)
3. Linguoversion—lingual to the normal position (Fig. 13.19C)
4. Labioversion—labial to the normal position (Fig. 13.19D)
5. Infraversion—inferior or away from the line of occlusion (Fig. 13.1E)
6. Supraversion—superior or extended past the line of occlusion (Fig. 13.1F)
7. Axiversion—the axial inclination is wrong; tipped (Fig. 13.19E).
8. Torsiversion—rotated on its long axis (Figs 13.1G, H and Figs 13.19B and F).
9. Transversion—transposed or changes in the sequence of position (Fig. 13.1I).

BENNETTE'S CLASSIFICATION OF MALOCCLUSION

Bennette classified malocclusions based on their etiology as:

CLASS I

Abnormal location of one or more teeth is due to local factors.



Fig. 13.19A: Right mandibular 1st molar is in mesioversion



Fig. 13.19B: The right lateral incisor and canine are in distoversion (black arrow), and the right 1st premolar is rotated mesio-buccally, i.e. in torsiversion



Fig. 13.19C: Maxillary left 2nd premolar is in linguoclusion



Fig. 13.19D: The maxillary canine and the mandibular 1st premolar are in bucco-occlusion



Fig. 13.19E: The mandibular 2nd molar shows an abnormal axial inclination-axiversion (the dotted white line depicts the present axial inclination where as the black line the ideal axial inclination)



Fig. 13.19F: Mesiopalatal or disto-buccal rotation of the maxillary 2nd premolar

CLASS II

Abnormal formation of a part or a whole of either arch due to developmental defects of bone.

CLASS III

Abnormal relationship between the upper and lower arches and between either arch and the facial contour, due to developmental defects of bone.

SIMON'S CLASSIFICATION OF MALOCCLUSION

Simon in 1930 was the first to relate the dental arches to the face and cranium in the three planes of space, i.e.

- Frankfort horizontal (vertically)
- Orbital plane (anteroposteriorly)
- Raphe or median sagittal plane (transverse).

FRANKFORT HORIZONTAL (VERTICALLY)

Frankfort horizontal plane (F-H Plane) or the eye-ear plane (E-EP) (Fig. 13.20) is determined by drawing a straight line through the margins of the bony orbit directly under the pupil of the eye to the upper margins of the external auditory meatus (the notch above the tragus of the ear).

This plane is used to classify malocclusions in the vertical plane. Vertical deviations with respect to the plane are:

1. *Attractions* When the dental arch or part of it is closer to the Frankfort horizontal plane it is referred to as attraction.
2. *Abstractions* When a dental arch or a part of it is further away from the Frankfort horizontal plane, it is referred to as abstraction.

ORBITAL PLANE (ANTERO-POSTERIORLY)

This plane is perpendicular to the eye-ear plane (Frankfort horizontal plane) at the margin of the bony orbit directly under the pupil of the eye (Fig. 13.21).

Here it is pertinent to mention the law of the canine. According to Simon in normal arch relationship, the orbital plane passes through the distal axial aspect of the maxillary canine.

Malocclusions described as anterior-posterior deviations based on their distance from the orbital plane are-

1. *Protraction* The teeth, one or both, dental arches, and/or jaws are too far forward, i.e. placed forward



Fig. 13.20: Frankfort horizontal plane



Fig. 13.21: Orbital plane

or anterior to the plane as compared to the normal; where the plane passes through the distal incline of the canine.

2. *Retraction* The teeth one or both dental arches and/or jaws are too far backward, i.e. placed posterior to the plane than normal.

RAPHE OR MEDIAN SAGITTAL PLANE (TRANSVERSE)

The raphe or median sagittal plane is determined by points approximately 1.5 cm apart on the median raphe of the palate. The raphe median plane passes through these two points at right angles to the Frankfort horizontal plane (Fig. 13.22).



Fig. 13.22: Mid-sagittal plane

Malocclusions classified according to transverse deviations from the median sagittal plane are:

1. *Contraction* A part or all of the dental arch is contracted towards the median sagittal plane.
2. *Distraction* A part or all of the dental arch is wider or placed at a distance which is more than normal.

SKELETAL CLASSIFICATION

Salzmann is 1950 was the first to classify on olcclusion based on the underlying skeletal structures.

SKELETAL CLASS I

These malocclusions were purely dental with the bones of the face and jaws being in harmony with one another and with the rest of the head. The profile is orthognathic (Fig. 13.23A).

The skeletal Class I was divided further according the dental malocclusion present as:

Division 1

Local mal-relations of incisors, canine and premolars (Fig. 13.23B).

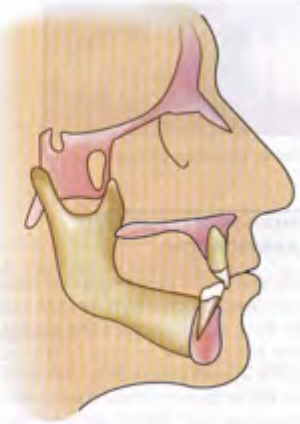


Fig. 13.23A: Skeletal pattern I

Division 2

Maxillary incisor protrusion (Fig. 13.23C).

Division 3

Maxillary incisors in linguoversion (Fig. 13. 23D).

Division 4

Bimaxillary protrusion (Fig. 13.23E).

SKELETAL CLASS II

These included malocclusion with a subnormal distal mandibular development in relation to the maxilla (Fig. 13.24).

The skeletal Class 2 was further divided into two divisions based on the features commonly seen with a mandible placed in retruded position.



Fig. 13.23B: Skeletal Class I division 1; local malrelations of incisors, canine and premolars



Fig. 13.23C: Skeletal Class I division 2; maxillary incisor protrusion



Fig. 13.23D: Skeletal Class I division 3; maxillary anteriors in linguo-version



Fig. 13.23E: Skeletal Class I division 4 malocclusion, bimaxillary protrusion

Division 1

The maxillary dental arch is narrower with crowding in the canine region, cross bite may be present and the vertical face height is decreased. The maxillary anterior teeth are protruded and the profile is retrognathic.

Division 2

The maxillary incisors are lingually inclined, the lateral incisors may be normal or in labio-version.

SKELETAL CLASS III

Here there is an over growth of the mandible with an obtuse mandibular plane angle. The profile is prognathic at the mandible (Fig. 13.25).

ACKERMAN-PROFITT SYSTEM OF CLASSIFICATION

Ackerman and Profitt proposed a very comprehensive system of classification which divided malocclusions in all the three planes of space and tended to give an indication towards the severity of the malocclusion present. The system proposed by Ackerman-Profitt is based on the set theory, where a set is defined on the basis of morphologic deviations from the ideal. The classification was illustrated using the Venn symbolic logic diagram (Fig.13.26A). The classification considered five characteristics, and their inter-relationships were assessed. The five characteristics are as follows.

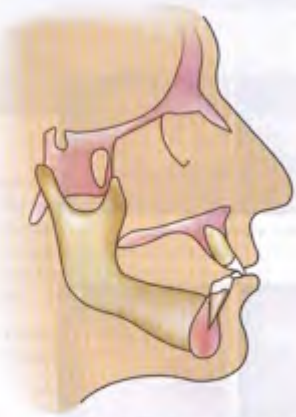


Fig. 13.24: Skeletal pattern II

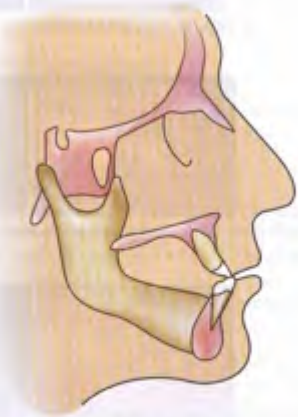


Fig. 13.25: Skeletal pattern III

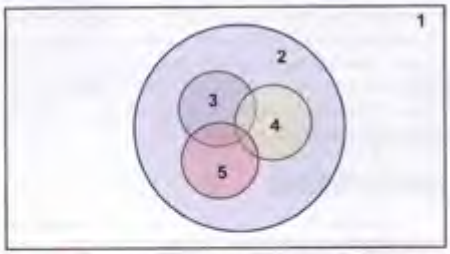


Fig. 13.26A: Venn diagram representing the 5 characters

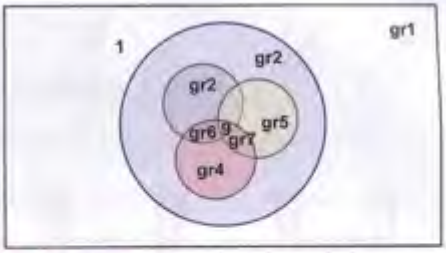


Fig. 13.26B: The 9 groups formed using the Venn diagram model

CHARACTERISTIC 1—ALIGNMENT

Intra arch alignment and symmetry are assessed as when seen in the occlusal view. A dental arch is classified as ideal/crowded/spaced.

CHARACTERISTIC 2—PROFILE

The profile can be convex/straight/concave. This also includes the assessment of facial divergence, i.e. anterior or posterior divergence.

CHARACTERISTIC 3—TRANSVERSE RELATIONSHIPS

These include the transverse skeletal and dental relationships. Buccal and palatal cross bites are noted. These are further subclassified as unilateral or bilateral. Distinction is made between skeletal and dental cross bites.

CHARACTERISTIC 4—CLASS

Here the sagittal relationship of the teeth is assessed using the Angle classification as Class I/Class II/Class III. A distinction is made between skeletal and dental malocclusions.

CHARACTERISTIC 5—OVERBITE

Malocclusions are assessed in the vertical plane. They are described as anterior open bite/posterior open bite/anterior deep bite/posterior collapsed bite. Here again a distinction is made as to whether the malocclusion is skeletal or dental.

The first characteristic is represented as a square which contains a larger circle representing the profile or characteristic 2. This contains three smaller circles overlapping each other partially, representing the transverse, sagittal and vertical deviations respectively. The confluence of these sets form nine groups, each a combination of certain characteristics. The ninth group represents the most complex malocclusion with all possible features.

INCISOR CLASSIFICATION

The incisor classification is considered simpler and more relevant than Angle's classification. It was adopted by the British Standards' Institute in 1983, and is based upon the relationship of the lower incisor edges and the cingulum plateau of the maxillary central incisors.

CLASS I

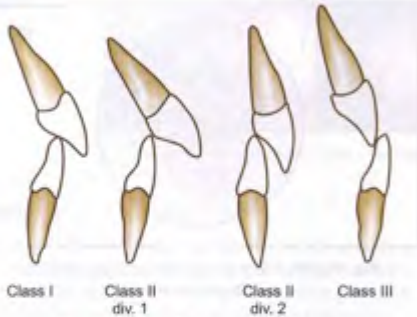
The mandibular incisor edges occlude with or lie immediately below the cingulum plateau of the maxillary central incisors (Fig.13.27A).

CLASS II

The mandibular incisor edges lie posterior to the cingulum plateau of the maxillary central incisors.

Division 1

The maxillary central incisors are proclined or of average inclination and there is an increased overjet (Fig. 13.27B).



Figs 13.27A to D: Incisor classification

Division 2

The maxillary central incisors are retro-clined; the overjet is normally minimum, but may be increased (Fig. 13.27C).

CLASS III

The mandibular incisor edges lie anterior to the cingulum plateau of the upper central incisors; the overjet is reduced or reversed (Fig. 13.27D).

All the relevant classifications have been discussed. The Ackerman and Profitt classification conveys the maximum information regarding the characteristics of a malocclusion, yet it is not frequently used. The incisor classification is the simplest to use, yet not the most frequently used. Angle's classifications with all its shortcomings, is still by far the most commonly used classification of malocclusion.

FURTHER READING

1. Ackerman JL, Proffit WR. The characteristics of malocclusion: a modern approach to classification and diagnosis. Am J Orthod, 1969;56:443-54.
2. Angle EH. Classification of malocclusion. Dental Cosmos, 1899;41:248-64.
3. Angle EH. Malocclusion of the Teeth. 7th ed. Philadelphia, SS White dental Mfg Co., 1907.
4. British Standards Institute. Glossary of Dental terms (BS 4492). London: BSI, 1983.
5. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
6. Hellman M. Variations in occlusion. Dent Cosmos 1921;63:608-18.
7. Lischer BE. Principles and Methods of Orthodontics. Philadelphia, Lea and Febiger, 1912.
8. Moyers RE. Handbook of Orthodontics, ed. 3, Chicago, 1973, Year Book.
9. Salzmann JA. Practice of Orthodontics, J B Lippincott Company, 1996.
10. Simon P. Grundzge einer systematischen diagnostic der Gebiss-Anomalien. Berlin, Meusser, 1922.
11. White TC, Gardiner JH, Leighton BC. Orthodontics for Dental Students, 3rd ed., Macmillan Press Ltd, 1976.

14 Etiology of Malocclusion—Classifications

Gurkeerat Singh

- Introduction
- White and Gardiner's classification
- Salzmann's classification
- Moyer's classification
- Graber's classification

INTRODUCTION

WHAT CAUSES A MALOCCLUSION?

This question has to be answered correctly before any decision can be taken regarding its prevention or correction. Researches have grouped the common etiologic factors associated with malocclusions and presented various classifications. These classifications help us in understanding the etiology of a malocclusion. These will help the clinician in identifying situations which they can either prevent or intervene, thus avoiding the severity of the malocclusion from expressing itself.

The various classifications proposed are:

- White and Gardiner's classification
- Salzmann's classification
- Moyer's classification
- Graber's classification.

WHITE AND GARDINER'S CLASSIFICATION

This was one of the first attempts to classify malocclusion. It tried to make a distinction between the skeletal and dental etiologic factors. It also tried to distinguish between pre-eruptive and post-eruptive causes.

DENTAL BASE ABNORMALITIES

1. Antero-posterior malrelationship
2. Vertical malrelationship
3. Lateral malrelationship
4. Disproportion of size between teeth and basal bone
5. Congenital abnormalities.

PRE-ERUPTION ABNORMALITIES

1. Abnormalities in position of developing tooth germ
2. Missing teeth
3. Supernumerary teeth and teeth abnormal in form
4. Prolonged retention of deciduous teeth
5. Large labial frenum
6. Traumatic injury.

POST-ERUPTION ABNORMALITIES

1. Muscular
   a. Active muscle force
   b. Rest position of musculature
   c. Sucking habits
   d. Abnormalities in path of closure
2. Premature loss of deciduous teeth
3. Extraction of permanent teeth.

SALZMANN'S CLASSIFICATION

Salzmann defined three definite stages in which malocclusions are likely to manifest:

1. The genotypic
2. The fetal environment
3. The postnatal environment.

Since different factors effect these different stages hence, the division of the etiologic factors into prenatal, postnatal, functional and environmental or acquired.

PRENATAL

1. Genetic—included malocclusions transmitted by genes, where the dentofacial anomalies may or may not be in evidence at birth.
2. Differentiative—malocclusions that are inborn, engrafted in the body in the prefunctional embryonic developmental stage. Can be subdivided into:
   a. General—effect the body as a whole
   b. Local—effect the face, jaws and teeth only.
3. Congenital—can be hereditary or acquired but existing at birth. Can be subdivided as:
   a. General or constitutional
   b. Local or dentofacial.

POSTNATAL

Developmental

A. **General**
   a. Birth injuries
   b. Abnormalities of relative rate of growth in different body organs
   c. Hypo- or hypertonicity of muscles which may eventually affect the dentofacial development and function
   d. Endocrine disturbances which may modify the growth pattern and eventually affect dentofacial growth
   e. Nutritional disturbances
   f. Childhood diseases that affect the growth pattern
   g. Radiation.

B. **Local**
   a. Abnormalities of the dentofacial complex:
      1. Birth injuries of the head, face and jaws
      2. Micro- or macrognathia
      3. Micro- or macroglossia
      4. Abnormal frenal attachments
      5. Facial hemiatrophy.
   b. Abnormalities of tooth development:
      1. Delayed or premature eruption of the deciduous or permanent teeth
      2. Delayed or premature shedding of deciduous teeth
      3. Ectopic eruption
      4. Impacted teeth
      5. Aplasia of teeth.

FUNCTIONAL

A. **General**
   1. Muscular hyper- or hypotonicity
   2. Endocrine disturbances
   3. Neurotrophic disturbances
   4. Nutritional deficiencies
   5. Postural defects
   6. Respiratory disturbances (mouth breathing).

B. **Local**
   1. Malfunction of forces exerted by the inclined planes of the cusps of the teeth
   2. Loss of forces caused by failure of proximal contact between teeth
   3. Temporomandibular articulation disturbances.
   4. Masticatory and facial muscular hypo- or hyperactivity
   5. Faulty masticatory functions, especially during the tooth eruption period
   6. Trauma from occlusion
   7. Compromised periodontal condition.

ENVIRONMENTAL OR ACQUIRED

A. **General**
   1. Disease can affect the dentofacial tissues directly or by affecting other parts of the body indirectly disturb the teeth and jaws
   2. Nutritional disturbances especially during the tooth formation stage
   3. Acquired endocrine disturbances that are not present at birth
   4. Metabolic disturbances
   5. Trauma, accidental injuries
   6. Radiation.
   7. Tumors.
   8. Surgical pathologies.

B. **Local**
   1. Disturbed forces of occlusion
   2. Early loss of deciduous teeth
   3. Prolonged retention of deciduous teeth
   4. Delayed eruption of permanent teeth
   5. Loss of permanent teeth
   6. Periodontal diseases
   7. Temporomandibular articulation disturbances
   8. Infections of the oral cavity
   9. Pressure habits
   10. Traumatic injuries including fractures of the jaw bones.

MOYER'S CLASSIFICATION

Moyer identified etiologic sites, from where the variations were expected to arise. These sites included: a) the craniofacial skeleton, b) the dentition, c) the orofacial musculature, and d) other 'soft tissues' of the masticatory system. He based his classification on the premise that various factors may contribute to cause variations at these sites, more often in groups rather than individually.

1. Heredity
2. Developmental defects of unknown origin
3. Trauma:
   a. Prenatal trauma and birth injuries
   b. Postnatal trauma
4. Physical agents:
   a. Premature extraction of primary teeth
   b. Nature of food
5. Habits:
   a. Thumb sucking and finger sucking
   b. Tongue thrusting
   c. Lip sucking and lip biting
   d. Posture
   e. Nail biting
   f. Other habits
6. Diseases:
   a. Systemic diseases
   b. Endocrine disorders
   c. Local diseases:
      - Nasopharyngeal diseases and disturbed respiratory function
      - Gingival and periodontal disease
      - Tumors
      - Caries:
        — Premature loss of deciduous teeth
        — Disturbances in sequence of eruption of permanent teeth
        — Early loss of permanent teeth
7. Malnutrition.

GRABER'S CLASSIFICATION

Graber divided the etiologic factors as general or local factors and presented a very comprehensive classification. This helped in clubbing together of factors which make it easier to understand and associate a malocclusion with the etiologic factors.

GENERAL FACTORS

1. Heredity
2. Congenital
3. Environment:
   a. Prenatal (trauma, maternal diet, German measles, material maternal metabolism, etc).
   b. Postnatal (birth injury, cerebral palsy, TMJ injury)
4. Predisposing metabolic climate and disease:
   a. Endocrine imbalance
   b. Metabolic disturbances
   c. Infectious diseases (poliomyelitis, etc).
5. Dietary problems (nutritional deficiency)
6. Abnormal pressure habits and functional aberrations:
   a. Abnormal sucking
   b. Thumb and finger sucking
   c. Tongue thrust and tongue sucking
   d. Lip and nail biting
   e. Abnormal swallowing habits (improper deglutition)
   f. Speech defects
   g. Respiratory abnormalities (mouth breathing, etc.)
   h. Tonsils and adenoids
   i. Psychogenetics and bruxism
7. Posture
8. Trauma and accidents.

LOCAL FACTORS

1. Anomalies of number:
   a. Supernumerary teeth
   b. Missing teeth (congenital absence or loss due to accidents, caries, etc.).
2. Anomalies of tooth size
3. Anomalies of tooth shape
4. Abnormal labial frenum: mucosal barriers
5. Premature loss
6. Prolonged retention
7. Delayed eruption of permanent teeth
8. Abnormal eruptive path
9. Ankylosis
10. Dental caries
11. Improper dental restorations.

These factors shall be discussed individually in detail and an attempt will be made to understand how each one may cause a malocclusion. An endeavour will also be made to make the student of orthodontics aware as to when and how to intervene when an etiologic factor has been identified.

FURTHER READING

1. Graber TM. Orthodontics: Principles and Practice, ed. 3, WB Saunders, 1988.
2. Moyers RE. Handbook of Orthodontics, ed. 3, Chicago, 1973, Year Book.
3. Salzmann JA. Practice of Orthodontics, J B Lippincott Company, 1996.
4. White TC, Gardiner JH, Leighton BC. Orthodontics for Dental Students, 3rd edn., Macmillan Press Ltd, 1976.
5. White TC, Gardiner JH, Leighton BC, Valiathan A. Orthodontics for Dental Students, 4th ed., Oxford University Press, Delhi, 1998.

15 Etiology of Malocclusion—General Factors

Gurkeerat Singh

- Introduction
- Hereditary
- Congenital factors
- Predisposing metabolic climate and disease
  - Endocrine imbalance
  - Metabolic disturbances
  - Infectious diseases
- Dietary problems (nutritional deficiency)
- Abnormal pressure habits and functional aberrations
- Posture
- Trauma and accidents

INTRODUCTION

Graber divided the etiologic factors as general or local factors and presented a very comprehensive classification (Table 15.1). This helped in clubbing together of factors which made it easier to understand and associate a malocclusion with the etiologic factor.

This classification is one of the most detailed and comprehensive. For the purpose of simplification the sections of environmental factors and diseases have

Table 15.1: Graber's classification of malocclusion

General factors	*Local factors*
1. Heredity	1. Anomalies of number:
2. Congenital	• Supernumerary teeth
3. Environment	• Missing teeth (congenital absence or loss due to accidents, caries, etc.)
a. Prenatal (trauma, maternal diet, German measles, maternal metabolism, etc.).	2. Anomalies of tooth size
b. Postnatal (birth injury, cerebral palsy, TMJ injury)	3. Anomalies of tooth shape
4. Predisposing metabolic climate and disease	4. Abnormal labial frenum: mucosal barriers
a. Endocrine imbalance	5. Premature loss
b. Metabolic disturbances	6. Prolonged retention
c. Infectious diseases	7. Delayed eruption of permanent teeth
5. Dietary problems (nutritional deficiency)	8. Abnormal eruptive path
6. Abnormal pressure habits and functional aberrations:	9. Ankylosis
a. Abnormal sucking	10. Dental caries
b. Thumb and finger sucking	11. Improper dental restorations
c. Tongue thrust and tongue sucking	
d. Lip and nail biting	
e. Abnormal swallowing habits (improper deglutition)	
f. Speech defects	
g. Respiratory abnormalities (mouth breathing, etc.)	
h. Tonsils and adenoids	
i. Psychogenetics and bruxism	
7. Posture	
8. Trauma and accidents	

been clubbed together in the following discussion. Also, the section on malocclusion caused due to trauma has been subdivided into prenatal, at birth and postnatal.

HEREDITARY

Hereditary causes of malocclusion include all factors that result in a malocclusion and are inherited from the parents by the offspring. These may or may not be evident at birth, but are likely to express themselves as the child grows. These can be those influencing the

- Neuromuscular system
- Dentition
- Skeletal structures
- Soft tissues (other than the neuromusculature).

NEUROMUSCULAR SYSTEM

The anomalies that have been found to possess some inherited component include deformities in size, position, tonicity, contractility, and in the neuromuscular coordination pattern of facial, oral, and tongue musculature.

It is not possible to differentiate between the origins of certain habits. Certain tongue and lip habits can be learned because of imitation, by watching parents and other siblings of the soft tissue configuration, which may be inherited or may predispose to the same. Certain malocclusions may be associated with tongue size or lip length and tonicity and these may be found to reoccur within a family over generations and may be inherited.

DENTITION

Certain characteristics, especially related to the dentition are definitely inherited. These include:

Size and Shape of the Teeth

Studies on twins have proved that the size and relative shape of the teeth is inherited (Fig. 15.1A). Peg shaped lateral are the most commonly seen and noticed abnormally shaped teeth encountered clinically (Fig. 15.1B). To produce a malocclusion the discrepancy should exist between the basal bone and the teeth size, or the associated skeletal structures.



Figs 15.1A i and ii: Notice the similarities in size and shape of teeth among twins

Number of Teeth

The number of teeth is a partially inherited characteristic. It can vary considerably especially in cases with cleft palate and cleidocranial dysostosis. The latter condition is known for the significant hyperdontia generally associated with it. Hypodontia is more widely seen as compared to hyperdontia. Hypodontia is more commonly seen in the permanent dentition as compared to the deciduous dentition. The most frequently missing teeth are the maxillary lateral incisors (Fig. 15.1C) (the third molars not being considered).

Primary Position of Tooth Germ and the Path of Eruption

The position of tooth germs and the path of eruption are considered by some researchers to be inherited.



(i)



(ii)

Figs 15.1B i and ii: Peg-shaped maxillary lateral incisor



Fig. 15.1C: Missing lateral incisors

Similar cross-bites or other malocclusions might be a result of similar jaw structure and tooth size rather than the position of tooth germs. Yet, ectopic teeth have shown to occur more frequently in some families collaborating the theory that these anomalies are genetically determined.

Shedding of Deciduous Teeth and Sequence of Eruption

These two parameters are not only correlated but are the ones most commonly mentioned by the parents themselves.

Mineralization of Teeth

Inherited defects of the tooth structure differ from exogenic-induced defects in mineralization (Fig. 15.1D i) as they are present in both the deciduous dentition as well as permanent dentition and are localized in the enamel or the dentine. These may result in malformed teeth (Fig. 15.1D ii) and contribute towards producing a malocclusion.



Fig. 15.1D i: Exogenic-induced enamel defect. Generally seen as horizontal lines as compared to inherited defects, which are seen as vertical or irregularly located defects

SKELETAL STRUCTURES

The underlying basal bone and other associated cranial bone structures are partially inherited. This is not to say that they are not influenced by the prenatal and/or postnatal environmental factors, but certain skeletal malocclusions are definitely inherited. The Class III



Fig. 15.1D ii: Indogenic-induced enamel defect. Generally seen as horizontal lines as compared to inherited defects, which are seen as vertical or irregularly located defects



Fig. 15.1F: Abnormal thickness of the maxillary frenum



Fig. 15.1E: Class III skeletal pattern tendencies as seen in a father and his two children

skeletal pattern is most commonly associated with familial tendencies (Fig. 15.1E).

SOFT TISSUES (OTHER THAN THE NEUROMUSCULATURE)

These generally include the *size and shape of the frenums* especially the maxillary labial frenum (Fig. 15.1F). Broad flabby frenums are sometimes repeatedly seen in families. Also included in this group are *microstomia*, and *ankyloglossia* (Fig. 15.1G). Either of which is capable of causing or at least contributing towards a malocclusion.

CONGENITAL FACTORS

Congenital defects include those malformations that are seen at the time of birth. These are generally maldevelopments of the 1st and the 2nd branchial arches. The most frequently associated malformations are:



Fig. 15.1G: Ankyloglossia

MICROGNATHISM

Micrognathia literally means "small jaw." It can affect either of the jaws. The congenital variety is often seen associated with congenital heart disease and the Pierre

Robin syndrome. Micrognathia of the maxilla is frequently due to a deficiency in the premaxillary region. Mandibular micrognathia is characterized by severe retrusion of the chin, with a practically nonexistent chin button and a steep mandibular angle (Fig. 15.1H).



Fig. 15.1H: Mandibular micrognathia

OLIGODONTIA

Also known as *hypodontia*, is a rather common condition. Different teeth seem to be affected in raring degree with the third molars being involved most frequently.

ANODONTIA

Anodontia means absence of teeth. True anodontia is extremely rare and may be associated with hereditary ectodermal dysplasia.

CLEFT LIP AND PALATE

This is relatively more frequently seen anomaly. It can be identified as early as the 18 to 20th week of pregnancy. It is generally associated with under developed maxilla and related dental disorders.

PREDISPOSING METABOLIC CLIMATE AND DISEASE

Under this three separate conditions need to be stressed upon:

a. Endocrine imbalance
b. Metabolic disturbances
c. Infectious diseases.

ENDOCRINE IMBALANCE

The usually encountered anomalies include:

Disease	*Features*
Hypopituitarism (Dwarfism)	• Retarded growth • Decreased linear facial measurements • Decreased cranial base measurements • May result in an open bite • Delayed tooth eruption • Incomplete root formation with incomplete closure of the apical foramen
Hyperpituitarism (Gigantism/ acromegaly)	• Accelerated development seen especially of the mandible • Accelerated dental development and eruption • Enlarged tongue and other facial structures including the sinuses • Thickening of the cortical bones • Poor maturation • Osteoporosis • Hypercementosis
Hypothyroidism (Cretinism in children/Myxedema in adults)	• Growth retardation • Decreased vertical growth of the face • Decreased cranial base length • Anterior open bite tendency • Delayed eruption of teeth • Maxillary protrusion • Spacing between teeth
Hyperthyroidism	• Heat intolerance with increased BMR, and appetite • Accelerated skeletal growth • Irregular eruption of teeth

contd...

contd...

Disease	*Features*
	• Increased vertical facial height • Open bite tendency • Mild prognathism may be apparent • Osteoporosis
Hypoparathyroidism	• Retarded eruption • Early exfoliation • Enamel defects
Hyperparathyroidism (von Rechlingham's disease)	• Demineralization • Disappearance of lamina dura • Mobility of teeth
Gonadal dysfunction	• Delayed sexual development • Skeletal age advanced • Dental age is normal • Premature sexual development

METABOLIC DISTURBANCES

Acute febrile diseases are capable of affecting not only the general health of the child but might also affect the dentition and its surrounding hard and soft tissues. Usually if the severity and duration is not prolonged the child is able to recoup lost time and catch up growth is possible. Temporarily they are capable of slowing down growth and may cause delayed tooth eruption.

INFECTIOUS DISEASES

The affects of infectious diseases are dependent not only on the severity and duration of the disease but also at what age it affects the child of the mother. The frequently seen diseases are:

Disease	*Clinical features*
Bacterial infections:	
Osteomyelitis	• Caused by *Staphylococcus aureus* • Bone response to force is altered
Congenital syphilis	• Transmitted by infected mother to child • Peg-shaped lateral incisors • Mulberry molars • Enamel hypoplasia • Delayed eruption • Underdeveloped maxilla • Narrow maxillary arch • Depressed nasal bridge
Tuberculosis	• Generalized stunted growth • Delayed eruption
Viral infections:	
Mumps	• Caused by myxovirus • Highly contagious • Rapid enlargement of salivary glands If to mother during pregnancy: – Dental hypoplasia – Retarded eruption – Extensive caries • Inflammation, congestion and swelling of gingiva, palate and/or pharynx
Measles	• Might lead to airway obstruction
Rubella	• Retarded eruption of teeth • Dental hypoplasia • Retarded physical development Maternal during pregnancy – Congenital malformations including cleft lip and palate – Within first trimester—severe defects including miscarriage
Chickenpox	Maternal infection during pregnancy – Defective offspring

DIETARY PROBLEMS (NUTRITIONAL DEFICIENCY)

Nutritional imbalances in the pregnant mother have been associated with certain malformations in the child as:

Nutritional imbalance	*Clinical feature*
Hypervitaminosis A	• Cleft lip and palate
Riboflavin deficiency (vitamin B_{12})	• Cleft lip and palate
Folic acid deficiency	• Cleft lip and palate • Mental retardation
Insulin deficiency	• Cleft lip and palate • Retardation
Iodine deficiency	• Cretinism

In a growing child nutritional imbalances can further accentuate an existing problem or may by themselves be capable of producing certain malformations, which may lead to malocclusions. These include:

Nutritional imbalance	*Clinical feature*
Protein deficiency	• Delayed eruption • Decreased radicular osteocementum
Vitamin A deficiency	• Calcification of teeth is affected • Retarded eruption • Thickened—mandibular processes and zygoma • Periodontal tissues might be disturbed • General growth is slow
Vitamin B complex deficiency	• Loss of appetite. Deficient mastication • Disturbed digestion • Retarded growth • Pernicious anemia • Cheilosis (Riboflavin deficiency)
Vitamin C deficiency	• Disturbed collagen fiber formation • Red, edematous tender bleeding gums • Loosening of teeth • Atrophy and disorganization of odontoblasts
Vitamin D (Rickets)	• Delayed closure of fontanelles • Hypophosphatemia • Disturbed calcification of teeth • Poor quality of enamel • Retarded eruption • Early loss of deciduous teeth • Narrow maxillary arch • High palatal vault • Shortened or underdeveloped mandible • Open bite tendency may exist
Hypervitaminosis D	• Poorly calcified teeth • Decalcification of bones • Increased osteoclastic activity

ABNORMAL PRESSURE HABITS AND FUNCTIONAL ABERRATIONS

These are possibly the most frequently encountered causes of malocclusion. These include:

a. Abnormal sucking
b. Thumb and finger sucking (Figs 15.2A and B).
c. Tongue thrust and tongue sucking (Fig. 15.2C).
d. Lip and nail biting (Figs 15.2D and E).
e. Abnormal swallowing habits (improper deglutition)
f. Speech defects
g. Respiratory abnormalities (mouth breathing, etc.) (Fig. 15.2F).
h. Tonsils and adenoids (Fig. 15.2G)
i. Psychogenic habits and bruxism.

All of the above mentioned habits have one thing in common and that is—they are all functional abrasions which produce forces that are abnormal. Since these forces are produced repeatedly over time they are capable of bringing about a permanent deformity in the developing musculoskeletal unit. The deformity produced depends upon the intensity, duration and frequency of the habit.

The muscular elements of this unit are capable of being retrained but if the underlying skeletal structures grow or reach abnormal proportions the malocclusion may only be amenable to surgical correction following the resolution of the underlying habit/cause. All other corrections tend to camouflage the underlying skeletal component by orthodontic



Fig. 15.2A: Patient with a thumb sucking habit



Fig. 15.2B: Patient with a finger sucking habit



Fig. 15.2C: Tongue thrust habit because of an abnormally large tongue



Fig. 15.2D: Lip sucking



Fig. 15.2E: Lip biting



Fig. 15.2F: Typical features of a mouth breather. Note the gingival inflammation in the maxillary anterior region



Fig. 15.2G: Patient suffering from enlarged adenoids



Fig. 15.2H: Pretreatment and posttreatment results of a case of tongue thrust with dental compensation of a mild skeletal deformity

movement of the dentition (Fig. 15.2H). The above explanation basically follows the functional matrix theory of growth as proposed by Moss—in its simplest form it says that—"function creates form and normal function creates normal form".

Habits have been elaborated in chapter Oral Habits and Their Management.

POSTURE

Abnormal postural habits are said to cause malocclusions. Though not directly. They may be associated with other abnormal pressure or muscle imbalances increasing the risk of malocclusion.

TRAUMA AND ACCIDENTS

Trauma and accidents can be further subdivided into three categories depending upon the time at which the trauma occurred, as:

- Prenatal trauma
- Trauma at the time of delivery
- Postnatal trauma

PRENATAL TRAUMA

Prenatal intrauterine trauma is often associated with hypoplasia of the mandible and even facial asymmetries. The posture of the foetus and the exact kind, time and severity of the trauma play an important role in the resultant effects.

TRAUMA AT THE TIME OF DELIVERY

Trauma at the time of delivery or birth injuries as they are more frequently called, have reduced considerably in recent years. Previously forceps injuries to the TMJ could result in ankylosis of the joint, resulting in severely impeded mandibular growth.



Fig. 15.3A: Traumatized permanent tooth



Fig. 15.3B: Maxillary incisiors erupting palatally due to trauma in the region before the eruption of permanent teeth



Fig. 15.3C: Ankylosed 21, following an apicectomy

POSTNATAL TRAUMA

Postnatal trauma can occur at any age and may affect any region of the orofacial complex. The effect of the trauma is dependent not only on the nature and the region, but also on the timing of the trauma. The consequences are different if the injury occurs prior to the eruption of the deciduous teeth or to the deciduous teeth themselves or to the permanent teeth after their eruption (Fig. 15.3A).

Trauma often results in dilacerations, deformations and displacements (Fig. 15.3B). An orthodontist should be careful of the trauma to the permanent teeth as these might not only be non-vital (and undergo extensive root resorption during orthodontic movement) but at times may get ankylosed (Fig. 15.3C) and it might be impossible to move them at all.

FURTHER READING

1. Epker BN, Stell JP, Fish LC. Dentofacial deformties: integrated orthodontic and surgical correction, ed 2, St Louis, 1998, Mosby.
2. Gorlin RJ, Pindborg JJ, Cohen MM. Syndromes of the head and neck, ed 2, New York, 1990, McGraw Hill.
3. Graber TM. Cranio-facial morphology in cleft palate and cleft lip deformities. Surg Gynec Obstet, 1949;88:359-69.
4. Harris EF, Smith RJ. A study of occlusion and arch widths in families, Am J Orthod 1980;78:155-63.
5. Harris JE, Kowalski CJ, Watnick SS. Genetic factors in the shape of the craniofacial complex, Angle Orthod, 1073;43(1):107-111.
6. Jensen BL, Kreiborg S. Development of the dentition in cleidocranial dysplasia, J Oral pathol Med 1990;19:89-93.
7. Kamin S. Dysgnahic abnormalities in mental retardation and associated disorders, Bull. NY Soc dent Child, 1971;22:11-23.
8. Kharbanda OP, Sidhu SS. Study of the etiological factors associated with the development of malocclusion, J Clin Pediat, 1994;18:80-95.
9. Pruzansky S, Aduss H. Prevalence of arch collapse and malocclusion in complete unilateral cleft lip and palate, Trans Europ Ortho Soc, 1967;1-18.
10. Weinmann JP, Sicher H. Bone and Bones, 2nd ed., C.V. Mosby Co., 1955.

16 Etiology of Malocclusion—Local Factors

Gurkeerat Singh

- Anomalies of number
  - Supernumerary teeth
  - Missing teeth
- Anomalies of tooth size
- Anomalies of tooth shape
- Abnormal labial frenum
- Premature loss of deciduous teeth
- Prolonged retention of deciduous teeth
- Delayed eruption of permanent teeth
- Abnormal eruptive path
- Ankylosis
- Dental caries
- Improper dental restorations

These local factors shall be discussed individually in detail and an attempt will be made to understand how each one of them can cause a malocclusion.

Graber classified the local etiological factors as:

ANOMALIES OF NUMBER

Each jaw is designed to hold only a specific number of teeth at a particular age. However, if the number of teeth present increases, or size of teeth is abnormaly large, it can cause crowding or hamper the eruption of succedaneous teeth in their ideal positions. Similarly, if the number of teeth present is less than normal then gaps will be seen in the dental arch. The anomalies in the number of teeth can be of two types (i) increased number of teeth or supernumerary teeth and, (ii) less number of teeth or missing teeth.

SUPERNUMERARY TEETH

Supernumerary teeth (Fig. 16.1) can vary remarkably in size, shape and location. They may closely resemble the teeth of the group to which they belong, i.e. incisors, premolars or molars, etc. or they may bear little resemblance to the adjacent teeth.

Supernumerary teeth, which bear a close resemblance to a particular group of teeth and erupt close to the original sight of these teeth, are called *supplemental teeth*. They are most commonly seen in the premolar region (Fig. 16.2) or the lateral incisor region (Fig.16.3)



Fig.16.1: Supernumerary tooth seen in the maxillary pre-molar region

The most commonly seen supernumerary tooth is the "mesiodens" (Table 16.1). It is usually situated between the maxillary central incisors and can vary considerably in shape. It can be seen erupted (Fig.16.4A) or impacted (Fig.16.4B), singular or in parts. It is usually conical in shape with a short root and crown. It can occur in the maxilla or in mandible (Fig. 16.5).



Fig. 16.2: Supplemental teeth in the mandibular pre-molar region



Fig.16.3: Supplemental tooth in the maxillary lateral incisor region



Fig.16.4A: Erupted mesiodens

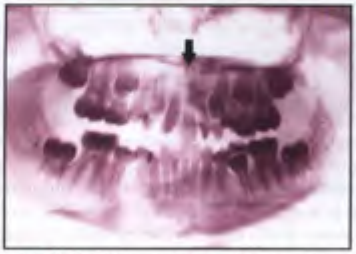


Fig.16.4B: An impacted inverted maxillary mesiodens

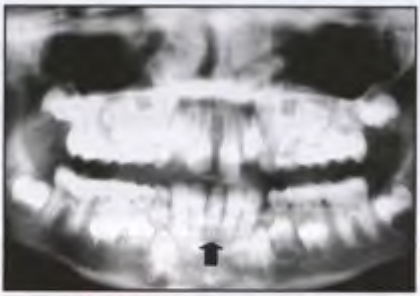


Fig.16.5: A mandibular mesiodense

Supernumerary teeth can cause

a. Noneruption of adjacent teeth (Figs 16.6A and B).
b. Delay the eruption of adjacent teeth (Fig. 16.7).
c. Deflect the erupting adjacent teeth into abnormal locations (Fig.16.8).
d. Increase the arch perimeter (increasing the over jet if in the maxillary arch or decreasing the over jet if seen in the mandibular arch.
e. Crowding in the dental arch (Fig. 16.4A)

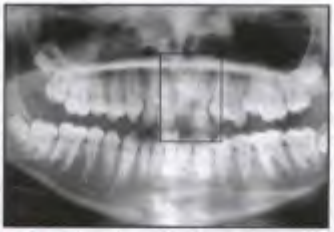


Fig. 16.6A: An inverted mesiodens preventing the eruption of the left maxillary central incisor



Fig. 16.6B: Close-up of the region, with the outline of the mesiodens drawn in blue colour

Table 16.1: Distribution of 50 supernumerary teeth in clinical practice (cases suffering from congenital or inherited diseases including clefts were not considered)

	Central incisor	*Lateral incisor*	*Canines*	*Pre-molars*	*Para-molars*
Maxilla	19	4	0	4	12
Mandible	2	0	0	9	0



Fig.16.7: Decreased space for the eruption of the lateral incisor causing a delay in its eruption



Fig. 16.8: Supernumerary tooth on the maxillary molar region has deflected the second permanent molar

MISSING TEETH

Congenitally missing teeth are far more commonly seen as compared to supernumerary teeth. The term used to describe one or more congenitally missing teeth is true *partial anodontia* or *hypodontia* or *oligodontia*. Certain teeth show a greater predilection to be congenitally missing (Table 16.2). The most commonly congenitally missing teeth are the third molars, followed by the maxillary lateral incisors (Fig.16.9).

Congenitally missing teeth can lead to:

a. Gaps between teeth (Fig. 16.10)
b. Aberrant swallowing patterns (Fig. 16.11)
c. Abnormal tilting/axial inclination or location of adjacent teeth (Fig. 16.12).
d. Multiple missing teeth can cause a multitude of problems (Fig. 16.13)



Fig. 16.9: Missing maxillary laterals



Fig. 16.10: Spacing between teeth due to missing maxillary lateral incisors



Fig.16.11: Tongue thrust habit developing due to the congenital absence of the maxillary lateral incisors

Table 16.2: Distribution of 100 congenitally missing teeth (third molars were not considered for this series)

	Central incisors	*Lateral incisors*	*Canines*	*1st premolars*	*2nd premolars*	*1st molars*	*2nd molars*
Maxillary arch	2	28	—	10	7	—	—
Mandibular arch	14	18	—	12	8	—	1



Fig. 16.12: Abnormal position of the maxillary right central incisor in contact with the right canine due to the absence of the right lateral incisor



Fig.16.13: Multitude of problems caused due to missing mandibular central incisors. Retrognathic mandible, convex profile, anterior deep bite, maxillary anterior crowding and end-on molar relationship

ANOMALIES OF TOOTH SIZE

Only two anomalies of tooth size are of interest to an orthodontist-microdontia and macrodontia, involving one or more teeth. The true generalized form of microdontia, where all the teeth are missing is rarely seen. It is usually associated with cases of pituitary dwarfism and, true generalized macrodontia, where all the teeth are larger than normal is seen in cases of pituitary gigantism. Relative generalized microdontia may be seen, but should be considered as an illusion of the true condition (Fig.16.14A).

The most commonly seen form of localized microdontia involves the maxillary lateral incisors. The tooth is called a 'peg lateral" (Fig. 16.14B) and exhibits a peg shaped crown with the mesial and distal sides converging incisally. The root may be shorter and more cylindrical than normally seen.

ANOMALIES OF TOOTH SHAPE

Anomalies of tooth shape include true fusion, gemination, concrescence, talon cusp, and 'dens in dente'. Dilaceration is also an anomaly of the tooth



Fig. 16.14A: Relative generalized microdontia. Here the jaws are too big for normal sized teeth



Fig. 16.14B: Peg-shaped maxillary lateral incisors

shape in which there is a sharp bend or curve in the root or crown (Fig.16.15). It generally does not effect orthodontic treatment planning but may complicate the extraction of the affected tooth.



Fig. 16.15A: Dilacerated roots of a maxillary first pre-molar



Fig. 16.15B: Dilacerated roots might also create problems when they have to be aligned

True fusion is seen when the tooth arises through the union of two normally separated tooth germs (Fig. 16.16A). It might lead to spacing (Fig.16.16B) or sometimes it might complicate its movement by orthodontic means (Fig.16.16C).

Geminated teeth are anomalies, which arise from division of a single germ by an invagination, leading to the formation of two incomplete teeth (Fig. 16.17A). The term 'twinning' has been used to designate the production of equivalent structures (Fig.16.17B). The term concrescence refers to fusion of teeth which occurs after root formation has been completed (Figs 16.18A and B)



Fig. 16.16A: Fusion



Fig. 16.16B: True fusion of 41 and 42



Fig. 16.16C: Fused 41 and 42; a larger bracket is required to attain proper rotational control of the tooth



Fig. 16.17A: Twinning



Fig. 16.17B: Two near equal sized teeth in place of the maxillary left lateral incisor



Fig.16.18A: Concrescence



Fig. 16.18B: Concresence following root completion

The talon cusp, is an anomalous structure projecting lingually from the cingulum area of a maxillary or mandibular permanent incisor (Fig. 16.19). It resembles an eagles talon, hence the name. It might



Fig. 16.19: Talon's cusp as seen on the maxillary lateral incisor



Fig. 16.20A: Talon's cusp on the right lateral incisor preventing its ideal alignment in the arch, it appears to be rotates mesiopalatally



Fig. 16.20B: Talon's cusp on the right lateral incisor preventing its ideal alignment in the arch, it appears to be rotates mesiopalatally.

interfere in proper occlusion (Figs 16.20A and B). It's grinding invariably leads to pulpal exposure necessitating root canal treatment.

The term 'Dens in Dente' is used to denote a developmental variation which radiographically may resemble a tooth within a tooth (Fig.16.21). It rarely has any clinical significance from an orthodontic point of view.

Congenital syphilis is often associated with the presence of peg-shaped laterals (Fig. 16.22) and mulberry molars. The tooth shape and material might need to be altered for esthetic maintenance of arch length.

Teeth with supernumerary roots might provide more resistance to movement. In other words, greater forces might need too be applied to move them.



Fig.16.21: Tooth within a tooth appearance seen radiographically in a mandibular 1st permanent molar



Fig. 16.22: Peg-shaped lateral as seen in a case of congenital syphilis

ABNORMAL LABIAL FRENUM

At birth the labial frenum is attached to the alveolar ridge with some fibers crossing over and attaching with the lingual dental papilla. As the teeth erupt, bone is deposited and the frenal attachment migrates superiorly with respect to the alveolar ridge. Some fibers may persist between the maxillary central incisors. These fibers which persist between these teeth are capable of preventing the two contralateral central incisors from coming into close approximation.

Midline diastema may persist even after the "ugly duckling stage" or close simultaneously (Fig.16.23) depending upon the amount of fibers crossing over interdentally. A midline diastema can exist due to various causes (Table 16.3) and the 'blanch test' (Table 16.4) is used to determine the role of frenum as a causative factor.

Table 16.3: Causes of the midline diastema

1. Deciduous dentition
2. Ugly duckling stage
3. Racial predisposition, Negroids
4. Microdontia
5. Congenital absence of lateral incisors
6. Supernumerary tooth in the midline
7. Abnormal frenal attachment
8. Abnormal pressure habits (digit sucking and tongue thrust habit)
9. Trauma
10. Impacted tooth in the midline

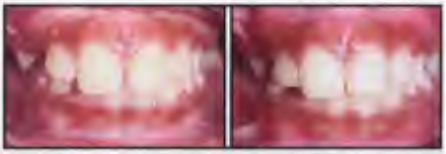


Fig.16.23: Closure of the midline diastema along with the eruption of the permanent canine

Table 16.4: The Blanch test

Step 1: The lip is pulled superiorly and anteriorly
Step 2: Any blanching in the interdental region is indicative of the fibers of the frenum crossing the alveolar ridge
Step 3: The blanch test can be collaborated with an IOPA of the region which shows a slight radiolucent wedging/ notching in the interdental alveolar ridge region

PREMATURE LOSS OF DECIDUOUS TEETH

The premature loss of a deciduous tooth can lead to malocclusion only if the succedaneous tooth is not sufficiently close to the point of eruption. In other words, the permanent successor does not erupt for sometime following the loss of the deciduous tooth, during which the adjacent teeth get time to migrate in its space. This can lead to a decrease in the over all arch length as the posterior teeth have a tendency to migrate mesially. This might cause the permanent successor to erupt malpositioned or get impacted or cause a shift in the midline (in case of anterior teeth).

In case an anterior deciduous is lost prematurely, there is a tendency for spacing to occur between the

erupted anterior teeth. It might also lead to a shift in the midline, towards the side where the deciduous tooth has been lost (Fig.16.24).

If one of the posterior deciduous teeth is lost, especially the deciduous second molars, the first permanent molars erupt mesially. This might lead to a loss in the arch length. This is seem most commonly in the maxillary arch where there is lesser space for the last anterior tooth, the canine, to erupt; which frequently erupts labially (Fig. 16.25). Mesially tilting of the erupting or just erupted mandibular first molars may cause the second premolars to remain impacted (Fig. 16.26).

Compensatory extraction for anterior deciduous tooth loss and space maintainer or the use of space regainers is highly recommended in case of the early loss of deciduous tooth. These are discussed in detail in the chapter on interceptive orthodontic procedures.



Fig.16.24: Midline shift towards the right in mandibular arch after the loss of the deciduous right canine



Fig.16.25: Labially erupting maxillary canines due to a lack of space in the arch



Fig. 16.26: Mesial tilting of the mandibular 1st permanent molars leading to a decreased space for the eruption of the 2nd premolars



Fig. 16.27: Labially erupting maxillary canines, due to the retained deciduous canines

PROLONGED RETENTION OF DECIDUOUS TEETH

Whatever the reason for the prolonged retention of deciduous teeth, they have a significant impact on the dentition. Which ever deciduous tooth may be retained beyond the usual eruption age of their permanent successor, is capable of causing:

i. Buccal/labial (Fig. 16.27) or palatal/lingual (Fig. 16.28) deflection in its path of eruption; or
ii. Impaction of the permanent tooth (Fig. 16.29).



Fig. 16.28: Lingually erupting mandibular lateral incisors, due to over retained deciduous teeth



Fig. 16.29: Impacted central incisor (black arrow), due to the presence of a deciduous incisor, an unerupted mesiodens is also visible (red arrow)

A palatal deflection in the maxillary arch might lead to the permanent tooth erupting is a crossbite (Fig. 16.30), which might be difficult to treat at a later stage. Permanent teeth that become impacted are even more difficult to correct orthodontically and might necessitate their surgical exposure. Most commonly impacted tooth is the maxillary canine (third molars not taken into account). The reasons for this include:

i. It is the last anterior tooth to erupt



Fig. 16.30: Left maxillary central incisor deflected palatally into cross-bite

ii. Space occupied by the deciduous canine is less than the mesiodistal width of the permanent canines
iii. The premolars might migrate mesially leaving limited space for the canines to erupt
iv. It has the longest path of eruption
v. Controversially, as it may seem, it is the only tooth to erupt after root completion.

DELAYED ERUPTION OF PERMANENT TEETH

Nature has provided for a particular sequence for the eruption of individual teeth in each arch. This sequence of eruption has a certain amount of flexibility built into it as well; but if one of the teeth does not occupy its designated place in this sequence there is a likelihood of migration of other teeth into the available space. As a result the tooth whose eruption has been delayed might get displaced or impacted.

Whatever the reasons for the delay in eruption (Table 16.5) it is important from a clinicians point of view to maintain and if required to create space for its eruption. Proper knowledge of preventive and interceptive orthodontics can definitely reduce the occurrence of malocclusions, if not prevent them from occurring; this can significantly reduce the severity of the malocclusion.

ABNORMAL ERUPTIVE PATH

Generally each tooth travels on a distinct path since its inception to the location at which it erupts. It can deviate from this eruption path because of many reasons (Table 16.6). The tooth that most frequently erupts in an abnormal location is the maximally canine (Figs 16.38A to C). Various reasons have been attributed for this behavior. These include:

a. It travels the longest distance, from near the floor of the orbit to the cover of the arch.

Table 16.5: Probable causes for the delayed eruption of permanent teeth

1. Early loss adjacent primary teeth with a consequential flaring or spacing between erupted permanent teeth. This may lead to decreased space availability for eruption of the succedaneous teeth (Fig. 16.31)
2. Early loss of primary tooth leading to mucosal thickening over the succedaneous tooth (Fig. 16.32). The mucosa might have to be incised to accelerate eruption
3. Early loss of the primary tooth might cause excessive bone deposition over the succedaneous tooth
4. Hereditary, in certain children teeth erupt much later than established norms
5. Presence of supernumerary tooth can block the erupting permanent tooth (Figs 16.6A and B)
6. Presence of odontomas (Fig. 16.33) or other cysts and tumors (Fig. 16.34) (in the path of eruption) might prevent the permanent tooth from erupting
7. Presence of deciduous root fragment that are not absorbed can block the erupting tooth or may deflect it preventing its eruption in an ideal location (Fig. 16.35)
8. Presence of ankylosed deciduous teeth (Fig.16.36). These might not get absorbed causing a delay in the eruption of the permanent tooth
9. The succedaneous tooth might be congenitally missing, delaying the loss of the primary tooth
10. In certain endocrine disorders the eruption of permanent teeth might be delayed, e.g. hypothyroidism

Table 16.6: Causes for an abnormal path of eruption

1. Tooth bud facing and/or placed or displaced from its ideal location
2. Presence of a supernumerary tooth may divert a tooth from its eruptive path
3. Presence of odontomas or a cyst or tremor may divert it if not altogether prevent its eruption (Fig. 16.34)
4. Unresorbed or retained deciduous teeth might force a tooth to erupt along a path of least resistance rather than in place of the deciduous tooth
5. Retained roof fragments (especially of deciduous molars) may deflect an erupting permanent tooth
6. A true arch length deficiencies or excess of tooth material may cause one or more teeth to deviate from their eruptive path (Fig. 16.37)

b. It is the last anterior tooth to erupt and loss in arch length—anterior or posterior may impinge on the space required for it to erupt.



Fig. 16.31: Surgical exposure of the impacted canine



Fig. 16.32: Mucosal thickning over the lateral incisors preventing their eruption



Fig.16.33: Presence of multiple odontomes preventing the eruption of the maxillary permanent canine



Fig. 16.34: Impacted canine and destruction associated with a cystic growth in the mandible



Fig. 16.35: Retained roots of the deciduous 2nd molar deflected the erupting 2nd pre-molar buccally



Fig. 16.36: Ankylosed deciduous canines, which did not exfoliate on time, resulted in labially erupting permanent canines



Fig. 16.37: A true arch length deficiency

c. Abnormal position of the tooth bud (Fig. 16.38). Ideally it should slide along the distal aspect of the root of the lateral incisor. Any problem in the position of the lateral incisor may divert the erupting canine. Since it has the longest path and is travelling for the longest time duration all other factors which might affect any tooth have a greater likelihood of effect it.

ANKYLOSIS

Ankylosis is a condition which involves the union of the root or part of a root directly to the bone, i.e. without the intervening periodontal membrane (Fig. 16.39). Ankylosis or partial ankylosis is encountered relatively frequently during the mixed dentition stage. Ankylosis of teeth is seen more commonly associated with certain infection endocrine disorders and congenital disorders, e.g. Cleidocranial dysostosis, but these are rare occurrences.



Fig. 16.38A: Abnormal path of eruption of the mandibular canines



Fig. 16.38B: Abnormal path of eruption of the maxillary canines



Fig. 16.38C: Abnormal location of the erupting maxillary canine (arrow)



Fig.16.39: Proximal decay in the 1st molar leading to decreased arch length

Ankylosis should generally be suspected in cases where there is a past history of trauma, or a mobile tooth has regained stability or apicoectomy has been performed.

DENTAL CARIES

Proximal caries are especially to blame for the reduction in arch length. This might be brought about by migration of adjacent teeth (Fig. 16.40A) and/or tilting of adjacent teeth into the space available (Fig. 16.40B) and/or supra-eruption of the teeth in the opposing arch. Caries can also lead to the premature loss of deciduous or permanent teeth.

A substantial reduction in arch length can be expected if several adjacent teeth involved by proximal caries are left unrestored. This is especially true for



Fig.16.40A: Mesial migration of the left posterior segment due to the presence of a grossly decayed deciduous 1st molar



Fig.16.40B: Right third molar tipped into the extraction space of the second molar

deciduous molars. The 'E-space' can very easily be lost in this way.

Premature loss of deciduous or permanent teeth can by themselves cause malocclusion, as explained earlier.

IMPROPER DENTAL RESTORATIONS

Malocclusions can be caused due to improper dental restorations. Under contoured proximal restoration can lead to a significant decrease in the arch length especially in the deciduous molars. Over contoured proximal restorations might bulge into the space to be occupied by a succedaneous tooth and result in a reduction of this space. Overhang or poor proximal contacts may predispose to periodontal breakdown around these teeth.

Premature contacts on over contoured occlusal restoration can cause a functional shift of the mandible during jaw closure, under-contoured occlusal restorations can lead to the supra-eruption of the opposing dentition.

FURTHER READING

1. Adler-Hradecky C, Adler P. Partial anodontia as an orthodontic problem, Oest Z Stomat 1969;66:294-7.
2. Edwards JG. The diastema, the frenum, the frenectomy, Am J Orthod 1977;71:689-508.
3. Graber TM. The finger sucking habit and associated problems, J Dent Children 1958;25:145-51.
4. Graber TM. The three "M's": muscles, malformation and malocclusion, Am J Orthod 1963;49:418-50.
5. Graber TM. Thumb and fingersucking, Am J Orthod 1959;45:258-64.
6. Gupta LD, Vacher BR. Supernumerary teeth and malocclusion, J Indiana Dent Assoc 1970;42:123-6.
7. Jacons RM. Muscle equilibrium: fact or fallacy, Angle Orthod 1969;39:11-21.
8. Kharbanda OP, Sidhu SS. Study of the etiological factors associated with the development of malocclusion, J Clin Pediat 1994;18:80-95.
9. Moyer RE. Handbook of Orthodontics, 3rd ed., Year Book Medical Publishers 1972.
10. Muller TP, Hill IN, Petersen AC, BlayneyJR. A survey of congenitally missing permanent teeth, JADA 1970;81:101-7.
11. Proffit WR, Norton LA. Influences of tongue activity during speech and swallowing, ASHA Reports, no. 5, Washington 1970;106-15.
12. Valiathan A, Shaikh SH. Malocclusion and the tongue, J Ind Orthod Soc 1998;31(II):53-7.

17 Dental Public Health Aspects of Orthodontics

Arun Grover, Gurkeerat Singh

- Introduction
- Prevalence of malocclusion
- Cleft lip and palate
- Assessment of orthodontic treatment need
- Orthodontic Indices
  - Index of orthodontic treatment needs (IOTN)
  - Peer assessment rating index (PAR)
- Factors affecting receipt of orthodontic treatment
  - Improvements in personal appearance
  - Self-perception and self-esteem
  - Gender and age
  - Peer groups
  - Social class
  - General Dentist's attitudes
  - Availability of resources
- Cost of treatment and orthodontist remuneration
- Trust in the health care system
- Conclusion

INTRODUCTION

Orthodontics is the branch of dentistry, which deals with the correction of malocclusion.

The aim of orthodontic treatment has in the past been defined as: *'to produce improved function by the correction of irregularities and to create not only greater resistance to disease, but also to improve personal appearance, which later will contribute to the mental as well as to the physical well-being of the individual'* (British Dental Association 1954). However, except for extreme variations in tooth/jaw alignment, minor intra- and/or inter-arch variations have little impact on periodontal health, caries exposure and jaw function.

While early correction of prominent incisors reduces the risk of trauma, its impact becomes less with increasing age. Also, while avoidance of impactions is desired, its pathological sequel has not been adequately studied. In most people with malocclusion, it is personal dissatisfaction, history of teasing and an inferiority complex, which leads to a loss of quality of life necessitating orthodontic correction.

Therefore, malocclusion in a majority of people today may be considered as a dental variant, the impact of which is primarily on the social and psychological well-being rather than susceptibility to dental diseases and loss of function. Thus, in recent years, the aim of orthodontic treatment has shifted to enhancement of social and psychological well-being through improvements in appearance.

Today in the era of evidence-based dentistry, a greater understanding of the prevalence of malocclusion, treatment needs assessment including indices applicable to orthodontic diagnosis, treatment priority and evaluation, and factors affecting receipt of orthodontic treatment, is required by the busy orthodontic specialist, the general dentist and the policy maker to tackle challenging problems of effective cost-risk balance along with quality assurance and equitable distribution of public health resources.

PREVALENCE OF MALOCCLUSION

Different surveys have reported data on the prevalence of different types of malocclusion. Most of the studies have been carried out in Europe and North America and a few in Asia. Most of these studies differ in their examination criteria, sampling techniques, age, sex, and availability of radiographs/study casts and examiner accuracy leading to difficulty in direct comparisons. A brief summary of these surveys is presented in Tables 17.1 and 17.2.

Table 17.1: Malocclusion studies in India

S.No	Authors and Year of Study	Size and City/State	Age Group	Malocclusion %	
1	Shourie KL (1952)	1057 (Punjab)	13-16 years	Class I Class II Class III	21.7 27.2 0.5
2	Shaikh HS (1960)	500 Orthod patients (Mumbai)	6-13 years	Class I Class II Class III	68.0 31.2 0.8
3	Miglani DC, Sharma OP (1963)	1158 (Punjab)	15-25 years	Malocclusion	19.6
4	Shaikh HS (1966)	400 Orthod patients (Mumbai)	7-21 years	Class I Class II Class III	72.98 25.75 1.27
5	Sidhu SS (1966-67)	500 dental patients (Delhi)	6-30 years	Malocclusion Class I Class II Class III	90.00 74.66 18.65 3.10
6	Jacob PP, Mathew CT (1969)	1001 (Trivandrum)	12-15 years	Malocclusion Class I Class II Class III	49.2 45.0 4.9 0.3
7	Prasad A Rajendra, Savadi Shivaratna C (1971)	1033 (Bangalore)	5-15 years	Malocclusion Girls-60% Boys-40% Class I Class II Class III Crowding	51.5 95.0 4.0 0.9 22.0
8	Nagaraja Rao G, Venkateswarlu M, Bhat KS, Subramanyan MV (1980)	511 (Udipi)	5-15 years	Class I Class II Class III	23.0 4.5 1.3
9	Jalili VP, Sidhu SS, Kharbanda OP (1993)	1085 Adivasi children (Mandu, MP)	6-14 years	Malocclusion Class II Overjet Overbite Crowd Max Crowd Mand	14.4 3.8 0.4 0.3 6.4 7.8
10	Gardiner JH and Valiathan A (1990)	500 (South Kanra)	10-12 years	Class II	14
11	Kharbanda OP, Sidhu SS, Sundaram KR, Shukla DK (1991)	2817 (Delhi)	5-9 years	Malocclusion Class I Class II Class III Crowd Max crowd Mand.crowd Overjet Overbite	20.3 11.7 6.0 2.6 4.2 11.7 3.1 3.5

Contd...

Contd...

S.No	Authors and year of study	Size and city/state	Age group	Malocclusion	%
12	Kharbanda OP, Sidhu SS, Sundaram KR, Shukla DK (1995)	2737 (Delhi)	10-13 years	Malocclusion	45.7
				Class I	27.7
				Class II	14.6
				Class III	3.4
				Crowd Max	9.5
				Mand.crowd	18.0
				Overjet	11.5
				Overbite	12.3
13	Alka A Singh, B Singh, Kharbanda OP, Shukla DK, Gosswami K, Gupta S (1998)	1019 (Rural Haryana)	12-16 years	Malocclusion	55.3
				Class I	43.6
				Class II	9.8
				Class III	0.6
				Bimaxillary Protrusion	0.5
				Crowd max	5.4
				Mand.crowd	16.1
				Overjet	3.5
				Overbite	12.9

Max = Maxilla, Mand = Mandibular, Ant = Anterior

Table 17.2: Prevalence of malocclusion

Country/city	Year	Prevalence	Type of malocclusion (%)
Mumbai (India)	1942	50%	
Denmark	1968	31%	
United States	1977	46%	
			Whites-Class I-52%
			Blacks-Class I-62%
			Whites-Class II-34%
			Blacks-Class II-18%
			Class III-14%
Johannesburg (South Africa)	1981	08% (Class II)	
Saudi Arabia	1990	16.4%	
Kenya	1993	11%	

Table 17.3: Incidence of cleft lip and/or palate per thousand live births

Caucasians	1%
Japanese	1.7%
Negroids	0.4%
American Indians	3.6%
Afghans	4.9%
Czechoslovakia Erst while	1.85%
Denmark	1.1%
Indians	1.7%

ORAL CLEFT LIP AND PALATE

There are variations in the reporting of oral clefts from one country to the other (Tables 17.3 and 17.4), probably owing to variations in the methodology of different studies. Orofacial clefts have been reported to occur in around 1 in 500 live Caucasian births and more frequently in orientals and less in blacks. There are also wide variations in the quality of care and treatment outcomes depending upon access to specialist care and availability of public health resources.

ASSESSMENT OF ORTHODONTIC TREATMENT NEED

The concept of need assessment is at the very core of orthodontic services. *Need does not always lead to utilization of dental health care services and utilization of dental health care services does not always imply need.* Two patients with similar oral health and similar occlusal discrepancies may receive different treatments owing to the influence of past experiences, their expectations, referring dentist/orthodontist preferences and dental health infrastructure.

Table 17.4: Incidence of cleft lip and cleft palate in India (hospital-based studies)

Hospital located in the city of	*Cleft lip and palate*	*Cleft lip*
Delhi	2.21%	0.71%
Delhi (All India Institute of Medical Sciences)	1.40%	0.30%
Chandigarh	1.0%	
Jaipur	1.12%	0.35%
Patna	1.5%	—
Lucknow	1.09%	—
Ajmer	0.90%	—
Bombay (Mumbai)	1.30%	0.20%
Ahmedabad	1.06%	0.24%
Madras (Chennai)	1.04%	0.10%
Kolkata	0.63%	0.16%
Hyderabad	1.90%	1.90%

In an attempt to define need effort must be directed to include effectiveness, cost of service delivery and the values contained in the WHO (1947) definition of *'health as a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity'*.

Need has been defined by Bradshaw in 1972 as—*'Normative'* need is that which the expert or professional, administrator or social scientist defines as need in any given situation. *'Felt'* need is expressed as the individual's own assessment of his or her requirement for health care. *'Expressed'* need is felt need translated into action by seeking assistance. *'Comparative'* need is assessed by comparing health care received by different people with similar characteristics. Carr and Wolfe in 1979 defined *'Unmet'* need, as the difference between those health care services judged necessary to tackle defined health problems and those services being actually provided.

While majority of orthodontic treatment needs assessment, in the past has been based on clinical examinations (normative need); patient and parent perceptions in relation to impairment, disability, and handicap are more important determinants of orthodontic treatment demand.

Impairment is defined as 'a loss or abnormality of mental, physical, or biochemical function either present at birth or arising out of disease or injury', such as edentulousness, periodontium loss or malocclusion. *Disability is 'any limitation in or lack of ability to carry out socially defined tasks and roles that individuals generally are expected to be able to do'. Handicap is 'the disadvantage experienced by impaired and disabled people because they do not or cannot conform to the expectations of society or the social groups to which they belong'*.

Based on the above discussion, orthodontic needs assessment should include a thorough clinical examination, measurement of the degree of impairment and social dysfunction, health orientation, knowledge and attitudes to health, description of acceptable treatments and skills required to carry them out. Orthodontic Indices are a valuable tool for orthodontic need assessment.

ORTHODONTIC INDICES

A lot of work (Bjork et al 1964, Grainger 1967, Salzmann 1968, Summers 1971, Baume et al 1973, Linder-Aronson 1974, British Standard 1983, Brooke and Shaw 1989, Richmond et al 1992a, 1992b, to name a few) has gone into the development of orthodontic indices for diagnostics, data collection and analysis, treatment prioritisation and treatment evaluation. This led to the development of various indices, each meant for a different purpose. While some are used to classify malocclusion, i.e. developed for diagnostic purposes, e.g. British Standards Institute's Incisor Classification (discussed in detail in Chapter 14). Other indices were developed to measure treatment need, e.g. Index of Orthodontic Treatment Need (IOTN), or treatment outcome, e.g. Peer Assessment Rating Index (PAR). While it is not within the scope of this chapter to delve deeper into all Indices, the Index of Orthodontic Treatment Needs (IOTN) and the Peer Assessment Rating Index (PAR) will be discussed briefly.

INDEX OF ORTHODONTIC TREATMENT NEEDS (IOTN)

Index of orthodontic treatment needs attempts to rank malocclusion based on the level of treatment needed or treatment priority. The index intends to identify people who would most likely benefit from orthodontic treatment. It has a dental health and an aesthetic component (Brook and Shaw 1989) wherein due significance is given to occlusal traits affecting individual dental health and perceived dental aesthetic impairment. Both components can be applied to study models as well as the patient clinically.

The Dental Health Component (DHC) of IOTN records and measures various features of malocclusion with a specially designed ruler. Scores for individual traits are not summed. In the Aesthetic Component (AC) of IOTN, a series of pre-selected and standardized dental photographs are ranked for overall dental attractiveness on a 10 point scale, 1 being the most attractive and 10 the least aesthetically pleasing. This value indicates the patient's aesthetic concerns and reflects the socio-physiological need. The IOTN has its limitations when it is applied to the mixed dentition patients. Nonetheless, the dental health component of the IOTN provides a structured method for the assessment of a malocclusion. It can be used as an epidemiological tool.

PEER ASSESSMENT RATING INDEX (PAR)

The index is used to determine the treatment outcome. It compares the pre- and post-treatment study models of the patient and assesses the outcome of the treatment in terms of the dento-occlusal change. It measures the following features of the malocclusion using a specially designed measuring ruler—overjet, overbite, midline relationship, buccal segment relationship and the maxillary and mandibular anterior alignment.

Peer assessment rating is totally dependent on the patient's study models and does not account for improvement in the facial profile, tooth inclinations, arch width and spacing between posterior teeth. It does not penalize inappropriate dental expansion. It also is not appropriate for assessment of mixed dentition treatment results. It is a reliable tool in assessing performance of practitioners or services and can also be used as an epidemiological tool.

FACTORS AFFECTING RECEIPT OF ORTHODONTIC TREATMENT

Whether a person with a malocclusion will eventually seek orthodontic treatment or not is dependent on the characteristics of the patient, the parent, the general dentist, the specialist orthodontist and the health care delivery system.

IMPROVEMENTS IN PERSONAL APPEARANCE

Past studies across different population groups and countries have demonstrated that improved appearance was the strongest motivational factor for seeking orthodontic treatment. Other factors included better dental health and function. Greater the deviation from the 'ideal' occlusion, the greater was the motivation for orthodontic treatment.

SELF-PERCEPTION AND SELF-ESTEEM

Self-perception of acceptable and unacceptable occlusion has been shown to influence receipt of orthodontic treatment. Further, people with low self-esteem greatly underrate their dental appearance when compared to people with high self-esteem, irrespective of their occlusal characteristics.

Wide variations have, however, been observed, with some people with moderate to severe malocclusion being visibly satisfied with their occlusion, while others with minor or no discrepancies in occlusion demonstrating great displeasure. These discrepancies may have resulted due to the imperfect way in which these individuals regard their occlusion before the orthodontic visit since most people failed to describe their dentition accurately.

GENDER AND AGE

It has been reported that more girls, especially in their teens receive orthodontic treatment in spite of the uniform prevalence of malocclusion between the sexes, reflecting a greater societal emphasis of high physical attractiveness on the female.

PEER GROUPS

Peer pressure influences uptake of orthodontic treatment and varies according to the culture and societal norms, which may vary from one place to another.

SOCIAL CLASS

Social class may also influence the uptake of orthodontic treatment. It has been shown that uptake of service is more in higher social class compared to lower social class. This difference may be because of the treatment cost, regularity of dental visits and

dentist: population ratio being in favor of more affluent sections of the society.

GENERAL DENTIST'S ATTITUDES

The general dentist plays an important role in referring patients for orthodontic services. The attitudes, beliefs and awareness of the general dentist and the orthodontist influence orthodontic service utilizations. The dentists are at times more discriminating about what is acceptable or unacceptable occlusion. Orthodontic service utilization is also influenced by the dentist/orthodontist's attitudes to the number of hours that he or she is willing to work.

The increase in the number of adult patients requesting orthodontic treatment is partly due to the motivation provided by the general dentist. The service utilization by this segment of the population is likely to improve further with increased awareness, use of fixed prosthodontic replacement and the positive correlation between poor oral hygiene and malocclusion.

AVAILABILITY OF RESOURCES

Availability of trained manpower (dentists, specialist orthodontists, dental assistants) and orthodontic laboratories and clinical settings influence uptake of orthodontic services in any area.

Over the last couple of years there has been a steady increase in the number of dentists and orthodontists in most nations. The nature of work—full-time or part-time—also influences the amount of service utilization.

COST OF TREATMENT AND ORTHODONTIST REMUNERATION

Orthodontic service utilization and the nature of treatment rendered are also dependent on the cost of the treatment and the remuneration system. Cost of treatment is a barrier to effective service utilization and dependent on the family's ability and willingness to pay. It has been observed that orthodontic treatment is still considered an aesthetic treatment by most compensating insurance companies. The long-term detrimental aspects of malocclusion are still not fully appreciated by these agencies.

In many industrialized nations the cost of orthodontic treatment is fully or partially borne by the state or the insurance agency and influences the number and the nature of orthodontic service utilization. Free services or subsidized services are more readily accepted than the paid ones.

TRUST IN THE HEALTH CARE SYSTEM

It has been shown that greater the trust in the health care system and the orthodontic treatment outcome, greater is the utilization of orthodontic services.

CONCLUSION

While orthodontic services are on a rise in most nations today, the demand is far greater than the supply. This has presented complex problems in the distribution of public health resources. Orthodontics thus has an interesting aspect of Dental Public Health and there is a greater need for further research and to fully understand the distribution and determinants of orthodontic services within the overall health care system.

FURTHER READING

1. Baldwin DC. Appearance and esthetics in oral health. Community Dental and Oral Epidemiology 1980;8:244-56.
2. Brook PH, Shaw WC. The development of an index of orthodontic treatment priority. Eur J Orthod 1989;11:309-32.
3. Brook, PH, Shaw WC. The development of an orthodontic treatment priority index. European Journal of Orthodontics 1989;11:309-20.
4. Cons NC, Jenny J, and Kaheut FJ. The dental aesthetic index. University of Iowa, Iowa, 1986.
5. Downer MC, Gelbier S, Gibbons DE. Introduction to Dental Public Health. FDI World Press, London, 1984
6. Draker HL. Handicapping labio-lingual deviations: A proposed index for public health purposes. Am J Orthod, 1960;46:295-305.
7. Helm S. Reappraisal of the Criteria for Orthodontic Treatment. PhD Thesis, University of Oslo, 1980.
8. Holmes A. The prevalence of orthodontic treatment need. Br J Orthod, 1992;19:177-82.
9. Ingervall B, Ronnerman A. Index for treatment need of orthodontic treatment. Odontol Revy 1975;26:59-82.
10. Kenealy P, Frude N and Shaw WC. The influence of social class on the uptake of orthodontic treatment. British Journal of Orthodontics 1988;16:107-11.
11. Kharbanda OP. What is the prevalence of malocclusion in India? Do we know Orthodontic treatment needs of our country? 1999;32(I):33-41.

12. Little R. The irregularity index: a quantitative score of mandibular anterior alignment, Am J Orthod 1975;68:554-63.
13. McGuinness NJ, Stephens CD. An introduction to indices of malocclusion, Dent Update 1994;21:140-144.
14. Otuyemi OD, Jones SP. Methods of assessing and grading malocclusion: a review, Aust Orthod J 1995;14:21-27.
15. Pine, Cynthia M. Community Oral Health. Wright: Oxford, 1997.
16. Prahl-Anderson B. The need for orthodontic treatment, Angle Orthod 1978;48:1-9.
17. Pruzansky S, Aduss H. Prevalence of arch collapse and malocclusion in complete unilateral cleft lip and palate, Trans Europ Ortho Soc, 1967;1-18.
18. Richmond S, et al. The development of the PAR index (Peer Assessment Rating): reliability and validity, Eur J Ortho 1992;14:125-39.
19. Richmond S, Roberts CT, Andrews M. Use of the Index of Orthodontic Treatment Need (IOTN) in assessing the need for orthodontic treatment pre- and post-appliance therapy. Br J Orthod 1994;21:175-84.
20. Shaw WC, Richmond S, O'Brien KD, Brook P, Stephens CD. quality control in orthodontics: indices of treatment need and treatment standards, Br Dent J 1991;170:107-12.
21. Shaw WC. The influence of children's Dentofacial appearance on their social attractiveness as judged by peers and lay adults, Am J Orthod 1981;79:399-415.
22. Summers CJ. The Occlusal index. A system for identifying and scoring Occlusal disorders. Am J Orthod 1971;59:552-67.
23. Tang EL, So LL. Prevalence and severity of malocclusion in children with cleft lip and / or palate in Hong Kong, Cleft Palate Craniofac J 1992;29:287-91.
24. Turner SA. Occlusal indices revisited. Br J Orthod, 1990;17:197-203.

Section Three

TREATMENT PLANNING

18. Treatment Planning
19. Biology of Tooth Movement
20. Mechanics of Tooth Movement
21. Methods of Gaining Space
22. Anchorage in Orthodontics
23. Retention and Relapse in Orthodontics
24. Surgical Procedures in Orthodontics
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18 Treatment Planning

Gurkeerat Singh

- Introduction
- Orthodontic diagnosis
- Formulation of a problem list
- Setting priorities for the orthodontic problem list
- Planning space requirements
- Treatment possibilities
- Choice of mechanotherapy
- Planning retention
- Factors in the choice of a specific treatment plan
- Discussion with the patient and patient consent

INTRODUCTION

Treatment planning is the second step in the treatment of any patient; the first step being diagnosis of the problem. Treatment planning can commence once a diagnosis has been arrived at. It entails the formulation of a detailed problem list, setting up of treatment objectives, and finalizing the treatment plan after discussing it with the patient or the patient's guardians. It also involves, planning space requirements, choice of appliance and the retention regimen. Putting it simply, it involves producing a road map of each step to be executed sequentially for a particular case so as to achieve the desired results.

ORTHODONTIC DIAGNOSIS

Orthodontic diagnosis involves three steps—collection of data, processing of the collected data and finally drawing conclusions. Step one is generally the simplest. It basically involves the taking of case history, intraoral and extra-oral examination of the patient, making of study models and taking the relevant radiographs or other diagnostic records.

The second step involves the processing of all this collected information into understandable and coherent data. This will involve undertaking cephalogram and study model analyses. The resulting information should be able to give a concise and exact location of the malocclusion. A statement of diagnosis should include the exact problem as perceived by the clinician and why and/or what is (etiology) causing the problem. For example, for example: a 12-year-old male patient, suffering from mild crowding of the upper and lower anterior teeth, with a Class II skeletal and dental malocclusion due to a short and retro-positioned mandible with proclined upper anteriors and an open bite of 2 mm due to persistent thumb sucking habit. Another important aspect, which the diagnosis should reflect upon, is the growth potential. The diagnosis should comment on the amount of growth potential available and this may involve the use of additional radiographs (hand-wrist radiograph) or other supplemental diagnostic aids. Treatment can vary considerably for growing and non-growing individuals.

FORMULATION OF A PROBLEM LIST

Formulation of a problem list is an important step and should be done in consultation with the parents and patients. For most patients, esthetics may be the most potent factor for demanding orthodontic treatment. But on examination, the orthodontist has to take into consideration the general health of the patient, especially the oral health.

The problem list should include comments on the periodontal condition of the patient, his/her status of caries/restorations and vitality of teeth. Only then should the clinician formulate the orthodontic problem list. Due importance should be given to the patient's desires, however, the clinician should also weigh options and possibilities from the standpoint of treatment.

SETTING PRIORITIES FOR THE ORTHODONTIC PROBLEM LIST

Setting priorities for orthodontic problems is important, as the space requirements are limited in most cases. If the case requires a lot of space for the retraction of teeth and there is some amount of crowding also present, then a compromise might need to be arrived at, decrowding along with limited retraction or retraction to desired limit and limited decrowding. Similarly, priorities will have to be made regarding correction of molar relations, derotations and uprightening of certain teeth.

It is always important to remember the goals of orthodontic treatment—the Jackson's triad of functional efficiency, structural balance and esthetic harmony, should always be the hallmark of all corrections planned.

PLANNING SPACE REQUIREMENTS

Space creation and utilization is important because of the overall size of the oral cavity. Extraction of a premolar may create as less as 6 mm of space or as much as 7.5 mm of space. The measure of error is very small as we deal only in a few millimeters of space. If even a small amount of space is lost, the overall goals of treatment might not be achieved to perfection. Not achieving the treatment goal not only compromises treatment results, but also functional efficiency and long-term stability of treatment results.

Corrections required as part of treatment:

1. Retraction of protruded teeth
2. Correction of crowding
3. Alignment of rotated anterior teeth
4. Alignment of rotated posterior teeth
5. Correction of molar relationship
6. Leveling the curve of Spee

RETRACTION OF PROTRUDED TEETH

For every millimeter of retraction required, 2 mm of space is required.

Protruded teeth are the most frequent reason for patients to approach the orthodontist. Unless the retraction required is very less or/and the dental arches are spaced, extraction of certain teeth might be required to create space for retraction of proclined teeth.

CORRECTION OF CROWDING

For every millimeter of decrowding, the same amount of space is required for aligning the teeth.

Crowded teeth are as unsightly as proclined teeth but maybe more harmful for the gums. The correction of crowding requires calculating the exact mesiodistal dimensions of the teeth to be aligned and accordingly space can be created for alignment. Use of Kessling's diagnostic setup can be of additional help.

ALIGNMENT OF ROTATED ANTERIOR TEETH

For every millimeter of derotation required, the same amount of space is required for aligning the teeth.

The anterior teeth are broader mesiodistally and occupy less space when they are rotated. Alignment of such teeth requires additional space in the dental arch. Provision should be kept for overcorrection as the tendency of such teeth to relapse is high.

ALIGNMENT OF ROTATED POSTERIOR TEETH

Space is created when rotated posterior teeth are aligned. The space created depends upon the tooth and the amount of rotation present.

The posterior teeth are broad labiolingually and can be compared to a parallelogram when viewed from the occlusal aspect. When they are rotated, they occupy more space; hence, space is actually created by aligning such teeth.

CORRECTION OF MOLAR RELATIONSHIP

The space required for mesial or distal movement of the molars is as per the actual movement planned.

To achieve a stable molar relationship, it is essential to have a full Class I, II or III relation. End-on relation

is not stable and space might be required to bring the maxillary or mandibular molar mesially to achieve stability. The exact space required can be calculated on the study models.

LEVELING THE CURVE OF SPEE

For every 1 mm of leveling, approximately 1 mm of space is required.

Skeletal malocclusions are very commonly associated with an increase in the curve of Spee. No malocclusion can be fully corrected, especially involving the camouflage of an underlying skeletal problem, without leveling the curve of Spee. An excessive curve will not only limit the amount of retraction of the maxillary anteriors but can also aid in the relapse of the condition.

ANCHORAGE

All appliances generate tooth moving forces from certain other intraoral anchor teeth. In trying to move the maligned teeth, certain amount of undesired movement has been noticed in the anchor teeth. This anchorage loss or the forward movement of the anchor teeth into the extraction space has been calculated to be approximately between 30 and 40 percent of the total space created by the extractions. The space lost is dependent upon the appliance used and the treatment mechanics involved.

If greater amount of space is required for the resolution of the malocclusion, additional means should be used to prevent anchorage loss. These may involve the use of extraoral or intraoral appliances (Nance palatal button, trans-palatal arches or lingual arches).

TREATMENT POSSIBILITIES

Correction of a particular malocclusion can be achieved in various different ways. For example; correction of a mild skeletal and dental Class II malocclusion can be achieved by:

- Extraction of maxillary first premolars and retraction of the maxillary anteriors and finishing with molars in Class II relation.
- With the extraction of all first premolars and finishing with molars in Class I relationship.
- If the patient is growing, the mandible can be made to grow and the case can be finished with the molars in Class I relationship.
- The maxillary molar can be distalized to a full Class I relation and the space created can be used to retract the maxillary anterior teeth.
- Another treatment option can be to defer treatment till the patient has completed growth and then plan orthodontic correction with surgical intervention.
- Finally, it is not always essential to treat a case; however, it is the clinicians duty to enlighten the patient regarding the consequences of not undertaking orthodontic correction.

Each treatment possibility has an advantage and a corresponding disadvantage. Compromises might have to be made regarding extraction of teeth, skeletal vs dental corrections, or amongst various dental corrections required.

Treatment possibilities should be listed and the possibility, which best serves, the particular patient at that particular age with maximum improvement in esthetics and function should be chosen.

CHOICE OF MECHANOTHERAPY

Why treat a case using a particular appliance? Is it essential to treat each and every case using the Begg's appliance or the Straight wire appliance because the clinician has been trained in its use? All appliances were designed to treat all kinds of malocclusions. Some manage to do them more simply, others require more time and maybe still do not give the desired results.

The appliance should be chosen so as to attain all the possible treatment results within the least possible time with as little tissue irritation/damage as possible. It is at times a compromise between the patient's desires and the ability of the clinician.

PLANNING RETENTION

The malocclusion dictates the kind of retention that is planned. Rotations and diastemas are more prone to relapse and hence retention—the type, kind and duration should be planned accordingly. The most frequently used Hawley's appliance still remains the

favorite of most clinicians today. Still as the number of adult patients is increasing, so is the use of fixed retainers.

The retention planned should be mentioned in the treatment plan that is presented to the patient.

FACTORS IN THE CHOICE OF A SPECIFIC TREATMENT PLAN

The final treatment plan is the result of a discussion between the patient and the orthodontist. It is designed keeping in mind the priorities given to the various problems in the problem list. The choice of a specific treatment plan is based upon:

1. The type of tooth movements required
2. Patient's expectations
3. Growth potential of the patient
4. Patient's ability to maintain oral hygiene
5. The cost of the treatment
6. The skills of the treating clinician.

THE TYPE OF TOOTH MOVEMENTS REQUIRED

Simple tipping movements can be achieved using removable appliances. If multiple, complex tooth movements are desired, it is advisable to use one of the available fixed orthodontic appliances. Certain fixed appliances provide three-dimensional control over individual teeth and allow complex movements to be undertaken simultaneously.

PATIENT'S EXPECTATIONS

Patients who have high expectations are expecting ideal finishes which might not be possible using removable appliances. Such patients are concerned about their esthetics to such an extent that the labial appliances might not be an option. They might desire the use of lingual appliances. A compromise might need to be arrived at regarding treatment results and the patient's expectations, it is advised to inform the patient exactly what is achievable with which appliance, to the best of the clinician's ability before commencing the treatment.

GROWTH POTENTIAL OF THE PATIENT

Growing patients can be a boon as well as bane. Results achieved during growth are more stable yet sometimes the return of an abhorrent growth pattern following completion of treatment can result in relapse of the treatment results. This is especially true for Class III skeletal pattern cases. Sufficient planning and follow-up is advised in growing patients.

PATIENT'S ABILITY TO MAINTAIN ORAL HYGIENE

Certain age groups or patients with compromised motor functions might not be able to maintain adequate oral hygiene with fixed appliance therapy. Such patients can be treated using removable appliances with compromised treatment results.

THE COST OF THE TREATMENT

Fixed orthodontic treatment is more costly as compared to removable appliance therapy. Sometimes the patient might not be able to afford costly yet ideal treatment plans. The financial implications of the treatment should be considered and explained to the patient at the time of deciding upon a particular treatment plan.

THE SKILLS OF THE TREATING CLINICIAN

It is always better to work within your means and to present treatment plans that can be achieved. It is not possible for every clinician to be good at everything he/she does. Being truthful to the patient before treatment is better than being sorry for him/her following treatment.

It is the duty of the clinician to choose an appliance that is appropriate for the particular case and not just appropriate for the clinician. If one has to continue to treat cases, the clinicians need to upgrade their knowledge and skills with the change in developing technology.

DISCUSSION WITH THE PATIENT AND PATIENT CONSENT

Patient today act as co-decision makers. Hence, it is the orthodontist legal and moral duty to discuss the risk/benefit of the treatment and alternatives as well as the risks of no treatment at all.

Written consent is an adjunct to show willingness to achieve informed consent in litigation cases. Consent is of two types—informed and implied. Implied consent is generally required when undertaking surgery. Informed consent can and should be taken

after providing the patient with enough information to have an understanding of the condition (malocclusion), its severity and the proposed treatment—its goals and objectives. He/she should be made to understand the commitment required on his/her part—both regards to the time and financial. Risks involved, of the treatment and of not getting treatment, should also be explained.

FURTHER READING

1. Daugaard-Jensen I. Extraction of first molars in discrepancy cases 1973;64;115-36.
2. Enlow DH, Moyers RE, Hunter WS, McNamara JA. A procedure for the analysis of intrinsic facial form and growth, Am J Orthod 1969;56:6-14.
3. Horowitz SL, Hixon EH. The Nature of Orthodontic Diagnosis, St Louis, CV Mosby, 1966.
4. KamedaA. Diagnosis and treatment planning in the orthodontic practice, Tokeyo, 1978, Isyo Publishers Inc.
5. Proffit SR, Ackerman JL. Diagnosis and treatment planning in orthodontics, in Graber TM, Swain BF (eds), Orthodontics, Current Principles and Technique, St Louis, CV Mosby, 1985.
6. Ricketts RM. Planning treatment on the basis of the facial pattern and an estimate of its growth. Angle Orthod 1957;17:14-37.
7. Schwanninner B, Shaye R. Management of cases with upper incisors missing, Am J Orthod 1980;100(5):710-2.
8. Thampson FG. Second premolar extraction in Begg technique, J Clin Orthod 1977;11:610-3.
9. Wagers LE. 8-tooth extraction cases using Begg technique, J Clin Orthod 1977;11:526-38.

19 Biology of Tooth Movement

Gurkeerat Singh

- Introduction
- Theories of orthodontic tooth movement
  - Pressure tension theory
  - Blood flow theory
  - Piezoelectric theory
- Phases of tooth movement
- Bone resorption
  - Direct/frontal resorption
  - Undermining/rearward resorption
- Bone formation
- Biochemical control of tooth movement

INTRODUCTION

The most common concept regarding orthodontists is that—they are the people who move teeth. Moving teeth is not as simple as it appears. Tooth movement is noticed following trauma, in certain pathologic conditions, or at the time of extracting a tooth. These are all tooth movements, which are caused because of varied force levels and there exists a distinct difference in their pathophysiology. Tooth movements can be broadly divided into three types:

- Physiologic
- Pathologic/(Pathologic migration)
- Orthodontic.

The term physiologic tooth movement designates, primarily, the slight tipping of the functioning tooth in its socket and secondarily, the changes in tooth position that occur in young persons during and after tooth eruption. These are normal or routine in nature and the tooth and its supporting structures are designed to undertake and withstand such movements.

The minor changes in tooth position observed in growing persons and adults are usually called tooth migration. These are generally associated with periodontal breakdown or/and altered force levels in the dental arches.

The orthodontic treatment is based on the simple premise that *whenever pressure is applied to a healthy tooth for a sufficient long duration of time, its surrounding bone remodels.*

THEORIES OF ORTHODONTIC TOOTH MOVEMENT

- Pressure tension theory
- Blood flow theory
- Piezoelectric theory

PRESSURE TENSION THEORY

Schwartz proposed the pressure tension theory in 1932. This is the simplest and the most widely accepted theory. According to this theory:

Whenever a tooth is subjected to an orthodontic force, it results in areas of pressure and tension. The alveolar bone is resorbed whenever the root, for a certain length of time, causes compression of the periodontal ligament, i.e. the pressure side. New alveolar bone is deposited whenever there is a stretching force acting on the periodental ligament fibers, i.e. the tension side (Fig. 19.1).

These seemingly obvious statements will be subjected to numerous variations and exceptions when factors such as the magnitude, direction and duration of the forces are introduced.

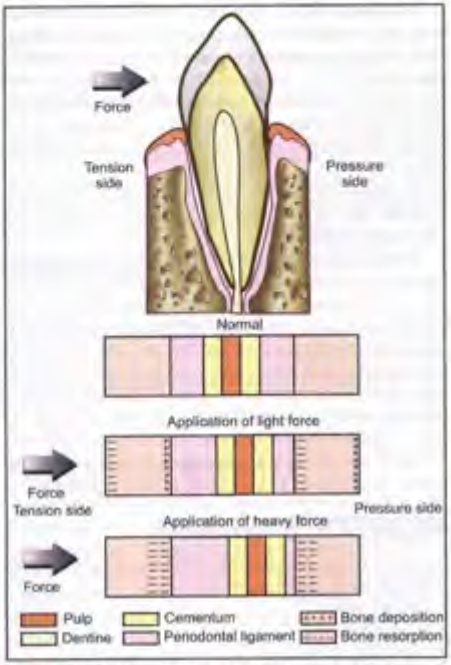


Fig. 19.1: Changes according to pressure tension theory

BLOOD FLOW THEORY / FLUID DYNAMIC THEORY (Fig. 19.2)

Bien (1966) has been credited for proposing the fluid dynamic or the blood flow theory. According to this theory:

Tooth movement occurs as a result of alterations in fluid dynamics in the periodontal ligament.

Periodontal space is a confined space and the passage of fluid in and out of this space is limited. The contents of the periodontal ligament create a unique hydrodynamic condition resembling a hydraulic mechanism. When a force of short duration is applied to a tooth, the fluid in the periodontal space escapes through tiny vascular channels. When the force is removed, the fluid is replenished by diffusion from capillary walls and recirculation of the interstitial fluid.

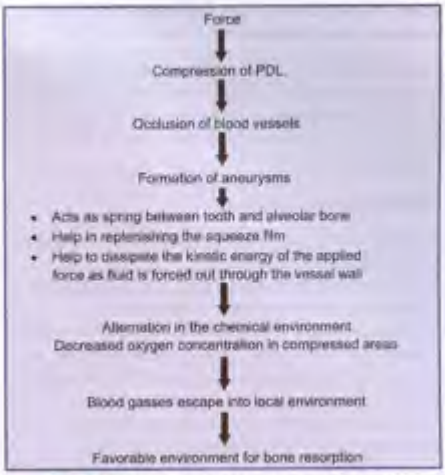


Fig. 19.2: Blood flow theory/fluid dynamic theory

A force of greater magnitude and duration causes the interstitial fluid in the periodontal ligament space to get squeezed out and move towards the apex and cervical margins. This results in the slowing down of the tooth movement and is called the *"squeeze film"* effect.

Bien characterized three distinct but interacting fluid systems in the periodontal ligament:

1. Vascular system
2. Cellular system
3. Interstitial fluid system.

When an orthodontic force is applied, it results in compression of the periodontal ligament on the pressure side. The blood vessels in this region also get compressed and this results in their stenosis. The blood vessels beyond the stenosis balloon up, resulting in the formation of aneurysms. The formation of aneurysms causes the blood gases to escape into the interstitial fluid thereby creating a favorable environment for resorption.

BONE BENDING/PIEZOELECTRIC/ BIOELECTRIC THEORY

Piezoelectricity is a phenomenon observed in many crystalline materials. The deformation of the crystal structure produces a flow of electric current as electrons are displaced from one part of the crystal lattice to another.

PIEZOELECTRIC SIGNALS

Piezoelectric signals have two unique characteristics:

1. A quick decay rate and
2. The production of an equivalent signal opposite in direction, when the force is released.

To put it simply—the piezoelectric signal is created in response to the force, but it quickly reaches zero even though the force is maintained. The piezoelectric signal is again produced, this time in the opposite direction, when the force is removed. Both these characteristics are explained by the migration of electrons within the crystal lattice as it is distorted by pressure.

Not only is bone mineral a crystal structure with piezoelectric properties but so is collagen. Hence, the possible sources of electric current are:

1. Collagen
2. Hydroxyapatite
3. Collagen hydroxyapatite interface
4. The mucopolysaccharide fraction of the ground substance.

When the force is applied on a tooth, the adjacent alveolar bone bends. Areas of concavity are associated with negative charge and cause bone deposition. Areas of convexity are associated with positive charge and cause bone resorption (Fig. 19.3).

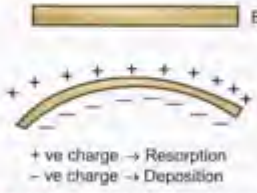


Fig. 19.3: Areas of concavity and convexity produced on bone bending

Ions in the fluids that bathe living bone interact with the complex electric field generated when the bone bends, causing temperature changes as well as electric currents. As a result, both convection and conduction currents can be detected in the extracellular fluids. These currents are affected by the nature of the fluids. The small voltages that are thus generated are called the *"Streaming Potentials."*

Endogenous electric signals can also be observed in bone that is not stressed. These are called the *"Bioelectric Potentials"*.

Today, it is a proven fact that adding exogenous electric signals can modify cellular activity. The effects presumably are felt at cell membranes. The external electric signals, probably affect cell membrane receptors, membrane permeability, or both. It has also been proved that when low voltage direct current is applied to the alveolar bone, it modifies the bioelectric potential and increases the rate of tooth movement. Also, a pulsed electromagnetic field increases, the rate of tooth movement, apparently by shortening the initial "Lag Phase" before tooth movement begins.

PHASES OF TOOTH MOVEMENT

Burstone categorized three distinct yet overlapping stages of tooth movement. They are:

- Initial phase
- Lag phase
- Post-lag phase.

INITIAL PHASE

The initial phase of tooth movement is immediately seen following the application of a force on a tooth. The phase is characterized by a sudden displacement of the tooth within its socket. The movement of the tooth into the periodontal space and the bending of the alveolar bone probably cause it. The extent of movement achieved is nearly same for both light and heavy forces.

LAG PHASE

The lag phase is characterized by very little or no tooth movement. It is the phase where the cellular components around the area of interest get activated to cause tooth movement.

The lag phase is longer if high forces are applied, as the area of hyalinization created is large and the resorption is rearward.

Shorter duration of the lag phase is noticed for lighter forces. There is very little, if any area of hyalinization and frontal resorption is noticed.

POST-LAG PHASE

This phase is characterized by the removal of the hyalinized tissue and tooth movement. The movement is mediated by osteoclasts and there is either direct resorption of the bony surface facing the periodontal ligament or rearward bone resorption.

BONE RESORPTION

Bone resorption basically means that the bone is being removed by the various cellular changes at the site of pressure. Two types of bone resorption are seen depending upon the magnitude of the applied force:

- Direct/frontal
- Undermining/rearward.

DIRECT FRONTAL RESORPTION

The term frontal resorption implies that osteoclasts are formed directly along the bone surface in the area corresponding to the compressed periodontal fibers. If such a reaction is to be obtained, the periodontal fibers must be compressed only to a certain extent (so as not to occlude the capillaries) and must cause little or ideally no hyalinization. This is only possible when the forces are close to the capillary pulse pressure, i.e. 20-26 gm/sq cm of root surface area.

Oppenheim and Schwarz have been given credit for discovering the optimum orthodontic force levels. These force levels move teeth rapidly in the desired direction with least possible damage to the surrounding tissues and hence resulting in minimal patient discomfort. It is rare if not impossible to calculate the exact forces under clinical conditions, but the use of light continuous forces are recommended (Table 19.1).

UNDERMINING/REARWARD BONE RESORPTION

Undermining bone resorption is seen when heavy forces are used for the purpose of tooth movement. The use of heavy forces causes the blockade of blood vessels in the pressure areas, due to their compression between the root of the tooth and the alveolar bone. In this region there is a gradual shrinkage of the periodontal ligament, with sterile necrosis of cellular elements within the periodontal ligament, which becomes nonfunctional. Because of the histologic appearance of the cells in the region (which loose their distinct structure, the nuclei may shrink and/or disappear) the avascular area has been referred to as "hyalinized" (Fig. 19.4).

Table 19.1: Physiological response to sustained light pressure against a tooth

Phase	*Time*	*Changes*
Initial	< 1 sec	PDL fluid incompressible, alveolar bone bends, piezoelectric signals generated
	1-2 sec	PDL fluid expressed tooth moves within PDL space
	3-5 sec	Blood vessels within PDL partially compressed on pressure side, dilated on tension side, PDL fibers and cells mechanically distorted
Lag	Minutes	Blood flow altered, oxygen tension begins to change, prostaglandins and cytokines released
	Hours	Metabolic changes occurring chemical messengers affect cellular activity, enzyme levels change
	4 hours	Increased, cAMP levels detectable, cellular differentiation begins within PDL
Post-lag	2 days	Tooth movement begins as osteoclasts/osteoblasts remodel bony socket

PDL—periodontal ligament

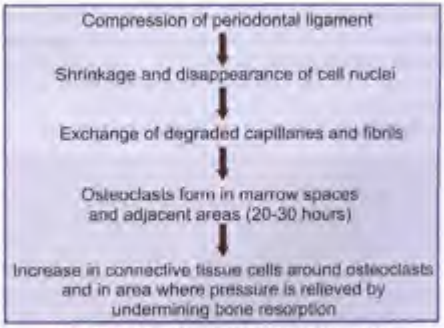


Fig. 19.4: Changes observed during formation of hyalinized zone

It is important to make a distinction here between hyaline connective tissue and the "hyalinized' zone seen during tooth movement. The hyalinized zone is not hyaline connective tissue, but it represents the inevitable loss of all cells when the blood supply is totally cut off. Location and extent of hyalinized area depend upon various factors (Table 19.2).

After a delay of several days, cellular elements from the adjacent undamaged periodontal ligament begin to invade the hyalinized area and the osteoclasts within the adjacent bone marrow spaces begin to remove the bone adjacent to the necrotic periodontal ligament. This process has been described as *undermining resorption*, since the attack is from the underside of the lamina dura rather than the periodontal ligament proper as in frontal resorption. Tooth movement results following a prolonged lag phase of tooth movement—when the hyalinized tissue has disappeared after undermining bone resorption takes place (Table 19.3).

The resorption patterns alter for the various types of forces (Table 19.4). In clinical situations, light, continuous forces are found to produce most efficient tooth movement with the least amount of patient discomfort. Heavy intermittent forces, though less efficient, can be clinically acceptable. Heavy continuous forces are to be avoided clinically because of their potential deleterious effects (Table 19.5).

The most common type of movements associated with orthodontic tooth movement are—tipping, bodily movements, intrusion and extrusion. Diagrammatically, it is easier to understand the relationship of bone resorption produced and the amount of force required for producing the particular type of movement (Figs 19.5A to C).

Table 19.2: The location and extent of hyalinized areas depend upon

Mechanical factors
- Nature of movement, i.e. tipping, bodily, intrusion, etc.
- Magnitude of force, i.e. light or heavy
- Rate of decay of force, i.e. continuous, interrupted or intermittent

Anatomic factors
- Form of bone, i.e. cancellous or cortical
- Outline of the bone surface

Table 19.3: Physiologic response of sustained pressure (HIGH) against a tooth

Phase	*Time*	*Changes*
Initial	1 sec	PDL fluid incompressible, alveolar bone bends, piezoelectric signal generated
	1-2 sec	PDL fluid expressed, tooth moves within PDL space
	3-5 sec	PDL fluid squeezed out, tissue compressed, pain, and blood vessels within the PDL occluded on pressure side
Lag	Minutes	Blood flow cut off to compressed PDL area
	Hours	Cell death in compressed area
Post-lag	3-5 days	Cell differentiation in adjacent marrow spaces, undermining resorption begins
	7-14 days	Undermining resorption removes lamina dura adjacent to compressed PDL, tooth movement occurs

PDL—Periodontal ligament

Table 19.4: Orthodontic forces

Orthodontic force duration is classified according to the duration of decay as:

Continuous Force maintained at some appreciable fraction of the original from one patient visit to the next, for example, elastics, Ni Ti coil springs, etc.

Interrupted Force levels decline to zero between activations. Produced by appliances such as screws, etc.

Intermittent Force levels decline abruptly to zero intermittently when the orthodontic appliance is removed by the patient. Produced by all patient activated appliances, such as removable plates, headgear, etc.



Fig. 19.5A: 50-75 gm of force is sufficient to tip a tooth

Table 19.5: Deleterious effects of orthodontic forces

Effects on the pulp
- Modest and transient inflammatory response within the pulp, at least at the beginning of tooth movement, with no long-term significance
- A large enough abrupt movement of the root apex could severe the blood vessels as they enter
- According to some studies, endodontically treated teeth are slightly more prone to root resorption during orthodontics than are teeth with normal vitality

Effects on root structure
- Root remodeling is a constant feature of orthodontic tooth movement, but permanent loss of root structure would occur only if repair did not replace the initially resorbed cementum
- Above average resorption can be anticipated if the teeth have:
  - Conical roots with pointed apices
  - Distorted root form
  - History of trauma
  - Root apices in contact with cortical bone
  - Excessive force during orthodontic treatment, particularly if heavy continuous forces are used

Effect on alveolar bone height
- Excessive loss of crestal bone height is almost never seen as a complication of orthodontic tooth movement
- Almost never exceeds 1 mm, greatest changes at extraction sites

Mobility
- Radiographically, it can be observed that the periodontal ligament space widens during orthodontic tooth movement
- Heavier the orthodontic force—greater the amount of undermining resorption expected—greater the mobility.
- If a tooth becomes extremely mobile during orthodontic treatment, all forces should be discontinued until the mobility decreases to moderate levels

Pain related to orthodontic treatment
- Pain of any type involves a great deal of individual variation.
- Pain is related to the development of ischemic areas in the periodontal ligament. Hence, higher forces, more pain.
- If light forces are used, the amount of pain experienced by patients can be decreased by having them engaged in repeated chewing during the first 8 hours after the orthodontic appliance is activated

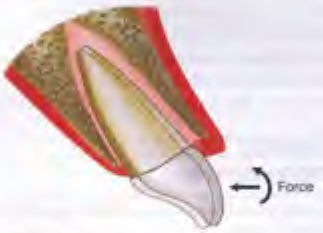


Fig. 19.5B: 100-150 gm force is required for bodily movement



Fig. 19.5C: 15-25 gm are needed to produce intrusion. Extrusion would produce no area of compression within the PDL

BONE FORMATION

Bone formation is basically the result of deposition of osteoid by osteoblasts. As a forerunner to bone formation, the number of fibroblasts and osteoblasts increase on the tension side. The increase in number occurs by mitotic cell division. The newly formed cells have a characteristic appearance with darkly stained nuclei. The first signs of this increase in number are seen 30 to 40 hours following the initial application of force.

Shortly after the start of cell proliferation, the osteoid gets deposited along the stretched fiber bundles-resulting in the formation of bone lamellae. Calcification of the deepest layer of osteoid starts as the new tissue increases in thickness. The newly calcified tissue along with that of longer existence is called bundle bone. The superficial layers of the osteoid remain uncalcified.

When the new bundle bone attains a certain thickness, it reorganizes into lamellated bone, with finer fibrils in its matrix. This reorganization is dependent upon the physiologic movement of the tooth and the age of the patient. The age of the patient may also play a role in the type and amount of bone formed.

BIOCHEMICAL CONTROL OF TOOTH MOVEMENT

Cells respond to signals from other cells and to changes in the environment.

Extracellular signal can be:

- Endocrine—endocrine organs release hormones, usually carried by blood to the distant target cells.
- Paracrine signaling—the cell is close to the target cell and the compound that is released (local mediator) effects only the group of cells adjacent to it.
- Autocrine signaling cells respond to substance that they themselves release.

Some hormones bind to receptors within the cells; others bind to cell surface receptors:

- Intracellular receptors—steroids, retinoic acid and thyroxine, being hydrophobic, enter the cell and bind to specific receptors in the cytosol or nucleus and act on nuclear DNA to alter transcription of specific gene.
- Cell surface receptors—peptide and protein hormones, prostaglandins, amino acids epinephrine and other water-soluble signaling molecules called ligands act as 1st messengers and bind to cell surface receptors proteins and thereby activate enzymes that generate an increase or decrease in the concentration of intracellular signaling compounds termed 2nd messengers (these include compounds such as adenosine 3', 5' monophosphate (cyclic AMP), guanosine 3', 5'- monophosphate (cGMP), 1, 2 diacylglycerol and inositol 1, 4, 5—triphosphate.

Surface receptors may open or close certain gated ion channels in the plasma membrane and in turn may allow the influx of certain ions into the cell. Ca^{2+} has been shown to act as a 2nd messenger. Certain prostaglandins have also been shown to act as local mediators during paracrine signaling.

Tissue trauma stimulates prostaglandin release. Their concentration tends to increase even following the gentle manipulation of tissues. Ischemia has been shown to trigger prostaglandin synthesis. Epinephrine, angiotensin, prolactin and histamine have also been shown to increase prostaglandin synthesis.



Fig. 19.6: Summary of biochemical reactions

The biochemical control of orthodontic tooth movement is a complex and as yet not completely understood phenomenon. For the time being we will limit ourselves to the various theories of tooth movement and their interrelationship with the basic mediators (Fig. 19.6).

FURTHER READING

1. Bassett CAL. Beneficial effects of electromagnetic fields. J Cell Biochem. 1993;51:387-93.
2. Darendeliler MA, Darendeliler A, Sinclair PM. Effects of static magnetic and pulsed electromagnetic fields on bone healing. Int J Adult Orthod Orthognathic Surg. 1997;12:43-53.
3. Davidovitch Z, Finkelson MD, Steigman S, et al. Electric currents, bone remodeling and orthodontic tooth movement. I. the effect of electric currents on periodontal cyclic nucleotides. Am J Orthod 1980;77:14.

4. Greenbaum KR, Zahrisson BU. The effect of palatal expansion therapy on the periodontal supporting tissues, Am J Orthod 1982;81:12-21.
5. Linge BO, Linge L. Apical root resorption in the upper front teeth during orthodontic treatment: a longitudinal radiographic study of the incisor root lengths, in McNamara JA Jr, Ribbens KA (Eds), Malocclusion and the Periodontium, monograph 15, Craniofacial Growth Series, Ann Arboor, Mich, Cente for Human Growth anf Development, University of Michigan, 1984.
6. Melcher AH, Beersten W. The physiology of tooth eruption, in McNamara JA Jr (Ed), The Biology of Occlusal Development, monograph 7. Craniofacial Growth Series. Ann Arbor, Mich, Center for Human Growth and Development, University of Michigan, 1977;1-240.
7. Melcher AH. Biological processes in tooth eruption and tooth movement, in Cohen B, Kramer IRH (eds), Scientific Foundations of Dentistry. London, Heinemann Medical Book Shops, 1976.
8. Melsen B. Biologic reaction of alveolar bone to orthodontic tooth movement, Angle Orthod 1999;69(2):151-8.
9. Melsen B. Tissue reaction to orthodontic tooth movement: a new paradigm, Eur J Orthod 2001;23(6):671-81.
10. Reitan K. The initial tissue reaction incident to orthodontic tooth movement as related to th influence of function, Acta Odontol Scand 1951;Suppl 6:1-240.
11. Storey E, Smith R. Force in orthodontics and its relation to tooth movement, Aust Dent J, 1952;56:11-18.
12. Zengo AN, Pawluk RJ, Basset CAL. Stress-induced bioelectric potentials in the dentoalveolar complex, Am J Orthod, 1973;64:17.

20 Mechanics of Tooth Movement

Gurkeerat Singh

- Introduction
- Forces as vectors
- Force and movement
- Types of forces

INTRODUCTION

A clinician is in part an engineer. Any one trying to move teeth requires to use force, and *'mechanics is the study of the effect of forces on a body.'* Hence, knowledge of mechanics is a must for every student of orthodontics. Since a majority of the students do not have a background of engineering, this chapter is aimed at simplifying the concepts and their potential for clinical application.

FORCES AS VECTORS

Force can be defined as 'an act upon a body that changes or tends to change the state of rest or of motion of that body.'

Forces can be represented using vectors. They have specific magnitude and direction. In addition, the point of application must be taken into account and has great significance from an orthodontic perspective. Forces are represented as vectors as they possess both magnitude and direction. The point of application of a force is indicated by the origin of the arrow (Fig. 20.1), which is at the bracket. This is simply the point of contact between the body being moved and the applied force. Direction is indicated by the body of the arrow itself and the arrowhead. Without the head of the arrow, the body alone indicates the line of action. The sense, is determined by the end on which the arrow is put.

Almost every force applied in clinical conditions will have effects in three planes of space. It is easier to understand the basic principles when they are considered only in two planes, yet under clinical conditions

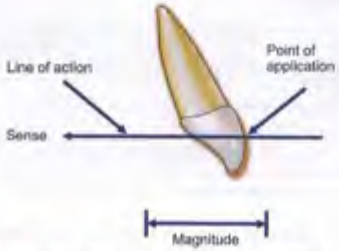


Fig. 20.1: Forces may be treated as vectors

the effect of forces should be analyzed in all the three dimensions of space.

To understand how a body reacts to more than one force requires the creation of a vector diagram. In the simplest scenario, with the point of application of say two forces being at a common point, the resultant is indicated by the diagonal of the parallelogram drawn using the vectors of the two forces (Fig. 20.2).

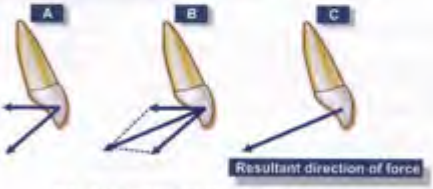


Fig. 20.2: Resultant of two forces determined using the parallelogram method

When the two forces are acting at two different points on the same body the parallelogram is drawn by selecting a point of application along the line of action of one of the forces. The line of action may be extended anywhere off the tooth to construct a totally artificial point of application in space (Fig. 20.3).

Sometimes a single force may be resolved into components to simplify or study its effect on a particular body. Usually this is done by splitting the force vectors into two components at right angles to each other, into a vertical and horizontal component (Fig. 20.4).

FORCE AND MOVEMENT

CENTER OF RESISTANCE

Every unrestrained body has a point at which it can (at least in theory) be perfectly balanced. This point is called the *center of gravity*. When we talk about teeth, we are talking of a body which is restrained by adjacent structures like the periodontal ligament etc. for such restrained bodies the analogous point to the center of gravity is called the *center of resistance*. By definition, a force with a line of action passing through the center of resistance produces translation. The center of resistance of a single-rooted tooth is on the long axis of the tooth, probably between one third and one half of the root length apical to the alveolar crest (Fig. 20.5). For a multirooted tooth, the center of resistance is probably between the roots, 1 or 2 mm apical to the furcation (Fig. 20.6).

Center of resistance varies with:

- Root length.
- Alveolar bone height.
- The root morphology- single or multirooted teeth.

The tooth movement resulting from a force delivered at the bracket depends upon the distance of the line of action of the force from the center of resistance. Identical forced applied to teeth with difference root lengths or brackets placed at different heights can have different effects. Also, the movement of teeth in adults with alveolar bone loss will be different than in adolescents (Fig. 20.7).

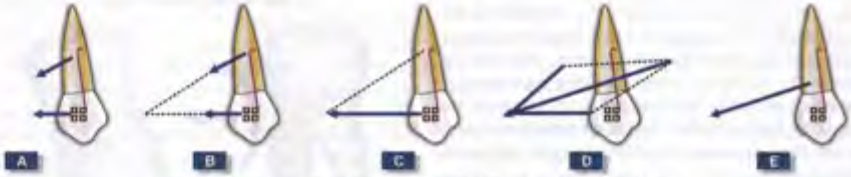


Fig. 20.3: The resultant of two forces with different points of application



Fig. 20.4: The parallelogram method for resolving a force into vertical and horizontal components



Fig. 20.5: Center of resistance of a single-rooted teeth



Fig. 20.6: Center of resistance of multirooted teeth



Fig. 20.7: Change in centre of resistance of tooth following alveolar bone loss

TYPES OF TOOTH MOVEMENTS

A tooth can move in one of three general ways:

1. Translation
2. Pure rotation, or
3. Combined rotation and translation

Translation, or bodily movement, occurs when all points on the tooth move an equal distance in the same direction (Fig. 20.8A). Translation occurs when the line of action of an applied force passes through the center of resistance of a tooth, the tooth responds with a pure bodily movement (translation) in the direction of the line of action of the applied force. Pure translatory movements are seen during orthodontic extrusion or intrusion or bodily movement during retraction or protraction of teeth. True translatory movements are difficult to achieve under clinical circumstances even though they remain the ultimate goal of every clinician.

Rotation is said to take place when there is movement of points of a tooth along the arc of a circle, with the center of resistance being the center of the circle (Fig. 20.8B). During orthodontic tooth movement the rotations can be of two types:

- Transverse rotations (Figs 20.9A to C) Rotations in which the angulation of the long axis of the tooth changes, e.g. crown tipping or root torquing.
- Long-axis rotations (Fig. 20.9D). The rotation takes place on the long-axis of the tooth (the angulation of the long-axis of the tooth remains unaltered).

Any movement that is not pure translation or rotation can be described as a combination of these two forms of movement (Figs 20.8C and 20.9C).

Moment of force When the line of action of an applied force does not pass through the center of resistance,



Fig. 20.8A: Pure translation



Fig. 20.8B: Pure rotation



Fig. 20.8C: A combination of translation and rotation



Figs 20.9A to C: Transverse rotation with center of rotation (A) at crown tip (B) at root apex (C) at some distance from root apex



Fig. 20.9D: The concept of a center of rotation can be used to define any type of tooth movement in any plane of space

the force will produce some rotation. The potential for rotation is measured as a *moment*. The magnitude of the moment is equal to the magnitude of the force multiplied by the perpendicular distance of the line of action of the force to the center of resistance (Fig. 20.10A).

$M = F \times d$

where,

M is the moment,

F, the magnitude of force, and

d, the perpendicular distance of the point of application from the center of resistance.

The moment is measured in units such as gram-millimeters. Hence, the moment of force can be altered by changing the magnitude of the force or by changing the perpendicular distance of the line of action of the force to the center of resistance. Hence, if the magnitude of the moment needs to be decreased, the force can be applied closer to the center of resistance of the tooth.

If the line of action of a force does not pass through the center of resistance of a tooth, a moment is necessarily created. To produce a purely translatory movement of a tooth, a moment to force ratio of 8:1 to 10: 1 is required (depending upon the length of the root).

Combined translation and rotation: Whenever a force is applied to a tooth which does not pass through its center of resistance, it will cause a movement of the tooth where in, the center of resistance will translate as if the force did pass through it, but the tooth will also rotate, since the applied force produces a moment about the center of resistance. The result is a combination of translation and rotation (Fig. 20.10B).

A couple A couple consists of two forces of equal magnitude but opposite in direction, with parallel but non-colinear lines of action. When two forces are

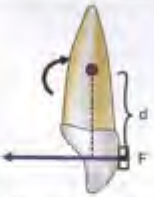


Fig. 20.10A: Moment-magnitude of force (F) × perpendicular distance of the point of application from the center of resistance (d)



Fig. 20.10B: The force at the bracket, will translate the tooth but, in addition, will cause a rotation because of the moment created at the center of resistance

applied in this manner the resultant produced is a pure moment (the translatory effect of the individual forces gets cancelled) (Fig. 20.11).

The center of rotation is the point around which rotation actually occurs when an object is being moved/rotated. The center of rotation can be at any position on or off a tooth (Fig. 20.12 and Figs 20.9A to D). As the center of rotation moves towards the apex, the more the displacement of the crown and vice versa. The actual movement of a tooth does involve a series of changing centers of rotation.

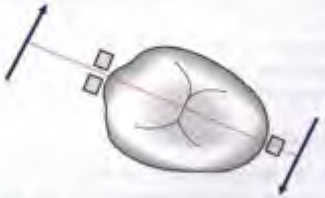


Fig. 20.11: A couple consists of two equal magnitude opposite in direction with parallel but non-colinear lines of action



Fig. 20.12: Center of rotation outside the tooth during intrusion or extrusion

Theoretically, a single force plus a single couple can produce any type of tooth movement. This may sound very simple but is extremely difficult to achieve clinically. To produce only bodily movement, the force system at the bracket must be equivalent to a force with no couple at the center of resistance.

TYPES OF FORCES

Under clinical circumstances, it must be remembered that whatever the mechanics, the forces have a tendency to decrease over a period of time. For orthodontic tooth movement to be possible the force levels should remain slightly above the critical. If force levels decrease below this critical, the movement generating capacity of the force is lost and precious time is lost till the next activation.

Based on the duration of application, the forces can be of three types:

- Continuous force
- Intermittent force
- Interrupted force

CONTINUOUS FORCE

A force is considered to be continuous if its magnitude does not decrease appreciably over time or in other words, the force decay is only a fraction of the original, between visits to the clinician for reactivation of the appliance (Fig. 20.13A). Ideally, light continuous forces produce the most efficient tooth movement causing mainly frontal resorption. Light flexible wires (e.g. NiTi wires) used over small deflections and light elastics as used in the light wire differential force technique produce continuous forces.

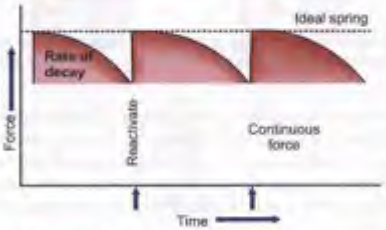


Fig. 20.13A: Continuous forces are maintained between activations

INTERMITTENT FORCES

Intermittent forces decline to zero magnitude intermittently, when the appliance is removed by the patient or clinician (Fig. 12.13B). Such forces are produced by all patient activated appliances and removable plates, such as appliances incorporating screws, labial bows or springs.

The movement produced is generally because of undermining resorption and the force levels are high initially and decrease following the initial tooth movement.

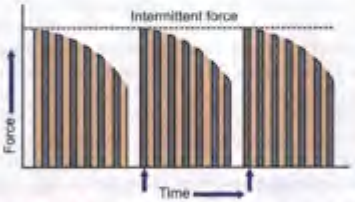


Fig. 20.13B: Intermittent forces fall to zero when the appliance is taken out and resume when the appliance is reinserted into the mouth

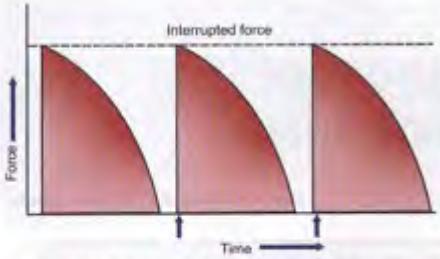


Fig. 20.13C: Interrupted forces drop to zero between activations

INTERRUPTED FORCE

Interrupted forces decay to zero between activations. There is genuine time lag between the reactivation of the force system (Fig. 12.13C). The initial forces are high and decrease overtime to zero, this gives time to the tissues to recover before the force system is reactivated. Examples of appliances exerting interrupted forces include headgears or face-masks worn for a particular duration everyday or retraction in fixed orthodontic appliances using loop mechanics.

It should be the endeavor of the clinician to produce tooth movement in the desired direction using force systems that are ideal for that individual case. The force system chosen should produce as little damage to the surrounding structures as possible. Theoretically light continuous forces are ideal for producing tooth movements by frontal resorption but clinically this might not be possible all the time.

The biologic response to tooth movement is still not completely understood and also the 'ideal' appliance is yet a distant dream.

FURTHER READING

1. Burstone CJ, Koeing HA. Force systems from an ideal arch, Am J Orthod 1974;65:270.
2. Burstone CJ, Koenig HA. Optimizing anterior and canine retraction, Am J Orthod 1976;70:1.
3. Burstone CJ. Biomechanics of the orthodontic appliance, in Current Orthodontic Concepts and Techniques, 2nd ed. Philadelphia, WB Saunders, 1975.
4. Burstone CJ. The biomechanics of tooth movements, in Kraus BS, Riedel RA (Eds) Vistas in Orthodontics. Philadelphia, Lea and Febiger, 1962.
5. Choy K, Pae EK, Kim K, et al. Controlled space closure with a statistically determinate retraction system, Angle Orthod 2002;72(3):191-8.
6. Christiansen R, Burstone CJ. Centres of rotation within the periodontal space, Am J Orthod 1969;55:353.
7. Halazonetis DJ. Ideal arch force systems: a centre –of-resistance perspective, Am J Orthod Dentofacial Orthop 1998;114(3):256-64.
8. Mulligan T. Common sense Mechanics. Phoenix, Ariz, CSM, 1982.
9. Pryputniewicz RJ, Burstone CJ. The effects of time and force magnitude on orthodontic tooth movement, J Dent Res 1979;58:1154.
10. Quinn RS, Yoshikawa DK. A reassessment of force magnitude in orthodontics, Am J Orthod 1985;88:252-60.
11. Smith RJ, Burstone CJ. Mechanics of tooth movement. Am J Orthod 1984;85:294-307.
12. Storey E, Smith R. Force in orthodontics and its relation to tooth movement, Aust Dent J 1952;56:11-18.



21 Methods of Gaining Space

Gurkeerat Singh, Tapasya Juneja

- Introduction
- Proximal stripping
- Arch expansion
- Distalization of molars
- Uprighting of tilted posterior teeth
- Derotation of posterior teeth
- Proclination of anterior teeth
- Extraction
- Third molars

INTRODUCTION

For the resolution of a majority of malocclusions space is required. For achieving majority of the treatment objectives (Table 21.1) space has to be created within the jaws. How much space is required to resolve a particular malocclusion has been—discussed in detail, in Chapter 20, on treatment planning. In this chapter we will discuss the various ways in which space can be created.

Table 21.1: Space is required for

- Alignment of crowded teeth
- Retraction of proclined teeth
- Correction of molar relationship
- Derotation of anterior teeth
- Leveling the curve of Spee
- Intrusion

The various methods of gaining space include:

1. Proximal stripping
2. Arch expansion
3. Distalization of molars
4. Uprighting of tilted teeth
5. Derotation of posterior teeth
6. Proclination of anterior teeth
7. Extraction

PROXIMAL STRIPPING (REPROXIMATION)

Proximal stripping or *reproximation* involves the selective reduction of the mesiodistal width of certain teeth to create space. The procedure is also called *slenderization*, disking or *proximal slicing*.

The teeth that are usually proximally stripped are the mandibular incisors. Other teeth including the maxillary anteriors and the premolars of both the arches can also be stripped proximally to create space. The teeth selected depend upon:

- The location of excess tooth material, mandibular anterior segment or the maxillary anterior segment or the mandibular or maxillary posterior segments.
- The amount of discrepancy.
- The thickness of enamel present on the teeth of the region.
- The carious or oral hygiene status of the patient.

INDICATION FOR PROXIMAL STRIPPING

- Done when space requirement is minimal (2.5-3 mm).
- Generally undertaken when there exists a Bolton's tooth material excess (less than 2.5 mm).
- Usually when the excess exists in the mandibular anterior segment, this does not mean that it cannot be performed in other parts of the dentition.

CONTRAINDICATIONS FOR PROXIMAL STRIPPING

- Patients who are susceptible to caries.
- Proximal stripping is avoided in young individual as their teeth may possess large pulp chambers.

PROCEDURE

The procedure for under taking proximal stripping involves three steps:

1. Assessing space requirements.
2. Selecting the teeth and amount of enamel to be stripped.
3. Enamel stripping.

Assessing Space Requirements

The arch perimeter analysis or the Carey's analysis is used to assess the space requirements in the two arches. A case with tooth material excess of less than 2.5 mm per arch is an ideal candidate for proximal stripping .

The Bolton's analysis can also be used to assess the excess tooth material and for locating the area in which the fault lies.

Selecting Teeth and the Amount of Enamel to be Stripped

The most frequently stripped teeth are the mandibular incisors but all the teeth baring the banded molars can be stripped. The maxillary anterior teeth can be stripped if there is an excess tooth material in the maxillary anterior region and the enamel thickness is sufficient.

To assess the thickness of the enamel, it is advised to take intraoral periapical views of the region. The long-cone technique is favored as the amount of distortion is less. No more than half the thickness of enamel can be removed. It is advised to distribute the amount of space to be created over a larger number of teeth and between the mesial and distal surfaces, so as to reduce the amount of enamel to be stripped from one particular location.

Enamel Stripping

Enamel stripping is generally performed using:

- *Metal abrasive strips* (Fig. 21.1A) Metal strips with abrasive particles stuck to them are available. They are usually safe sided, i.e. only one side has the coating of abrasive particles. Special holders are available commercially to aid their use (Fig. 21.1B). Depending upon the size of the particles coated the strips can be—coarse, medium or fine. Usually fine abrasive strips are used; this avoids the deep scratching of the enamel.
- *Perforated diamond disks* (Fig. 21.1C) Perforated diamond disks are extensively used for the purpose. They are relatively flexible and strip both the adjacent teeth.
- *Safe sided corborundum disks* These were used extensively initially. But have the inherent problem of being rigid and brittle. The chances of their breaking and causing injury to the patient and clinician are maximum. They are difficult to use in the posterior region.



Fig. 21.1A: Safe side metallic abrasive strip



Fig. 21.1B: Special abrasive strip holder



Fig. 21.1C: Perforated diamond disk

- *Thin fissure burs* Thin straight or tapered burs (Fig. 21.1D) can be used for proximal stripping. They usually leave deep scars on the enamel and hence need to be followed by metallic abrasive strips to polish the region.

The proximal stripped teeth tend to be more sensitive because of the reduction in the enamel thickness. This predisposes them to be more prone to sensitivity and caries. The scratched enamel surface also attracts more plague. This requires that a strict regime be followed for the maintenance of oral hygiene and fluoride application. This not only reduces sensitivity but also protects these teeth from acid attacks and resulting caries.



Fig. 21.1D: Long thin diamond burs

Advantages of proximal stripping

- It may be possible to avoid extractions in borderline cases where space requirements are minimal.
- Tooth material excess can be reduced, achieving better interdigitation, overbite and overjet.
- Broad contacts may add to stability of results.
- Localized malalignments can be corrected without involving too many teeth, especially in adult patients.

Disadvantages of proximal stripping

- Sensitivity is most frequently seen following the procedure.
- The roughened surface of enamel increases caries susceptibility.
- Difficult to reproduce exact morphology of the tooth. This is especially true in case of maxillary anterior teeth. The shape created may not be as esthetic.
- Loss of proximal contacts may result in food lodgment.

ARCH EXPANSION

The expansion of the arch has been one of the oldest means of creating space the dental arches. Yet, expansion has remained a dogma to the orthodontists as it has been afflicted with controversy after controversy. The rapid expansion versus slow expansion. If rapid then till what age? Timing? And how much is enough? When slow and when rapid expansion? The controversies will continue and so will the use of expansion devices.

What is clear is that basically based on the duration of time taken to achieve the desired expansion, expansion devices can be classified as:

- Rapid maxillary expansion devices.
- Slow expansion devices.

RAPID MAXILLARY EXPANSION DEVICES

The first reported use of a rapid expansion device, dates back to the year 1860, when Emerson C. Angell first used a double jackscrew kind of an appliance to expand the maxillary arch in a 14½ years of a girl (Fig. 21.2A). He achieved an increase in arch width of 0.25 inches in two weeks with a resultant midline diastema. The second instance of a simpler appliance without the use of a screw was in the year 1877, when Walter



Fig. 21.2A: Diagramatic representation of the expansion appliance used by Emerson Angell

Coffin demonstrated the expansion of the maxillary arch using his coffin spring. The coffin spring was known to cause the separation of the mid-palatal suture in young children.

Yet, the rapid maxillary expansion devices of the time did not gain popularity. Slow expansion devices remained in vogue and it was as late as 1956 when Korkhaus reintroduced the appliance in the United States of America. It was the hard work, with extensive research on animals, that Andrew Haas managed to popularize the rapid maxillary appliance.

PHILOSOPHY FOR THE USE OF RME APPLIANCES

The RME appliance is essentially a dentofacial orthopedic appliance, which tends to produce its changes by splitting the mid-palatine suture. The rationale being that if extreme forces are applied on to the palatal shelves, the interlying suture splits and results in true skeletal changes. The teeth are generally used for the purpose of transmitting the forces onto the maxillary bone proper.

ANATOMY OF THE MID-PALATINE SUTURE AND THE MAXILLA

The hard palate is composed of the palatine process of the maxilla and the maxillary process of the palatine bones. The palatine bones together with the maxilla also form the floor of the nose and a part of the lateral walls of the nasal cavity. The palatine bone articulates with the maxilla by a transverse palatal suture and up the lateral wall of the nasal cavity. Posteriorly, the palatine bone articulates with the pterygoid process of sphenoid. The maxillary bones are joined posteriorly and superiorly to various bones including the frontal, ethmoid, nasal, lacrimal, zygomatic, etc. Thus, the anterior and inferior aspects are relatively free.

The inter-palatine suture joins the paired palatine bones at their horizontal plates and is a continuation of the intermaxillary suture. Theoretically, it forms the junction of the three opposing pairs of bones—the premaxillae, the maxilla and the palatines. Practically, they are treated as a single entity—the mid-palatine suture (MPS).

Studies have indicated that the development of the mid-palatine suture passes through three distinct stages. It shows a large individual variation to closing, ranging from 15 to 19 years of age. A greater degree of obliteration occurs posteriorly than anteriorly with maximum obliteration in the third decade of life.

EFFECTS OF THE RME

On the Maxillary Teeth and Alveolar Bone

The posterior teeth are used as handles to transmit forces to the maxilla. They tend to tip buccally (Figs 21.2B and C) due to the compression of the periodontal ligament on the pressure side. There is bending of the adjacent alveolar process along with limited tipping and/or extrusive orthodontic movement of the teeth.

There is distinct appearance of a midline diastema (Fig. 21.2Di), which appears within days of initiating RME therapy. The diastema is generally half the distance of the distance by which the screw is activated. The diastema is reported to close simultaneously within 6 months due to the trans-septal fiber traction (Fig. 21.2Dii).

Maxillary Skeletal Effects

The palatine processes separate in a triangular or wedge-shaped manner when viewed occlusally (Fig. 21.2E). The most anterior and inferior points move the maximum distance with the fulcrum somewhere with in the nasal airway. A similar triangular opening is also seen in the supero-inferior direction, maximum towards the oral cavity and progressively less towards the nasal aspect (Fig. 21.2F).

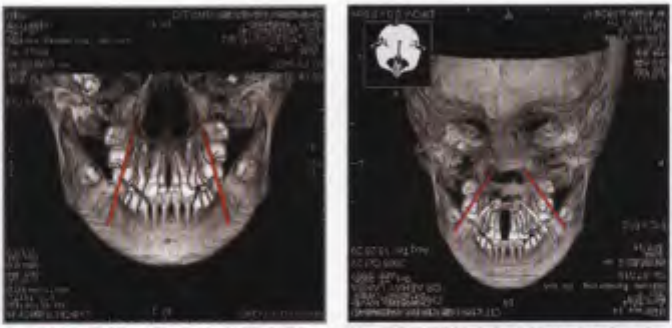


Fig. 21.2B: (1) Normal axial inclination of the anchor molars, (2) Buccally tipped anchor molars



Fig. 21. 2C: Pre-and during treatment views of a patient with Hyrax type of banded RME appliance (Patient PS)



Fig. 21. 2Di: The effect of rapid maxillary expansion on the midpalatal suture. Note the midline diastema



Fig. 21. 2Dii: Midline diastema closes within 6 months due to trans-septal fiber traction

On the Mandible

The mandible rotates downward and backwards due to the downward movement of the maxillary posterior teeth in a buccal direction. The palatal cusps of the maxillary posterior teeth, which should ideally occlude in the occlusal grove of the mandibular posterior teeth,

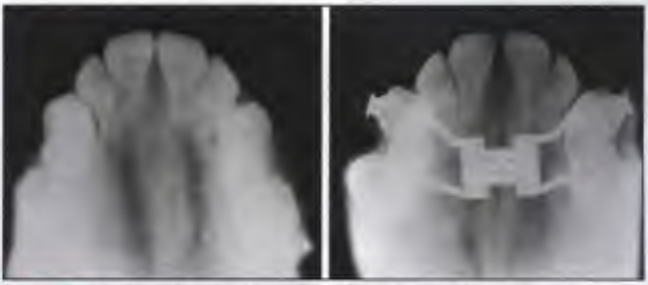


Fig. 21.2E: The triangular split of the mid-palatine suture is evident on the occlusal view radiograph (patient PS)



Fig. 21.2F: Triangular split of the maxilla in the supero-inferior view

tend to occlude with the lingual slopes of the buccal cusps of these teeth, there by giving the effect of opening the bite (Fig. 21.2C).

On the Nasal Cavity and Adjacent Cranial Bones

The RME tends to increase the intranasal space as the outer walls of the nasal cavity move apart and the palatal shelves flatten out, making the nasal floor broader. The effects can be sufficient at times to correct a deviated nasal septum. Improvement in the nasal breathing is almost universally accepted.

The parietal as well as the zygomatic bones show signs of some form of realignment at the sutures, especially in younger individuals.

Indications for RME use

RME appliances are ideally indicated in growing individuals with severely constricted maxillary arches, involving airway impairment or mouth breathing tendencies. They are also indicated in other cases of:

- Posterior cross bites with real or relative maxillary deficiency
- Cleft patients
- Along with facemask therapy
- Class III cases with minor maxillary deficiency
- As part of interceptive orthodontics

TYPES OF RAPID MAXILLARY EXPANSION APPLIANCES

Over the years numerous types of RME appliances have been used. They can be best classified as:

- Removable appliances
- Fixed appliances
  - — Tooth-borne
  - — Tooth and tissue-borne.

Removable RME Appliances

The efficiency of removable RME appliances is doubtful. The appliance basically consists of a screw in the midline with retentive claps on the posterior teeth. The acrylic plate is split in the middle and activations of the screw forces the two halves apart to result in the desired expansion.

This appliance is more effective when used in the early mixed dentition phase. Its efficiency in the late mixed dentition and older patients is suspect because of the ossification of the mid-palatal suture and the

resulting delay in splitting causes the retention of the appliance to get compromised. Patient compliance is paramount to all removable appliances.

Fixed RME Appliances

The fixed RME appliances can be either tooth-borne or tooth and tissue-borne.

The Isaacson type or the Hyrax type of appliance best exemplifies the tooth-borne appliances.

ISAACSON RME APPLIANCES

The Isaacson type of appliance (Fig. 21.2G) consists of a metal famework soldered both labially as well as palatally on the first premolar and molar bands. A spring loaded screw often called the front expander (developed at the University of Minnesota, dental school) is soldered on the palatal extension of the metal framework. Closing a nut, which tends to compress the spring, activates the expander.



Fig. 21.2G: Isaacson type of expansion appliance using Minne expander

HYRAX RME APPLIANCES

This type of appliances makes use of the HYRAX screw, named after the ability to keep it clean (the hygienic rapid expander). The screw has heavy wire extensions, which can be adapted to follow the contour of the palate and are soldered to either metal bands (Fig. 21.2C and 21.2Hi) or cast cap splints or a wire framework that has acrylic splints (Fig. 21.2Hii) or embedded in acrylic splints (Fig. 21.2Hiii).



Fig. 21.2H(i): Hyrax type of expansion appliance



Fig. 21.2H (ii): Pre- and postexpansion views of acrylic cap splint RME appliance (Patient XY)

The Derichsweiler or the Hass Type of appliances best exemplifies the tooth and tissue-borne RME appliances.



Fig. 21.2H (iii): RMC screw with acrylic splints (Photograph courtesy; *Scheu-Dental, Germany*)



Fig. 21.2J: Hass type of expansion appliance

DERICHSWEILER RME APPLIANCES

Wire tags are soldered to premolar and molar bands; these are incorporated in an acrylic plate which contains a screw in the midline (Fig. 21.2I). This appliance is rarely used nowadays.

HASS RME APPLIANCE

This appliance is a rigid appliance which not only transmits forces on to the teeth but also on to the palatal shelves directly. It has a rigid wire framework, which is soldered to the first premolar and molar bands both buccally and palatally. The palatal extensions of the 1.2 mm diameter wire are incorporated in an acrylic plate which contains an expansion screw in the midline (Fig. 21.2J).



Fig. 21.2I: Derichsweiler type of expansion appliance

ACTIVATION OF THE RME APPLIANCE

The basic principle of the appliance involves the generation of forces that are capable of splitting the mid-palatine suture. Hence, the forces should be definitely more than the usually used orthodontic forces. The forces generated are close to 10 to 20 pounds. An expansion of 0.2 to 0.5 mm should be achieved per day. The screw is activated at between 0.5 to 1 mm per day and about 1 cm of expansion can be expected in 2 to 3 weeks. The activation schedules tend to vary depending upon the age of the patient and form of the appliance.

Timms has suggested an activation of 90°, morning and evening for patients up to the age of 15 years. In patients above this age, he suggests an activation of 45° four times a day.

Zimring and Isaacson recommended, two turns per day for initial 4 to 5 days followed by one turn per day in growing individuals. For adults the recommended two turns each for the first two days followed by one turn per day for the next 5 to 7 days and then only one turn every alternate day till the desired expansion is achieved. Surgery can be used as an adjunct to RME therapy in adult patients, especially in the third decade of life or later.

Retention Following RME Therapy

Corrections achieved using the RME appliance are likely to relapse unless sufficient time is given for the reorganization of the concerned hard and soft tissues. The occlusion is relatively deranged and cannot be



Fig. 21.2K: Cold cure acrylic stop used to immobilize the expansion screw (patient XY)



Fig. 21.3A: Maxillary appliance incorporating a screw in the midline



Fig. 21.2L: A transpalatal arch used for retention (patient PS)



Fig. 21.3B: Mandibular appliance incorporating a screw (Photograph courtesy; Leone, Italy)

expected to aid in retention. Usually the same appliance can be used for retention after immobilizing the screw using cold cure acrylic (Fig. 21.2K). Alternatively the expansion can be maintained using a transpalatal arch (TPA) (Fig. 21.2L) or any of the other appliances. The TPA has the advantage that the fixed appliance treatment can proceed unhindered.

SLOW EXPANSION DEVICES

Slow expansion was the brainchild of the father of modern dentistry, Pierre Fauchard. Slow expansion involves the use of relatively lesser forces (2 to 4 pounds) over longer periods (2 to 6 months) to achieve the desired results. Slow expansion has been at times termed dentoalveolar expansion.

Indications of slow expansion

- Correction of unilateral cross bites.
- Correction of 'V' shaped arches as in "thumb suckers".
- Preparation for bone grafts in cleft cases.
- Minimal crowding in the upper arch (1-2 mm).
- Elimination of a displacement.

APPLIANCES USED FOR SLOW EXPANSION

Screw Appliances

Various screws have been used for the expansion of maxillary (Fig. 21.3A) and the mandibular arches (Fig. 21.3B). These screws have a smaller pitch and are activated less frequently as compared to screws used for RME appliances.

Coffin Spring

This appliance is capable of producing slow expansion, even though it has been shown to split the palate especially when used in patients in the early mixed dentition. It is an ideal appliance to treat unilateral cross bites. It has an advantage over screw appliances in that differential expansion can be obtained in the premolar and molar regions.

The appliance consists of an omega shaped 1.2 mm diameter wire, with the base of the omega placed posteriorly in the midline. Two separate acrylic wings are made around the wire framework on the slopes of the palate, these also contain the retentive clasps (Fig. 21.3C).

Simply pulling the wings apart activates the appliance. This should be done first in the premolar region and then in the molar region. It can also be activated using a three-pong plier at the base of the omega, but are rarely used as they tend to distort the spring. Care must be taken to maintain the sides of the appliance in the same plane during adjustment. Ideally marking holes should be drilled on the two wings and a divider should be used to measure the amount of activation given (Fig. 21.3D).



Fig. 21.3C: The coffin spring



Fig. 21.3D: A coffin spring (1.25 mm wire) for transverse arch expansion

Quad/Tri/ Bi-Helix

The quad-helix evolved from the coffin spring. The appliance is a precursor to the tri- and the bi-helix appliances. They are all named after the number of helices incorporated in the appliance. The quad helix consists of four helices made of 0.038" diameter wire, soldered to the molar bands (Fig. 21.3E). The increased length of wire increases the range of action and flexibility, and decreases the force levels. The tri- and the bi-helix appliances incorporate only three and two helices respectively.

The quad-helix consists of two anterior and two posterior helices. The portion of wire in between the two anterior helices is called the anterior bridge and that connecting the anterior helices and the posterior helices is called the palatal bridge. The free wire ends that are usually adapted close to the premolar teeth are called the outer arms. The outer arms are soldered to the molar bands.

The appliance is capable of producing differential expansion, i.e. it can be activated to produce different



Fig. 21.3E: The Quad helix palatal expansion appliance

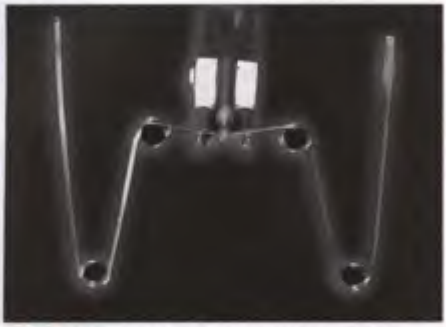


Fig. 21.3Fi: Activation at the anterior bridge produces expansion in the molar region



Fig. 21.3Fii: When the outer arms are activated, the premolar and canine region gets expanded

expansion levels in the premolar and molar regions. It can be activated prior to cementation of the bands by stretching the molar bands apart or in the mouth with the use of a three-prong plier. When the anterior bridge is adjusted the molar expansion is produced (Fig. 21.3Fi) and when the palatal bridges are activated, the premolar and canine region gets expanded (Fig. 21.3Fii).

Ni-Ti Expanders

The latest in the series of expanders are the nickel-titanium expanders (Fig. 21.3G). These make use of the high flexibility of the nickel-titanium alloy to produce gentle expanding forces in the range of 300-350 gm. The Ni-Ti expanders are available in various sizes and can be inserted in lingual sheaths welded on to molar bands.

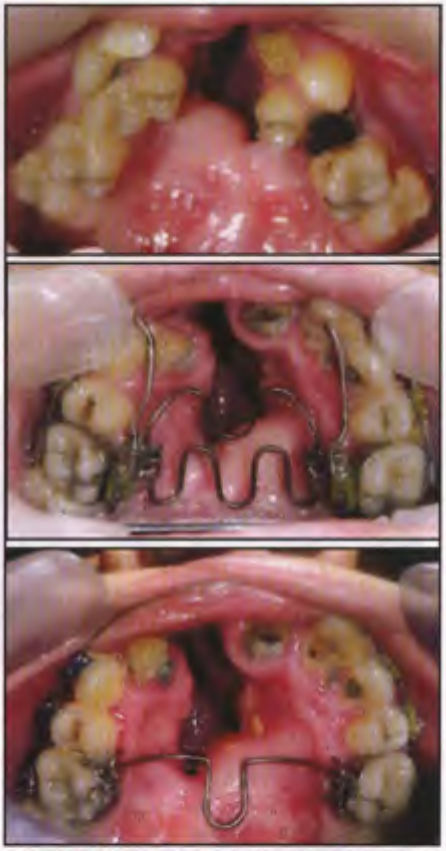


Fig. 21.3G: The Ni-Ti expander used in a cleft case

The Schwarz Appliance

This is a horse-shoe shaped removable appliance that fits along the lingual border of the mandibular dentition and is capable of expanding the mandibular arch.



Fig. 21.3H: The Schwarz appliance

Its inferior border extends below the gingiva along the lingual gingival margin. It has a expansion screw in the midline and is retained by ball clasps (Fig. 21.3H).

The appliance is activated once a week and produces an expansion of 0.25 mm in the midline. It is ideally indicated in early mixed dentition cases with mild to moderate crowding in the mandibular anterior region, with significant lingual tipping of the posterior dentition. It may be used for mandibular dentoalveolar decompensation prior to RME appliance therapy in the maxillary arch.

DISTALIZATION OF MOLARS

Distalizing of molars gained popularity, as it was sometimes difficult to convince the patient for extraction of otherwise healthy teeth. Basically the procedures involved have one purpose, i.e. to push the maxillary and/or mandibular terminal molars posteriorly. This increases the arch length by the same length as the amount of distalization achieved.

The distalization procedures are usually undertaken before the eruption of the second permanent molars. It is definitely much easier to move one molar distally as compared to two (i.e., first and second permanent molars). The appliances used for the purpose of distalization of molars can be classified as:

- Extraoral distalizing appliances
- Intraoral distalizing appliances.



Fig. 21.4A: The cervical headgear, frontal view



Fig. 21.4B: The cervical headgear, lateral view

EXTRAORAL DISTALIZING APPLIANCES

The most frequently used extraoral distalizing appliances are the headgears. The headgear assembly consists of

- Force delivering unit—face-bow, J hook
- Force generating unit
- Anchor unit—head cap, neck strap.

The basic philosophy of using headgears is to pit the molars against extraoral anchor units, e.g. the occiput or the cervical regions (Figs 21.4A and B). The forces generated by the force generating units can be so adjusted so as to distalize the maxillary molars.

Bilateral as well as unilateral distalization is possible using headgears. The forces can be so adjusted that the molars undergo bodily or a distal tipping movement in the posterior direction. A distal tipping movement is only recommended in cases with horizontal growth pattern cases with a square face and deep bites in excess of normal. In such cases, the tipping helps in opening the bite as well as increasing the lower anterior facial height. The treatment using headgears is most effective before the eruption of the second permanent molars. Also, the patient compliance is critical for successful results to be achieved. This refers not only regular wear but also the number of hours of wear. A minimum of 12 to 14 hours of wearing is recommended for orthopedic effect and 18-20 hours for orthodontic (molar distilization) effect.

INTRAORAL METHODS OF DISTALIZING MOLARS

At times patient compliance is a major problem with extraoral appliances. Hence, intraoral methods were devised for the purpose. Intraoral appliances generate tooth-moving forces by mainly three methods— the use of screws, open coil springs or wire springs incorporating helices. Magnets have been designed for intraoral use for distalizing, but are not very popular.

The intraoral appliances take anchorage from the palate and the anteriorly placed premolars. By pitting more root surface area and/or the rugae region of the palate these appliances are able to minimize the proclining effect of the reciprocal forces generated while distalizing the molars. Here also the efficiency of the appliances is more before the eruption of the second permanent molars.

The various intraoral distalizing appliances include:

- Schwartz plate
- Sagittal appliance
- First class
- Veltribilateral and monolateral sagittal screws
- Open coil springs
- Jones jig
- Distal jet appliance
- Fast back appliance
- Pendulum appliance
- Intraoral magnets



Fig. 21.4C: The 'Y' plate



Fig. 21.4D: The sagittal appliance

- Jasper jumper
- Lip bumper

Schwartz Plate

This is an early forerunner of the sagittal appliance, and was also referred to as the 'Y' plate because of the shape of the cuts on the base separating the plate into its component parts (Fig. 21.4C). It is rarely used nowadays.

Sagittal Appliance

This is a removable appliance with a screw incorporated for the distalization of the first permanent molars (Fig. 21.4D). The anchorage is gained by the remaining teeth anterior to the first permanent molars.



Fig. 21.4E: The first class appliance (Photograph courtesy Leone, Italy)

Retention clasps are used to hold the appliance in place. The activation of the screw causes the molars to be pushed distally.

These appliances did not gain popularity even though they can be used to distalize the maxillary or the mandibular molars primarily because the control achieved is not as good as with other appliances. The molars are tipped distally and true bodily movement is not achieved. The removable nature of the appliance also makes it patient dependent and compliance effect efficiency.

First Class

This is a screw-based appliance commercially available from Leone (Italy) (Fig. 21.4E). The anchorage is gained by a palatal plate, which is fixed to extensions from the first premolar bands. The force generating assembly consists of a telescopic screw mechanism where the activation of the screw causes a 0.1 mm movement of the molars in a distal direction. The recommended activation is one turn everyday till over correction is achieved.

Veltribilateral and Monolateral Sagittal Screws

These screws are marketed by Leone (Italy). The bilateral sagittal screw is used to achieve bilateral distalization of the maxillary first permanent molars (Fig. 21.4Fi). The appliance consists of a Nance button attached to the premolar segment of the screw (Fig. 21.4Fii). The monolateral screw design (Fig. 21.4Fiii) is different, but the appliance is constructed in the same manner.



Fig. 21.4Fi: The Veltri-sagittal screw appliance (Photograph courtesy Leone, Italy)



Fig. 21.4Fii: Veltribilateral sagittal screw



Fig. 21.4Fiii: Veltrimonolateral sagittal screw

Open Coil Springs

Various clinicians for the purpose of distalization of molars have assembled appliances using open coil



Fig. 21.4Gi: Bilateral Jones jig appliance



Fig. 21.4Gii: Unilateral Jones jig appliance



Fig. 21.4Giii: Following distalization

springs. The appliances are basically soldered to bands cemented to premolars and the molar teeth. Usually a buccal and/or palatal wire containing an open coil spring is used to achieve the desired forces. A palatal button is usually added to the premolars to augment retention.

Jones Jig

Jones Jig (Figs 21.4Gi-Giii) is a commercially available distalizing appliance available from American Orthodontics (USA). It consists of an open coil spring placed on the buccal aspect, which generates the required forces when it is compressed. Anchorage support is provided with a Nance appliance. It can be used for both unilateral as well as bilateral distalization. It has been shown to distalize molar teeth even after the eruption of the permanent second molars.

Distal Jet Appliance

The Distal Jet appliance is a piston and tube-based appliance commercially available from American Orthodontics (USA). The appliance is capable of distalizing the maxillary second permanent molars. The manufacturers claim the appliance generates a purely translatory movement.

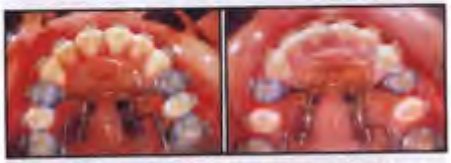
Fast Back Appliance

The fast back appliance is a type of open coil spring appliances (Fig. 21.4H), commercially available from Leone (Italy). It is by far the most advanced version among such appliances. It uses two different strength nickel-titanium springs (200 and 300 gm). The appliance also has a self-locking terminal stop, which makes the appliance fully programmable and considerably increases its safety during use. Fixed appliance can be initiated without having to wait until distalization is complete.

Pendulum Appliance

The pendulum appliance (Fig. 21.4I) is a hybrid appliance that uses a large Nance acrylic button in the palate for anchorage, along with 0.032" TMA springs that deliver a light, continuous force to the palatal aspect of the maxillary first permanent molars. Thus, the appliance produces a broad swinging arc or pendulum of force from the midline of the palate to the upper molars.





Figs 21.4H(I) and (II): Fast back appliance (Photograph courtesy Leone, Italy)



Fig. 21.4I: Pendulum appliance, start of- and post-treatment views



Fig. 21.4J: Distalization appliance incorporating repelling magnets

Intraoral Magnets

Magnets have been used along with the fixed orthodontic appliances for the purpose of space closure as well as regaining lost space. For the purpose of distalizing they are used in repulsion mode along with a Nance button for retention (Fig. 21.4J).

- Magnets used are
- Samarium cobalt magnets—$SmCo_5$ and Sm_2Co_{17}
- Neodymium iron boron magnets—$Nd_2 Fe_{14}B$

Magnets are not the preferred mode of distalizing molars due to their inherent disadvantages of cost, size and rapid force decay over distance moved.

Lip Bumper Appliance

The lip bumper is a simple appliance, which extends slightly beyond the mandibular incisors and connects distally onto the mandibular molars (Fig. 21.4K). It generally has a labial plastic sleeve or acrylic cover in the anterior region. This flat surface receives the forces exerted by the lower lip and transmits them to the mandibular molars. It should be used early in the mixed dentition phase to bring about minor distalization otherwise it can be used for the purpose of uprighting the mesially tipped mandibular molars.

A modification of the lip bumper is used to distalize the maxillary molars and is called the Denholz appliances. Here the lip bumper is attached on to the maxillary molars by a vertical extension. The functioning of the appliance is similar. The amount of actual distalization achieved is limited.



Fig. 21.4K: Lip bumper appliance

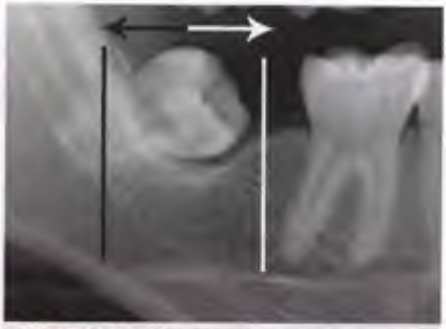


Fig. 21.5A: Mesially tipped molars occupy more space

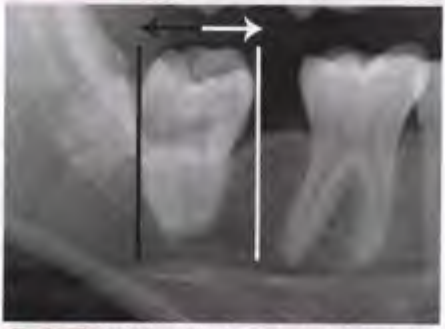


Fig. 21.5B: Uprighting of tilted posterior teeth creats space

UPRIGHTING OF TILTED POSTERIOR TEETH

Tilted posterior teeth always occupy more space (Figs 21.5A and B). Molars tend to tip mesially when the deciduous second molars are lost early or decay on the distal surface of this tooth is no/not restored at the appropriate time or with the ideal contour. A delayed eruption of the first or the second molar may also cause the posterior teeth to tilt mesially.

Uprighting of molars can lead to an arch length gain of 1-1.5 mm. Fixed appliances are ideally used for the purpose. Space regainers or the various screw appliances are also used frequently. The lip bumper and its modifications can also achieve good results.

DEROTATION OF POSTERIOR TEETH

Rotated posterior teeth occupy more space (Fig. 21.6A). Derotation of these teeth can help regain this space. The space regained varies upon the tooth concerned and the extent of rotation. For a similar degree of rotation, the molars occupy more space as compared to premolars; where as rotated anterior teeth occupy less space.

Derotation can be best achieved using a couple (forces equal in magnitude but opposite in direction) on the lingual and buccal surfaces of the tooth (Fig. 21.6B). Derotation springs are usually not effective for derotating posterior teeth. Any fixed appliance system with a two point contact has more efficient rotation control (Fig. 21.6C).

PROCLINATION OF ANTERIOR TEETH

Proclination of anterior teeth can be undertaken in cases where these teeth are retroclined or their proclination will not effect the soft tissue profile of the patient adversely or the stability of the results achieved. Any of the proclining springs ('Z' spring, mattress spring, etc.) or screws (medium-, mini-, or micro-screws) or fixed appliances (Fig. 21.7) can be used for the purpose.

EXTRACTION

Painless removal of teeth from its socket is termed as Extraction. It is one of the most common methods of gaining space in the arch. In orthodontics, establish-

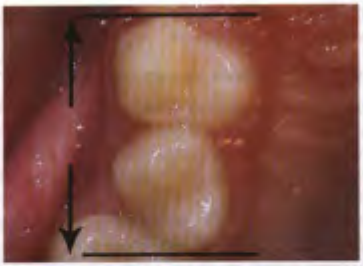


Fig. 21.6A i

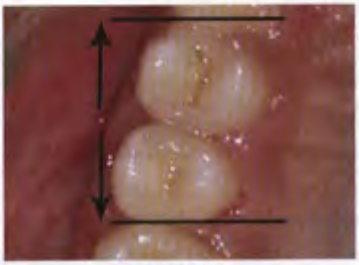


Fig. 21.6A ii

Figs 21.6A i and ii: Rotated posterior teeth occupy more space

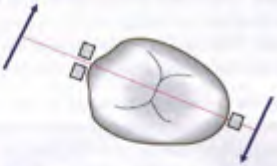


Fig. 21.6B: Couple of two forces used to achieve derotation

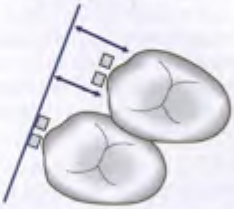


Fig. 21.6C: Two point contact in fixed appliances provides better rotational control







Fig. 21.7: Space gained by proclining the anterior teeth

ment of a normal functional occlusion in balance with supporting structures occasionally requires reduction of one or more teeth.

HISTORICAL BACKGROUND

As early as 1771, John Hunter recognized the role of extraction in orthodontics in his book *Natural History of the Teeth*. Extraction in orthodontics has remained a subject of speculation and contention over a long

period of years. Angle was the leader of the so called "new school" of orthodontics. He taught that the basic foundation for the correction of malocclusion was the retention of the full complement of teeth. According to him, if crowded teeth were aligned in correct relation to each other, improved function of the masticatory apparatus would result in growth of the jaws, creating adequate space for the dentition. Therefore, he advocated expansion of arches in all orthodontic patients. However, some of his contemporaries like Calvin Case (his former student) contended that teeth may be extracted occasionally to produce lasting results. They reasoned that jaw growth does not depend on function and if the jaws are too small to accommodate teeth, then extraction would be required to relieve irregularity of teeth. Neither esthetics nor stability would be satisfactory in the long run for patients undergoing expansion for alignment. This led to the Great Extraction Controversy of the 1920s between the two schools of thought.

By the late 1940's, extraction was reintroduced into orthodontics by Charles Tweed who found post-treatment occlusion more stable in patients treated with extractions. By the early 1960's, more than half the orthodontic patients had extractions of some teeth as part of their orthodontic treatment.

THE NEED FOR EXTRACTION

Extraction of teeth as a part of orthodontic treatment may be required in the following circumstances.

Arch Length—Tooth Material Discrepancy

Ideally the arch length and tooth material should be in harmony with each other. If the dentition is too large to fit in the dental arch without irregularity, it may be necessary to reduce the dentition size by the extraction of teeth. It is not normally acceptable to increase the dental arch size, because the increased dental arch dimension would not be tolerated by the oral musculature.

Guidelines for extraction in class I crowding/protrusion:

- Less than 4 mm arch length discrepancy—extraction rarely indicated.
- 5-9 mm arch length discrepancy—non-extraction or extraction possible; depends on the details of the therapy
- 10 mm or more arch length discrepancy—extraction almost always required.

Correction of Sagittal Interarch Relationship

Abnormal sagittal malrelationship such as Class II / III malocclusion may require extraction to achieve a normal interarch relationship.

In a Class I malocclusion (normal sagittal interarch relationship) it is preferable to extract in both the arches because it is not advisable to discourage the development of only one arch more than the other.

In most Class II cases with abnormal upper proclination, normal alignment of the lower teeth and where A point is abnormally forward relative to the B point, it is advisable to extract teeth only in the upper arch and to retract the maxillary incisors and canines. However, when the lower arch is crowded or molars are not in full cusp Class II molar relationship, it might be preferable to extract in both the arches.

Class III cases are usually treated by extracting teeth only in the lower arch.

Extraction for the Relief of Crowding

Extraction for the relief of crowding will be governed by:

Condition of the teeth Fractured, hypoplastic, grossly carious teeth , root canal treated teeth and teeth with large restorations are preferred for extraction over healthy teeth. The main consideration is the long-term prognosis for the tooth rather than the appearance.

Position of the crowding Crowding in one part of the arch is more readily corrected if extractions are done in that part rather than a remote area of the arch. However, incisor crowding is usually relieved by premolar extraction as it gives a more pleasing appearance and occlusal balance than with incisor extraction. The first premolar, positioned in the center of each quadrant, is usually near the area of crowding whether in the anterior or buccal segment. Hence, it is also the tooth most frequently extracted along with orthodontic treatment.

Position of the teeth Grossly malpositioned teeth which are difficult to align may often be the teeth of choice for extraction. The position of the apex of the tooth must be considered as it is more difficult to move the apex than the crown.

DIFFERENT EXTRACTION PROCEDURES

- Balancing extractions
- Compensating extractions
- Phased extractions
- Enforced extractions
- Wilkinson extractions
- Therapeutic extractions

Balancing Extractions

If a tooth is removed from one side of the dental arch which is crowded, or which has complete contact of teeth all around, there is a tendency for the remaining teeth to move towards the extraction space. This is in the form of forward movement of teeth behind the space, or movement of anterior teeth across the center of the arch, resulting in asymmetry. It is usual to balance extractions in order to prevent such asymmetry (Fig. 21.8).

Balancing extractions may be defined as the removal of a tooth on the opposite side of the same arch (although not necessarily the antimere) in order to preserve symmetry.

Compensating Extractions

Removal of the equivalent tooth in the opposing arch to maintain buccal occlusion. In some Class I crowding cases, it is necessary to extract in both the arches to maintain lateral symmetry. Compensating extractions preserve interarch relationship by allowing the posterior teeth to drift forward together.



Fig. 21.8: Early eruption of left lateral incision causing a midline shift to be compensated by extracting the deciduous canines

Phased Extractions

It may be possible to effect a change in molar occlusion by extracting in one arch only, or a few months earlier than in the other. This effect is particularly marked after premature loss of deciduous teeth and should be borne in mind when considering enforced extraction of these teeth.

Enforced Extractions

These extractions are carried out because they are necessary as in the case of grossly decayed teeth, poor periodontal status, fractured tooth, impacted tooth, etc.

Wilkinson Extraction

Wilkinson advocated extraction of all the four first permanent molars between the age of 8½ and 9 years. The basis for such extractions is the fact that first molars are highly susceptible to caries. The other benefits of extracting first molars at an early age are:

To avoid third molar impactions by providing additional space for their eruption.

To reduce crowding in the arch However, Wilkinson's extractions are not usually carried out because of various drawbacks. First molar extraction offers limited space for crowding correction, adjacent teeth tip into the extraction space and the principal anchor unit for orthodontic appliances is lost.

Therapeutic Extractions

These are extractions carried out for the purpose of treatment.

CHOICE OF TEETH FOR EXTRACTION

Choice of teeth to be extracted depends on local conditions which include:

- Direction and amount of jaw growth
- Discrepancy between size of dental arches and basal arches
- State of soundness, position and eruption of teeth
- Facial profile
- Degree of dentoalveolar prognathism
- Age of patient
- State of dentition as a whole

INCISORS

Maxillary Incisors

The incisors, especially the maxillary central incisors, are rarely extracted as a part of orthodontic therapy.

Indications for maxillary incisor extraction

i. Unfavorably impacted maxillary incisors.
ii. Buccally or lingually blocked out lateral incisor with good contact between central incisor and canines.
iii. If a lateral incisor is crowded in linguo-occlusion with its apex palatally displaced and if the canine is erupting in a forward position and is upright or distally inclined, lateral incisor extraction is indicated (Fig. 21.9A).
iv. Grossly carious incisor that cannot be restored.
v. Trauma/irreparable damage to incisors by fracture.

Mandibular Incisors

It is often very tempting to extract a lower incisor to relieve crowding particularly when it is confined to the anterior segment but its extraction should be avoided as far as possible because it causes:

a. Remaining anterior teeth to imbricate
b. Although crowding may be relieved in the short term, forward movement of buccal teeth leaves incisor contacts and positions less than ideal
c. Lower intercanine width (ICW) decreases resulting in a secondary reduction in the upper ICW with crowding in the upper labial segment
d. Deep bite
e. Retroclination of lower incisors
f. It is not possible to fit four upper incisors around three lower incisors, either an increase in overjet or upper incisor crowding have to be accepted.

However, in a few well-defined cases, extraction of lower incisors may be appropriate:

a. When one incisor is completely excluded from the arch and there are satisfactory approximal contacts between other incisors (Figs 21.9B and 21.9C).
b. Poor prognosis as in case of trauma, caries, bone loss, etc.
c. Severely malpositioned incisor.
d. Lower canines are severely inclined distally and lower incisors are fanned—it is very difficult to correct this condition by extractions further back in the arch. The most upright incisor is selected for extraction so that other teeth can be tipped into correct position.



Fig. 21.9A: Maxillary lateral incisor extraction



Fig. 21.9B: Mandibular central incisor extraction



Fig. 21.9C: Mandibular lateral incisor extraction

e. In mild Class III incisor relation with an acceptable upper arch and lower incisor crowding, a lower incisor may be extracted to achieve normal overjet, overbite and to relieve crowding.
f. Bolton's mandibular anterior excess ≥ 4 mm.

Contraindications for mandibular incisor extraction

i. Deep bite cases with horizontal growth pattern.
ii. All cases which require upper first premolar extraction while canines are in a Class I relationship.
iii. Bimaxillary crowding cases with no tooth size discrepancy in the incisor area.
iv. Cases having anterior discrepancy due to either small lower incisors or large upper incisors.

CANINES

The permanent canines are important teeth and are not frequently extracted as a part of orthodontic treatment. Their extraction causes flattening of the face, altered facial balance and change in facial expression.

When the lower canine is crowded, it is sometimes tempting to extract this tooth.

However, this is avoided because the approximal contact between the lateral incisor and first premolar is rarely satisfactory.

Indications

Canine may be extracted in one of the following instances:

- Mandibular canine may be extracted when it is likely to be very difficult to align, e.g. when it is excluded from the arch and the apex is severely malpositioned or when it is unfavorably impacted.
- Maxillary canines develop far away from their final location and have a long path of eruption from their development site to their final position in the oral cavity. Therefore, they are not uncommonly impacted or ectopic and their alignment is difficult, even impossible. Extraction may be required in such cases.
- When maxillary canine is completely excluded from the arch and approximal contact between lateral incisor and first premolar is good, extraction of the canine may be considered (Fig. 21.9D).



Fig. 21.9D: Black arrow indicating a mandibular canine which is totally out of the arch and might be extracted as part of orthodontic treatment plan, white arrow indicates the grossly decayed a maxillary second premolar

FIRST PREMOLARS

It is the tooth most commonly extracted as part of orthodontic therapy especially for the relief of crowding because:

- It is positioned near the center of each quadrant of the arch and is therefore near the site of crowding, i.e. the space gained by their extraction can be utilized for correction both in the anterior and posterior region.
- First premolar extraction is the least likely to upset molar occlusion and is the best alternative to maintain vertical dimension.
- The contact between the canine and second premolar is satisfactory.
- First premolar extraction leaves behind a posterior segment that offers adequate anchorage for retraction of the 6 anterior teeth.

Indications

1. Tooth of choice for extraction to relieve moderate to severe anterior crowding in both the arches. In lower arch crowding, where canines are mesially inclined, spontaneous improvement in incisor alignment will follow.
2. Correction of moderate to severe anterior proclination as in Class II div 1 or Class I bimaxillary protrusion.
3. In high anchorage cases, first premolar takes precedence over second premolar as the teeth to be extracted.
4. As a part of serial extraction (Fig. 21.9E).



Fig. 21.9E: Maxillary first premolars extracted as part of orthodontic treatment to achieve a full Class-II molar relationship

Timing of Extraction

The first premolars should not be extracted until all premolars, permanent incisors and canines have erupted sufficiently for brackets to be placed on them, as mesial migration is greatly increased by extraction. The only exception to this rule is when second premolars cannot erupt because they are impacted. The four first premolars should not be extracted more than three weeks before starting active treatment to avoid mesial migration of posterior teeth and therefore leaving insufficient space for retraction.

SECOND PREMOLARS

Indications for Extraction

1. When second premolar is completely excluded from the arch following forwards drift of first molar after early loss of deciduous second molar.
2. Second premolar extraction is preferred in mild anterior crowding cases as space closure and vertical control is easier after anterior alignment. The presence of first premolar anterior to extraction site strengthens the anterior anchorage, thereby facilitating closure from behind.
3. Second premolar extraction is preferred when one wishes to maintain soft tissue profile and esthetics.
4. Unfavorably impacted second premolars.
5. Grossly carious or periodontally compromised second premolar (Fig. 21.9D).
6. In open bite cases second premolar is preferred for extraction as it encourages deepening of the bite.

FIRST MOLAR

The first permanent molar has been esteemed as untouchable from the very beginning of the history of orthodontics. It is considered as the cornerstone of the dentition.

The first permanent molar has been the subject of considerable debate as to its value in the dental arch particularly as it has been the most susceptible permanent tooth in childhood. It is said that it should never be removed. Alternately it has been advocated that the first molar can be removed as a routine measure with benefit to dental arches. However, no single rule can be made which fits every individual.

Extraction of first molars is avoided because:

- It does not give adequate space to relieve anterior crowding.
- Deepening of bite
- Poor approximal contact between second premolar and second molar
- Second premolar and second molar may tip into extraction space
- Mastication is affected

Indications

1. Minimum space requirement for correction of anterior crowding or mild proclination
2. Grossly decayed/periodontally compromised molar with poor prognosis (Figs 21.9F and 21.9G)
3. Impacted molar—rarely seen.

Rules for Guidance to the Best Time for Extraction

When crowding is absent or confined to the premolar segment and no space is needed for anterior alignment then first molar is removed before second molar erupts to allow it to move forward during eruption and take up the first molar position. Also lower first molar needs to be removed earlier than upper first molar because second molar moves forward less readily in the lower jaw.

When space is required for alignment of anteriors, it is preferable to wait for second molar eruption before first molar extraction to avoid space closure by forward movement of second molar.

If fixed appliances are used skillfully most problems caused by enforced first molar extractions can be overcome. However, treatment lasts somewhat longer than with first premolar extraction.



Fig. 21.9F: Black arrow indicating a madibular first molar which was indicated for extraction because of periodontal complications



Fig. 21.9G: Grossly decayed right maxillary first molar indicated for extraction

SECOND MOLAR

Mandibular Second Molar

Mandibular second molar is positioned at the end of the dental arch and therefore is away from the site of crowding. Its extraction does not help in relieving the crowding, however, extraction may be indicated in the following cases:

1. To relieve impaction of second premolars: When forward drift of the first permanent molar following premature loss of the second deciduous molar causes insufficient space for second premolar eruption, second molar extraction allows distal movement of the first permanent molar. This provides enough space for premolar eruption.
2. To relieve impaction of mandibular third molar: Since the position of eruption of third molar is variable, extraction of second molar is not usually indicated to relieve third molar impaction. However, the conditions wherein lower second molar extraction can result in reasonable third molar position are:
   a. When third molar is upright or its long axis is not tilted mesially more than 30° to the long axis of second molar.
   b. When second molar is extracted only after calcification of third molar crown or just after root formation of third molar has started, usually between 12 and 14 years.
3. To relieve lower incisor crowding: minimum lower incisor alignment might be seen but this effect is usually transient.
4. To prevent lower incisor crowding: evidence shows that patients with lower second molar extraction suffered less lower arch shortening.
5. To correct mild to moderate arch length deficiencies existing with good facial profiles.
6. Severely carious, ectopically erupted or severely rotated second molar.
7. Open bite cases, extraction may help in correcting the anterior open bite (Fig. 21.9H).



Fig. 21.9H: Extraction of second molars might be done in anterior open-bite cases as it may help to reduce the negative over bite

MAXILLARY SECOND MOLARS

Indications

1. In mildly crowded cases, where less than 3-4 mm space is required for the labial segments, good results can be obtained after retraction of the buccal segments.

2. To make space for crowded second premolar by distalization of first molar.
3. When second molar is impacted against first molar, second molar extraction is preferred over extraction of severely impacted third molar for which there is no space in the line of occlusion.

Criteria for maxillary second molar extraction and replacement by third molar:

- The chronologic and dental age of the patient should be past the average time when second molars would erupt
- Size, shape and root area of third molar should be sufficient to serve in place of second molar
- Maxillary tuberosity should be insufficient to accommodate all 3 molars
- If second molar is in buccal occlusion and third molar is positioned in the tuberosity
- Maxillary third molar in favorable angulation for eruption
- Second molar severely carious with questionable prognosis.

Contraindications

1. Maxillary third molars positioned high in the tuberosity
2. Poor angulation in relation to second molar
3. Undersized crown or roots
4. Third molar bud is absent

Timing Mandibular second molar should be extracted as soon as it erupts provided the third molar crown is complete and before its roots begin to develop. Maxillary second molar should be extracted when the third molar has migrated sufficiently in the alveolar bone so that the occlusal surface is approximately level with the vertical midline of the second molar root.

Advantages of second molar extraction

- Facilitates treatment using removable appliances
- Eruption of third molar is faster
- Prevention of dished—in appearance of the face
- Few residual spaces at the end of treatment
- Good mandibular arch form
- Less chances of relapse
- Increases overbite hence, in openbite cases

Disadvantages

- Too much tooth substance is removed in mild crowding cases
- Extraction site away from area of crowding.
- It is not certain that third molars will erupt even after second molar extraction.
- Final third molar position may be unacceptable.
- Increases overbite.

THIRD MOLARS

Extraction of third molar during orthodontic treatment does not yield space for decrowding or reduction of proclination.

Indications

1. Impacted third molar: third molars are commonly impacted and unless other teeth are missing or have been extracted, there is rarely room to accommodate them in the arch. Third molar extraction is frequently carried out to relieve impaction (Fig. 21.9I). The conventional timing of extraction of a third molar is when two-thirds of its root is formed. Extraction of third molar should not be delayed because:
   - More difficult to remove when roots are completed.
   - Danger of root dilacerations which may make removal more difficult.
   - Pericoronitis can develop and cause bone loss and pocket formation may occur distal to second molar.



Fig. 21.9I: Impacted third molars indicated for extraction

2. Erupting mandibular third molars have been implicated to be the cause of late lower anterior crowding, although the evidence is not clear cut. In adolescence and early adult life, progressive crowding of anterior teeth is commonly seen. Late crowding develops around the eruption time of

third molars, which many dentists feel is due to the pressure from third molars. However, it is difficult to detect such a force. In fact, late anterior crowding often develops in individuals whose lower third molars are congenitally missing.

3. Malformed third molars, which interfere with normal occlusion, should be extracted.

FURTHER READING

1. Adkins MD, Nanda RS, Currier GF. Arch perimeter changes on rapid palatal expansion, Am J Orthod 1990;97:10-19.
2. Bjerregaard J, Burdgaard AM, Melsen B. The effect of the mandibular lip bumper and maxillary bite plane on tooth movement, occlusion, and space conditions in the lower dental arch. Eur J Orthod 1962;48:504-29.
3. Daugaard-Jensen I. Extraction of first molars in discrepancy cases 1973;64:115-36.
4. Gianelly AA. Distal movement of the maxillary molars. Am J Orthod Dentofcial Orthop 1998;114:66-72.
5. Haas. Palatal expansion: Just the beginning of Dentofacial orthopedics, Am J Orthod Dentofacial Orthop 1997;219-55.
6. Holm U. Problems of compensative extraction in cases with loss of first permanent molars. Trans Eur Orthod Soc 1970;409-27.
7. Huggins DG, NcBride LJ. The eruption of lower third molars following the loss of second molars: A longitudinal cephalometric study, Br J Orthod 1978;5:13-20.
8. Kalra JPS, Kharbanda OP, Sidhu SS, Gulati S. Maxillary molar distalization using intra-oral maethods, J Ind Orthod Soc 1994;25:64-69.
9. Kalra V. The K-loop distalizing appliance, J Clin Orthod 1995;29:298-301.
10. Nevant CT, Buschang PH, Alexander RG, Steffen JM. Lip bumper therapy for gaining arch length, Am J Orthod Dentofac Orthop 1991;100:330-6.
11. Sheridan JJ Ledoux PM. Air-rotor stripping and proximal sealants, J Clin Orthod 1989;23:790-4.
12. Sheridan JJ, Air-rotor stripping, J Clin Orthod 1985;19:43-59.
13. Spillane LM, McNamara JA. Maxillary adaptation to expansion in the mixed dentition, Seminars in Orthod 1995;1:176-87.
14. Spolyar J, A full coverage rapid maxillary expansion appliance, Am J Orthod Dentofacial Orthop 1984;136-45.
15. Thampson FG. Second premolar extraction in Begg technique, J Clin Orthod 1977;11:610-3.
16. Wagers LE. 8-tooth extraction cases using Begg technique, J Clin Orthod 1977;11:526-38.
17. Williams RT, Hosila FJ. The effect of different extraction sites upon incisor retraction, Am J Orthod 1976;69:388-410.
18. Williams RT. Single arch extractions- upper first molars or what to do when non-extraction fails, Am J Orthod 1979;76:376-93.
19. Wintner M. Surgically assisted palatal expansion: An important consideration in adult treatment, Am J Orthod Dentofacial Orthop 1991;85-90.

22 Anchorage in Orthodontics

Gurkeerat Singh

- Introduction
- Sources of anchorage
- Classification of anchorage
- Intraoral anchorage
- Extraoral anchorage
- Muscular anchorage
- Anchorage planning
- Classifying anchorage requirements
- Tweed's classification of anchorage preparation

INTRODUCTION

Whenever a force is applied, it produces an equal and opposite reactive force. For tooth movement to occur in the desired direction this reactive force should be equal to or greater than the force applied. The areas or units which provide the resistance to the reactive force thereby preventing undesirable tooth movement are called anchorage units.

White and Gardiner defined anchorage as *"the site of delivery from which a force is exerted"*.

Graber clarified this a bit further, when he defined anchorage as *"the nature and degree of resistance to displacement offered by an anatomic unit when used for the purpose of affecting tooth movement"*.

All orthodontic appliances can be said to have two components namely the active component and the resistance component. The active component is responsible for generating the force and the resistance component is responsible for providing the resistance to make this force effective; the former being useless without the latter.

SOURCES OF ANCHORAGE

These are anatomical units and / or regions which are used for the purpose of providing the resistance to movement, i.e. anchorage. These are further divided into two groups depending upon their location as (1) intraoral sources, and (2) extraoral sources.

INTRAORAL SOURCES OF ANCHORAGE

The anchorage units lie within the oral cavity. They include:

- The alveolar bone
- The teeth
- The basal bone
- The cortical bone
- The musculature

Alveolar Bone

Within limits the alveolar bone resists deformation. This can be seen from the rearrangement of trabecular pattern within the alveolar bone. Once the forces generated exceed those that can be resisted by the alveolar bone it permits tooth movement by bone remodeling.

Less dense alveolar bone offers less anchorage (Figs 22.1A and B). More mature bone increases anchorage. This takes place because of two factors—one, the bone becomes more calcified and dissolution takes time and two, the regenerative capacity of the bone decreases. Forces that are dissipated over a larger bone surface area offer increased anchorage.



Fig. 22.1A: Less dense trabecular bone of the maxillary anterior region



Fig. 22.1B: Dense alveolar bone with horizontal arrangement of the trabeculae in the mandibular posterior region

Teeth

Teeth by themselves resist movement. Forces can be exerted from one set of teeth to move certain other teeth. The anchorage potential of teeth depends upon a number of factors including—the root form, the size of roots, the number of roots, the position of the teeth, the axial inclination of the teeth, their intercuspation, etc.

Root form The root form, to a large extent is responsible for the degree of anchorage provided by a tooth. The root in cross section can be either round, flat (mesiodistally) or triangular (Fig. 22.2). The distribution of the periodontal fibers on the root surface aid



Fig. 22.2: Root cross-sections

in anchorage. The more the fibers the better the anchorage potential. The direction of attachment of the fibers also effects the anchorage offered by a tooth. Round roots have only half their periodontal fibers stressed in any given direction. Hence, offer the least anchorage. Mesiodistally flat roots are able to resist mesiodistal movement better as compared to labiolingual movement, as more number of fibers are activated on the flatter surfaces as compared to the relatively narrower labial or lingual surfaces. Triangular roots, like those of the canines are able to provide greater anchorage. Their flatness adds to resistance.

The tripod arrangement of roots (Fig. 22.3A), like that seen on maxillary molars also aids in increasing the anchorage. The round palatal root resists extrusion and the two flat buccal roots resist intrusion and the mesiodistal stresses. Under clinical situations where the buccal tube is bonded/welded on the buccal aspect of these teeth they show a tendency to 'roll' mesially, the crown rotating mesiopalatally under a mesially directed force (Fig. 22.3B).

Size of roots The larger or longer the roots the more is their anchorage potential. The maxillary canines, because of their long roots can, at times, be the most difficult teeth to move in certain clinical circumstances (Fig. 22.4).



Fig. 22.3A: Tripod arrangement of roots



Fig. 22.3B: Mesio-palatal rotation of the maxillary 1st molar

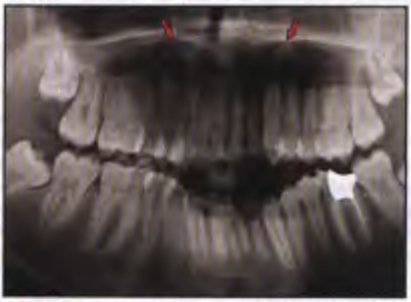


Fig. 22.4: Long roots of the maxillary canines increase their anchorage potential

Number of roots The greater the surface area the greater the periodontal support and hence, greater the anchorage potential. Multirooted teeth provide greater anchorage as compared to single rooted teeth with similar root length.

Position of tooth Sometimes the position of the teeth in the individual arches also helps in increasing their anchorage potential. As in the case of mandibular second premolars, which are placed between two ridges—the mylohyoid and the external oblique, they provide an increased resistance to mesial movement.

Axial inclination of the tooth When the tooth is inclined in the opposite direction to that of the force applied, it provides greater resistance or anchorage (Fig. 22.5).

Root formation Teeth with incomplete root formation are easier to move and are able to provide lesser anchorage.

Contact points Teeth with intact contacts and/ or broad contact provide greater anchorage.

Intercuspation Good intercuspation leads to greater anchorage potential (Fig. 22.6). This is mainly because the teeth in one jaw are prevented from moving because of the contact with those of the opposing jaw, this is especially true for teeth in the posterior segment which also show the presence of attrition facets.



Fig. 22.5: Inclination of the teeth



Fig. 22.6: Good intercuspation leads to greater anchorage potential

Basal Bone

Certain areas of the basal bone like the hard palate and the lingual surface of the mandible in the anterior region can be used to augment the anchorage. The Nance palatal button is one such appliance that makes use of the hard palate to provide resistance to the mesial movement of the maxillary molars (Fig. 22.7).

Cortical Bone

Ricketts floated the idea of using cortical bone for anchorage. The contention being that the cortical bone is denser with decreased blood supplies and bone turnover. Hence, if certain teeth were torqued to come in contact with the cortical bone they would have a greater anchorage potential. The idea as such remains controversial as tooth roots also show resorption in such conditions and the risk of non-vitality of such teeth is also more.

Musculature

Under normal circumstances the perioral musculature plays an important part in the growth and development of the dental arches. Hypotonicity of the perioral musculature might lead to spacing and flaring of the anterior teeth. The hypertonicity of the very same muscles has the reverse effect. Lip bumper is an appliance that makes use of the tonicity of the lip





Fig. 22.7: The Nance palatal button



Fig. 22.8: Lip bumper makes use of the tonicity of the lip musculature and enhances the anchorage potential of the mandibular molars preventing their mesial movement

musculature and enhances the anchorage potential of the mandibular molars preventing their mesial movement (Fig. 22.8).

CLASSIFICATION OF ANCHORAGE

A. Anchorage classified according to the manner of force application as:
   1. Simple
   2. Stationary
   3. Reciprocal.
B. Anchorage classified according to the jaws involved as:
   1. Intramaxillary
   2. Intermaxillary.
C. Anchorage classified according to the site where the anchorage units as:
   1. Intraoral
   2. Extraoral
   3. Muscular.
D. Anchorage classified according to the number of anchorage units as:
   1. Single
   2. Compound
   3. Reinforced.
E. *White and Gardiner* classified anchorage into six categories as:
   1. Simple
   2. Stationary
   3. Reciprocal
   4. Reinforced
   5. Intermaxillary
   6. Extraoral.

For understanding anchorage it is convenient to divide anchorage into—intraoral and extraoral anchorage. Further, intraoral anchorage can be subdivided into intramaxillary and intermaxillary anchorage. Both can be of three types—simple, stationary or reciprocal. Simple anchorage can be further subdivided as—single, compound and reinforced.

Extraoral anchorage can be of the following types depending upon the location of the support units as—cervical, occipital, cranial or facial.

INTRAORAL ANCHORAGE

This type of anchorage is said to exist when and only when all the anchorage units are present within the oral cavity. Anchorage from all the intraoral sources of anchorage including the teeth, palate, etc. can form part of this type of anchorage.

Intraoral anchorage can be further divided into intramaxillary or intermaxillary anchorage depending upon the location of anchorage providing elements between the two jaws.

INTRAMAXILLARY ANCHORAGE

When all the elements providing the anchorage as well as those to be moved are situated within the same jaw, the anchorage is described as *intramaxillary*. Here the teeth to be moved and the anchorage units lie within the same jaw, i.e. either the maxilla or the mandible. For example, when elastic chains are used to retract the anterior segment using the posterior teeth as anchorage units (Fig. 22.9).



Fig. 22.9: Intramaxillary anchorage, the anchor units (mandibular posterior teeth) and the teeth to be moved (maxillary canine) are present in the same arch

Intramaxillary anchorage can be further subdivided into three subtypes depending upon the manner of force application as:
1. Simple
2. Stationary
3. Reciprocal.

INTERMAXILLARY ANCHORAGE

When the anchorage units situated in one jaw are used to provide the force required to move teeth in the opposing jaw the anchorage is called *intermaxillary*. This type of anchorage is also termed as *Baker's anchorage*. For example, when Class II elastics are used to retract the maxillary anteriors the anchorage units are situated in the mandibular arch (Fig. 22.10).

Intermaxillary anchorage can also be further subdivided into three subtypes depending upon the manner of force application as:
1. Simple
2. Stationary
3. Reciprocal.

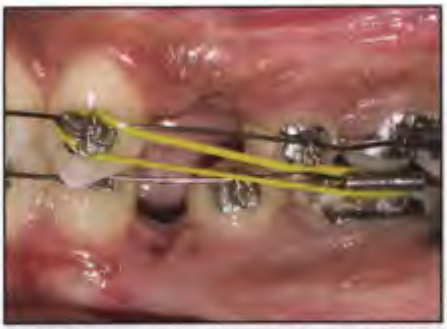


Fig. 22.10: Intermaxillary anchorage (stationary anchorage—the maxillary molars are bodily pitted against the tipping forces of the maxillary anteriors)

SIMPLE ANCHORAGE

Simple anchorage is said to exist when the manner and application of force is such that it tends to change the axial inclination of the tooth or teeth that form the anchorage unit in the plane of space in which the force is being applied. Thus, resistance to tipping of the anchorage units might be utilized to retract certain other teeth. Simple anchorage is obtained by engaging a greater number of teeth than are to be moved. The root surface area of the anchorage units should be at least double that of the units to be moved.

Anterior retraction with the help of a Hawley's appliance (Fig. 22.11A), or the movement of a single tooth using a screw appliance (Fig. 22.11B) are examples of simple anchorage as the root surface areas of the anchorage units is more than that of the teeth to be moved.

STATIONARY ANCHORAGE

Stationary anchorage is said to exist when the application of force tends to displace the anchorage units bodily in the plane of space in which the force is being applied. The anchorage potential of teeth being moved bodily is considerably greater as compared to teeth being tipped. For example, in the Stage II of the Begg technique, a combination of anchor bends and Class II elastics pits the mandibular molars against the maxillary anterior segment, the resistance to bodily movement of the mandibular molars helps in retracting the maxillary anteriors by tipping them (Fig. 22.9).



Fig. 22.11A: Anterior retraction using a removable appliance incorporating a long labial bow and retention clasps



Fig. 22.11B: Single tooth being pushed labially using an appliance incorporating a screw

RECIPROCAL ANCHORAGE

Reciprocal anchorage is said to exist when two teeth or two sets of teeth move to an equal extent in an opposite direction. Here the root surface area of the so-called anchorage units is equal to that of the teeth to be moved. The effect of the forces exerted is equal, i.e. the two sets of teeth are displaced in the opposing direction but by the same amount.

Cross elastics to correct molar cross-bite (Fig. 22.12A), arch expansion using a midline screw (Fig. 22.12B) and the molar rotator (Fig. 22.12C) are examples of reciprocal anchorage.



Fig. 22.12A: Cross-bite elastics are used to push the maxillary molars labially and the mandibular molars lingually (reciprocal anchorage), using elastics



Fig. 22.12B: Reciprocal anchorage is made use of in expansion of the upper arch using a rapid maxillary expander (RME) (Photograph courtesy: Scheu-Dental, Germany)

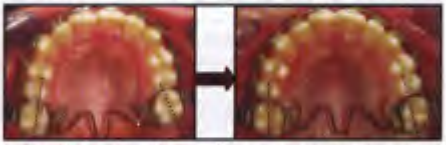


Fig. 22.12C: The Ni-Ti molar rotator is used to derotate molars

SINGLE OR PRIMARY ANCHORAGE

Cases where the tooth to be moved is pitted against a tooth with a greater alveolar support area is said to display primary or single anchorage. For example, a molar along with adjacent premolars used to align another molar (Fig. 22.13).



Fig. 22.13: Primary anchorage: a molar along with adjacent premolars used to align another molar

COMPOUND ANCHORAGE

This type of anchorage provides for the use of more teeth with greater anchorage potential to move a tooth or group of teeth with lesser support. For example, retracting incisors using loop mechanics in the fixed orthodontic appliances (Fig. 22.14).



Fig. 22.14: Loop mechanics used to retract anteriors

REINFORCED ANCHORAGE

Here the anchorage units are reinforced by the use of more than one type of resistance units. For example,

the use of headgears along with routine fixed mechanotherapy or (extraoral anchorage and intra-arch compound anchorage) or the use of a transpalatal arch (Fig. 22.15) in fixed mechanotherapy or simply the banding of the second molar for the retraction of the permanent canine (Fig. 22.16).



Fig. 22.15: A transpalatal arch is used to reinforce anchorage



Fig. 22.16: Anchorage potential of the posterior segment is reinforced by banding the maxillary 2nd molar

EXTRAORAL ANCHORAGE

As the name implies, here the anchorage units are situated outside the oral cavity or extraorally. The extraoral structures most frequently used at the cervical region (as with the use of the cervical pull headgear, (Fig. 22.17) the occiput (as with the occipital pull headgear Fig. 22.18) , the forehead and the chin (e.g., the face mask Fig. 22.19) with the use of extraoral anchorage the anchorage units are situated far away from the actual site where the movement is taking place hence there is hardly any chance of any changes taking place in the anchorage units. The biggest disadvantage of extraoral anchorage is the apparent lack of patient cooperation. The anchorage assembly is bulky and externally visible making patients



Fig. 22.17: Cervical headgear



Fig. 22.18: Occipital headgear



Fig. 22.19: The facemask uses extraoral anchorage units

conscious of their appearance and effecting the time for which they wear the appliance. Any decrease in the number of hours for which the anchorage assembly is worn affects the quality of results achieved.

MUSCULAR ANCHORAGE

The perioral musculature is not only very strong but also resilient. The forces generated by the musculature can sometimes be used to bring about tooth movement. The lip bumper appliance may be used to distalize the mandibular first molars (Fig. 22.8) or the transpalatal arch when kept away from the palate, may cause the intrusion of the teeth to which it is attached, the maxillary first molars.

ANCHORAGE PLANNING

At the time of determining the space requirement to resolve the malocclusion in a given case it is essential to plan for space that is likely to be lost due to the invariable movement of the anchor teeth. The anchorage requirement depends on:

a. *The number of teeth to be moved* the greater the number of teeth being moved the greater is the anchorage demand. Moving teeth in segments as in retracting the canine separately rather than retracting the complete anterior segment together will decrease the load on the anchor teeth.
b. *The type of teeth to be moved* teeth with large flat roots and/or more than one root exert more load on the anchor teeth. Hence, it is more difficult to move a canine as compared to an incisor or a molar as compared to a premolar.
c. *Type of tooth movement*—moving teeth bodily requires more force as compared to tipping the same teeth.
d. *Periodontal condition*—teeth with decreased bone support or periodontally compromised teeth are easier to move as compared to healthy teeth attached to a strong periodontium.
e. *Duration of tooth movement*—prolonged treatment time places more strain on the anchor teeth. Short-term treatment might bring about negligible amount of change in the anchor teeth whereas the same teeth might not be able to withstand the same forces adequately if the treatment becomes prolonged.

CLASSIFYING ANCHORAGE REQUIREMENTS

Begg, the inventor of the light wire differential force technique or the Begg technique, as it is frequently referred to estimated that one-third the extraction space is lost as anchor loss if no additional means are used to conserve anchorage. Based on this premise he classified cases depending upon the space requirements of the particular case as maximum anchorage, moderate anchorage and minimum anchorage.

MAXIMUM ANCHORAGE

These include cases where the anchorage demand is critical or in other words maximum space should be used to correct the malocclusion proper and anchor loss should be minimum. In such cases no more than one-fourth the extraction space can be lost to the forward movement of the anchor teeth, i.e. anchor loss. All care should be taken to preserve anchorage and the use of additional methods to augment anchorage should be planned in the treatment plan.

MODERATE ANCHORAGE

These are cases where the anchor teeth can be allowed to move forward into the extraction space for one-fourth to half the total extraction space. Reinforcing the anchorage might not be required.

MINIMUM ANCHORAGE

These include cases where a very less amount (less than half) of the extraction space is required for the actual resolution of the malocclusion. The rest of the space, i.e. more than half the extraction space needs to be closed by bringing the anchor teeth forward or to anchor loss.

TWEED'S CLASSIFICATION OF ANCHORAGE PREPARATION

Tweed is credited with refining the edge-wise appliance and it is important to understand that at the time headgears were used in practically each and every case. Also the forces used to bring about tooth movement were very high as compared to what we use today.

Tweed classified anchorage preparation so as the anchor molars would not move into the extraction spaces and sufficient space would be available to bring about the retraction of the anterior teeth.

First degree or minimal anchorage preparation was reserved for cases where the facial esthetics were good with an ANB angle equal to or less than 0 to 4°. The total discrepancy should be less than or equal to 10 mm.

The anchorage preparation consisted of inclining the terminal molars which are angulated such that the direction of pull of the intermaxillary elastic force during function will not exceed 90° when related to the long axis of these teeth.

Second degree or moderate anchorage preparation is usually required in cases where the ANB angle exceeds 4.5° with a Class II profile (retrognathic mandible).

Tweed recommended the banding of mandibular second molars in all such case with the terminal molars so angulated that their distal marginal ridge is at gum level. With such an anchorage preparation the direction of pull from the Class II elastics would be greater than 90° during function. Such a pull will further depress rather than elongate the terminal molars.

Third degree or *total anchorage* preparation was reserved for cases which had an ANB angle of more than or equal to 5° and the total discrepancy was 14-20 mm.

The anchorage preparation was such that all the molars and premolars were tipped distally with the distal marginal ridge of the second molar being located below the gum level.

Such anchorage preparation is usually not required nowadays.

FURTHER READING

1. Block MS, Hoffman DR. A new device for absolute anchorage for orthodontics, Am J Orthod Dentofacial Orthop 1995;107:251-8.
2. Gould E. Mechanical principles in extraoral anchorage. Am J Orthod 1957;17:319-33.
3. Hixon EH, et al. Optimal force, differential force, and anchorage, Am J Orthod 1969;55:437-57.
4. Melsen B, Bosch C. Different approaches to anchorage: a survey and an evaluation, Angle Orthod 1997;67:23-30.
5. Melsen B, Enemark H. Effect of cervical anchorage studied by the implant method. Tran Eur Orthof Soc 1969;435-47.

23 Retention and Relapse in Orthodontics

Gurkeerat Singh

- Introduction
- Causes of relapse
- Need for retention
- Schools of thought/philosophies
- Riedel's theorems of retention
- Length of retention period
- Types of retainers
  - Ideal requirements of retaining appliances
  - Fixed retainers
  - Removable retainers

INTRODUCTION

Any treatment is a failure unless the treatment results can be *retained*. Over the years, the concept of retention has undergone progressive modification making the orthodontist more and more responsible for retaining the final results achieved following orthodontic treatment. The period for which the results can be maintained or the duration of retention has also changed over time. Initially, the orthodontists were only responsible for achieving the desired results, they were not responsible for maintaining the same following cessation of treatment. Presently, the emphasis is for retaining results not for just a few years following the cessation of active orthodontic treatment but maintaining results for the lifetime of the patient.

The term "retention" has been defined as: "the holding of teeth in idealistic and functional positions" (Joondeph and Riedel, 1985).

CAUSES OF RELAPSE

Various causes have been proposed for the cause of relapse to occur (Table 23.1). The most basic of them all is the persistence of the etiology. If the underlying etiology is not removed, the treatment is destined to relapse (Fig. 23.1). It is mandatory for all clinicians to first diagnose a case properly, and plan the treatment and retention initially itself, keeping the etiology in mind. The removal of the etiologic factor before finishing is mandatory.

During tooth movement the trabeculae of bone are resorbed and reformed in a general direction parallel



Fig. 23.1: Relapse following fixed appliance therapy involving the extraction of all first premolars due to an unresolved tongue thrust habit

Table 23.1: Causes of relapse

1. Failure to remove the cause of malocclusion
2. Incorrect diagnosis and failure to properly plan treatment
3. Lack of normal cuspal interdigitation
4. Arch expansion, laterally and /or anteriorly
5. Incorrect arch size and harmony
6. Incorrect axial inclinations
7. Failure to manage rotations
8. Improper contacts
9. Tooth size disharmony

to that of the force applied to the tooth. This reorientation takes about six months to complete. After completion of tooth movement, the trabeculae are reoriented again in the direction of the long axis of the root of the teeth. This again takes about six months to complete. The bone during this period is found usually to be more responsive to the influence of pressure and relapse may occur if new position is not stable.

The soft tissues around the neck of the tooth are stretched. Because of their flexibility and elasticity, the forces they transmit to the bone stimulates a less complete response. The transseptal fibers of the periodontal ligament take the longest to reorient following correction of derotations and are the main cause of relapse following rotational correction of teeth. The orientation of gingival and other periodontal fibers is also disturbed during tooth movement. They tend to pile up in the path of tooth movement, especially if it is rapid. The perioral soft tissues take longer to adapt to the new position of the teeth than the bone.

Differential jaw growth in the young growing individuals also accounts for a large number of relapsed cases, especially with Class III skeletal pattern.

Generally speaking, the periodontal and gingival fibers are capable of producing inter-arch irregularities (rotations, spacing, crowding, etc.). The perioral musculature (comprising of the tongue, lip and cheeks) is capable of producing both intra-and inter-arch irregularities. The continuation of aberrant jaw growth can indirectly effect the perioral soft tissue envelope as well as by itself produce inter-arch relapse.

NEED FOR RETENTION

Retention is planned *"to antagonize the movement of the teeth in the direction of their tendency, and to allow the teeth freedom of movement in every direction except that toward which they tend to return."*

Basically, retention prevents the relapse from occurring or in other words prevents the teeth from returning to their original position of malocclusion. Earlier, *"retention was described as that period after active treatment when passive fixed/removable appliances were worn for approximately two years to stabilize the occlusion which had been created."* Now with our increased knowledge of the biomechanics involved in relapse, the concept of " lifetime retention" has evolved.

SCHOOLS OF THOUGHT / PHILOSOPHIES

Present concepts of retention are based basically on four schools of thought as follows.

THE OCCLUSION SCHOOL

In 1880, Norman Kingsley suggested that—*"the occlusion of teeth is the most important factor in determining the stability in a new position."* The statement has withstood the test of time and has been collaborated by various other researchers. Good interdigitation always aids in stability of treated results.

THE APICAL BASE SCHOOL

In the middle 1920s, Axel Lundstrom highlighted the importance of the apical base in the maintenance of treatment results. Hay's Nance in 1947 further researched the topic and concluded that:

- If a stable permanent result is to be attained following orthodontic treatment, mandibular teeth must be positioned properly in relation to the basal bone.
- Arch length may be permanently increased only to a limited extent.
- Excessive lingual as well as labial tipping must be avoided.

In short, the aligned mandibular teeth must lie upon their designated basal bone without being either too proclined or retroclined if their stability is to be maintained.

THE MANDIBULAR INCISOR SCHOOL

The mandibular incisor school was proposed by Grieve and Tweed. They maintained that for reasons of stability, the mandibular incisors must be placed upright or slightly retroclined over the basal bone.

THE MUSCULATURE SCHOOL

Paul Roger introduced the school of thought which included the necessity of establishing proper muscle balance.

All the above philosophies are interrelated, e.g. retention depends on the occlusion established and the occlusion established must be within the bounds of normal muscle balance, also the occlusion and muscle balance established are dependent upon the amount of apical base available and the relationship of apical bases to one another.

RIEDEL'S THEOREMS OF RETENTION

Riedel summarized all the different philosophies into nine theorems as follows.

THEOREM 1

"Teeth that have been moved tend to return to their former positions." This has been collaborated by various researchers and is an accepted fact. Suggested influences include musculature imbalance, apical base, trans-septal fibers and bone morphology.

THEOREM 2

"The elimination of the causes of a malocclusion should aid in the retention of its correction." Approximately 25 percent malocclusions are due to a local cause, i.e. they are preventable. About 2 percent are congenital, e.g. cleft lip/palate and the other 70 percent are hereditary in origin based on racial admixtures and perhaps the gradual recession of the face beneath the cranium. All efforts should be made to correct the inherent etiologic factors in malocclusions, which are associated with an identifiable etiologic factor.

THEOREM 3

"Overcorrection of a malocclusion is a safety factor in retention," Overcorrection of deep bite, overbite and rotations is an accepted procedure. Majority of the researchers have advocated overcorrection as means of countering eminent relapse. The rationale being that certain amount of relapse is to be expected after even the minutest of corrections.

THEOREM 4

"Occlusion is an important factor in retention." Proper interdigitation in post-treatment occlusion is important from the standpoint of stability. But even more important at times is the existence of reasonable occlusal balance during mastication and/or parafunction. The static occlusion should be examined, but importance should also be given to studying the functional occlusion (i.e., harmonious occlusal contacts during functional movements like mastication) of a case.

THEOREM 5

"Bone and adjacent tissues must be allowed to reorganize around of newly positioned teeth." The bone and the soft tissue surrounding the recently moved teeth require time to reorganize themselves. A reasonable period has to be provided before all restraining devices (retainers) can be done away with completely. The soft tissue envelope surrounding the oral cavity takes longer to orient itself to the new position of the teeth.

THEOREM 6

"Lower incisors must be placed upright over the basal bone". More stable results are obtained when the mandibular incisors are either upright or slightly retroclined over the basal bone. Raleigh Williams has proposed six keys which when followed can help achieve stable results in the mandibular teeth (Table 23.2).

THEOREM 7

"Corrections carried out during period of growth are less likely to relapse." Early intervention is the norm of the day and has several advantages:

- Prevents progressive, irreversible tissue damage.
- Maximizes the use of growth. With concomitant tooth eruption, allows interception of malocclusion prior to excessive dental and morphologic compensations (which may become more difficult to correct and retain).
- Allows corrections of skeletal malrelations while structures are morphologically immature and amenable to correction.
- Prevents the development of psychological problems associated with malocclusions, as the cases are treated before the child becomes conscious of his/her appearance.

THEOREM 8

"The further teeth have been moved, the less the likelihood of relapse." Thus, when the teeth have been moved over

Table 23.2: Raleigh Williams' six keys to lower retention

First key: *Incisal edges of the lower incisors should be placed on the A-P line or 1 mm in front of it.* This has been described as the optimum position for stability. It also creates optimum soft tissue balance in lower third of the face. Here, it is pertinent to add, incisor angulation of 90° to mandibular plane or 65° to FH plane is, only esthetically appropriate and stable for those who have optimal north European skeletal configurations, but not for patients of other ethnic origin.

Second key: *Lower incisors apices should be spread distally to the crowns,* more than is generally considered appropriate. The apices of the lower lateral incisors must be spread more than centrals. When the lower roots are left convergent or even parallel, crowns tend to bunch up and a fixed retainer has to be used.

Third key: *Apex of lower cuspid should be positioned distal of the crown.* This angulation of lower cuspid is important in creating post-treatment incisor stability, as it reduces the tendency of the cuspid crown to tip forward into the incisor area.

Fourth key: *All four lower incisor apices must be in the same labiolingual plane.* Spreading roots distally causes strong reciprocal tendency for crowns to move mesially.

Fifth key: *Lower cuspid root apex must be positioned slightly buccal to the crown apex.* The old concept that lower inter-canine width cannot be permanently increased is true only for some of the cases. After treatment, if lower cuspids are moved distally over a wider arch and roots apex more buccal to crown, stability will be maintained.

Sixth key: *The lower incisors should be slenderized as needed.* Lower incisors which have had no proximal wear have round, small contact points that are accentuated if the apices have been spread for stability. Subsequently, slightest amount of continuous mesial pressure can cause variable degrees of collapse. Flattening lower incisor contact points by stripping creates flat contact surfaces that help resist labiolingual crown displacement.

greater distances, the retention required is decreased. Positioning teeth far away from their original environment will produce equilibrium, is controversial.

THEOREM 9

"Arch form, particularly in the mandibular arch, cannot be permanently altered by appliance therapy." Altering the original arch form increases the risk of relapse. Studies have shown that:

1. The mandibular inter-canine width cannot be increased, except in clearly defined situations.
2. Premolar width can be increased approximately 2 mm and be confidentially expected to remain stable.
3. Molar width cannot be increased, unless buccolingual axial inclinations are being corrected.
4. Arch length will decrease throughout life, primarily before the age of 30 years. This generally manifests as uprighting of incisors, increasing the inter-incisal angle, crowding and displacement of anterior teeth and a recurrence of rotations.

LENGTH OF RETENTION PERIOD

The duration for which the retention has to be maintained can be critical. In certain malocclusions the retention has to be for a longer time and for others no retention might be required. Reidel has grouped malocclusions which require—no retention, retention for a limited period and permanent retention (Table 23.3).

Table 23.3: Retention planning

Reidel has grouped retention planning into 3 groups

1. *No retention required*
   - A. Cross bites
     - *Anterior:* When adequate overbite has been achieved
     - *Posterior:* When axial inclination of teeth remain reasonable after correction
   - B. Dentitions treated with serial extractions
   - C. Corrections achieved by retardation of maxillary growth once the patient has completed growth
   - D. Dentitions in which teeth have been separated to allow for eruption of previously blocked out teeth
2. *Limited retention*
   - A. Class I non-extraction cases with spacing and protrusion of maxillary incisors (until normal lip and tongue function has been achieved)
   - B. Class I and II extraction cases
   - C. Early correction of rotated teeth to their normal position before root completion
   - D. Cases involving ectopic eruption or the presence of supernumerary teeth
   - E. Corrected deep bites
   - F. Class II division II cases. Extended retention to allow for muscle adaptation
3. *Permanent or semipermanent retention*
   - A. In many cases, to maintain existing esthetics extraction may not be done. The only way to create space in such cases is through expansion. These cases, especially in mandibular arch require permanent or semipermanent retention.
   - B. Cases of considerable generalized spacing
   - C. Severe rotation or severe labiolingual malposition
   - D. Spacing between maxillary central incisors with an otherwise normal occlusion

TYPES OF RETAINERS

Retainers are passive orthodontic appliances that help in maintaining and stabilizing the position of a single tooth or group of teeth to permit reorganization of the supporting structures. Retainers can be simply classified as—*removable* and *fixed*, based on the patient's ability to remove the appliance. Retainers have also been classified by Leyin (Table 23.4).

Table 23.4: Leyin's classification of retainers

Marton A Leyin classified retentive appliances as:

1. *Temporary*
   - A. Fixed
     - Intra-coronal
     - Extra-coronal
   - B. Removable
     - Extra-coronal
2.
   - A. Fixed
     - Intra-coronal
     - Extra-coronal
   - B. Removable
     - Extra-coronal

IDEAL REQUIREMENTS OF RETAINING APPLIANCES

Graber put forward certain criteria that any retaining appliance should possess. These include:

1. It should restrain each tooth in its direction of relapse.
2. It should permit the forces associated with functional activity to act freely on the teeth, permitting them to respond in as nearly a physiologic manner as possible.
3. It should be as self-cleansing as possible and should be reasonably easy to maintain optimal hygiene.
4. Should be as inconspicuous as possible, esthetically good.
5. Strong enough to bear the rigors of day-to-day usage.

FIXED RETAINERS

Fixed retainers are generally cemented or bonded to the teeth. They are generally used in situations where intra-arch instability is anticipated and prolonged retention is planned (Table 23.5). They are gaining popularity due to their relative invisibility and reduced dependence on the patient for wearing (Table 23.6). They have a few disadvantages (Table 23.7) and these are also becoming minimized with the development of better bonding techniques.

Temporary Fixed Intra-coronal Retainers

Temporary fixed intra-coronal retainers are not usually used in day-to-day practice. They are important more from a theoretical standpoint and are not recommended for routine use because of their inherent disadvantages (Table 23.8) and the availability of better materials. These include essentially combinations of

Table 23.5: Indications for fixed retainers

1. Maintenance of lower incisor position during late mandibular growth
2. Following closure of diastemas
3. Maintenance of bridge pontic space
4. Compromised periodontal conditions with the potential for post-orthodontic teeth migration
5. Prevention of rotational relapse
6. Prevention of relapse after the correction of palatally erupted canines, especially if proper overbite has not been achieved
7. Prevention of opening up of closed extraction space, especially in adult patients

Table 23.6: Advantages of fixed retainers

1. Reduced need for patient cooperation
2. Can be used when conventional retainers cannot provide same degree of stability
3. Bonded retainers are more esthetic
4. There is no tissue irritation unlike what may be seen in tissue bearing areas of Hawley's retainer
5. There is no jiggling of teeth, which are present when removable appliances are removed and reinserted
6. Recall visits are reduced
7. Can be used for permanent and semipermanent retention
8. Are better tolerated by the patient
9. Do not affect speech, which is frequently affected when removable retainers with a base plate are worn

Table 23.7: Disadvantages of fixed retainers

1. More cumbersome to insert
2. Increased chair-side time
3. More expensive
4. Banded variety may interfere with oral hygiene maintenance
5. Are more prone to breakages as compared to the removable retainers

Table 23.8: Disadvantages of intra-coronal retainers

- Loss of healthy tooth material
- Tend to discolor
- Potential sights of sensitivity and caries
- Maintenance of oral hygiene might get compromised
- If fracture, replacement is tedious



Fig. 23.2: Fixed intra-coronal silver amalgam retained (the amalgam should not form an overhang in the interproximal region)

amalgam and/or wire and acrylic or composite restorative material.

Adjacent teeth are joined together by preparing continuous proximal channels and placing reinforcing wires in these channels. The defect is filled with either composite, silver amalgam (Fig. 23.2) or any of the restorative cements.

In the anterior segment discontinuous lingual channels can be prepared and a multi-stranded wire can be imbedded in it. The channel can be closed with composite.

Another method is the circumferential intra-coronal wire and acrylic or composite splint. Circumferential channels are cut into the facial and lingual surfaces of anterior teeth and a thin (0.01") stainless steel wire is ligated in a figure of eight manner. The channels are then closed using composite restorative material. These are no longer advocated.

Temporary Fixed Extra-coronal Retentive Appliances

Direct contact splinting As the name suggests, here adjacent teeth are bonded together at contact points (Fig. 23.3); using composite resins. However, breakage



Fig. 23.3: Direct contact splinting of the maxillary central incisors to maintain the diastema closure

of adhesive is a recurrent problem and they are less esthetic, less hygienic and more difficult to remove.

Lingual 3 to 3 retainers: banded/bonded

These are of two types:

- Banded (Fig. 23.4A)—0.036/0.04" wire
- Bonded (Fig. 23.4B)— 0.036" + mesh on canine
- Bonded (Fig. 23.4C)—mesh throughout the length of the retainer.

Both the retainers are frequently used and possess certain advantages and disadvantages (Tables 23.9 and 23.10). The particular case should determine the choice.



Fig. 23.4A: Banded retainer (band on canine)



Fig. 23.4B: Bonded wire retainer with mesh on canine



Fig. 23.4C: Commercially available bonded retainer with mesh throughout the length of the retainer

Table 23.9: Advantages of bonded over banded extracoronal retainers

1. Completely invisible from the front
2. Reduced caries risk, as complete adhesion to the tooth surface
3. Reduced need for long-term patient cooperation
4. No time gap between removal of fixed appliance and bonding of retainer (can even be placed before debonding of brackets)
5. Can be bonded directly/indirectly

Table 23.10: Disadvantages of banded type extracoronal retainers

1. Lack of esthetics, the metallic bands are visible
2. Build up of debris and plaque around bands and the connecting wire
3. More susceptible to caries in the cement washout areas
4. Not always effective against the return of flaring, spacing or incisor torque changes

Flexible Spiral Wire Retainer

Two dimensions of wire are generally used:
1. Thick wire (0.032")
2. Thin wire (0.02")

Thin wire is used for various retainers (Figs 23.5A and B) in which all the teeth in a segment are bonded. These retainers are the most frequently used. They possess many advantages and very few disadvantages (Table 23.11).

Mesh Pad Retainers

Here a wire mesh pad is directly bonded to the lingual or palatal aspect of the teeth (Fig. 23.6).

REMOVABLE RETAINERS

These are the most frequently delivered retainers in routine clinical practice. Removable retainers are

Table 23.11: Advantages and disadvantages of spiral wire retainers

Advantages of spiral wire retainers
• Cheapest
• Twists in the wire provides adequate retention, hence no pads are required
• Allow slight movement of teeth which is required for functional movements
• Generally thin enough so as not to interfere with occlusion
• Can be used along with other removable retainers/appliances
Disadvantages of spiral wire retainers
• Good oral hygiene is mandatory
• May result in movement of teeth if wire is not passive prior to bonding
• May interfere with occlusion in deep bite cases



Fig. 23.5A: Bonded wire retainers (thick wire)



Fig. 23.5B: Bonded spiral wire retainers (thin wire)



Fig. 23.6: Bonded mesh retainer



Fig. 23.7: Hawley's retainer on the maxillary arch



Fig. 23.8A: Hawley's retainer with long labial bow



Fig. 23.8B: Retainer with long labial bow soldered to Adam's clasp

passive appliances that can be removed and reinserted by the patient.

1. *Hawley's retainer:* Charles Hawley designed the Hawley's retainer in 1920 (Fig. 23.7). It is the most popular removable appliance in use today. The retainer consists of a labial bow extending from canine to canine with retentive clasps (Adam's) on the first permanent molars. It has good retention and is capable of preventing the anterior teeth from rotating or developing gaps. The design by itself prevents the extraction spaces from opening up and is capable of closing minor spacing in the anterior segment.
2. *Hawley's retainer with long labial bow:* A simple modification to the original appliance where the labial bow has 'U' loops on the premolar distal to the canine (Figs 23.8A and B). This modification allows the closure of spaces distal to the canine.
3. *Hawley's retainer with contoured labial bow:* Again a modification of the original Hawley's retainer, the labial bow is contoured to the anterior teeth. The advantage is of better control over the anterior teeth.
4. Hawley's retainer with the labial bow crossing distal to the lateral incisor and a short distal extension controlling the canine helps in keeping the retentive arms of the labial bow from interfering with occlusion (Fig. 23.9). The control over the canine is still sufficient for retention. Closure of spaces in the anterior segment is not possible.
5. *Hawley's retainer with continuous labial bow soldered to clasps* (Fig. 23.10). This allows for space closure in the anterior as well as the extraction/premolar region. It is well tolerated by the patient and prevents spaces opening up in the region where the extractions were undertaken.
6. *Begg's retainer* (Fig. 23.11). The Begg's retainer is named after the late P.R. Begg, who was

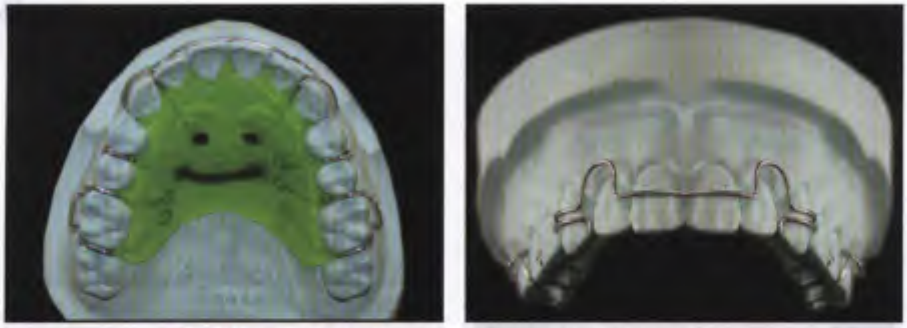


Fig. 23.9: Hawley's retainer with labial bow crossing distal to lateral incisor



Fig. 23.10: Retainer with labial bow soldered to Adam's clasp

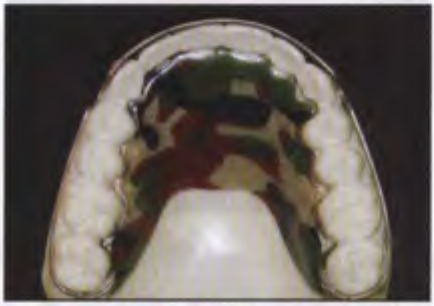


Fig. 23.11A: Begg's retainer
(Photograph courtesy; Scheu-Detnal, Germany)

responsible for popularizing this retainer. In this retainer the labial bow extends distally posterior to the last erupted molar to be imbedded in the acrylic base plate. It is ideal for cases where settling of occlusion is required; especially in the posterior segments, as there is no wire framework crossing the occlusion.

7. *Modified Hawley's retainer with light elastic replacing the labial bow* (Fig. 23.12). This retainer is rarely used nowadays. The use of elastics in the anterior region put unnecessary forces on these teeth and has a tendency to flatten the arch.
8. *Single arrowhead partial wraparounds retainer* (Fig. 23.13). This retainer is a modification of the Begg's retainer and is advocated in case with partially



Fig. 23.11B: Wrap around Begg's retainer

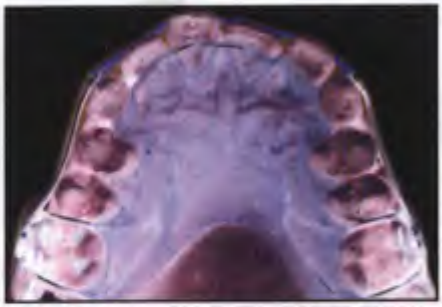


Fig. 23.12: Modified Hawley's retainer with light elastics replacing the labial bow



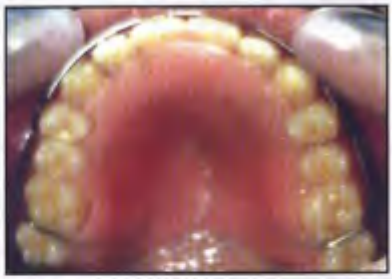


Fig. 23.13: Single arrowhead partial wraparounds retainer

erupted third or second molars. The wire bending can be tedious.

9. *Spring retainer* (Fig. 23.14) The spring retainer or the spring realigner was designed to be used exclusively in the anterior segments. It is capable



Fig. 23.14: The spring retainer

of aligning as well as retaining the corrected alignment of these teeth.

10. *Kesling's tooth positioner* (Fig. 23.15). H.D. Kesling developed the tooth positioner in 1945. It is made up of thermoplastic rubber material and covers the upper and lower clinical crowns and part of the adjacent gingiva. The patient is unable to speak with the appliance in place. Minor adjustments for settling of occlusion can be made with this appliance.
11. *Osamu's invisible retainers* (Fig. 23.16). These retainers are made of thin thermoplastic sheets. They are relatively inconspicuous and well accepted by all patients. The material fully covers the clinical crown and extends partly on to the



Fig. 23.15: Kesling's tooth positioner

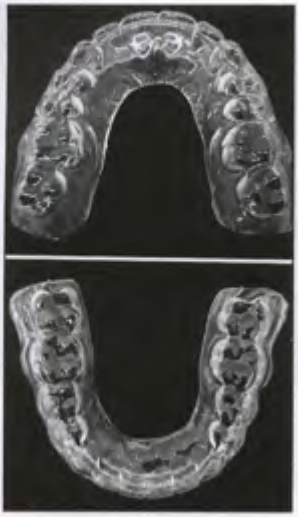


Fig. 23.16: Osamu's invisible upper and lower retainers (photograph courtesy Dr Vikram Gandhi, New Delhi)

adjacent gingiva. Some authors advise the removal of the material from the incisal/occlusal one-third of the clinical crown. This allows the teeth to settle better.

FURTHER READING

1. Bearn D. Bonded orthodontic retainers: A review, Am J Othod Dentofac Orthop 1995;108:207-13.
2. Blake M, Bibby K. Retention and stability:a review of the literature, Am J Othod Dentofac Orthop 1998;114:299-306.
3. Edwards JG. A long-term prospective evaluation of the circumferential supracrestal fiberotomy in alleviating orthodontic relapse, Am J Orthod Dentofac Orthop 1988;93:380-7.
4. Edwards JG. Soft tissue surgery to alleviate orthodontic relapse, Dent Clinics North America 1993;37:205-25.
5. Joondeph DB, Riedel RA. Retention. In Graber TM, Vanarsdall RL (Eds): Orthodontics: current principles and techniques, ed 3, St. Louis, Mosby.
6. Nanda RS, Nanda SK. Considerations of dentofacial growth in long term retention and stability. Is active retention needed? Am J Orthod Dentofac Orthop 1992;101:297-302.
7. Ponitz RJ. Invisible retainers, Am J Orthod 1971;59:266-72.
8. Reitan K. Principles of retention and avoidance of post-treatment relapse, Am J Orthod 1969;55:776-90.
9. Reitan K. Tissue rearrangement during the retention of orthodontically rotated teeth, Angle Orthod 1959;29:105-13.
10. Richarson ME. The etiology of late lower crowding alternative to mesially directed forces: a review, Am J Orthod Dentofac Orthop 1994;105:592-7.
11. Sheridan JJ, et al. Essix retainers: Fabrication and supervision for permanent retention, J Clin Ortho 1993;27:37-45.
12. Shiridan JJ, LeDoux W, McMinn R. Essix retainers: Fabrication and supervision for permanent retention, J Clin Orthod 1993;27:37-45.

24 Surgical Procedures in Orthodontics

Sanjeev Kumar, Gurkeerat Singh

- Introduction
- Surgical aids to orthodontics
- Soft tissue procedures
  - Labial frenectomy
  - Lingual frenectomy
  - Pericision
  - Exposure of impacted teeth
- Hard tissue procedures
  - Creation of space by extraction of teeth
  - Removal of obstruction in path of eruption
  - Removal of impacted teeth
  - Prophylactic removal of third molar germs
  - Corticotomy
  - Transplantation
  - Osteotomy for rapid palatal expansion
  - Serial extractions

INTRODUCTION

All surgical procedures in conjunction with orthodontics require careful planning. Detailed clinical, radiological and model analysis is necessary for most procedures if predictable and stable results are to be achieved.

SURGICAL AIDS TO ORTHODONTICS

As the title suggests, several surgical procedures can be carried out as part of the overall orthodontic treatment plan. The role of these surgical interventions is to:

1. Facilitate correction of malocclusion by orthodontic techniques
2. Help stabilize post-orthodontic results
3. To prevent relapse.

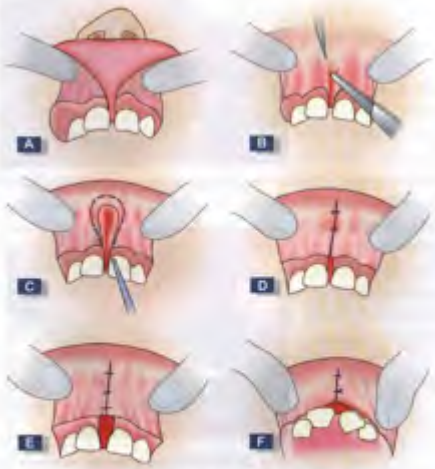
By themselves, these procedures do not bring about spatial changes in the way the teeth occlude.

SOFT TISSUE PROCEDURES

LABIAL FRENECTOMY

Indications

When a median diastema is being caused or held open by a thick, short and fibrous labial frenum which is attached to the incisive papilla (Figs 24.1A to 24.3D).



Figs 24.1A to F: Technique of labial frenectomy




Figs 24.2A and B: Thick and bulbous labial frenum: (A) frontal view, (B) occlusal view



Fig. 24.2C: The frenum held with a forceps before the cuts are made



Fig. 24.2D: The defect following tissue removal



Fig. 24.2E: Postoperative healing as seen after 7 days



Fig. 24.3A: Bulbous labial frenum



Fig. 24.3B: Frenum held with an artery forcep



Fig. 24.3C: Wound following removal of the tissue



Fig. 24.3D: Sutures placed closer to the lip, the inferior portion of the wound is covered using a perio-pack

Sometimes, this frenum may insert in the intermaxillary suture area on the palatal aspect. When tension is applied to the frenum, incisive papilla should blanch.

Frenectomy is usually done only after eruption of permanent lateral incisors and canines fails to close the median diastema. It can be done either before or after appliance therapy has approximated central incisors.

Technique (Figs 24.1A to 24.3D)

The purpose of frenectomy is to eliminate the fibrous tissue between the roots of the central incisors so that there is no obstruction to approximation of these teeth by appliance therapy.

Local anesthetic is infiltrated on either side of the frenum and an assistant holds the lip outwards and forward while exerting pressure on the lateral aspect, thereby reducing the resultant bleeding. With a no. 15 knife, incisions down to the bone are made on either side of the frenum, going in-between the teeth and joined around the incisive papilla. With a periosteal elevator, the underlying fibrous tissue is detached from the palatal bone and in-between the teeth. This releases the frenum, which is left attached to the lip at its anterior end. It is then excised and the wound closed after clearing all fibrous tissue from the bone.

Residual defect on the gingiva is covered by a periodontal pack. Sutures are removed on the 7th day and healing is normally uneventful (Fig. 24.2E).

LINGUAL FRENECTOMY

ANKYLOGLOSSIA

The band of tissue connecting the tongue to the floor of the mouth is called the lingual frenum or frenulum. Occasionally this frenum might be congenitally short, thick, or tight, or may extend too far down along the tongue or the gum. An unusually thick, large, or tight lingual frenum can seriously constrict the movement of the tongue and this condition is called "tongue-tie" or ankyloglossia (Fig.24.4A). The incidence of ankyloglessia is about 4.8%. Incidence is more in male at almost (3:1).

SYMPTOMS

Children may have difficulty breastfeeding as infants and may later develop lisping. The patient is unable to clear away food from the roof of the palate and from labiobuccal sulci. Occasionally, irregularity of the lower incisors may develop as a result (Fig.24.4B). Some patients may develop an open bite because of the pull of the frenum on the jaw and tongue thrusting. In the edentulous patient the frenum may interfere with the fit of the lower denture causing its displacement every time the tongue moves.

Clinical Features

The tongue acquires a heart shape when raised (Fig. 24.4C). The patient cannot extend tongue out to a point and it curves down when extended.

An unusually short range of tongue extension may indicate the need for a lingual frenectomy.

Treatment

A frenectomy is performed using either a scalpel or a CO2 laser. The surgeon excises the frenum (Fig.23.4D) or performs a Z-plasty (Fig.23.4E) in order to mobilize the tongue. When conducted with a laser, the surgery tends to cause very little bleeding, does not require sutures, and often results in very little post-procedure discomfort. The procedure can be performed using local anesthesia, sometimes with an intravenous sedative. Very young children may have to undergo the procedure under general anesthesia.

PERICISION

Indications

It is generally assumed that a stable position of the teeth in the dental arch after orthodontic tooth movement can only be established when the connective tissues of the gingiva have been allowed to adapt to the newly created situation. Supracrestal gingival fibers of an orthodontically moved tooth get stretched and undergo readaptation very slowly. The pull of these fibers is a major factor in relapse. If these supracrestal fibers are sectioned and allowed to heal while the teeth are held in the proper position, relapse caused by gingival elastic fibers is greatly reduced. Reattachment of these fibers at a new relaxed position on the root surface stabilizes the tooth in its new position. This procedure is effective in controlling relapse of derotated teeth.

Technique

Edwards's technique: *Circumferential supracrestal fibrotomy (CSF)* Under local anesthesia, a No. 11 knife



Fig. 24.4A: Ankyloglossia



Fig. 24.4B: Irregularity of the lower incisors due to a "tongue tie"



Fig. 24.4C: The tongue acquires a heart shape when raised



Fig. 24.4D: Surgical excision of the lingual frenum



Fig. 24.4E: "Z" plasty done for the lingual frenum

is passed through the gingival sulcus up to the crest of alveolar bone. Cuts are made inter-proximally on each side of a rotated tooth and along the labial or lingual gingival margin. No periodontal pack is necessary and there is only minor discomfort after the procedure (Fig. 24.5).



Fig. 24.5: Pericison

Alternative technique: Under LA, an incision is made in the center of each gingival papilla separating it from below the margin to 1-2 mm below the height of the bone buccally and lingually.

Either of these procedures is done only at the end of the finishing phase of orthodontic treatment. After the procedure, the teeth are held in good alignment until healing occurs in a few weeks.

EXPOSURE OF IMPACTED TEETH (e.g., canine)

Indications

An unerupted canine may be a candidate for surgical exposure if:

1. There is no sign of the tooth even after 12 years of age
2. Adequate room in the arch is present or can be created orthodontically or by extraction of some other tooth.
3. Potential path of eruption is unobstructed by other teeth.
4. The apex of canine comes as close to normal as possible after eruption so that it does not look unsightly. This will happen if the tooth erupts through the site at which the canine apex is normally situated.
5. Radiographically the root is not dilacerated.

Technique

Under LA or GA, cruciform incision is made over the estimated position of the crown of the unerupted tooth. The four triangular flaps are raised and after determining the crown position, the flaps are excised (Figs 24.6A and 6B). A sharp chisel or gouge is used with hand pressure to remove the overlying bone. The tip of the cusp, the cingulum and the greatest mesial and distal convexities of the crown are exposed. The surrounding bone is carefully chiselled to create a shallow cavity (saucerization). Care should be taken to preserve labial or palatal mucoperiosteum and bone so that the gingival margin is not raised up when the tooth erupts. The cavity is packed with cotton impregnated with zinc-oxide eugenol paste for 10-14 days. A mattress suture may be required to retain the pack. A bracket may be cemented at the time of exposure or later to aid in eruption (Fig. 24.6C).

A similar procedure may be employed to expose impacted second permanent molars. The flap is triangular in shape, with a wide base (Fig. 24.6D). The third molar can be enucleated in the same sitting if it is so desired.



Fig 24.6A: Technique of canine exposure



Fig. 24.6B: Bilateral exposure of the impacted maxillary canines



Fig. 24.6C: The exposed canines being brought into alignment

Submerged teeth Nine percent of children aged between 3 and 12 years have one or more of their primary molars in infra-occlusion. The cause is unknown but the condition is familial and more common in certain ethnic groups. The permanent successor is frequently absent and these teeth may be ankylosed. Removal is indicated for orthodontic reasons if alignment of adjacent teeth is disturbed.

Retained deciduous teeth should be extracted if:

1. Mobility is present.
2. Permanent successor is present, which is getting deviated and can be orthodontically brought into occlusion (Fig. 24.7).



Fig. 24.6D: Exposure of impacted mandibular right 2nd molar, the 3rd molar is visible (incision line is drawn in white)



Fig. 24.7: Retained deciduous tooth displacing the erupting permanent central incisor

HARD TISSUE PROCEDURES

CREATION OF SPACE BY EXTRACTION OF TEETH

Creation of space by extraction of teeth (e.g., normal healthy teeth, submerged teeth, retained deciduous teeth).

Indications

Normal healthy teeth: Therapeutic extraction of erupted healthy teeth is scheduled as part of the overall orthodontic planning in order to gain space. Various combinations of teeth may be required to be extracted after a complete diagnostic exercise. Usually however, symmetrical extractions of premolar or molar teeth are planned in order to avoid a shift in midline.

3. Space created can be covered when crowding is corrected.

Technique

All therapeutic extractions should be carried out as atraumatically as possible with preservation of both buccal and lingual cortical plates. Any loss of alveolar bone may prevent ideal positioning of teeth orthodontically. While extracting maxillary premolars, a sustained downward traction while luxating, will prevent breakage of the slender roots. Preoperative radiographs are helpful in planning and executing extractions.

Submerged teeth are frequently ankylosed to bone and may have to be excised out with a drill.

REMOVAL OF OBSTRUCTION TO ERUPTION (e.g., supernumerary teeth, odontomes)

Indications

Supernumeraries should be extracted because:

1. In the anterior maxillary region, supernumeraries may prevent eruption of permanent incisors.
2. May cause pressure on the root and lead to malpositioning of adjacent teeth.
3. If erupted, can be the cause for crowding in the arch or may cause periodontal complications (Fig. 24.8A).
4. There may be a cyst associated with them.

Odontomes may be complex or compound and are generally diagnosed accidently on an X-ray only when they cause delayed eruption or gross displacement of related permanent teeth (Fig. 24.8B). Swelling may be an associated finding. Once detected, an odontoma (Fig. 24.8C) should be removed as soon as possible to without damaging the adjacent teeth or tooth germs.

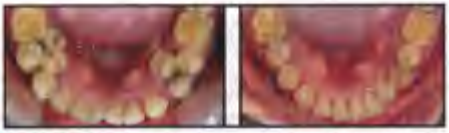


Fig. 24. 8A: Supernumeraries removed from the premolar region and the arch aligned with fixed orthodontic appliance. Note the improvement in periodontal health



Fig. 24.8B: An odontoma preventing the eruption of the permanent maxillary canine



Fig. 24.8C: An odontoma removed along with a retained deciduous canine

Technique

Depending on the position, either a buccal or a palatal approach is used to extract the supernumerary tooth. Preoperative radiographs are essential to determine the position. Flaps are raised in the usual manner, bone removed and the tooth delivered with minimum pressure on adjacent standing teeth. If the root is dilacerated, it is best to section the tooth and then remove the root separately.

The compound odontomes have a fibrous capsule, which facilitate their removal. Large complex odontomes have irregular surfaces, which interdigitate with the investing bone making their removal difficult. These may then have to be excised by sacrificing surrounding bone carefully.

REMOVAL OF IMPACTED TEETH (e.g., canine)

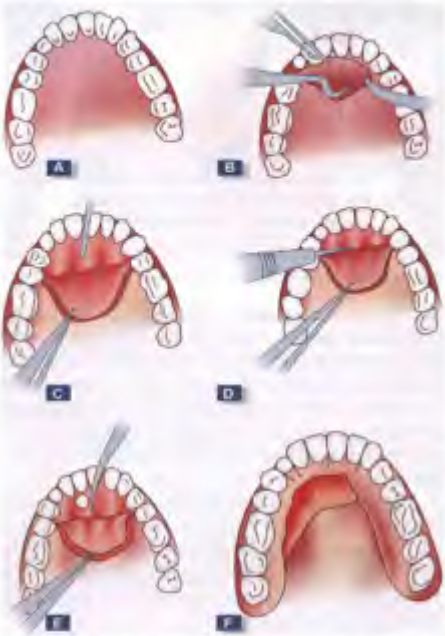
Indications

Impacted canine is indicated, for extraction if:

1. It is ectopically placed
2. Adjacent teeth are in good contact, e.g. lateral incisor and first premolar.
3. It is causing pressure on the root of a standing tooth leading to its resorption or malposition.
4. There is a pathology associated with it.

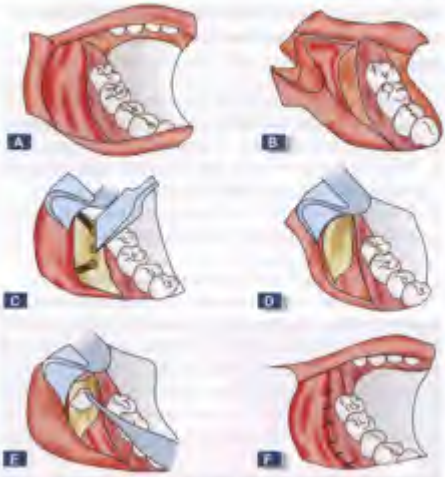
Technique

The position of the impacted tooth is ascertained preoperatively with the help of radiographs. Clark's tube shift (parallax) method is a reliable method to determine whether the tooth is lying buccally or palatally. Vitality and presence of mobility of the



Figs 24.9A to F: Extraction of a palatally impacted canine

lateral incisor and first premolar is also ascertained preoperatively. In case the procedure renders these teeth non-vital or mobile, RCT and splinting of the affected teeth may be indicated. Either a buccal or palatal flap is raised to approach the buried canine (Figs 24.9A to F). The overlying bone is removed with a bur or chisel to expose the entire crown including the tip if it can be done without endangering the standing teeth. The tooth may now be delivered if the root pattern permits with a Warwick-James elevator applied to its mesial side. If the tooth crown is impacted, then the canine should be sectioned and removed in pieces in order to avoid damage to the roots of the standing teeth. The wound is debrided and closed with interrupted sutures. A clear acrylic palatal splint may be inserted to support the palatal flap postoperatively.



Figs 24.10A to F: Lateral traphination technique of Bowdler-Henry

PROPHYLACTIC REMOVAL OF THIRD MOLAR GERMS

Indications

Some orthodontists believe that crowding of lower incisor teeth is produced by the ineffectual attempts of impacted mandibular third molars to erupt. Therefore, in children who show a marked disproportion between the tooth size and the jaw size, prophylactic removal of either the third molar germ at 7-9 years of age or at 16 years when the roots are one-third formed may be carried out. An operation at these ages is simple and produces less pain, swelling, infection etc. Also, the wisdom tooth is removed before it can affect the second molar periodontally or cause crowding in the lower arch.

Technique

Bowdler Henry's technique: *lateral treplination (1969)* Under LA or GA, an extended S-shaped incision is made in the retromolar area and the mucoperiosteal flap retracted (Figs 24.10A to F). A round bone bur is used to drill a series of holes horizontally over the



Fig. 24.11: Corticotomy for anterior teeth

position of the crypt. Then with the same bur a vertical cut is made at its anterior margin. A second cut through the outer plate is made at the posterior end of the crypt at an angle of 45° from the row of trephine holes. With the help of a chisel the buccal window thus outlined, is out fractured and removed. The crown of the wisdom tooth should be visible within its follicle. It is now delivered with the help of a Warwick-James elevator. The wound is debrided and the sutured with 3-0 silk or Vicryl.

CORTICOTOMY

Indications

This procedure is usually carried out on the anterior maxillary teeth in young adults when the duration of appliance therapy needs to be shortened. One or more teeth can be moved rapidly orthodontically if corticotomy is performed prior to appliance therapy.

Technique

Large labial and palatal mucoperiosteal flaps are raised under LA or GA, to expose both the labial and palatal cortices of the teeth to be moved. Vertical cuts of predetermined width are made with a bur on either side of each tooth through both the cortices parallel and away from the roots (Fig. 24.11). The apical ends of these cuts are joined by horizontal cuts through the compact bone alone thus leaving the teeth to be aligned supported by cancellous bone. The flaps are replaced and sutured. After a delay of 2-3 days, the orthodontic appliance can be fitted and tooth movement rapidly achieved. Retainers are required for a period of 6 months to stabilize the result.

TRANSPLANTATION (e.g., canine)

Indications

Autogenous transplantation is usually carried out for misplaced maxillary canines when adequate room is present in the arch. It is usually performed in younger adults in whom bone is elastic and the canine can be removed with minimum damage to its periodontium.

OSTEOTOMY FOR RAPID PALATAL EXPANSION

Indications

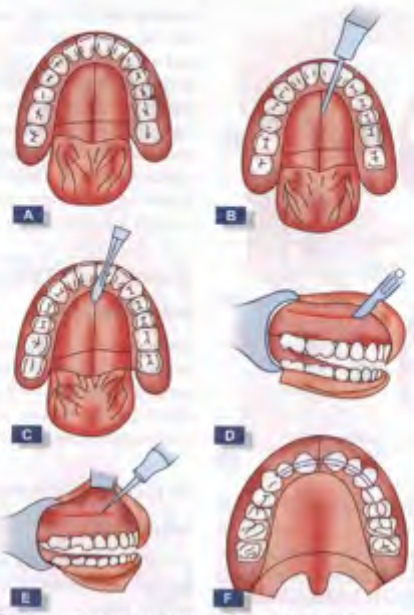
Adults with skeletal maxillary constriction. Rapid palatal expansion is not possible with orthodontic means alone in these patients because of fusion of midpalatal and lateral maxillary sutures.

Technique

A jackscrew expansion device is cemented before surgery and then corticotomies are performed in the lateral antral walls bilaterally (Figs 24.12A to F). The midpalatal suture is also osteotomized through a small vertical incision. The jackscrew is activated and expansion is carried out daily in small increments until complete. A stabilization period of 6 weeks is required for bony consolidation to occur.

SERIAL EXTRACTIONS

This technique of extracting deciduous teeth in a planned fashion relies on growth of the jaws and eruption of permanent teeth to bring about a change in occlusion. The patient may require no future active orthodontic treatment or treatment time get shortened.



Figs 24.12A to F: Technique for rapid palatal expansion: (A) Paragingival incision in palate, (B) Midline palatal incision made anteroposteriorly for entire length of exposed bony palate, (C) Midpalatal bony incision continued anteriorly to crest of inter-radicular bone between maxillary central incisor teeth, (D) 4 cm horizontal incision made 1 cm cephalad from junction of free and attached mucosa with root of zygomatic arch as its midpoint, (E) 3 cm bony horizontal incision in exposed lateral antral wall, (F) Rapid palatal expansion device cemented into position

FURTHER READING

1. Boese LR. Fiberotomy and reproximation without lower retention, nine years in retrospect: art 1, Angle Ortho 1980;50:88-97.
2. Edwards JG. The diastema, the frenum, the frenectomy: A clinical study, Am J Ortho 1977;71:489-08.
3. Henny TG, Atherun TJ. Periodontal problems associated with the surgical exposure of unerupted teeth. Br J Orthod 1976;3:79-85.
4. Levin MP, D'Amico RA. Flap design in exposing unerupted teeth, L Am Dent Assoc 1971;82:836-40.
5. Northway WM, Meade JB. Surgically assisted rapid palatal expansion: a comparison technique, response and stability, Angle Orthod 1997;73(4):309-20.
6. Pinson RR, Strahan JD. The effect on the relapse of orthodontically rotated teeth after surgical division of the gingival fibers- Pericision, Brit J Ortho 1974;1:87-91.
7. Vanarsdall RL, Corn H. Soft tissue management of labially positioned unerupted teeth, Am J Orthod Dentofacial Orthop 1977;72:53-64.
8. Vermette ME, Kokich VG, Kennedy DB. Uncovering labially impacted teeth-apically positioned flap and closed-eruption techniques, Angle Orthod 1995;65:23-32.
9. Vermette ME, Kokich VG, Kennedy DB. Uncovering labially impacted teeth, Apically positioned flap and closed eruption techniques, Angle Orthod 1995;65:23033.
10. Wintner M. Surgically assisted palatal expansion: An important consideration in adult treatment, Am J Orthod Dentofacial Orthop 1991;85-90.
11. Wintner ML. Surgically assisted palatal expansion: An important consideration in adult treatment, Am J Otrthod Dentofacial Orthop 1991;85-90.

25 Orthognathic Surgery

Sanjeev Kumar, Gurkeerat Singh

- Introduction
- Indication for orthognathic surgery
- Planning orthognathic surgery
- Procedures

INTRODUCTION

Orthognathic surgery is the surgical correction of skeletal anomalies or malformations involving the mandible or the maxilla. Orthognathic surgery is also called surgical orthodontics because, just as an orthodontist repositions teeth, an oral and maxillofacial surgeon uses orthognathic surgery to reposition whole or part of one or both jaws. Because moving the jaws also moves the teeth, orthognathic surgery is performed in conjunction with orthodontics so that the teeth are in proper position after surgery.

Malformations of the jaws may be present at birth, or they may become evident as the patient grows and develops. This can cause chewing and eating difficulties, abnormal speech patterns, early loss of teeth, and disfigurement and dysfunction of the temporomandibular joint.

The objective of orthognathic surgery is the correction of a wide range of minor and major facial and jaw irregularities, and benefits include an improved ability to chew, speak and breathe. In most cases it results in improved harmony of the face.

INDICATION FOR ORTHOGNATHIC SURGERY

The indication for surgery is a problem too severe for orthodontics alone. The limits of orthodontic treatment can be determined somewhat by the "envelope of discrepancy" (Fig. 25.1).

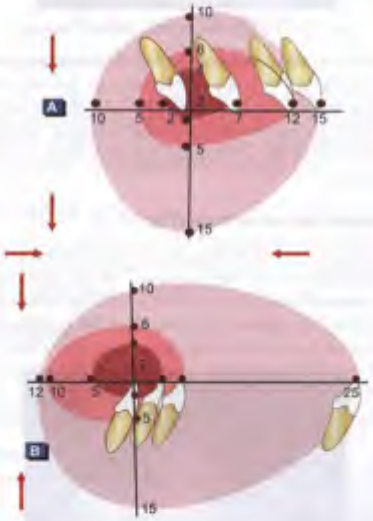


Fig. 25.1: The envelope of discrepancy

ABNORMALITIES OF THE MAXILLARY BASE

Maxillary Prognathism (Fig. 25.2)

Maxillary base may be anteriorly placed (antemaxillism) or may be large in all dimensions (macro-



Fig. 25.2: Patient with vertical maxillary excess

maxillism). Maxillary excess may cause either protrusion of the upper jaw or elongation of the face, with downward displacement of the mandible. In vertical maxillary excess, the disfigurement causes a "long-face syndrome" with accompanying distortion of facial features.

Maxillary Retrognathism (Fig. 25.3)

Maxillary base may be posteriorly placed (retromaxillism) or may be too small in all dimensions (micromaxillism). In the latter condition, also called maxillary hypoplasia, the growth of the maxilla does not match that of the lower jaw. There is a collapse of the normal mid-face supporting structures. In addition to causing difficulties with eating and speech, this deficiency may be associated with anomalies of the supporting structures of the nose and cheeks. Partial obstruction of the nasal passages may be present. Reconstruction of the nasal and malar tissues may be intimately related to the treatment for maxillary deficiency.



Fig 25.3: Patient with mid-face hypoplasia

Maxillary Asymmetry (Fig. 25.4)

When the maxillary base is asymmetric in length and width, e.g. hemifacial microsomia. Lateromaxillism may occur when a normal maxillary base is positioned laterally.



Fig. 25.4: Patient with hemifacial microsomia

ABNORMALITIES OF THE MANDIBULAR BASE

Mandibular Prognathism (Fig. 25.5)

It could either be that the mandible is too large in all dimensions (macromandibulism) or that the base of the body is positioned anteriorly (antemandibulism).



Fig. 25.5: Patient with mandibular excess

Excess mandibular bone causes protrusion of the lower jaw beyond the normal alignment with the upper jaw; with a resultant Class III malocclusion. This can prevent effective biting and chewing of food and hastens periodontal disease. Temporomandibular joint function and speech may be impaired. In addition there may be chin hyperplasia or malposition which will require correction.

Mandibular Retrognathism (Fig. 25.6)

This could be as a result of the mandible being too small in all dimensions (micromandibulism) or the base of the body being positioned posteriorly (retromandibulism). This deficiency of the mandibular bone does not allow the upper and lower teeth to come together when chewing food and may affect speech. Sleep may also be impaired due to a retruded or deficient lower jaw. A deficiency of bone supporting the chin may require surgery to build up the tissue and provide a normal framework for the chin.



Fig. 25.6: Patient with bilateral TMJ ankylosis

Mandibular Asymmetry (Fig. 25.7)

The two halves of the base of the mandible have unequal dimensions; this may be seen in patients with hemimandibular hyperplasia, hemimandibular hypertrophy. Both halves of the base of the mandible may have equal dimensions but may be shifted to one side; this is called lateromandibulism.



Fig. 25.7: Mandibular asymmetry

ABNORMALITIES OF THE CHIN

The chin should be evaluated separately from the mandible. The chin prominence includes both bone and soft tissue that may require separate surgical management. Common abnormalities are:

Macrogenia

The chin is too large in all dimensions. An anteriorly placed normal sized chin prominence (antegenia) will give a macrogenic appearance.

Microgenia

The chin is small in all dimensions. A normal sized chin, placed posteriorly (retrogenia) should be distinguished from microgenia.

ABNORMALITIES OF THE ALVEOLAR PROCESSES

The alveolar process abnormalities should be assessed independently of the anomalies of the bases of the mandible and maxilla. The alveolar processes may be abnormal either in size, i.e. macro-/micro- or in position, i.e. retro-/ante. In addition they may be either too high or too low.

Other abnormalities which require surgical correction include long face and short face syndromes and open bite (apertognathism).

PLANNING ORTHOGNATHIC SURGERY

CLINICAL EXAMINATION

This should include a general medical examination to rule out any systemic disorders, e.g. acromegaly. Local oral examination should include overall dental health. Any pulpal or periodontal infections should be eradicated before surgery. The TMJ is assessed for any pre-existing pathology, e.g. clicking, locking, tenderness, deviation, etc. Rule out any normal imbalance specially pituitary.

SOCIO-PSYCHOLOGICAL EVALUATION

Assessment of the patient's awareness of his/her dentofacial deformity and expectation from treatment should be done. This helps in determining the patient's motivation towards surgery. The patient's social status should also be evaluated.

RADIOLOGICAL EXAMINATION

A complete dental radiographic survey can be done with an orthopantomogram (OPG) (Fig. 25.8) to rule out a periapical or periodontal pathological condition. The X-ray will also aid in the determination of the stability of teeth in the supporting tissue and their ability to withstand the stresses of fixation devices and immobilization. Any impacted/embedded or ectopic teeth, which may come in the line of the osteotomy cut, should be preferably extracted 6 months prior to surgery. The position of the ID canal and the anteroposterior width of the ramus is assessed when mandibular ramus osteotomy is planned. The flare of the rami is assessed on a submentovertex view (Fig. 25.9) when intraoral approach for ramus osteotomy is planned. If extra or intra-oral approach is to be used.

Photographs

Preoperative photographs are necessary in order to have a record of pretreatment profile. Morphometric measurements can also be done on these photographs. Frontal and lateral photographs are usually taken in a natural head positions.

CEPHALOMETRIC EVALUATION

This is essential for preoperative evaluation of all patients regardless of the type of deformity. Lateral cephalogram (Fig. 25.10) and/or anteroposterior cephalogram (Fig. 25.11) (in asymmetry cases) is most helpful in determining precisely the location of the deformity and in selecting the proper operative sites for surgical correction. Soft tissue outline on the cephalogram is marked by painting barium on the midline of the patient's face prior to shooting the radiograph. A combination of commonly used land-



Fig. 25.8: Orthopantomogram of a patient with facial deformity. Note the difference in the inter-occlusal distance between the right and the left side



Fig. 25.9: Sub-mentovertex view of skull, of a patient with facial deformity. Note difference in the position of the two mandibular condyles



Fig. 25.10: Lateral cephalogram, of a patient with facial deformity



Fig. 25.11: Frontal cephalogram, of a patient with facial deformity

marks and measurements determine the degree and location of dento-skeletal deformity. Legan's Burstone and cephalometrics for orthognathic surgery (COGS analysis) is also used as it relies on linear rather than angular measurements, which is helpful in planning surgery.

STUDY MODELS

Two sets of dental stone models are constructed from the patient's impressions. Bite registration is useful while mounting the models on an articulator. One set of study models are evaluated for intra-arch, inter-arch discrepancies and for occlusion. The study models are invaluable aids when assessing the feasibility of surgical correction as they provide a permanent three-dimensional record of the dental and underlying skeletal structures. They also present the various permutations of movement area involved that will need to be explored to correct the presenting facial and jaw disharmony. A second articulated set is used as working models on which mock surgery is performed.

PREDICTION TRACING

The postoperative profile of the patient can be predicted with some degree of accuracy by cephalometric means. This is called "prediction tracing". Essentially, after knowing the location and severity of deformity; the osteotomy and the extent of movement of the osteotomized segment is determined. On an acetate tracing of the cephalogram, the osteotomized segment is cut out and moved as calculated. The soft tissue follow the movement of bone in a ratio determined by the type of movement and the technique performed (Table 25.1). However, these soft tissue changes are only meant to be a guide for prediction tracings and are variable. These tissue changes are marked on the tracing to give the postoperative profile.

MODEL SURGERY

Using prediction tracings; a surgical plan is decided upon and then the surgery is simulated on articulated working models. The models are cut and repositioned in the desirable position and the segments secured in their new position with sticky wax. The occlusion achieved is evaluated for stability and any modifi-

Table 25.1: Ratio of movement produced in the soft tissue to the movement of the underlying bone with various surgical procedures

Procedure	*Technique*	*Bone: soft tissue*	*Ratio of movement*
Mandibular setback	BSSO	Pogonion: Soft tissue chin	1:1
	BSSO	Patient B: Inferior labial sulcus	1:0.9
	BSSO	Lower incisor: Lower lip	1: 0.8
	BSSO	Pogonion: Superior labial sulcus	5:1
Mandibular advancement	BSSO	Pogonion: Soft tissue chin	1:1
	BSSO	Lower incisor: Lower lip	1:0.75
	BSSO + Sliding genioplasty	Pogonion: Soft tissue chin	3:2
Genioplasty (augmentation)		Pogonion: Soft tissue chin	4:3
Genioplasty (reduction)		Pogonion: Soft tissue chin	5:4
Maxillary advancement	Le-Fort I	Upper incisor: Upper lip	2:1
	Le-Fort I	ANS: Nasal tip	7:2
Premaxillary setback	Wassmund	Upper incisor : Upper lip	3:2
	Wassmund	Upper incisor : Lower lip	3:1

cations required noted. Splints are then constructed which are of immense help during surgery.

PROCEDURES

In orthognathic surgery, a bone cut (osteotomy) is made in the affected jaw, and the bones are repositioned in a more normal alignment. Generally, the bones are held in their new positions with plates, screws and wires. The patient may also need arch bars placed on both jaws to add stability. It is usually performed under general anesthesia as an inpatient procedure. In some cases, adjunctive procedures such as a reconstructive rhinoplasty, malar augmentation, genioplasty and bone grafting procedures are needed to correct deformities associated with malformation syndromes. Patients with deficient bone tissue may require grafts from their ribs, hips or skull. Alloplastic replacement of missing bone may also be required.

Both jaws can be osteotomized and repositioned in all the three planes of space, i.e. anteroposterior, vertical and transverse in order to achieve a balanced profile and occlusion. Needless to say that commonly a combination of movements is required in either one or both jaws.

ANTEROPOSTERIOR CORRECTION

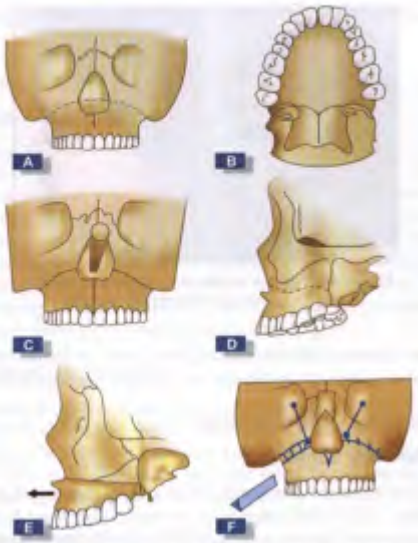
Maxillary Surgery

Advancement Le-Fort I (Figs 25.12A to F) down-fracture and advancement is the preferred technique for maxillary retrognathism. The length of the vascular pedicle and soft tissue compliance limits the extent of anterior movement.

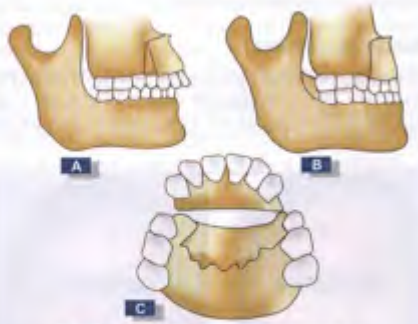
Retraction Retraction of a Le-Fort I segment is difficult because of the presence of the pterygomandibular plates and tuberosity. Therefore anterior segmental osteotomy (**Wassmund** (Figs 25.13A to C) **or Wunderer procedure or Cupar's technique**) after extraction of a premolar on either side is most commonly performed in maxillary prognathism cases.

Mandibular Surgery

Advancement Bilateral sagittal split osteotomy (BSSO) (Figs 25.14 and 25.15) is currently the most preferred technique since it can be performed easily intraorally.



Figs 25.12A to F: Le-Fort I osteotomy for maxillary repositioning



Figs 25.13A to C: Wassmund's procedure



Fig. 25.13D: Pre and post-treatment photographs of a case treated with upper first premolar extraction and anterior maxillary subapical set-back



Figs 25.14A to F: Sagittal split technique for mandibular setback or advancement

Inverted L osteotomy and C-osteotomy (Figs 25.16A to D) are also procedures performed in the ramus for advancement of the mandible. The former can be performed intraorally whereas the C-osteotomy is



Fig. 25.15: Mandibular advancement using the bilateral sagittal split osteotomy (BSSO) technique



Fig. 25.17: Bilateral sagittal split osteotomy (BSSO) used for achieving a mandibular setback



Figs 25.16A to D: (A) Normal relations, (B) Vertical subsigmoid osteotomy (C) Inverted L osteotomy, (D) C-osteotomy of mandible

done extraorally. Anterior segmental subapical osteotomy can be performed if only the alveolar segment needs to be advanced without moving the chin-point.

Setback Bilateral sagittal split osteotomy (BSSO) (Fig. 25.17) or transoral vertical or oblique ramus osteotomy are usually performed for this movement. If closure of bilateral edentulous spaces or a narrowing of the arch is required, then a body *ostectomy* is performed where a segment of full-thickness bone is removed. Anterior segmental subapical osteotomy and posterior movement of the dentoalveolar segment can be performed in case of mandibular excess with chin deficiency.

VERTICAL CORRECTION

Maxillary Surgery

Both superior positioning (for long face correction) (Fig. 25.18) and inferior positioning (for short face correction) can be performed by Le-Fort I down-fracture technique. Inferior movements however is less stable and usually require insertion of bone graft or hydroxyapatite blocks between the segments in order to increase stability. Simultaneous ramus osteotomy is helpful in preventing relapse.

Mandibular Surgery

Shortening of vertically excessive mandible should be done by inferior border osteotomy and chin augmentation horizontally. Elongation of lower facial



Fig. 25.18: Pre- and post-treatment photographs after Le-Fort I down fracture and superior repositioning of the maxilla

height can be done with BSSO, which rotates the mandible down and forward.

TRANSVERSE CORRECTION

Maxillary Surgery

Expansion of maxillary arch is usually performed in conjunction with Le-Fort I down-fracture in which parasagittal osteotomies immediately medial or lateral to the nasal wall with an extension going between the roots of central incisors is carried out. Bone graft is needed to fill the space created by lateral movement of the posterior segments. If constriction of the arch is required, bone is removed from the osteotomy sites as determined by pre-surgical planning.

Mandibular Surgery

Because of the TMJs transverse corrections are difficult in mandible. Anteriorly, extraction of a tooth and ostectomy can be performed to achieve constriction of the arch. Expansion is better done by distraction osteogenesis rather than osteotomy.

SKELETAL OPEN-BITE CORRECTION (APERTOGNATHIA)

Skeletal open-bite is a difficult problem to treat, thus a separate mention is being made. Skeletal open-bite commonly occurs in long-face individuals who have vertical maxillary excess, anteroposteriorly deficient mandible with short ramus height. Lower anterior teeth may be over-erupted. Le-Fort I down-fracture and superior repositioning of the maxilla especially posteriorly best treat these patients. The mandible autorotates upward and forward, which brings the chin anteriorly. If further anterior placement of the chin is desired, an augmentation genioplasty is performed. If lower teeth interfere with occlusion, they can be intruded orthodontically or anterior segmental surgery can be performed to depress this segment.

GENIOPLASTY

The chin can be moved in all three planes after osteotomy or may be augmented by an onlay autograft or allograft. Genioplasty is done to improve results of mandibular advancement or reduction or to correct asymmetry.

MALAR AUGMENTATION

This is done through the mouth and can give added height and fullness to the cheeks. An allograft is normally inserted after taking impression of face and making a face model into a pocket of soft tissue through an incision in the buccal vestibule which is stabilized with the help of suture, screw or wire.

Patients with deficient bone or soft tissues of the face may require distraction osteogenesis. A distraction device is applied. Bone osteotomies are performed. The distraction device is then used to slowly apply a distractive force at the osteotomy site until new bone is formed. Once the desired reconstruction is achieved, the device is left in place until the bone is healed and then the device is removed. This enables a surgeon to elongate a facial bone and the adjacent soft tissue envelope.

FURTHER READING

1. Bell WH, Fonseca RJ, Kennedy JW, et al. Bone healing after posterior maxillary osteotomy. J Oral Surg 1971;29:313-22.
2. Bell WH. Le Forte I osteotomy for correction of maxillary deformities. J Oral Surg 1975;33:412-26.
3. Edler RJ. Problems in orthodontic management of orthognathic cases. Eur J Ortho 1990;12:420-37.
4. Epker BN, Stell JP, Fish LC. Dentofacial deformities: integrated orthodontic and surgical correction, ed 2, St Louis, 1998, Mosby.
5. Gregoret J, Tuber E. Orthodontics and Orthognathic Surgery Diagnosis and Planning, Barcelona: Espaxs, 1997.
6. Proffit WR, White RP. Surgical-orthodontic treatment, 1991, Mosby Year Book, Missouri.
7. Proffit WR, Epker BN. In Bell, et al (editors). Surgical correction of dentofacial deformities, 1980, Saunders, Philadelphia.
8. Vanarsdall RL, Corn H. Soft tissue management of labially positioned unerupted teeth. Am J Orthod 177;72(1):53-64.
9. Von der Heydt K. The surgical uncovering and orthodontic positioning of unerupted maxillary canines. Am J Orthod 1975;68(3):256-76.

26 Implants to Mini-Screws

Abhay Lamba, Gurkeerat Singh

- What are dental implants?
- History
- Types of dental implants
- Biomaterials for dental implants
- Indications for dental implants
- Orthodontic anchorage

WHAT ARE DENTAL IMPLANTS?

DEFINITION

"A dental implant is a biomedical device, which is usually composed of an inert metal or metallic alloy, which is placed on or within the osseous tissues."

Implants are now being used in orthodontics for the purpose of augmenting anchorage.

HISTORY

The history of implants or implant-like devices attached to prosthesis can be traced to ancient civilizations like *Egyptians* (2000 years), *Ancient Chinese* (4000 years), *Incas* (1500 years), etc. Different materials were implanted in place of missing teeth; ranging from teeth taken from slaves, prisoners, or from animals. In Inca skulls, researchers found precious stones implanted in the jaws to replace missing teeth. In *Pre-Columbian* skulls, they found carved stones replacing missing teeth. *Arabian* surgeons used ox bone to replace missing teeth.

In recent time *Maggioli* in 1809, used root-shaped gold pieces. In the year 1887, *Harris and Berry* reportedly used teeth made of ceramic or porcelain into which lead-coated platinum posts were fitted. In the early 1900s, *Lambotte* fabricated implants made of aluminium, gold, silver, brass, copper, steel, magnesium, plated with nickel and gold. *Greenfield* in 1909, designed a lattice-cage type implants made of iridoplatinum. It used to be placed surgically and had a mediocre success. This was the first implant design that differed from the root form design.

Stork in 1938, introduced surgical cobalt chromium molybdenum alloy implant that he used to replace a left maxillary central incisor and it lasted for 15 years. In 1946, *Stork* designed a two-stage screw implant, which was inserted without a premucosal post and later after bone healing took place, the crown and abutment were attached to it. This interface between bone and implant was called ankylosis and it can be equated with the clinical term as *rigid fixation*. Rigid fixation defines the clinical aspect of this microscopic bone contact with an implant and in the absence of mobility with a 1 to 500 gm force applied in a vertical or horizontal direction. The first submerged implant placed by Stork lasted for more than 50 years. Bone fused to titanium was first reported and documented by Bothe *et al* in 1940.

In 1952, *Branemark* started extensive experimental clinical studies on microscopic microcirculation in bone marrow healing. The 10-year studies regarding implant placement in the jawbone of the dogs started in 1960 and in humans these started in 1965 and were reported in 1977 that led to the term *osseointegration*. Osseointegration was defined as *"the contact established between normal and remodeled bone and an implant surface without the interposition of non-bone or connective tissue,"* or *"direct structural and functional connection between ordered, living bone and the surface of a load-carrying implant."* Osseointegration can also be defined as a direct interaction of bone to an implant surface. As a

result, the implant fixture is immobilized in the bone and lends itself to function as an anchor for orthodontic anchorage.

TYPES OF DENTAL IMPLANTS

Dental implants can be subdivided into three major types based on their mode of attachment to the bone structure as: endo-osseous, subperiosteal and transosseous.

ENDO-OSSEOUS IMPLANTS

These implants are screwed, tapped or drilled directly into the bone. They osseo integrate with the bone. These implants provide better initial stability/retention. A minimum healing period of 3-4 months is required before they can be loaded.

These are available in many designs depending upon the bone condition and the type of abutment to be used. Due to the limited amount of space available, high cost and long waiting period for them to osseo-integrate before loading other solutions were proposed.

Root Form—(Also Used in Orthodontics)

a. *According to the shape*
   - Straight/cylinders
   - Tapered
   - Stepped

b. *According to surface finish*
   - Smooth
   - Threaded
   - Rough
     — Sand blasted
     — Acid etched
   - Coated
     — Titanium plasma sprayed
     — Hydroxyapatite
     — Aluminium oxide

c. *Combination*
   - Straight smooth
   - Straight threaded (screw)
   - Tapered threaded (screw)
   - Stepped-tapered threaded (screw)
   - Stepped cylinder
   - Combination of root form implants with different surface coatings and design

d. *According to stages of surgery*
   - Single stage
   - Two stage

e. *According to implant abutment interface design*
   - Internal
   - External

Blade Form

- First introduced by Linkow in 1967
- Flat and taper from shoulder towards the base
- Numerous holes for interlocking (retention)
- Cut a groove and tap into the bone
- Indicated for thin alveolar ridges

Ramus Frame

Metallic markers
Used in orthodontics and growth studies.

SUBPERIOSTEAL IMPLANTS

Mainly used in completely edentulous jaw conditions:
1. Unilateral
2. Complete

TRANS-OSSEOUS IMPLANTS

These are used in certain edentulous conditions and require major surgical procedures.
1. Staple
2. Staple pins
3. Multiple pins

BIOS IMPLANT SYSTEM (BIO-RESORBABLE IMPLANT SYSTEM)

Biodegradable polylactide with a metal super-structure.

MICRO/MINI IMPLANTS

Bicortical titanium screws (most frequently used in orthodontics)

BIOMATERIALS FOR DENTAL IMPLANTS

There are many biocompatible materials available today but the main emphasis is on metals, metal alloys, ceramics, polymers, composites and carbons.

METALS AND METAL ALLOYS

- Titanium
- Tantalum

- Alloys of titanium/aluminium/vanadium
- Cobalt/chromium/molybdenum
- Chromium/iron/nickel
- Titanium and its alloys are most widely used.

CERAMICS AND CARBONS

- Aluminium oxide (aluminium and sapphire) ceramics
- Carbon
- Carbon silicon compounds.

POLYMERS AND COMPOSITES

- Polymethylmethacrylate
- Silicon rubber
- Polyethylene
- Polylactide

INDICATIONS FOR DENTAL IMPLANTS

Dental implants were mainly developed for the replacement of missing teeth. The high rate of success achieved with osseo integrated (fused with jaw bone) dental implants allowed patients to enjoy the benefits of fixed rather than removable restorations/prosthesis. The main indications for implants restoration in the partially edentulous patients—with free end distal extension (no back teeth available for support) where no posterior abutment is available and the long edentulous span is present. In both these situations, the conventional dental treatment plan would include a removable partial denture. However, with the advent of implant abutments, the patient can benefit from fixed resto-rations. Additionally, in short edentulous span (missing teeth); the single implant is becoming a more popular option.

The indications for implants are many and varied (Table 26.1). Further research and technical advancement in the field of implant placement has permitted the use of implants in other allied fields, such as orthodontics, where implants are used as anchorage units. The increased demand for orthodontic treatment by adult patients and the importance of not loosing anchorage has fueled extensive research on the topic. Still care must be taken so as not to be overzealous with implant placements and due considerations should be given to the conditions which may contraindicate their use (Table 26.2).

Table 26.1: Indications for dental implants

Indications
1. Edentulous mandible
2. Edentulous maxilla
3. Frontal region upper jaw
4. Partially edentulous jaws (one or two missing teeth)
• Kennedy's class II and III
5. Single tooth implantation
6. Extraoral implantation. (epithesis)
7. Immediate implantation
• Trauma (bone situation is to be considered)
• Periodontal problems
• Periapical pathology, and resorption of roots
• Agenetic elements; (by birth missing teeth)
• Caries
8. Orthodontic anchorage

Table 26.2: Contraindications for dental implant placement

Contraindications
1. *Medical*
• Temporal (flu, pregnancy, etc.)
• (Auto) immune diseases
• Terminal illness
• Inability to restore with prosthesis
• Use of corticosteroids
• Radiotherapy of the head, (tumoricidal radiation of implant site)
• Severe Diabetes mellitus
• Psychological problems (unrealistic patient expectation)
2. *Dental*
• Anatomy-nerves (too close), sinus, etc.
• Local pathology-cyst, roots stumps, gum problems, etc.
• Microbiology-bacterial sensitive.
• Bad Oral hygiene
• Lack of operator expertise
• Motivation
• Non cooperative patient
3. *General*
• Finance
• Touring job (unable to keep appointments)
• Attitude
• Spastic patient

ORTHODONTIC ANCHORAGE

With the advent of prosthetic implants and their predictable results, the orthodontists saw an opportunity to use them for the purpose of anchorage. Routinely used dental implants are unsuitable for use as orthodontic anchorage units as their size precludes

their use, unless edentulous regions exist in the mouth. Initially routine dental implants of relatively lesser diameter 3.5-4.5 mm and varying lengths (10-16 mm)were used in orthodontics. They were of the self-tapping variety with the threads having a sandblasted or acid-etch surface finish. The polished trans-mucosal neck was either 2.5 or 4.5 mm long. Because of their size they were generally placed in the palate or in the retromolar region (Fig. 26.1).

Following their success, implants were especially designed for anchorage in orthodontics (Fig. 26.2). They are smaller in diameter generally 0.9-1.6 mm in diameter and ranged from 6-12 mm in length. The implant head has a hole and / or a groove to accept an orthodontic wire or other orthodontic accessories. They can be of the self-tapping or the self-drilling variety (Table 26.3) decrease in size has also led to their being placed rather easily in other sites like in the interdental region, between the molars (Figs 26.3A and 26.3B). Their small size has led to them being called-"mini-implants, micro-implants, mini-screws or mini-pins". Five main systems are available and the rest are derivatives of the same-

- SAS systems, Sendai Japan
- OMAS Systems, Taipei Taiwan, Lomas-Mondial, Germany
- ORLUS Systems, Yonsei University, Seoul, Korea
- Mia Systems, Kyungpook University, Daedu, Korea
- TOMAS, Dentaurum, Germany

Orthodontic implants are now gaining in popularity for their ability to provide anchorage in difficult conditions (Table 26.4). The "mini-implants" have the advantage of being practically immovable when used for the purpose of exerting tooth moving forces. This ability of providing absolute anchorage helps in achieving difficult movements like molar distalization (Fig. 26.4A), enmass retraction (Fig. 26.4B), etc routinely. This in turn is responsible for the increased acceptance of orthodontic treatment by adults and other esthetically conscious patients, as segmental treatment becomes possible (Figs 26.4C and 26.4D). They are capable of providing excellent anchorage for a relatively minor increase in the cost of orthodontic treatment, also decreasing treatment time.

Implants have been used to distalize maxillary and mandibular molars and groups of teeth, and to obtain tipping, uprighting, intrusion, extrusion and transfer

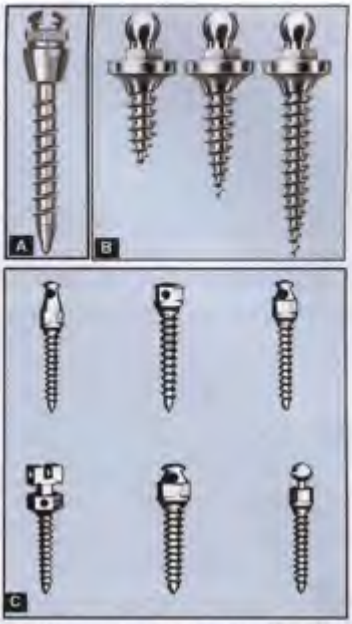


Fig. 26.2: Commercially available mini-implants (A) TOMAS Dentaurum (Germany), (B) Bredent (Germany), (C) Dentos (Korea)



Fig. 26.1: Palatal implant used to stabilize the maxillary canines, which are use to distilize the maxillary molars

Table 26.3: Micro-implant surgical procedures

- *Direct method*
  To place mini-implant directly without an Incision
  Indicated in placements over 'attached gingiva'
  In majority of the cases
  More predictable results
- *Indirect Method*
  Placements over 'unattached gingiva'
  Will require a vertical incision of 2 to 5 mm in length.
  Relatively less commonly used
  The implant will be covered by the gingival tissue

Micro-implant Driving Methods

- Self Tapping and
- Self Drilling

Self Tapping

- Pre-Drilling with a suitable drill 0.2 mm less than that of the mini implant to be implanted

Self-Drilling

- No need to pre-drill
- Just use a round bur or a small 2 to 4 mm drill to get a 'purchase point', especially when angulating the implant

Surgical Procedure for Self Drilling



Step I—isolate the region and apply surface anesthetic (15% Lidocanine)



Step II—anesthetize using infiltration 0.2 ml anesthetic



Step III—mark the exact location using the periodontal probe.



Step IV—using the tissue punch expose the bone



—exposed bone would cause the bleeding point to be visible



Step V—under copious irrigation make pilot hole (using a round bure or drill-2 to 4 mm in length) through the cortical bone (optional but preferable)



Step VI—using the adaptor/screw driver provided screw the mini-implant into the bone, or use an implant physio-dispenser.



—mini-implant after placement.

Surgical procedure for removal of mini-implant
Since the mini-implant does not osteo-intigrate the mini-implant can be easily unscrewed using the screw driver provided. It leaves small bleeding point which heels without any medication or suturing required



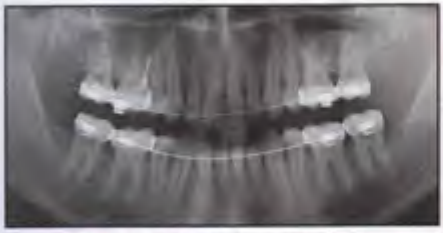


Fig. 26.3A: Mini-implant placed at an angle between 16 and 15

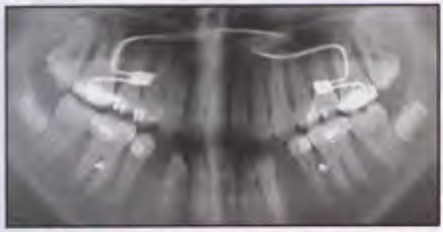


Fig. 26.3B: Horizontally inserted mini-implants in the mandible

Table 26.4: Contraindications for dental implant placement

a. General contra-indications:
The microimplant must not be used if the patient has-
1. History of immune deficiency,
2. History of steroid therapy (in the past 6 months),
3. Bleeding or clotting disorders,
4. Uncontrolled endocrine disease,
5. Bone disease,
6. Rheumatic ailments,
7. Cirrhosis of the liver, or any other acute disease.

b. Local contra-indications:
1. The osteomyelitis of the jaws,
2. Receives radiation therapy in the head and neck region,
3. Has receding gingival disease or
4. Unsatisfactory oral hygiene.

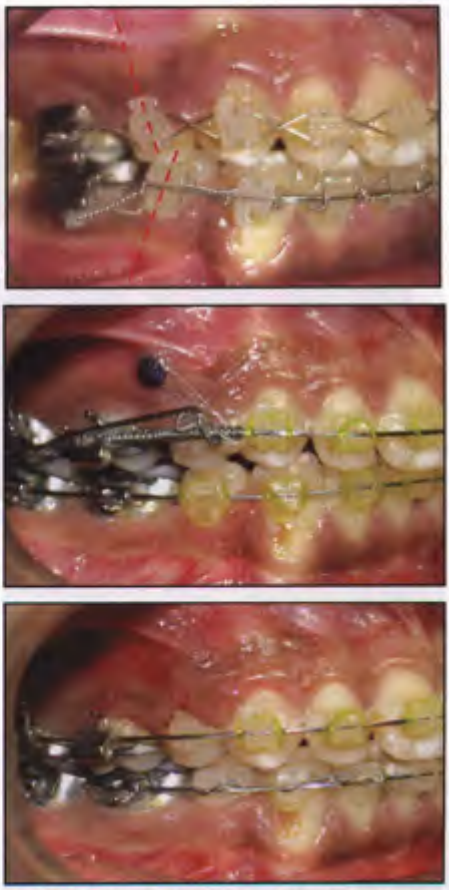


Fig. 26.4A: Distillization of the maxillary posterior segment using a mini-implant

of anchorage to other parts of the mouth. The implants and the new bicortical titanium screws are so convenient to place that the line of action of the orthodontic force can be made to coincide with the level of the center of resistance of the teeth to be moved resulting in a favorable translatory tooth movement (Fig. 26.5). The implant assisted orthodontic treatment helps to minimize anchorage loss and decrease the overall duration of treatment, as these can be loaded immediately. Headgears and other extra-oral means



Fig. 26.4B: Enmass retraction in a critical anchorage case



Fig. 26.4C: Segmental treatment used to align an impacted maxillary canine



Fig. 26.4D: Segmental treatment used to intrude the mandibular incisors



Fig. 26.5: Enmass retraction of maxillary and mandibular incisors with the point of application of force closer to the center of resistance of the teeth to be retracted

of anchorage are eliminated. Most importantly, orthodontic treatment is now possible in cases where multiple teeth are missing (Fig.26.6) or the other anchorage units are compromised. Also, treatment is no longer dependent on patient cooperation.

There are few contraindications to the use of mini-screws (Table 26.5) but it is advised to be cautious in their use especially when treating young individuals below the age of 14 years, because young patients have more spongy bone which at times doesn't allow the primary stability to be achieved at the time of initial placement.

Mini-screws can be placed at various sites (Table 26.6) to either provide direct or indirect anchorage.

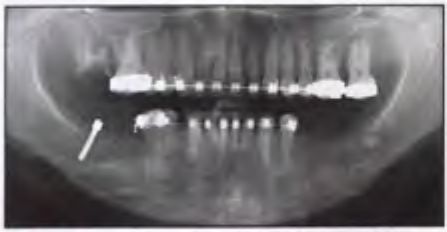


Fig. 26.6: Implant placed in the endentulous region to retract the remaining teeth in the arch

Table 26.5: Various sites for micro-implants

Various Sites of Implants
• Maxilla
– Infrazygomatic crest area
– Maxillary tuberosity area
– Intra radicular between the roots both buccally and palatally
– Mid palatine area
• Mandible
– Retro molar area
– Intra radicular area
– Mandibular symphysis
• Others
– Edentulous areas

Direct anchorage potential is said to be used when the forces are afflicted directly from the screw head (Fig.26.7A) eg. E-chains used to retract teeth. Indirect anchorage is said to exist when the mini –screw is used to immobilize or augment the anchorage potential of the molars (Fig. 26.7B).

Table 26.6: Uses of implants in orthodontics

Orthodontic anchorage
• Used for retraction of anterior teeth,
• Uprighting of molars,
• Mesiodistal tooth movement,
• Open bite correction (archived by intruding posterior teeth: skeletal anchorage)
• Distalization of 1st and 2nd molars
• Intrusion of teeth
• Compromised anchorage in periodontally involved teeth where anchorage is a problem/congenital anomalies and developmental defects of jaws which may result in inadequate anchorage.
• Replacement of missing teeth after the completion of orthodontic treatment (should be done only after completion of craniofacial growth)



Fig. 26.7A: Direct anchorage to mesialize the molar





Fig. 26.7B: Indirect anchorage

Mini-screws are likely to revolutionize the way orthodontic treatment is planned and executed with anchorage planning having become simplified and treatment time decreasing, more and more patients are likely ot become motivated to seek orthodontic treatment.

FURTHER READING

1. Bae SM, Park HS, Kyung HM, Kwon OW, Sung JH. Clinical Application of Micro-implant anchorage 2002;36:298-302.
2. Costa A, Raffaini M, Melson B. Miniscrew as orthodontic anchorage: a preliminary report, Int J Adult Orthod Orthognath Surg 1998;13:201-09.
3. Gainsforth BL. A study of orthodontic anchorage possibilities in basal bone. Am J Orthod Oral Surg 1945;31:406-417.
4. Kanomi R. Mini-implant for Orthodontic Anchorage. J Clin Orthod 1997;31:763-67.
5. Lee JS, Park HS, Kyung HM. Micro-implant anchorage for Lingual Treatment of a skeletal Class II Malocclusion. J Clin Orthod 2001;35:643-47.
6. Maino HS, Kyung HM, Sung J. A simple method of molar uprighting with micro-implant anchorage. J Clin Orthod 2002;36:592-96.
7. Paik CH, Woo YJ, Kim J, Park JU. Use of mini screws for inter maxillary fixation of lingual orthodontic surgical patients. J Clin Orthod 2002;36:132-36.
8. Park H, Bae S, Kyung H, Sung J. Micro-implant anchorage for treatment of skeletal Class I bialveolar protrusion. J Clin Orthod 2001;35:417-22.
9. Park HS, Kyung HM, Sung JH. A simple method of molar uprighting with micro-implant anchorage, J Clin Orthod 2002;36(10):592-96.
10. Roberts WE, Nelson CL, Goodacre CJ. Rigid implant anchorage to close a mandibular first molar extraction site, J Clin Orthod 1994;28:693-704.
11. Umemori M, Sugawara J, Nagasaka H, Kawamura H. Skeletal anchorage system for open-bite correction. Am J orthop 1999;115:166-74.
12. Wehrbein H, Glatzmaier J, Mundwiller U, Diedrich P. The orthosystem: A new implant system for orthodontic anchorage in the palate. J Orofac Orthop 1996;57:143-53.



27 Genetics in Orthodontics

Gurkeerat Singh

- Introduction
- Mode of transmission of malocclusion
- Tracing the gene in family pedigree studies
- Penetrance and expressivity
- Inbreeding and consanguineous marriages—its consequences
- Dental and skeletal characteristics that are inherited

INTRODUCTION

Genetics, is the science of the study of genes. It is a vast field with practically unlimited potential. The only thing that most people associate this science with is Gregor Mendel, the father of modern genetics, and his law of segregation. Lately the cloning of sheep and proposed cloning of humans have again brought it in the news. But why should a student of orthodontics be interested in genetics? The reason is very simple, what ever affects the growth, development and function of the oral and facial structures is of interest to the student of orthodontics. We have to know exactly why or how a malocclusion occurs, to what extent does it express in the next generation, what is its prevalence and how will it react to a certain treatment plan. And, most importantly, if it can be prevented.

Genetics sheds light on all these questions. It helps us lo segregate the genetic or inherited malocclusions or aberrations of growth from those due to the effect of environmental factors. Thus, it helps us diagnose, treat and subsequently maybe prevent it from occurring in the next generation.

MODE OF TRANSMISSION OF MALOCCLUSION

There are three types of transmission of malocclusion from the standpoint of genetics.

REPETITIVE TRAITS

The recurrence of a single dentofacial deviation within the immediate family and in the progenitors. The same trait is seen generation after generation.

DISCONTINUES TRAITS

The recurrence of a tendency for a malocclusal trait to reappear within the family background over several generations. The trait is seen in the family but not in all generations.

VARIABLE TRAITS

The occurrence of different but related types of malocclusion within several generations of the same family. These traits are seen with a variable expression for example, missing teeth, which are commonly seen feature in some families, but the same teeth may not be missing in different generations and/or within the same generation.

For an anomaly to be considered of hereditary origin, it should occur and be a well-defined variation in family groups. A diagnosis of genetic malocclusion should not be made on the basis of a single case of recurrence in the family. Longitudinal studies of pedigree same family are a great help in recognizing and quantifying such malocclusions.

Dobzhansky realized the role of the environment when he stated that, "the individual never fully

realizes the genetic pattern in postnatal life. Human potentialities are determined by the genotype, but their manifestation depends on environment". He was of the opinion that, growth pattern possesses a genetically determined plasticity which makes it possible for environmental conditions to influence it.

According to Neel, genetic factors were entirely or largely responsible for not more than 20 percent of all malformations; chromosomal defects (un-inherited but heritable) account for about 10 percent of all malocclusions.

Evidence of genes being responsible for a particular characteristic in the production of an anomaly can be frequently masked by environmental conditions such as climate, economic conditions, oral hygiene, the quality of dental care available during the formative years, and other variables. According to Neel, majority, nearly 60 percent, of all malocclusions are caused due to environmental factors.

Acquired characteristics are not genetically transmissible. However the genes are subject to mutation. Knowledge of human inheritance is possible only from the study of pedigrees and not on experimentation and actual crossbreeding as in animals.

TRACING THE GENE IN FAMILY PEDIGREE STUDIES

The inheritance of a particular gene has to be studied over several generations of a family to be able to pinpoint its characteristics and isolate the influence of environmental factors.

AUTOSOMAL DOMINANT INHERITANCE

Characteristics of autosomal dominant inheritance are:

1. The trait appears in every generation.
2. An affected child must have at least one affected parent.
3. About one half of the offspring of an affected person are affected; the recurrence risk is 50 percent at each conception.
4. Both male and female persons are affected.
5. The characteristic is not transmitted in the progeny of the unaffected individuals.

AUTOSOMAL RECESSIVE INHERITANCE

Abnormal recessive genes are transmitted through heterozygotes. Their existence is found out only when two heterozygotes marry and the homozygote appears.

Characteristics of autosomal recessive inheritance are:

1. The trait is visible only in siblings, but not in their parents or other relatives.
2. The parents of an affected person may have been blood relatives (consanguineous).
3. About one-fourth of the children of such parents are affected; the recurrence risk at each birth is 25 percent.
4. Both male and female children have equal chance of being affected.

SEX-LINKED RECESSIVE INHERITANCE

This type of inheritance is mostly X-linked and predominantly males are affected (due to their hemizygous condition). Heterozygous females are carriers and are expected to produce affected and normal sons in the ratio of 1:1. An affected male never produces an affected son, for example hemophilia.

Characteristics of X-linked Recessive Inheritance

1. Males are affected more frequently than females
2. When the female parent is carrying the trait then 50 percent of her sons have a chance of being affected, and 50 percent of the daughters would be carriers but phenotypically normal.
3. The trait can be transmitted through several generations by carrier females.
4. The affected male parent cannot transmit the trait directly to his sons, i.e. the trait will skip a generation.

Sex-linked Dominant Inheritance

Characteristics of X-linked dominant inheritance are:

1. The affected male parent transmits the trait to all his daughters but not to the sons.
2. When affected females are homozygous, they transmit the trait to all their children irrespective of their sex.

3. When affected females are heterozygous, only 50 percent of their children of both sexes have a chance of being affected.
4. Affected females transmit the trait to their progeny in a manner similar to that in autosomal dominant inheritance.

POLYGENIC DISORDERS AND MULTIFACTORIAL INHERITANCE

The polygenes have small additive effects. The clinical features are due to cumulative effects of all the polygenes as well as other factors. These other factors may be certain other genes that have not been identified or local or general environmental factors. The term multifactorial inheritance is now preferred, as it gives a more precise meaning—multiple factors associated with the inheritance of the trait. Cleft lip and/or palate is a classic example of such type of inheritance.

PENETRANCE AND EXPRESSIVITY

These terms are used to describe variable gene expression. *Penetrance is the proportion of individuals that show an expected phenotype.* When a gene is completely penetrant it is always expressed; when incompletely penetrant, the gene is expressed in some individuals, not in others, the proportions depending upon the degree of penetrance. *Expressivity is the degree to which a gene is expressed in the same or in different individuals.* A genetic variation may produce peg laterals, or absence of lateral incisors or absence of one lateral incisor and a peg-shaped lateral on the contralateral side.

INBREEDING AND CONSANGUINEOUS MARRIAGES—ITS CONSEQUENCES

Inbreeding is defined as mating between close relatives. Consanguineous individuals have at least one not-too-remote ancestor in common.

The main genetic consequence of inbreeding is an increase in the proportion of homozygotes. Through inbreeding, recessive genes are more easily brought to the fore and are thus expressed. Studies involving such individuals help researchers to obtain an estimate of the amount of hidden genetic variation.

Consanguinity can cause unmasking a hidden recessive gene. Mating between relatives, or inbreeding causes an increase in the frequency of homozygotes among the offspring. Recessive phenotypes appear with greater frequency among the progeny of inbred matings than in the general population.

Many researchers have contended that racial admixture increases the occurrence of malocclusion. The contention is not without its distractors yet it is established that the occurrence of malocclusion and cleft lip and palate is more in offspring's of consanguineous marriages.

DENTAL AND SKELETAL CHARACTERISTICS THAT ARE INHERITED

Salzmann enumerated the malocclusions of genetic origin (Table 27.1). Since then various other parameters have been studied and are included in the following discussion. It is being repeatedly stressed that, *developmental hereditary characteristics are influenced by local or general environmental factors and their penetrance and expressivity can be greatly modified by these influences.*

Occlusal variations are polygenic, i.e. controlled by both, many genes and various environmental influences. Extreme deviations are generally due to chromosomal or single gene defects.

Stockard's studies on the crossbreeding of pure-bred dogs suggest that one set of genes predetermines the structural pattern of the maxilla, and other of the mandible. It can hence be assumed that growth of the two jaws is independent of one another.

Class II and Class III malocclusions have a polygenic mode of inheritance, i.e. they are influenced by the action of many genes and environmental effects. Redman and Shapiro proposed that genes on X-chromosome cause a lengthening of the mandible relative to the maxilla. This has been co-repeated by the studies of Horowitz and Morishima, who found a very high percentage of Class II relationships in XO (Turner's syndrome) subjects. However, Litton, *et al* and Bookman, *et al* found no evidence of sex linkage in their studies of Class III malocclusion. But researchers have found strong co-relation when studying the "Haspsburg Jaw" and in some eastern Aleut families (here the trait is considered due to a single chromosomal or gene defect).

Genetic variation has a major effect on arch width and length. A genetic contribution to arch shape (the maxillary being greater than the mandibular) was

found by Richards, *et al*. The reverse is true for the over all size of the jaws, with effect being greater on the mandible. Significant genetic variance has been reported for dental arch and palate dimensions, but environmental influences seem more important for occlusal traits.

Chug, *et al* and Schull and Neel separately studied inbreeding effects in Japanese children and reported an increased occurrence of malocclusion in the offspring of consanguineous marriages. Investigators have also suggested an increased occurrence of malocclusion due to racial admixture.

Separate studies done in Hawaii and Sweden concluded that the degree of genetic determination was greatest for the width of the upper central incisors and decreased in order for object overbite, and the sagittal molar relationship.

Genetic determination of maxillary and mandibular dentition has been found to be independent of each other. Wider ranges of genetic factors have been found to influence the mandibular rather than the maxillary teeth. Crown dimensions are largely under genetic control.

Corruccini, *et al* have reported variable and frequently insignificant genetic variance for overbite, overjet, sagittal molar relationship, posterior cross-bite, and rotations of anterior teeth.

BUTLER'S FIELD THEORY

Butler divided the mammalian dentition into several developmental fields. For example in humans,- the molar/premolar field, the canine field and the incisor field. According to his theory, among the fields the maximum variability manifests itself in the distal and the least in the mesial direction. Hence, maximum variability will be seen for the third molars or the lateral incisors as compared to the first molars or the central incisors respectively.

As an overview it would suffice to say that even though the jaw size and shape are under genetic control, they show wide variation due to the influences of local and general environmental factors. The tooth shape, number and size anomalies are genetically predetermined with variable expression based on the theory of multifactorial inheritance.

POPULATION DIFFERENCES

Most interesting genetic difference suggested by the epidemiological data concerns the relatively high frequency of Class II and low frequency of Class III occlusion in North American Caucasian and European populations and the reverse situation (high frequency of Class III, low frequency of Class II) in some groups of Asian origin, including Polynesians, Alaskan Eskimos, Aleuts, American Indians, and Pacific islanders in general. Grewe *et al* reported that the tendency towards Class II relationships in North American Indians increased in relation to the proportion of Caucasian ancestry; Baume has observed a similar effect in Polynesian-Caucasian hybrids.

These observations strongly suggest the presence of quantifiable genetic variation in the sagittal molar relationship among human populations.

Long-term evolutionary changes in the dentofacial complex apparently have involved a reduction in jaw size in association with the needs of cephalization and upright posture.

Table 27.1: Malocclusion of genetic origin include

1. Prognathism
2. Extreme micromandibular development
3. Bimaxillary protrusion
4. Bimaxillary atresia (small mouth and underdeveloped arches)
5. Teeth of extraordinarily large size and abnormally small jaws, or vice versa
6. Hypoplasia and discoloration of teeth
7. Abnormalities of the number and arrangement of the teeth
8. Facial clefts, cleft lip and cleft palate
9. Ectodermal dysplasia—craniofacial dysostosis
10. Characteristic crowding of the teeth with rotation and ectopic position of certain teeth, notably the maxillary canines in cases where deciduous teeth have not been exfoliated too early
11. High palate associated with extremely narrow face and head
12. The pattern of the tooth crowns, roots, presence of Carabelli's cusps and pits and fissures of the teeth, shovel-shaped incisors, enamel extensions and taurodontism can be attributed to heredity, according to Kraus
13. Upper face height, nose height, head height and bigonial width show the greatest genetically determined variation

TWIN STUDIES

Identical twins are derived from a single fertilized egg, and so are genetically identical. Any differences between them must, therefore, be due to the environment. Nonidentical twins are just like any

brothers and sisters, but happen to be born at the same time.

Monozygotic (identical/MZ) twins (Fig. 27.1) originate from one fertilized egg that divides later on, whereas dizygotic (nonidentical/DZ) twins originate from two separately fertilized eggs. Monozygotic twins are identical in genetic makeup and sex. Dizygotic twins (Fig. 27.2) have a different genetic composition, and half the pairs are different sexed.

Monozygotic twins are seen with a frequency of 3.5 to 4 per thousand maternities in all races, at all maternal ages, and for all parties. The frequency of



Fig. 27.1: Monozygotic twins



Fig. 27.2: Dizygotic twins

DZ twins varies from 3.5 to 18 per thousand and increases with maternal age and parity. DZ twins also show large racial variations. The inheritance of DZ twinning is confined to be female line, an increased twinning rate being found among the relatives of the mothers and not of the fathers of twins.

Early twins studies and intra-familial comparison indicated that genetic factors would have a more important influence than non-genetic ones for occlusal traits. This led orthodontists to the idea that only genes would cause malocclusion. This conclusion, however, was premature and the matter seemed much more complex as our knowledge on the subject has increased.

Twin studies have revealed that:

- Genetic variation has a major effect on arch width and length.
- A genetic contribution to arch shape (the maxillary being greater than the mandibular).
- Identical twins were not occlusally identical.
- Highest heritability coefficient for the proportion facial height to facial depth and for the proportion maxillary to mandibular sella-apical base.
- Greater genetic basis for tooth size and shape.
- Crown dimensions were largely under genetic control.
- A wider range of genetic factors were found to influence the mandibular teeth as compared to maxillary teeth.

FUNCTIONAL COMPONENTS OF THE FACE

Tongue movements, mouth opening and closing are the first muscle activities in the facial region, starting around the ninth week after conception. Between the tenth and fourteenth week, the trigeminal nerve innervated zones start reacting to stimulus. Human fetuses swallow from about the twelfth week *in utero*.

In very early development, predominantly hereditary factors are active. It is therefore believed that the genetic information for facial growth is primarily situated in the neuromuscular systems and soft tissues. Genes are important in determining shape and surface of muscles and other soft tissues, especially the lip shape (Figs 27.3A and B). This indirectly influences the hard tissue growth.



Figs 27.3A and B: Characteristic shape of the lower lip in a father and daughter

Developmental abnormalities of cleft lip and/or palate could result from:

- Functional abnormalities, because of the lack of attachment of the muscles of the lip and the nares onto the septum and the anterior nasal spine.
- Malformed growth of the facial buds.

Results from MZ and DZ twin studies has revealed that:

- The structure of the individual bones seems to be under the influence of rather rigid hereditary forces but that the greatest variation in the craniofacial complex in each group was found in the spatial arrangement of the bony elements rather than within those elements. This supports the notion that the cranial base and mandible have areas or zones that may permit spatial adjustment during growth and development responding to functional demands.
- Knowledge of the inheritance of functional components and their heritability is as yet not clear.

CONCLUSION

Our knowledge of the inheritance of oral and facial structures has grown over the years. Yet, there is scope for further research and longitudinal studies of families (family pedigree studies) as well as random samples of total populations are necessary to understand the genetic contribution of variations in occlusion. The task has been made more difficult because of inbreeding and outbreeding, leading to a lack of availability of pure genetic pools.

It is important to understand that since the expression of heredity is partially dependent on the environment, hence it may be possible to influence the development of hereditary characteristics by changing the environment of a person or in future, by modifying the genetic coding in individual chromosomes by genetic engineering.

FURTHER READING

1. Harris EF, Johnson MG. Heritability of craniometric and occlusal variables: a longitudinal sib analysis, Am J Orthod Dentofac Orthop 1991;99:258-68.
2. Harris EF, Smith RJ. A study of occlusion and arch widths in families, Am J Orthod 1980;78:155-63.
3. Harris JE, Kowalski CJ, Watnick SS. Genetic factors in the shape of the craniofacial complex, Angle Orthod 1973;43:107.
4. Harris JE, Kowalski CJ. All in the family: use of familial information in orthodontic diagnosis, case assessment, and treatment planning, Am J Orthod 1976;69:493.
5. Hartsfield JK Jr, Everett ET, Al-Qawasmi RA. Genetic factors in external apical root resorption and orthodontic treatment. Crit Rev Oral Biol Med 2004;15(2):115-22.
6. Lauweryns I, Carels C, Vlietinck R. The use of twins in Dentofacial genetic research, Am J Orthod Dentofac Orthop 1993;103:33-38.
7. Litton SF, Ackerman LV, Isaacson RJ, Shapiro B. A genetic study of Class III malocclusion, Am J Orthod 1970;58:556-77.
8. Missey PA. The heritability of malocclusion. 1. Genetics, principles and terminology, Br J Orthod 1999;26:103.
9. Missey PA. The heritability of malocclusion. 2. The influence of genetics in malocclusion, Br J Orthod 1999;26:195.
10. PeckS, Peck L, Kataja M. Mandibular lateral incisor-canine transposition, concomitant dental anomalies, and genetic control, angle Orthod 1998;68(5):455-66.
11. PeckS, Peck L, Kataja M. Mandibular lateral incisor-canine transposition, concomitant dental anomalies, and genetic control, angle Orthod 1998;68(5):455-66.
12. Thesleff I. The genetic basis of normal and abnormal craniofacial development, Acta Odontol Scand 1998;56:321.
13. Vanco C, Kasai K, Sergi R, et al. Genetic and environmental influences on facial profile, Aust Dent J 1995;40:104.
14. Wolff G, Wienker TF, Sander H. On the genetics of mandibular prognathism: analysis of large European noble families, J Med Genet 1993;30:112-6.

28 Cosmetic Contouring in Orthodontics

Gurkeerat Singh

- Introduction
- Procedure
- Uses and advantages

INTRODUCTION

Orthodontic therapy is still considered to be exclusively an esthetic procedure. The alignment and shape of the anterior teeth play a major role in defining the beauty of a smile. As a student of orthodontics, you will be expected to treat cases which will involve a multidisciplinary approach towards treatment. It is sometimes preferred to recontour a tooth rather than do cosmetic restorations with their inherent chances of fracture. The decision for such treatment should be made before starting active treatment.

Cosmetic contouring has been used for esthetic purpose for a long time. It is the ideal treatment for small fractures and chips. When performed successfully, it is generally the most preferred therapy because no anesthesia is required, it is relatively inexpensive, and takes less time than most other procedures.

PROCEDURE

The procedure involves the use of fine diamond burs to provide the desired contour to the incisal edges of the teeth. This may involve the use of long tapered burs or the doughnut bur, depending upon the requirement. Finishing is done with the smoother (less abrasive) finishing burs and the final polishing using a pumice paste and rubber cups.

USES AND ADVANTAGES

Cosmetic contouring is a simple, painless procedure performed by reducing some of the tooth structure with finely ground diamond burs. The considerations which should be kept in mind before undertaking cosmetic contouring (Table 28.1) are mainly with the amount of enamel required to be removed. The amount of tooth reduction involved is generally minimal and hence no anesthesia is required. It is generally a onetime procedure and once treatment is complete, no replacements or touch-ups are necessary. The cost and time involved are minimal. Extensive contouring can cause exposure of the dentine, discoloration, susceptibility to future decay and sensitivity.

Table 28.1: Considerations to be kept in mind before undertaking cosmetic contouring

1.	The thickness of enamel
2.	Shape and location of the pulp canals
3.	The length of the tooth
4.	The length and position of the adjacent teeth

Contouring when combined with orthodontics can help overcome certain disadvantages inherent in the technique. Contouring will cause a chipped tooth to appear shorter than its adjacent teeth unless orthodontics is used to increase its clinical crown length. This can be easily achieved by the orthodontist; by altering the height of the bracket during placement. The bracket on the tooth to be elongated is placed more gingival to the brackets on adjacent teeth. Thereby once the teeth are aligned this particular tooth appears elongated but following cosmetic contouring the alignment is restored (Figs 28.1 to 28.3).



Fig. 28.1A: Shape and length of the incisors before incisal contouring at the end of orthodontic treatment



Fig. 28.1B: More esthetically contoured teeth seen after incisal contouring



Fig. 28.2A: Pre-treatment photographs showing a chip on the mesio-incisal angle of the right central incisor. Mamolons are also very prominent in this case



Fig. 28.2B: The bracket on the right central incisor is placed 0.5 mm gingival to the contra-lateral bracket. It appears elongated as compared to the left central incisor



Fig. 28.2C: The post-treatment view after cosmetic contouring and completion of the orthodontic therapy

Cosmetic contouring can also be done to achieve a more esthetic appearance even after the completion of orthodontic treatment. Female teeth appear more rounded as compared to male teeth. A more rounded contour can be imparted to teeth following completion of active orthodontic treatment using the cosmetic contouring technique (Fig. 28.4).

Cosmetic contouring is just another esthetic procedure which should be kept in mind at the conceptual stage of orthodontic treatment planning.



Fig. 28.3A: The post-treatment view after cosmetic contouring and completion of the orthodontic therapy



Fig. 28.3B: The post-treatment view after cosmetic contouring and completion of the orthodontic therapy



Fig. 28.3C: The post-treatment view after cosmetic contouring and completion of the orthodontic therapy



Fig. 28.4A: Intraoral view before undertaking cosmetic contouring, the teeth appear spatulate. The patient was recommended a combination of periodontal surgery to decrease the length of her crowns; and cosmetic contouring to change the shape of her teeth. The patient refused periodontal surgery, as it would involve injections and surgery per se



Fig. 28.4B: Intraoral photograph after cosmetic contouring a more rounded or feminine appearance

Since the procedure is relatively simple and decreases the chances of repeated touch-ups, its advantages over cosmetic restorations (Table 28.2) should be weighed before imparting treatment.

Table 28.2: Advantages of cosmetic contouring over cosmetic restorations

1. It is a one time procedure which does not require repeated and time consuming touch-ups
2. Time required is minimal
3. Less expensive
4. No chances of discolorations or fracture

FURTHER READING

1. Goldstein Ronald E. Cosmetic Contouring: Ideal for Minor Damage; Change Your Smile. 3rd Edition; Quintessence Publication Company Inc 1996;91-92.

29 Detrimental Effects of Orthodontics Treatment

Gurkeerat Singh

- Introduction
- Tissue damage during treatment
- Increased predisposition to dental disease and dysfunction

INTRODUCTION

Orthodontic treatment has its shortcomings. These perceived shortcomings are not restricted to a lack of ability to treat certain malocclusions but to the possibility of actual tissue damage during the actual course of treatment, an increased susceptibility to dental disease and dysfunction following completion of treatment, and partial or complete failure to accomplish the goals of treatment. The detrimental effects of orthodontic treatment cannot be segregated from the shortcomings in the implementation of the treatment per se. Only part of the treatment is in the hands of the clinician. From the perspective of an ideal treatment plan the patient's cooperation (Table 29.1) is paramount for achieving ideal result.

Table 29.1: Patient's cooperation for an ideal treatment

During orthodontic treatment the patient is supposed to
• Maintain proper oral hygiene
• Not damage or break parts of the appliance, this will involve abstaining from certain hard and sticky foodstuffs like, chocolates, toffees, etc.
• Wear the advised elastics/headgears and retainers for the required duration
• Report for appointments regularly
• Meet his/her financial obligations towards the treatment

TISSUE DAMAGE DURING TREATMENT

TRAUMATIC ULCERATIONS

Pain associated with traumatic ulcerations (Fig. 29.1) or abrasions are the most common complaints reported following the placement of fixed appliances. A study conducted by us found the incidence to be as high as 56 percent over all; with females complaining more as compared to males. The patients treated with the Begg appliance had more problems, mainly because of the sharp ends of the lock-pins used.

Such problems can be relieved by adjusting the appliance, using good quality lock pins/brackets or using relief silicone (Fig. 29.2), or relief wax (Fig. 29.3). The relief silicon is preferred over relief wax as it does not melt or freeze or dry out with change in storing temperature.



Fig. 29.1: Traumatic ulcer associated with fixed orthodontic appliance



Fig. 29.2: Relief silicon



Fig. 29.3: Relief wax

PERIODONTAL DISEASE

A generalized, mild to moderate gingivitis occurs within 6 weeks of placement of fixed orthodontic appliances (Fig. 29.4). This may persist until the appliance is removed and may exacerbate during treatment depending upon the patient's compliance with oral hygiene procedures.

At times the hyper-plastic response can be florid and might necessitate the removal of the fixed appliance prematurely (Fig. 29.5) and/or intervention by a periodontist to maintain acceptable levels of oral hygiene.



Fig. 29.4: Generalized gingivitis



Fig. 29.5: A florid response to fixed orthodontic appliance necessitated premature removal for periodontal reasons

Maintenance of poor oral hygiene while wearing removable orthodontic appliances can lead to an inflammation of the gums (Fig. 29.6A) especially of the palatal tissues. Elastometrics worn along with fixed orthodontic appliances have a tendency to accumulate food debris (Fig. 29.6B). Candidial infections in the



Fig. 29.6A: Calculas deposits and over-all poor oral hygiene maintenance associated with removable appliance wear



Fig. 29.6B: Elastometric chains can cause plague accumulation

palatal region may rarely be seen along the palatal folds (Fig. 29.7).

Poor oral hygiene may lead to a generalized loss of alveolar bone height. This can be expected more adjacent to the extraction sites. Loss of attachment (Fig. 29.8) can be 0.5-1.5 mm in 5-10 percent of the patients treated. It is pertinent to note that loss of attachment is more for teeth that have been excessively tipped.

CARIES

The incidence of caries increases during orthodontic treatment. This is especially true if the patient does not follow proper oral hygiene procedures and / or the bands are loose (Fig. 29.9A).



Fig. 29.7: Candidial infection in the palate along with removable appliance therapy



Fig. 29.8: Loss of attachment following fixed orthodontic appliance therapy

Characteristics lesions (Fig. 29.9B) can be seen around brackets following debonding. Food tends accumulate around brackets, especially gingivally,



Fig. 29.9A: Hypocalcification and an increased predisposition to caries seen following orthodontic treatment



Fig. 29.9B: Characteristic hypo-calcification lesions gingival to bracket

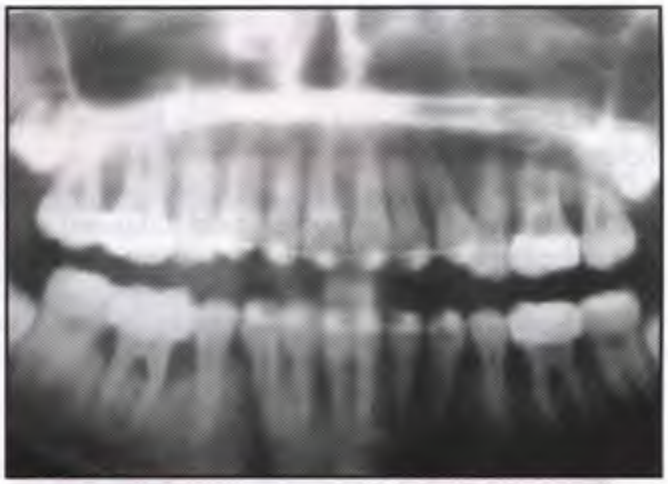


Fig. 29.10: Extreme bone loss and mobility following excessive use of force and tipping

causing hypo-calcification of enamel. These can be entirely prevented by maintaining a proper oral hygiene regime and the regular use of fluoride mouth washes.

Susceptibility to proximal caries also increases if proximal stripping is undertaken. The use of course diamond burs and a lack of finishing procedures increases the risk.

ROOT RESORPTION

Root resorption is a frequent occurrence during orthodontic procedures. It is usually small in amount, irreversible and difficult to predict.

It has been often associated with the excessive use of force, or tipping (Fig. 29.10) or when the roots are moved beyond the cancellous bone, closer to the cortical bone (as during anchorage preparation in the edge-wise technique). The amount of root resorption is considerably more for teeth that have undergone root canal treatment, are non-vital or have been subjected to previous trauma (Fig. 29.11).



Fig. 29.11: Excessive root resorption following orthodontic treatment indicated by the blunting of the root apices, in teeth with a previous history of trauma

PULPAL DAMAGE

The minor circulatory changes accompanying orthodontic tooth movement generally have no adverse pulpal effects. If excessive forces are applied, due to the overzealous wearing of elastics by the patient or in-expert handling of the orthodontic appliance, pain may ensue, which may occasionally result in irreversible pulpal damage and pulpal death.

Pulpal damage has also been reported with the use of removable appliances where a labial bow may be excessively activated to produce tooth movement.

INCREASED PREDISPOSITION TO DENTAL DISEASE AND DYSFUNCTION

PERIODONTAL DISEASE

If appropriate oral hygiene is maintained and ideal finish is achieved there is no increase in the predisposition to periodontal disease following orthodontic treatment.

However, if proper oral hygiene has not been maintained during treatment or if ideal results have not been achieved following orthodontic treatment then the risk of periodontal disease is considerably increased.

This is especially true if extraction spaces open up. The gap created causes frequent food lodgment and pocket formation (Fig. 29.12). If an excessive overbite is created, it might lead to a traumatic overbite and periodontal breakdown is the maxillary and mandibular incisor region. This is more frequently seen when treatment is done using a removable appliance (Fig. 29.13).

MANDIBULAR DYSFUNCTION

Orthodontic therapy has often been blamed for causing mandibular dysfunction, but no statistical correlation has been found between fixed orthodontic treatment and mandibular dysfunction. It is important to note that with advancing age the adaptability of the temporomandibular joint (TMJ) decreases. Special care should to exercised, when treating adult patients.



Fig. 29.12: Food lodgement and pocket formation mesial to maxillary first molars in a second premolar extraction case



Fig. 29.13: Unresolved deep bite and resultant trauma from occlusion in a case treated with removable orthodontic appliance



Fig. 29.14: Partial treatment failure; extraction spaces have opened up partially, right molars are in end-on relationship, the midlines are not coinciding and the over-bite is increased



Fig. 29.15: Total treatment failure; extraction spaces have reopened in all the four quadrants, anteriors are crowded and the deep bite persists. The photographs give an appearance of pre-treatment records!

Do not forget to examine and monitor their TMJ before, during and after treatment.

FAILED TREATMENT

Treatment failure, partial (Fig. 29.14) or total (Fig. 29.15) is perhaps the greatest risk. Whatever the reasons (Table 29.2) for treatment failure this should only stimulate further research and help provide more stringent quality orthodontic treatment.

Table 29.2: Reasons for treatment failure

• Underestimation of skeletal discrepancy
• Misjudgement of space requirements
• Misjudgement of anchorage requirements
• Incorrect choice of appliance
• Faulty technique
• Poor patient compliance

FURTHER READING

1. Booth-Mason D, Birnie D. Penetrating eye injury from headgear, Eur J Orthod 1988;10:111-4.
2. Barber AF, Sims MR. Rapid maxillary expansion and external root resorption in man: A scanning electron microscope study. Am J Orthod 1981;79:630-52.
3. Bishara SE. Oral Lesions caused by an orthodontic retainer: A case report. Am J Orthod Dentofacial Orthop 1995;108:115-7.
4. Blaschko A. Nickel eczema, Br J Dermat 1953;65:84-85.
5. Count A, Millar MA, Khakharia ML, Strang S. Nickel allergy associated with a transpalatal arch appliance, J Orthofacial Orthop 2002;6:501-9.
6. DeShields RW. A study of root resorption in treated Class II, Division 1 malocclusion. Angle Orthod 1969;39:231-45.
7. Geiger AM. Mucogingival problems and the movement of mandibular incisors. A clinical review. Am J Orthod 1980;78:511-27.
8. Grieg A. Contact dermatitis and cervical headgear, Br Dent J 1983;1:12-14.
9. Grieg DGM. Contact dermatitis; Reaction to a metal buckle on a cervical head gear, Br Dent J 1983;155:61-62.
10. Hall AM. Upper incisor root resorption during stage II of the Begg technique: Two case reports, Br J Orthod 1978;5:47-50.
11. Kameda A. A case with crestal bone loss caused by orthodontic procedures, J Jap Orthod Soc 1973;32:334-5.
12. Kerosuo H, Kullaa A , Kerusuo E, Kanerva L, Hensten PA. Nickel allergy in adolescents in relation to orthodontic treatment and piercing of ears, Am J Orthod Dentofacial Orthop 1996;109:148-54.
13. L'Abee EM, Sanderink GCH. Apical root resorption during Begg treatment, Am J Orthod, 1985;19:60-61.
14. Mirabella AD, Artun J. Risk factors for apical root resorption of maxillary anterior teeth in adult orthodontic patients, Am J Orthod Dentofacial Orthop 1995;108:48-55.
15. Zachrisson BU, Alnaes L. Periodontal condition in orthodontically treated and untreated individuals. I. Loss of attachment, gingival pocket depth and clinical crown height. Angle Orthod 1973;43:402-11.
16. Zachrisson BU. Gingival condition associated with orthodontic treatment. II. Histological findings. Angle Orthod 1972;41:352-7.

Section Four

ORTHODONTIC MATERIALS

30. Material Used in Orthodontics—Introduction and Archwire Materials
31. Bracket Material and Auxiliary Force Delivery Systems
32. Impression Materials
33. Luting Materials
34. Adhesion Promoters and Bonding Materials
35. Orthodontic Instruments
36. Sterilization in Orthodontics

30 Material Used in Orthodontics—Introduction and Archwire Materials

Gurkeerat Singh

- Introduction
- Classification of orthodontic appliance materials
- Archwire materials
- Classification of archwire materials

INTRODUCTION

The rapid advancement seen in the field of orthodontics has been primarily due to the improvement in the field of material sciences. The better understanding of biologic problems and advancements in orthodontic materials has lead to improved appliance designs and treatment strategies.

This chapter will aim to cover in brief, the materials used commonly in the day to day practice of orthodontics. The aim is to provide the students an understanding of the latest means and ways in which orthodontic treatment is done. The profession still does not have specifications for orthodontic materials and the classification provided is only to categorize these materials and to make their study easy.

CLASSIFICATION OF ORTHODONTIC APPLIANCE MATERIALS

1. Archwire materials
2. Bracket and attachment materials
3. Auxiliary force delivery systems
4. Impression materials
5. Luting materials
6. Sealants and Adhesion promoters
7. Etching/conditioning and crystal growth systems
8. Bonding materials

The categories defined are broadly based on the use of the particular material in the field of orthodontics. These materials will overlap and each should be studied based upon its application in the field of orthodontics. Certain topics, for example the impression material, have been covered in less detail. Only alginates are covered, as this is the most frequently used impression material in orthodontics. It is recommended that the students refer relevant books on the topic for further clarification.

ARCHWIRE MATERIALS

Archwires are the base wires, which are engaged in brackets of the various appliance systems. These are used to provide a proper arch form and / or provide a stable base to which the auxiliaries can be attached to generate the tooth moving forces.

Characteristics of orthodontic wires, which are considered desirable for optimal performance during treatment include:

1. Large springback
2. Low stiffness
3. High formability
4. High stored energy
5. Low surface friction
6. Biocompatibility and environmental stability
7. Capability to be welded or soldered to auxiliaries and attachments.

These characteristics also change according to the stage of treatment and the purpose for which the arch wire is being used.

SPRINGBACK

Springback is also referred to as maximum elastic deflection or working range. Springback is related to the ratio of yield strength (YS) to the modulus of elasticity (E) of the material (YS/E) (Fig. 30.1).

Higher springback values provide the ability to apply large activations with a resultant increase in working time of the appliance; thus, decreasing the number of archwire changes. It is also a measure of how far a wire can be deflected without causing permanent deformation.

STIFFNESS OR LOAD DEFLECTION RATE

This is the force magnitude delivered by an appliance and is proportional to the modulus of elasticity (E).

Low stiffness leads to an ability to apply lower forces, a more constant force to be delivered over time and greater ease and accuracy in applying a given force.

FORMABILITY

High formability provides the ability to bend a wire into desired configurations such as loops, coils ,etc. without fracturing the wire.

MODULUS OF RESILIENCE M_s

This property signifies the energy storing capacity of the wire. It is represented by the area under the line describing elastic deformation of the wire (Fig. 30.2).

FRICTION

The preferred wire material for moving teeth relative to the wire should produce the least amount of friction at the bracket/wire interface. Excessive friction can result in loss of anchorage or binding accompanied by little or no tooth movement.

BIOCOMPATIBILITY AND ENVIRONMENTAL STABILITY

Biocompatibility includes resistance to corrosion and tissue tolerance to elements of the wire. Environmental stability ensures the maintenance of desirable properties of the wire for an extended period of time after manufacture. These are essential to ensure the predictable behavior of the wire when in use.

CAPABILITY TO BE WELDED OR SOLDERED TO AUXILIARIES AND ATTACHMENTS

This increases the utility of the wire since more auxiliaries can be fixed onto it.

CLASSIFICATION OF ARCHWIRE MATERIALS

1. **Classification of archwire materials based on material constituent**
   a. Gold
   b. Stainless steel
   c. Chrome-cobalt
   d. Nickel-titanium

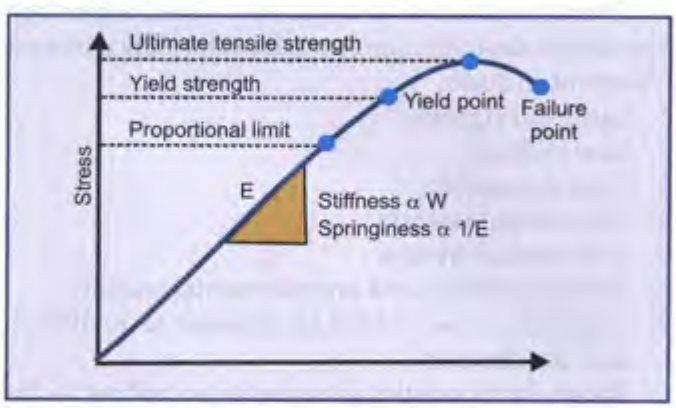


Fig. 30.1: Stress and strain curve for an orthodontic wire

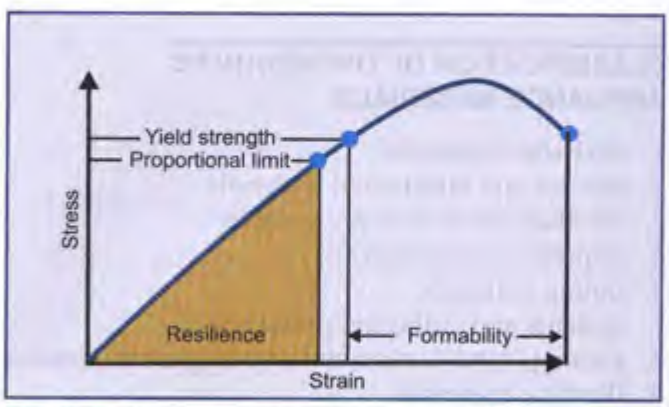


Fig. 30.2: Resilience and formability are defined as an area under the stress-strain curve and a distance along the X-axis respectively

- Martensitic, and austenitic
- Superelastic, and thermodynamic/temperature transforming

e. Beta titanium
f. Alpha titanium
g. Titanium niobium alloy
h. Multi-stranded archwires
i. Composite/coated wires
j. Optiflex archwires

2. **Classification of archwires according to cross-section:**
   a. Round
   b. Square
   c. Rectangular
   d. Miscellaneous
3. **Classification of archwires based on the diameter of the archwire**
   a. Round
      - 0.08″
      - 0.10″
      - 0.12″
      - 0.14″ etc.

   b. Square
      - 0.16″ × 0.16″
      - 0.17″ × 0.17″ etc.

   c. Rectangular
      - 0.17″ × 0.25″
      - 0.17″ × 0.28″ etc.

4. **Classification of archwires according to the microstructural arrangement**
   a. Simple cubic
   b. Face centered cubic
   c. Body centered cubic.

GOLD

Gold alloys were used prior to the 1930s. They were inert, biocompatible and environmentally stable. The other materials available were unable to tolerate the extracting oral conditions.

According to American Dental Association classification gold alloys are of two types:

a. Type I—increased gold content
b. Type II—relatively lesser content of gold

Composition
Gold—15-65%
Copper—11-18%
Silver—10- 25%
Palladium—5-10%
Platinum—5-10%
Nickel—1-2 %
Zinc—traces

Addition of copper permitted age hardening. Silver was mainly added to counter the color of copper. Palladium and platinum increased the melting temperature. Nickel increased the strength and tarnish resistance of the alloy. Zinc provided the antioxidant properties to the alloy.

Advantageous properties

1. Extremely formable
2. Strength can be increased by heat treatment as well as cold working
3. Low modulus of elasticity
4. Good environmental stability
5. Good joinability
6. Excellent biocompatibility.

Disadvantageous properties

1. Low yield strength
2. Low springback
3. High cost.

STAINLESS STEEL

Introduced in 1929 by Wilkinson. Ever since this material was introduced to orthodontics, it has formed the basis of most orthodontic wires. Its stiffness and resiliency were of great importance. Stainless steel was derived by the addition of chromium to iron. Mainly the austenitic form is made use of in orthodontics.

Both, round (Fig. 30.3A) and rectangular (Fig. 30.3B) wires are made from stainless steel. Their use is dependent on the technique practiced, the stage of treatment and the stiffness required (the purpose for which it is being used- retraction/ aligning/ finishing etc.).

Composition
Iron—71%
Chromium—18%
Nickel—08%
Carbon less than—0.2%

Advantageous properties

1. High stiffness
2. High yield strength- 1400 MPa approx.
3. High resilience

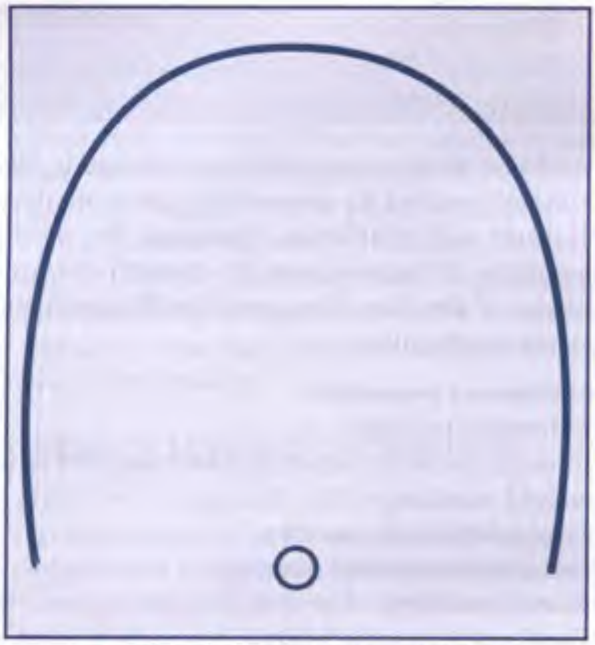


Fig. 30.3A: Round stainless steel wire

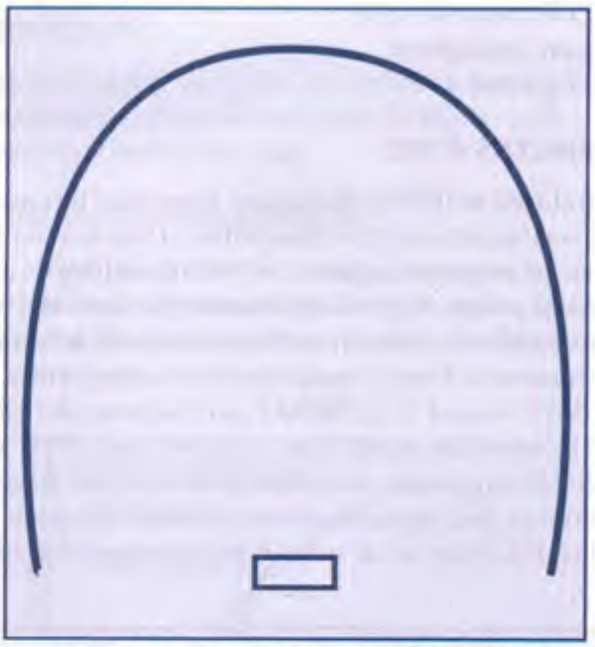


Fig. 30.3B: Rectangular stainless steel wire

4. Good formability
5. Good environmental stability
6. Good joinability
7. Adequate springback
8. Biocompatible
9. Corrosion resistant, except at weld sites
10. Economical.

Disadvantageous properties

1. Soldering is demanding
2. Lower springback than Nickel-titanium alloys.
3. High modulus of elasticity.
4. More frequent activations are required to maintain the same force levels.
5. Heating to temperatures of 400-900 degrees causes the release of nickel and chromium, thereby decreasing the corrosion resistance of the alloy.

Australian Stainless Steel Wires

Dr PR Begg in collaboration with Mr AJ Wilcock, an Australian metallurgist developed a more tensile wire material which was thin enough to distribute optimal tooth moving forces for long periods, over long distances with minimal loss in the intensity of force. The diameter of these wires has been decreasing with the changing concepts of lower force levels being used in orthodontics.

They are of the following types:

1. Regular (Fig. 30.4A)
2. Regular plus (Fig. 30.4B)
3. Special (Fig. 30.4C)
4. Special plus (Fig. 30.4D)
5. Special plus pulse straightened (Fig. 30.4E)
6. Premium (Fig. 30.4F)
7. Premium Plus (Fig. 30.4G)
8. Premium plus pulse straightened (Fig. 30.H)
9. Supreme (Fig. 30.4I)
10. Supreme pulse straightened (Fig. 30.4J)

These wires are available as spools as well as in straight lengths.

The manufacture of these wires involves two processes, the spinner straightening, for regular to extra special wires. The pulse straightening process is used for the newer premium and supreme wires. Spinner straightening involves the pulling of the wire in its cold drawn condition through rotating bronze rollers which torsionally twist the wire into a straight condition. The wire so formed has certain amount of resultant deformation, a decrease in yield stress values and it becomes strain softened.

In pulse straightening, the wire is pulsed in a special machine, permitting high tensile wires to be straightened and smaller diameter wires can be manufactured. This wire has a smoother finish and a higher tensile strength. These wires show a significantly higher working range and good recovery patterns.

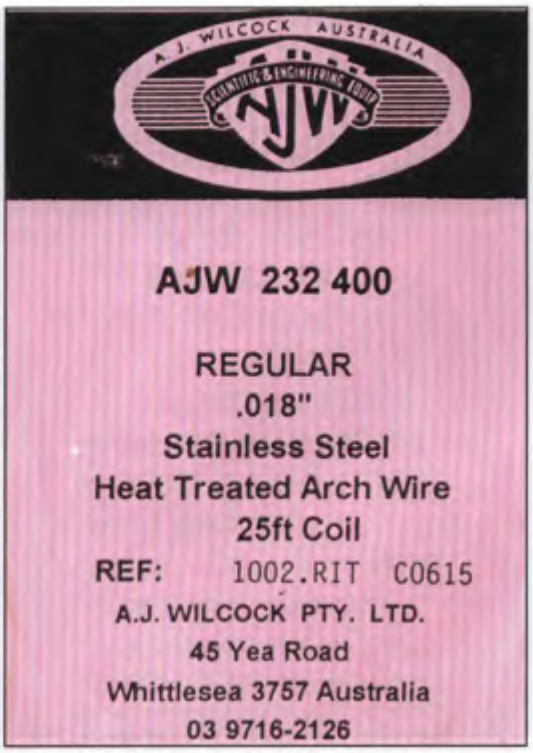


Fig. 30.4A: Regular AJ Wilcock wire packing

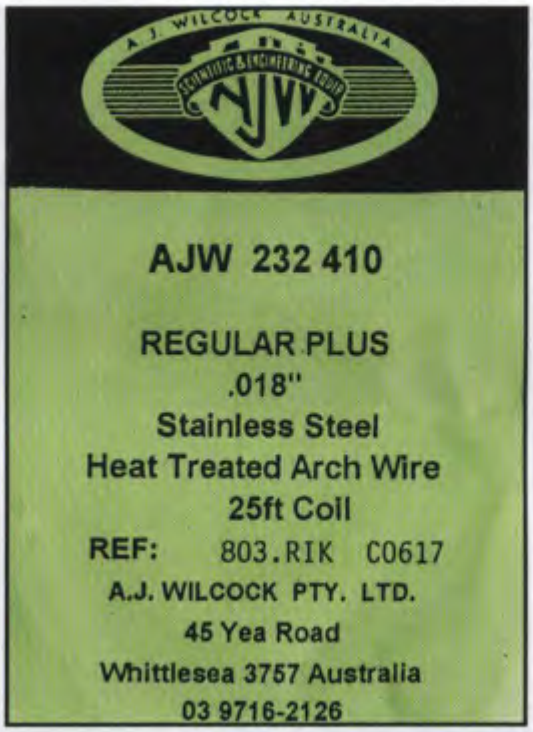


Fig. 30.4B: Regular Plus AJ Wilcock wire packing

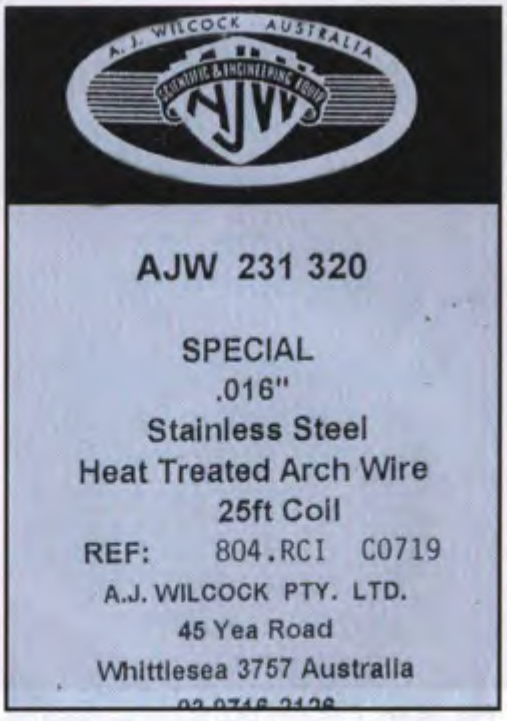


Fig. 30.4C: Special AJ Wilcock wire packing

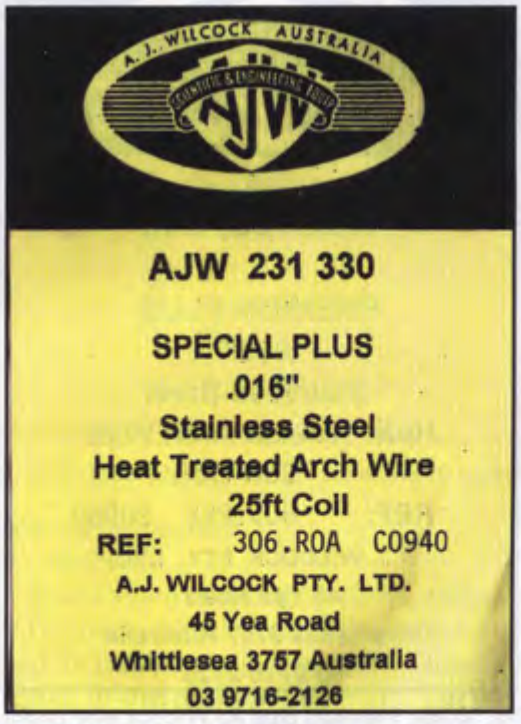


Fig. 30.4D: Special Plus AJ Wilcock wire packing

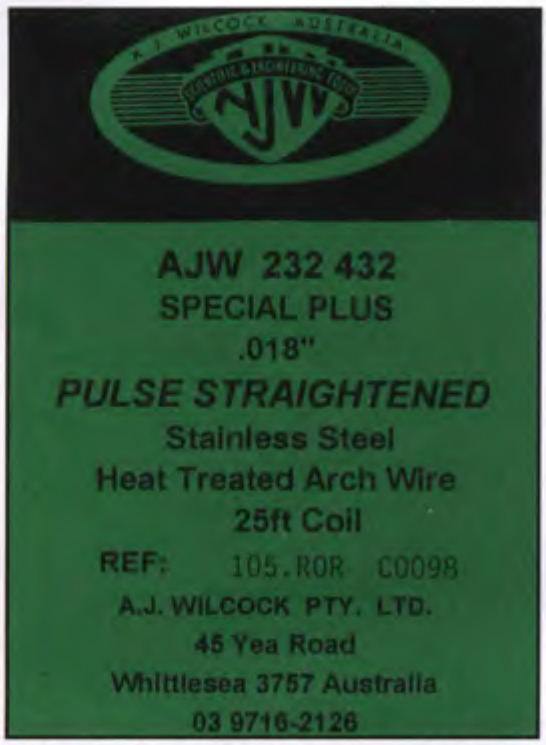


Fig. 30.4E: Special plus pulse straightened AJ Wilcock wire packing

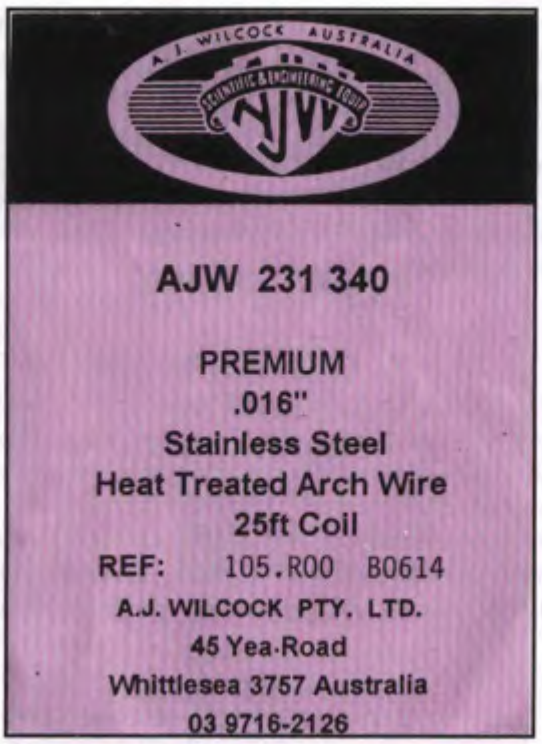


Fig. 30.4F: Premium AJ Wilcock wire packing

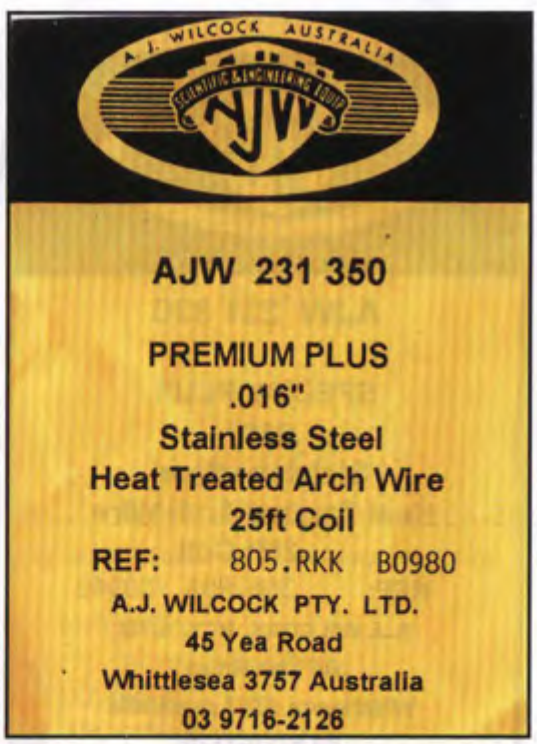


Fig. 30.4G: Premium plus AJ Wilcock wire packing

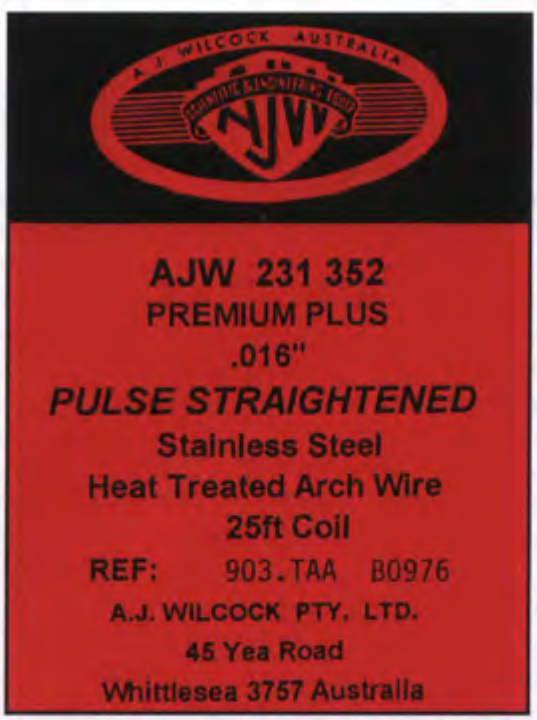


Fig. 30.4H: Premium plus pulse straightened AJ Wilcock wire packing



Fig. 30.4I: Supreme AJ Wilcock wire packing



Fig. 30.4J: Supreme pulse straightened AJ Wilcock wire packing

CHROME-COBALT

Also known as **Elgiloy.**

These wires have properties similar to those of stainless steel but can be supplied in the softer and more formable state and then could be hardened by heat treatment. This process increases the strength of the wire significantly.

Composition
Cobalt—40%
Chromium—20%
Nickel—15%
Iron—15.4%
Molybdenum—07%
Manganese—02%
Beryllium—0.4%
Others—0.05%

This alloy is manufactured in four tempers, depending on the amounts of cold work:

- Blue-soft and easy to bend (Fig. 30.5)
- Yellow—ductile



Fig. 30.5: Blue Elgiloy (preformed) archwire packing

- Green—semi-resilient
- Red—resilient

The wires made from this alloy are generally supplied in the ductile form, allowing them to be easily deformed and shaped into appliances. These are then heat treated to increase their strength. The standard heat treatment involves heating to 483 degrees

centigrade for 7 to 12 minutes. Low temperature heat treatment causes a phase change and stress relief. Heating to 1100-1200 degrees centigrade and quenching can soften the wire.

Advantageous properties

1. Excellent tarnish and corrosion resistance.
2. Greater resistance to fatigue than stainless steel.
3. Greater resistance to distortion.
4. Good formability.
5. Functionally remains active for longer duration if used as a resilient spring

Disadvantageous properties

1. Has to be heat treated.
2. Soldering is demanding. A low fusing solder has to be used. These wires should be soldered with a silver solder in the presence of a fluoride flux or can be joined by spot welding.
3. The modulus of elasticity is high causing higher forces to be delivered for similar activations as stainless steel wires.

NICKEL-TITANIUM

Composition
Nickel—55%
Titanium—45%

This alloy was developed in 1971, and marketed as 'Nitinol'. The name nitinol is an acronym derived from the elements which comprises the alloy (Nickel, ti-titanium, nol-naval ordinance laboratory). It had excellent springback properties (Fig. 30.6).

Modifications to the initial composition provided alloys, which had shape memory, elasticity and flexibility. Newer alloys are even thermal activated, i.e. exert tooth moving forces only after reaching a certain temperature. This was achieved with the addition of small amounts of copper.

Nitinol is basically is of two types:

1. Thermal nitinol, and
2. Elastic nitinol

Thermal Ni-Ti Alloy

Initially, composed of equal parts of nickel and titanium.

Composition
Nickel—54-55%
Titanium—43-44%
Cobalt—1.6-3%

Thermal nitinol (Fig. 30.7) shows shape memory in the martensitic phase. These archwires are formed to the desired shape in the martensite form and they go through the transition temperature range (TTR) to the austenite grain structure (Fig. 30.8). In the austenite grain structure it is deformed to confirm to the irregularities in the arch form; taking the wire through TTR again will result in its original shape in the martensitic form. A number of variations of the Ni-Ti alloy have been developed in dentistry. Compositional variations lead to changes in the martensitic and austenitic start and finish temperatures and mechanical properties. The wires with austenitic finish temperatures less than 37 degree centigrade exhibit superelasticity.

Elastic Ni-Ti Alloy

Elastic Ni-Ti alloy is used in the martensitic phase. It maintains its high elasticity and flexibility. This wire also exhibits the desirable property of lighter continuous forces on deformation.

Advantageous properties

1. High spring back
2. High stored energy
3. High elasticity.

Disadvantageous properties

1. High friction as compared to stainless steel.
2. Low stiffness cannot be used at the completion stages of orthodontic treatment.
3. Fractures easily if bent over a sharp edge.
4. Very limited bending is possible.
5. Cannot be welded or soldered.
6. Expensive as compared to stainless steel wires.

Copper Ni-Ti Alloys

This alloy was developed by Dr Rohit Sachdeva and Miyasaki in 1994.

Composition
Titanium—42.99%
Nickel—49.87%
Chromium—0.50%
Copper—5.64%



Fig. 30.6: Various form of NiTi alloy wire available commercially (a) preformed round (b) preformed rectangular, or (c) spools



Fig. 30.7: Heat activated Ni-Ti wire. Note the high flexibility of the wire

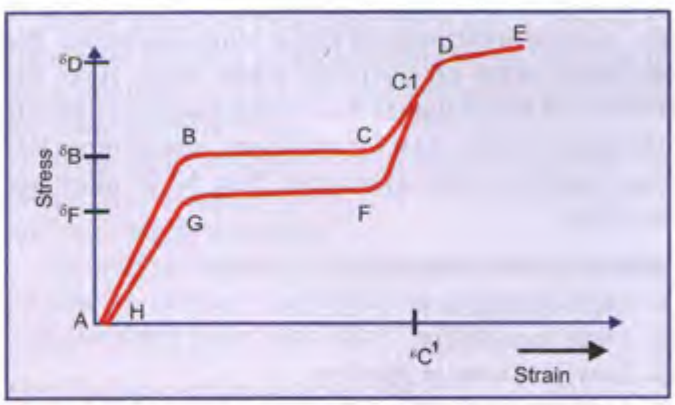


Fig. 30.8: A stress-strain curve illustrating superelasticity due the stress-induced transformation from the austenitic to the martensitic phase. Point F indicates the maximum stress on which the stress-induced martensitic structure on unloading can exist, and at that point the reverse transformation to austenite begins

The addition of copper decreases the difference between loading and unloading forces causing delivery of more constant forces for small activations. Or in other words, unloading forces more closely approximate loading forces. The addition of copper also increases surface smoothness making the surface roughness similar to untreated TMA wires. Copper content also plays an important role in controlling the transformation temperature of the alloy.

The stress induced martensite is responsible for the superelastic characteristic of Ni-Ti alloys. However, martensite transformation is also temperature dependent. The stability of the martensite and/or austenite phase at a given temperature is based upon the transformation temperature of the alloy. The most important marker is the materials Austenitic finish (Af) temperature. To exploit superelasticity to its fullest

potential, the working temperature of the orthodontic appliance should be greater than the Af temperature.

Four types of copper Ni-Ti alloys were developed:

Type I
- — At 15°C
- — not used clinically
- — exerts very high forces.

Type II
- — At 27°C
- — normally used in patients with average pain tolerance
- — periodontium should be healthy
- — constant force is generated.

Type III
- — At 35°C
- — Used in patients with a low threshold
- — Normal to slightly compromised periodontium
- — Used only where low forces are desired.

Type IV
- — At 40°C
- — Used in patients with low pain threshold
- — Where tooth movement is to be slow
- — Intermittent forces are generated
- — Used as an initial aligning archwire.

Advantages of copper Ni-Ti alloys

1. More resistant to permanent deformation
2. Better springback as compared to other Ni-Ti alloys
3. More constant forces are exerted over small activations.



Fig. 30.9: CNA arch wires

BETA TITANIUM OR TMA WIRE OR CNA WIRE (FIG. 30.9)

Composition
Titanium—79%
Molybdenum—11%
Zirconium—06%
Tin—04%

In these wires the metastable BCC structure of titanium is retained at room temperature by using a variety of alloying additives like molybdenum, vanadium and/or chromium.

Distinctive features of this wire include—good springback, low force delivery levels, good formability and weldability. The process of ion implantation for the surface treatment of these wires decreases the frictional forces produced by these wires. Also, the absence of nickel makes these wires useful in patients allergic to nickel. Ideal for situations where forces less than stainless steel and more than Ni-Ti alloy are required.

Advantageous properties

1. High springback.
2. High formability.
3. Low modulus of elasticity.
4. Low load deflection rate.
5. Low stiffness.
6. Environmentally stable.
7. Excellent corrosion resistance.
8. Can be joined by electrical resistance welding.

Disadvantageous properties

1. More friction than stainless steel or chrome-cobalt alloys. The friction can be decreased using the ion implantation method where by titanium oxide and nitride are deposited on the wire to produce a smoother finish.
2. Become brittle on overheating.

Weldability of B-titanium Wires

The wire "sets down" about 80% into the opposing wire under electric resistance welding. The process does not need to be reinforced.

Flat-to-flat electrodes are recommended along with a light capacitance welding process.

ALPHA TITANIUM

Composition
Titanium—90%
Aluminium—06%
Vanadium—04%

This alloy is made up of closely packed hexagonal crystals. This structure increases the number of slip planes between the crystals, making the alloy more ductile. Alpha titanium alloy wires are more stiff as compared to nickel titanium wires.

TITANIUM NIOBIUM ALLOY

This alloy was introduced to orthodontics in early 1995, by Dr Rohit Sachdeva.

Wires made of this alloy have less stiffness as compared to TMA wires resulting in an increase in the formability of the wire. The load deflection rate is the same as TMA wires.

These wires are ideal as finishing wires as they can be bent more easily and still are able to maintain the low force levels required.

There is no leaching out of nickel from this alloy. Canine to canine fixed retainers are also being manufactured from this alloy.

MULTI-STRANDED ARCHWIRES

They are subclassified according to cross-section as:

- Round (Fig. 30.10A)
- Rectangular (Fig. 30.10B)
- Subclassification based on the number of constituent strands
  - — 3 strands (Fig. 30.10C)
  - — 6 strands (Fig. 30.10D), etc.
- Subclassification based on the mode of joining the constituent strands-
  - — braided (Fig. 30.10E)
  - — twisted (Fig. 30.10F)

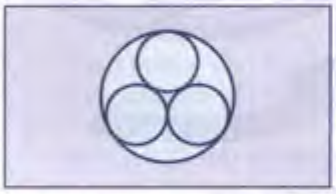


Fig. 30.10A: Multi-stranded round wire (cut-section)

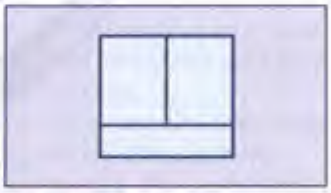


Fig. 30.10B: Multi-stranded rectangular wire (cut-section)

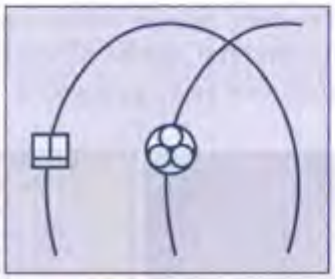


Fig. 30.10C: Three stranded arch wire

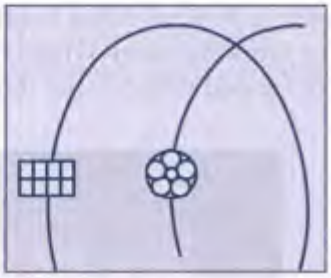


Fig. 30.10D: Multi-stranded arch wire



Fig. 30.10E: Braided wire



Fig. 30.10F: Twisted wire

Coaxial Archwire

Coaxial archwires are made of a central core wire of 0.006 inch diameter wire with 5 or 6 outer wires (Fig. 30.11).

These wires are more flexible and were very frequently used for initial aligning of teeth before the advent of Ni-Ti wires.

COMPOSITE/COATED WIRES

These wires are made of a combination of materials coated one on top of another. The coating fibers include fiberglass (Fig. 30.12) and aramid. The candidate resins

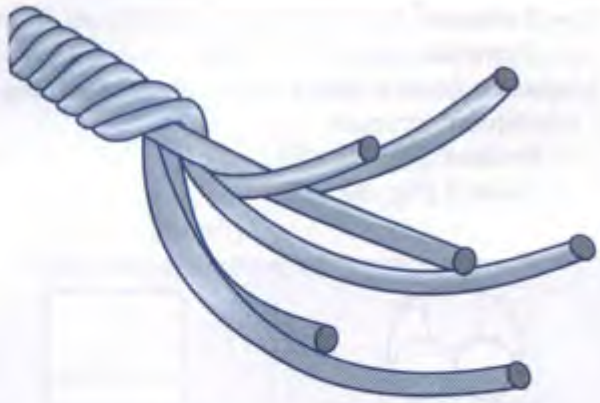


Fig. 30.11: Coaxial wire

include polycarbonate and polyethylene terephthalate glycol. For each fiber/resin system, there is a heating or working range where the material can be formed or shaped without any degradation in its properties.

OPTIFLEX ARCHWIRES

These are composed of a silicon dioxide core which provides the force or resiliency to the wire. The silicon resin forms the middle layer. This adds strength to the wire and also protects the core from moisture. The nylon outer layer makes the wire stain resistant and also prevents it from damage. These wires are available in the round as well as rectangular cross- sections and are tooth colored, i.e. are more esthetic than other metal alloy wires. These wires provide light continuous forces and are used during the initial aligning phase of orthodontic treatment. To prevent permanent deformation sharp bends should be avoided during ligation to brackets.

All major types of wires have been discussed and an effort has been made to provide information regarding the clinical usage of the wires. Table 30.1 provides a comparison of the most frequently used wires and the important characteristics of these wires.



Fig. 30.12: A composite coated wire

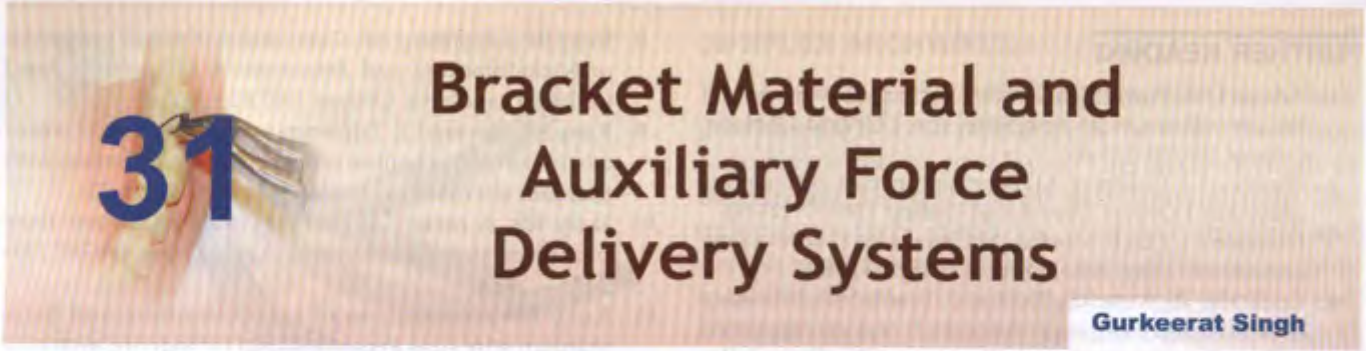
Table 30.1: Comparison of composition and desirable clinical characteristics of orthodontic wires

Wire type	*Spring back*	*Stiffness*	*Forma-bility*	*Stored energy*	*Friction*	*Biocompatibility and environ-mental stability*	*Joinability*
Stainless steel	Low	High	Good	Low	Low	Good	Solderered and Weldable
Cobalt-chromium	Low	High	Good	Low	Low to moderate	Good	Solderered† Weldable‡
Nickel-titanium	High	Low	Poor	High	Low to moderate	¤¤	Not joinable
Beta-titanium	Average	Average	Good	Average	High	Good	Welded
Multistranded	High	Low	Poor	High	Not known	Good	Solderered and Weldable

‡-blue and yellow elgiloy only
†-soldered with some difficulty
¤¤some corrosion and failure noted

FURTHER READING

1. Adams DM, Powers JM, Asgar K: Effects of brackets and ties on stiffness of an arch wire, Am J Orthod Dentofac Orthop 1987;91:131-36.
2. Burstone CJ, Goldberg AJ. Betatitanium new orthodontic alloy, Am J Orthod Dentofacial Orthop 1980;77:121-33.
3. Burstone CJ, Qin B, Morton JY: Chinese NiTi wire: a new orthodontic alloy, Am J Orthod 1985;87:445-52.
4. Cobb NW III, Kula KS, Phillips C, Proffit WR. Efficiency of multistrand steel, superelastic NiTi and ion-implanted NiTi arch wires for initial alignment, Clin Orthod Res 1998;1:12-19.
5. Grandhi RK, Combe EC and Speidel TM. Shear bond strength of stainless steel orthodontic brackets with a moisture insensitive primer. Am J Orthod Dentofac Orthop 2001;119:251-55.
6. Kapila S, Sachdeva R. Mechanical properties and clinical applications of orthodontic wires, Am J Orthod Dentofac Orthop 1989;96:100-9.
7. Kusy RP, Dilley GJ, Whitley JQ: Mechanical properties of stainless steel orthodontic archwires, Clin Materials 1988;3:41-59.
8. Kusy RP, Greenberg AR. Comparison of elastic properties of Nickeltitanium and Betatitanium arch wires, Am J Orthod Dentofacial Orthop 1982;82:199-205.
9. Kusy RP, Stevens LE. Triple stranded stainless steel wires-evaluation of mechanical properties and comparison with titanium alternatives, Angle Ortho 1987;57:18-32.
10. Kusy RP. A review of comtemporary archwires: their properties and characteristics, Angle Ortho 1997;67:197-207.
11. Kusy RP: Comparison of nickel-titanium and beta-titanium wire sizes to conventional orthodontic arch wire materials, Am J Orthod 1981;79:625-29.
12. Kusy RP: The furture of orthodontic materials: the long view, Am J Orthod Dentofac Orthop 1998;113:91-95.
13. Miura F, Mogi M, Yoshiaki O, et al. The super-elastic property of the Japanese NiTi alloy wire for use in orthodontics, Am J Orthod 1986;90:1-10.
14. Stonert MM. Wire: clinical considerations. In Graber TM, Swain BF (editors): Current orthodontic concepts and techniques, ed. 2, Philadelphia, 1975, W.B.Saunders.
15. Waters NE. Superelastic nickel titanium wires, Brit J Ortho 1992;19:319-22.



31 Bracket Material and Auxiliary Force Delivery Systems

Gurkeerat Singh

- Brackets
  - Classification
  - Austenitic stainless steel
  - Polycarbonate brackets
  - Fibre-glass reinforced brackets
  - Ceramic brackets
  - Metal reinforced ceramic brackets
  - Titanium brackets
- Bracket bases
- Auxiliary force delivery systems
  - Elastics and elastic modules
  - Springs
  - Magnets in orthodontics

BRACKETS

A bracket is defined as a device that projects horizontally to support auxiliaries and is open on one side usually in the vertical or horizontal.

CLASSIFICATION

Brackets can be classified according to

Material used in Manufacture

- Metal
- Plastic
- Polycarbonate
- Fibre glass reinforced plastic
- Polyurethane
- Ceramic
  a. Alumina based:
     — Monocrystalline
     — Polycrystalline
     — Laminated brackets.
  b. Zirconia based brackets
- Titanium

Morphology of the Bracket

- Siamese
- Mini-twin
- Single wing
- Self-ligating, etc.

Technique for Which it is Used

- Begg light wire appliance
- Edge-wise appliance
- Straight wire appliance
- Tip-edge appliance
- Lingual pre-adjusted edge-wise appliance, etc.

Slot Size of the Bracket

- 0.018″ × 0.025″
- 0.022″ × 0.028″, etc.

Materials used for the manufacture of brackets have seen a vast improvement in the past 25 years. The esthetic needs of the patients have led to the use of materials other than metals in the manufacture of brackets. Yet, the metal brackets are the most frequently used for routine treatment.

AUSTENITIC STAINLESS STEEL

The most commonly used metal in the manufacture of brackets is austenitic stainless steel or **AISI 304 steel**, AISI standing for—American Iron and Steel Institute. The composition of AISI 304 (Table 31.1), has nickel 8 percent and chromium 18 percent hence, is also called

Table 31.1: Composition of AISI 304 steel

Fe	71 percent
Ni	08 percent
Cr	18 percent
C	< 0.2 percent

18-8 steel. These brackets are most frequently milled from the metal (Fig. 31.1).

AISI 316 steel is used for the manufacture of brackets using the casting technique. These brackets are one piece brackets (Fig. 31.2), with no separate mesh base; AISI 316 is too hard to be milled.

POLYCARBONATE BRACKETS

Polycarbonate brackets (Fig. 31.3) were described and tested by Newman in 1969. These brackets got stained easily, rendering them unanesthetic. They distorted easily and were prone to fracture, particularly from torsional forces or 'creep" under such forces. The surface finish was poor and this led to an increased friction in the appliance system. Polycarbonate brackets with steel inserts were also introduced but have not been clinically popular.

FIBER-GLASS REINFORCED BRACKETS

These brackets are basically polycarbonate, i.e. approximately 60 percent, reinforced with fiber glass. These fibers are about 2-3 mm in length and approximately 0.8 mm in diameter. The plastic conditioner is methylmethacrylate monomer to dissolve the polycarbonate base to enhance adhesion with the adhesive. Clinically acceptable bonding strengths are achieved when these are used as per the instructions of the manufacturer, i.e. along with the primer (Fig. 31.4).



Fig. 31.1: Metal bracket with mesh base (brackets of two different companies)

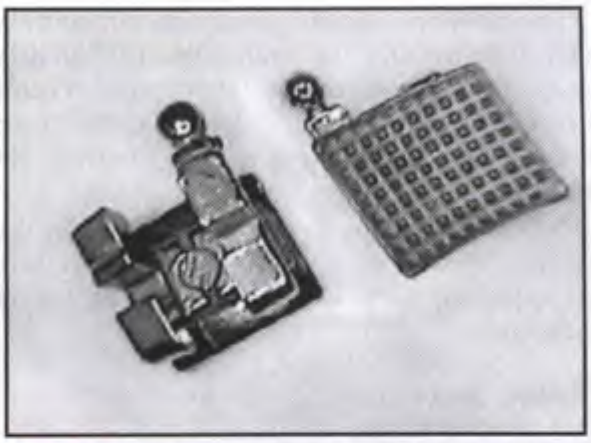


Fig. 31.2: Single piece bracket, note the indentations on the base (and, a lack of the usually seen mesh)



Fig. 31.3: A Begg polycarbonate (plastic) bracket



Fig. 31.4: A fiber-glass reinforced bracket

Fibre glass reinforced brackets do not show any tendency for fracture like ceramic bracket and do not pose any hazard in debonding. They can be debonded like metal brackets. No enamel damage unlike ceramic brackets has been encountered during their debonding.

The only two disadvantages seen with these brackets are—they tend to get worn off if in contact with opposing teeth and they cannot be recycled satisfactorily.

CERAMIC BRACKETS

Advances in material sciences and the demand for more esthetic brackets led to the introduction of brackets made of ceramic (Fig. 31.5). Ceramic brackets were first introduced in 1987 and have practically replaced most other type of esthetic brackets used today.

The ceramic brackets developed initially had some shortcomings; which included—excessive bond strength (resulting in enamel fracture on debonding) brittleness of the bracket and surface finish (rough finish increases friction). These have been largely addressed in the second generation of ceramic brackets and they rarely pose any problems now.

Classification

Ceramic brackets may be classified based upon:

1. The crystal formation as:
   a. Monocrystalline or
   b. Polycrystalline brackets.
2. Depending on their retentive mechanisms into:
   a. Mechanical
   b. Chemical
   c. Combination—mechanochemical
3. Based on the material constituents into:
   a. Pure ceramic
   b. Laminated brackets.
4. Based on the material constituent into:
   a. Alumina based
   b. Zirconium based materials.

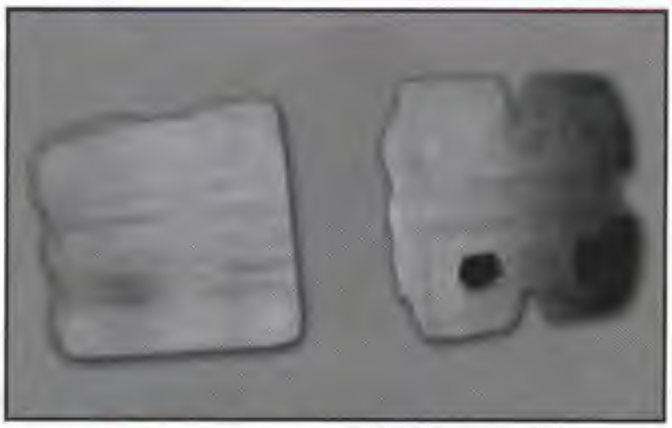


Fig. 31.5: A ceramic bracket with undercut channels in the base

Advantages of ceramic brackets

1. The brackets are extremely esthetic. Ceramic brackets are either transparent (monocrystalline) or opaque (polycrystalline) which accounts for their "invisibility".
2. They resist discoloration unlike polycarbonate brackets.
3. Marginal benefits include use in patients undergoing magnetic resonance imaging and also in patients who are allergic to nickel.

Disadvantages of ceramic brackets

1. Enamel abrasion of opposing teeth as in deep bite cases.
2. Brittleness of the bracket material makes it more prone to fracture.
3. High bond strength particularly with silane primed ceramic bases leading to enamel fracture on debonding.
4. Brittle, fracture of the bracket on debonding makes debonding, technique sensitive.
5. Due to the inherent nature of the material accurate bracket positioning is demanding.
6. High cost of the material.

Manufacturing process Monocrystalline brackets are manufactured from larger chunks of alumina called "boules". These larger chunks or "boules" are cut using diamond, rotary saws, laser and/or ultrasonic methods. The manufacturing process itself leaves behind surface roughness and micro cracks predisposing to the brittle nature of the bracket. These lead to an increased surface roughness and the tendency to fracture, frequently seen in the first generation of ceramic brackets.

Polycrystalline brackets are manufactured by sintering aluminium oxide with particle size of approximately 0.3 microns. A binding material is

mixed with these alumina particles to hold them together. In the older method the sintered rod was machined to the bracket shape. It was then heat treated to relieve stress and surface imperfections. This method resulted in an optimal grain size of about 20 to 30 microns.

The second generation brackets are manufactured by the injection moulding process. In this method the alumina mix is injected into a mould under pressure and then sintered to produce a bracket. This process enables obtaining complex bracket shapes, i.e. the contoured bases to fit the tooth morphology and tie wings capable of resisting fracture and hooks on the canine and premolar brackets. The surface finish is much better and more rounded edges can be achieved, which clinically permit much lesser friction.

Retention mechanism for ceramic brackets First generation ceramic brackets depended on silane coating to ensure adhesion. The silane coupling led to excessively high bond strengths and a resultant damage to the enamel at the time of debonding. Some bracket designs had mechanical undercuts in the form of grooves or recesses. A few brackets had a combination of both.

Bond strength remained particularly high, whatever the method used. This problem has been solved in the second-generation brackets by incorporating a polycarbonate base or the base can be sprayed with atomized glass. This ensured that at the time of debonding the failure occurres at the bracket adhesive interphase. It also eliminates the possibility of fracture of the brackets on debonding.

METAL REINFORCED CERAMIC BRACKETS

These are in vogue because of their possible reduction in enamel damage during debonding. The brackets with metal (stainless steel) slots (Fig. 31.6) also decrease the friction values, which are comparable to other stainless steel brackets.

TITANIUM BRACKETS

Titanium is the latest metal to be used for the manufacture of brackets. It is more biocompatible and allows superior finish thereby decreasing friction. Titanium brackets are single piece cast brackets. They are ideal for use in patients with nickel hypersensitivity. Titanium brackets are more expensive than stainless steel brackets.



Fig. 31.6: Ceramic bracket with metal slot

BRACKET BASES

The bracket has to be attached to the tooth. The brackets can either be welded to bands, which are then cemented to individual teeth or can be bonded. Bracket that are meant for welding have broad bases of thin metal to provide for space for spot or laser welding (Fig. 31.7). For the purpose of bonding the base is either welded separately or in the case of single piece



Fig. 31.7: Metal extensions for the purpose of welding as seen on an edge-wise bracket

brackets, indentations (Fig. 31.2) are provided during the manufacturing process itself. Two configurations which are most frequently used are *microlock*-spherical photoetching (Fig. 31.8) and *dynalock*-undercut channels (Fig. 31.9). These may be further laser etched to increase retention.



Fig. 31.8: Microlock base



Fig. 31.9: Dynalock base(brackets of two different companies)

A fine or coarse mesh is generally used. The fine mesh has been found to provide the maximum bond strength. Nonmetal brackets have channels or provision for chemical treatment prior to immediate bonding.

Individual bracket configuration depending upon the technique used have been discussed in detail along with the individual fixed orthodontic appliances.

AUXILIARY FORCE DELIVERY SYSTEMS

Auxiliary force delivery systems include:
A. Elastics and elastic modules
B. Springs
C. Magnets

ELASTICS AND ELASTIC MODULES

These are of three types based on the constituent material:

1. Latex and latex based systems:
   a. Plain
   b. Colored
2. Polyurethane based systems:
   a. Plain
   b. Colored.

   Subclassified according to their ability to release fluoride as:
   - Fluoride releasing; and
   - Nonfluoride releasing
3. Silicon based—used for positioners.

Elastics

Elastics are easily the most frequently used auxiliary force delivery systems used in modern day orthodontics. There is hardly any phase of fixed orthodontic treatment which is completed without their use. They provide the cheapest and relatively reliable force delivery.

Elastics can be of *latex or non-latex* material. In other words they can be made from either *natural rubber or from synthetic poly- urethane elastomers*. Elastics exhibit stress relaxation, owing to their viscoelastic nature. The force exerted by them will decrease as a function of time. Non-latex elastics deteriorate less as compared to the latex elastics, in the oral environment.

Elastics are available in various strengths, which is dependent upon their diameter and thickness. The elastics are chosen according to the purpose of their use. They may be color coded according to strength (Table 31.2).

SPRINGS

Various types of springs are used as auxiliaries to generate tooth-moving forces. Springs are mainly used for tooth uprighting and torquing in the Begg appliance therapy and the tip edge appliance. Springs may be used to open spaces (open coil springs) or to close spaces (closed coil springs).

Table 31.2: Color code and diameter of elastics of a frequently used brand

Force diameter	*2 oz*	*3.5 oz*	*4.5 oz*	*6 oz*	*8 oz*	*12 oz*
1/8"	White				Clear/tooth colored	Clear/tooth colored
3/16"		Red	Gray	Fiesta pink	Clear/tooth colored	Clear/tooth colored
1/4"		Blue	Orange	Teal	Clear/tooth colored	Clear/tooth colored
5/16"	Yellow	Green	Tan	Mauve	Clear /tooth colored	Clear/tooth colored
3/8"		Pink	Lavender	Navy	Clear/tooth colored	Clear/tooth colored

Springs used along with the fixed orthodontic appliances are:

- Uprighting springs (to upright teeth)
- Rotating springs (to rotate teeth in a particular direction)
- Torquing springs (to bring about root movement)
- Open coil springs (to open or maintain or regain space)
- Closed coil spring (to retract or close already existing or created spaces).

These can be made from either stainless steel or nickel- titanium alloys. The force exerted by springs is directly proportional to the diameter of the constituent wire and the modulus of elasticity of the material. Hence, stainless steel springs will exert a greater force than nickel-titanium springs for a given length and diameter of the wire used in their construction.

Comparison of Certain Properties of Nickel-Titanium and Stainless Steel Coil Springs

Nickel-Titanium	Stainless Steel
1. Low and constant force	High initial forces
2. Expensive	Relatively cheap
3. Clinically effective	Clinically effective
4. Tend to fracture between eyelet and spring	More resistant to fracture
5. More frequently used	The cheaper option but lesser range of action has led to a decrease in use

Individual springs have been discussed along with the technique in individual chapters. From the material point of view it is essential to know the two materials of which the springs are usually made of and the effect of the length and thickness of the material constituent on the force levels generated by the springs.

To summarize, stainless steel springs generate more force than the nickel—titanium springs. The force generated by any spring is inversely proportional to its length or in other words the longer the wire used to fabricate the spring the lesser the force generated and longer the range of action. The thicker the wire used in fabricating the spring the higher the force generated, all other parameters remaining the same.

MAGNETS IN ORTHODONTICS

Magnets have been used for the generation of tooth moving forces in both repulsion as well as attraction mode. For the purpose of space closure they are used in attraction mode and for regaining lost space in repulsion mode.

Types of Magnetic Materials Used

In the various dental application of magnets, the following materials have been used:

- Platinum cobalt (PtCo).
- Aluminium-nickel-cobalt (AlNiCo)
- Ferrite
- Chromium-cobalt-iron
- Samarium-cobalt (Sm_2Co_{17})
- Neodymium-iron-boron ($Nd_2 Fe_{14} B$)

Magnets used presently are:

- Samarium-cobalt magnets ($SmCo_5$ and Sm_2Co_{17})
- Neodymium-iron-boron magnets ($Nd_2 Fe_{14}B$)

Early work with magnets involved Platinum cobalt (PtCo) alloys which were very expensive and prevented frequent experimentation.

Aluminium-nickel-cobalt (AlNiCo) alloy was then used, but owing to its unfavorable height-diameter

ratio magnets were bulky and so their applications were limited.

A Samarium-cobalt magnet is powdered metallurgically processed intermetallic alloy of cobalt and rare earth metals and their main components can be expressed as Sm Co_5 and Sm_2Co_{17}.

Properties of Samarium-cobalt magnets include:

1. Field flux density (B) similar to AlNiCo and 2 to 7 times more than ferrite and Pt-Co.
2. Magnetic force of Sm Co found to be twice as large as the others; stronger and flat magnets used for dental purposes is an advantage.
3. In volume Samarium-Cobalt magnets may be considerably smaller than the others.
4. Samarium-cobalt magnets possess very large demagnetization properties.
5. Samarium-cobalt magnets do not deteriorate at 200 °C and are less likely to be affected by thermal changes.
6. Samarium-cobalt magnets of 5 mm or less can generate tooth moving forces.
7. Corrosion resistance.
8. Hardness is very high and elongation is nearly zero.

Applications of magnets in orthodontics include:

- Diastema closure (magnets used in attraction mode)
- Arch expansion (magnets used in repulsion mode)
- Distal driving of molars (magnets used in repulsion mode)
- Removable appliance for treating impacted teeth (magnets used in attraction mode)
- Active vertical corrector (magnets used in attraction mode)
- Magnetic bracket system.

Advantages of the use of magnets as auxiliary force delivery systems:

1. Decreased patient cooperation
2. Frictionless mechanics
3. Predictable force levels
4. Force does not decay over time but over distance, hence, periodic reactivations are movement dependent.

FURTHER READING

1. Adams DM, Powers JM, Asgar K. Effects of brackets and ties on stiffness of an arch wire, Am J Orthod Dentofac Orthop 1987;91:131-36.
2. Barlow WF. Rubber compounding: Principles, materials, and techniques. 2nd ed, Marcel Dekker, Inc. 1993;26-27.
3. Bertl W, Droschl H. Forces produced by orthodontic elastics as a function of time and distance extended, Eur J Orthod 1986;8:198-201.
4. Billmeyer FW. Textbook of polymer science. 3rd ed., John Willey and Sons, 1984;372-73.
5. Blechman AM. Magnetic force systems in orthodontics, Am J Orthod, 1985;87:201-10.
6. Darendeliler MA, Darendeliler A, Mandurino M. Clinical application of magnets in orthodontics and biological implications: a review, Eur J Orthod 1997;19:431-442.
7. Darendelilier MA, et al. Clinical applications of magnets in orthodontics and biological implications: A review, Eur J Ortho, 1997;19:431-42.
8. Gianally AA, Vaitas AS, Thomas WM. The use of magnets to move molars distally, Am J Orthod, 1989;96:161-7.
9. Gianelly AA, Bonds PW, Johnson WM. Distalization of molars with repelling magnets, J Clin Orthod 1988;22:40-44.
10. Harper CA. Handbook of plastics, elastomers, and composites. 4th ed., McGraw-Hill, 1975;767.
11. Josell SD, Leiss JB, Rekow ED. Force degradation in elastomeric chains, Sem Orthod 1997;3:189-197.
12. Keith O, Kusy RP. Zirconia brackets: an ev
13. Kusy RP, Whitley JQ. Friction between different wire-bracket configurations and materials, Sem Orthod 1997;3:166-77.
14. Lu TC, et al. Force decay on elastomeric chain_ a serial study Part II, Am J Orthod Dentofac Orthop 1993;104:373-7.
15. Matasa CG. Direct bonding metallic brackets: where are they heading? Am J Orthod Dentofac Orthop 1992;102:552-60.
16. Matasa CG. Plastics, Polymers, Resins: A necessary evil. The Orthodoncti Materials Insider. March 2002;14(1):1-4.
17. Matasa CG. Polymers in Orthodonctics: A present danger? The Orthodontic Materials Insider. 2004;16(1):1-8.
18. Mundstock KS, et al. An in vitro evaluation of a metal reinforced orthodontic ceramic bracket, Am J Orthod Dentofac Orthop 1999;116:635-41.
19. Rosen SL. Fundamental principles of polymeric materials. 1st ed., John Wiley and Sons, 1982;314-17.
20. Samuels RH, et al. A clinical study of space closure with Nickel-Titanium closed coil spring and an elastic module, Am J Orthod Dentofac Orthop 1998;114:73-79.
21. Saunders CR, Kusy RP. Surface topography and frictional characteristics of ceramic brackets, Am J Orthod Dentofac Orthop 1994;106:76-87.
22. Vardimon AD, Graber M, Drescher D, Bourauel C. Rare earth magnetics and impactions, Am J Orthod Dentofacial Orthop 1991;100:494-512.

32 Impression Materials

Pankaj Dutta

- Introduction
- Irreversible hydrocolloids (Alginate)
  - Advantages
  - Disadvantages
  - Uses
  - Composition
  - Properties
  - Rate of deformation
  - Clinical considerations
  - Manipulation of alginates

INTRODUCTION

The study models of the patient are one of the essential diagnostic records. For the purpose of achieving accurate study models it is essential to have good impressions. Even though many impression materials are available in the market, the irreversible hydrocolloids are most frequently used for this purpose in day-to-day orthodontic practice.

IRREVERSIBLE HYDROCOLLOIDS (ALGINATE)

Alginates were developed just prior to 1940, as a substitute to agar-agar. Alginates are based on alginic acid, which is derived from brown seaweed (algae). Alginic acid is a peculiar mucous extraction. This natural substance was later identified as a linear polymer with numerous carboxyl acid groups and named anhydro-β-d-mannuronic acid (alginic acid). Alginic acid and most of the inorganic salts are insoluble in water, but the salts obtained with sodium, potassium, and ammonium are soluble in water. These water-soluble salt have molecular weight of 20,000 to 200,000. Alginate is called an irreversible hydrocolloid because it forms an elastic material through a chemical reaction that cross-links its polymer chains.

ADVANTAGES OF ALGINATES

Alginate impression material (Fig. 32.1) became more popular than other impression materials available, because of the following reasons:



Fig. 32.1: Commercially available alginate impression material

Alginate impression materials are:

1. Easy to manipulate
2. Comfortable for the patient
3. Relatively inexpensive because it does not require elaborate equipment
4. Have pleasant taste
5. They are able to displace the blood and saliva
6. They are hydrophilic
7. They are compatible with stone, so it is easy to pour and retrieve the cast
8. They can be used with stock trays.

DISADVANTAGES OF ALGINATES

1. Alginates may tear easily on removal from the mouth

Table 32.1: Formula for the powder component of an alginate impression material

Ingredient	*Function*	*Weight percentage*
Potassium alginate	To dissolve in water and react with calcium ions (hydro gel former)	18
Calcium sulfate dihydrate	To react with potassium alginate to form an insoluble calcium alginate gel, source of Ca^{2+} ions which cause cross-linking of the alginate chains (provides calcium ions) reactor	14
Potassium sulfate, potassium zinc fluoride, silicates or borates	To counteract the inhibiting effect of hydrocolloid on the setting of gypsum (setting of model)	10
Diatomaceous earth or silicate powder or zinc oxide	To control the consistency of the mixed alginate and the flexibility of the set impression, gives body (controls consistency)	56-60
Sodium phosphate	To react preferentially with calcium ions to provide working time before gelation, (as retarder)	2
Glycols	To make powder dust free	Small
Pigments	To provide color	Trace
Peppermint	To produce a pleasant taste	Trace
Disinfectants such as chlorhexidine and quaternary ammonium salts	To help in disinfection of the viable microorganisms	1-2
Sodium silico-fluoride	Controls pH	4

2. They must be poured immediately after removal from mouth, as they are dimensionally unstable
3. They have limited detail reproduction
4. They can be used for pouring the cast only once
5. They are incompatible with epoxy resin

USES OF ALGINATE

Alginate impression materials are used for a variety of applications.

Alginate is commonly used for the preparation of study or diagnostic casts.

In prosthodontics, they are used for recording impressions of edentulous and partially edentulous arches.

In orthodontics, they are used for recording impressions. To make study models and to make working cast for appliance construction.

COMPOSITION (TABLE 32.1)

The chief active ingredient of the irreversible hydrocolloid impression materials is one of the soluble alginates, such as sodium or potassium alginates. When the soluble alginates are mixed with water, they form a sol. The sols are quite viscous even in low concentrations, but the soluble alginates form sols quite readily if the alginate powder and water are mixed vigorously. The greater the molecular weight the more viscous the sol. The exact proportion of each chemical to be used varies with the type of raw material.

The function of the diatomaceous earth is to act as filler. It increases the strength and stiffness of the alginate gel. It helps in producing a smooth texture.

It also ensures a firm gel surface that is nonsticking. Without a filler, the gel formed lacks firmness and exhibits a sticky surface covered with exudates produced by syneresis. Some alginates are more fluid than others because they contain less filler. It also aids in forming the sol by dispersing the alginate powder particle in the water.

Reactor

Calcium sulfate can be used as the reactor. The dihydrate form is generally used, but under certain

circumstances, the hemihydrate produces an increased shelf life of the powder and a more satisfactory dimensional stability of the gel.

Accelerator

- Potassium titanium fluoride, is added as an accelerator
- It helps in setting of the stone so that a hard, dense stone cast surface is produced.

Retarder

Sodium phosphate acts as retarder, some products are faster setting than others as they contain less of sodium phosphate. The amount of sodium phosphate, is adjusted by the manufacturer to produce either regular or fast setting alginates.

Glycol

The alginate powder is finely divided and considerable dust may be involved during dispensing. If inhaled they may be harmful, and produce fibrogenesis and carcinogenesis. Hence the inhalation must be avoided. Coating the powder with a glycol results in dustless alginates.

Disinfectants

Alginates containing chlorhexidine, etc. reduce the viable organisms up to 80 percent, still additional disinfection by solutions or sprays should be carried out after making impression.

Setting Process

When mixed with water, a chemical reaction occurs that cross links the polymer chains. Simultaneously a physical change is also taking place, forming a three dimensional network structure. This is an irreversible process; therefore this material can be used only once.

$$\text{Sol} \xrightarrow[\text{Chemical reaction}]{} \text{Gel}$$

Setting Reaction

The setting process of alginate can be explained in a simplified manner as follows:

We know that, potassium and sodium salts of alginic acid are water-soluble. When these water-soluble salts react with calcium salts (calcium sulfate), they produce an insoluble elastic gel called as calcium alginate. Calcium sulfate reacts rapidly to produce the insoluble calcium alginate from the potassium or sodium alginate in an aqueous solution. If this reaction is allowed to undergo in an unaltered way, it does not allow sufficient working time. To retard the rate of reaction sodium phosphate is added in the powder. The strategy is that the calcium sulfate will react with the other salt (sodium phosphate) in preference to the soluble alginate. Hence powder containing (soluble alginate, calcium sulfate and sodium phosphate) is mixed with water.

$$(CaSO_4)\ H_2O \longrightarrow 2Ca^{2+} + 2SO_4^{2-} + H_2O$$

$$Na_3PO_4 \longrightarrow 3Na^{+} + PO_4^{3-}$$

Calcium ions from the calcium sulfate dihydrate react preferentially with phosphate ions from the sodium phosphate to form calcium phosphate. The reaction between the calcium sulfate and the soluble alginate is prevented as long as there is unreacted sodium phosphate. Thus sodium phosphate is called as the retarder, as it prolongs the working time.

$$3Ca^{2+} + 2PO_4^{3-} \longrightarrow Ca_3(PO_4)_2$$

The reaction in totality can be depicted as:

$$2Na_3PO_4 \pm 3CaSO_4 \longrightarrow Ca_3\ (PO_4)_2 + 3Na_2SO_4$$

When the phosphate ions are consumed, the calcium ions react with the soluble potassium alginate to form an insoluble calcium alginate gel. The reaction results in tying together of a chain of molecules of the sol into a network structure typical of gels. The calcium ions that are released from the calcium sulfate, act as a cross linking agent.

When the supply of sodium phosphate is exhausted, the calcium ions begin to react with the potassium alginate to produce calcium alginate as follows:

$$K_2nAlg + n\ CaSO_4 \longrightarrow n\ K_2SO_4 + CanAlg$$

PROPERTIES

There are several properties for alginate impression material that are important from a clinical viewpoint. These include working time, setting time, consistency or viscosity, strength, and dimensional stability

Working Time

The working time may be defined as the period from the beginning of mix until the impression material no longer is able to adapt and reproduce fine detail from a polished surface. The working time of alginate depends upon whether the material is designated as regular or fast set. In general, the fast setting alginates exhibit a working time of 1.5 to 2 minutes. The regular set alginates, on the other hand, usually have a working time of 3 minutes. According to ADA specification number 18 for alginate impression materials, the working time cannot be less than 1.25 minutes, whereas the working time for regular setting alginate may be as long as 4.5 minutes. From a practical point of view the impression must be thoroughly mixed, loaded into the tray, and seated in place during this period of time. With a mixing time of 45 seconds for the fast set and 60 seconds for the regular set, it leaves, (around 45 to 75 seconds for fast set and 2-3.5 minutes for the regular set) of working time for the material to be loaded in the tray and impression to be made.

A comparison of regular- and fast-set alginate

	Regular-set	*Fast-set*
Mixing time (minutes)	1	0.75
Working time (minutes)	3-4.5	1.25-2
Setting time (minutes)	1-4.5	1-2

Setting Time

The setting time of regular alginate is normally 2 to 3 minutes. Whereas that for the fast setting type is about one minute. The ADA specification requires that the regular set alginate sets in no less than 2 minutes. As per the ADA specification number 18 the setting time should be at least 15 seconds longer than the stated working time by the manufacturer.

The setting time can be modified to some extent by controlling the temperature of the mixing water. Decreasing the water temperature increases the setting time. Using water at an elevated temperature, of course, has the opposite effect of reducing the working time and setting time both by accelerating the rate at which sodium phosphate is consumed and by subsequently increasing the rate of the cross- linking reaction. Altering the setting time by changing the powder water ratio should be avoided. In general, temperatures outside a range of 18 to 24 °C are not advisable. The setting rate can be approximately doubled by a temperature increase of 10 °C. In contrast to the reversible hydrocolloids, alginate material adjacent to the oral tissues sets more rapidly, while that adjacent to the cooler tray wall sets more slowly. Hence, one must ensure that the impression tray is not moved during setting, otherwise distortion occurs. The clinical setting time is detected by a loss of surface tackiness. Color changing alginates provide a visual indication of working and setting time. The mechanism of the color change is a pH related change of a dye.

Dimensional Stability

The structure of the set alginate forms a fibrous network with water occupying the capillary spaces. Most alginate impression materials are quite accurate at the time of removal from the oral cavity, alginate gels lose water which is entrapped within the gel by evaporation and shrink. Thermal changes also contribute to dimensional change. With alginates, impressions shrink slightly because of the thermal differential between mouth temperature (37 °C) and room temperature (23 °C). But primarily they change dimension due to syneresis and imbibitions. Once the impression is removed from the mouth and exposed to the air at room temperature, some shrinkage will take place due to syneresis and evaporation. Conversely, if the impression is immersed in water, swelling will occur as a result of imbibition.

It is clear that the impression should be exposed to air for as short a time as possible if the best results are to be obtained. It is important if the cast can be poured immediately. If for some reason models cannot be made immediately then the impression should be stored in 100 percent relative humidity in a plastic bag or wrapped in damp cotton.

Strength

The impression must exhibit sufficient strength to resist rupture or tearing and to ensure elastic recovery of the impression on its removal from the mouth. Alginate gels have poor mechanical properties and are liable to tear when removed from deep undercuts, particularly in interproximal and subgingival areas.

Factors under the control of the clinician that affect the gel strength are:

Water: Powder Ratio

Decreasing the water to powder ratio increases the compressive strength as well as the tear strength. If too much or too little water is used in mixing, the final gel will be weakened, making it less elastic.

Spatulation Time

Insufficient spatulation results in failure of the ingredients to dissolve sufficiently and it results in decreased strength.

Over mixing breaks up the calcium alginate gel network and or by incorporating air bubbles reduces its strength.

RATE OF DEFORMATION

The compressive and tear strengths increase with increasing rates of deformation.

ADA specification does not have minimal requirements for tear strength although it does require minimum values for compressive strength. The minimum compressive strength required by the specification is 3.5 kg/cm^2 (50 psi or 0.3 MPa) and tear strength varies from 400-700 gm/cm. Normally, most commercially available alginates exhibit properties at 1.5 to 2 times this value.

Permanent Deformation

Compression up to 10 percent is a usual value when the alginate impression is removed from the undercut areas. This value depends upon the degree of undercut and the thickness of the material between the tissue and the tray. As per the ADA specification elastic recovery from deformation should be more than 95 percent or permanent deformation should be less than 5 percent when the material is compressed about 20 percent for 5 seconds. Normally all commercial products have recovery value around 98 percent, which means permanent deformation of 2 percent. The degree of cross-linking continues to increase after the material has apparently set. Waiting a minute or two before removing the impression enhances the elastic nature of the material.

Permanent deformation is a time-dependent property. Its value depends on:

- Percent compression
- Time duration for which it remains compressed
- Recovery time after the release of the load.

Clinically it is important to understand its significance. Ideally there should be bulk of material between the tissue and the tray to reduce the percent compression. Secondly, the impression should be removed in a snap shot manner so that the time duration for which the material remains compressed is less.

The degree of cross-linking continues to increase after the material has apparently set. Waiting a minute or two before removing the impression enhances the elastic nature of the material.

Flexibility

A reasonable amount of flexibility is required for the ease of removal of the impression. ADA specification permits a range of 5-20 percent at a stress of 1 kg/cm^2. Most alginates have a value of 14 percent.

Reproduction of Surface Detail

Not only must the impression material be able to register details of oral mucosa and teeth, but it must be capable of transferring these details to a stone cast. In this regard, the ADA specification for alginate states that for a material to be certified it must be capable of transferring a "V" shaped 0.075 mm wide groove from a metal block to a gypsum cast.

Viscoelasticity

Since hydrocolloids are strain-rate dependent. Their tear strength is increased when the impression is removed with a snap. Patient's comfort should not be compromised while removing it quickly. It is always best to avoid torquing or twisting the impression in an effort to remove it quickly. Permanent distortions due to viscoelastic effects and tearing are reduced slightly by using a large bulk of material. It is better to have approximately 3-5 mm of material between the tissue and tray.

Disinfection

The need to disinfect impressions is well established. Because the hydrocolloid impression must be poured within a short time after removal from the mouth, the disinfection procedure should be relatively rapid to prevent dimensional change.

Disinfection of impression is a matter of great concern as HIV, hepatitis B, etc. can be transferred to gypsum model. Alginate impression should be disinfected before pouring with the gypsum.

The impression can be immersed in disinfectant like 1 percent sodium hypochlorite or 2 percent glutaraldehyde. Significant dimensional changes are seen with such a protocol.

The current protocol for disinfecting hydrocolloid impressions recommended by the Centers for Disease Control and Prevention is to use household bleach (1 to 10 dilution), iodophors, or synthetic phenols as disinfectants. The distortion is minimal if the recommended immersion time is followed after this impression is thoroughly rinsed; the disinfectant is sprayed liberally on exposed surface. The impression should not be submerged or soaked in the disinfectant solution. Immediately wrap the impression in a disinfectant-soaked paper towel and place it in a sealed plastic bag for 10 minutes. Finally remove the wrapped impression from the bag, unwrap, rinse thoroughly shake off the excess water, and pour the model with the stone of your choice.

Compatibility with Gypsum

The impression must be rinsed well in water to remove saliva and blood. After disinfection, all the free water should be removed before pouring in stone. As excess of water causes soft, chalky surface of the model. If at all the alginate impression is stored for more than 30 minutes it should be washed in cold water to remove the exudates on the surface due to syneresis, as this type of exudates retards the setting of gypsum. The set gypsum should not remain in contact with the alginate for long duration of time as it is detrimental to the quality of the stone model.

CLINICAL CONSIDERATIONS

The viscosity of freshly mixed material is quite low. It can be modified by the percentage of the filler content. The low viscosity with a degree of pseudo plasticity, classifies alginates as mucostatic impression materials. Hence, they are supposed to record the tissue in undisplaced state. This can be disadvantageous sometimes as while recording the depth of lingual sulcus. A higher viscosity is required to displace the lingual soft tissues in order that the full depth is recorded.

Dispensing

Alginate is marketed in the form of light colored powder (Fig. 32.2). It is normally available in either a sealed pre-weighed packet or in bulk form. The individual pouches are preferred because there is less chance for contamination during storage. The bulk form of packing is more economical but the container must be resealed as soon as the required amount of powder has been removed to avoid contamination. For the correct proportioning of the powder and water the manufacturers supply a suitable measuring spoon. Its shelf life is affected by storage temperature and moisture.

Materials stored for 1 month at 65 °C are unsuitable for dental use, either failing to set at all or setting much too rapidly. The powder should be mixed thoroughly before use to eliminate the seggregation that may occur during storage, and to incorporate the surface layer which is often contaminated with moisture picked up from the atmosphere.

Orthodontists use alginate frequently to make impressions of young patients. For this market, the manufacturers have "flavored" the material.

If the powder in the can is fluffed before measuring, it is important to avoid breathing the dust, which will rise from the can when the lid is removed. Some of the silica particles in the dust are of such a size and

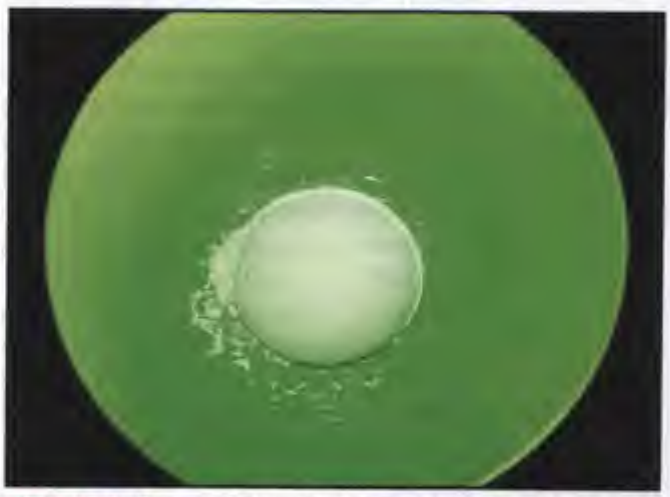


Fig. 32.2: Scoop of alginate dispensed in the rubber bowl

shape as to be a possible health hazard. In an effort to reduce the dusting encountered after tumbling, manufacturers have incorporated glycerin into the alginate powder to agglomerate the particles. These materials are now available as dust-free powders that overcome any potential irritation due to fine dust particles entering the atmosphere and being inhaled because the powder become more dense than in the uncoated state.

Modified Alginates

The traditional alginate is used as a two-component system, a powder and water. There is no reaction until the water is added to the powder to initiate the reaction.

The alginate can also be dispensed in the form of a sol containing the water but without any source of calcium ions. A reactor of plaster of Paris can then be added to the sol. Hence in this case, the second component is the reactor, not the water.

Alginates modified by the incorporation of silicone polymers have been developed. These are supplied as two pastes which are mixed together. One contains the alginate sol and the other contains the calcium reactor. A color contrast between the pastes enables thorough mixing to be achieved although this can be difficult because the pastes are of widely differing viscosity in some products. Impression materials of this type may be supplied both in a tray viscosity and in a syringe viscosity.

MANIPULATION OF ALGINATES

Mixing Alginate Impression Material

Alginate impression materials are easy to use.

Equipment Checklist

1. Alginate (bulk container or individual package). It is normally available in either a sealed pre-weighed packet or in bulk form. Refer to section on dispensing.
2. Plastic measuring cylinder for water, a plastic cylinder with special markings is provided for measuring the correct amount of water.
3. Supplied scoop for powder (if using bulk material).
4. Rubber mixing bowl. The same type of rubber bowl is used to mix plaster.
5. Stiff, wide-bladed steel spatula: Alginates are mixed by hand in rubber bowls with stiff, wide-bladed steel spatulas.
6. Prepared metal or plastic impression tray. The mixture is placed in a suitable tray, which is carried into place in the mouth. It is imperative that the impression adheres to the tray so that it can be withdrawn from around the teeth. Therefore, a perforated tray or a metal rim-lock tray is selected (Fig. 32.3). Thin layers of alginate are weak; therefore, the tray must fit the patient's arch so that there is a sufficient bulk of material. The thickness of the alginate impression between the tray and the tissues should be at least 3 mm.
7. Disinfectant and plastic bag.

Portioning

Measure cool (20°C or 70°F) water for required number of scoops, most manufacturers provide the user with a plastic cylinder that has three marks indicating the volume of water to be used with one, two, or three scoops (portions) of alginate fluff container or package.

The amount of alginate powder depends upon the size of the arch. Normally 18-20 gm of powder is sufficient for an impression of one arch. When dispensing the powder, the scoop is used to remove the appropriate amount of powder by filling it and leveling it with the blade of the spatula (Fig. 32.4).



Fig. 32.3: Plastic perforated high flange stock tray for alginate impressions

Ideally, the powder should be weighed and not measured volumetrically by means of a scoop, as many manufacturers suggest. However, unless one uses a grossly incorrect method of scooping the powder, it is improbable that the variation in powder weight per scoop is greater than 0.2 to 0.4 gm. Such variations in individual mixes would have no measurable effect on the physical properties.

Add Powder to Bowl

The correct amount of water is emptied into the mixing bowl first. Then the alginate is carefully dispensed onto the surface of the water. The procedure should be carried out slowly to minimize incorporation of air into the mix.

Mixing

Stir powder and water vigorously to wet powder completely; care should be taken to avoid whipping air into the mix. To avoid this problem a vacuum mixer can be used. Improper mixing of alginate materials can impair the quality of the final impression. Vigorous figure-eight motion is best, with the mix being swiped or stropped against the sides of the rubber-mixing bowl with intermittent rotations (180°) of the spatula to press out air bubbles. It is important to get all the powder dissolved—if residual powder remains, a good gel cannot form and the properties are compromised.

Wipe mix against side of bowl for 60 seconds to homogenize and remove bubbles. The entire spatulation process should take approximately 1 minute; fast setting alginate should be completed in no more than 45 seconds. The strength of the gel can be reduced, by as much as 50 percent if the mixing is not complete. Care is taken not to over mix, because this limits the working time and breaks up the gel that is forming, thus reducing the strength of the final alginate. Likewise, inadequate mixing produces a grainy material with low strength.



Fig. 32.4: Level scoop of alginate dispensed in rubber bowl

Visually inspect mix for creamy, thick consistency. The result should be a smooth, creamy mixture that does not drip off the spatula when it is raised from the bowl.

Filling Tray and Taking Impression

Wipe alginate into tray with spatula from posterior region forward continue wiping in from posterior until tray is full with uniform layer and minimal material is left in the posterior region. The trays come in stock sizes, and the proper one should be selected and tried in the patient before mixing the material.

What is the reason for being concerned about the amount of material in the tray?

It is important to have a uniform layer of impression material in the tray to avoid missing any of the tissues. Also, the amount of material in the posterior region is important because on seating the tray, the impression material in the posterior portion of the tray may be displaced down the patient's throat, stimulating a Gag reflex. Therefore, the tray is seated in the patient's mouth from the posterior region first, to displace the material anteriorly in the patient's mouth.

The clinician may take a small amount on a gloved finger and flow the material into the critical area like vault of the palate, central pits and fosse and into the fissures of the occlusal surfaces. This technique reduces the chance of trapping air bubbles when the tray is seated in the mouth.

Seat tray from posterior region first to displace material in anterior direction, before seating the impression, the material should have developed sufficient body so that it does not flow out of the tray and choke the patient. Clinicians must learn to recognize the viscosity changes so that they seat the impression during the critical interval between the running stage and the non-running stage.

Press middle and front of tray against tissue to produce uniform layer of material. Hold tray in place until alginate is set, as determined by probing with finger (4-5 minutes). To prevent distorted, unclear, or multiple impressions of the oral cavity, the impression should not be removed until sufficiently set. When the material on the peripheral portion of the tray or in the mixing bowl is no longer tacky, the impression can be removed with a sudden jerk or snap. Although the tendency is to remove the impression prematurely, it is possible to leave an alginate impression in the mouth too long. With certain alginates, it has been shown that if the impression is held for 6 to 7 minutes, rather than 2 to 3 minutes after gelation, significant distortion results.

Compressive Strength of an Alginate Gel as a Function of Gelation Time

Time from gelation (min)	*Compressive strength (MPa)*
0	0.33
4	0.77
8	0.81
12	0.71
16	0.74

To remove impression, lift lips and cheek away with fingers to break seal. Grasp handle and pull tray away from teeth with quick motion. The impression must record the details up to the sulcus (Fig. 32.5).



Fig. 32.5: Ideal impression should have at least 3 mm of space for the impression material and the sulcus should be recorded in the impression

Cleanup and Disinfection

The impression is washed under cool running water to eliminate saliva and blood. The excess water is shaken out, and the impression is then disinfected. Spray impression with disinfectant and seal in plastic bag for 10 minutes. Peel rubbery alginate from bowl and spatula and dispose of in trash. Pour impression as soon as possible (if waiting up to 1 hour, store in moist paper towels in container).

Other Applications of Alginate

Laminate technique. In this method impression is made with the combined agar-alginate technique. The tray hydrocolloid is replaced with a mix of chilled alginate that bonds to the syringe agar. The agar gels by means of contact with the cool alginate rather than the water circulating through the tray and alginate gels by a chemical reaction.

Since agar-agar in place of alginate is in contact with the prepared teeth, maximum detail is reproduced.

Advantages of this technique

- Cost of the equipment is lower because only the syringe material needs to be heated
- The preparation time is also less as little material is to be prepared.

Disadvantages of this technique

- The higher viscosity alginate displaces the agar during seating
- The bond between the agar and the alginate is not always strong
- The dimensional inaccuracy of the alginate limits the use to single units.

Duplicating Materials

Both alginate and agar-agar are used to duplicate dental casts or models. Agar-agar is the material of choice for this work as it is inexpensive and can be used multiple times for this job. The duplicated cast is used in the construction of prosthetic appliances and for orthodontic models.

Troubleshooting

Problems may sometimes be encountered when using alginate hydrocolloids. The following should serve as a guide for troubleshooting problems with these materials:

1. *Inadequate working or setting time:*
   - The temperature of the mixing water may be too high. If the mixture is incompletely spatulated, it may be inhomogeneous and may set prematurely
   - If the water/powder ratio is too low as the result of incorrect dispensing, the setting time could be too fast
   - Improper storage of the alginate powder can result in deterioration of the material and shorter setting times.
2. *Distortion:*
   - If the tray moves during gelation
   - If the impression is removed prematurely
   - Improper removal from the mouth
   - The weight of the tray can compress or distort the alginate impression while pouring
   - If the impression is not poured immediately, distortion could occur.
3. *Tearing:*
   - Inadequate bulk of the material in the tray
   - If, the impression is removed from the mouth before it is adequately set
   - The rate of removal may be a factor. Since the tear strength of alginate increases with the rate at which a stress is applied, it is desirable to rapidly remove the impression from the mouth
   - Thin mixes are more prone to tearing than those with lower W/P ratios
   - The presence of undercuts also can produce tearing.
4. *Loss of detail:*
   - Premature removal from the mouth.
5. *Dimensional change:*
   - Delay in pouring the cast.
6. *Poor stone surface:*
   - Excess water in the impression
   - Inadequate cleaning of impression.

FURTHER READING

1. Braden M, Causton B, Clarke RL. A polyether impression rubber. J Dent Res 1972;51:889.
2. Cook W. Alginate dental impression materials: Chemistry, structure and properties. J Biomed Mater Res 1986;20:1.
3. Johnson GH, Craig RC. Accuracy and bond strength of combination agar-alginate hydrocolloid impression materials. J Prosthet Dent 1986;55:1.
4. Salem NS, Combe EC, Watts DC. Mechanical properties of elastomeric impression materials. J Oral Rehabil 1988;15:125.
5. Wilson HJ. Impression materials. Br Dent J 1988;164:221.

33 Luting Materials

Pankaj Dutta, Gurkeerat Singh

- Introduction
- Dental cements
- Phosphate-based cements
  - Zinc phosphate cement
  - Zinc polycarboxylate cements
  - Glass ionomer cements
- Manipulation
- Protection of the cement while setting

INTRODUCTION

Luting materials mainly include dental cements. These were used very extensively before the advent of bonding materials. Their use has seen a significant decrease in recent times. Yet, they are used routinely throughout the world for cementation of orthodontic bands and other appliances.

DENTAL CEMENTS

Although dental cements are used only in small quantities, they are perhaps the most important materials in clinical dentistry because of their application as:

1. *Luting agents,* to bond preformed restorations and orthodontic attachments in or on to the tooth
2. *Cavity liners and bases* to protect the pulp (thermal and chemical insulators) and as foundation and anchor for restorations
3. *Restorative materials* (temporary or permanent).

This multiplicity of applications requires more than one type of cement because no one material has yet been developed that can fulfill the varying requirements.

Four types of cements are available, they are classified according to the matrix forming species as:

i. Phosphate bonded
ii. Phenolate bonded
iii. Polycarboxylate bonded
iv. Polymethacrylate bonded

Numerous brands of each type are available, and there is some overlap between their properties. Since clinical and *in vivo* evaluation of cements is still very limited, the predictive value of laboratory data for assessment of clinical performance requires knowledgeable interpretation, since generalizations on specific types of cements cannot be made on the basis of the behavior of one or two brands.

Orthodontic application of cements is limited to luting of appliances such as bands

Ideal requirements of these cements are:

- Adequate working and setting time
- High tensile, compressive and shear strength
- Resistance to dissolution
- Clinically acceptable bond strength
- Anticarcinogenic property
- Low adhesive remnant index following debonding.

PHOSPHATE-BASED CEMENTS

ZINC PHOSPHATE CEMENT

Application

Zinc phosphate cement (Fig. 33.1A) is one of the oldest luting cements used in dentistry. Because of their long history, these materials have the widest range of applications from the cementation (luting) of orthodontic bands to fixed (cast alloy and porcelain) restorations. Their use as a cavity liner or base to protect pulp from



Fig. 33.1A: A commonly available commercial packing of the zinc phosphate cement

mechanical, thermal, or electrical stimuli is well documented. It has been used as a temporary or permanent restorative material as well.

Composition

Powder	
Zinc oxide	90 percent
Magnesium oxide	10 percent
Silica or alumina	Small amounts

The addition of magnesium oxide to these cements results in improvement of mechanical properties as well as color stability. It also reduces the calcination temperature.

Various cement powder formulations may include small amounts of silica or alumina, which increases the mechanical properties and add variety of shades to these products.

Some brands contain fluoride in the form of stannous fluoride. These type of products are generally recommended for cementation of orthodontic bands because of their anti-cariogenic effect from the release of fluoride.

The powder is mainly zinc oxide with up to 10 percent magnesium oxide and small amounts of pigments. The components of the powder are fired at high temperature (1,000-1,400 °C) for several hours and sintered into small particles. This procedure reduces the reactivity of the powder and moderates the setting reaction. Generally smaller the particle size faster the cement set.

Liquid

Phosphoric acid	45-60 percent
Water	30-55 percent
Aluminium	2-3 percent
Zinc	0-8 percent

Water controls the ionization of the acid, hence controls the rate of acid-base reaction between powder and liquid. The zinc is a moderator of the reaction between powder and liquid, allowing adequate working time and permitting a sufficient quantity of powder to be added for optimum properties in the cement.

Setting Reaction

As the cement powder and aqueous liquid are mixed together, the phosphoric acid attacks the surface of the particles to release the zinc ions into the liquid. A complex of aluminium and phosphoric acid reacts with zinc to form zinc-alumino-phosphate.

Role of aluminium is not well defined but it is suggested that aluminium may produce complexes with phosphoric acid, forming a glassy zinc alumino-phosphate gel on the surface of unreacted zinc oxide particles. Aluminium is essential to the cement-forming reaction, whereas zinc is a moderator of the amorphous zinc-alumino-phosphate, which when formed, binds together the unreacted zinc oxide and other components of the cement. The set cement consists of a cored structure of residual zinc oxide particles in a phosphate matrix (reaction products):

Zinc oxide + phosphoric acid→amorphous zinc phosphate

Chemically,

$$3ZnO + 2H_3PO_4 + H_2O \longrightarrow Zn_3(PO_4)_2 . 4H_2O$$

The structure of the set cement consists of residual zinc oxide particles (termed as core) bound together with a matrix (reaction products) of amorphous, relatively insoluble gel of zinc, magnesium and aluminium phosphate (Fig. 33.1B).

Manipulation

Mixing time is 60 to 90 seconds.

Powder to liquid ratio: It is not necessary to use a measuring device for proportioning powder or liquid,

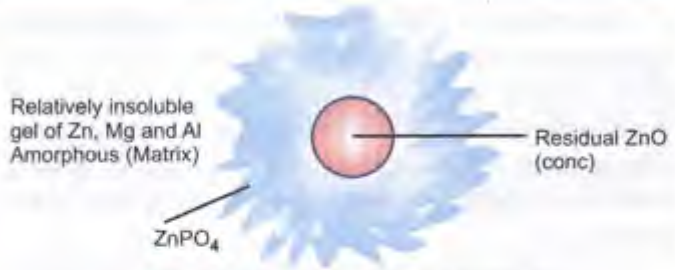


Fig. 33.1B: Structure of set cement

but always try to incorporate maximal amount of powder to ensure maximum strength and minimum solubility. If measuring is to be done, then follow the manufacturer's recommended powder liquid ratio.

The mixing slab must be thoroughly dried before use. The powder is added to the liquid in small (increments) and mixed in brisk circular motion (spatulation) to achieve the desired consistency. Each increment is added and mixed for 15-20 seconds. Dissipation of the heat of the chemical reaction is achieved by mixing over a large area of the slab. The use of a cooled slab will allow a greater incorporation of powder in a given amount of liquid. The cool glass slab prolongs the mixing and setting time, therefore allows more of powder to be incorporated into the liquid thereby increasing the strength. The cement must be undisturbed until the end of the setting time.

The liquid should not be dispensed onto the glass slab until mixing has to be initiated, otherwise the water will evaporate. The cement liquid is kept separate to prevent changes in the water content. If the liquid in the bottle becomes cloudy, it should be discarded. Ideally, maximum amount of powder should be incorporated in the liquid. Advantages of increasing the powder/liquid ratio gives a more viscous mix, shorter setting time, higher strength, lower solubility, and less free acid.

Factors Affecting Setting Time

Factors in Control of Manufacturer

Sintering temperature: Higher the temperature of sintering slower the reactivity of the cement.

Particle size: Finer particles will react faster, as the surface area is greater.

Water content: Insufficient amount of water will retard the ionization of the acid, hence slows down the reaction. Excess amount of water accelerates the reaction.

Factors in Control of Dentist

P:L ratio With reduced P:L the working time as well as setting time is increased. The pH of set mass is reduced and the compressive strength of the cement reduces.

Temperature of the mixing slab: High temperature accelerates the reaction and reduces the setting time.

Mixing time: With longer mixing time beyond limits the matrix is broken, and it requires extra time to rebuild the matrix (exactly opposite of the gypsum).

Rate of addition of the powder to the liquid: If the powder is added slowly the rate of reaction is slow and setting time is increased.

Properties

Physical properties As per ADA Specification No. 96 for water based cements.

Setting time also varies between 2.5-8 minutes.
Extended working time and shorter setting time can be achieved by use of cold mixing slab, which permits up to an approximate 50 percent increase in the amount of powder, improving both strength and resistance to dissolution.

Compressive strength—104 MPa
There is a rapid initial rise in cement strength in 4-7 minutes after mixing, reaching 50 percent of the final strength. The cement attains ¾ of its strength in the first day after cementation.

There is a linear relation between the compressive strength and the powder liquid ratio. Low powder liquid ratio, along with the alteration in the water content reduces the strength. The minimum strength for adequate retention of restorations is about 70 MPa

Tensile strength is 5.5 MPa.
Huge difference in compressive strength and tensile strength reflects the brittle nature of these cements.

Modulus of elasticity is 13 GPa
It shows that the cement is stiff and resistant to elastic deformation.

Powder liquid ratio is 1.4 gm to 0.5 ml
It has low solubility in water, but the solubility

increases in organic acids. The solubility in organic acid solutions, such as lactic or citric acid, is 20 to 30 times higher the solubility and disintegration in distilled water after 24 hours. It may range from 0.04 to 3.3 percent. The standard permissible limit is 0.2 percent.

Factors affecting the solubility of the cements include:

- Powder : liquid: Increased P:L shows less solubility
- Moisture contamination: Any contamination with moisture will cause increase in solubility. In such cases varnishes are always very beneficial
- Water content of the liquid: Altered content of the liquid also increases the solubility
- Solubility of $ZnPO_4$ cement in dilute acids such as lactic acid or acetic acid is 20 times more than that of water.

Effects of Solubility

- Dissolution of the luting cement may result in plaque retention and subsequent development of primary caries
- Loosening of the orthodontic bands.

Film Thickness

The cement must have the ability to wet the tooth and restoration, flow into the irregularities on the surfaces it is joining, and fill in and seal the gaps between the restoration and the tooth.

Band placement should be done when the cement mixture flows; because with time, the viscosity increases and results in greater film thickness, leading to poorly retained and inadequately adapted bands. Film thickness is critical as adhesion is not documented between $ZnPO_4$ and orthodontic bands. Retention of bands is attained by mechanical interlocking. Therefore film thickness of cement placed between bands and the tooth is of critical importance. Thin film results in better cementation and adaptation of bands to the tooth.

The minimum value of film thickness is dependent on:

- Powder particle size
- Powder/liquid ratio
- Mix viscosity

According to ADA specification (no. 96), type I cements should give a film thickness of 25 mm or less than 25 mm without fragmentation. For type II acceptable value is 40 mm or less than 40 mm. Thinner film is more advantageous as it has a better seating reaction, cementation and it fills the air spaces in the casting.

In prosthodontic practice, the cement fills in the inaccuracies between the restoration and the tooth and allows most castings to serve satisfactorily. Unless escape ways or vents are provided with full crowns, separation of powder and liquid may occur, with marginal defects in the cement film.

Biologic Effects

The freshly mixed zinc phosphate (at 2 minutes) is highly acidic with a pH of 2. Even after 1 hour of setting, the pH may still be below 4. After 24 hours, the pH may still be around 5.5. After 24 hours, the pH is around 7. Pain after cementation is not only due to the free acid in the mix but also because of a osmotic movement of fluid through the dentinal tubules.

Hydraulic pressure developed during seating of the restoration may also contribute to pulpal damage.

Thermal Properties

This cement is a thermal insulator; hence at times it can be used as a base under restorative materials (amalgam).

Optical Properties

The cement is radiopaque. It can be seen separately if used as a base under a silver amalgam restoration.

Advantages

- Zn phosphate cement has good handling properties. It can be mixed easily and set to a relatively strong mass
- The longevity of the cement in the mouth is quite good
- The set cement has a strength that is adequate for clinical service, so manipulation is less critical compared to other cements.

Disadvantages

- It does not bond with the tooth structure; hence retention of the restoration is only by means of mechanical retention
- The acidity of the cement is its biggest disadvantage, which may cause pulpal irritation
- The cement has no anticariogenic effect, like silicates
- The cement appears opaque, hence cannot be used as an anterior restorative material
- It lacks antibacterial action
- The cement is brittle.

ZINC POLYCARBOXYLATE CEMENTS

Zinc polycarboxylate cement (Fig. 33.2) was discovered by Smith in 1968. This was the first dental material developed that had potential to adhesive to enamal and dentin. They combine the desirable properties of zinc phosphate and zinc oxide eugenol cements.

Composition

This cement is supplied as a white powder and a clear, syrupy liquid. The constituents of the powder are zinc oxide and magnesium oxide, and the liquid is a 30-40 percent aqueous solution of polyacrylic acid.

Powder

The powder is based on the same formulation used for the zinc phosphate cements, containing zinc oxide with approximately 10 percent magnesium oxide, or sometimes tin oxide. Silica, alumina or bismuth salts and small amounts of stannous fluoride (4-5%) may be incorporated. Fluoride content increases the strength while controlling the setting time. Pigments may also be added to provide different shades.

Manufacturing involves firing of zinc and magnesium oxide between 900 to 1000 °C for 8-12 hours, grinding the sintered mass to appropriate particle size, and reheating for another 8-12 hours. The powder is fired at a high temperature to control the rate of reaction.



Fig. 33.2: A commonly available commercial packing of the zinc polycarboxylate cement

Liquid

The liquid is usually a copolymer of polyacrylic acid with other unsaturated carboxylic acids, such as itaconic and maleic acid. The acid concentration is approximately 40 percent by weight, and the molecular weight of the polyacids varies from 25000 to 50000. The high molecular weight increases the strength of the cement but has an undesirable effect such as short shelf life and difficulties in manipulation, due to high viscosity of the liquid.

In more recent formulations, the acid is freeze dried and then added to the powder, in which case, the liquid component is distilled water. This method was developed in order to achieve a correct ratio between the components, which was difficult before because of the high viscosity of the liquid.

Setting Reaction

Setting of zinc polycarboxylate cements occurs by acid-base reaction between the zinc oxide powder and polycarboxylic acid to form polycarboxylate salts.

Upon mixing the powder and the liquid, the acid attacks the powder and causes a release of zinc and magnesium ions. At the same time the ionization of the polycarboxylic acid takes place. The initial stage is followed by interaction between the carboxyl group of adjacent polyacid chains and the metal ions to form cross-linked polycarboxylate salts. This acts as the cement matrix. This setting mechanism is similar to glass ionomer except that in this case the zinc provides the cross-links rather than calcium and aluminium.

The result of the reaction is a cored structure in which the unreacted powder particles are bound by a matrix of zinc polyacrylate.

Properties (As per ADA Specification No. 96)

Mixing time

Zinc polycarboxylate cement has a much shorter setting time than zinc phosphate cements, the setting reaction proceeds rapidly; mixing should be completed within 30-60 seconds to ensure an adequate working time. The viscosity of these cements does not rise as rapidly as for the zinc phosphate cements.

Working Time and Setting Time

In general, the higher the powder to liquid ratio or the higher the molecular weight of the copolymer, the shorter the working time will be. *The recommended powder to liquid ratio for luting purposes is 1.5:1 by weight.*

Working time varies from 2 to 5 minutes, at room temperature. The setting time ranges from 3 to 7 minutes.

The powder should be incorporated into the liquid in large quantities to optimize working and setting time.

Factors affecting setting time include:

- Powder to liquid ratio, higher the P:L, shorter is the ST
- Powder composition
- Concentration and molecular weight of polycarboxylic acid. Higher the molecular weight of copolymer, shorter is the ST.

Working time can be altered by

- By lowering the temperature of the working slab the working time can be increased
- Storing the powder in the refrigerator, though it (refrigeration) may cause the gelation of the liquid. Therefore, liquid should not be kept in refrigerator
- Tartaric acid has the beneficial property of extending the working time without markedly affecting the setting time of the cement.

Most common mistake committed by the dentist is to produce a thinner mix by reducing the powder to liquid ratio under the misapprehension that this will make the cement flow more readily. However, in doing so, the properties of the cement are considerably impaired.

Though polycarboxylate cement mixture has thicker consistency than $ZnPO_4$, but it flow, readily because zinc polycarboxylate cement has the property of being pseudo-plastic, and shows shear thinning on mixing and seating of orthodontic bonds. This means that although the material may appear to be too thick to flow properly whilst it is being placed, the pressure that is exerted makes it flow quite satisfactorily.

Biocompatibility

Zinc polycarboxylate has a low pH initially around (3.0-4.0). It does not have any adverse effect on the pulp because of the rapid rise of pH to neutrality, the inherent inability of the polyacids to penetrate the dentin and the acid is weakly dissociated.

The zinc polycarboxylate cements act as a barrier to the ingress of bacteria by virtue of its antibacterial property and its adhesive nature. Therefore, it provides no path of ingress to bacteria.

Stannous fluoride is incorporated into the cement; fluoride release appears to be sufficient to have a beneficial effect on the enamel and dentin.

Mechanical Properties

When the cement is prepared to a consistency suitable for luting purposes, the *compressive strength of the fully set cement is in the region of 50-85 MPa.* Eighty percent of the final strength is attained within 1 hour.

This strength depends upon:

- The powder to liquid ratio.
- Presence of additives such as alumina and stannous fluoride.

The *diametric tensile strength is approximately 6 MPa.* The tensile strength is higher, however, being in the range of 8-12 MPa. The *elastic modulus is around 4-6 GPa,* which is about half that of the zinc phosphate cement. These cements are inferior to zinc phosphate in compressive strength and have slightly higher diametric strength.

As already mentioned, the zinc polycarboxylate cements set quite quickly, this cement exhibits a property of plastic deformation in contrast to brittle behavior of zinc phosphate cements. Long-term storage in water does not appear to have an adverse effect on the mechanical properties.

Solubility

The *solubility in water is low,* in the range of 0.1-0.6 percent by weight, with higher values for solubility

seeming to occur with the cements containing stannous fluoride.

This solubility is observed at the unreacted or partially reacted particles rather than in the salt matrix. Greater dissolution is seen in cements containing copolymers of maleic acid than copolymers of itaconic acid. These cements have lower resistance to dissolution in acidic environment, but as yet this does not appear to be sufficiently serious to be of any clinical significance, as indicated by the good clinical results obtained when using this cement. When failure has occurred this is more often than not due to the improper handling of the material. This is usually related to the use of a powder to liquid ratio that is too low, possibly in an attempt to extend the working time.

Film Thickness

The film thickness of polycarboxylate cement is slightly more than that of $ZnPO_4$ cements. It ranges between 25-48 μm.

Adhesion

A feature of the zinc polycarboxylate cements that sets them apart from the zinc phosphate and zinc oxide-eugenol cements is their ability to *adhere to enamel and dentin.*

The bonding mechanism is the same as that of the glass ionomer cements, in which polycarboxylic chains may form chelates with calcium ions present in enamel and dentin. Or they may develop an ionic attraction caused by polyacrylate formation between polyacrylic acid and the hydroxyapatite constituent of enamel and dentin. Bonding of polycarboxylate is assured when the cement is glossy at the time of cementation, as this indicates presence of unreacted carboxyl group.

In vitro cement-enamel tensile bond strength is in the range of 4-6.5 MPa. The bond strength is higher with enamel than dentin signifies the role of hydroxyapatite in the adhesion to the tooth structure.

Bonding to some metallic surfaces is possible with the zinc polycarboxylate cements, and this can be very beneficial when it is used as a luting agent with cast restorations. This again involves specific ions binding to the metallic surface. These cements are capable of bonding with surfaces of metallic restoration, prostheses and appliances.

Superior bond strengths are obtained with the base metal alloys (giving rise to cohesive rather than adhesive failures on testing the bond strength), and this is probably related to the presence of an oxide layer that provides the necessary metallic ions.

Applications

By using the appropriate powder to liquid ratio, the zinc polycarboxylate cements can be used as *cavity bases, as luting agents, and for the cementation of orthodontic bands.*

They have the advantages that:

- They bond to enamel and dentin as well as some of the metallic cast restorations
- They have a low irritancy
- Their strength, solubility and film thicknesses are comparable to that of zinc phosphate cement

They have disadvantages as well

- Their properties are highly dependent upon handling procedures
- They have short working times
- An exacting technique is required to ensure bonding.

GLASS IONOMER CEMENTS

These materials were formulated in the 1970s by Wilson and Kent by bringing together the silicate cement (strength and fluoride release potential) and zinc polycarboxylate cement (adhesive property). The glass ionomer cement (Fig. 33.3) is formed by mixing an ion leachable glass powder similar to that of silicate cement with polyalkenoic acids similar to those in the polycarboxylate cement liquids. The use of an acid-reactive glass powder together with polyacrylic acid solution leads to a translucent, stronger cement that can be used for luting and as a restorative purpose.

Synonym

- Polyalkenoate cement
- Alumino-silicate-polyacrylic-acid (ASPA).

Application

Glass ionomer cements are used for:

- The cementation of cast-alloy and porcelain restorations (Figs 33.3A and 33.3B)
- Cementation of orthodontic bands (Fig. 33.3B)



Fig. 33.3A: A commonly available commercial packing of the glass ionomer luting cement



Fig. 33.3B: Band cementation glass ionomer cement



Fig. 33.3C: Light could bracket bonding glass ionomer cement

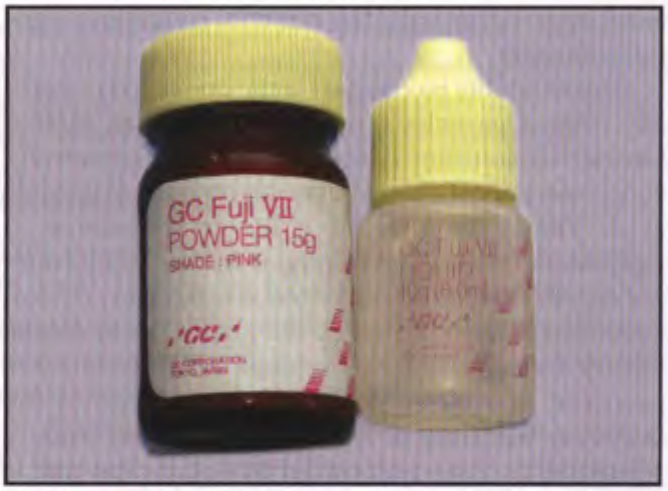


Fig. 33.3D: A commonly available commercial packing of the glass ionomer cement



Fig. 33.3E: A commonly available commercial packing of the glass ionomer cement

- Bonding of brackets with GIC has an advantage of avoiding acid etching, therefore elimination of mineral loss, that occurs during debonding with adhesive resins (Fig. 33.3C).
- As cavity liners or base materials (Fig. 33.3D)
- As an esthetic restorative material for class V cavity (erosion lesions) preparation (Fig. 33.3D)
- As an esthetic posterior restorative (Fig. 33.3E)
- As pit and fissure sealant (Fig. 33.3D)
- As a core build up material.

Glass ionomer became more popular (Table 33.1) in orthodontics during late 80's because of the following reasons:

Table 33.1: Advantages and disadvantages of glass ionomer cements

Advantages	*Disadvantages*
• Easy to mix	• Initial slow setting
• High strength and stiffness	• Moisture sensitivity
• Leachable fluoride (anti-cariogenic)	• Variable adhesive characteristics
• Good resistance to acid dissolution	• Radiolucency
• Potentially adhesive characteristics	• Possible pulpal sensitivity
• Translucency	• Vulnerable to wear
• Reasonably biocompatible	• Lack of fracture toughness

- Higher survival rate, compared to zinc phosphate cement
- Their fluoride release potential
- They are self-adhesive to both enamel and dentin, hence favored because while bonding brackets with them, there is no need of etching enamel, which causes mineral loss that occurs during debonding when adhesive resins are used
- Thermal expansion coefficient similar to dentin
- No heat is produced during setting
- Biocompatibility in host environment.

There are few disadvantages of using glass ionomer in orthodontics:

- Initial sensitivity of glass ionomer to moisture and dehydration
- Prolonged setting time
- Slow development of strength
- Short working time and no command set
- Low fracture toughness
- Low wear resistance.

Types and their Use

- *Type I*—for luting
- *Type II*—for restoration
- *Type III*—as liner and bases

Composition

Powder
Silica (SiO_2)—42 percent
Alumina (Al_2O_3)—28.6 percent
Aluminium fluoride (AlF_3)—1.6 percent
Calcium fluoride (CaF_3)—15.7 percent
Sodium fluoride (NaF)—9.3 percent
Aluminium phosphate ($AlPO_4$)—3.8 percent

Liquid

Liquid contains

- Polyacrylic acid
- Tartaric acid
- Water

Polyacrylic acid is used in concentrations of 50 percent. Tartaric acid improves the handling characteristics, increases the working time and shorten the setting time. Water is the most important constituent of the liquid, as it forms the medium of reaction and it hydrates the reaction product.

As the liquid is quite viscous and gets gelled very quickly, hence in most of the recent glass ionomer liquids, the acid is in the form of a copolymer with itaconic acid, maleic acid and tricarboxylic acid. This has the advantage of increasing the reactivity of the liquid, decreasing the viscosity and reducing the tendency of gelation. The liquid should not be placed in the refrigerator as it becomes too viscous.

In some materials the solid polyacrylic acid copolymer is freezed dried and mixed with glass ionomer powder, and the solution contains tartaric acid; in others, all the ingredients are in the powder, and the liquid is water. This increases the working time and shortens setting time. These cements have unlimited shelf life. Water-hardening glass ionomer cements are less viscous than the conventional formulations. Such cements are referred as water suitable GICs or anhydrous GICs (Fig. 33.4).

Manufacturing

Fluoride component acts as a ceramic flux. The raw material, which contains (cement powder, quartz, alumina, calcium fluoride, aluminium fluoride, lanthanum, strontium, barium or zinc oxide), is fused into

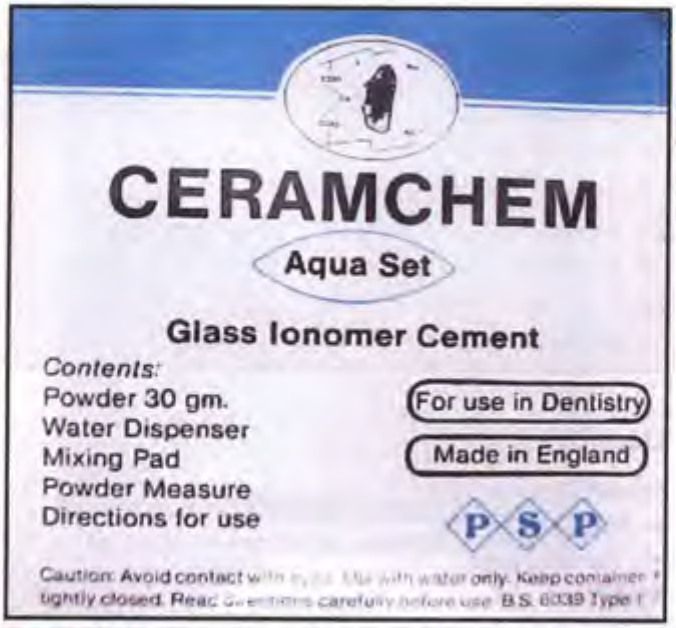


Fig. 33.4: A commonly available commercial packing of the glass ionomer cement with the liquid being distilled water (aqua set)

glass by heating them to temperature of 1100 °C to 1500 °C. The resulting glass is cooled in water and grinded to yield a frit (particles of glass). The desired particle size depends on the prospective use of the cement. Small particle size glasses (15 µm) are intended for luting cements, to obtain a higher powder liquid ratio, rapid setting and desired film thickness. Lanthanum, strontium, barium or zinc oxide additions provide radiopacity. The powder (calcium aluminium fluorosilicate) glass is crushed into the particle sizes around 25 µm for the filling materials.

Chemistry of Setting

The setting reaction of conventional glass ionomer cement is acid (liquid)-base (powder) reaction leading to the formation of polycarboxylate salts that comprise the cement matrix.

The reaction occurs in three distinct stages:

- Dissolution
- Gelation
- Final maturation stage.

1. *Dissolution stage* is characterized by the dissolution of polyacids in water and an acid attack on the glass particles. This releases Ca^{2+} ions and Al^{3+} ions into the aqueous phase. During the dissolution stage, the carboxyl (COOH) groups are dissociated to carboxylate (COO^-) groups and hydrogen (H^+) ions. The positively charged hydrogen ion attacks the surface of the glass particles, releasing calcium and aluminium ions in the form of fluoride complexes. The calcium ion concentration rises more rapidly than the aluminium ion concentration in the cement sol.
2. *Gelation stage* is characterized by the reaction of calcium ions with polyacid chains to form calcium polyacrylate.

   During gelation stage, the more mobile and readily available calcium ions are complexed with the carboxyl groups, and a weak ionic cross linking is formed, which corresponds to the initial setting of the cement that is observed clinically. During this initial stage moisture contamination is detrimental to the cement, disturbing the matrix formation.
3. *During the final maturation stage*, the Al^{3+} ions are increasingly deposited in the matrix, leading to a three dimensional, highly cross linked calcium-aluminium carboxylate gel, gradual hydration of the salt matrix and a rapid increase in the cement strength.

Sodium and fluoride do not participate in the cross linking of the cement. Some of the sodium ions may replace the hydrogen ions of carboxylic group, where as the rest combines with the fluoride to form the sodium fluoride uniformly dispersed in the set mass, which provides the anticariogenic property to the cement.

Structure of the Set Mass

The set mass consists of agglomerates of unreacted and partially reacted glass powder particles surrounded by silica gel and embedded in a cross-linked calcium and aluminium polycarboxylate salt matrix.

Factors Affecting the Rate of Reaction

- Temperature
- Powder-liquid ratio
- Powder particle size
- Presence of tartaric acid.

The tartaric acid serves to increase working time and gives a sharp setting for forming metal ion complexes.

Glass + polyelectrolyte→polysalts hydrogel + silica gel
(base) (acid) (matrix) (coating)

Factors which can inhibit this acid-base reaction are:

- Insufficient reactivity of glass particles
- Low water concentration
- Low acidity of the liquid.

Role of Water in Setting Process

Water acts as a reaction medium.

Water hydrates the cross-linked matrix, thus increasing the strength, this hydration is critical in yielding a stable gel structure. This water can be lost by desiccation and is called as loosely bound water. With time this loosely bound water becomes tightly bound, as it hydrates the matrix. The set mass becomes stronger and less susceptible to moisture. Therefore the critical care of the setting mass is necessary.

Protection

If the setting mass is exposed to air without any covering, the surface will crack or craze due to desiccation.

If the setting mass is exposed to water then dissolution of the matrix takes place. Resulting in a weaker and more soluble cement.

MANIPULATION

PREPARATION OF THE TOOTH SURFACE

The tooth should be clean for effective adhesion of cement. Before cementation of orthodontic bands, the tooth should be cleaned using pumice powder and a polishing brush. This leaves a plaque free surface.

The cement can be used as a filling/restorative material. The smear layer present after cavity preparation tends to block off the tooth surface, and so should be removed to achieve adhesive bonding. This can be done by pumice or polyacrylic acid. The objective is the removal of smear layer but still leave the collagenous tubule plug in place. This plug acts as a barrier to the penetration of acid from the cement. Apply 10 percent polyacrylic acid for 10-15 seconds, and then rinse with water for 30 seconds. This process of removing the smear layer is called as conditioning. After conditioning and rinsing the surface is dried but not desiccated. It should be kept free of contamination with saliva or blood as these interfere with the bonding. Tooth surface should be clean and free from saliva but not dehydrate.

PROPORTIONING

Powder Liquid Ratio

The proportioning should be done as per the manufacturer's instruction. Low P:L ratio reduces mechanical properties and increases the chances of cement degradation. Water contamination alters the acid-water balance. The powder and liquid is dispensed just prior to mixing.

A cool and dry slab is preferred as it allows all the powder to be incorporated into the mix and yet maintain the plasticity. But the temperature of the glass slab should not be below the dew point, as moisture may condense on the slab and change the acid-water balance. Best results are obtained by mixing the powder with the liquid on a chilled slab.

The powder is divided into 2 equal halves, the first half is incorporated into the liquid rapidly with the stiff spatula to produce a homogenous consistency. The remainder of the powder is then added, the mixing is done in a folded method to preserve the gel structure. A good mix has a glossy finish; this indicates the presence of residual polyacids and ensures proper bonding to the tooth surface. A mix with dull surface should be discarded as it indicates prolonged mixing and reduces the adhesion. The restorative mix should have a putty like consistency and a glossy surface. The lining mix is somewhat more viscous, depending on the brand.

Mixing time is approximately 45 seconds. The mixed cement is immediately packed into the prepared cavity.

GIC is also supplied in capsules containing proportioned powder and liquid and is mixed in an amalgamator at a very high speed. Its advantages are controlled P:L ratio; convenience and less mixing time. The hand mixing allows better shade matching to achieve desired esthetic results.

PLACEMENT AND PROTECTION OF THE MATERIAL

The mixed cement is packed by means of plastic instrument into the cavity.

Prior to seating of the band or the bracket, varnish should be applied to the adjacent uncovered enamel surface to assure the easy removal of excess cement. The excess cement should be care fully removed.

PROTECTION OF THE CEMENT WHILE SETTING

GIC is extremely sensitive to moisture and air during setting, hence immediately after placement into the cavity, a matrix is applied to protect the cement from the environment, i.e. protect cement from loosing or gaining water.

Provide the desired contour, so that minimum finishing will be required. The matrix should be left in place for a minimum of 5 minutes. The cement should be allowed to dry in ambient conditions and not with compressed air. Later the cement layer is protected with varnish or unfilled light cure resin bonding agent or cocoa butter. Hand instruments are to be preferred than the rotary instruments to avoid ditching, while removing the excess.

PROPERTIES

Setting Time

- For the luting materials, *the setting time is in the range of 6 to 9 minutes*
- The lining materials set in 3 to 4 minutes
- The restorative materials set in 3 to 4 minutes
- Materials that are light cured set in approximately 30 seconds when exposed to visible light source The acid-base reaction continues slowly and properties further improve over time.

Hardness

Surface hardness is about 48 KHN.

Film Thickness

Ideally it should be in the range of 25-35 μm in thickness. Though it is difficult to achieve it due to, increased P : L ratio and delayed seating of bands/brackets. But clinically it is managed due to its pseudo-plastic nature.

Film thickness in the range of 25 to 35 μm, which is adequate to seat castings satisfactorily, although the flow properties are quite dependent on powder/liquid ratio.

Strength

For the luting cements, the compressive strength increases over 24 hours to 90 to 140 MPa, which exceeds that of zinc polycarboxylate and zinc phosphate cement.

The tensile strength also increases similarly to 6 to 8 MPa.

The *modulus of elasticity is about 7 GPa (3-14).* The modulus of elasticity of glass ionomer cement is higher than that of zinc polycarboxylate cement and about one-half that of zinc phosphate cement. Thus glass ionomer demonstrate more elastic deformation than the zinc phosphate cements and less than that of zinc polycarboxylate cement.

The lining materials have compressive and tensile strengths in the same range with some light-cured materials at the higher end of the reaching 150 to 160 MPa in compression and 10 to 12 MPa in tension.

The restorative materials range from 140 to 180 MPa in compression and 12 to 15 MPa in tension.

The light cured restorative materials may have strengths as higher as 200 MPa in compression and 20 MPa in tension. Some silver containing materials are in this range, and even higher strengths have been achieved in recent materials.

In general, with light-cured materials, properties are dependent on the depth of cure.

Fracture Toughness

It is defined, as the energy required to fracture the material. GIC is inferior to composites in this respect.

Solubility

The solubility of the cements in water is about 0.4 to 1 percent for luting material, and this is higher in lactic acid. The solubility in water of fully set glass ionomer cement is considerably lower than that of zinc polycarboxylate and zinc phosphate cements. Initial susceptibility is very high (first 5-10 minutes) after the start of mixing, with a rapid decrease occurring over the following 24 hours. When it is exposed to the acid attack, glass ionomer cement gets eroded; this erosion begins at pH 4. Good resistance to dissolution is observed under oral conditions. Varnish protection of conventional cements improve resistance to dissolution and disintegration.

Adhesion

Glass-ionomer cements exhibit bonding to enamel, dentin, and these are similar in manner to zinc polycarboxylates. The mechanism of bonding is due to reaction between the carboxyl groups of the polyacids and the calcium of enamel and dentin. The bond to enamel is always higher than that to dentin, may be due to greater inorganic content (96%) of enamel and its greater homogeneity, than dentin. *In vitro* and *in vivo* adhesiveness is variable and is affected by surface conditions. Slight and variable marginal leakage has been observed. Bonding to dentin for conventional materials is not improved by pretreatment with polyacrylic acid solutions, whereas with light-cure materials it is dependent on the use of the dentin primers. Bond strength values reported for glass ionomer cement is 3-7 MPa, in shear stress. The ability of glass ionomer cements to bond with enamel/dentin is superior to the bond between the cement and the base metal/bracket/stainless steel bands. This may explain the failure mode of cements during debonding/debonding, which essentially involves adhesive fracture at the band- glass ionomer or bracket-glass ionomer interface.

Resin modified glass ionomer cements appear to provide significantly higher bond strength than the conventional glass ionomer cements and a decreased probability for bond failure.

Esthetics

Esthetically they are inferior to silicates and composites.

They lack in translucency and feel rough in surface texture.

BIOLOGIC EFFECTS

Fixed orthodontic therapy presents few challenges like, caries, enamel demineralization and development of while spots adjacent to bands/brackets, GIC due to their capacity to release fluoride can minimize these risks. Pulpal response to the lining and restorative materials appears generally favorable. Variable behavior has been reported for the various luting materials with instances of postoperative sensitivity. This has been attributed to a prolonged initially low pH coupled with the effect of the toxic ions. The pulpal reaction is greater than zinc oxide eugenol but less than zinc phosphate. The water soluble cements are more acidic. Type I GIC is more acidic than type II because of lower powder/liquid ratio.

Leaching of fluoride and uptake by adjacent enamel occurs with these cements, and this continues for at least a year with potentially carciostatic effects. Anti-bacterial action has been attributed to low initial pH.

Resin Modified Glass Ionomers

Conventional GICs have the disadvantage of moisture sensitivity and low early strength. Their drawbacks are covered up by formulations that impart additional curing process by addition of polymerizable functional groups. This gives improved lining and restorative materials with an immediate command set with higher early strength and water resistance. Some commercial materials contain a preponderance of polymeric components with minimal acid-base reaction. They can be activated by light or chemicals. This group of material is identified as light cured GIC, dual cured GIC (for light cured and acid-base reaction), tri-cured (dual cured, plus chemical cured).

Table 33.2: Properties of three major types of cement used in orthodontics, a comparative analysis

Properties	*Zinc phosphate cement*	*Zinc polycarboxylate cement*	*Glass ionomer cement (luting consistency)*
Working time (min)	3-6	2-5	3-5
Setting time (min)	2-8	3-7	5-9
Compressive strength MPa	80-140	50-80	90-220
Diametral tensile strength (MPa)	5	6	6-8
Tensile strength (MPa)	5-7	8-12	6-8
Film thickness (μm)	25	25-48	25-35
Solubility (wt%)	0.04-3.3	0.1-0.6	1
Modulus of elasticity (GPa)	9-13	3-8	3-14

They are called dual cured, if the setting takes place by {(acid-base reaction + light cured (activation) or chemical cured (activation)}.

They are called tri-cured, if the setting takes place by {(acid-base reaction + light cured (activation) + chemical cured (activation)}.

The properties of the discussed cements are tabulated in Table 33.2.

FURTHER READING

1. Mount GJ. Clinical placement of modern glass ionomer cements. Quintessence in 1993;22:99-107.
2. Mount GJ. Glass ionomer cements and future research. Am J Dent 1999;7:286-92.
3. Nakajima H, Watkins JH, Arita K, Hanaoka K, Okabe T. Mechanical properties of glass ionomers under static and dynamic loading. Dent Mater 1996;12:30-7.
4. Powis DR, Folleras T, Merson SA, Wilson AD. Improved adhesion of glass ionomer cements to enamel and dentine. J Dent Res 1982;61:1416-22.

34 Adhesion Promoters and Bonding Materials

Pankaj Dutta

- Introduction
- Adhesive science
  - Diagram
- The range of orthodontic adhesives
- Resin-Ionomer hybrids
  - Classification and terminology
- Enamel and dentin bonding
- Acid etching
  - Acid etching procedure
  - Iatrogenic effects of etching
- Generations of dentin bonding agents
  - Etchant
  - Primers/coupling agent/dentin conditioner
  - Adhesive
- Factors affecting the bonding of the brackets to the enamel
- Bond failures
- Composite

INTRODUCTION

Over the past two decades, the evolution of adhesive techniques has transformed the scope of dental practice. One of the most successful developments in dentistry has been the meteoric rise of the use of dental adhesives. Because of its many advantages (Table 34.1) development of an adhesive approach has revolutionized the restorative and preventive dentistry.

Table 34.1: Advantages of adhesive dentistry

• Better esthetics
• More conservation of tooth tissue
• Improved crown strength
• A wider range of techniques
• Reduced potential for pulpal sensitivity

Adhesive bonding is important for orthodontics, especially in terms of the fixation of brackets to teeth. This situation involves the joining of two solid substrates or adherents by an intervening layer of adhesive agent.

Two things that are crucial here are:

- Surface interface characteristics and
- The inherent properties of the adhesive

Many aspects of the situation are rather general. That is, they are not entirely restricted to the orthodontic context itself.

We shall first sketch sufficient background of adhesive science to facilitate appreciation for:

1. The necessary requirements/properties of orthodontic adhesives.
2. Outline the range of materials that have been considered for use as orthodontic adhesives.
3. Discuss more detailed treatment of the monomer and monomer-composite systems in extended use.
4. The associated surface modification regimes for the tooth and bracket substrate will briefly be addressed.

ADHESIVE SCIENCE

The characteristic requirements and properties of adhesive agents for orthodontics must be understood in terms of the molecular and structural mechanisms of adhesion. One of the basic questions of physicochemical science is "Why do materials cohere at all?" On the basis of molecular theory, the answer is given

in terms of a range of attractive forces that may operate in and between molecules. These may produce bonds of varying *strength* (that is, the energy required for their disruption), ranging from covalent and ionic bonds to hydrogen bonds and other relatively weak intermolecular forces.

There are a few solids that will spontaneously self-cohere when brought into sufficient proximity. Two familiar examples from dentistry are cohesive gold foil and waxes. Both of these materials are sufficiently plastic in deformation as to self-adapt topographically at the molecular interfacial level, though some physical agency is needed to promote this phenomenon: Mechanical force upon gold foil, and gentle heat in the case of waxes. Other examples of joining-coherence may arise under more extreme conditions, such as metals at soldering and welding.

Unfortunately like most other solids, tooth and the orthodontic bracket, do not cohere upon touching. Why is it so?

This is because, though the surface forces are present but,

1. Such forces operate over very small distances and decrease rapidly in magnitude with the inverse sixth power of separation.
2. The solids in question are microscopically rough. Hence, when the solids (A & B) are bought into "contact," (Fig. 34.1) the situation is like two mountain ranges being superimposed en *face*. The points of actual molecular contact are only a few percent of the whole area (lack of large surface area contact).

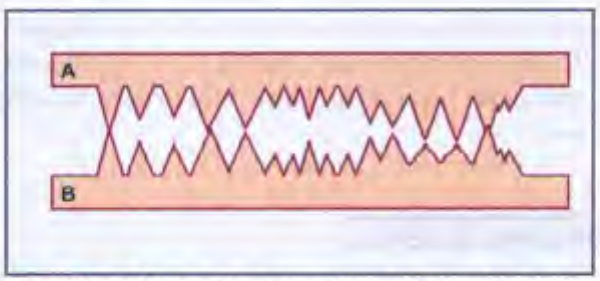


Fig. 34.1: Microscopic view of two solids in contact

DIAGRAM

What can be Done to Bring such Solids Together?

In such a situation if a fluid agent is introduced between the solids in question, that adequately wets both surfaces (increases the area of contact), it promotes intermolecular bonding at the interface with each solid. This is very apparent if we take a pair of dry microscopic slides, which can be separated very easily, but once wetted by water, it is not so easy to pull them apart. However shear forces may debond them. In this case the water has done the trick, and it is all due to adhesion.

Adhesion is the process of forming an adhesive joint. The initial substrate is called the *adherent*, whereas the material producing the interface is called the adhesive. Like in the above stated example two microscopic slides are adherent and water acts as an adhesive. The adhesive has produced two interfaces, at the junction of water and the glass plates.

What are the requirements for forming optimally bonded interface?

1. The surface of the substrate should be *clean*, and it should be kept clean until the adhesive is applied. Enamel or dentin prepared with rotary instruments contains a debris layer that is smeared onto their surfaces, called the *smear layer*. This layer is few micrometers thick and adheres weakly to the substrate. Thus it is essential to remove this layer or penetrate it with adhesives. Most common approach is to remove it or to chemically dissolve it.
2. The adhesive should *wet* the substrate well, and to do so it should have a low contact angle, and spread onto the surface. Clean dentin is hydrophilic and will be wet by hydrophilic adhesive. Adding solvents to adhesive promotes lower viscosity and good flow.
3. *Intimate approximation* of the adhesive material to the substrate without entrapping air or any other material.
4. The interface should include the *sufficient physical, chemical or mechanical strength* to resist debonding forces.
5. The adhesive should be *well cured*. On solidification of the adhesive, the ideal would be no change whatsoever in the adhesive-zone dimensions. In orthodontics, the problem is less severe, because the tooth/bracket system can more readily accommodate changes in thickness *across* the adhesive interfacial layer Nevertheless, any *lateral* shrinkage strain components will generate disruptive bond stresses.

In summary, adhesive solidification is essential. It may bring some associated problems of shrinkage strain and stress.

The bonding mechanisms holding the bracket to the tooth can be subdivided into two components:

- Adhesion (chemical)
- Attachment (mechanical)

Thus, bonding = Adhesion + Attachment

Under *adhesion* we would group all those contributions to bonding attributable to specific molecular interlinking *via*

1. Primary valence forces
   - Ionic bond
   - Covalent bond
   - Metallic bond.
2. Secondary valency forces like hydrogen bonds, London forces, and other van der Waals forces.

Under *adhesion*, we can also include the kind of molecular chain intermeshing or interpenetration of networks now known to be formed at the dentin-bond hybrid zone (generation 4 and 5 bonding agents).

Under *attachment*, we think especially of the so-called "tag" formation established with acid etched dental enamel. This arises in situations where a highly rigid but porous substrate allows penetrating resin flow and solidify *in situ*. Mechanical interlocking is thereby attained. Similarly at the bracket/adhesive interface, *attachment* is the dominant contribution to bonding *via* the gross surface "undercut" detail of the fitting surface.

Ideal requirements of orthodontic adhesives should be (Table 34.2).

A wide variety of adhesive systems have been introduced in recent years, such adhesives were unable to satisfy the stringent requirements that are placed upon a dental adhesive.

Table 34.2: Ideal requirements of orthodontic adhesives

- To have suitable flow properties
- Wettability
- Penetration without undue slumping or bracket drift; this rheological characteristic is often expressed as *thixotropy*
- Provide high bond strength to enamel and dentin
- Provide an immediate and durable bond
- Prevent of the ingress of bacteria
- Be safe to use, biocompatible
- Be simple to use
- To minimize setting shrinkage, their overall water-absorbing tendency should be minimum
- Aesthetic
- Color stability

THE RANGE OF ORTHODONTIC ADHESIVES

Most orthodontic adhesives are variations on adhesive and direct-restorative formulations manufactured for use in restorative dentistry. There are two competing categories of nonmetallic direct restorative biomaterials. These may be denoted the salt-matrix (GIC) and the resin-matrix (RC) types. A third category of material is also available, which is a combination of salt-matrix and resin-matrix. These materials are known as resin-ionomer hybrids. Conventional GIC we have already discussed in chapter 33 and resin composites will be discussed later in the chapter let us first see the resin-GIC hybrids.

During the 1990s, a major development has been the *hybridization* of the technology underlying resin composites (RC) and glass-ionomer cements (GIC) (Fig. 34.2). That is, components from both systems have been combined in various ways with the aim of developing materials that will ideally exhibit the best characteristics of each "parent."

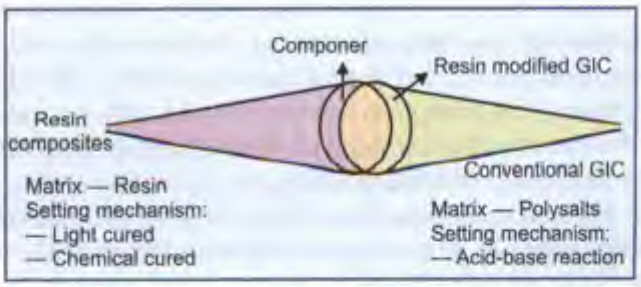


Fig. 34.2: Hybridization of technology underlying resin composites and glass-ionomer cements

Combining the characteristics (Table 34.3) of both types entails a combination of setting mechanisms and thus a mixture of network types. These various hybrids occupy positions on an almost continuous spectrum between the extremes of the pure resin composites (RC) and the pure glass-ionomer cements (GIC). However, in practice the spectrum is discontinuous at the point where water is either included in or excluded from the formulation.

Table 34.3: Characteristics of composite and GIC

Characteristics	*Salt-matrix (GIC)*	*Resin-matrix (RC)*
Ceramic particles	Reactive	Nonreactive
Size	Diameter > 10 μm	Diameter 0.05-5 μm
Release of fluoride	Yes	No
Matrix precursors	Polyelectrolytes	Dimethacrylate monomers
Setting mechanism network type	Salt formation: covalent/ ionic network	Addition polymerization: covalent network
Particle-matrix interface	Silica gel	Silane coupling agent
Mechanical properties	Low	High

RESIN-IONOMER HYBRIDS

CLASSIFICATION AND TERMINOLOGY

Some manufacturers use the term *glass ionomer* in an extended sense to denote resin-based products that contain ion-leachable glasses but that bear only slight resemblance to traditional glass-ionomers. Strictly speaking the term *glass ionomer* should only be used when a substantial part of the setting procedure involves an acid-base reaction.

Hybrid materials have been developed because traditional GICs have several disadvantages, like:

- Short working time
- Long setting time (not command set)
- Cracking on desiccation
- Poor resistance to acid attack
- Low fracture toughness
- Low abrasion resistance
- Initial sensitivity to moisture

Actually speaking these hybrid materials may all be called *composite materials* since they consist of a matrix *phase* and a dispersed phase.

Earlier, these materials were referred to as (visible) light-cured glass-ionomers (VLC-GIC). But now as per the ISO (International Organization for Standardization, Geneva, Switzerland) they are termed *light activated-water-based cements*. The LC-RM-GIC are dual selling cements. On mixing of powder and liquid, the acid-based reaction takes place as in conventional GIC, along with free radical polymerization once exposed to light. This light curing may retard the acid-base reaction rate.

But in chemically cured RM GIC, once the powder and liquid are mixed, the acid-base reaction along with free radical polymerization takes place. This means the, products that fall within the scope of the standard is described as "water-based and set by multiple reactions which include an acid-base reaction and polymerization."

Advantage of such materials

- Ability to bond to enamel and dentin with greater strength
- Fluoride release
- Prolonged working time
- Command set
- Improved resistance to desiccation
- Enhanced strength.

Currently available resin-ionomer hybrids exhibit a wide range of composition.

The principal variables that may be:

1. Ceramic filling powder and
2. Organic matrix- forming molecules.

The ceramic powder, a common feature of virtually all these hybrids is the utilization of some form of GIC-type powder component, i.e. an ion-leachable glass. This provides a potential for acid-base reactivity and fluoride release. The glass content in formulations is typically in the range 70-75 percent by weight.

Therefore, it follows that the differences between hybrid types consist primarily in the organic components, including especially the mechanisms available to activate setting. There is a spectrum of possibilities, ranging from a pure salt matrix to a pure resin matrix. These may be categorized as described in the following sections.

Resin-Modified Glass Ionomers (RM-GIC)

These set by an acid-base reaction and by free-radical addition polymerization (which may be light or chemically activated). They contain components present in both GICs and resin composites.

Significant alterations are made in the liquid component of LC-GIC. Most important changes are replacement of water by water-HEMA mixture and incorporation of photoinitiator and/or chemical initiator for free radical polymerization. Reduction of water and variation in acidity of the liquid appears to influence the acid-base reaction.

Use of dentin bonding agent under them is contraindicated as it decreases the fluoride release. RM-GIC set by a combined acid-base ionomer reaction and light cure resin polymerization.

Advantages

- They are more esthetic than glass ionomers.
- They bond with the tooth structure without use of dentin bonding agent.
- Their transverse strength is double that of conventional GIC. They release more fluoride than compomers and composites.

Compomers (Polyacid-modified Resin Composites)

Compomer is a contraction of "composite and "Ionomer," suggesting a material with intermediate characteristics and properties. Compomers are packaged and handled much like composites. These are supplied as anhydrous single paste.

Contents

Powder contains aluminium fluorosilicate glass, sodium fluoride and chemical and light cured initiators.

Liquid contains polymerizable methacrylate/carboxylic acid monomer, and diacrylate monomer. Compomers have the major ingredients of both resin composites and glass ionomers, except for water. Compomers contain an additional molecule with carboxylic acid groups, similar to the molecules in conventional and resin-modified glass ionomers. This implies that compomers can also undergo an acid-base setting reaction like glass ionomers. Compomers, however, do not contain water (i.e. they are anhydrous). Exclusion of water ensures that initial setting occurs only by polymerization and is essential in preventing premature setting of the material in the container.

Setting Mechanism

Primarily by light, but acid-base reaction also occurs. An acid base reaction may occur later as the material absorbs water *in vivo*. Although the extent to which such a reaction can occur is probably limited. This cannot take place without appreciable water diffusion. By the time this has occurred, the self-limiting VLC-generated network will have sufficient cross-link density to suppress extensive reaction.

Compomers have properties that are intermediate to those of composites and resin-modified glass-ionomers but are closest to composites.

Advantages

- They have excellent esthetics.
- Low solubility
- High bond strength
- High fracture toughness

Drawbacks

They require bonding agents to bond with the tooth structure.

They have generally been shown to have less fluoride release than glass ionomers.

Orthodontic uses of Resin-Ionomer Hybrids

Among the preceding group of materials, it is mainly the resin-modified glass-ionomers that have attracted attention for orthodontic use. The perceived benefits are the more rapid achievement of a polymer network via free radical initiation, coupled with the release of fluoride. It is not so obvious that the compomer or similar formulations have a great role as orthodontic adhesives.

For the third category of orthodontic adhesives (composites) to be discussed any further, it is essential to first have a working knowledge regarding their mechanism of bonding. Therefore, let us go through the acid etching and dentin bonding agents before discussing composites.

ENAMEL AND DENTIN BONDING

Much has changed since those first bonded composites. The number of clinical application for this

modality has exploded. In the current age of adhesive dentistry or microdentistry, it is essential to study the requirements that the adhesive need to bond a variety of materials (e.g. composites, metals, ceramics) to two very different substrates namely (e.g. enamel and dentin).

In this section, the methods of bonding composites and resins to enamel and dentin will be considered.

To name a few scientists who contributed significantly in the field of bonding adhesive system are:

Michael Buonocore (etching of enamel by phosphoric acid and bonding to acrylic resin, 1955).

RL Bowen (Development of Composite resin 1962)

Nobuo Nakabayashi (Resin reinforced hybrid layer, 1982).

Takao Fusayama, *et al* (Total etch teeth 1979).

J Kanca, *et al* (Moist bonding technique 1992).

ACID ETCHING

Dr Michael Buonocore pioneered acid Etch Technique, in the late 1950s and early 1960s. Since the surface of enamel is smooth and has little potential for bonding by micro mechanical attachment. But to overcome this shortcoming the surface of enamel can be modified considerably by treatment with certain acids.

The acid etch technique consists of applying an acid in an appropriate concentration to the enamel surface. Within 60 seconds the etchant dissolves away portions of the individual enamel rods. The depth of the dissolution typically ranges between 10 and 15 µm. The highly irregular and tortuous surface serves to hold the composite resin restoration in place. This surface is now suitable for micro mechanical attachment since it contains a myriad of small undercuts into which resins can gain ingress, set and form a 'mechanical lock'. Procedurally, a resin of thin viscosity is applied to the etched surface. After flowing into the multiple surface porosities the resin polymerizes and forms a strong mechanical bond to the enamel surface. In essence the resin forms thousands of small "tags" into the enamel itself.

ACID ETCHING PROCEDURE

1. Surface treatment: Before etching is initiated the enamel surface should be cleaned adequately with pumice or other suitable agent free from oils or other organic components. Failure to clean the surface adequately may prevent the etchant from properly etching the enamel.
2. Application of acid: Phosphoric acid may be applied with brush, or injected in viscous gel form (Figs 34.3A and B).



Fig. 34.3A: Commercially available etchants in syringe



Fig. 34.3B: Commercially available etchants in a bottle

Application with brush has certain advantages:

- Fine tip confines the acid to the enamel periphery
- Soft bristles prevent heavy rubbing application, which may reduce the retention by causing the fracture of interstitial enamel surrounding the micropores.

3. Acid concentration: Although this subject is a bit controversial, clinically it is seen that concentrations of 30-40 percent are most reliable in creating microporous enamel surface.
4. Type of acid: Either an aqueous solution or phosphoric acid gel is used. Aqueous solutions are easy to use, but difficult to control because of their free flow. Because of this difficulty, lately acid gels have become more popular. They have improved the acid etching procedures. They are viscous enough to allow controlled placement in the required area. These gels contain phosphoric acid and pigment, which further helps in application of the acid.
5. Etching time: This should be sufficient to cause effective etching as evidenced by a chalky white, frosted or matted appearance on the treated section of enamel. Etchant should remain in the surface for at least 30-60 seconds. Etching should not continue long enough for dissolved apatite to reprecipitate as phosphates onto the etched surface.

   However, the etching time should be increased to 1 minute in case of fluorosed or deciduous enamel because both are resistant to acid etching.
6. Washing stage: The surface should be washed for at least 20 seconds. The prolonged water lavage is necessary to remove contaminant residue, consisting mainly of soluble calcium salts, from the treated enamel surface before bonding.

   After etching the enamel surface should be washed with copious amounts of water to remove debris.
7. The drying stage. The surface of the etched enamel should be very thoroughly dried. It is imperative that the air directed across the surface of the tooth be free of oil or moisture, as they act as contaminant and reduce the bond strength with resin. Although chemical-drying agents may be used, warm air-drying is preferred. At this stage the enamel surface is said to be most sensitive to contamination. If even a small amount of saliva contacts the etched surface, within a short time the microporous surface becomes obliterated by firmly adherent contaminant layer composed of mainly salivary proteins. If this occurs the surface can be rendered clean only after re-etching for 20 seconds.

The use of acid etching in conjunction with composite resins offers a number of basic advantages:

1. Reduction or elimination of microleakage: As all restorative materials have different coefficient of thermal expansion than tooth structure, which leads to the influx of fluids along the tooth-restoration interface.
2. Minimal tooth reduction: Since it is possible to bond the resin to the enamel surface mechanically, it is not necessary to depend totally upon undercuts within the preparation itself. Acid etching aids in the retention of the composite fillings. Use of an adhesive system allows the conservation of considerable quantities of tooth substance, which would otherwise be lost in cavity preparation.
3. Defects on the enamel surface can be treated first by removing the affected area, then acid etching, and finally inserting the restorative material. By this technique, it is possible to veneer the entire facial or labial surface of teeth masking out the dark discoloration caused by tetracycline staining or any congenital enamel defects. Another application of the acid-etch technique is the attachment of acrylic or porcelain labial veneers in order to improve the appearance of stained, discolored, or misshapen teeth.
4. To modify the anatomic form of the tooth itself considerably. Diastema closures can be accomplished readily by adding composite resin to the proximal surfaces. As the treatment of choice for restoring the tooth contours and function, for example such as peg shaped lateral.
5. *Fissure sealants* are now widely used for preventing pit and fissure caries.
6. Resin systems are now widely used for attaching *orthodontic brackets*. These resins are normally supplied as two components carrying relatively high loadings of initiator and activator respectively. One component is applied to the etched enamel surface and the other to the bracket. When the two are pressed together rapid setting takes place. Alternatively, conventional composite resin materials can be used for this application.

7. Composite resins are gaining in popularity for the attachment of *bridges*. These types of bridges can be Maryland or Rochette bridge.

IATROGENIC EFFECTS OF ETCHING (Table 34.4)

While most clinicians accept acid etching of enamel as a routine technique there are some possible iatrogenic effects of acid etching of enamel.

Table 34.4: Iatrogenic effects of acid etching

- Fracture and cracking of enamel upon debonding
- Increased surface porosity, which increases the possibility of staining. Etched enamel is porous, making it susceptible to retention of stains
- Loss of acquired fluoride in outer 10 μm of enamel surface
- Loss of enamel during etching
- Resin tags retained in enamel-possible discoloration of resin
- Rougher surface if over-etched

Keeping these side effects in mind, what are the other alternative methods?

Alternative Techniques to Acid Etching

- Air abrasion
- Laser
- Crystal growth

Is there any difference between adhesion to enamel and dentin?

Dentin Adhesion

Micro-mechanical adhesion of resin materials to enamel is a well-accepted clinical procedure. By comparison the dentin bonding agents have had a turbulent history. Many have come and gone, but at each stage of their development there has been an encouraging improvement. Perhaps some of the dentin bonding agents now being marketed will survive the test of time. An important goal in the development of dentin bonding systems has been to achieve bond strengths such as to overcome the polymerization shrinkage of the overlying composite.

Adhesion to dentin has been more of a challenge due to:

- Dentin is a living tissue in comparison to enamel.
- Etched dentin contains many open dentinal tubules, the number of which depends on the location in the tooth. For example, only 4 percent of the dentin surface near the dentin-enamel junction may contain tubules, whereas near the pulp, where the tubules are packed much closer together, 30 percent of the surface area of the dentin may contain tubules. Dentinal tubules are filled with dentinal fluid (20% by volume). Because of that stringent requirements are placed on materials that can be effective coupling agents.
- Danger of biological side effect on the pulp, of various chemicals.
- Enamel is composed almost entirely of inorganic mineral; nearly 50 percent of the volume of dentin is made up of water and organic material, mainly collagen protein. Thus, the composition of dentin is much different than that of enamel. The presence of water and organic components lowered the surface energy of the dentin and made bonding with existing resins essentially impossible.
- As the dentin is cut by a dental instrument, a layer of loosely adhered debris is left covering the dentinal tubules. Because of its appearance, this layer, which contains the components of the ground dentin, is referred to as the smear layer, which has to be removed for better bonding.

Therefore adhesion to dentin is more difficult than dentin.

GENERATIONS OF DENTIN BONDING AGENTS

While the term "generation" has no scientific basis in the realm of dental adhesives, and is to a great extent arbitrary, it has served a useful purpose in the organization of the myriad of materials into more comprehensible categories.

The "generational" definitions help in:

- The identification of the chemistries involved
- The strengths of the dentinal bond
- The ease of use for the practitioner

Ultimately, this type of classification benefits the dentist in terms of simplifying the chairside choices.

Modern bonding agents contain three major ingredients

- Etchant
- Primer/coupling agent and
- Adhesive.

All of them may be packaged separately or combined. Multicomponent systems usually contain three separate components: etchant, primer, and adhesive resin. The procedure for the use of a typical three-component system is described, although not all adhesives are used in exactly the same manner.

ETCHANT

- They are organic acids (citric, maleic, tartaric or EDTA) or
- Mineral acids (phosphoric, nitric) or
- Polymeric acid (polyacrylic acid)

Acid etchants are also called as conditioners; they can be in the form of solutions or gel. Gels are made by adding little amount of cellulose; they flow under slight pressure but do not flow under their own weight.

Function of an Etchant

1. To remove totally or at least alter the smear layer by demineralizing the hydroxyapatite.
2. It also exposes the underlying dentin or at least makes the smear layer more permeable for the next step.
3. In addition, a significantly roughened surface is produced. Although the surface is not as rough as etched enamel, it is more permeable than normal dentin or a normal smear layer.

Method of Application of Etchant

The etchant is applied to the dentin and enamel with a brush, allowed to stand for 15 seconds, and then washed with a copious water spray; the surface is then dried, either by lightly blowing air or by blotting with cotton. For nearly all materials, it is important not to over dry the tooth because bonding is enhanced when some moisture remains in the tubules. This has been referred to as 'wet bonding."

PRIMERS/COUPLING AGENT/DENTIN CONDITIONER

These substances seek to make the surface of the substrate more amenable to accepting a bond (Fig. 34.4).



Fig. 34.4: Dentin conditioner

Primers are hydrophilic monomers, carried in a solvent. Solvents used in a primer are acetone, ethanol-water or water. A few primers are solvent free.

Direct comparison of the solvents used for primers (Table 34.5).

Table 34.5: Comparison of solvents used for primers

Solvent	*Advantage*	*Disadvantage*
Acetone	Dries quickly	Can evaporate from container, multiple applications required, sensitive to wetness of dentin
Water	Slow evaporation, not sensitive to wetness of dentin	Long drying time, water interferes with adhesive if not removed
Ethanol/ water	Less sensitive to wetness of dentin, evaporates slowly	Long drying time
Solvent free	Single coat, no drying	High film thickness

Such solvents are very effective at displacing the water in the dentin and in the process pull the adhesive into the dentin.

The primer contains monomers and hydrophilic molecules (such as HEMA, a coupling agent).

Coupling agents serve as wetting agents to improve the penetration of the monomers into the demineralized dentin surface. The depth of penetration is usually aided by the use of solvent carrier such as ethanol or acetone. Ethanol or acetones are very effective at seeking out water and displacing it, carrying the coupling agent along with it.

Coupling agents make the dentin surface more hydrophobic, thus prevents the shrinking away of the resin tags away from the dentin.

Because the acid in the top few micrometers of the surface has removed much of the mineral, the coupling agent (HEMA) penetrates into a mostly organic material composed of collagen fibrils sticking up from the sound dentin to which they are strongly connected. This surface should not be allowed to dry after the etch process. Upon drying, the collagen fibrils collapse and effectively 'seal off' the surface from the primer and adhesive. The resins do not penetrate, therefore, and adhesion is reduced.

The primer is applied with a brush. It is not washed off, nor is it dried excessively.

One-component systems have:

A combined etchant and primer (so-called "self-etching primer)

Or

A combined primer and adhesive.

In the latter, an acid etch is usually used as the first step, and primer/adhesive is applied after the etch has been washed off. Therefore, some one-component systems actually require two steps.

ADHESIVE

The adhesive is essentially an unfilled or lightly filled resin, similar in composition to the resin in composites except that hydrophilic molecules have been added. The adhesive is brushed onto the prepared dentin surface and is thinned to a uniform layer with the brush; it coats as well as partially penetrates the dentin surface. The adhesive is then light-cured for approximately 10 seconds. The adhesive bonds to the dentin, mostly by surrounding the exposed collagen fibrils and mechanically locking into the rough dentin surface once the adhesive monomers become polymerized. This interface region has been shown to be more resistant to demineralization by acids, suggesting that a zone of resin-reinforced dentin forms to link the resin to the tooth structure. This zone has been called the 'hybrid layer'.

First Generation Dentin Bonding Agents

The 1st generation adhesives were developed in the late 1970s, while their bond strength to enamel was high (generally all the generations of adhesives bond well to the microcrystalline structure of enamel; it is their bond strength to the semi-organic dentin that is the major problem facing dentists), their adhesion to dentin was pitifully low, typically no higher than 3 MPa.

Mechanism of Bonding

Bonding was achieved through chelation of the bonding agent to the calcium component of the dentin. While tubular penetration did occur, it contributed little to the retention of the restoration.

Drawbacks

- It was common to see debonding at the dentinal interface within several months due to poor bonding strength.
- Postoperative sensitivity was common when these bonding agents were used for posterior occlusal restorations.

Uses

These bonding agents were recommended primarily for small, retentive Class III and Class V cavities.

Examples

The first commercial system of this type (Cervident, SS White) added a surface-active comonomer N-phenylglycine glycidyl methacrylate *(Bowen 1965)* to the BiS-GMA resin to facilitate chelation with surface calcium.

Second Generation Dentin Bonding Agents

In the early 1980s, a distinct 2nd generation of adhesives was developed.

These products attempted to use the smear layer as a bonding substrate. This layer is bonded to the underlying dentin at a negligible level. The bonding strengths of this generation to dentin were 2-8 MPa.

Drawbacks

- Due to poor bond strength mechanical retention form in cavity preparations were still required.
- Restorations with margins in dentin saw extensive microleakage.
- Posterior occlusal restorations were likely to exhibit significant postoperative sensitivity.
- The long-term stability of 2nd generation adhesives was problematic.

Content

This generation of dentin adhesive agents primarily used polymerizable phosphates added to BIS-GMA resins. Adhesives used a phosphate group to promote bonding to the calcium in mineralized tooth structures were generally referred to as phosphate bonding systems.

Examples

Scotch Bond (3M Dental, MN contains a halophosphorous ester of Bis-GMA). Others are, Clearfil (Kuraray Co. Japan, contains a reaction product of 2-HEMA and phenyl P), Bondlite, Creation Bond, Prisma Universal Bond, Kulzer Dentin Adhesive.

Third Generation Dentin Bonding agents

In the late 1980s, two component primer-adhesive systems were introduced. Bonding strength to dentin increased significantly to 8-18 MPa.

Advantages

- It diminished the need for retention form in the cavity preparation
- Erosion, abrasion, and bifurcation lesions were treatable with minimal tooth preparation or more conservatively
- There was a noticeable decrease in postoperative sensitivity with posterior occlusal restorations
- Third generation adhesives were the first 'generation that bonded not only to tooth structure, but to dental metals and ceramics as well.

Disadvantage

The downside to these bonding agents was their longevity.

Content

This system utilized a conditioning step either to modify or remove smear layer, Bowen, et al developed a multi step adhesive system that has been called as an oxalate bonding system. This system uses a dentin conditioner of 2.5 percent nitric acid in combination of ferric oxalate or aluminium oxalate. This conditioning step was followed by sequential treatments of NTG-GMA and PMDM also referred to as F-N-P system).

This multistep procedure can be described as. *Etch+ Prime + Bond*

Examples

- Mirage bond, Scotch bond 2
- Prisma Universal bond 2 and 3
- With the advent of 4th generation DBA, 1st, 2nd, and 3rd generations have become obsolete and not marketed now.

Fourth Generation Dentin Bonding Agents

In the early '90s, 4th generation bonding agents transformed dentistry. It was developed by Fusayama and Nakabayashi in Japan in the 1980s, introduced to North America by Bertollotti and popularized by Kanca.

Advantages

- It has high bond strength to dentin in the range of 17-25 Mpa.
- Decreased postoperative sensitivity in posterior occlusal restorations encouraged many dentists to begin the switch from amalgam to direct posterior composite fillings.
- With this 'generation" the concept of hybridization at the interface of the dentin and the composite began.
- Moist dentin bonding, earlier, air drying was recommended for the dentin but now the adhesives are designed to work best on well hydrated or moist dentin (Moist bonding technique, Kanca, 1992).

Hybridization is the replacement of the hydroxyapatite and the water in the surface dentin by resin. This resin, in combination with the remaining collagen fibers, constitutes the hybrid layer. Hybridization in-

volves both the dentinal tubules and the intratubular dentin, dramatically improving bond strength to dentin.

Contents

4th generation dentin bonding agents may be again described as,

Etch (phosphoric acid) + Primer (NTG-GMA, N-tolyglycine –glycidyl methacrylate) + Bond (Bis-GMA/TEGDMA)

Examples

All bound-2 (BISCO), **Scotch bond**
Multipurpose (3M), Prime and bond
Comfort bond (Heraeus Kulzer) (Fig. 34.5A)

Fifth Generation Dentin Bonding

In order to simplify dentin bonding, manufacturer introduced systems that combine the primer and adhesive agents. These systems have generally been reported to as one component system. This led to the development and the great popularity of the 6th generation dental adhesives. These materials consist of hydrophilic and hydrophobic resins simultaneously dissolved in solvents like alcohol or acetone, displacing water and achieving an intimate contact to dentinal structures.

Advantages

- These materials adhere well to enamel, dentin, ceramics, and metal.
- A single component, single bottle characterizes them. There is no mixing, and thus, less possibility for error.
- Bond strengths to dentin are in the range of 20-25 Mpa.
- These bonding agents, easy to use and predictable.
- Postoperative sensitivity has been reduced appreciably.

These 'one bottle' systems are sensitive to even mild desiccation of acid conditioned dentin leading to significantly reduced bond strengths, indicating that the window of opportunity of optimal adhesion depends on keeping the demineralized collagen network moist.

Contents

This system may be described as, *E (phosphoric acid) + PB (PENTA, methacrylated phosphonates)*

Examples

One step (BiSCO), Single bond (3M) (Fig. 34.5B), Clearfil SE bond (Kuraray medical Inc.) (Fig. 34.5C), Opti bond solo (KERR) (Fig. 34.5D), Xeno iii (Denstply) (Fig. 34.5E).

Sixth Generation Dentin Bonding Agents (No etch, No rinse, No Cure Technology)

In an effort to eliminate etching or to include it chemically in one of the other steps 6th generation bonding agents were developed. While this "generation" is not universally accepted, there are a number of dental adhesives, which are designed specifically to eliminate the etching step.

The bond strength to the dentin is around 18-25 Mpa, while it is bond to the unetched, unprepared enamel.

The multiple components and multiple steps in the various 6th generation' techniques can cause confusion, and lead to error.

Contents

These products have a dentin-conditioning liquid in one of their components; the acid treatment of the dentin is self limiting. And the etch by-products are incorporated into the dental-restorative interface permanently.

- This system can be described as
- EPB (methacrylated phosphates).

Examples

- Prompt-L-Pop (ESPE, Germany)
- One UP bond F (Fig. 34.5F)

This system comes with etchant, primer, adhesive and microbrush sealed in a triple lollipop-shaped aluminium foil package (blister pack). The pack contains two basic chambers. The uppermost chamber contains initiators, stabilizers and methacrylated phosphoric esters. The second chamber contains stabilizers, water and a fluoride complex.



Fig. 34.5A: Confort bond (Heraeus Kulzer)



Fig. 34.5B: Single bond (3 m) ESPE



Fig. 34.5C: Clearfil SE bond (Kuraray medical Inc., Japan)



Fig. 34.5D: Opti bond solo (Kerr)



Fig. 34.5E: Xeno iii, (Denstply)



Fig. 34.5F: One up bone F (Tokuyam dental)

Squeezing the upper chamber and then folding the chamber upon itself activate the system. The second chamber is subsequently squeezed, forcing the material into the pocket, which contains the application device, i.e. microbrush. The saturated microbrush is then lightly rubbed across the surface of cavity preparation for 15 to 20 seconds. After air dispersing, the restorative composite is applied. Photo curing of the adhesive surface is optional. The activated adhesive has a pH value of approximately 1. It produces the known surface porosity used for micromechanical retention in enamel and dentin.

Advantages

No etching, no washing and air dispersing, no-photocuring of DBA.

Hence, two steps are required:

1. Simple application
2. Gentle air dispersing.

So far we have discussed the adhesives in detail, now let us discuss about the substrate (tooth), and what are the factors that can modify their adhesiveness.

Understanding various characteristics of human enamel assists the orthodontist in the proper preparation of the tooth surface, and in selection and application of appropriate orthodontic cements/adhesives. Knowing the location of a bond failure allows the orthodontist to modify its bonding technique, and instruct the patient on the care of their appliance.

Let us see the effects of enamel preparation on the bonding of brackets.

FACTORS AFFECTING THE BONDING OF THE BRACKETS TO THE ENAMEL

ETCHING VS NONETCHING

Resin composite does not bond well to unetched enamel; however, hybrid ionomer orthodontic cements have bond strengths to moist, unetched enamel ranges from 8 to 25 MPa.

TYPE AND CONCENTRATION OF ACID

In orthodontics, bond strength must be sufficient to retain the brackets but low enough to allow easy cleanup of adhesive when the case is completed and the brackets are removed. In contrast, the restorative materials require a lot of bond strength.

ACID

Bond strengths produced by some of the commonly used acids are: etching with 10 percent or 37 percent phosphoric acid produce the highest bond strengths (28 MPa) to enamel.

Use of 10 percent maleic acid for etching results in a lower bond strength (18 MPa).

And if no etching is done it yields very low bond strength.

TIME

No drastic differences are seen in the bond strengths between 15-second and 60-second etching with 37 percent phosphoric acid.

The only advantage in lesser etching time is that it results in less enamel damage on debonding.

Reducing the etching time to less than 10 seconds reduces bond strength (less than 3 MPa) significantly.

EFFECTS OF FLUORIDE

Teeth with a higher concentration of fluoride are generally considered more resistant to acid etching than normal teeth and may require an extended etching time.

DIFFERENCES AMONG TEETH

No difference is observed in bond strength among any tooth like incisors, premolars, or molars. Similarly there is not much of difference between the buccal and lingual surfaces.

OLDER VS YOUNG TEETH

Older permanent teeth tend to produce slightly higher bond strength than younger permanent teeth.

USE OF PUMICE

Pumice or a prophylactic paste is often used to clean the enamel surface before acid etching and bonding. However, bond strength appears to be unaffected whether pumice is used or not. Ideally the bonding surface must be clean and devoid of contaminants.

AIR ABRASION (MICROETCHING)

In this technique, particles of Aluminium oxide are propelled against the surface of enamel or any another substrate with high air pressure, causing abrasion of the surface.

The bond strengths to air-abraded enamel are only about half of those to acid-etched enamel. This technique is more commonly used in prosthodontics, for the cementation of resin-bonded bridges (Maryland and rochette).

CRYSTAL-GROWING SOLUTIONS

A proposed alternative to etching enamel for retention of an adhesive is to grow crystals on the enamel surface. This technique is called crystal bonding. Crystal bonding involves application on enamel of a polyacrylic acid solution containing sulfate ions, which cause growth of calcium sulfate dihydrate crystals on the enamel surface. These crystals in turn retain the adhesive. Since crystal bonding produces bond strengths of 60-80 percent of the bond strength obtained with acid etching.

Advantages

- Easier debonding
- Less residual adhesive left on the tooth surface
- Less damage to enamel

ACIDIC PRIMERS

Another alternative to etching enamel with phosphoric acid is to use an acidic primer of the type used to bond restorative composites to enamel and dentin. Although these primers are expensive, comparable bond strengths are found.

LASER ETCHING

The application of laser energy to an enamel surface causes localized melting and ablation.

Mechanism of Action

- Etching results mainly from the micro-explosion of entrapped water in the enamel.
- Also there may be some melting of the hydroxyapatite crystals.

Laser Used

Laser etching of enamel is done by a neodymium-yttrium-aluminium garnet (Nd: YAG) laser.

Disadvantages

- It produces lower bond strengths than does acid etching.
- The thermal effects of laser etching on the enamel are yet under research.
- Expensive

MOISTURE RESISTANT PRIMERS

A moisture resistant primer (Transbond MIR 3M/ Unitek) can be applied to etched enamel that may be contaminated with moisture or saliva. This is an alternative to bonding to dry enamel, as it provides more freedom to the operator.

The primer contains a hydrophilic methacrylate monomer that will wet enamel contaminated with saliva. The bond strength of a resin composite adhesive applied to enamel primed with the moisture-resistant primer is similar to that of resin composite adhesive applied to etched, dry enamel.

CHLORHEXIDINE

Bond strength is reduced if the chlorhexidine is applied on etched enamel or on the sealant before the adhesive is applied.

But the bond strength is not affected if the chlorhexidine is applied after bonding has been completed or as a prophylactic paste on enamel before etching.

Function

Chlorhexidine is applied on the teeth and over orthodontic appliances during treatment to reduce bacterial colonization and activity.

BLEACHING

Recently bleached teeth have lower bond strengths to resin composites. The bleach produces oxygen, which inhibits free radical polymerization of resin composites.

BOND FAILURES

Bonding of orthodontic bracket typically utilize a resin composite adhesive and require that the enamel be etched, whereas orthodontic bands are usually cemented with glass-ionomer cement without etching of tooth structure.

As bond failure of brackets or bands is one of the most frustrating occurrences in clinical orthodontic practice.

BONDING FAILURE CAUSES

- Increased treatment time
- Additional costs in materials and personnel
- Unexpected additional visits by the patient.

These failures can be divided into two categories depending upon the site of failure—

1. Adhesive-enamel bond failure
2. Adhesive-bracket bond failures

Possible Causes of Adhesive-enamel Bond Failures

Clinically it is seen as—adhesive left on bracket, little left on tooth

1. Contamination of the etched enamel by saliva, moisture or oil from water line
2. Insufficient rinsing of etchant from tooth before bonding
3. Inadequate drying of enamel surface precludes penetration of resin
4. Over-etching demineralizes enamel, reduces depth of resin tags penetration, and removes excessive amounts of enamel
5. Faulty bonding materials, materials with expired date
6. No activator was placed on enamel surface when a no-mix adhesive was used

Possible Causes of Adhesive-bracket Bond Failures

Clinically adhesive left on tooth, little left on bracket

- Excessive force exerted on bracket from occlusion or excessive force from appliance
- Movement of bracket during initial setting of adhesive
- Contaminated bracket mesh (oil from hands, glove powder or rebonded bracket)
- Adhesive not buttered into base firmly
- Activator not placed on bracket in paste-primer system
- Inadequate cure of light cured resin composite

COMPOSITE

INTRODUCTION

A composite, as the name implies consist of a mixture of two or more components, a combination of hard, (inorganic) filler particles bonded to soft (organic) dimethacrylate polymer, to provide overall properties superior to those of either constituents. Because of the filler component they had the mechanical properties better than that of unfilled resins. Example of a natural composite is bone consisting of collagen and calcium apatite. The collagen component is soft but strong; calcium apatite on the other hand is hard but brittle. Composites were introduced in 1960. The resin-based composite restorative materials have the following major components:

- An organic resin matrix
- An inorganic filler
- A coupling agent
- Initiator-accelerator system
- Pigments

Two major reasons which led to the development of filling material based on synthetic polymers.

1. To have material that could overcome the major deficiencies of the silicate materials, namely, high dissolution, discoloration, lack of translucency, erosion, brittleness, acidity and a moisture sensitivity, which demands very careful manipulation. Silicate cements were the first direct esthetic restorative materials. It was introduced in the late 1800s; though they have a big advantage of fluoride release.
2. Rapid developments in polymer technology. Self-cure unfilled resins replaced silicate cements in 1945. Resins had the advantage of less soluble, more color stable, easy to use, polishable, and good initial esthetics. Resin could be readily cured at mouth temperature, with the aid of pigments and fillers could be made to resemble the natural tooth in appearance.

Their disadvantages were high shrinkage upon polymerization, large thermal dimensional change, eventual discoloration, and high wear rate.

COMPOSITION AND STRUCTURE

The Resin Matrix

Matrix (resins) All composites consist of a mixture of resin and filler. Matrix is composed of mainly monomers and comonomer. Most composite consist of monomers of molecular weight of 100-1000 g/mole. Two most commonly used monomers are Bis GMA and urethane dimethacrylate. A diluent is added to control the viscosity of the final product. Triethylene glycol dimethacrylate (TEGMA), which is a comonomer often, used to control the viscosity of the unmixed materials. C = C is the functional group of both monomers (Bis-GMA) and comonomers (TEGDMA). Hence, the monomer and comonomer molecules are difunctional methacrylate. Each carbon-carbon double bond is able to take part in a free radical addition polymerization, to give a highly cross-linked resin after setting.

Polymerization is activated via a chemical reaction (chemical cure), light activation (light cure) or both (dual) cured.

Bis GMA was developed by Dr Rafel Bowen is a difunctional methacrylate which is normally formed by a reaction between bisphenol A and glycidyl-methacrylate. It is an oligomer, formed of many monomers.

Features of Bis-GMA

- It has two reactive C = C groups, as each can participate in the formation of a growing chain, that is why it is called difunctional. Difunctional monomers result in cross-linking and greatly improved strength of the polymer.
- The hydroxyl groups increase chain-to-chain hydrogen bonding.

Properties of Bis-GMA

- Due to its high molecular weight it has lower polymerization shrinkage than methyl methacrylate, which is an advantage.
- But because of the same reason Bis-GMA (also urethane dimethacrylate monomers) is highly viscous fluid and addition of even a small amount of filler would produce a composite with a stiffness that is improper for the clinical use.

As a solution to this problem low molecular weight (low viscosity) monomers are added, they are known as *viscosity controller or diluents*. Their examples are such as methyl methacrylate (MMA), ethylene glycol dimethacrylate (EDMA) and *triethylene* glycol dimethacrylate (TEGDMA); the latter of these is most commonly used. But the addition of these low molecular weight dimethacrylates increases the amount of polymerization shrinkage. Hence the manufacturer has to maintain a very delicate balance between the two.

Clinical Significance

High concentration of acrylate or methacrylate groups do remain unreacted after setting due to the following reasons:

- Large size the monomer and comonomer molecules.
- Rapid increase in viscosity during setting, which does not allow the reactive methacrylate groups to migrate to the reaction sites.

Beneficial properties contributed by the resin

- The resin can be moulded at ambient temperatures.
- Resin sets by polymerization that is achieved in a conveniently short time.

Drawbacks of Matrix

- It is the weakest and the least wear resistant phase of dental composite.
- It absorbs water and can stain and discolor.

Why can't Resin be Used Without Fillers? Or What are the Disadvantages of using Resin Without Fillers?

The mechanical properties

- The low value of *modulus of elasticity* indicates that acrylic resin is a far more flexible material than either enamel or dentin. Flexing of restorations under load can lead to marginal breakdown.
- The lower *compressive strength* and *hardness* values of acrylic resin are reflected in a *poor durability*, particularly when restorations are subjected to abrasive forces, such as tooth brushing.
- The materials undergo a considerable *setting contraction* (6% by volume). If uncontrolled, this could

produce a significant marginal gap down which fluids could penetrate.
- Material loss by *wear* is a phenomenon associated with these relatively soft materials.
- The *coefficient of thermal expansion* value for acrylic resin is some ten times greater than that for tooth substance. The potential for *percolation* of fluids down the restoration—tooth interface when the patient takes hot or cold food and drink is, therefore, significant.

Biological properties
- All materials contain a certain level of residual methylmethacrylate monomer, which is *irritant* to pulp
- *Temperature rise* during setting caused by a highly exothermic polymerization reaction, which necessitates the use of a protective cavity base (calcium hydroxide) material.

Filler

Filler particles are of inorganic composition (ceramic).

Advantages

- High polymerization shrinkage of unfilled resin is reduced.
- The coefficient of thermal expansion of unfilled resin is high. This coefficient is reduced by the addition of ceramic fillers, which comes closer to that of tooth tissues.
- Water absorption is reduced in composites in comparison to unfilled resin.
- Abrasion resistance is enhanced.
- The mechanical properties such as tensile strength, compressive strength, modulus of elasticity and hardness are increased. Fillers also enhance the rigidity.

Uses

1. Quartz, advantage of naturally occurring quartz is it's inertness (chemically stable) and strong, but its disadvantage is its hardness, therefore very difficult to polish and it may cause abrasion of opposing tooth and restoration.
2. Glasses, fine-sized particles may be composed of barium or lithium aluminium silicate glasses; borosilicate glass; or barium, strontium, or zinc glasses. They have proper strength, hardness, chemical and optical properties.
3. Colloidal silica particles in microfine composites.

As mentioned earlier the physical properties of the composite depend on the fillers quantity. Improvement in the properties is even better if the filler particles are bonded to the resin matrix.

To increase the physical properties of composite maximum amount of filler is to be incorporated in the matrix.

This can be done by:
1. Selecting filler particles of different sizes (so that they can be condensed)
2. The irregularly shaped particles are preferred since they are less easily dislodged from the surface.
3. Amount of filler also depends on the surface area of the filler, for example if colloidal silica is used which has a large surface area can bond with the resin and thicken the resin (increase the viscosity). Therefore they are added only in small amounts.

However there is a limit to the amount of filler that can be added. If all filler particles are not properly wetted by the liquid monomers, voids and gaps between the fillers result. These voids do not resist any stress placed on the material but also concentrate stress in the material in the vicinity of the void.

There has been a change in the trend of filler particles from strongest most abrasion resistant material to somewhat softer materials. As softer particles are more likely to wear down rather than be pulled out of the matrix when abrasion occurs. If the particles are pulled out, the surface will be left with the resin that will wear quickly.

The type, concentration, particle size and particle size distribution of the filler used in a composite material are major factors controlling properties.

Coupling Agent

Silanes are called coupling agents because they form a bond between the inorganic and organic phases of the composites. Purpose of a coupling agent is to develop a bond between the filler and the resin matrix. A bond between the resin and filler is very important.

Functions of Coupling Agent

- To increase the physical and mechanical properties of the material.

- To increase the content of the filler particles, so that it resists abrasion.
- A bond between filler and matrix allows the distribution of stresses generated under function.
- It prevents water from penetrating the interface between resin and filler.

A bond between filler particle and matrix in the set composite is achieved by use of a silane-coupling agent (methacryloxypropyl trimethoxy silane).

Mechanism of Action

Silane coupling agents work as soap, the silane molecule has reactive groups at both its ends. They react with the polymer matrix at one end while the other end reacts with the ceramic filler. The manufacturer coats them on the filler particle surface before mixing with the monomer. During polymerization, double bonds on the silane molecule also react with the polymer matrix. The bond between the filler and the resin can be degraded by water adsorbed by composite during clinical use.

Initiators and Accelerators

Light cured composite is activated with blue light with a peak wavelength of 470 nm, which is absorbed by photo-activator as camphorquinone. Camphorquinone is added in concentration between 0.2 and 1 percent. The reaction is accelerated by amine.

Chemical cured composites are activated by organic amines (accelerator) reacting with peroxide (initiator) to produce free radicals.

Inhibitors are added to prevent the premature polymerization and ensure an adequate long shelf life for the composite. Mostly used inhibitor is hydroquinone, in amounts of 0.1 percent.

Pigments and Other Components

Numerous shades are supplied from white to yellow gray. An ultraviolet absorber may be added to minimize color changes caused by oxidation.

CLASSIFICATION OF THE COMPOSITES

Composites can be classified in the following manner

1. Based on ADA specification no. 27
2. Based on the filler
3. Based on the method of polymerization

A: As per ADA Specification No. 27

Composites are classified in to two types and three classes.

Type I Polymer based materials suitable for restorations involving the occlusal surface.

Type II Other polymer-based materials

Class I Self cured materials

Class II Light cured materials

Class III Dual cured materials

B: Classification of Composites Based on Fillers

- Macrofilled composite
- Microfilled composite
- Small particles composite
- Hybrid composite

Macrofilled (Traditional) Composites

They were the first type of dental composite to be developed in 1960s. These are composites which contains quartz/ glass filler particles with the particle size of 10-50 μm and filler content is 60 -80 percent by weight.

Relation between weight and volume Since the filler phase is much denser than the resin phase, the volume percent is typically 10 -15 percent lower than weight percentage. The manufacturers like to report by weight percent where as the physical properties are determined by volume percent.

Macrofilled composites have the disadvantages

- Large particles did not permit adequate polishability
- The surface finish was very poor, with the surface having a dull appearance due to filler particles protruding from the surface as the resin was preferentially removed around them
- Retention of plaque, due to the rough surface.
- Greater chances of staining
  Precaution: it precludes using a metal spatula to mix chemical cure material.

Uses

- Some orthodontists still use them, as rough feel and easy detection give them an advantage when removing bonded orthodontic brackets or appliances.
- For class III, IV and V restoration.
- Limited use in class II, and I due to wear.

As these composites are strong and hard but difficult to polish because of large particles, which leave the surface rough. To enhance the polishability and ultimately the esthetics of these composites, small reinforcing fillers were added. These particles were silica particles, also called as pyrolytic or fumed silica (microfilled resins).

Microfilled Resins

The first Microfilled resins were introduced in the late 1970's, and contain submicron particles (colloidal silica) having particle size between 0.03 and 0.5μm, with an average particle size of 0.04 μm.

Filler loading in these composites is therefore limited to about 20 to 50 percent by volume or 35 to 60 percent by weight.

Because of very small particle size and their high surface area 100-300m^2/g, it is not possible to incorporate very high filler loadings of this small particle size into resin and yet produce a material of good handling characteristics. This limitation has a detrimental effect on the strength and stiffness of the material.

Manufacturers adopted a special technique of incorporating the smaller particles, as direct blending with resin is difficult. To ensure adequate filler loading, a two-stage procedure for the incorporation of the filler has been developed. First prepolymerized resin fillers are added into paste. This material is then polymerized and ground into particles of 10-40 μm in size. This is then used as filler with monomer, comonomers, initiators or activators to form pastes.

Thus, what is finally obtained is a composite containing composite filler particle. Since they are already polymerized, the resin of the composite filler particles does not increase polymerization shrinkage.

Advantage

The small size of the filler particles means that the composite can be polished to a very smooth, lustrous surface finish.

Disadvantages

- High resin content results in an increased coefficient of thermal expansion.
- Lower strength, due to high resin content.
- Low polymerization shrinkage

Use

- Microfilled composites are used where esthetics is a dominant concern.
- Class IV restoration
- Veneers, where translucency is to be added over the core build up.
- Class V restoration, as it has a lower modulus of elasticity it can flex with the tooth structure.

Small Particles Composites

They were developed in 1980s. The primary objective was to develop composites that would be acceptable restorations in Class I and Class II.

Filler content is 80-85 percent by weight and 60 to 77 percent of the composite by volume.

Average particle size is 1-5 μm, the range is between 0.5 and 10 μm.

The smaller sized filler particles allow composites to be polished to a smoother surface finish than the larger particle sizes, but this is at the expense of lower filler loading, which may have an adverse effect on the wear resistance.

In order to increase the filler loading to its maximum, it is possible to select fillers with two or more complementary particle size distributions. The filler with the smaller particle size distribution fills in the spaces left between the larger filler particles. This has meant that the packing density of composite restorative materials has been increased, while the size of the filler has been reduced.

Advantages

- They have the best physical properties
- Surface is not as rough as macrofilled composite, but also not as smooth as microfilled.

Use

Reasonably good materials for use in Class I and Class II cavities.

Hybrid or Blend Composites

The ideal combination of esthetics and durability is achieved with the material called as hybrids. These composites were developed in late 1980s. They are called as hybrids or blended composites because they contain a blend of both conventional glass and quartz particles together with some submicron, particulate silica.

Using filler loadings of about 75 percent conventional size (1-50 μm) and 8 percent submicron size (0.04 μm average), total filler content of 83 percent or greater can be achieved. The colloidal particles fill the matrix between fine particles. To have efficient packing of filler into the smallest possible volume and enable maximum filler loadings some hybrid products contain a blend of at least three different particle sizes of filler.

In fact now-a-days all composites now contain small amounts of colloidal silica.

Advantages

- These composites are strong.
- They are polishable.

Use

- Their abrasion resistance is acceptable for small to medium Class I or Class II restoration.
- As the surface finish is as good as the microfilled composite they can be used in Class III and Class IV restoration.

Conventional, microfilled and hybrid composites are all available as either chemically activated or light-activated products.

C: Classification of Composites based on Method of Polymerization

The process by which the composite paste turns into a hard material is the *polymerization* of the resin matrix. This can be of three types:

- Chemical cured material (Fig. 34.6A)
- Light cured material (ultraviolet or visible light) (Fig. 34.6B)
- Dual cured material (Fig. 34.6C).

Chemical Cure

In the early composite, this was achieved by supplying two pastes, a mixture of which would contain the necessary ingredients for polymerization. One paste contains the tertiary amine (0.5%) while the other paste contains the benzoyl peroxide (1%) initiator.

When the two pastes are mixed, the inhibitor destroys the free radicals produced for a short period of time. This gives a short period of working time.

Systems that rely on chemical activation are as follows.

- Paste/paste system: As discussed above.
- Powder/liquid system: In this system, the powder contains filler particles and peroxide initiator whilst the liquid contains monomer, comonomer and chemical activator.
- Paste/ liquid system: In which the paste contains monomers and peroxide and the liquid contains monomers and the activator.
- Encapsulated materials in which the filler, mixed with peroxide, is initially separated within a



Fig. 34.6A: Commercially available chemically cured composite adhesive material (Reli-on, USA)



Fig. 34.6B: Commercially available ultraviolet light cured composite adhesive material (Kurasper F, Japan)





Fig. 34.6C: Dual cure adhesive
(Panavia F, Kuraray medical Inc., Japan)

capsule from the monomers containing the chemical activator. On breaking the seal between the two parts of the capsule the reactive components come into contact and are mixed mechanically (just like amalgam).

Disadvantages of Chemical Cure

- Air entrapment during mixing
- Limited working time.

Light Cured Material

They are supplied as single paste. They contain monomers, comonomers, filler and an initiator, which is unstable in the presence of either ultraviolet (UV) or high-intensity visible light. First, the ultraviolet light activated composites became available.

For UV-activated materials, the most commonly used initiator is benzoyl methyl ether. At certain selected wavelengths within the UV range, this molecule is able to absorb radiation and undergo decomposition to form free radicals. The radicals initiate polymerization, which then continues further.

Advantage

- Unlimited working time.
- Sets on command.

Disadvantage

Serious drawbacks with the use of the ultraviolet light cured systems.

Visible Light Cured

For visible light-activated materials the initiator system comprises a mixture of a diketone and an amine. Camphorquinone is a commonly used diketone that rapidly forms free radicals in the presence of an amine and radiation of the correct wavelength and intensity.

Advantages

- No chair side mixing required so no air entrapment.
- Manufacturers make the paste thicker with more filler and less matrix, the voids are minimized. The restoration is always stronger than chemical restoration.
- Working time is directly in control of dentist.

Disadvantages

Light activated materials require the use of a specialist light source.

Precautions

- Exposure to sunlight, or operating light may initiate the process of polymerization; hence care must be taken while storing.
- Lid must be replaced immediately after using the material.

Methods of Dispensing Light Cured Material

- Two paste system
- Syringes
- Compules, each compule containing material for at least for one restoration.

Advantage of Syringe

- It is convenient for the operator to dispense material.
- The material remaining in the syringe is not exposed to light.

Difference between chemical cured and light cured material (Table 34.6).

Table 34.6: Difference between chemical cured and light cured material

Light cured	*Chemical cured*
Polymerization is always at the surface close to the light source	Polymerization is always uniform
Less wastage of material	More wastage of material
Curing is done in increments	Curing is in one phase
Finish is always better	Finish is poor
Strength is always higher	Strength is lower
Command sets	Sets within 1 minutes
Working time is more	Working time is less
No mixing is required	Mixing is required
More color stable	Less color stable
More resistant to wear	Less resistant to wear

NEW COMPOSITE MATERIALS

Flowable Composites (Fig, 34.6D)

These composites with altered viscosity and reducing the filler content to less than 45 percent by volume makes handling characteristics. They flow into the cavity due to their low viscosity. They are easily dispensed from a very small gauge needle directly into the cavity preparation. The result is a weaker, less abrasion resistant material. They are recommended for cervical lesions, pediatric restoration. They have low modulus of elasticity, high polymerization shrinkage and lower wear resistance. Because of their viscosity it is easy to dispense them in a syringe.

Condensable Composites

Compactable composites are again easier to place in the cavity. The only difference is in the filler quality. These composites have similar filler volume as normal hybrid composite but the heavy consistency is produced by using modified fillers or altering the distribution of particles, so that it inhibits the sliding of the filler particles over one other. The result is a



Fig. 34.6D: Commercially available flowable composite

thicker and stiffer material. They have low polymerization shrinkage, radiopacity and wear rate (3.5 µm/year). They are packaged in the unit—dose compules. Their recommended use is class I, II and class VI cavity.

PROPERTIES

Setting Characteristics (Table 34.7)

Table 34.7: Skeletal composition of the curing of chemical curing and light curing resins

Chemical curing		*Light curing*
Paste A Monomer Initiator	Paste B Monomer Activator	Paste
		Monomer Initiator Accelerator

On mixing A and B, or light curing paste following occurs:

- Initiator + activator (accelerator)—activated initiator
- Activated initiator + monomer—activated monomer
- Activated monomer +monomer—polymer

Chemically Activated Materials

Setting begins immediately after mixing the two components (two paste system). One paste contains tertiary amine and other contains benzoyl peroxide.

The rate of set is uniform throughout the bulk of the material causing a gradual increase in viscosity. Setting time for chemically activated composite ranges

for 3-5 minutes. Initially on mixing, the inhibitor destroys the free radicals for a short time, this results in short working time.

As two pastes are mixed, air bubbles are incorporated during mixing.

Since setting occurs uniformly throughout the material it is safe to assume that a hard surface indicates that the material has set right through to the base of the cavity.

The material should not be disturbed after the working time has ended and the initial setting period has begun. Such activity disrupts polymerization, thereby reduces strength and esthetics and produces voids.

Any material, which is not covered by the matrix during setting, is likely to have a tacky surface layer due to inhibition of the polymerization reaction by oxygen.

For both self-cure and light cure material it is desirable to place plastic matrix strip onto its surface before light activation.

Function of Mylar (plastic) Strip

- Oxygen inhibits the polymerization reaction; therefore covering the surface with a nonporous strip keeps oxygen away and allows maximum hardening.
- Matrix produces a very smooth surface.

Light-activated Materials

Polymerization is related to the application of light to the material, around 75 percent of polymerization takes place in the first 10 minutes. The curing continues for more than 24 hours.

Characteristics

- They have longer working time.
- Before exposure to the light there is very little increase in the viscosity of the material.
- Rate of polymerization is very high. Exposure times of between 10 seconds to 40 seconds are enough to cause setting. This ability to set fast is termed *command setting*.
- The pattern of setting is first achieved in the surface layers of material where the light intensity is greatest.
- Since a certain level of intensity is required to cause activation it follows that light-activated materials have a *limited depth of cure.*

Depth of Cure

The thickness of composite cured by a typical light source is called depth of cure. Ideally any composite restoration should be cured fully to its depth. If it is not cured completely, than following may happen

- Lack of cure provides a poor foundation or support for the restoration and may lead to its fracture.
- Secondary caries at the cervical margins, caused by washout of the uncured restorative material.

Reason for incomplete curing

- Deep restoration
- Proximal boxes of posterior composites, particularly when metal matrix bands are being used.

Choice between visible light and UV light

Visible light activate (VLA) composites have replaced the ultraviolet (UV) systems because:

- The depth of cure that can be achieved with visible light is more (2-3 mm), in comparison to ultraviolet light (1.5-2 mm).
- Visible light is more safer for the operator
- Intensity of visible light remains the same over a period of time whereas the UV light falls rapidly.
- Visible light works in the range of 400 -500 nm (intensity of light greatest at around 480 nm) whereas the UV light works between 360 and 400 nm.

There are a number of points that need to be emphasized. The light source used with VLA composites is more accurately described as *blue light* rather than *visible light of extremely high intensity*. The typical output from a good quality, visible-light source would produce a spectrum. The selectivity is necessary to ensure optimum degree and depth of cure.

For any light-activated composites, the conversion from a paste to a solid material relies on the ability of the light to access and initiate the curing in all parts of the restoration. The degree to which the light can penetrate the composite is limited, so the depth to which the materials can be cured is limited.

Factors Affecting the Depth of Cure

1. **The type of composite** With darker shades of composite the penetration of light is reduced. Therefore the depth of curing is reduced.

Solution

- Using an incremental technique of placing restoration
- Long exposure times.

Particle size and filler content are critical to dispersion of light beam. For this reason microfilled composite with smaller and more numerous particles scatter more light than hybrid composite with larger and fewer glass particles. Longer exposure time is required to obtain adequate depth of cure of microfilled composite.

2. **The quality of the light sources**
   - The maximum light output should be at approximately 480 nm.
   - Quality of the output is checked at regular intervals. Deterioration of the light sources occurs, and it is important that it is periodically checked.
3. **The method used**
   - Distance of the tip from the restoration should be minimum. In fact, the light intensity on unit surface area drops off with the inverse square of the distance between the light source and resin.
   - Light tip should not be contaminated with composites, as this will reduce the curing efficiency on subsequent use.
   - The material should be exposed to the light no less then the recommended time (20-60 seconds).
   - Fanning should not be done in case of large restoration, as it is impossible to tell how long any particular area of the surface has been exposed. It is necessary to step the light across the surface of large restoration so that the entire surface receives a complete exposure.
   - In situation where light access presents a problem, (such as distal boxes of an MOD restoration in a posterior), aids to curing such as light conducting wedges and transparent matrices must be considered.

Fundamental rules are, avoid curing to a depth greater than 2 mm, cure for at least 40 seconds and use if possible incremental method of packing.

Compatibility of Light Sources and Composite Materials

Most currently available light-activated composite materials utilize a similar catalyst system and most light-activation units are designed to deliver radiation, which has a high intensity at the relevant wavelength. There are marked differences in performance between the units however, with a variation in intensity of light around 470 nm.

The distance of the light source from the surface of the material is important. The polymerization reaction of composite materials is exothermic in nature. The rise in temperature may cause severe and irreversible damage to pulp. Rise in temperature for light activated material is more than chemical cured material because:

- The heat of polymerization is liberated over a small period of time.
- The heating effect of the light-activation unit further increases the temperature.

To reduce the effect of light cure unit, filters are added which remove the hotter parts (red part of spectrum) of white light. Therefore the light appears blue.

Light (Safety)

It can be either high intensity ultraviolet light or visible light, commonly used for polymerization. One should not expose oneself unnecessarily to these light sources. It may have some harmful effects, such as

- Damage to the retina
- Long exposure to these lights can upset one's color perception. So shade selection of composites then becomes a real problem.

Protection

- Avoid unnecessary exposure to light.
- Avoid direct exposure to light; by using protective shaded eye wear.

Light Curing Units

Before we discuss the light curing units let us make some of the key terms clear.

Power Number of photons per second emitted by light source.

Units-Mw Intensity (power density): number of photons per second emitted by light source per unit area of curing tip

Unit Mw/cm^2

Energy Power × density

Units Joules

Energy density Power density × time

Units Joules/cm^2

Presently there are two types of light units

- *Quartz-tungsten-halogen light (Fig. 34.7A)*
- *Plasma arc lights*
- *LED lights (Fig. 34.7B)*

Quartz-tungsten-halogen light

Its peak wavelength varies from about 450-490 nm. In general the output from various lamps decreases with its continuous use. Its intensity is not uniform for all areas of light tip. The intensity also decreases with the distance from the source. Intensity is important for the depth of cure of composite. Average life of the bulb is 50 -100 hours. Most of the current light curing units have the light source and the intraoral tip together and are held by a gun type device with a trigger. The power source is a separate unit attached to the gun by an electrical cord. A large amount of heat is generated from the light bulbs during operation. When the bulb overheats, the unit will shut down and be inoperable till the bulb cools. For cooling purpose a fan is mounted within the gun.

Precautions

- Prevent retinal damage to the eyes. Don't look directly.
- Protect eyes with glasses and shields

Plasma arc curing (PAC) lights

These are high intensity light curing units. Light is obtained from the electrically conducive gas filled between the tungsten electrodes. The light wavelength varies from 380-500 nm, with its peak at 480 nm.

Advantage PAC lights save time of curing; it can reduce it up to 10 seconds of exposure, which is enough for polymerization.



Fig. 34.7A: Commercially available, quartz-tungsten-halogen curing light



Fig. 34.7B: Commercially available LED curing light

Disadvantage

- The polymerization shrinkage is increased.
- Expensive

Packaging of Composites

Light cured composites are supplied in syringes and Compules. Syringes and Compules are made of opaque plastic to protect the material from exposure to light.

Advantages of Compule

- It is easy to place the composite in the cavity.
- It reduces the chances of cross infection.
- Protection of material from exposure to ambient light.

Self cured material – they are packaged in syringes or tubs of paste.

Polymerization Shrinkage

Polymerization shrinkage is a direct function of the amount of resin present in the composite. The setting contraction of composite resins is considerably smaller (1.5%) than that observed for unfilled acrylic resins (6%).

Reasons for that are:

- Use of larger monomer and comonomer molecules, which effectively reduces the concentration of reactive groups in given volume of material.
- The additions of fillers, which take no part in the setting reaction.

During polymerization the composites shrink. Ideally, the polymerization shrinkage of the composite should be as low as possible. Polymerization shrinkage has been a major disadvantage with composites.

Cause of polymerization shrinkage: The setting contraction depends on the number of addition reactions which take place during polymerization.

Effects of Polymerization

- It reduces the marginal adaptation of the restoration and so increases the possibility of recurrent caries.
- As shrinkage creates polymerization stresses as high as 10-15 Mpa between the composite and the tooth. These stresses strain the interfacial bond between composite and tooth.
- Stress placed on tooth substance, particularly on the residual cusp of posterior teeth when composite materials are used in relatively large class II cavities. "Pulling in" of the cusp to which it adheres. Explanation of this is such that the polymerization stresses can exceed the tensile strength of enamel and result in stress cracking and enamel fracture.
- Shrinkage may also cause postoperative pain.

The polymerization shrinkage of a composite is depends on:

- The type of resin employed like Bis GMA has a relatively low setting contraction but this is increased proportionately according to the amount of diluent monomer (e.g. TEGMA) used.
- The amount of resin present in its unpolymerized form
- The amount of filler, higher proportion of glass filler results in a lower final shrinkage.

Remedy

As we know the amount of polymerization shrinkage depends on the volume of composite to be polymerized. Therefore use of incremental technique of placing composite.

Slight amount of expansion in composite takes place due to water sorption, which offsets the effect of shrinkage. It cannot counteract the instantaneous shrinkage that occurs on setting. In due course, the slight swelling may well improve the marginal adaptation of the restoration, but the chances are that by then it will be too late.

Water Sorption

The water sorption should be kept as low as possible for composites. The intrinsic water sorption for the resin appears to be around 40-45 $\mu g\ mm^{-3}$, but for the composites the water sorption is two to three times what might have been expected. The reasons for such behavior are:

- High water sorption values for a composite indicate that the material has a high soluble fraction, which dissolves and leaves a space into which the water can flow (this is possibly due to incomplete cure of the resin).
- The glass may be partially dissolved.
- The resin may contain air voids, introduced during mixing or placement.
- Hydrolytic breakdown of the bond between the filler and resin, allowing adsorption to the surface of the filler particles.

Failure of bond between filler and resin causes

- If the bond between the filler particles and the resin is lost, the filler will lose its effectiveness as a reinforcing agent, resulting in a rapid deterioration of the restoration.
- The filler particles lose their surface cohesion, resulting in a high rate of wear.

Effect of water sorption

- Detrimental effect on the color stability
- Discoloration, due to absorption of oral fluids
- Poor the wear resistance, due to interface failure between filler and resin
- Decreases in surface hardness.

Mechanism of water sorption

- It occurs as a direct absorption by the resin.
- The glass filler will not absorb water into the bulk of the material, but can adsorb water onto its surface.

Amount of water sorption is dependent on

- The resin content of the composite
- The quality of the bond between the resin and the filler.

Solubility

The water solubility of composite varies from 0.01-0.06 mg/cm^2. Inadequate polymerized resin has a greater water sorption and solubility. This solubility is clinically manifested as early color instability.

Coefficient of Thermal Expansion

Coefficient of thermal expansion of the composites needs to be as close as possible to that of tooth tissue (Table 34.8). The glass fillers have a low coefficient of expansion while the resin has a high coefficient of expansion. The thermal properties of composite materials depend primarily on the inorganic filler content. It can be seen that as the filler content increases the coefficient of thermal expansion decreases.

Effects of difference in COTE between tooth and composite:

- This mismatch in COTE may cause percolation of fluids down the margins when patients take hot or cold foods.
- Thermal stresses place strain on the bond to tooth structure.

Table 34.8: Thermal properties of typical composite resins

	Thermal diffusively $\times cm^2/s'$	Coefficient of thermal expansion $\times 10^{-6}/°C$
Conventional Composite	5.0	32
	2.5	60
Microfilled Composite	1.0	90
Unfilled acrylic		
Dentin	2.0	8.3
Enamel	—	11.4

- The cyclic effect of thermal changes can lead to material fatigue.

Mechanical Properties

The mechanical properties of composite materials depend upon

- Method of curing
- The *filler content*
- The *type of filler*
- The efficiency of the filler—resin *coupling* process
- The degree of *porosity* in the set material.

Compressive Strength

For composite materials compressive strengths are several times higher than tensile strengths, reflecting the somewhat brittle behavior.

It is important to know the significance of this value.

The common way in which a restoration fails is under tension (due to the application of bending forces), composites have a very low tensile strength rather than compression.

Thus the compressive strength is but a poor indicator of a material's resistance to failure, as there is no simple relationship between materials compressive and tensile strengths.

Why chemical cured composite is weaker than light cured?

Because chemical activated composite is supplied as two components that need to be mixed and during mixing porosities (2-5%) is introduced due to entrapment of air.

A correctly cured, light-activated, conventional composite may, typically, have a compressive strength value of 260 MPa, whereas an equivalent chemically activated material, containing 3 percent porosity, is likely to have a compressive strength of 210 MPa.

Heavily filled, conventional composites undergo brittle fracture. As the filler content is reduced a transition to a more ductile failure is observed. Microfilled composites, which generally have filler content of 50 percent by weight or less, normally exhibit a yield point at a stress considerably lower than that for fracture. Values of compressive strength for microfilled materials are often similar to or even higher than those for conventional composites, but the lower

yield stress value is probably more significant for these products since it represents the point of irretrievable breakdown of the material.

The significantly lower value of modulus of elasticity for the microfilled materials may have clinical significance. These products may potentially deform under stress, leading to a breakdown of the marginal seal. This is recognized as a problem with unfilled acrylics, where a modulus value of 2 GPa is normal. Whether or not the increase from 2 GPa to 6 GPa is sufficient to prevent breakdown is not known.

The values of compressive strength are for a porosity-free material. Porosity also has a significant effect on the fatigue limits of composite materials.

Porosity can be incorporated at two stages

- During the process of incorporating the filler particles into the resin.
- During mixing two components.

Diametral Tensile Strength

As with the above discussion, it is clear that composites are more likely to fail in a tensile mode so it is wiser to measure the tensile strength. But the measurement of the tensile strengths of brittle materials is extremely difficult.

The reason for this is:
Such materials are highly susceptible to the presence of internal flaws or small cracks in their surfaces.

Therefore, the tensile strengths of composites are dependent upon the quality of surface finish.

Alternative method for measuring tensile strength is *diametral tensile test*. This test is applied to brittle materials. It indicates that the material is brittle and therefore suffers from a lack of toughness.

As composites are used more and more widely for the restoration of posterior teeth, fracture of the restorations is likely to become increasingly significant cause of failure; it may be that the above properties will then provide a useful indicator of the resistance to such fractures.

Modulus of Elasticity

The elastic (Young's) modulus is a measure of a material's stiffness. A material with low elastic modulus deflects under stress. Composites have elastic moduli that are only a fraction that of enamel.

The lower filler content of microfine composites results in elastic moduli of one quarter to one half that of the more highly filled fine-particle composites, and are therefore recommended for cervical (Class V) restorations since deflection could reduce stresses at the tooth/composite interface.

Hardness

At one time, it was thought that the hardness would provide a good indicator of the wear resistance of a composite, and this is true up to a point.

The original acrylic resins were very soft materials, but their hardness and wear resistance were much improved by the addition of filler. The bulk hardness value of the composite, however, increases as the filler content increases. Hardness is also related to the degree of polymerization. The Vickers hardness number for unfilled resin is about 18 whereas that for a heavily filled hybrid composite approaches 100. The Microfilled materials have values around 30.

Measurement of the hardness initially gave some indication of the wear resistance, but this relationship unfortunately breaks down at the high filler loadings.

As a group, the hardness of composites is a fraction of that of enamel but is similar to or higher than that of dentin.

The knoop hardness of composites is 22-80 kg/mm^2 in comparison to 343 kg/mm^2 of enamel and 110 kg/mm^2 of amalgam.

Wear

Wear is the process by which material is removed by the interfacial forces, which are generated as two surfaces rub together. If the wear becomes excessive it may change the anatomical shape of the restoration. When considering composites for posteriors, understanding of the mechanism of wear is a must.

Abrasive Wear

Two body contact When two surfaces rub together, the harder of the two materials may cut away material from the other surface. It occurs in the mouth whenever there is direct restoration material – opposing tooth cusp contact. It is commonly seen at the occlusal surface.

Three body contact Where an abrasive foodstuff may be involved as the third body between the material and the opposing tooth cusp. Three-body abrasion dominates in non-contact areas.

Fatigue Wear

Once again seen on the occlusal surface due to cyclic masticatory loading also causes fatigue wear in which surface failure occurs following the development of small surface and subsurface cracks. These cracks often form below the surface, and initially grow parallel to it before veering towards the surface or coalescing with other cracks.

Corrosion Wear

Common sites of chemical attack on composites are:
- The hydrolytic breakdown of the resin
- The breakdown of the resin-filler interface.

Causes of Chemical Wear

- Certain solvents in the drinks and foodstuff may soften the resin.
- Acids may cause the degradation of the filler.

Light cured material is more resistant to wear than chemical cured materials because:
- Chemical cured materials have more porosity (2-5%).
- In chemical cured materials the curing begins as soon as the two components are mixed, but due to the partial interference during the cavity filling the polymerization process is inhibited. Since the strength of the resin depends on the size of the molecule, the strength and wear resistance of chemical cured material is less.

Factors Contributing to Wear

- Filler content—increased filler volume results in decreased wear.
- Particle size – smaller particle size causes increased wear resistance.
- Porosity – internal porosity increases the wear.
- Degree of polymerization – wear resistance is directly proportional to molecular size or degree of polymerization. Heat cured inlays have greater wear resistance.
- Coupling agent—absence of coupling agent reduces the wear resistance drastically.
- Method of finishing—use of diamond bur or carbide bur reduce the wear resistance, because of formation of microcracks or degradation of matrix due to heat generation.
- Position of tooth in the arch—more posterior the location of the restoration in the arch higher is the rate of wear.

Wear in composite can be reduced by:
- High filler loading
- Smooth surface finish
- Hydrolytically stable resin
- Strong bond between the filler and the resin

Radiopacity

When composites are used as a posterior restorative material, their radiopacity (impenetrability by X-rays) should be greater than the enamel. Radiopacity can be conferred by incorporating elements of high atomic number such as barium, strontium and zirconium or ytterbium to the filler. Radiopacity of composite is less than that of amalgam.

Advantage

- They are made radiopaque then they cannot be used in posterior restoration, as secondary caries developing under the restoration cannot be detected.
- If the material is too radiopaque then it may mask out caries lying behind the restoration.

Color Stability

Composite materials, when freshly placed, offer an excellent match with surrounding tooth substance. But self-curing systems exhibit some darkening and a color shift to yellow or gray due to the presence of the tertiary amine accelerator, which produces colored product upon oxidation. Since light cured systems do not contain a tertiary amine and have shown considerably improved color stability over long periods of time.

Appearance

Appearance of composite has improved drastically due to

Table 34.9: Comparison of various properties of enamel, dentin and various composites

	Enamel	*Dentin*	*Unfilled acrylic*	*Conventional composite*	*Microfilled composite*	*Small particles composite*	*Hybrid composite*
Inorganic filler content (vol%)	89	45	0	50-60	30-55	50-60	65-70
Compressive strength(Mpa)	350-380	280-300	70	210-300	170-350	230-400	300-475
Tensile strength (Mpa)	10-12	50-53	40	35-65	25-50	35-90	50-90
Yield stress (Mpa)				260	160	220	300
Modulus of elasticity (Gpa)	50-60	15-18	2-3.5	7-15	3-7	9-20	7-14
Hardness (knoop)	343	68	20	55	20-35	50-80	50-60
Polymerization shrinkage (%)	–	–		1-1.7	2-4	1.5-4	1-1.7
Water sorption (mg/cm^2)	–	–	2.5	0.50	1.2		
Average filler size (μm)			0	20	0.04	0.5-1.0	1-3

- The availability of a variety of shades
- Combined with a degree of translucency imparted by the filler.

Appearance may change due to

- Polishing with carbide or diamond burs that reduce the gloss.
- Abrasion may further increase surface roughness.
- Stained surface due to deposition of colored foodstuffs or tobacco tars.

The microfilled products are capable of maintaining a smoother surface than either the conventional or hybrid materials. Providing the resin of the material is inherently color stable or contains effective stabilizers, these products should be more resistant to surface staining.

BIOCOMPATIBILITY

Nearly all the major components of the composites are found to be cytotoxic *in vitro*. But the biological liability of the cured composite depends upon the release of these components. Components of composite are known allergens. Use of composite as direct pulp capping agent's poses a higher risk for adverse biological response.

The various properties of enamel dentin and various composites have been compared in Table 34.9.

FURTHER READING

1. Bowen RL, Eichmiller FC, Marjenhoff WA, Rupp NW. Adhesive bonding of composities. J Am Coll Dent 1989;56:10.
2. Hobson RS, McCabe JF, Hogg SD. Orthodontic bond strength on different teeth [abstract]. J Dent Res 1999;78:547.
3. Meehan MP, Foley TF, Mamandras AH. A comparison of bond strength of two glass ionomer cements. Am J Orthod Dentofac Orthop 1999;115:125-32.
4. Reynolds IR. A review of direct Orthodontic bonding. Br J Orthod 1975;2:171-8.
5. Webster MJ, Nanda RS, Duncanson MG, Khajotia SS, Sinha PK. The effect of saliva on shear bond strengths of hydrophilic bonding systems. Am J Orthod Dentofac Orthop 2001;119:54-58.
6. Zeppieri IL, Chung CH, Mante FK. Effect of saliva on shear bond strength of an orthodontic adheisve used with moisture insensitive and self etching primers. Am J Orthod Dentofac Orthop 2003;124:414-19.

35 Orthodontic Instruments

Gurkeerat Singh

- Introduction
- Separating pliers
- Scissors
- Band seater
- Mershon band pusher
- Boone gauge
- Bracket positioning height gauge
- Double beak pliers
- Johnson contouring pliers
- Standard light wire pliers
- Jarabak light wire pliers
- Angle wire bending pliers
- Tweed loop forming pliers
- Nance loop forming pliers
- De La Rosa contouring pliers
- Weingart universal pliers
- Angle/tweed ribbon arch pliers
- Howe pliers
- Ligator
- Mosquito forceps
- "Mathieu" needle holder
- Ligature adjuster and tucker
- Pin and ligature cutters
- Pin and ligature cutter 45°
- Hard wire cutters
- Heavy wire cutters
- Distal end cutters
- Bracket removing pliers
- Posterior band removing pliers
- Anterior band removing pliers
- Adam's plier
- Adams' clasp bending pliers
- Arrow clasp former
- Arrow clasp bending pliers
- Young loop bending pliers
- Face bow bending/cutting pliers
- 3-Prong pliers
- Turrets

INTRODUCTION

For a student of orthodontics, it is essential to know the instruments that he or she will have to use routinely. A brief description of the commonly used orthodontic instrument is provided. It is expected to increase the working knowledge of the student and also prevent misuse of the more delicate instruments.

SEPARATING PLIERS

The separating plier or the separator-placing plier (Fig. 35.1) is made of stainless steel with a spring back action. It is used for expanding elastic separators or separating rings before positioning them interdentally.

SCISSORS

Scissors are either straight (Fig. 35.2A) or curved (Fig. 35.2B). They are made from especially hardened steel and are used for cutting thin metal bands or band material.

BAND SEATER

Band seater is available in various shapes and are generally made of high impact plastics (Fig. 35.3A) or wood (Fig. 35.3B). The biting surface is generally tin inlay. Its shape is round or triangular with a serrated



Fig. 35.1: Force module separating pliers

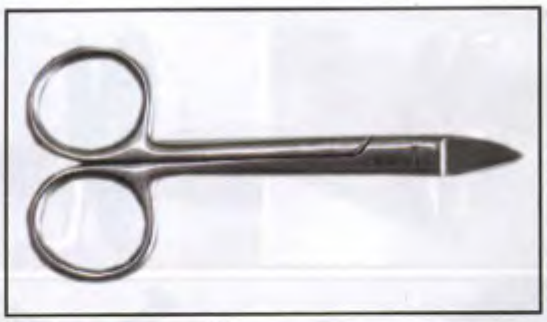


Fig. 35.2A: Crown scissors straight

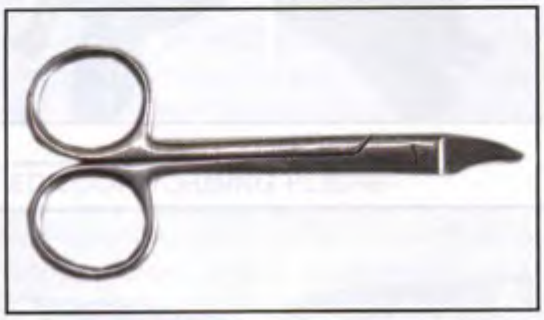


Fig. 35.2B: Crown scissors curved

surface finish (Fig. 35.3C). The patient is instructed to bite on the surface with the tin inlay tip resting on the lug or the band edge.

MERSHON BAND PUSHER

As the name suggests, the band pusher (Fig. 35.4) it is used to push bands so as to seat them and/or adapt them to the exact contour of the teeth. A hollow anatomically formed grip handle makes the band pusher light and the serrated rectangular tip provides for a good transfer of force when positioning bands.

BOONE GAUGE

The most frequently used bracket-positioning aid (Fig. 35.5). This is made of stainless steel. It accurately measures height of bracket placement from the incisal edge at 3.5, 4, 4.5 and 5 mm.

BRACKET POSITIONING HEIGHT GAUGE

This device simplifies the seating of brackets on the teeth with exactly the right distance between bracket slot and incisal edge. It is generally made of aluminium or stainless steel (Fig. 35.6).



Fig. 35.3A: High heat bite stick



Fig. 35.3B: High heat bite stick—molded high impact plastic with stainless tips

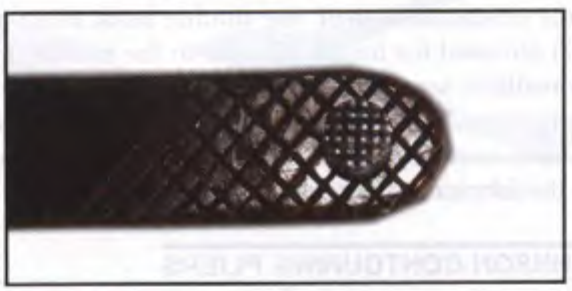


Fig. 35.3C: Band seater with a wooden handle



Fig. 35.4: Band pusher



Fig. 35.5: Boone gauge stainless steel



Fig. 35.6: Aluminium height gauge



Fig. 35.7: Double beak plier

DOUBLE BEAK PLIERS

Made of stainless steel, the double beak pliers (Fig. 35.7) are used for forming bands in the mouth. These are available separately for anterior and posterior band fabrications. These were of immense importance when all teeth used to be banded. They are still important for the fabrication of well fitting bands.



Fig. 35.8: Johnson contouring plier

JOHNSON CONTOURING PLIERS

The Johnson contouring plier (Fig. 35.8) plier is ideal for contouring and adapting bands or crowns. It can be used to recontour band edges that sometimes get bent during band placement.



Fig. 35. 9A: Light wire plier with serrations (arrows). The serrations prevents the slipping of wire from grip

STANDARD LIGHT WIRE PLIERS

The light wire plier is especially used for fine wire-bending work in the light wire technique. It comes with (Fig. 35.9A) and without (Fig. 35.9B) serrations on its flat beak. It can be used for spring hard wires up to 0.5 mm/.020" diameter.



Fig. 35. 9B: Light wire plier

JARABAK LIGHT WIRE PLIERS

The Jarabak light wire plier (Fig. 35.10) has a shape, which is slightly different from the original light wire plier. Serves the same function and can be used to bend spring hard wires up to 0.5 mm/0.020" diameter.



Fig. 35. 10: Jarabak light wire plier

ANGLE WIRE BENDING PLIERS

This sturdily constructed plier (Fig. 35.11), has hard tips and the beaks are cone and pyramid shaped. It is available in two beak lengths—short and long.

TWEED LOOP FORMING PLIERS

The loop-forming plier (Figs 35.12A and B) is used for fine bending work, which involves the bending of loops. Multiple loops of the same dimension can be easily bent with this plier. It can be used for hard wires up to 0.5 mm/.020" diameter.

NANCE LOOP FORMING PLIERS

Nance loop forming pliers (Fig. 35.13) is ideally suited for forming different loops and adjusting preshaped arches for the fixed appliance technique. It has four-step beaks which are ideal for bending loops of different sizes in both round and rectangular wires. This plier can bend wires up to a diameter of 0.7 mm/0.028".

DE LA ROSA CONTOURING PLIERS

The De La Rosa (Fig. 35.14), as it is frequently called, has guiding grooves for forming round and square arches 0.016", 0.018", 0.020" and 0.022". It helps to accentuate the curvature in the arch wire.

WEINGART UNIVERSAL PLIERS

The Weingart plier (Fig. 35.15) is used for positioning the arch and bending the arch ends. It has accurately closing serrated tips. It is capable of bending hard wires up to a diameter of 0.5 mm / 0.020".



Fig. 35.11: Band seating plier

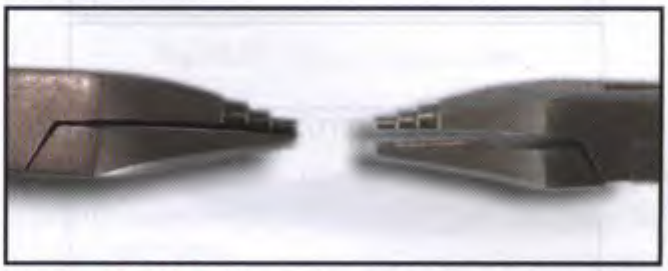


Fig. 35.12A: Standard tweed loop forming plier



Fig. 35.12B: Loop forming plier, tweed style



Fig. 35.13: Nance loop forming pliers



Fig. 35.14: The De La Rosa contouring plier



Fig. 35.15: The Weingart plier

ANGLE/TWEED RIBBON ARCH PLIERS

These pliers (Fig. 35.16) are generally used in pairs for applying torque to edgewise wires. Parallel grip prevents crushing of wire. They are used for wire up to the diameter of 0.56 -0.70 mm or 0.022-.028".

HOWE PLIERS

Are mainly of two types: straight or curved.

Straight Howe pliers (Fig. 35.17A)—are utility pliers have long, slender lip-safe tips. They are used to hold wires. The special tip design makes these pliers also suited to seating individual anterior bands.

Curved Howe pliers (Fig. 35.17B)—are also utility pliers with long, slender, curved lip-safe tips, which increase its efficiency in posterior areas. The tips are bent at 40° for better access.

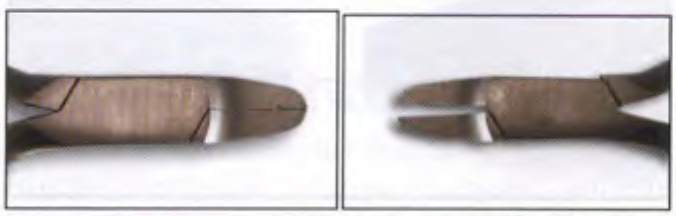


Fig. 35.16: Angle/tweed ribbon arch pliers



Fig. 35.17A: Howe style utility pliers



Fig. 35.17B: Similar to the straight Howe pliers except tips are angle at 40° for accessing lingual and other hard to reach areas

LIGATOR

The ligator (Fig. 35.18) is used for fast ligating of the complete arch. The 'Y'-shaped tip simplifies the twisting of the ligature. It can be used for ligature wires up to 0.3 mm / 0.012" diameter.



Fig. 35.18: Coon style ligator

MOSQUITO FORCEPS

Mosquito forceps (Fig. 35.19) are used for placing elastic ligatures and tightening the ligature wire around brackets.

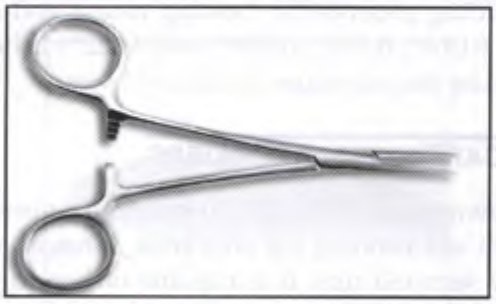


Fig. 35.19: Mosquito hemostat

"MATHIEU" NEEDLE HOLDER

"Mathieu" needle holder (Fig. 35.20) has a convenient and practical design and is ideal for ligation. It has serrated tips, which allow better gripping of the thin ligatures.



Fig. 35.20: Mathieu needle holder

LIGATURE ADJUSTER AND TUCKER

The ligature adjuster and tucker (Fig. 35.21) is usually a double ended instrument. It is used to tuck the cut ends of the ligature wires so that they do not hurt the soft tissues. It can also be used to hold the arch wires in the bracket slot at the time of ligating the bracket.



Fig. 35.21: Double ended ligature director

PIN AND LIGATURE CUTTERS

Pin and ligature cutters (Fig. 35.22) are especially designed for accuracy right to the tip, for smooth cutting of soft ligature wires and lock pins. Used for cutting ligature wires while ligating brackets. They are also available with tungsten carbide inserts.



Fig. 35.22: Pin and ligature cutter

PIN AND LIGATURE CUTTER 45°

45° angled cutting tips (Fig. 35.23) for easy cutting of ligatures especially in the posterior areas and in the lingual technique.



Fig. 35.23: Pin and 45° ligature cutter

HARD WIRE CUTTERS

Hard wire cutters (Fig. 35.24) have hard metal tips or tungsten carbide tips. These are heavier and larger than the pin and ligature cutters. These are used to cut all wires up to .020" round.



Fig. 35.24: Hard wire cutter

HEAVY WIRE CUTTERS

Heavy wire cutters (Fig. 35.25) are also called heavy gauge side cutters. They are capable of cutting wires of up to 1.3 mm diameter. Are generally non-sterilizable and are used mainly in the lab.



Fig. 35.25: Heavy wire cutter

DISTAL END CUTTERS

These distal end cutters (Fig. 35.26) have a cut and hold design. The distal end cutter is capable of cutting wires up to 0.56 × 0.70 mm/ .022" × .028". Used exclusively for cutting the distal end of wire protruding out of the molar tubes.



Fig. 35.26: Distal end cutters

BRACKET REMOVING PLIERS

As the name suggests, bracket removing pliers (Fig. 35.27) are used for removing bonded brackets. The tips wedge between both the edges of the base of the bracket and the tooth surface, easily lifting off the bracket. Available in two forms as straight (for anterior debonding) and with a 60° angled tip (which allows better access to posterior areas).



Fig. 35.27: Anterior band removing plier

POSTERIOR BAND REMOVING PLIERS

Posterior band removing pliers (Fig. 35.28) are used to remove posterior metal bands. The plastic head rests on the occlusal surface to the tooth and the sharp tip surface below the gingival contour of the band. Pressure at handles causes the band to lift off the tooth.



Fig. 35.28: Posterior band removing plier, long

ANTERIOR BAND REMOVING PLIERS

Anterior band removing pliers (Fig. 35.29) have a narrow groove into which the incisal edge of the anterior tooth is placed, instead of the rubber head as in the posterior band remover. The sharp end is inserted gingival to the gingival extension of the anterior band.

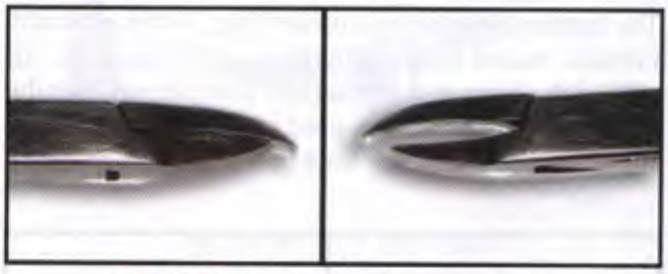


Fig. 35.29: Anterior band removing pliers (arrow indicates the groove)

ADAM'S PLIER

Adam's plier is used in the fabrication of the Adam's clasp and has two smooth rectangular beaks (Fig. 35.30).

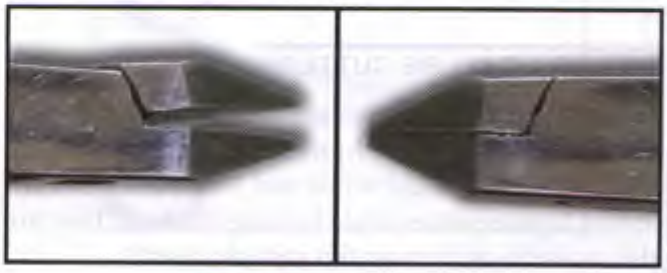


Fig. 35.30: Adam's pliers

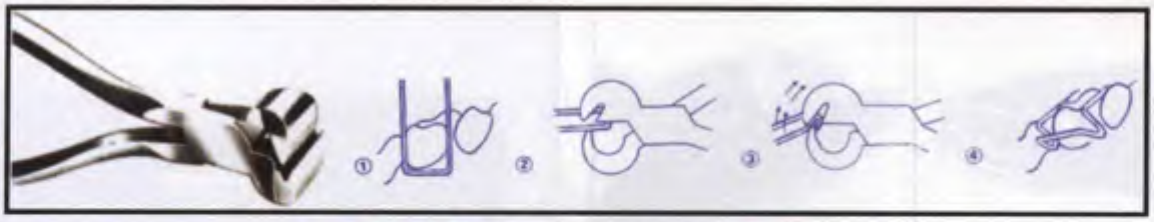


Fig. 35.31: Adams' clasp bending pliers

ADAMS' CLASP BENDING PLIERS

Adams' clasp bending pliers (Fig. 35.31) are special pliers for easy forming of Adams' clasps in one step. Can be used for wires up to the diameter of 0.7 mm.

ARROW CLASP FORMER

Arrow clasp former (Fig. 35.32) is used for hard wires up to 0.7 mm/.028". They form the clasp of the shape as shown in the Figure 35.31.



Fig. 35.32: Arrow clasp former

ARROW CLASP BENDING PLIERS

Arrow clasp bending pliers (Fig. 35.33) are used to bend the arrow clasp so that the arrow head can engage the retentive under cut. Used for wires up to the diameter of 0.7 mm.



Fig. 35.33: Arrow clasp bending pliers

YOUNG LOOP BENDING PLIERS

Young loop bending plier (Fig. 35.34) is a universal pliers for different size loops. It is ideal for labial arches. Provides a uniform dimension to the loops. For hard wires up to 0.7 mm/28 units.

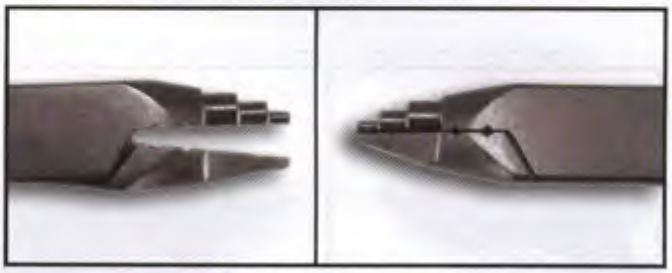


Fig. 35.34: Young loop bending plier

FACE BOW BENDING/CUTTING PLIERS

The face bow bending pliers (Fig. 35.35) are ideal for bending and cutting the outer bows of a face bow. These can be used to bend wires up to a diameter of 1.8 mm.



Fig. 35.35: Face bow bending pliers

3-PRONG PLIERS

As the name suggests the three prong plier (Figs 35.36A and B) has three precision aligned tips, which ensures consistent bends. It is capable of bending wires up to a diameter of .030". It is also used for the activation of the quard-helix appliance.

TURRETS

These are used to provide an arch form to the arch wire in the edge wise and pre-adjusted appliances. Are

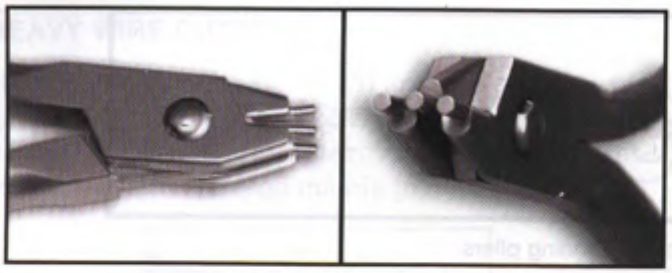


Fig. 35.36A: 3-Prong plier

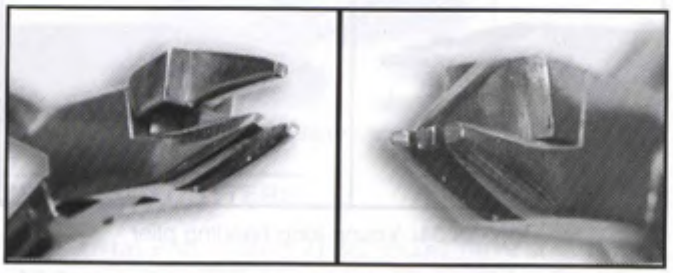


Fig. 35.36B: 3-Prong plier (different design)

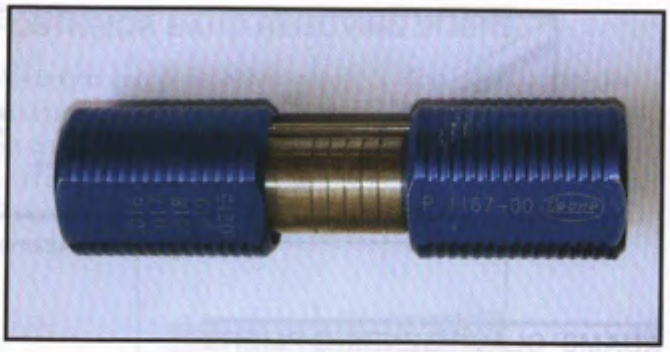


Fig. 35.37: Turret

available with and without the torque options. The straight length of the arch wire is simply wound in the turret to provide the desired curvature (Fig. 35.37).

FURTHER READING

1. Meehan MP, Foley TF, Mamandras AH. A comparison of bond strength of two glass ionomer cements. Am J Orthod Dentofac Orthop 1999;115:125-32.

36 Sterilization in Orthodontics

Gurkeerat Singh

- Introduction
- Steps in sterilization/disinfection
- Methods of sterilization
- Methods of disinfection
- Hand disinfection

INTRODUCTION

Sterilization has been defined as the destruction of all life forms. This includes all microorganisms as well as their spores. In comparison, *disinfection is the destruction of most microorganisms but not the highly resistant spores.* Sterilization should be undertaken to protect the patient as well as to protect the clinician.

Barrier protection has to be made use of to protect the clinician from any disease that the patient may be suffering from and has the potential of transmitting to the clinician. The barriers routinely used are surgical gloves, mouth masks and eye protection goggles. These should be changed after every single use.

There are three possible pathways of cross contamination and each should be handled in a specific way.

CRITICAL

These include instruments that penetrate the mucosa and must be sterilized.

SEMI-CRITICAL

This segment includes instruments that touch the mucosa but do not penetrate it (Table 36.1). These should be sterilized. These include mouth mirrors, probes, tweezers, etc.

Table 36.1: Instruments requiring sterilization

• Mirrors
• Explorers
• Banding and bonding instruments
• Bands
• Pliers
• Ligature directors

LEAST CRITICAL

This segment includes surfaces touched during treatment (Table 36.2). These should be disinfected. Such surfaces include, band/bracket trays, air/water syringes, saliva ejector handles, chair control buttons, supply drawers, etc.

Table 36.2: Surfaces that should be disinfected

• Bracket and band trays
• Air/water syringes
• Saliva ejector handles
• Chair control buttons
• Operatory light handles
• Chair armrests and headrests

STEPS IN STERILIZATION/DISINFECTION

The basic steps remain the same for the two procedures. These include:

1. *Rinsing* All instruments, irrespective of the instrument should be rinsed/washed thoroughly.



Fig. 36.1: Ultrasonic cleaner

This will remove all non-sticky debris from the instrument.

2. *Debridement with ultrasonic cleaner* (Fig. 36.1) This will remove all materials including sticky cements or dried blood from the instrument. The cycle lasts from 2-15 minutes depending upon the ultrasonic cleaner and the type of debris sticking to the instruments.
3. *Dry thoroughly* The drying process can be done under hot air or using a sponge followed by drying under the fan. This step is essential to avoid any damage to the instruments during the next stage of sterilization/disinfection.

METHODS FOR STERILIZATION

1. *Steam pressure* Majority clinics make use of autoclaves (Figs 36.2A and B), which work on this principle. The ideal combinations are 250°C at 15-psi pressure for 15 minutes or 270°C at 30 psi pressure for 3 minutes. It is unacceptable for orthodontic pliers because of the severe corrosion produced at the plier joints.
2. *Chemical* Chemical vapor sterilizers use formaldehyde, alcohol and water at 270°C at 20 to 40 psi pressure for at least 20 minutes.
3. *Dry heat ovens* (Fig. 36.3) This safe and convenient method is still in vogue with clinicians and involves maintaining the temperature at 340°F for 1 hour or 320°F for 2 hours or 250°F for 6 hours or more. Ideal for cutters and other sharp instruments as less chance for damage due to corrosion.
4. *Boiling water* Boiling water is used mainly to sanitize, i.e. the number of microbial contaminants





Fig. 36.2A: Front loading autoclave



Fig. 36.2B: Top loading autoclave



Fig. 36.3: Hot air oven

is reduced to safe or relatively safe levels as judged by public health requirements, without the destruction of certain viruses and resistant spores. Immersing instruments in boiling water at 100°C (212°F) for 30 minutes at sea level will kill most vegetative bacteria. An immersion lasting 60 minutes is recommended to compensate for the temperature lag in the load during the initial part of the boiling cycle and changes in altitude. For every 1000 feet increase above sea level, boiling time should be increased by 5 minutes. Boilers (Fig. 36.4) of various sizes are available commercially. The method is not recommended for orthodontic instruments as it really does not sterilize and the chances of corrosion are maximum.

5. *Salt or glass bead sterilizers* (Fig. 36.5) The glass bead sterilizers use small glass beads 1.2 to 1.5 mm in diameter. The heat generated is very high in a very short span of a few seconds. 424 to 450°F (217-232°C) for 3 to 15 seconds but not exceeding 482°F (250°C) is considered sufficient for bands. The larger the instrument the longer the time required. Ideal for chair side sterilization of instruments. A narrow, deep well is preferred to a wide, shallow well. The instruments should be placed deep and near the sides of the wall for best results.
6. *Hyperbaric gas (ethylene oxide) sterilization* It is ideal for instruments that are prone to corrosion or heat



Fig. 36.4: Boiler

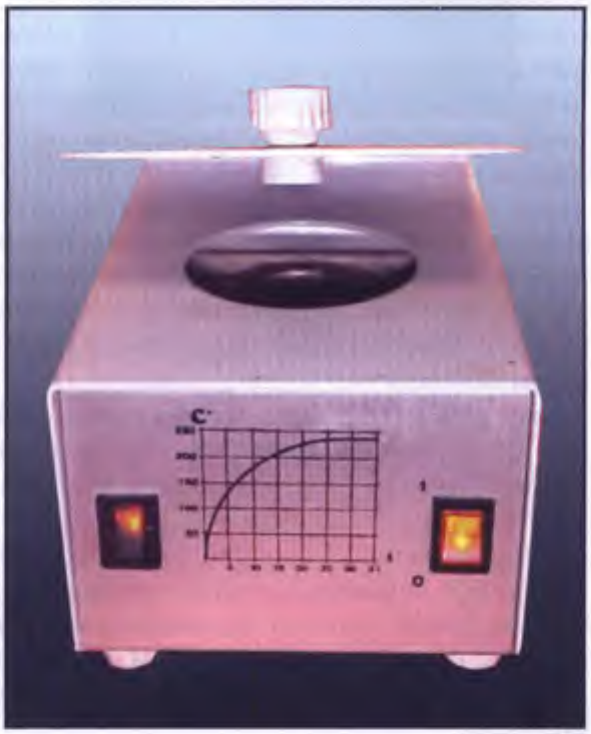


Fig. 36.5: Glass bead sterilizer

damage. Since the gas by itself is highly toxic and has a tendency to retain in the material sterilized, the sterilized instruments cannot be used immediately and a need exists to allow for the gas to dissipate. Depending upon the temperature, sterilization time varies from 4 to 12 hours. It is 12 hours at room temperature and 4 hours at 56°C (2½ to 5½ hours at temperatures ranging from 125 to 135 °F with a relative humidity at 40-80%).

METHODS OF DISINFECTION

1. *Cidex (activated glutaraldehyde, 2%)* (Fig. 36.6) is one of the most commonly used disinfection agents. It acts rapidly, is nonstaining and does not cause rusting. Instruments should be completely immersed in it for 10 minutes for disinfection and for a minimum of 10 hours at a pH of 7.5 to 8.5 to achieve sterilization. The instruments need to be washed thoroughly with sterile water before use.
2. *QAC (quaternary ammonium compound)* Exposure to this compound reduces the surface tension between the bacteria and an object, thus disrupting the bacterial cell wall. It is used routinely for disinfection of hand instruments as the metal remains bright and does not show any sign of corrosion. These compounds also have a pleasant odor and a short-time cycle. They become inactive in the presence of soaps and organic matter. These have a limited effectiveness against gram-negative organisms, spores and viruses.
3. *Phenol* Phenol in high concentration is a rapid protoplasmic poison that penetrates the cell wall and precipitates the cell protein. Phenolic solutions are not sporicidal but are tuberculocidal and virucidal. These are good germicidal cleaners for floors, tabletops, etc.
4. *Alcohol* Alcohol (Fig. 36.7) is a moderate disinfectant. It behaves similarly as QAC and disrupts the bacterial cell wall. Isopropyl alcohol is generally used in 70 percent aqueous solution and is more effective than ethyl alcohol. Ethyl alcohol (70-95%) is effective against vegetative organisms and tubercle bacilli but both are ineffective against spores. It can cause rusting of metal instruments. Alcohols become ineffective as soon as they evaporate.
5. *Chlorine* It is used in aqueous solution. Even in minute quantities it is rapidly bactericidal. Its mode of mechanism is still not exactly known. The aqueous solution of chlorine is unstable and has to be changed daily. It has the potential to corrode metals and soften plastics.
6. *Iodine and iodophors* Iodine is a faster disinfectant than QAC or Chlorine. Free iodine forms salts with the bacterial protein thus killing the cell. Concentrated iodine is mixed with softened or distilled water to form a disinfectant solution.



Fig. 36.6: Commercially available glutaraldehyde solutions



Fig. 36.7: Commercially available alcohol based disinfectant

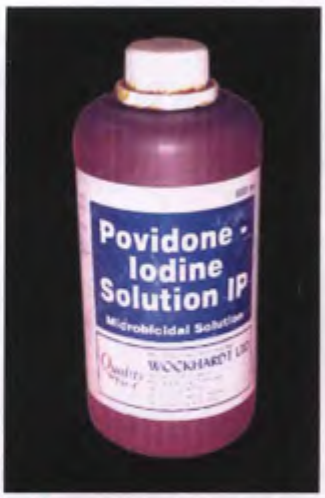


Fig. 36.8: Povidone Iodine solution for hand disinfection



Fig. 36.9: Commercially available chlorhexidine gluconate hand rub

HAND DISINFECTION

Ideally, it is advised to wear gloves. If that is not possible, simply disinfect by washing for at least 20 seconds with 10 percent povidone iodine (Fig. 36.8), or 4 percent chlorhexidine gluconate (Fig. 36.9) or 4 percent isopropanol (Fig. 36.10).

Adequate precautions should be in place at all times to prevent infection, and protect both patients



Fig. 36.10: Commercially available alcoholic rub-in hand disinfectant containing 2-propanol and 1-propanol

and staff. It is essential to train auxiliary staff and form protocols, which should be strictly adhered to, to maintain and implement a safe and realistic infection control program.

FURTHER READING

1. Council on Dental Materials, Instruments and Equipment. Infection control recommednations for the dental office and the dental laboratory. J Am Dent Assoc 1988;116;148.
2. Foster TD. A Textbook of Orthodontics, 2nd ed., Blackwell Scientific Publications, London.
3. Pucher JJ, Daniel JC. The effects of chlorhexidine digluconate on human fibroblasts in vitro. J periodontol. 1992;63(6):526-32.
4. Schutt RW. Bactericidal effect of a disinfectant dental stone on irreversible hydrocolloid impressions and stone casts. J Prosthet Dent 1989;62(S):605.
5. Setcos JC, Ping L, Palenik CJ. The effect of disinfection procedures on an alginate impression material. J Dent Res 1984;63:235.
6. Shaffer SE, Barkmeirer WW. Effect of disinfections/ steriilization on in-vitro enamel bonding. Journal of Dental Education 1985;49:658-59.

Section Five

ORTHODONTIC APPLIANCES

37. Orthodontic Appliances—An Introduction
38. Removable Orthodontic Appliances
39. Fixed Orthodontic Appliances
40. The Edgewise Appliance
41. The Begg Appliance
42. The Pre-Adjusted Edgewise Appliance
43. The Tip Edge Appliance
44. Lingual Orthodontics
45. Orthopedic Appliances
46. Functional Appliances

37 Orthodontic Appliances—An Introduction

Gurkeerat Singh

- Introduction
- Classification of orthodontic appliances
  - Removable orthodontic appliances
  - Semi-fixed orthodontic appliances
  - Fixed orthodontic appliances
  - Mechanical orthodontic appliances
  - Functional orthodontic appliances
- Ideal requirement of an orthodontic appliance
  - Biologic requirements
  - Mechanical requirements
  - Esthetic requirements

INTRODUCTION

Orthodontics has come far since the days when finger pressure was being advocated to move teeth. With the development of this branch of dentistry is associated an inseparable quest of researchers to create appliances which can move teeth "ideally".

This endeavor to achieve "ideal" tooth movement has led clinicians to create numerous appliances, which move teeth. *Orthodontic appliances can be defined as devices, which create and/or transmit forces to individual teeth/a group of teeth and/or maxillo-facial skeletal units so as to bring about changes within the bone with or/without tooth movement which will help to achieve the treatment goals of functional efficiency, structural balance and esthetic harmony.*

Most of the orthodontic appliances are restricted to bringing about tooth movement. But as our knowledge of growth and development of the maxillo-facial unit has increased, so has our endeavor to modify the growth of underlying skeletal structures.

CLASSIFICATION OF ORTHODONTIC APPLIANCES

The simplest classification is probably based on the patient's ability to remove the orthodontic appliance. Based on this premise the appliances can be classified as—removable, semi-fixed or fixed.

REMOVABLE ORTHODONTIC APPLIANCES

Removable orthodontic appliances are those that can be removed by the patient, e.g. Howley's retainer (Fig. 37.1), or a Kesling wrap-around retainer (Fig. 37.2).

SEMI-FIXED ORTHODONTIC APPLIANCES

Semi-fixed orthodontic appliances have some part of the appliance fixed on to the tooth surfaces which the patient cannot remove but the rest of the appliance can be removed, e.g. lip bumper (Fig. 37.3).



Fig. 37.1: Hawley's retainer



Fig. 37.2: Kesling wrap-around retainer



Fig. 37.3: The lip-bumper appliance is a semi-fixed appliance; the molar bands are 'fixed' whereas the bumper can be removed



Fig. 37.4: The pre-adjusted edge-wise appliance

FIXED ORTHODONTIC APPLIANCES

Fixed orthodontic appliances includes those appliances which the patient cannot remove. These appliances are capable of bringing multiple movements with limited patient co-operation, e.g. the pre-adjusted edge-wise appliance (Fig. 37.4).

Orthodontic appliances can be also classified as—mechanical or functional, based on the way they generate or transmit forces. Based on the patient's ability to remove them, they can be sub-classified as removable or fixed.

MECHANICAL ORTHODONTIC APPLIANCES

Mechanical orthodontic appliances possess active components, which are themselves capable of generating forces. These appliances are capable of generating forces that can move individual teeth, group of teeth and /or the jaws. Mechanical appliances may be fixed or removable.

Removable Appliances

As the name suggests, these appliances can be removed from the mouth by the patient. The patient can insert and remove these appliances without the intervention of a clinician. They may be active or passive, depending upon their capability to exert/generate forces.

Active removable appliances Active removable appliances are designed to achieve tooth movement (mainly tipping) by means of active components, e.g. wire springs, screws (Fig. 37.5) etc. They are capable of generating tooth moving forces.

Passive removable appliances Passive removable appliances are designed to maintain teeth in their designated or present position, e.g. space maintainers, retainers etc. (Fig. 37.1).



Fig. 37.5: Appliance with micro-screws in place



Fig. 37.6: Fixed space maintainer bonded on the lingual aspect of mandibular anteriors

Fixed Appliances

Fixed appliances are orthodontic devices in which attachments are fixed to the teeth and forces are applied by arch wires or other auxiliaries via these attachments.

These can be further classified as active and passive, depending upon their ability to generate forces.

Active Fixed Appliances

Active fixed appliances are attached (fixed) onto the tooth surface and are capable of generating forces which are capable of bringing about tooth movements (Fig. 37.4).

Passive Fixed Appliances

Passive fixed appliances do not generate forces and are responsible for maintaining the attained position of the teeth, e.g. fixed retainers (Fig. 37.6), fixed space maintainers, etc.

FUNCTIONAL ORTHODONTIC APPLIANCES

These are appliances which engage both arches and act principally by holding the mandible away from its resting position, they harness and transmit the natural forces of the circum oral musculature to the teeth and/or alveolar bone. These appliances generally cause a change in the surrounding soft tissue envelope of the teeth thereby leading to a more harmonious relationship of the jaws to each other and to the other bones of the facial skeleton, e.g. the Frankel appliance (Fig. 37.7).

They can be either fixed or removable.

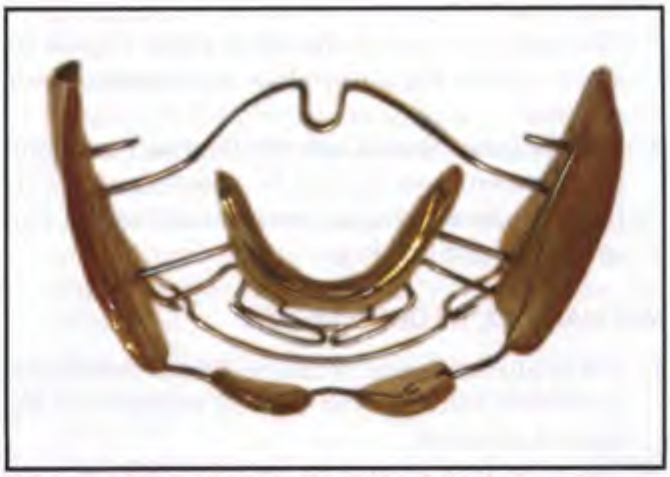


Fig. 37.7: The FR-2 appliance of Fränkel

IDEAL REQUIREMENT OF AN ORTHODONTIC APPLIANCE

All appliances, which are used with the purpose of bringing about orthodontic tooth movement, should fulfill certain requirements. The appliances should try to fulfill most of these requirements even though no single appliance till date has managed to fulfill all of these.

These requirements can be considered under the following three headings:

- Biologic requirements
- Mechanical requirements
- Esthetic requirements.

BIOLOGIC REQUIREMENTS

1. The appliance should fulfill its basic purpose of bringing about the desired tooth movement.
2. In bringing about the desired tooth movement it should not have a detrimental impact on the teeth, and/or periodontium. For example—it should not lead to root resorption or non-vitality of teeth etc.
3. It should move only those teeth that it is designed to move. In other words the anchor units should remain in their original position.
4. The appliance should not hamper normal growth.
5. It should not interfere or inhibit normal functions.
6. The appliance should allow for proper oral hygiene maintenance. It should be easy to clean the appliance as well as continue with all and hygienic maintenance regimes continuity.
7. The material used in its fabrication should be biocompatible and not produce any allergic or toxic reactions.
8. The appliance should not disintegrate in the oral environment and should be able to sustain its functions in the rugged environment of the oral cavity without breakage.

MECHANICAL REQUIREMENTS

1. The appliance should be able to deliver continuous controlled forces of the desired intensity in the desired direction.
2. The appliance should be able to withstand the routine masticatory forces and not get damaged easily.
3. The appliance should be easy to fabricate and activate.
4. It should not be bulky and uncomfortable for the patient to wear.
5. The appliance should be universally applicable and accepted, i.e. it must be able to correct various malocclusions and different orthodontists should be able to activate it similarly.



Fig. 37.8: The lingual appliance
(Photograph courtesy Dr Vinod Verma)

ESTHETIC REQUIREMENTS

The appliance should be esthetically acceptable to the patient. In other words it should be as inconspicuous as possible.

The above requirements are very stringent and no single appliance has yet been designed which incorporates all these requirements. For example- the lingual appliance (Fig. 37.8) fulfills the esthetic requirements most completely, yet it may interfere with proper speech, violating a biologic requirement, of not interfering with normal functions.

FURTHER READING

1. Adams CP. The Design and Construction of Removable Orthodontic Appliances. 4th edition, John Wright and Sons, Ltd. Bristol 1970.
2. Badcock JH. The screw expansion plate. Trans. Brit. Soc. Orthod pp 1911;3-8.
3. Crozat GB. Possibilities and use of removable labiolingual spring appliances. Internat J Orthodontia 1920;6:1-7.
4. Graber TM, B Neumann. Removable Orthodontic Appliance. WB Saunders Co. Philadelphia, 1977.
5. Houston WJB, et al. A textbook of orthodontics, ed. 2, 1993, Wright, Oxford.
6. Schwarz AM, M Gratzinger. Removable Orthodontic Appliances. WB Saunders Co, Philadelphia, 1966.
7. Swain BF. The Begg technic. In TM Graber, BF Swain (Eds), Current orthodontic concepts and techniques (2nd edn). Philadelphia: WB Saunders 1975;7:665-991.
8. Tulley WJ, AC Campbell. A Manual of Practical Orthodontics. J Wright and Sons, Bristol, 1960.

38 Removable Orthodontic Appliances

Tapasya Juneja, Gurkeerat Singh

- Introduction
- Advantages of removable appliances
- Disadvantages of removable appliances
- General principles of removable appliances
- Active components
- Retentive components (fixation)
- Framework/base plate
- Instructions to the patient
- Common failures for no tooth movement

INTRODUCTION

As the name suggests, these are appliances that can be removed by the patient without any supervision by the orthodontist. Removable orthodontic appliances are useful in a variety of situations but present the inherent disadvantage of the treatment being in the control of the patient. Also, movement of teeth in all the three planes of space cannot be carried out simultaneously. To understand these appliances better we will first study their advantages over other orthodontic appliances and then learn to design such appliances.

ADVANTAGES OF REMOVABLE APPLIANCES

1. The patient can continue with routine oral hygiene procedures without any hindrance. The oral cavity as well as the appliance can be kept clean. All restorative procedures can also be carried out during such an orthodontic appliance therapy.
2. Most forms of tipping movement can be carried out successfully.
3. These appliances are less conspicuous than fixed appliances and hence, generally more acceptable to the patients.
4. Since these are relatively simple appliances they can be delivered and monitored by the general dentist.
5. Appliance fabrication is done in specialized labs and hence the chair side time for appliance delivery is considerably less as compared to the fixed appliances.
6. Since only a few movements are carried out simultaneously with these appliances the time required by the clinician to activate an appliance is less. This allows the clinicians to see more patients in a lesser time.
7. The patient can remove a broken or otherwise uncomfortable/impinging appliance. Thus, a broken appliance is never an emergency for the clinician.
8. These appliances require a limited inventory to be maintained as compared to more complex fixed appliances.
9. These appliances are relatively cheap as compared to the fixed appliances.

DISADVANTAGES OF REMOVABLE APPLIANCES

1. Patient cooperation is the key word in removable appliance therapy. The duration for which the appliance is worn is the duration for which the appliance is able to act. Hence, the treatment can become prolonged depending on patient compliance.

2. These appliances are capable of only certain types of movements, they do not give three-dimensional control over the teeth to be moved. This limits their utility.
3. Multiple movements are difficult, if not impossible to carryout. Since all corrections cannot be carried out simultaneously the treatment time may be increased considerably.
4. The patient has to have a certain amount of dexterity and skill to be able to remove and replace the appliance for successful treatment to be possible.
5. The chance of appliance loss and/or breakage is more.

GENERAL PRINCIPLES OF REMOVABLE APPLIANCES

A removable appliance works by tipping a tooth around its center of resistance, which is located between 30 and 40 percent from the root apex when considering the whole length of the tooth.

The forces exerted are dependent on:

- The kind of appliance
- The harnessing of forces from the adjacent soft and hard tissues or incorporation of springs or elastics
- The type of contact the active component makes with the tooth/teeth to be moved.

APPLIANCE DESIGN

Components of Removable Appliances

The design and construction of any removable appliance must begin with a detailed plan of the tooth movement that is to be carried out and should consider the morphologic characteristics, the age and eruption status of the patient, the psychologic findings and the treatment objectives.

The removable orthodontic appliances are made up of three components:

1. Force or active components—comprises of springs, screws or elastics.
2. Fixation or retentive components—usually include clasps.
3. Base plate or framework—can be made of cold cure or heat cure acrylic.

ACTIVE COMPONENTS

These constitute the components of the removable appliance, which apply forces to the teeth to bring about the desired tooth movement. The active components include:

a. Springs—made up of 0.5, 0.6 or 0.7 mm diameter stainless steel wire.
b. Bows—made from 0.5 or 0.7 mm diameter stainless steel wire.
c. Screws
d. Elastics

The three basic components of removable appliances are as follows.

SPRINGS

A wide variety of springs are available for incorporating in the removable appliance. Springs can be broadly classified into:

Based on the presence of helices

- Simple spring (Fig. 38.1A)—no helix present
  Compound spring (Fig. 38.1B)—helix incorporated
- Helical springs (Fig. 38.1B)—helix is present
  Looped spring (Fig. 38.1C)—no helix, but a loop is included in the design

Based on the mode of support provided to maintain the integrity of the spring

- Self-supported springs—these springs are made up of thicker wire to avoid distortion by the patient.
- Supported springs—these springs are made up of thinner wire and therefore to protect these delicate springs, a guidewire may be provided. Alternately they may be supported by an additional sleeve or 'boxed' by acrylic to ensure adequate stability.



Fig. 38.1A: Simple spring

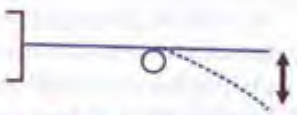


Fig. 38.1B: Spring with helix incorporated



Fig. 38.1C: Spring with 'U' loop incorporated

Designing a Spring

The most suitable material for orthodontic springs is 18/8 stainless steel (ss) wire as it combines elasticity and malleability in excellent proportions, is tasteless and immune to corrosion by oral secretions.

In scientific terms, there is a relationship between the length, diameter and amount of deflection of a spring which is expressed as:

$$D \propto \frac{PL^3}{T^4}$$

Where, D = amount of deflection
P = amount of pressure
L = length of spring
T = thickness/diameter of spring.

The effect of each of these variables is explained as follows.

Thickness/diameter of spring (T) According to the formula, if the diameter is doubled, the deflection/flexibility of a spring decreases by 16 times, i.e. a spring made from thinner wire generates less force and has greatly increased flexibility, thus, remaining active over a longer time period.

Length of wire (L) Doubling the length of the wire increases the flexibility of the spring by eight times and also reduces the force exerted. Increasing the length of wire, however, increases the range of action of the spring and therefore it is better to incorporate helices or loops into a spring, which effectively increases its length within the limits of the appliance. A double helix provides further increase in flexibility by incorporating more wire in a given length of spring.

Pressure/force (P) Deflection of a spring is double, when the pressure is doubled. The pressure to be applied is on an average 20 gm/cm^2 of root area and can vary according to the number of teeth to be moved, root surface area and patient comfort.

Other requirements to be kept in mind while designing a spring are:

a. Ensure that the spring will act over the distance and the direction needed to move the teeth, e.g. to move a teeth labially a spring should be palatally positioned and vice versa.
b. The spring should be mechanically strong to withstand interferences that occur due to eating, speaking and cleaning.

TYPES OF SPRINGS

Finger Spring

The most useful spring for removable appliance is the single, cantilever/finger spring (Fig. 38.2A). It is constructed using 0.5 or 0.6 mm hard round SS wire. It is made up of a coil or helix near the point of attachment and a free end, which moves, in a well-defined arc.

The free end is the active arm, 12-15 mm in length and is placed towards the tissue, the helix is about 3 mm in internal diameter and the retentive arm (minimum of 4-5 mm in length) is placed away from the tissue and ends in a retentive tag.

Construction The spring is constructed such that the helix is positioned opposite to the direction of intended tooth movement. The helix should also be placed along the long axis of the tooth to be moved and perpendicular to the direction of tooth movement (Fig. 38.2B).



Fig. 38.2A: Finger spring



Fig. 38.2B: The helix should lie on the long axis of the tooth to be moved

Finger springs must be guarded and guided with care to ensure that they work smoothly. Since they are constructed from a thin gauge wire, the spring should be either boxed in wax or guards should be made. Care should be taken to ensure that the cavity formed by 'boxing' does not become a food trap, thus, leading to inflammation of gum tissue.

Indication The finger spring is used for mesiodistal movement of teeth, e.g. closure of anterior diastemas (Fig. 38.2C). However, it should only be used on teeth, which are in line of the arch or centered bucco-lingually.

Activation The finger spring is activated by opening the coil (Fig. 38.2D) or moving the active area towards the tooth to be moved (Fig. 38.2E). About 3 mm of activation is considered optimum.



Fig. 38.2C: Finger springs being used to close a midline diastema



Fig. 38.2D: Activation of finger spring by opening the helix

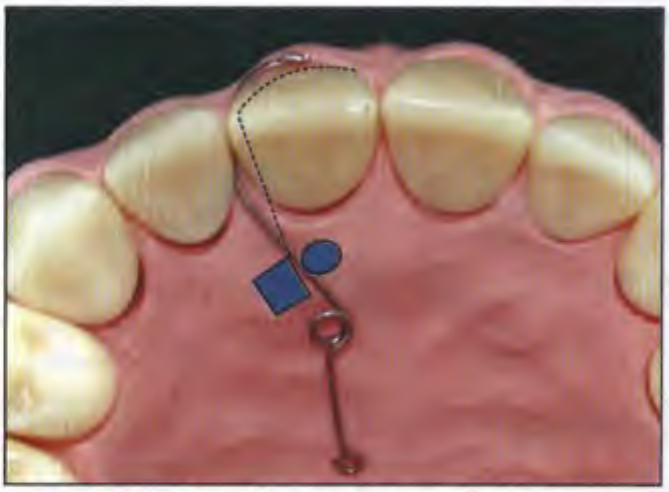


Fig. 38.2E: Activation of finger spring by moving the active arm

Double Cantilever/Z-Spring

A useful variation of the cantilever spring is the double cantilever/Z-spring (Fig. 38.3A) where a second limb is formed with a second coil. Such a spring can also be used to move 2 or more teeth in the same direction over equal distances as when proclining 2 or more upper incisors.

Construction It is made up of 0.5 mm hard round SS wire. It consists of 2 helices of small internal diameter and can be made for one, two or more incisors. The spring is positioned perpendicular to the palatal surface of the tooth with a long retentive arm (placed away from tissue) about 12 mm in length. The Z-spring is a supported spring (Fig. 38.3B) and needs to be boxed in wax prior to acrylization (Fig. 38.3C). Z-spring is activated by opening both the helices up to 2-3 mm at a time. Only one helix may be activated to correct mild rotations. It is ideal for the correction of anterior tooth crossbites where the overlap is less than the free way space (Fig. 38.3C).

T-Spring

It is made up of 0.5 mm hard round SS wire and is used for buccal movement of premolars and sometimes canines. As the name suggests, the spring has a T-shaped arm, the ends of which is embedded in the baseplate (Fig. 38.4). Loops incorporated in the arms of the T-loops can be opened up to remain in contact with the tooth as it moves buccally. Activation

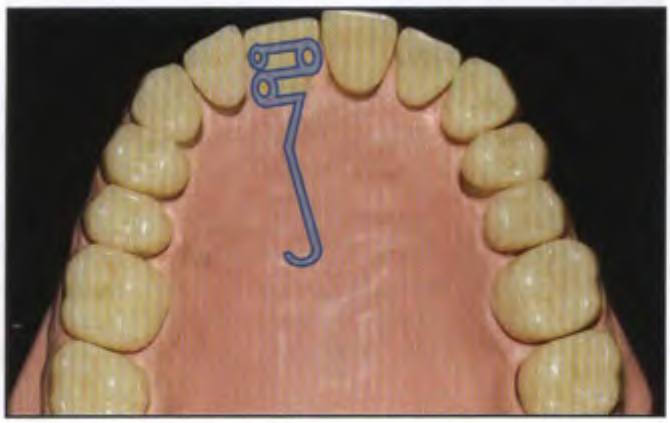


Fig. 38.3A: Z spring



Fig. 38.3B: Note the acrylic cover over the 'Z' springs placed in relation to the lateral incisors



Fig. 38.3C: Ideal case for correction using 'Z' springs, 11 and 21, in negative overbite less than 3 mm and mildly rotated teeth

is done by pulling the free end of the 'T' towards the intended direction of tooth movement.

Mattress Spring

Mattress spring is used for the correction of the labial movement of teeth in crossbite. It is usually used in cases where sufficient space exists for the correction of the crossbite and if the tooth in question is sufficiently complete in its development (Fig. 38.5).

Construction Usually made of 0.6 mm diameter wire. It is shaped like a mattress with 'U' loops extending





Fig. 38.4: T spring

till the retentive arm. It engages the tooth close to the gingival margin.

Helical Coils Spring

It is a free-ended spring with two helices placed on different arms (Fig. 38.6). It is supported by an envelop of acrylic. Is ideally used to regain lost extraction space.

Construction It is generally made of 0.6 mm wire with the connecting arm between the springs acting as part of the retentive arm. Opening the helices activates the springs. The two sides can be activated by different amounts depending upon the amount of movement required.

Coffin Spring

This is an omega-shaped spring which helps to bring about arch expansion (Fig. 38.7A). Walter Coffin introduced it in the year 1881. It is indicated in patients with a narrow maxillary arch as it brings about slow dentoalveolar arch expansion.

Construction It is made up of 1.25 mm hard round SS wire. It has an omega/U-shaped loop in the center which stands 1.0 mm away from the palate with retentive arms embedded in the acrylic base plate.

Holding both the ends in the region of the clasps and pulling the sides gently apart activates this spring (Fig. 38.7B). It can also be activated by flattering the omega loop at its curvature (Fig. 38.7C). It should be activated up to 2 mm (1 mm/side) at a time.



Fig. 38.5: A mattress spring is a free-ended spring. It is used for labial movement of anterior teeth in crossbite



Fig. 38.6: Helical coil springs are used for mesial or distal movement after teeth have drifted into an edentulous area

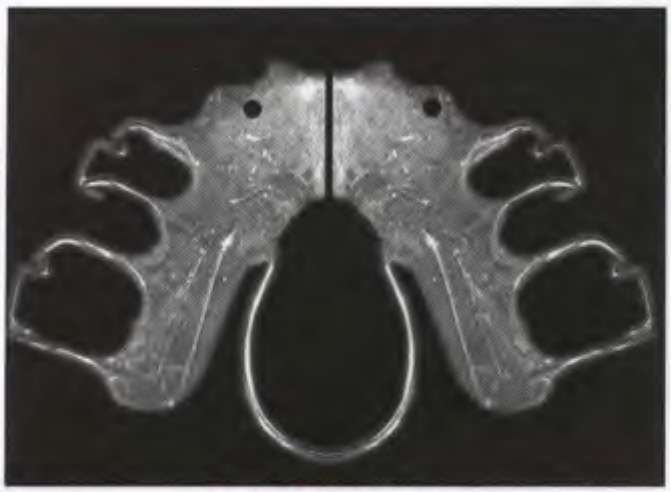


Fig. 38.7A: Coffin spring

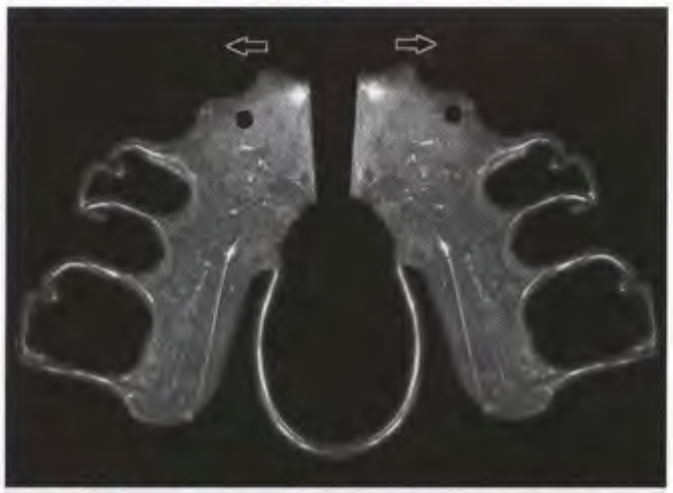


Fig. 38.7B: Activation incorporated by expanding the coffin spring

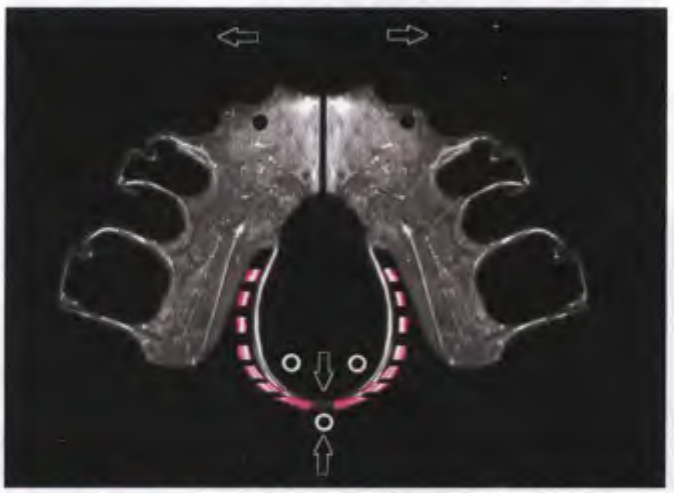


Fig. 38.7C: Flattering the omega loop using a three pong plier causes expansion

CANINE RETRACTORS

These are springs that bring about distal movement of canines. Canine retractors can be classified as:

Based on their Location

i. Buccal (Fig. 38.8A)—placed buccally
ii. Palatal (Fig. 38.8B)—placed palatally.

Based on Design

i. Helical canine retractor (Fig. 38.8B)—helix incorporated in the design
ii. Looped canine retractor (Fig. 38.8A)—loop incorporated in the design.

Based on Mode of Action

i. Push type
ii. Pull type

Maxillary canine retraction is usually done by palatally placed canine retractors, but sometimes they can be done using buccally placed, self-supporting springs of 0.7 mm wire.

1. *Palatal canine retractor* It is made up of 0.6 mm diameter SS wire (Fig. 38.8B). It consists of an active arm placed mesial to the canine, a helix of 3 mm diameter and a guide arm. The coil is placed along the long axis of canine (Fig. 38.8C). It is important for these springs to have the point of attachment sufficiently far forwards to ensure that the spring acts along the line of the dental arch. A palatal canine retractor is indicated for retraction of palatally positioned canines. Opening the helix 2 mm at a time activates it.
2. *Buccal self-supported canine retractor* As the name suggests, this canine retractor is made from a thicker gauge wire (0.7 mm), which helps resist deformation of the spring. It is indicated for retraction of buccally placed canines and is particularly useful when the canine overlaps the lateral incisor and is not accessible from the lingual side of the arch. It is made up of an active arm, a helix of 3 mm diameter and a retentive arm (Fig. 38.8D). The active arm is placed away from the tissues and the helix is positioned distal to the long axis of the canine.
3. *"U" loop canine retractor* When minimal canine retraction (1-2 mm) is required, a relatively simple

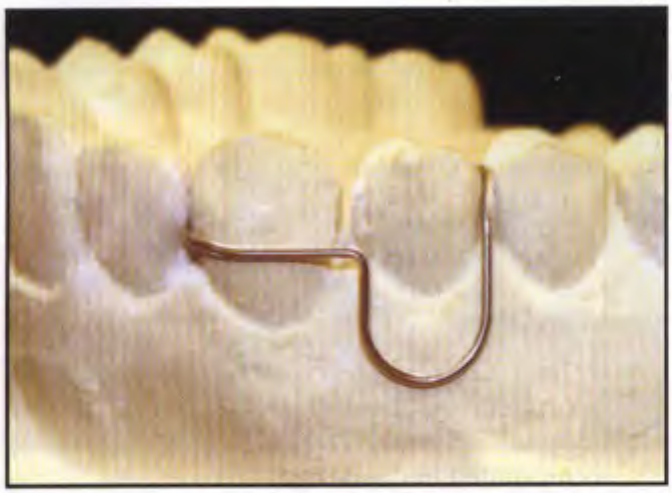


Fig. 38.8A: 'U' loop buccal canine retractor



Fig. 38.8B: The helix is placed along the long axis of the canine

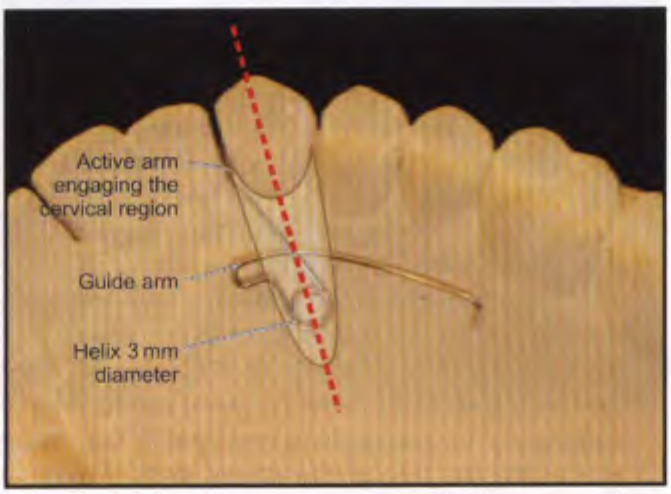


Fig. 38.8C: Palatal canine retractor with helix

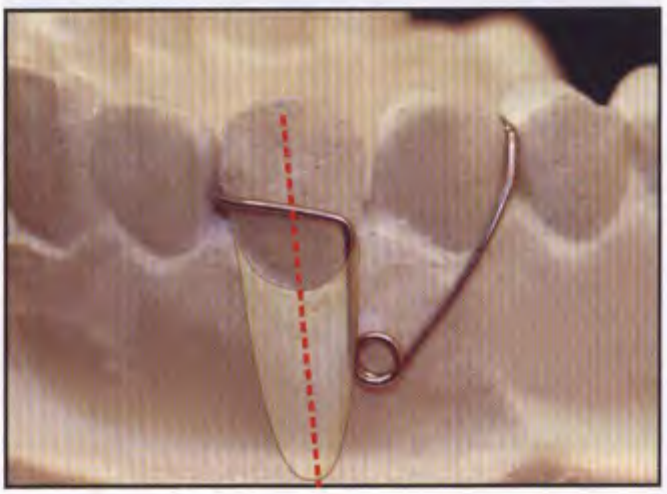


Fig. 38.8D: Self supported buccal canine retractor with helix located distal to the long axis of the canine

and less bulky retractor can be used, such as a U-loop retractor. However, it is mechanically less effective than the other retractors. It is made up of 0.6 or 0.7 mm SS wire and consists of an active arm, U-loop and a retentive arm. The base of the U-loop is placed 2-3 mm below the cervical margin, the active arm is bent at right angles from the mesial leg of the loop and adapted around the canine (Fig. 38.8A). The distal leg of the loop extends as the retentive arm. This retractor is activated by compressing the loop or by cutting the free end of the active arm by 2 mm and readapting it.

4. *Helical canine retractor* It is made up of 0.6 mm round SS wire and consists of an active arm (towards the tissue), a helix of 3 mm diameter and a retentive arm. It is designed as a loop with the helix at its base; the distal arm is bent at right angles to form the active arm, which engages the canine (Fig. 38.8E). The mesial arm is adapted between the premolars and ends in a retentive tag. The helix is placed 3-4 mm below the gingival margin.

Activation is done by opening the helix by 2 mm or by cutting off 2 mm from the end of the active arm and readapting it around the canine.

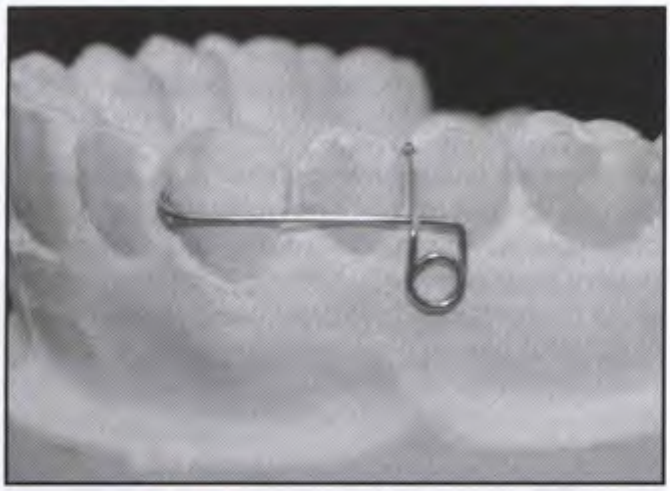


Fig. 38.8E: Helical canine retractor

For the canine retractors, whether buccal or palatal, to be successful, it is important for the canine to be mesially angulated prior to treatment (Fig. 38.8F). If the canine is normal or distally angulated prior to treatment, a removable canine retractor will cause an unsightly distal angulation of the canine at the completion of retraction, which in turn will take a long time to correct with fixed appliances. For this reason, use of removable appliances for canine retraction is declining as fixed appliances have greater control over tooth movement.

LABIAL BOWS

These are components that are used for both overjet reduction and for providing anterior fixation. A wide variety of labial bows are available for use in orthodontics. They are as follows.

Short Labial Bow

The short labia bows are made from 0.7 mm round SS wire. The labial bow is constructed in such a way that the bow contacts the most prominent labial surfaces of the anterior teeth and ends in two U-shaped loops that extend as retentive arm between the canine and premolar before getting embedded in the acrylic base plate (Fig. 38.9A).

They are used for retention purposes, as a component of the Hawley's retainer (Fig. 38.9B) and

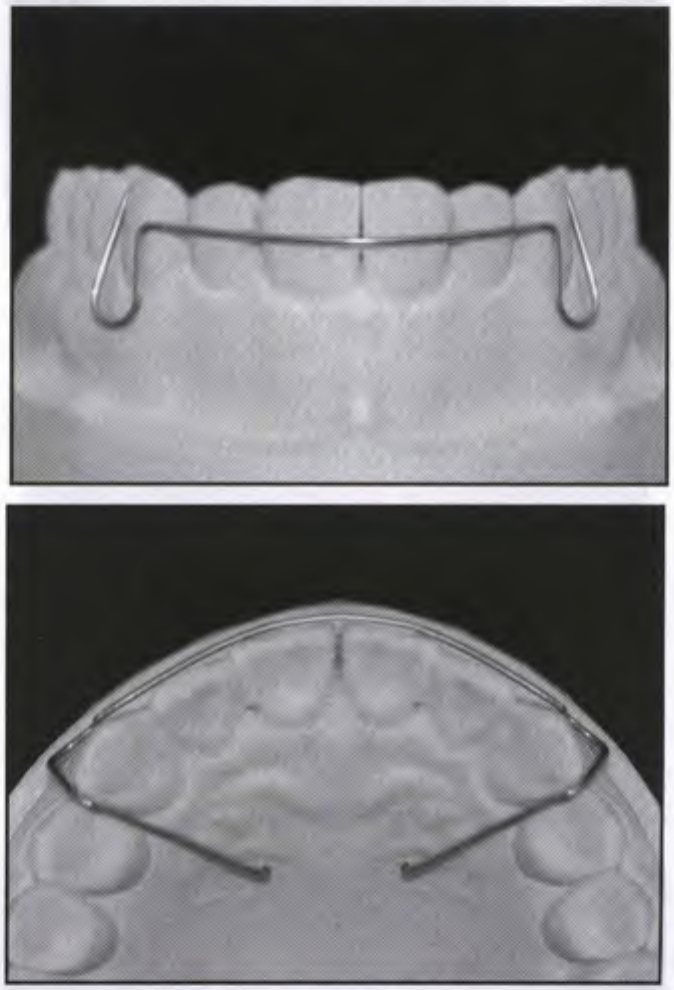


Fig. 38.9A: Short labial bow



Fig. 38.8F: Mesially inclined canine being aligned using the helical canine retractor



Fig. 38.9B: Short labial bow as part of Hawley's appliance

can also bring about minor overjet reduction and anterior space closure. Their range of action is limited because of stiffness and low flexibility.

For space closure, the bow is activated by compressing the loops of the bow by 1-2 mm.

Long Labial Bow

It is a modification of the short labial bow design, in that it extends from the first premolar of one side to that of the contralateral side (Fig. 38.9C). The distal arm of the U-loop extends between the two premolars and ends as the retentive arm.

It can be used as an active and retentive component of the removable appliance. It is indicated in minor overjet reduction, small amounts of anterior space closure, closure of space distal to canine and also for guidance of canine during canine retraction.

It is also activated by compressing the loop 1-2 mm so that the bow is displaced palatally by 1 mm.

Modification Labial bow soldered to Adams' clasp (Fig. 38.9D). In extraction cases following orthodontic treatment, closed spaces can be retained with a Hawley's retainer in which a long labial bow is soldered to the bridge of the Adams' clasp (Fig. 38.9D). A short labial bow is not feasible in such cases as the distal arm can cause opening of the extraction space between canine and premolar.



For maxillary arch (side view)



For mandibular arch (occlusal view)



Fig. 38.9C: Long labial bow



Fig. 38.9D: Long labial bow soldered to Adams' clasp

Split Labial Bow

This is a modification of the conventional short labial bow in that it is split in the middle (Fig. 38.9E). This is done to increase the flexibility of the otherwise stiff short labial bow.

The bow is made up of 0.7 mm round SS wire and has 2 separate short buccal arms, each with a U-loop ending distal to canine. This labial bow is effective in anterior retraction. It has also found use in closure of midline diastema, for which it has been modified such that the 2 buccal arms extend across the opposite central incisor and engage onto its distal surface (Figs 38.9F and 38.9G).

Activation is done by compressing the 'U' loop by 1-2 mm.



Fig. 38.9E: Split labial bow for retraction of anteriors

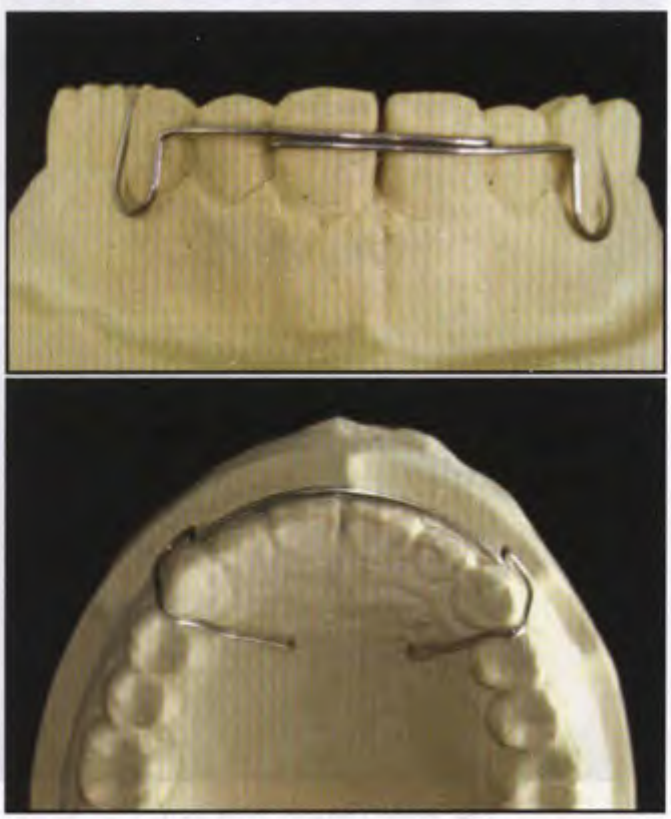


Fig. 38.9F: Split labial bow (for closure of midline diastema)

Robert's Retractor

This labial bow is made of 0.5 mm round SS wire, which is of a much thinner gauge than the conven-



Fig. 38.9G: Pre-treatment , during treatment using a split labial bow (and post-treatment photographs) as used for diastema closure

tional labial bows. It extends over the labial surfaces from canine to canine and instead of a regular loop it incorporates a 3 mm internal diameter helix at the base of the loop (Fig. 38.9H). The combination of a thin gauge wire and a helix makes this labial bow highly flexible and susceptible to distortion as it lacks stability in the vertical plane. To overcome this, the distal arms of the loops are supported in softened stainless steel tubes of 0.5 mm internal diameter (Fig. 38.9I).

Along with Adams' clasp on the buccal teeth for retention, this retractor can be used in patients with severe anterior proclination as it produces lighter forces over a longer span of activation. It can also be used in adult patients for the same reason.

Reverse Labial Bow

This type of labial bow is so called because, activation of the bow is done by opening the U-loop, instead of compressing as is seen in the conventional labial bows. The loop is placed distal to the canine and the distal arm is bent at right angles to extend anteriorly as the labial part of the bow (Fig. 38.9J). The free end of mesial arm is adapted between the canine and first premolar and eventually gets embedded in the acrylic base plate.

Activation is done by opening the loop which results in lowering of the labial bow in the incisor region. To maintain the proper level of the bow, a compensatory bend is then given at the base of the U-loop.



Fig. 38.9H: Robert's retractor

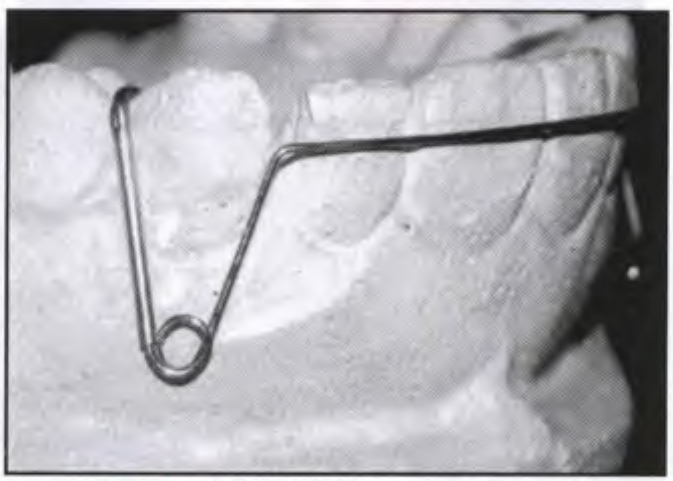


Fig. 38.9I: Note the sleeve covering the distal aspect of the retractor

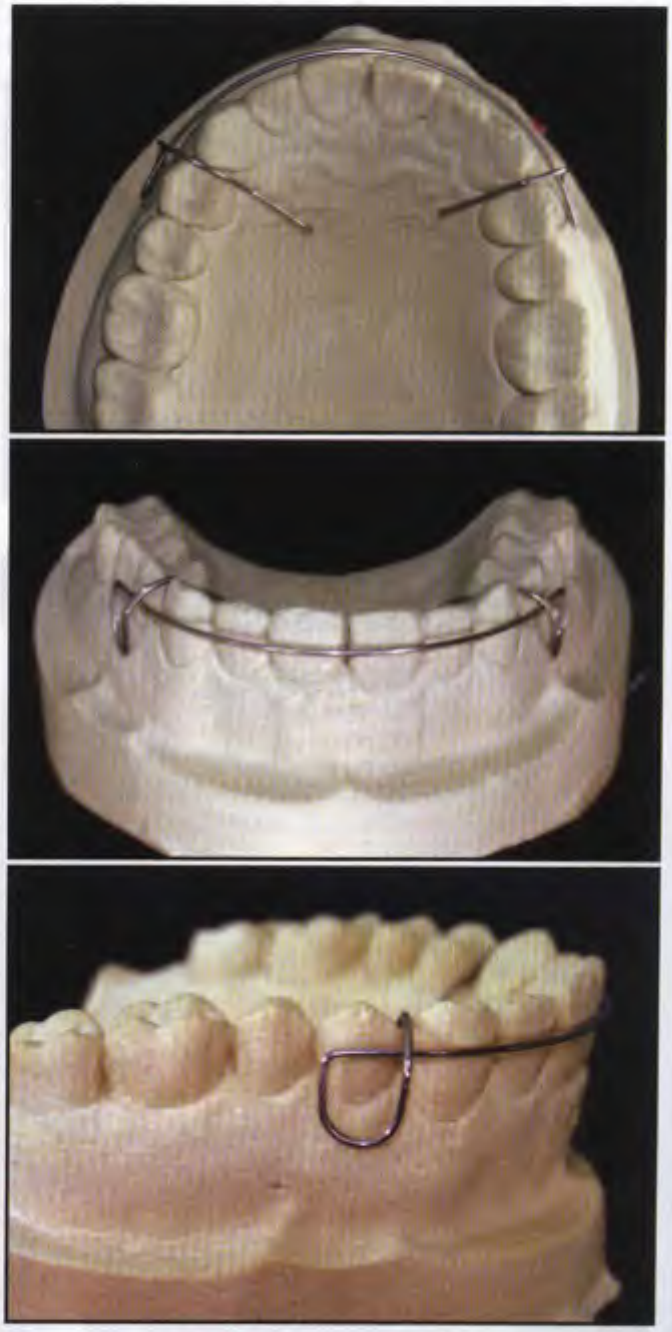


Fig. 38.9J: Reverse labial bow

Mill's Retractor

This is a complexly designed labial bow made of 0.7 mm SS wire which has extensive looping in its design to increase the flexibility and range of action of the retractor (Fig. 38.9K). The anterior part of the bow extends till mesial of the canine and then forms a complex loop gingivally before ending in a retentive arm distal to the canine. This type of a labial bow is indicated in patients with increased overjet. However, due to difficulty in construction and poor patient compliance, it is not widely used.



Fig. 38.9K: Mill's labial bow

High Labial Bow with Apron Springs

As the name suggests, this type of labial bow extends high into the labial vestibule. It is made up of a thicker gauge SS wire (0.9-1 mm). The labial bow acts as a support onto which apron springs (made from 0.4 mm wire) are attached/ wound (Fig. 38.9L). Apron springs

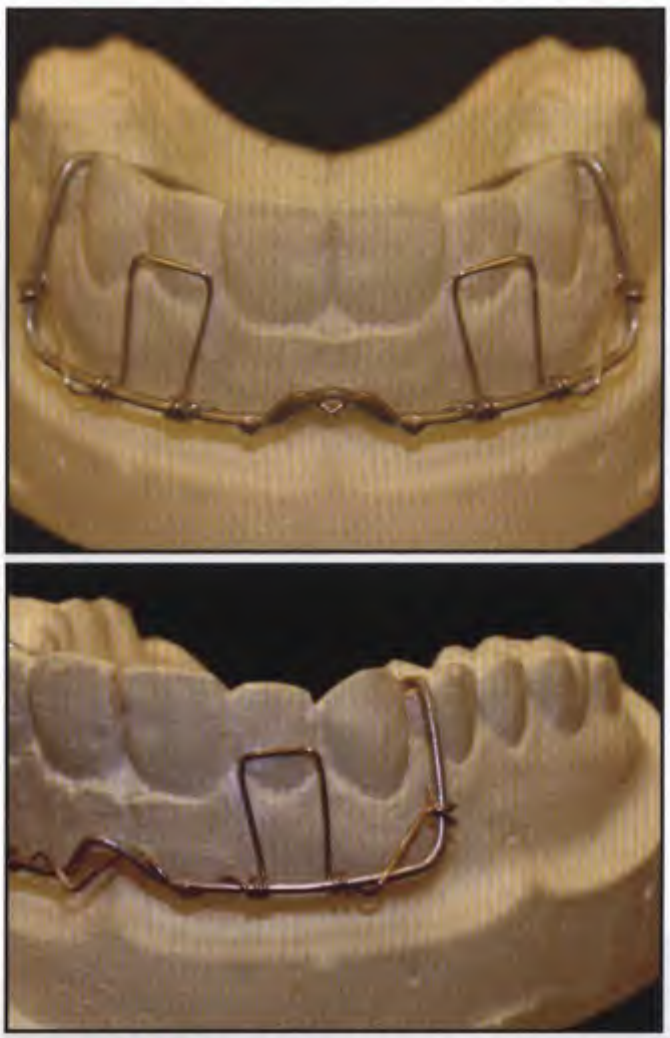


Fig. 38.9L: High labial bow with apron springs

help in retraction of one or more upper anteriors (Fig. 38.9M). This type of bow is made highly flexible because of the springs and is therefore used for retraction in cases with large overjet.

Apron spring is activated by bending it towards the teeth, up to 3 mm at a time. Since it generates light forces, it is also useful in adult patients. However, it is difficult to construct and can cause soft tissue injury. It may also lack patient compliance as too much wire is visible.

Fitted Labial Bow

This type of labial bow is so called, as it is adapted to the contours of the labial surface of anteriors (Fig. 38.9N). It is mainly for retention after completion of

fixed orthodontic treatment. The U-loop is smaller compared to the conventional labial bows.





Fig. 38.9M: High labial bow with apron spring



Fig. 38.9N: Fitted labial bow

SCREWS

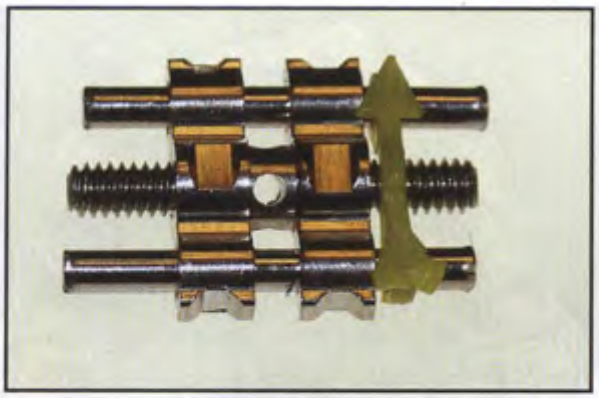
Screws are active components that are used to provide intermittent forces in removable appliances. Screws can be used to bring about various kinds of tooth movement.

A screw consists of a rod with left and right hand threads at both ends and a nut in the center, which is turned for activation (Fig. 38.10A). The threads turn in metal blocks that are embedded in the baseplate, which is split at right angles to the screw. The appliance is retained with Adams' clasps on posterior teeth. When the screw is turned, the two parts of the base plate separate and put pressure on the teeth. This causes the teeth to get slightly displaced and over time teeth move to new positions by remodeling of the overlying bone. Therefore, a wide variety of tooth movements are possible based on the location of the screw, number of screws and location of the split in the plate.

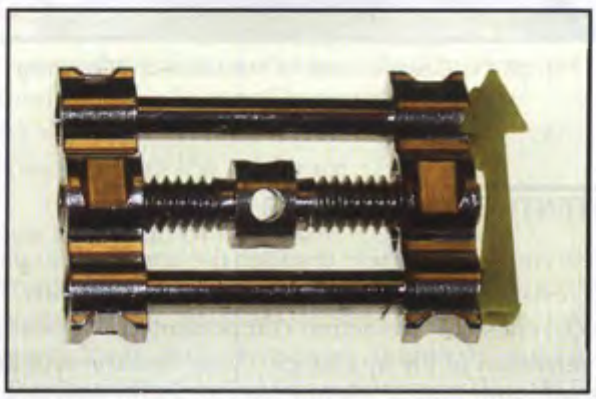
Advantage of Screw Over Springs

1. Appliances with screws are easier to manage than those with springs. Therefore, they are useful in the less skillful patient.
2. Screws are activated by the patient at regular intervals using a key, therefore, they are more valuable in patients who cannot visit the dentist frequently.
3. Appliance with a screw has fewer tendencies to get dislodged than those with springs. Therefore, they offer more stability for moving several adjacent teeth in the same direction.
4. Forces generated can be controlled, based on the amount of activation done.

The patient or parent using a key activates the screw. Activations may be done either once or twice a week or more frequently, depending on the type and amount of tooth movement required. Ideal tooth movement is achieved by turning the screw a quarter turn every 3-7 days. Most screws produce 0.2-0.25 mm movement per quarter turn. The movement produced is a direct function of the thread height (Fig. 38.10B). More the thread height , more the opening and higher the forces generated. The amount of force applied to each tooth by a screw appliance also depends on the number of teeth being moved, each tooth receiving a part of the total force. Screws should not budge too much out of the acrylic (Fig. 38.10C). Based on the



(i) Screw before activation



(ii) Screw following activation

Fig. 38.10A: Screw

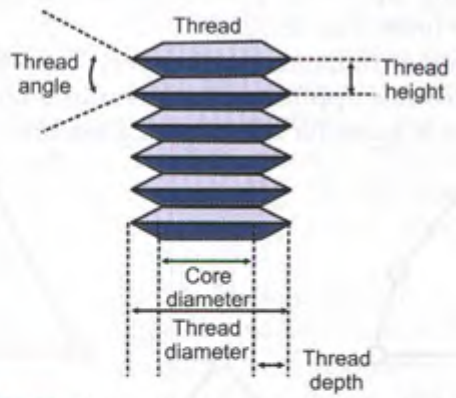


Fig. 38.10B: Cut section of screw showing the threads

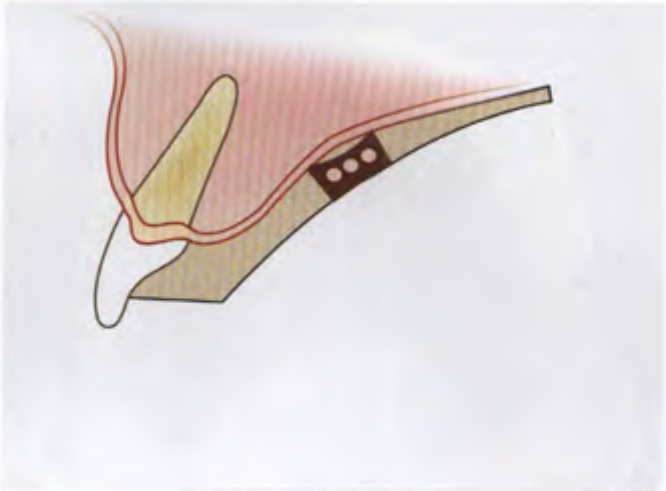


Fig. 38.10C: (a) Correct placement of expansion screw, (b) Incorrect placement of expansion screw



Fig. 38.10D: Removable appliances incorporating screw: Appliance for arch expansion

location of the screw and the acrylic split, three types of tooth movements can be brought about by screw appliances:

a. Arch expansion (Fig. 38.10D)—screw placed in the center of the arch.
b. Labial/buccal movement of one or a group of teeth (Fig. 38.10E).
c. Mesial/distal movement of one or more teeth (Fig. 38.10F).



Fig. 38.10E: Removable appliances for buccal movement of a group of teeth



Fig. 38.10F: Removable appliance for distal movement of teeth

ELASTICS

Elastic bands have for many years been used as a convenient means for applying pressure in orthodontic appliances. Elastics are routinely used in conjunction with fixed appliances but can provide the force component in removable appliances in suitable circumstances. Elastics can be used along with removable appliances for retraction of anterior teeth (Fig. 38.11). For this purpose, elastics are attached to hook made in the labial bow distal to the canine. Elastics are stretched across the incisors, between the canines. However, drawbacks of such appliances are:

1. Flattening of the arch form due to lack of control
2. Gingival stripping due to slippage of the elastics.

Advantage

Better esthetics, as they are less visible.

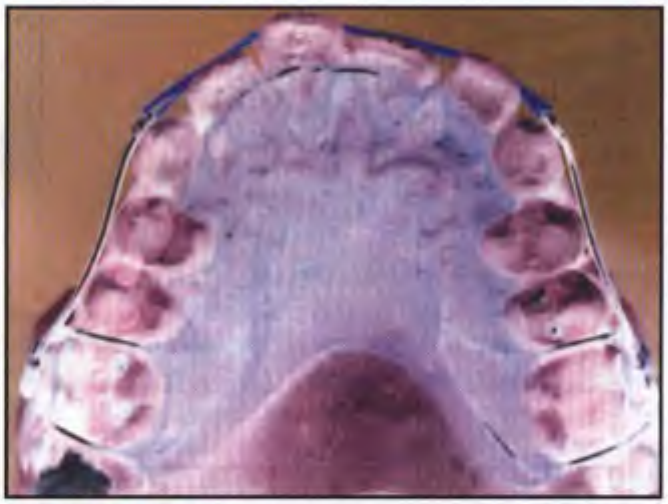


Fig. 38.11: Elastics used for retraction and/retaining the space closure

RETENTIVE COMPONENTS (FIXATION)

These components help to retain the appliance in place and resist displacement due to active components. The effectiveness of the active components is dependent on retention of the appliance. Good fixation will help patient compliance, anchorage and tooth movement.

Tammoscheit (1969) described three types of anchorage systems for active removable plates. His description was based on geometric designs, depending upon the placement of the support/retentive units (Fig. 38.12A).

Retentive components are a very important part of a removable appliance. Retention in a removable appliance is given for the following reasons:

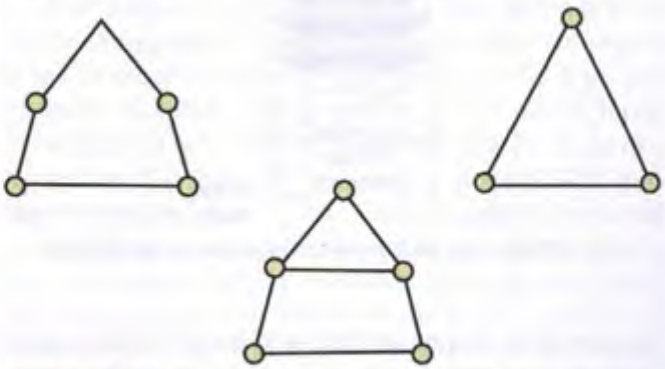


Fig. 38.12A: Schematic representation of intramaxillary anchorage in active plates: (1) trapezoidal anchorage, (2) triangular anchorage, (3) triangular-trapezoidal (ideal) anchorage

1. Active forces from bows, springs, screws and elastics can displace the appliance and make it ill fitting.
2. A loose-fitting appliance is uncomfortable and if it is continually moving in the mouth, it can lead to metal fatigue and failure.
3. Because of the above reasons, patient compliance will be poor and necessary tooth movements will not take place.

Good fixation is required to minimize such problems. Adequate retention in a removable appliance is aided by wire components, which are known as clasps.

CLASPS

These are the retentive components of most removable orthodontic appliances. They are supposed to 'clasp'/ hold the teeth in such a manner so as to resist the displacement of the appliance.

Mode of Action of Clasps

Between the maximum circumference of any tooth and anatomical neck, there are surfaces which slope inward towards the tooth axis on every side to produce areas of the teeth that are called undercuts (Fig. 38.12B). Clasps engage these undercut areas to aid in retention of a removable appliance.

There are 2 types of undercuts:

a. *The proximal undercuts* The mesial and distal undercuts extend from the contact area to the neck of the tooth. These undercuts appear soon after a tooth has erupted and are more pronounced, therefore they are more efficient than cervical undercuts in providing retention. They are visible from the buccal aspect (Fig. 38.12B). The Adams' clasp and Crozat's clasp make use of these undercuts.

b. *The cervical undercuts* These undercuts are present on the buccal and lingual surfaces of the teeth below the area of maximum circumference and are visible from the mesial aspect (Fig. 38.12B). They are less extensive than the proximal undercuts and therefore less retentive. However, they cannot be used until the teeth are fully erupted to the anatomical neck. Circumferential and Jackson's clasps are examples of clasps that engage the cervical undercuts.



Fig. 38.12B: Buccal and lingual undercuts (in black). Proximal undercuts (in blue)

Requirements of an ideal clasp

1. Easy to fabricate.
2. Provide adequate retention.
3. No interference with occlusion.
4. Should not apply active force.
5. Able to use on both fully and partially erupted teeth.
6. No impingement on soft tissues.

DIFFERENT TYPES OF CLASPS

Circumferential / C-clasp

This clasp is also known as the **three quarter clasp.** It is one of the simplest clasp in design and fabrication. It is made from 0.7 mm diameter SS wire. The C-clasp engages the buccal cervical undercut (Fig. 38.12C). It extends in the form of a "C" from one proximal undercut along the cervical margin to the other proximal side and is then brought occlusally over the embrasure to end as the retentive arm. It normally starts from the mesial side and ends on the distal side. However, it cannot be used in teeth that are partially erupted, as the cervical undercut cannot be seen.

Jacksons / Full Clasp

This "U"-shaped clasp was introduced by Jackson in 1906. It is also made from 0.7 mm SS wire. This clasp is adapted along the buccal cervical margin and extends along the mesial and distal undercuts (Fig. 38.12D), over the occlusal embrasure to end in two

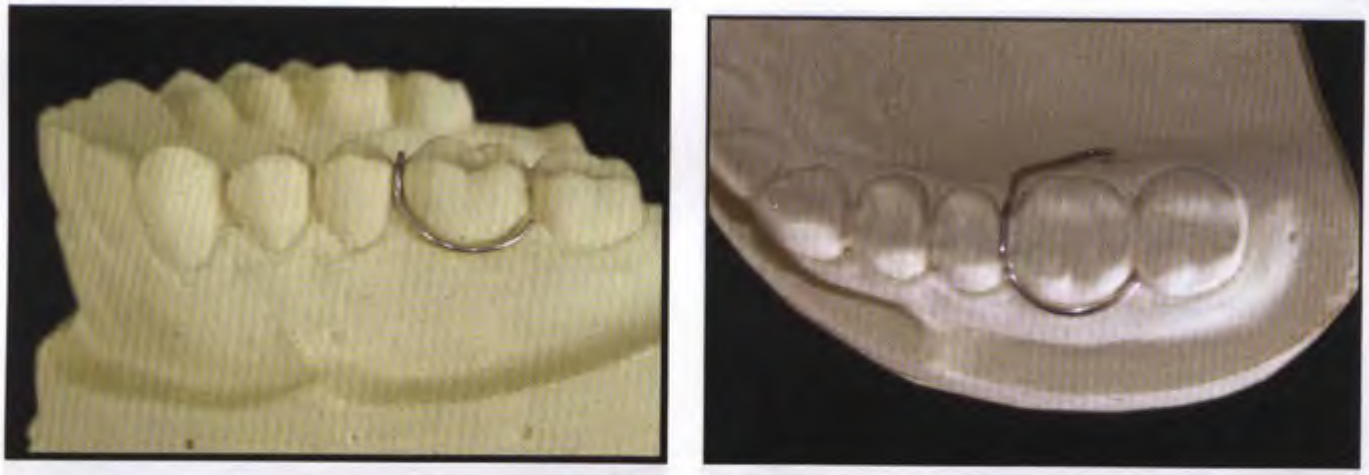


Fig. 38.12C: 'C' clasp



Fig. 38.12D: Full clasp

retentive arms on either side of the teeth. Like the C-clasp, it cannot be used on partially erupted teeth. In fully erupted teeth, it provides adequate retention.

Schwarz Clasp

This clasp is made up of a number of arrowheads which make use of the proximal undercuts between the molars and between premolars and molars (Fig. 38.12E). Therefore, it is also called the arrowhead clasp. It is not really used now because of the following drawbacks:

1. It occupies a lot of space in the buccal vestibule.
2. It can irritate the soft tissues - patient compliance is not good.
3. Need special pliers for fabrication.
4. Chances of breakage are high because of its design and elasticity.
5. Difficult to fabricate and (time consuming).

Adams' Clasp

Devised by Professor C Philip Adams in 1948, the Adams' clasp is one of the most effective clasps. It makes use of the mesial and distal proximal undercuts of the first permanent molars (Fig. 38.12F). It is also known as **modified arrowhead, universal and Liverpool clasp**. It is made from 0.7 mm round SS wire. This clasp offers maximum retention as it engages the undercuts on the mesial and distal embrasures of first



Fig. 38.12E: Schwarz clasp





Fig. 38.12F: Adams' clasp (A) buccal view (B) occlusal view

permanent molars. The Adams' clasp can be used on premolars, permanent molars and even deciduous molars in which case 0.6 mm diameter wire is used.

The Adams' clasp has a lot of advantages over other clasps, which are:

1. It is simple, strong and easily constructed.
2. It offers excellent retention.
3. It can be used on any tooth be it incisor, premolars or molars.
4. It is neat and unobtrusive and it makes an appliance easy to insert and remove using the bridges of the clasp.
5. Good patient compliance as it is comfortable to wear and resistant to breakage.
6. It can be used on both deciduous and permanent teeth.
7. A number of modifications enable its use in a wide variety of appliances.
8. No special instrument is required for its fabrication.

Fabricating the Adams' Clasp

The Adams' clasp is made of the following constituents:

a. Two arrowheads
b. Connecting bridge
c. Two retentive arms with tags.

There are 3 stages in the formation of Adams' clasp and each arrowhead is made by 3 distinct bends:

A 7-8 cm long piece of wire is taken.

i. The 1st bend is a little more than a right angle. Two such bends are made, which are connected by a bridge long enough to span the tooth. The length of the bridge is usually two/third the mesiodistal width of the tooth or the distance between the two buccal cusptips (Fig. 38.12G).
ii. The 2nd bend is made in 2 stages of 90° each. The wire is first bent at right angles. The clasp is tilted downwards against the pliers and the arrowhead is formed by bending outside the tip of the beak. This second bend forms a U-turn in the wire of 180°. The slope of the arrowheads is adjusted to follow the gingival margin.
iii. The 3rd bend is given to bring the tags of the clasp over the embrasure between the teeth and on to the lingual side to get embedded in the base plate. The arrowhead is grasped from the inside of the clasp with half the length of the arrowhead



Fig. 38.12G: The length of the bridge

between the beaks of the pliers and the tag is bent through 90°. Holding the arrowhead at the top of the pliers, the tag is bent through a further 45° and then tried on the tooth. The retentive arm is kept slightly away from the mucosa and tags are made at the ends.

Modifications of Adams' Clasp

A number of modifications are available to permit additional uses:

i. *Adams' clasp with single arrowhead* This type of clasp is indicated in a partially erupted tooth usually the last erupted molar. The single arrowhead is positioned in the mesial undercut. Instead of a distal arrowhead, the bridge is modified to encircle the tooth distally and end in a retentive arm (Fig. 38.12H).

ii. *Adams' clasp with additional arrowhead* When additional retention is required and a single Adams' clasp is not sufficient, an accessory arrowhead clasp can be fabricated on the adjacent tooth and soldered to the bridge of the main Adams' clasp (Fig. 38.12I), e.g. Adams' clasp on the first molar with an additional arrowhead on the second premolar.

iii. *Adams' with distal extension* A distal extension can be incorporated in the distal arrowhead of the Adams' (Fig. 38.12J). This acts as a traction hook for engaging elastics.

iv. *Adams' clasp with J-hook* Another accessory for engaging elastics is a J-hook that is soldered to the bridge of the clasp (Fig. 38.12K).

v. *Adams' clasp with helix* A helix can also be incorporated in the bridge of Adams' for engaging elastics (Fig. 38.12L).

vi. *Adams' clasp with soldered buccal tube* Tubes can be soldered to the bridge of claps (Fig. 38.12M) for use of extraoral attachment.

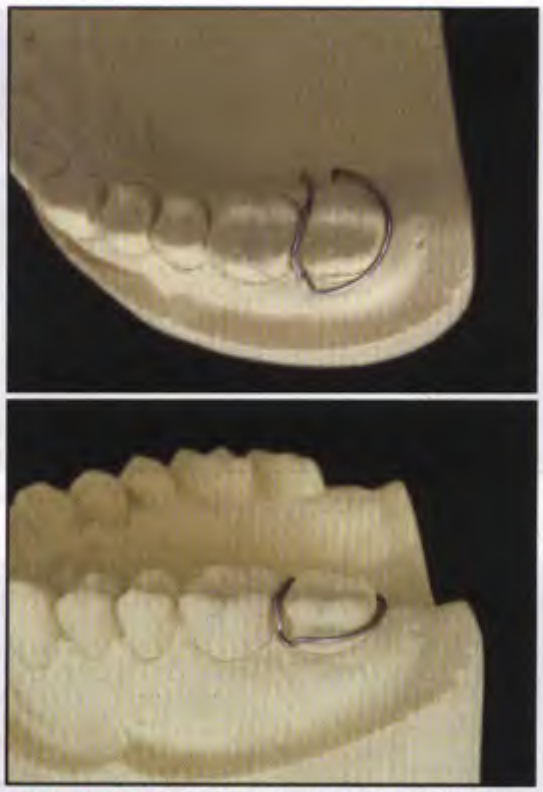


Fig. 38.12H: Single arrowhead Adams' clasp

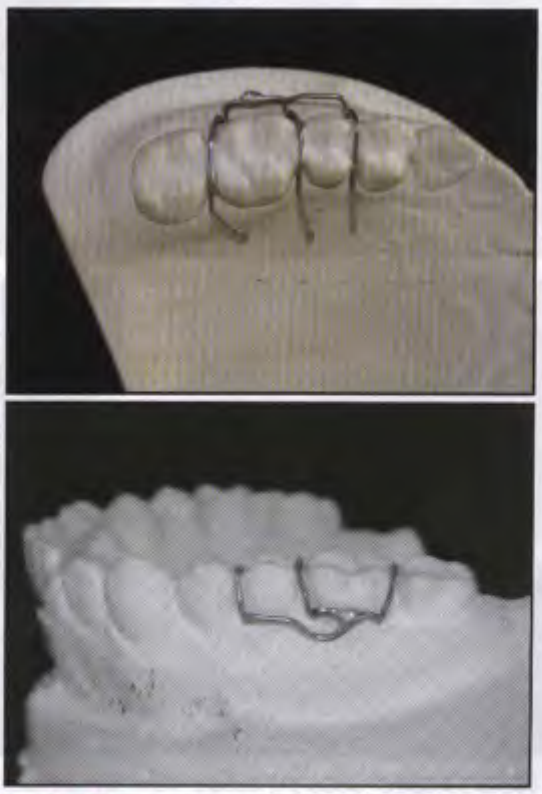


Fig. 38.12I: Adams' clasp with additional arrowhead

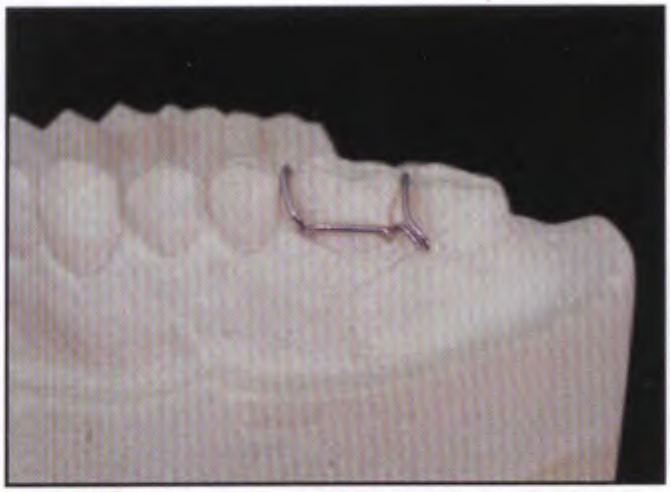


Fig. 38.12J: Adams' clasp with distal extension

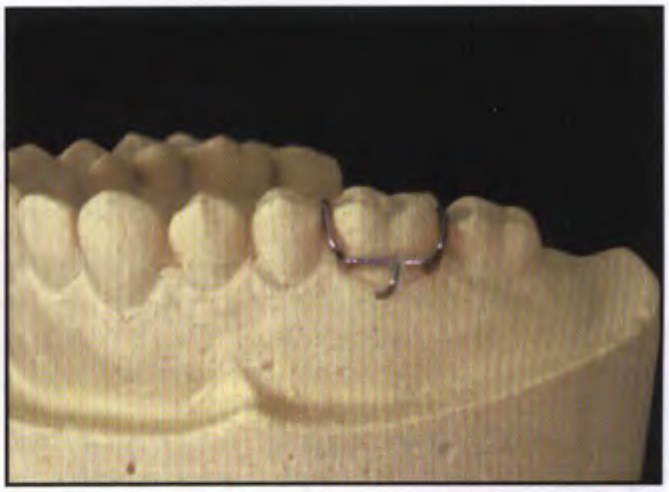


Fig. 38.12K: Adams' clasp with J hook





Fig. 38.12L: Adams' clasp with helix





Fig. 38.12M: Adams' clasp with soldered buccal tube

vii. *Adams' clasp on incisors and premolars* Adams' can be fabricated on any tooth and for even a span of two teeth (Fig. 38.12N).

In every case, the basic form of the clasp is maintained so that clasping efficiency is undiminished.

Southend Clasp

This clasp is used for retention in the anterior region. The clasp is constructed along the gingival margin of both the maxillary central incisors (Fig. 38.12O) and the distal ends end as retentive areas on the palatal side. This clasp can be used when upper incisors are not proclined and there is a limited undercut. In case of proclined incisors, the clasp is flexed unnecessarily during placement and removal of the appliance and can fracture frequently.



Fig. 38.12N: Adams' clasp on incisors



Fig. 38.12O: Southend clasp

Triangular Clasp

These are small triangular-shaped clasps, which are used to provide additional retention. Used alone, they cannot provide adequate retention and are therefore used as accessory clasps. This clasp engages the proximal undercuts between the 2 posterior teeth (Fig. 38.12P) and is carried over the occlusal embrasure to end as a retentive arm on the palatal aspect.

Ball-End Clasp

As the name suggests this clasp is made up of a stainless steel wire (0.7 mm diameter) with a sphere or ball-like structure on one end (Fig. 38.12Q). This ball makes use of the mesial and distal undercuts between 2 adjacent posterior teeth. The ball end clasp can be fabricated with a silver solder and is also available in a preformed state. These also provide additional retention.

Crozat's Clasp

It looks like Jackson's clasp, which has a piece of wire, soldered at the base (Fig. 38.12R). This wire engages the mesial and distal proximal undercut. The advantage is that it offers better retention than the full clasp.

FRAMEWORK/BASE PLATE

The material most often used for base plate is cold cure or heat cure acrylic. It forms a major part of the removable appliance. Base plate (Fig. 38.13A) acts as



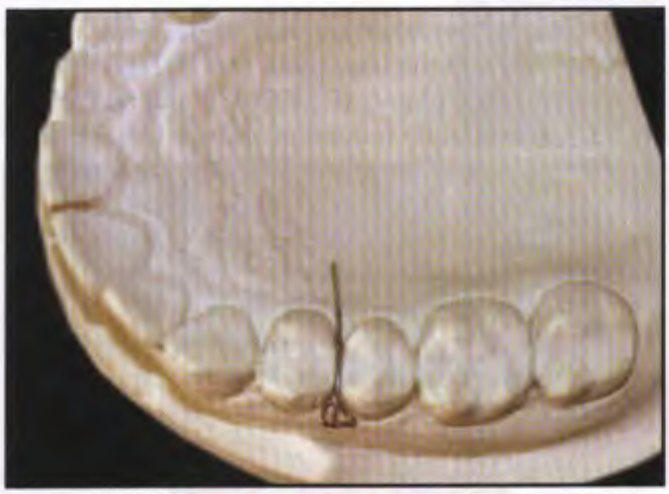


Fig. 38.12P: Triangular clasp

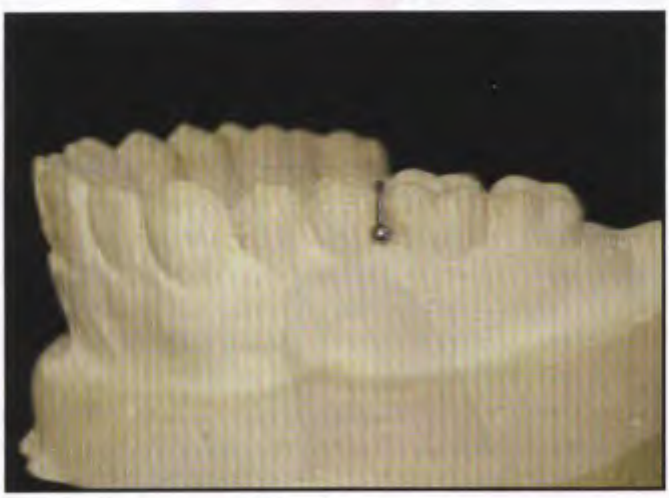


Fig. 38.12Q: Ball-end clasp



Fig. 38.12R: Crozat's clasp

a support for pressure sources and distributes the reaction of these forces to the anchorage areas.

USES OF BASE PLATE

1. It incorporates both the retentive and active components into a single functional unit.
2. It helps in anchorage and retention of the appliance in the mouth.
3. It helps resist unwanted drift during tooth movement.
4. It distributes the forces from the active components over a large area.
5. It protects the palatal springs against distortion in the mouth (Fig. 38.3B).
6. Bitie planes can be incorporated into the base plate and used to treat specific problems.

THICKNESS OF BASE PLATE

Base plates should not be made unduly thick. It should be of minimum thickness to be comfortable to the patient. A single thickness of wax (1.5-2 mm) is sufficient in upper base plates. Base plate should not be thickened over area to embed the tags of the clasps (Fig. 38.13B) if the base plate is thick it fills up the mouth, interferes with speech and will not be tolerated by the patient.

EXTENSION OF BASE PLATE

In maxillary arch, if too much of the palate is covered by acrylic, it can produce nausea for the patient. This problem can be minimized by extending the base plate

till the distal of the first molar and slightly cutting it forward in the midline (Fig. 38.13C). This ensures adequate strength and gains maximum anchorage at the same time.

The lower base plate is not extended too deep to avoid irritation to the sulcus and displacement by the tongue. In case of a lingual undercut, the undercut should be blocked before acrylization (Fig. 38.13D) to facilitate easy removal. The edges should be rounded to avoid tissue injury (Fig. 38.13D).



Fig. 38.13A: The acrylic base plate



Fig. 38.13B: Cut section of maxillary base plate



Fig. 38.13C: 'U' shaped maxillary base plate



Fig. 38.13D: Cross-section of a mandibular plate in the posterior area. The borders should be rounded (right), sharp (left). Undercuts should be filled in (green)

Modification of Base Plate

Bite platforms, whether anterior or posterior can be incorporated into the base plate.

Anterior bite planes (Figs 38.13E and 38.13F) are required for overbite reduction and are made behind the incisors and canines. The biteplane should be flat and not inclined. This is to avoid proclining forces on the mandibular incisor teeth. The thickness should be sufficient to open the bite in the premolar region by 4-5 mm. As the overbite reduces, additional acrylic can be added to raise the platform and continue overbite reduction. Grooves can be provided in the anterior bite

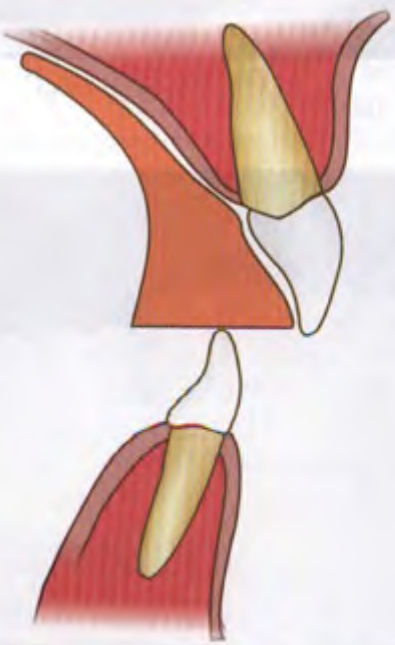


Fig. 38.13E: A correctly executed flat anterior bite plane



Fig. 38.13F: Anterior bite-plane

plane to support the incisal tips of the mandibular incisors (Fig. 38.13G). Also, the maxillary incisors may be capped to prevent their supra-eruption or flaring (Fig. 38.13H). It also aids in retention and increases the anchorage potential of the appliance. An inclined guide plane can also be provided as a modification of the anterior bite plane (Fig. 38.13I). This will cause the patient to bite more forward as compared to normal and may cause the mandible to grow forward. It can also procline the mandibular incisors.

Posterior bite planes (Fig. 38.13J) are used mainly when teeth have to be pushed over the bite. The height of the platform should be sufficient enough to free the teeth, that are to be moved, from occlusal interference with the opposing teeth. It is better to adjust the posterior bite planes to obliterate the freeway space to aid compliance.



Fig. 38.13G: For mandibular incisor edges

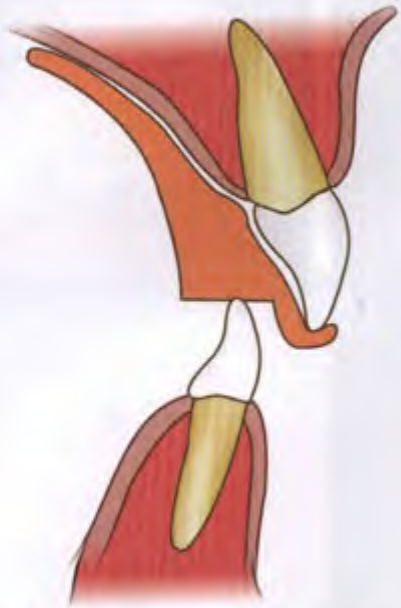


Fig. 38.13H: Anterior bite plane with "capped" maxillary incisor



Fig. 38.13I: Schematic drawing of an inclined anterior guide plate

The material of choice for the framework is usually cold cure acrylic, although heat cure acrylic can also be used. This is because it is easy to use and much faster to fabricate. However, care must be exercised to ensure that laboratory processing has eliminated as much residual monomer as possible, which also reduces the porosity in the appliance.

DELIVERY OF REMOVABLE APPLIANCE

At the time the appliance is to be delivered, a number of things should be checked:

1. Prior to placing the appliance, clinician should check for any minute pimples due to blow holes in the cast that could irritate the mucosa and the free edges should be rounded and smooth.
2. The base plate may need some trimming while fitting the appliance in the mouth.
3. Once the appliance is inserted, check for the position of the active and retentive components. The wire components should not irritate/ impinge on any soft tissues. Clasps should fit the teeth accurately.
4. Show the patient in a mirror how to insert and remove the appliance.
5. The patient should be called for a recall visit every 3 weeks.

INSTRUCTIONS TO THE PATIENT

The success of any removable appliance is certain if the patient follows the instructions carefully. The patient and parent should be adequately counseled verbally and it should be reinforced with a written list of 'do's and don'ts'.

1. The patient should be shown in a mirror the insertion and removal of the appliance. Insist that the appliance be maneuvered by the bridges of the clasp and not the labial bow or springs.
2. Patient should be instructed to wear the appliance for 24 hours a day and to remove the appliance only while brushing and also during contact sports and swimming.
3. A high standard of oral hygiene should be insisted upon to avoid the possibility of enamel decalcification.
4. The patient should be instructed to clean the appliance by brushing it with soap and water. Care should be taken while cleaning so as not to bend/ distort any component.

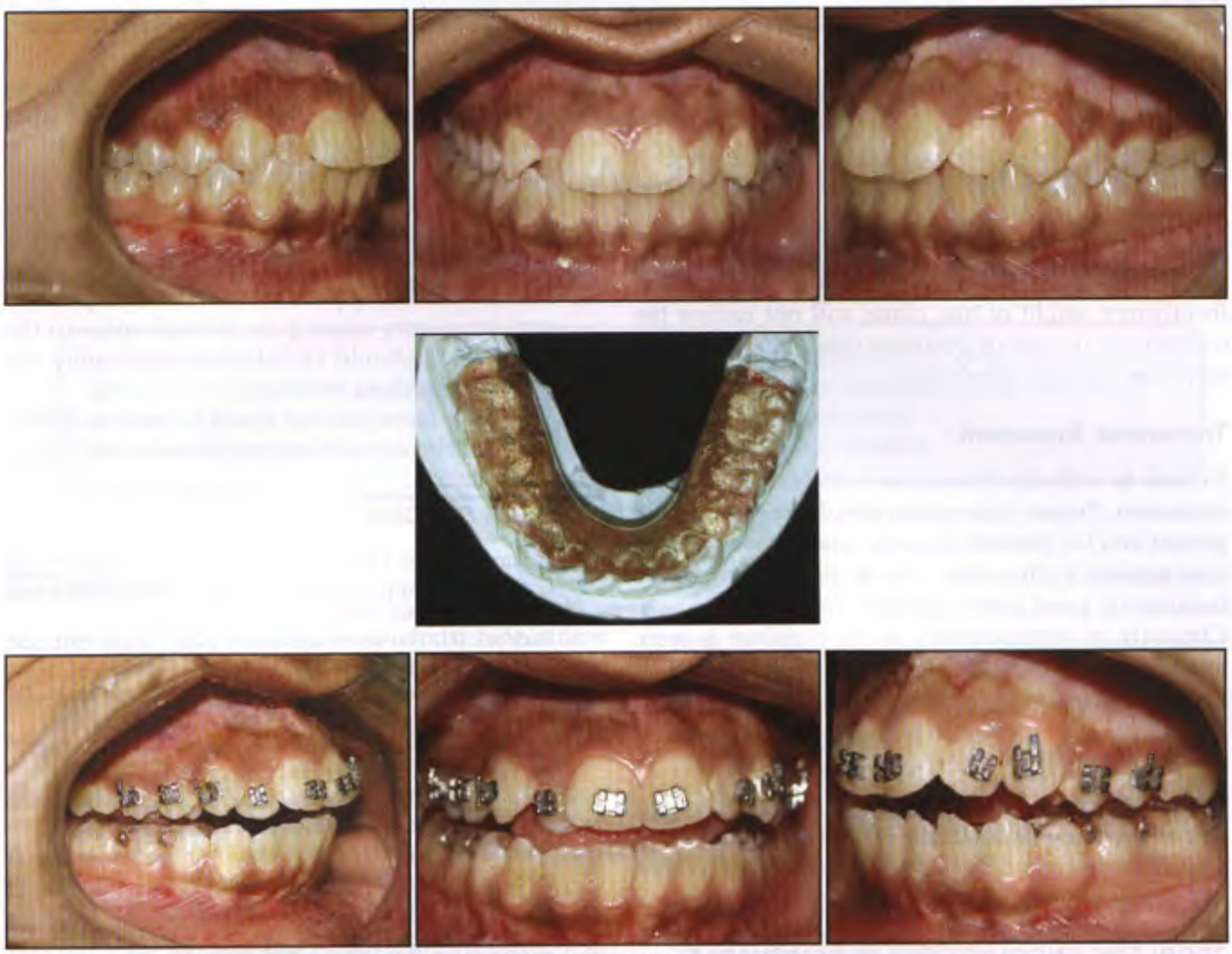


Fig. 38.13J: Posterior bite-plane

5. In case of pain or appliance damage, patient must be told to report immediately to the clinic.
6. Patients having an appliance with screws should be given instructions on how to activate the screw.
7. Patients should be instructed not to leave the appliance out of the mouth for a long period of time as it enhances chances of it getting damaged or distorted.
8. Care should also be taken to keep the appliance away from pet animals when the appliance is not being worn.

COMMON FAILURES FOR NO TOOTH MOVEMENT

ANTEROPOSTERIOR MOVEMENT

Reduction in Overjet

- Sometimes, upper incisors may not be retracted as efficiently. The reason may be that acrylic has not been removed behind the upper incisors.
- Another reason may be the presence of an overbite, which prevents incisor retraction.

Proclination of upper anteriors Inadequate clearance of occlusion prevents teeth from moving anteriorly.

Vertical

The anterior/posterior bite planes should be of such a height that they do not obliterate the freeway space. Thickness of the bite plane can be increased once neurophysiological adaptation has taken place. If the bite plane is too thick it will not be worn by the patient. Insufficient height of bite plane will not reduce the overbite or, in case of posterior bite planes, will not eliminate occlusal interference.

Transverse Movement

Failure to activate the screw will lead to lack of expansion. Proper instructions should be given to the patient and/or parents. In some cases, lower molars also expand at the same rate as the upper molars because of good intercuspation between the two. Clinically, no improvement of the crossbite is seen; lower intermolar distance should be measured to identify this problem.

Patient Compliance

The success of any removable appliance is dependent on patient compliance. Compliance can be improved by providing a good fitting, well-designed appliance and giving clear instructions to the patient.

PROBLEMS ENCOUNTERED IN REMOVABLE APPLIANCE THERAPY

i. Lack of oral hygiene maintenance will lead to gingival inflammation and enamel hypoplasia. Patient should be instructed to clean the appliance as well as maintain the oral hygiene. Improper cleaning of the teeth can also result in caries. Appliance should be designed in such a way that food traps are not created which also increase the incidence of caries.
ii. Soft tissue irritation can result if the appliance edges are sharp and not rounded off. There should be no sharp nodules and the edges should be smooth to avoid soft tissue irritation and ulceration. Wire components can also cause irritation, e.g. loop of the labial bow can cause vestibular irritation.
iii. Excessive forces applied by the active components can sometimes cause pain or tenderness in the teeth. Care should be taken to apply only the optimum amount of force.
iv. Excessive force can also result in tooth mobility. This can also occur in cases of traumatic occlusion.

FURTHER READING

1. Adams CP. The Design and Construction of Removable Orthodontic Appliances. 4th edition, John Wright and Sons, Ltd. Bristol 1970.
2. Badcock JH. The screw expansion plate. Trans. Brit. Soc. Orthod pp 1911;3-8.
3. Banks PA, Carmichael G. Modified arrow-head clasps for removable biteplanes. J Clin Orthod 1998;32:377-78.
4. Crozat GB. Possibilities and use of removable labiolingual spring appliances. Internat J Orthodontia 1920;6:1-7.
5. Graber TM, B Neumann. Removable Orthodontic Appliance. WB Saunders Co. Philadelphia, 1977.
6. Locks A, Westphalen GH, Ritter DE, Ribeiro GU, et al. A new wraparound retainer design. J Clin Orthod 2002;36:524-26.
7. Noar JH, Evans RD. Rare earth magnets in orthodontics: an overview, Brit J Ortho 1999;26:29-37.
8. Nord CFL. Loose appliances in orthodontia. Dental Cosmos 1928;70:681-87.
9. Schwarz AM, M Gratzinger. Removable Orthodontic Appliances. WB Saunders Co, Philadelphia, 1966.
10. Tulley WJ, AC Campbell. A Manual of Practical Orthodontics. J Wright and Sons, Bristol, 1960.
11. Zachrisson BU. Bonding in orthodontics. In Graber TM, Vanarsdall RL(Eds). Orthodontics: current principles and techniques, ed 3, St Louis, Mosby.

39 Fixed Orthodontic Appliances

Gurkeerat Singh

- Introduction
- Advantages of fixed orthodontic appliances
- Disadvantages of fixed orthodontic appliances
- Indications of fixed appliances
- Contraindications to fixed orthodontic appliances
- Components of fixed orthodontic appliances
  - Active components
  - Passive components

INTRODUCTION

As the name suggests, fixed orthodontic appliances include orthodontic devices, which have attachments that are fixed on to the tooth surface, and forces are exerted via these attachments using archwires and/or other auxiliaries. The appliances cannot and should not be adjusted or removed by the patient.

With fixed orthodontic appliances the control over treatment mechanics shifts more directly into the clinicians hands and the patient is restricted to simply maintaining the appliance and oral hygiene and may be changing certain force applying devices, e.g. elastics. Patient compliance is rarely a problem. The control achieved with fixed orthodontic appliance is far greater as compared to removable appliances and the teeth can be moved virtually in all the three planes of space.

ADVANTAGES OF FIXED ORTHODONTIC APPLIANCES

1. *Precise tooth control is possible.* The movement achieved is precise and makes it possible to move individual teeth in the three planes of space to achieve perfect alignment of teeth both inter and intra arch.
2. *Multiple tooth movements are possible.* Individual teeth can be moved in all the three planes of space simultaneously, i.e. a tooth can be intruded as well as retracted simultaneously. Also, different teeth can be moved in different directions at the same time, i.e. while one tooth is being derotated another can be retracted, etc.
3. *Patient cooperation is reduced* in comparison to removable appliance wear, but cannot be dispensed with completely.

DISADVANTAGES OF FIXED ORTHODONTIC APPLIANCES

1. *Oral hygiene requirement* Oral hygiene maintenance becomes more difficult. Food debris tend to accumulate around the attachments and their removal becomes difficult.
2. *Esthetics* Fixed appliances are generally made of metal that might not be esthetically acceptable to the patient. The advent of the lingual technique and tooth-colored brackets (made of ceramic/composites/fiber glass) has helped overcome this disadvantage to a large extent.
3. *Special training for operator* Only orthodontists are trained to handle and monitor these appliances. Special training is a must to achieve acceptable results.
4. *Increased cost of treatment* Fixed orthodontic appliances are costly as compared to removable appliances. The attachments used with these appliances are expensive and hence, the cost of the treatment goes up.

5. *Increased chair side time* Since the appliance is fixed, and cannot be removed from the patient's mouth, hence, all adjustments have to be made in the patient's mouth by the operator. This increases the chair side time.
6. Anchorage control is more difficult as compared to removable appliances.
7. Treatment monitoring is more difficult. The patient has to be recalled at regular intervals for appliance adjustments/reactivations. Long-term monitoring is essential to achieve stable results.

INDICATIONS OF FIXED APPLIANCES

Fixed orthodontic appliances are indicated whenever multiple tooth movement is required, e.g. intrusion, derotation, controlled space closure at extraction sites, bodily movement, extrusion or torque control, etc.

CONTRAINDICATIONS TO FIXED ORTHODONTIC APPLIANCES

1. *Poorly motivated patient* The patient should understand that his/her cooperation will be required throughout treatment. The patient's responsibility is not limited to maintaining good oral hygiene but will also involve wearing elastics and/or headgear and keeping appointments at regular intervals, etc.
2. *Poor dental health* A patient, who does not maintain oral hygiene routinely, cannot be expected to maintain the stringent oral hygiene procedures required with fixed appliances in place. Careful consideration should be given to the patient's periodontal status as well. Patients with poor oral hygiene are more likely to suffer from periodontal diseases.
3. *Malocclusions beyond the scope of fixed orthodontic appliances* Malocclusions that are skeletal in nature or otherwise beyond the scope of orthodontics should not be attempted. If the patient refuses surgical intervention as part of an orthodontic treatment plan, he should be properly counseled regarding its necessity rather than proposing compromises and not achieving stable results.
4. *Appropriate training of operator* Only orthodontists are qualified to impart treatment using the fixed orthodontic appliances. Care should be taken by students of dentistry, to only attempt something, which is within the preview of their curriculum and should not try behaving as orthodontists without undertaking proper training from a recognized institution.

COMPONENTS OF FIXED ORTHODONTIC APPLIANCES

The components which form any fixed orthodontic appliance system can be divided into two categories depending upon their ability to generate forces:

ACTIVE COMPONENTS

These include components which are capable of generating tooth moving forces. These include:

a. Separators
b. Archwires
c. Elastics
d. Elastomerics
e. Springs
f. Magnets

Separators

Separators are used to create spaces in between two adjacent teeth, generally for the purpose of banding them.

Initially *soft brass wires*, wires of 0.5 or 0.6 mm diameter were passed interdentally and twisted (Fig. 39.1) to create space. These brass wire separators were painful, the force exerted was not controlled and the twisted end often caused laceration injuries to the buccal mucosa and/or gingival (Fig. 39.2).



Fig. 39.1: Brass separators in place medial and distal to the maxillary left first molar



Fig. 39.2: Laceration injury caused because of loosening of the twisted end of the brass separator

Kesslying separators These are made of 0.016" special plus Australian wire with helices at the closed end (Fig. 39.3A). The open straight arm passes below the contact (Figs 39.3B and C) sufficient space is created within 48 hours of application.

Ring separators These are small elastic rings (Fig. 39.4A) that are stretched and passed through the interdental contacts using the separator placing pliers (Figs 39.4B and C) or using two pieces of dental floss (Fig. 39.4D). The elastic material used to make these ring separators can be either round or with edges. Round ring separators are the most comfortable for the patient as they fit snugly in the interdental region (Fig. 39.4E). Separation takes about 7 days.

Dumb-bell separators These consists of a dumb-bell shaped piece of elastic that is stretched and passed through the contacts between adjacent teeth (Fig. 39.5). The elastic of the separator constricts over time to regain its original space and causes separation.

Archwires

Archwires are available of variable dimensions and materials (discussed in detail in Chapter 30). Archwires are available in the prefabricated mould. They may be of various shapes depending upon the arch form type (Fig. 39.6). The arch form closest to the patient should be chosen unless some change is planned in the arch width.



Fig. 39.3A: The short arm of the separator is held in a Weingart plier



Fig. 39.3B: The long, hooked arm is placed under the contact point and the short arm is pulled laterally by the plier



Fig. 39.3C: The separator is rotated into position with the long, hooked arm of the separator over the contact point and the short arm under the contact point

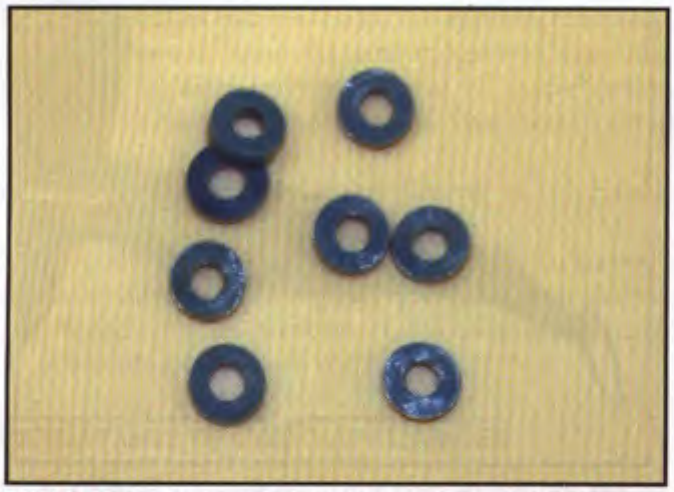


Fig. 39.4A: Elastic separators. The lose ones have a rectangular cut section whereas the ones on the stick are round

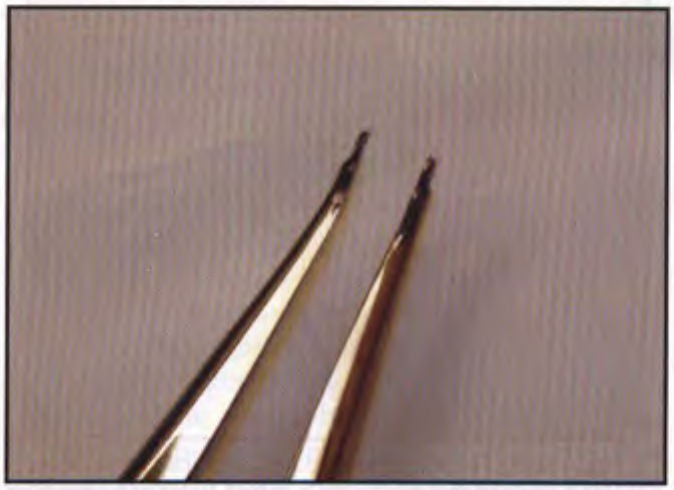


Fig. 39.4B: The separator-placing plier



Fig. 39.4C: Separator-placing plier with a separator stretched on its beaks

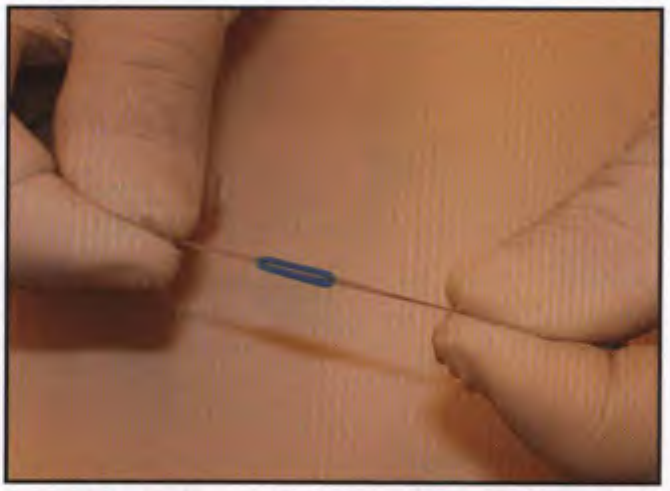


Fig. 39.4D: Placement of elastomeric separators using dental floss. Two pieces of floss are placed through the hole in the center of the separator and are held one in each hand

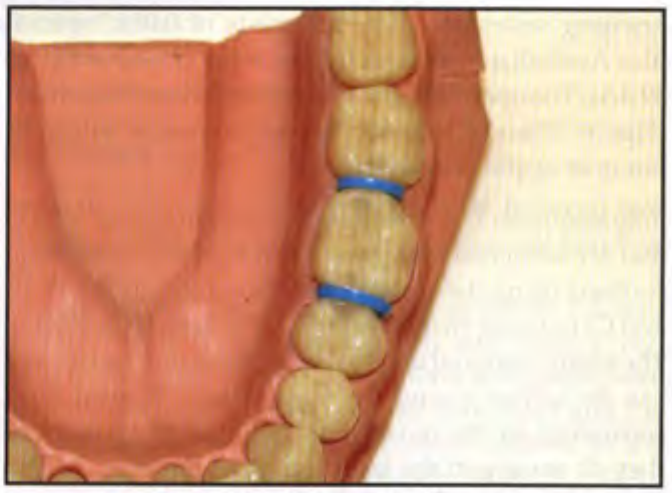


Fig. 39.4E: Snugly fitting elastic separators

Elastics

Elastics (Fig. 39.7) can be of latex or non-latex material. Non-latex elastics deteriorate less as compared to the latex elastics in the oral environment.

Elastics are available in various strengths, which is dependent upon their diameter and thickness. The elastics are chosen according to the purpose of their use. They may be color coded according to strength.

Elastics are used mainly in the following six ways.

Class I elastics These are intra-arch elastics placed mainly between the molars and the anteriors in the same arch (Fig. 39.8). They are used to close the

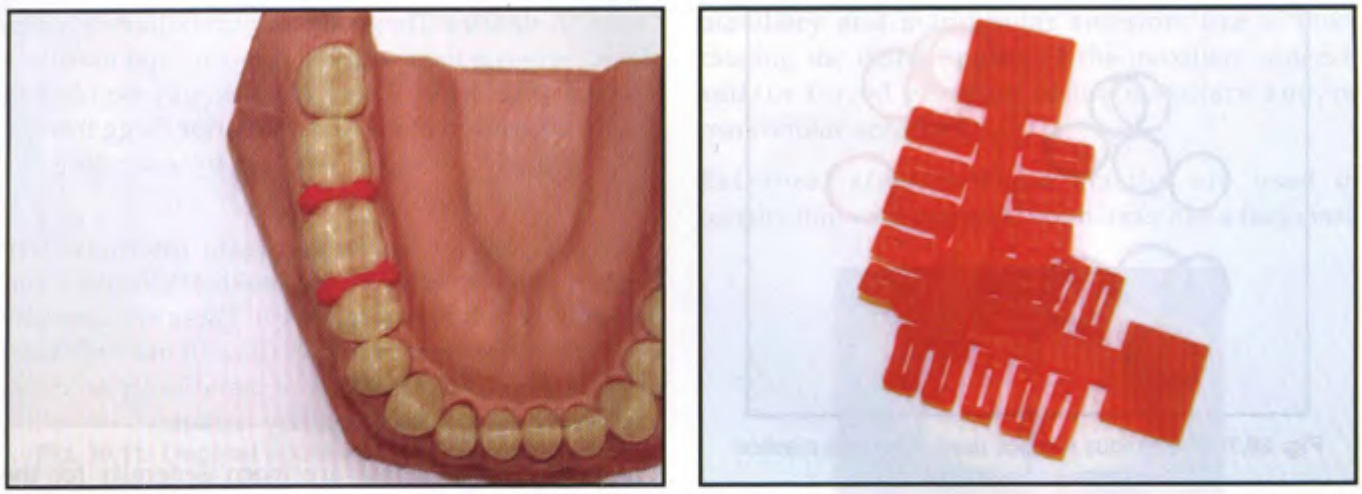


Fig. 39.5: Dumbell separator



Fig. 39.6: Various arch forms



Fig. 39.7: The various elastics used in routine practice

extraction spaces by retracting the anteriors (lighter force elastics) or protraction of posterior teeth (heavier force elastics).

Class II elastics These are intermaxillary elastics placed between the mandibular molars and maxillary anterior (Fig. 39.9). These elastics may be used to produce intrusion of maxillary anterior (Begg therapy stage I) or decrease the over jet by retracting the maxillary anterior.

Class III elastics These are again intermaxillary elastics placed between the maxillary molars and mandibular anteriors (Fig. 39.10). These are generally used in the treatment of Angles Class III malocclusions to bring about the retraction of mandibular anteriors and protraction of the maxillary molars.

Diagonal elastics These are worn generally for the correction of midline deviations. The elastic is worn across the anterior teeth diagonally (Fig. 39.11).



Fig. 39.8A: Class I elastics, the horizontally placed green elastics seen in the above photographs



Fig. 39.9: Class II elastics are placed between the mandibular molars and the maxillary anteriors



Fig. 39.8B: Horizontal pink colored elastics are Class I elastic

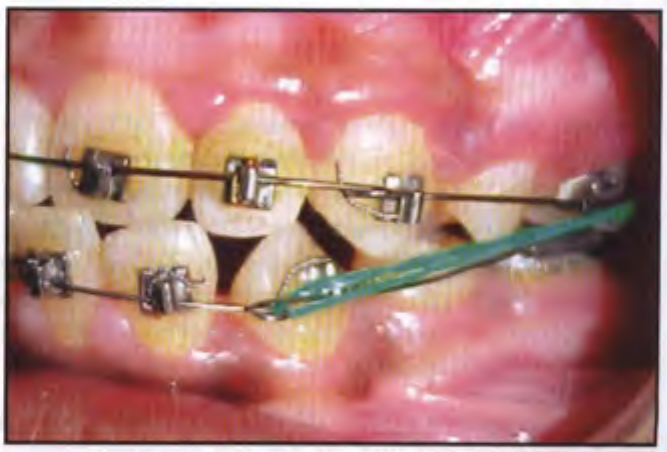


Fig. 39.10: Class III elastics



Fig. 39.11: Diagonal elastic worn to correct the midline

Cross bite elastics These intermaxillary elastics are used to correct cross bites in the buccal segments (Fig. 39.12). Their placement is dependent upon the tooth in cross bite, generally from the palatal surface of the maxillary molars or premolars to the buccal of mandibular molars or premolars. Small dimension elastics are used for this purpose.

Box elastics These elastics are used to correct anterior open bites (Fig. 39.13). They extend between the maxillary and mandibular anteriors like a 'box', causing the distal tipping of the maxillary anterior and/or forced eruption of the maxillary and/or mandibular anteriors.



Fig. 39.12: Cross bite elastics



Fig. 39.13: Box elastic

Extraoral elastics These elastics are used in conjunction with extraoral appliances like a face mask



Fig. 39.14: Extra-oral elastics (arrows)

(Fig. 39.14). Generally exert high forces (8 oz to 14 oz)

Elastomerics

Elastomerics are used in various forms along with fixed orthodontic appliances. These are generally made of synthetic polyeurythane materials. The various forms of elastomerics used are:

Elastic chains More commonly referred to as E-chains. These are mainly used for space closure (Fig. 39.15). These are available in three different strengths based on the distance between the rings as continuous (Fig. 39.16A) or closed short (Fig. 39.16B) and long (Fig. 39.16C).

Elastic thread or cotton thread Made of special elasticized cotton, it is used to exert forces, which are used to correct derotations, consolidation of anterior spacing (Fig. 39.17), etc.

Elastic ligatures These are used to secure the archwire in edge wise or pre-adjusted edgewise brackets (Fig. 39.18A). These can be easily engaged under bracket tie wings. They are available in various attractive colors (Fig. 39.18B).

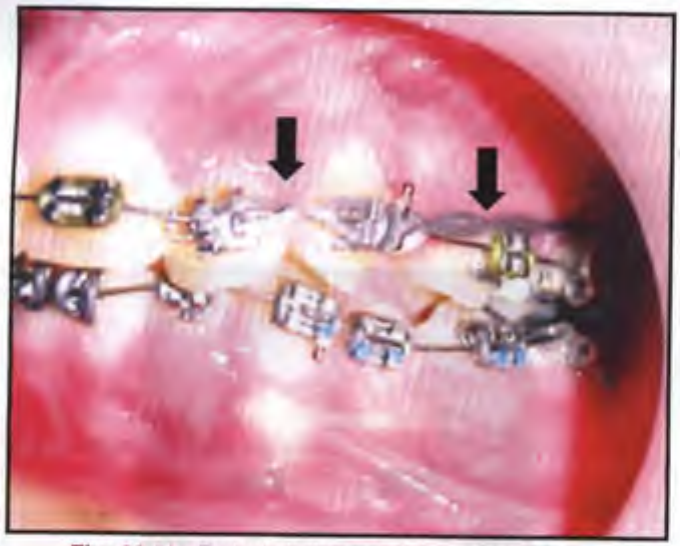


Fig. 39.15: E chain being used for space closure



Fig. 39.16A: Continuous elastic chain

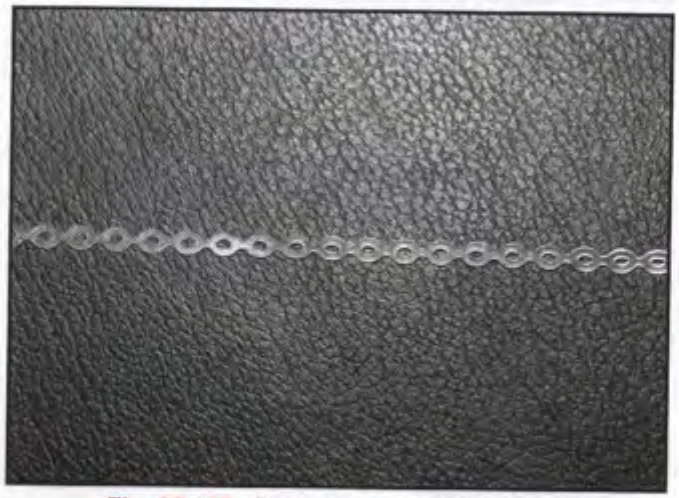


Fig. 39.16B: Closed or short elastic chain

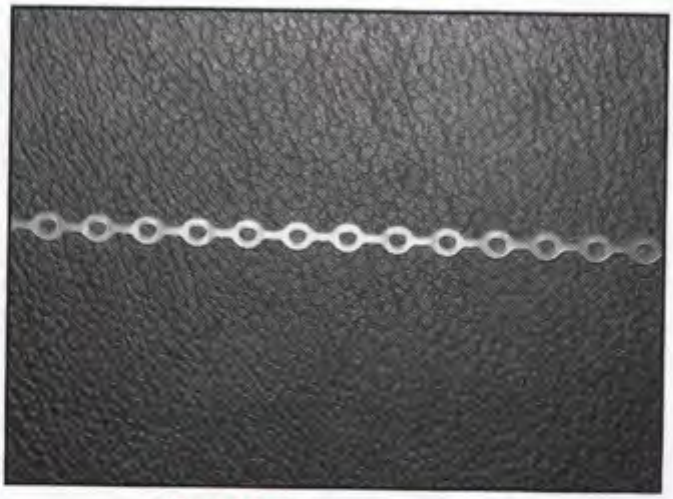


Fig. 39.16C: Long elastic chain



Fig. 39.17: Figure of 8 placement of the cotton thread

Elastic modules or elastomeric links They are made of two elastic rings separated by a variable distance. They are available in variable sizes based on the interring distance (Fig. 39.19). These are generally used to closed spaces or for derotation of teeth.

Springs

Various types of springs are used as auxiliaries to generate tooth moving forces. Springs are mainly used for tooth uprighting and torquing in the Begg's appliance therapy and the tip edge appliance. Springs may be used to open spaces (open coil springs) or to close spaces (closed coil springs). Springs used along with the fixed orthodontic appliances are:





Fig. 39.18A: Elastic ligatures holding the wire in the bracket slot

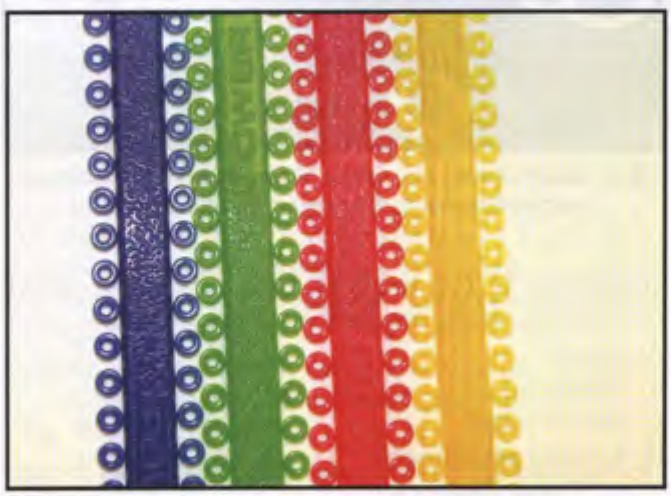


Fig. 39.18B: Elastic ligatures available in various attractive colors

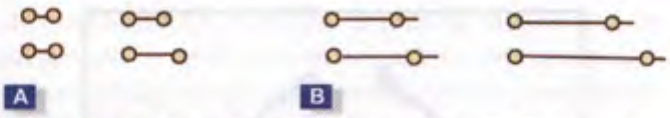


Fig. 39.19: (A) E-1 thru E-4 smaller sizes, (B) E-5 thru E-8 larger sizes

- Uprighting springs
- Rotating springs
- Torquing springs
- Open coil springs
- Closed coil spring

Uprighting springs Generally made of 0.012" or 0.014" Australian wire. They move the tooth root in a mesial or distal direction (Fig. 39.20). The standard designed spring can be used with the Begg and the Tip-edge brackets whereas, the side-winder design was especially made for use with the Tip-edge bracket.

Rotating springs Rotating springs, as the name suggests, provide for a simple and effective means of derotating teeth without the removal of the archwire. These springs are used in the vertical slots of the Begg and the Tip-edge bracket. They are capable of both clockwise and counter clockwise movement depending on their design (Fig. 39.21).

Torquing springs Torquing springs are usually made of 0.012" or 0.014" Australian wire. They are capable of moving the tooth roots in a labial or lingual/palatal direction (Fig. 39.22). Force is generated when the

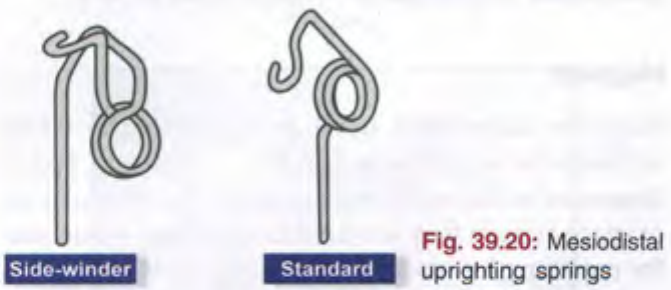


Fig. 39.20: Mesiodistal uprighting springs

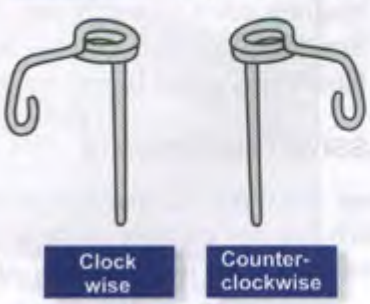


Fig. 39.21: Rotating springs



Fig. 39.22: Torquing spring used for buccolingual root movement

spring is deformed and engaged along the archwire. Force is transmitted to the tooth crown by the spurs, which contact the teeth.

Open coil springs Open coil springs are either made of stainless steel or nickel titanium alloy. The force exerted also, depends upon the diameter of the wire of which the spring is made. The spring of appropriate length is compressed between two or more teeth to open up the space between its points of attachment (Fig. 39.23).

Closed coil springs Closed coil springs can be made of stainless steel or nickel titanium alloys. They are used to close spaces. Once the spring is stretched and attached at two ends, it tries to achieve its prefabricated length by closing the gap between its points of attachment (Fig. 39.24).

Magnets

Magnets have been used along with the fixed orthodontic appliances for the purpose of space closure as well as regaining lost space. For the purpose of space closure they are used in attraction mode and for regaining lost space in repulsion mode.

Magnets used presently are:

- Samarium cobalt magnets—$SmCo_5$ and Sm_2Co_{17}
- Neodymium iron boron magnets—Nd_2 $Fe_{14}B$

PASSIVE COMPONENTS

These are those components of the fixed appliances which are not capable of generating tooth moving forces but help in providing attachment for other auxiliaries to the tooth or retaining other active components of the appliances. These include:

A. Bands
B. Brackets
C. Buccal tubes
D. Lingual attachments
   a. lingual buttons
   b. lingual seating lugs



Fig. 39.23: Open coil spring in place



Fig. 39.24: Closed coil spring stretched from the molar to canine bracket for the retraction of the canine

c. lingual eyelets
d. lingual cleats
e. lingual sheaths
f. lingual elastilugs
g lingual ball hooks

E. Lock pins
F. Ligature wires

Bands

These are metal attachments that are cemented to individual teeth and provide a place for attachment of other auxiliaries like buccal tubes, lingual buttons, etc. These auxiliaries can be either welded or soldered to the bands.

Bands can be either custom fabricated for individual teeth (Table 39.1 and Figs 39.25A to F) or selected from the various sizes available commercially for different teeth (Fig. 39.26).

Banding is preferred on teeth that are likely to experience excessive forces, e.g. mandibular molar (Figs 39.27A and B), mandibular premolars (Fig. 39.28), maxillary second molars (Fig. 39.29) or anterior teeth in cross-bite (Fig. 39.30). Banding might also be employed in teeth that have large metal restorations (structurally weak) or having metal prosthesis/crowns (bondings is difficult or weak).

Table 39.1: Steps of banding

Step I Separation of adjacent teeth can be achieved using separators for a duration of 2 to 7 days depending upon the separator used.
Step II Selection of band material is critical. Thinner band material lesser in width is used for anterior (0.010 × 3.80 mm) teeth and thicker band material broader in width is used for premolars (0.12 × 4.55 mm) and molars (0.15 × 4.55 mm).
Step III Pinching the band—Band material of adequate length is cut and welded at the ends (Fig. 39.25A). The band is adapted around the teeth using a band pusher (Fig. 39.25B) and pinched using the band pinching pliers or a Howe plier (Fig. 39.25C). The pinched band is removed from the tooth and welded close to the pinched ends. Extra band material is cut and bent in a distal direction and welded (Fig. 39.25D). The margins are smoothered and gingival contouring done on the mesial and distal gingival margins using a dental stone (Fig. 39.25E).
Step IV Fixing the attachments—Attachments can be welded or soldered in place. Welding is more commonly performed (Fig. 39.25F)
Step V Cementation of the band can be done using any of the luting cements. Adequate moisture control is essential during cementation. Excess cement can be removed using an explorer after the initial set of the luting cement.



Fig. 39.25A: The band material is welded at the ends



Fig. 39.25B: The band pusher is used to adapt the band



Fig. 39.25C: The band is pinched using a band pinching plier or a Howe plier



Fig. 39.25D: The extra band material is cut and welded after bending it distally



Fig. 39.25E: The mesial and distal gingival aspects are contored



Fig. 39.25F: The tube or other attachment are welded in place

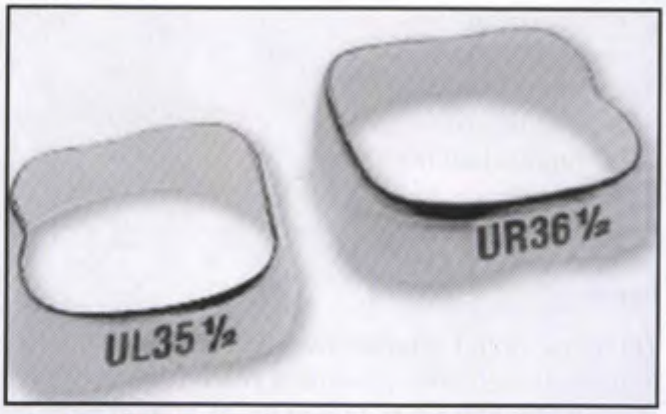


Fig. 39.26: Commercially available molar bands



Fig. 39.27A: Banded mandibular 1st molars



Fig. 39.27B: Mandibular molars are the most frequently banded teeth



Fig. 39.28: Mandibular pre-molars might experience frequent bonding failures and might require banding



Fig. 39.29: Banded maxillary 1st and 2nd maxillary molar



Fig. 39.30: A mandibular incisor which was in cross bite was banded

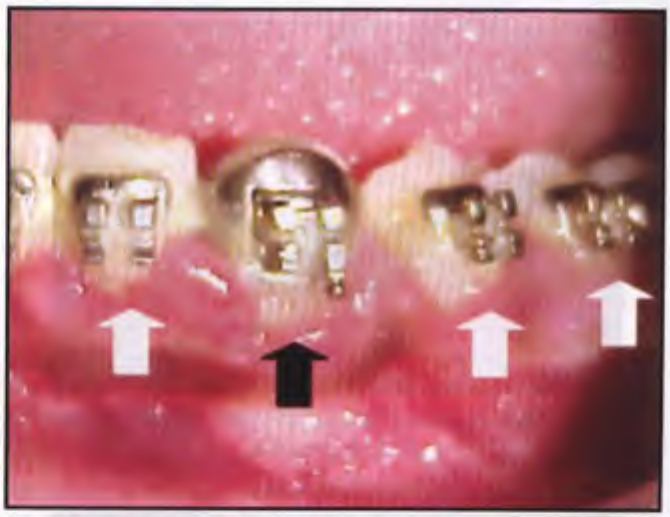


Fig. 39.31: A bracket has been welded to a band and cemented on the mandibular left canine (black arrow), the rest of the brackets have been bonded (white arrows)

Brackets

A bracket is defined as a device that projects horizontally to support auxiliaries and is open on one side usually in the vertical or horizontal.

Brackets are of various types depending upon the technique used. They are discussed in detail along with the individual fixed orthodontic appliances and the chapter on orthodontic materials.

Brackets can either be welded to bands (Fig. 39.31), which are then cemented to individual teeth or can be bonded (Table 39.2 and Figs 39.32A to G). Bonding has its own inherent advantages (Table 39.3) and disadvantages (Table 39.4) over banding.

Buccal Tubes

Buccal tubes are horizontal hollow tubes, round, rectangular or oval in shape. They are generally used on molars and help provide better three dimensional control of these anchor teeth. They can be classified as:

a. Classification based on mode of attachment
   - Weldable—can be welded on-to bands (Fig. 39.33A)
   - Bondable—bonded directly to the tooth surface (Fig. 39.33B)

b. Classified according to lumen shape as
   - Round (Fig. 39.34A)
   - Oval (Fig. 39.34B)
   - Rectangular (Fig. 39.34C)

c. According to the number of tubes
   - Single (Fig. 39.35A)

Table 39.2: Steps in bonding

Step I Cleaning is done using water slurry of pumice with a rubber cup or polishing brush (Fig. 39.32A)
Step II Moisture control is achieved using cheek and tongue retractors in conjunction with cotton rolls and saliva ejectors
Step III Enamel conditioning is generally achieved using 27 percent phosphoric acid in gel on liquid form for 15 to 30 sec. (Fig. 39.32B). After which the etched surface is washed and dried leaving behind a white frosty appearance (Fig. 39.32C)
Step IV Sealing agent is painted over the entire etched enamel surface using a small form pellet on brush with a single gingivo-incisal stroke (Fig. 39.32D)
Step V A coat of sealant is also applied on the bracket base. This is followed by a sufficient amount of composite being spread on the bracket base. The bracket is accurately placed under pressure into the tooth surface (Fig. 39.32E). Excess flash is removed using a sickle scaler (Fig. 39.32F). Brackets should appear distinct after bonding (Fig. 39.32G)



Fig. 39.32A: Cleaning done using pumice powder and polishing brush



Fig. 39.32B: Etchant placed on the teeth



Fig. 39.32C: Frosted appearance following etching



Fig. 39.32D: Primer applied to the teeth



Fig. 39.32E: Bracket placed under pressure



Fig. 39.32F: Excess composite removed with a sickle scaler



Fig. 39.32G: Bonding of brackets completed

Table 39.3: Advantages of bonding over banding

1. Bonded attachments are esthetically superior
2. It is faster and simpler
3. It is more comfortable for the patient
4. Arch length is not increased
5. More precise bracket placement is possible
6. Oral hygiene procedures can be performed more easily
7. Proximal stripping can be performed
8. Composite build-ups can be done on the interproximal areas
9. Inventory is reduced as various band sizes don't have to be stored
10. Certain appliances like lingual appliance can only be bonded
11. No band space is left after debonding
12. Caries or hypo-calcification is generally not a problem with bonding

Table 39.4: Disadvantages of bonding over banding

1. A bonded attachment is weaker as compared to a cemented band
2. Rebonding is more complex as compared to re-cementing of bands
3. Debonding is more complex and time consuming than debanding
4. Bonding on the lingual aspect can be difficult at times
5. Bonding might not provide sufficient strength when headgears, etc. are used i.e. auxiliaries which exert large forces are used
6. Protection against interproximal caries is missing

- Double (Fig. 39.35B) used for auxiliary wires or headgear
- Triple (Fig. 39.35C) three tubes—two rectangular and one large round for headgear or lip bumper.

d. Classified according to the technique

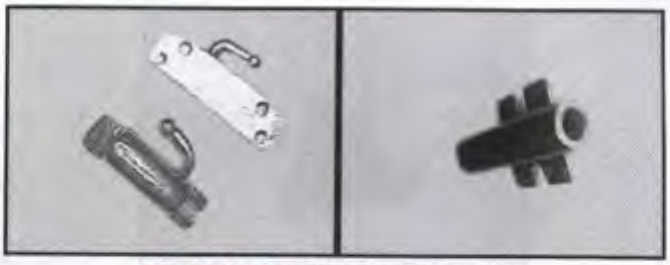


Fig. 39.33A: Weldable molar tubes

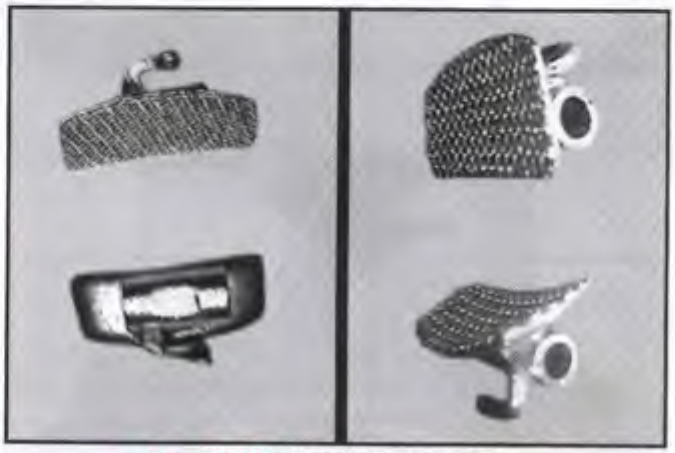


Fig. 39.33B: Bondable molar tubes

- Begg tube (Figs 39.34A and B), round or oval
- Edgewise tube (Fig. 39.35B) rectangular 0° tip and torque values
- Preadjusted edgewise (Fig. 39.35C) rectangular with prescribed in-out, tip and torque values.

Lingual Attachments

These are accessory attachments other than brackets and tubes which are placed on the lingual aspect of teeth (bonded) or bands (welded). These include:

a. *Lingual buttons* (Fig. 39.36) Buttons with variable shaped bases for attachment of elastics or elastomerics. Flat base for centering on molars, curved for mesial or distal placement on molars or extra-curved for use on premolars.

b. *Lingual seating lugs* (Fig. 39.37) These help in seating of bands. Are flat for anteriors and molars and curved for cuspids and bicuspids.

c. *Lingual eyelets* (Fig. 39.38) These are used to tie elastic threads or ligature wires. Hollow in the middle and welded on the two sides.

d. *Lingual cleats* (Fig. 39.39) These are again used for attachment of elastics or elastomerics. Are welded

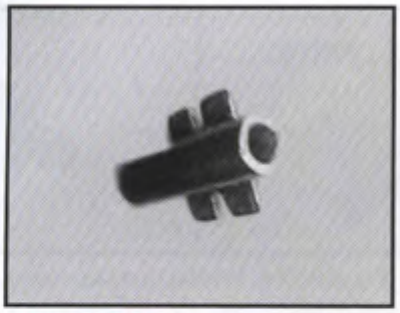


Fig. 39.34A: Round molar tube

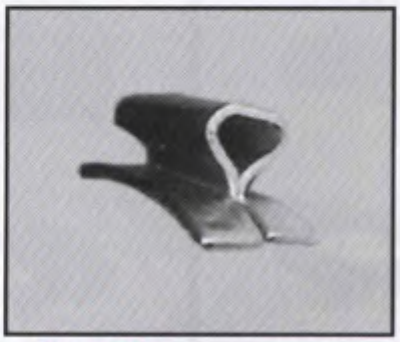


Fig. 39.34B: Oval molar tube



Fig. 39.34C: Rectangular tube



Fig. 39.35A: Single molar tube (Pre-adjusted edgewise)



Fig. 39.35B: Double molar tube (Edgewise), the headgear tube is placed occlusally



Fig. 39.35C: Triple molar tube (pre-adjusted edgewise)

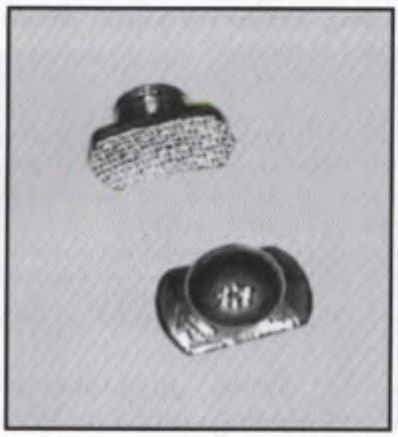


Fig. 39.36: Bondable lingual buttons

in the middle with the ends being open, are also available with a mesh base for bonding.

e. *Lingual sheaths* (Fig. 39.40) These are used for attaching accessories such as transpalatal arches, Ni-Ti molar rotators and expanders.
f. *Lingual elastilugs* (Fig. 39.41) These are used for attaching elastics and are available as curved for posteriors and flat for anteriors. Both weldable and bondable lugs are available.
g. *Lingual ball hooks* (Fig. 39.42) These are small balls attached to a weldable flat arm. The offset can be mesial or distal. They are used to attach elastics or elastomeric chains/rings from the lingual aspect.

Lock Pins

Lock pins (Fig. 39.43) are either made of brass or soft steel. These are used to hold the wire in bracket slots in the Begg technique or accessories in the tip edge technique.

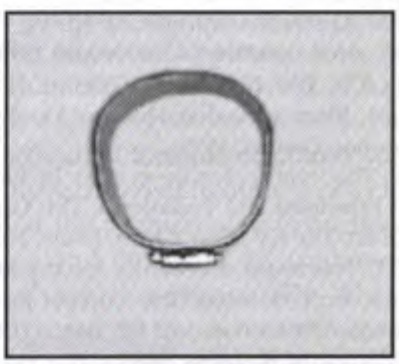


Fig. 39.37: Lingual seating lug welded to a premolar band

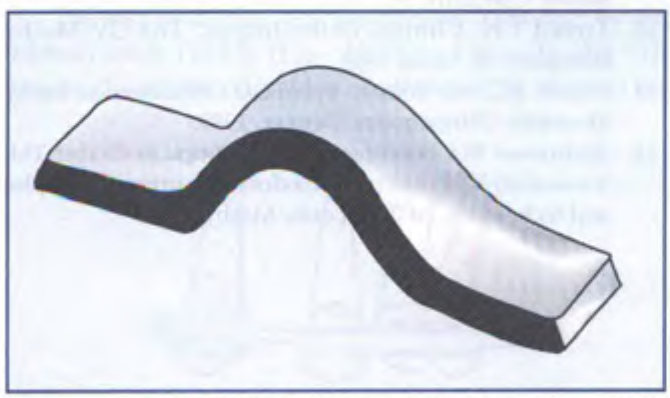


Fig. 39.38: Easy-threading eyelets



Fig. 39.39: Versatile precision cleats

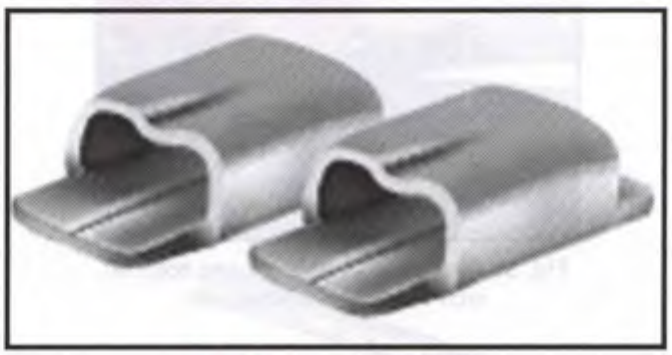


Fig. 39.40: Lingual sheaths



Fig. 39.41: Elastilugs



Fig. 39.42: Lingual ball hook

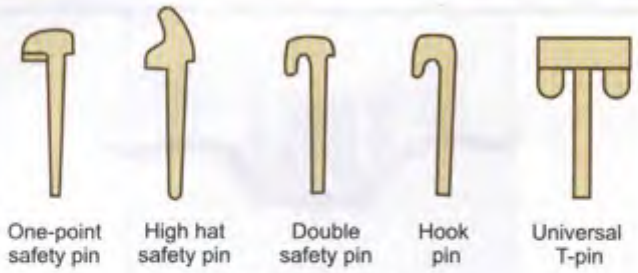


Fig. 39.43: Lock pins



Fig. 39.44A: Ligature wire used to hold the arch-wire in the bracket slot

Ligature Wires

Ligature wires are soft stainless steel wires of 0.008 to 0.010 inch in diameter. These may be used to hold / ligate the archwire in brackets (Fig. 39.44A) or to tie segments of teeth together (Fig. 39.44B).



Fig. 39.44B: Teeth ligated to prevent spaces opening up

FURTHER READING

1. Angle EH. Treatment of malocclusions of the teeth. Angle's system (7th edn). The SS White Dental Manufacturing Company Philadelphia, 1907:191.
2. Hobson RS, Rugg-Gunn AJ, Booth TA. Acid-etch patterns on the buccal surface of human permanent teeth. Arch Oral Biol 2002;47:407-12.
3. Lazzara DJ. Lingual force on the Goshgarian palatal bar. Unpublished Master's Thesis, Loyola University, Chicago, 1976.
4. Lisenby WC, Bowman SJ. Accurate band positioning in impressions. J Clin Orthod 2002;36:500.
5. Mandall NA, Millett DT, Mattick CR, Hickman J, Worthington HV, Macfarlane TV. Orthodontic adhesives: a systematic review. J Orthod 2002;29:205-10.
6. McNamara JA. Jr Utility arches. J Clin Orthod 1986;20:252-56.
7. Noar JH, Evans RD. Rare earth magnets in orthodontics: an overview, Brit J Ortho 1999;26:29-37.
8. Park DK. Australian uprighting spring for partially impacted second molars. J Clin Orthod 1999;33:404-405.
9. Ricketts RM, RW Bench, CF Gugino, JJ Hilgers, RJ Schulhoff. Bioprogressive Therapy Hocky Mountain Orthodontics, Denver, 1979.
10. Root TL. The level anchorage system. In: Orthodocntics: Current Principles and Techniques TM. Graber and BF Swain (Eds). The CV Mosy Co. St. Louis, 1985.
11. Roth RH. Treatment mechanics for the straight wire appliance. In: Orthodonctics: Current principles and Techniques. TM Graber and BF Swain (Eds). The CV Mosby Company, St. Louis, 1985.
12. Roth RH. Treatment mechanics for the straight wire appliance. In: Orthodontics: Current Principles and Techniques. TM Graber and BF Swain (Eds). The CV Mosby Company, St. Louis, 1985.
13. Tweed CH. Clinical Orthodontics. The CV Mosby Company, St. Louis 1966.
14. Wilson RC, WL Wilson. Enhanced Orthodontics. Rocky Mountain Orthodontics. Denver, 1988.
15. Zachrisson BU. Bonding in orthodontics. In Graber TM, Vanarsdall RL(editors): Orthodontics: current principles and techniques, ed 3, St Louis, Mosby.

40 The Edgewise Appliance

Gurkeerat Singh

- Introduction
- Treatment steps
- Bracket specifications
- Bracket position
- Archwire fabrication
- First order bends
- Second order bends
- Third order bends

INTRODUCTION

The term "edgewise" refers to the method by which a rectangular archwire is inserted into the bracket, i.e. on edge. The edgewise appliance was introduced to orthodontics in 1925 by Dr Edward H Angle.

Dr Angle's appliance design reflected his changing need for individual tooth control and space requirement to achieve different treatment objectives. In 1907 he advocated the pretreatment extraction of teeth in certain cases and designed an appliance to tip the adjacent teeth into these spaces (Fig. 40.1). By 1910 he became convinced that a full compliment of teeth was essential and advocated expansion for gaining space. His endeavor to achieve three dimensional tooth controls led to the advent of the pin and tube appliance (Fig. 40.2) the same year.

The pin and tube appliance was followed by the ribbon arch (1915) (Fig. 40.3) and finally the "tie bracket" and the edgewise appliance (Fig. 40.4) in the year 1925. The edgewise bracket proved to be far superior to its predecessors and not only provided three dimensional control of individual teeth but also facilitated wire changes.

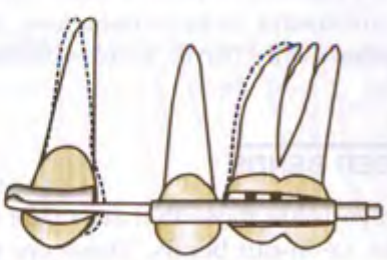


Fig. 40.1: Appliance designed by EH Angle (1907)



Fig. 40.2: Pin and tube appliance

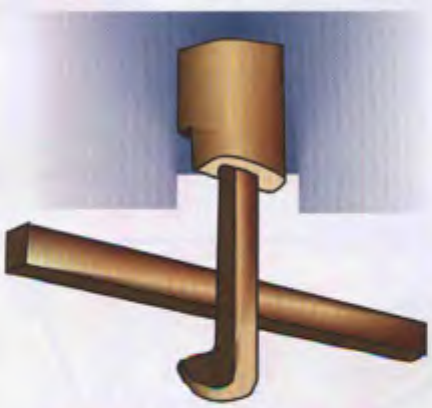


Fig. 40.3: Ribbon arch appliance

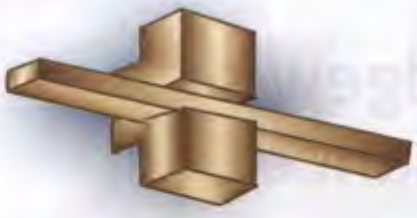


Fig. 40.4: Edgewise appliance

Charles H Tweed joined case and others in recommending extraction of teeth as means of gaining space to correct malocclusions. Tweed can be credited with establishing a method of closure of extraction spaces in a proper sequential manner for optimum results in orthodontic treatment.

TREATMENT STEPS

Tweed used the diagnostic facial triangle (Fig. 40.5) for diagnosis and treatment planning (discussed in the chapter on Cephalometrics). He also advocated the concept of "anchorage preparation". Anchorage preparation was done to prevent the mandibular and maxillary molars from drifting anteriorly in response to the intermaxillary elastics used for retracting the anterior teeth.

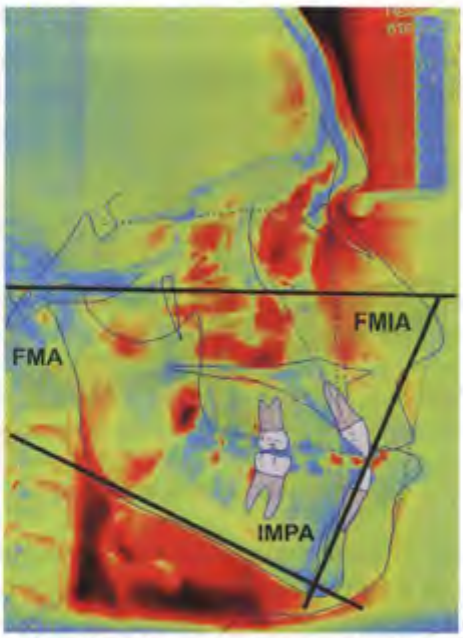


Fig. 40.5: Cephalometric tracing with planes and diagnostic angles

BRACKET SPECIFICATIONS

The edgewise bracket has a bracket slot measuring 0.022" × 0.028" with single or double tie-wings. The slot projects horizontally from the base of the bracket (Fig. 40.6). Both, bondable and weldable brackets are available.



Fig. 40.6: Edgewise brackets

BRACKET POSITION

The brackets on the maxillary centrals, laterals and cuspids were placed 3.5, 3.0 and 4.5 mm, respectively from the incisal edge to the bracket base. The maxillary bicuspid brackets were placed 3.5 mm from the buccal cusp tips and the molar brackets/tubes were placed in the middle third of the crown. The mandibular incisor brackets were placed 2.5 mm from the incisal edges. The mandibular cuspid brackets were placed 3.5 mm from the incisal tips and the bicuspids 3.0 mm. The mandibular molar tubes were placed in the middle third of the crowns. All the brackets were centered mesiodistally on the buccal surfaces of the teeth.

ARCHWIRE FABRICATION

The basic archwire is formed on an edgewise arch former using the Bonwill Hawley chart (Fig. 40.7). The width of the archwire is primarily dictated by the inner cuspid and the inner buccal segment width in the original malocclusion. After the archwire width and symmetry are found to be satisfactory, first order, second order and third order bends can be incorporated.

FIRST ORDER BENDS

First order bends are those that are made in the horizontal plane, i.e in-out bends. These are required to make the wire to conform anatomically to the labial and buccal contours of the teeth in a manner that

arranges these teeth in the most ideal position in respect to the inter-, intra-arch and underlying skeletal structure (Figs 40.8A and B).



Fig. 40.7: The Bonwill-Hawley chart



Figs 40.8A and B: First order bends and arch form. (A) Maxillary, (B) Mandibular

SECOND ORDER BENDS

Second order bends are made in the vertical plane (Fig. 40.9) and are used for anchorage preparation or uprightening teeth. They are also used for the paralleling of the roots, and elevation or depressing certain teeth.



Fig. 40.9: Second order bends

THIRD ORDER BENDS

Third order bends are torsion bends (Fig. 40.10) used to tip the crowns or roots labially or lingually or buccally.

The outline of treatment mechanics as proposed by Tweed for the correction of bi-maxillary protraction malocclusion was:

1. Leveling of maxillary and mandibular arches – by sequentially increasing the diameter of the wire used from /0.012" to 0.020" or 0.016" × 0.016" to 0.018" × 0.018" square wires (Fig. 40.11).
2. Space closure
   a. Maxillary and mandibular cuspid retraction—using open coil springs (Fig. 40.12) loops headgears to augment anchorage.
   b. Mandibular incisor retraction on 0.019" × 0.026" archwires with closing loops (Fig. 40.13).
3. Mandibular anchorage preparation—using tip back bends in the buccal segments on a 0.0195" × 0.026" wire (Fig. 40.14).
4. Maxillary Anterior Retraction—bodily retraction with special helical closing loops in a 0.0215" × 0.0275" archwire (Fig. 40.15).
5. Final inter-digitation of the teeth in the buccal segments and artistic positioning of the anteriors—using decreased tip back bends, Class II and/or vertical elastics for settling along with a high pull headgear (Fig. 40.16).

Once the occlusion settles, the appliance can be debanded. Debanding, is followed by a Hawley's type retention appliance.

The technique though far advanced than any previously known was complex and required the clinician to be extremely dedicated and meticulous in his/her wire bending. Patient cooperation in wearing headgears was a must. Since the forces used were heavy the incidence of patient discomfort and root resorption were high.

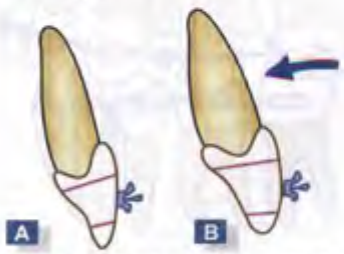


Fig. 40.10: Third order bends, active torque. (A) Lingual root torque, (B) Labial crown torque

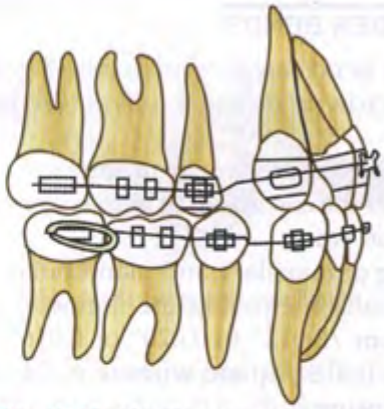


Fig. 40.11: Maxillary and mandibular dentitions after leveling

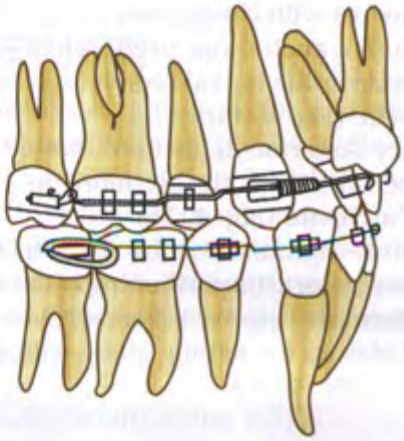


Fig. 40.12: Maxillary cuspid retraction (using open coil springs)

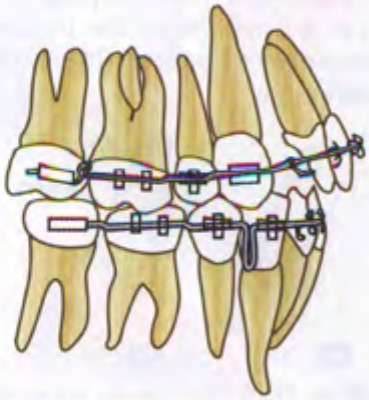


Fig. 40.13: Mandibular incisors retraction

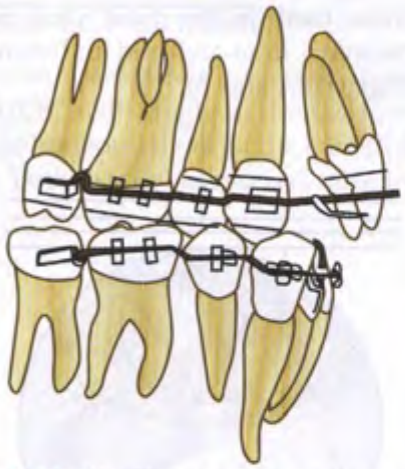


Fig. 40.14: Mandibular anchorage preparation

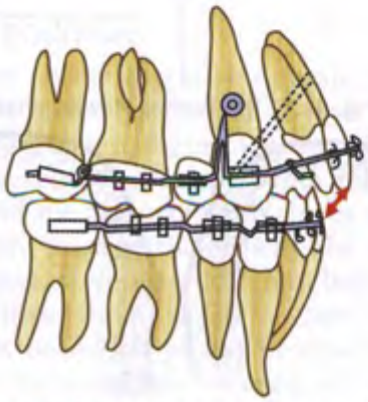


Fig. 40.15: Maxillary anterior retraction

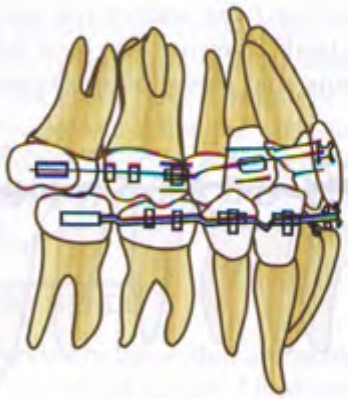


Fig. 40.16: Final interdigitation and artistic positioning

FURTHER READING

1. Angle EH. Orthodontia-ribbon arch mechanism and some new auxiliary instruments, Dental Cosmos, 1920;62:1157-76, 1279-94.
2. Angle EH. Some form of orthodontic mechanism and the reason for their introduction, dental Cosmos, 1916;58:969-94.
3. Angle EH. The latest and best in orthodontic mechanisms, Dent Cosmos 1928;70:1143-58.
4. Angle EH. Treatment of malocclusion of the teeth, ed. 7, Philadelphia, 1907, Thee SS White Dental Manufacturing Company.
5. Bonwill WGA. The geometrical and mechanical laws of the articulation of human teeth- the anatomical articulator. In Litch WF, editor: The American system of dentistry in treatises by various authors: operative and prosthetic dentistry, vol. 2, Philadelphia, 1886-87, Lea and Febiger pp 486-98.
6. Lindquist JT. Edgewise appliance: Orthodontic current principles and technique, edited by Graber TM, Swain BF, St Louis, 1985, CV Mosby Company.
7. Moussa R,O'Reilly MT, Close JM. Long-term stability of rapid palatal expander treatment and edgewise mechanotherapy. Am J Orthod Dentofacial Orthop 1995;108:478-88.
8. Tweed CH. Clinical Orthodontics, CV Mosby Co., 1966.
9. Tweed CH. The diagnostic facial triangle in the control of treatment objectives, Am J Orthod 1969;55:651.
10. Tweed CH. Treatment planning and therapy in the mixed dentition, Am J Orthod 1963;49:900.

41 The Begg Appliance

Gurkeerat Singh

- Introduction
- Components used in the Begg technique
- Diagnosis in the Begg technique
- Three stages of Begg technique

INTRODUCTION

Dr PR Begg introduced the Begg Appliance, to the profession in the 1950s. Dr Begg's studies on the normal occlusion of man made him realize that the teeth continuously migrate mesially and vertically to compensate for attritions of their proximal and occluso-incisal surfaces. Based on this premise, he devised *the light wire differential force technique.*

The technique is designed such that it permits teeth to move towards their anatomically correct positions in the jaws under the influence of very light forces, as would occur naturally in the presence of attrition. Dr Begg advocated the tipping of teeth crowns instead of bodily movement, which were later uprighted, roots paralleled and repositioning achieved. Dr Begg modified the ribbon arch brackets and placed them 'upside down', allowing free tipping.



Fig. 41.1A: Modified ribbon arch type bracket permits both free crown tipping and root movement from auxiliaries when desired



Fig. 41.1B: Frontal view of the Begg bracket

COMPONENTS USED IN THE BEGG TECHNIQUE

MODIFIED RIBBON ARCH BRACKETS (Figs 41.1A to F)

Brackets have a single vertical short, which faces gingivally. The bases are either flat or curved. The brackets can be either welded to bands or directly bonded to the teeth at predetermined distances from incisal edges or cusp tips (Fig. 41.2A). They are usually centered mesiodistally on the labial or buccal surfaces of the teeth (Fig. 41.2B).



Fig. 41.1C: Begg bracket, gingival view. The vertical slot is visible

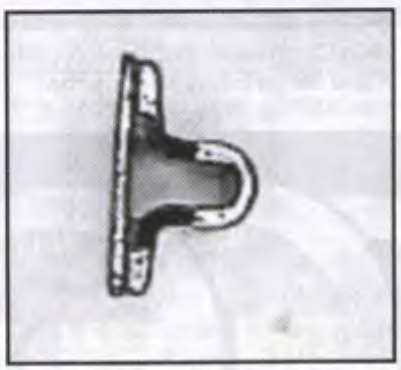


Fig. 41.1D: Begg bracket, occlusal view. The vertical slot is visible



Fig. 41.1E: Begg bracket, lateral view. The archwire slot is well defined



Fig. 41.1F: Bondable Begg brackets

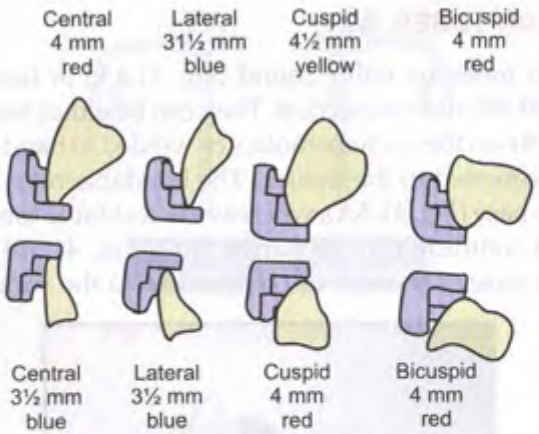


Fig. 41.2A: Standard positioning of brackets with jigs

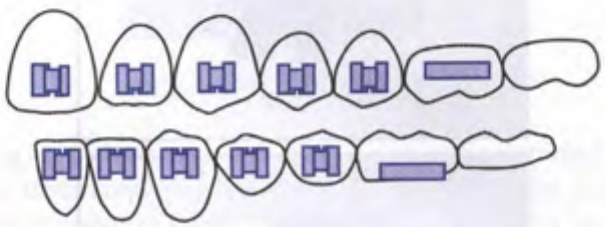


Fig. 41.2B: Brackets are accurately bonded or banded at desired distances from incisal edges on cusp tips



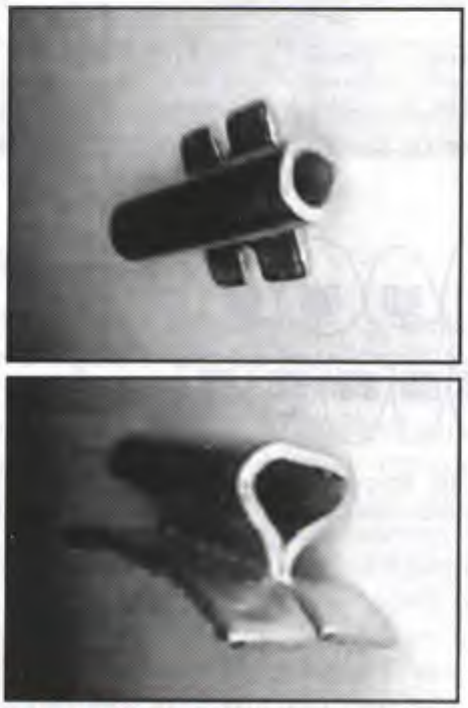
Fig. 41.3: Various types of lock pins used with ribbon arch type brackets. Each is designed to co-act with the archwire and bracket in a different manner to provide the type of tooth movement or control desired

LOCK PINS

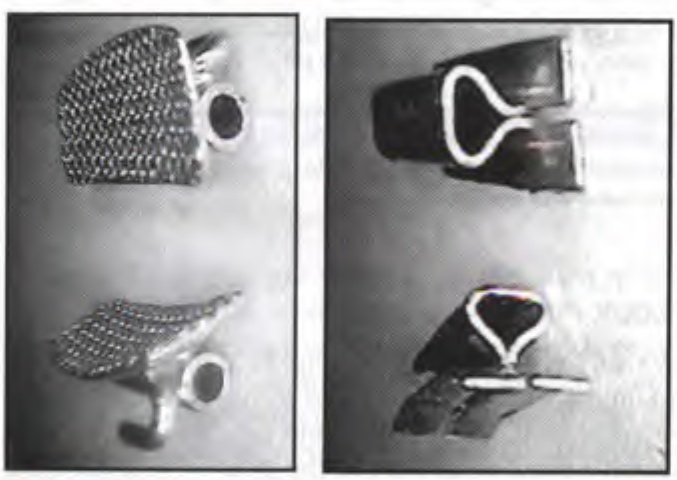
Various types of lock pins (Fig. 41.3) made of brass or stainless steel were designed to hold the wire in the bracket slots. One point safety pin provides a single point contact of the wire on the tooth surface allowing free tipping, which is essential in stages I and II of the Begg technique.

MOLAR TUBES

Molar tubes are either round (Fig. 41.4A) or flat-oval (Fig 41.4B) in cross section. They can be either bonded directly on the anchore molars or welded to bands that are cemented to the molars. The bondable tube has a mesh base (Fig. 41.5A), whereas the weldable tube has a flat contoured metal flange base (Fig. 41.5B). The mesh base is broader in comparison to the weldable base, for adequate bond strength (Fig. 41.5C). They are designed to permit free mesiodistal sliding of the archwire, which is necessary to permit the free disto-lingual tipping of the anterior teeth from the forces generated by the vertical loops and/or elastics.



Figs 41.4A and B: (A) Round molar tube (weldable), (B) Oval molar tube (weldable)



Figs 41.5A and B: (A) Mesh base is provided for tubes that can be bonded. (B) Long flange is available on tubes that are to be welded to metal bands



Fig. 41.5C: Comparison of the mesh (red arrow) and flange bases (black arrow)



Fig. 41.6: Various diameters of the special plus Australian wire spools

ARCHWIRE

High tensile, high strength wires produced by AJ Wilcock of Australia, were especially manufactured for use in the Begg technique. Archwires are available in various diameters and tempers (Fig. 41.6).

ELASTICS

Latex or non-latex elastics of different diameters (Fig. 41.7) are used to apply forces of different magnitude depending upon the stage of treatment.



Fig. 41.7: The various elastics used

ROTATING SPRINGS

Rotating springs, as the name suggests, provide for a simple and effective means of derotating teeth without the removal of the archwire. These springs are used in the vertical slots of the Begg bracket. They are capable of both clockwise and counter-clockwise movement depending on their design (Fig. 41.8).

UPRIGHTENING SPRINGS

Uprightening springs are generally made of 0.012" or 0.014" Australian wire. They move the tooth root in a mesial or distal direction (Fig. 41.9).

TORQUING SPRINGS

Torquing springs are usually made of 0.012" or 0.014" Australian wire. They are capable of moving the tooth roots in a labial or lingual/palatal direction (Fig 41.10). Force is generated when the spring is deformed and engaged along the archwire. Force is transmitted to the tooth crown by the spurs, which contact the teeth. The number of spurs can be altered depending upon the number of teeth to be torqued.

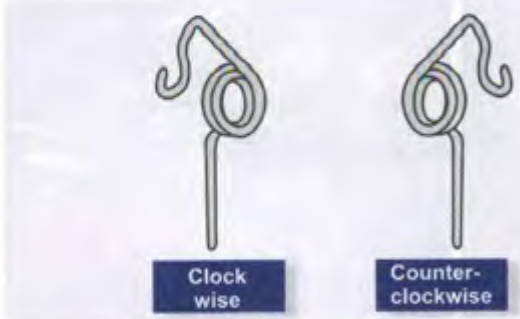


Fig. 41.8: Rotating springs: Clockwise movement

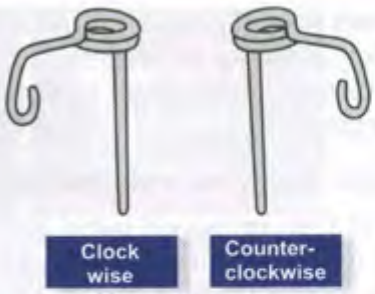


Fig. 41.9: Uprightening springs

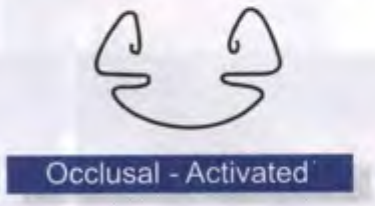


Fig. 41.10: Torquing springs

DIAGNOSIS IN THE BEGG TECHNIQUE

Both the extraction and non-extraction treatments can be carried out using this technique, depending upon the space requirements.

The decision to extract is based upon:

1. Type of malocclusion
2. Severity of malocclusion
3. Treatment goals
4. Age of the patient
5. Skeletal pattern of the patient
6. Anticipated anchor loss
7. Anticipated patient cooperation
8. Ability and experience of the operator.

THREE STAGES OF BEGG TECHNIQUE

From a clinical standpoint, the Begg technique has been divided into three treatment stages. The first two stages involve crown tipping and the third stage is restricted to root tipping.

OBJECTIVES OF STAGE I

1. Open (or close) the anterior overbite
2. Eliminate anterior crowding or spacing

3. Overcorrect rotated cuspids and bicuspids
4. Correct any posterior crossbites
5. Overcorrect any mesiodistal relationship of the buccal segment.

Characteristic Archwires and Elastics of Stage I

Ni Ti (Fig. 41.11A) or looped initial archwires (Fig. 41.11B) are used for initial aligning. Shift to plain archwires as soon as possible (Fig. 41.11C).

Class II elastic of 2-2.5 oz force levels are used in angles Class I or Class II malocclusion.

OBJECTIVES OF STAGE II

Maintain all corrections achieved during the first stage and close any remaining posterior spaces.

Characteristic Archwire and Elastics of Stage II

Plain 0.018" archwire with pre-molar offsets and slight decrease in anchor bends. Class I horizontal elastics with class II elastics (Fig. 41.12) are used to close along spaces.



Fig. 41.11 A: Stage I 0.016" special plus Australian archwire (plain, not looped) in place with Class II yellow elastics. Helices are incorporated mesial to the canine brackets and anchor bends are kept 3-4 mm mesial to the molar tubes



Fig. 41.11B: Stage II 0.018" special plus Australian wire with pre-molar offsets. Class I blue and Class II yellow elastics are also visible



Fig. 41.11C: Stage I .016" special plus Australian archwire in place alows 41.11A: initial alignment down using .016" NiTi wires



Fig. 41.12: Stage II 0.018" special plus Australian wire with pre-molar offsets. Class I blue and Class II yellow elastics are also visible



Figs 41.13 A to C: Stage III 0.020" special plus Australian wire in place with a two spur torquing auxiliary on the maxillary central incisors and uprightening springs on the maxillary and mandibular lateral incisors, canines and pre-molars. Class II elastics are also in place

OBJECTIVES OF STAGE III

All corrections achieved during stage I and stage II are maintained and mechanics are undertaken to achieve desired axial inclination of all teeth.

Characteristic Archwire and Elastics of Stage III

The 0.020" base archwire is used with molar offsets. Uprightening and torquing auxiliaries are engaged in the brackets to correct axial inclinations of individual teeth. Light force Class II or Class III elastics might be made use of, as per requirement (Figs 41.13A to C).

The Begg technique was the first to make use of very light forces. It incorporated overcorrection of the teeth as part of its treatment goal. This was done to compensate for the natural tendency for relapse that occurs when orthodontic appliances are removed. Another outstanding feature of this technique is the long-time duration of 4-6 weeks in between appointments. The technique is popular all over the world, especially Asia and Australia. It is more economical as compared to any other fixed orthodontic technique. Here, we find it pertinent to emphasize that the third stage of this technique is essential and should be completed to perfection to achieve long-term stability of results. As with all orthodontic corrections, the retention phase is mandatory following the completion of the active treatment.

FURTHER READING

1. Begg PR, Kesling PC. Begg orthodontic theory and technique, ed 3, Philadelphia, 1977, W.B.Saunders.
2. Begg PR. Differential force in orthodontic treatment, Am J Orthod 1956;42:481-510.
3. Begg PR. Stone Age man's dentition, Am J Ortho. 1954;40:298-312.
4. Cadman G R. A vade mecum for the Begg technique: Technical principles, Am J Orthod, 1981;67:477-512.
5. Fletcher GGT. The Begg appliance and technique, London. John G. Wright, PSG Inc, 1982.
6. Graber TM, Swain B. Current Orthodontics Concepts and Techniques,, 2nd ed, W.B Saunders 1975.
7. Graber TM, Swain BF. Orthodontics current principles and techniques, St Louis, 1985, CV Mosby Company.
8. Jayade VP, Kakodkar S. Rotational control in the Begg appliance, J Ind Orthod Soc, 1999;32(2):50-57.
9. Jayade VP. Refined Begg for modern times, 1st ed, 2001.
10. Singh Gurkeerat, Shetty VS. Extraction space closure in Stage II of Begg technique, J Ind Orthod Soc, 1999;32(2):58-64.

42 The Pre-Adjusted Edgewise Appliance

Gurkeerat Singh

- Introduction
- Anchorage control
- Leveling and aligning
- Overbite control
- Overjet reduction and space closures
- Finishing and detailing

INTRODUCTION

Until the mid 1970s, the edgewise appliance had become the most popular fixed appliance in use in the United States of America and most probably, the world over.

The standard edgewise bracket, either in single or twin form, having a 90° bracket base and bracket slot angulations required meticulous archwire bending skills by the orthodontist to achieve adequate results. The archwire bending increased the chair side time and, if not performed to perfection resulted in results that appeared 'artificial', failing to achieve ideal tooth relationships compromising the long-term stability.

In 1972 Lawrence Andrews listed the ingredients of occlusion which he considered essential to accomplish the anatomical goal and achieve harmony of occlusion as:

1. Molar relationship
2. Crown angulation
3. Crown inclination
4. Rotational control
5. Good proximal contact
6. Flat curve of Spee

In the edgewise bracket system, to achieve an ideal alignment of teeth all the bends—first order (in and out), second order (mesiodistal) and third order (torquing) have to be built into the archwire by the clinician. But as the name suggests, in the pre-adjusted edgewise appliance (PEA) all these are built into the brackets or the appliance (Figs 42.1A to C).



Fig. 42.1A: First order or in and out bends built with the bracket PEA base



Fig. 42.1B: Second order or mesiodistal tip incorporated into the bracket PEA



Fig. 42.1C: Third order or torquing incorporated into to PEA bracket

Each PEA bracket has particular base thickness (Figs 42.1A and 42.2A) to compensate for the first order bends (in-out bends). When a wire is engaged, the horizontal plane of the wire remains the same while teeth align themselves labiolingually in ideal occlusion (Fig. 42.2B). The slot of the bracket is angulated with respect to the long axis of the tooth. This leads to the teeth being positioned in the ideal mesiodistal angulation from the beginning of the treatment. The torque (or the third order bend) is, either incorporated by angulating the slot with respect to the base (Fig. 42.3A) or by angulating the base of the bracket with respect to the slot (Fig. 42.3B). When a rectangular wire is engaged in the slot, the torque values start expressing themselves.

Based on the "prescription" i.e. the in out, tip and torque values—various clinicians have brought out various PEA systems. Andrew proposed the first

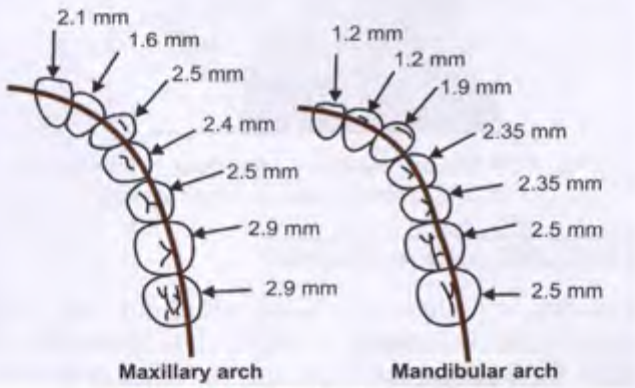


Fig. 42.2A: First order effects

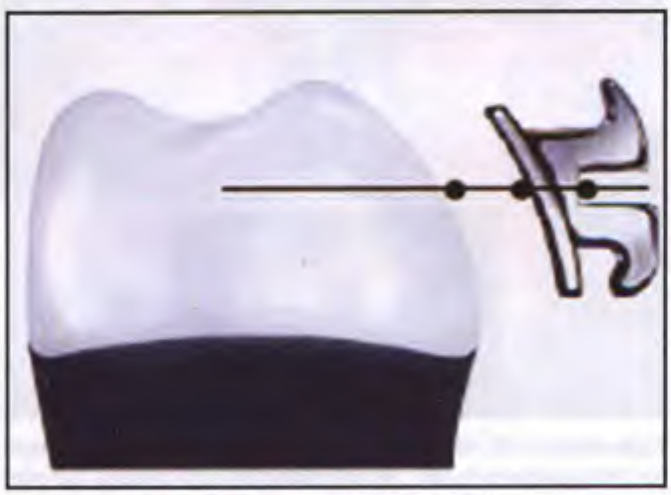
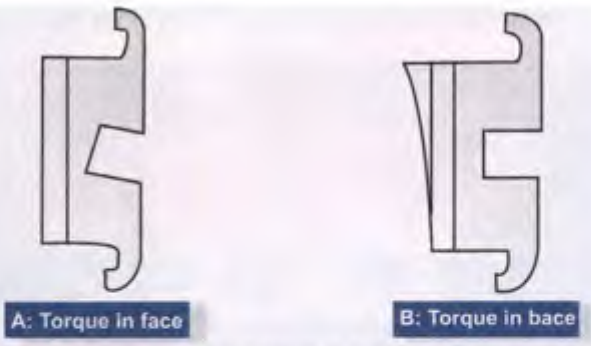


Fig. 42.2B: Positioning in PEA



Figs 42.3A and B: (A) Torque in face, (B) Torque in base

prescription for the PEA and called it the straight wire appliance. In fact, Andrew created various prescription based on the malocclusion, extractions and the underlying skeletal structure of the patient. He advocated the placement of brackets on the Andrew's plane, which is the plane or surface on which the mid-transverse plane of every crown in an arch will fall when the teeth are ideally positioned (Fig. 42.4).

Roth modified the tip and torque values of his prescription (Table 42.1) making a series which was common for extraction and non-extraction cases. He also modified the bracket placement as shown in Figure 42.5.

When treating cases with the pre-adjusted edgewise appliance, the management can be divided into six distinct yet overlapping stages as:

1. Anchorage control
2. Leveling and aligning
3. Overbite control
4. Overjet reduction
5. Space closures
6. Finishing and detailing



Fig. 42.4: Andrew's plane

Table 42.1: The tip and torque values of the Roth prescription

Maxillary	*Torque*	*Angulation/ Tip*
Central incisor	12	5
Lateral incisor	8	9
Canine	-2	13
1st Pre-molar	-7	0
2nd Pre-molar	-7	0
1st Molar	-14	0
Mandibular		
Central incisor	-1	2
Lateral incisor	-1	2
Canine	-11	7
1st Pre-molar	-17	0
2nd Pre-molar	-22	0
1st Molar	-25	0

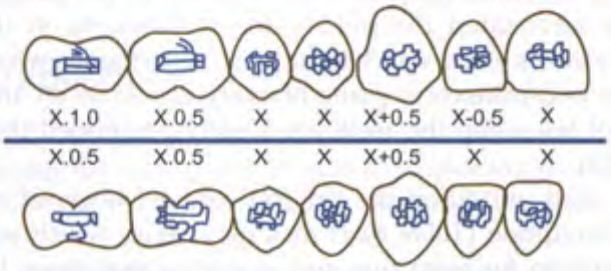


Fig. 42.5: Bracket positioning values

ANCHORAGE CONTROL

Anchorage control can be achieved using intraoral means like transpalatal arches (Fig. 42.6) or Nance palatal button (Fig. 42.7) etc. or extraoral means, e.g. head gears (Fig. 42.8).



Fig. 42.6: Transpalatal arch (TPA) in place. The TPA can be soldered to the molar bands or be placed in the lingual sheaths that are welded on the molar bands, as shown here



Fig. 42.7: Nance palatal button in place



Fig. 42.8: Patient wearing a head-gear to prevent the maxillary molars from drifting mesially

LEVELING AND ALIGNING

Leveling and aligning is done with light continuous force wires like, nickel titanium alloy wires sequentially increasing in stiffness and diameter (Figs 42.9A to C).



Figs 42.9A to C: (A) Round 0.014" diameter NiTi wire placed for initial alignment, (B) As the alignment progresses the wire dimension and stiffness is increased, (C) Stainless steel base archwire along with .016" NiTi wire to align upper central incisior

OVERBITE CONTROL

Overbite control is achieved using utility arches (Fig. 42.10) or wires with a reverse curve of Spee (Figs 42.11A to B[ii]). Molar extrusion might even be achieved using headgears.

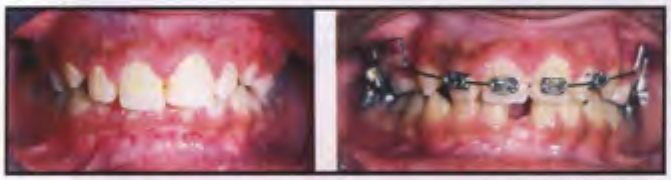


Fig. 42.10: Pre-treatment and during treatment photographs (with intrusion utility arch in place). Note the decrease in overbite following the use of the utility arch

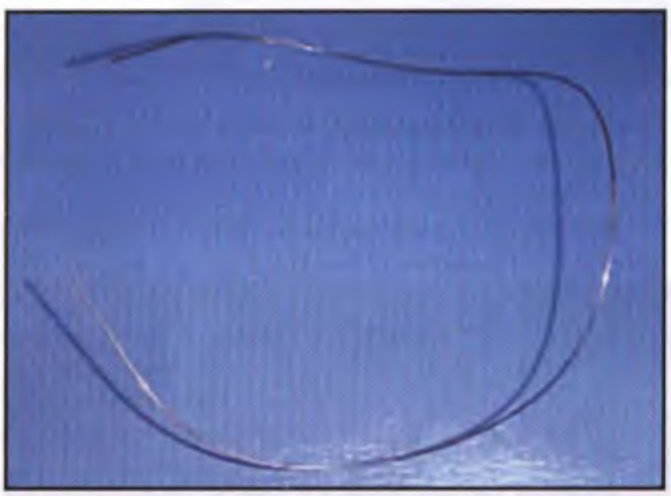


Fig. 42.11A: A rectangular (nickel titanium alloy) wire with a reverse curve of Spee incorporated in it



Fig. 42.11B (i): A rectangular (nickel titanium alloy) wire with a reverse curve of Spee incorporated in it seen passively placed in accessory molar tubes

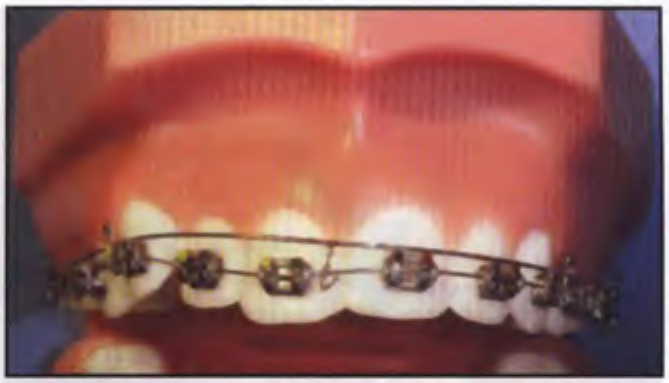


Fig. 42.11B (ii): A rectangular (nickel titanium alloy) wire with a reverse curve of Spee incorporated in it, seen ligated in the midline

OVERJET REDUCTION AND SPACE CLOSURES

Overjet reduction and space closures are accomplished with the help of elastics (Fig. 42.12) closed coil springs (Fig. 42.13) or elastic modules (Fig. 42.14), or elastic chains (Fig. 42.15) or loops incorporated into the arch wire (Fig. 42.16).



Fig. 42.12: Elastics may be used to retract teeth or for closing residual spaces



Fig. 42.13: Closed coil spring is stretched from the molar to the canine, for canine retraction

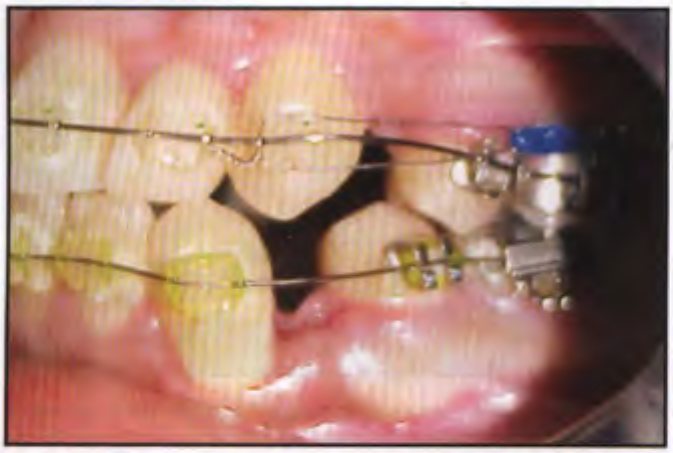


Fig. 42.14: Elastic module tied to the canine bracket using a ligature wire to retract the canine



Fig. 42.15: Elastic chain used for extraction space closure



Fig. 42.16: Loops incorporated in the archwire for retraction and bite opening

FINISHING AND DETAILING

Finishing and detailing involves the use of stiff rectangular stainless steel wires with or without the use of artistic bends.

The stages are sequential in their order, with the effective management of one stage being a prerequisite for the successful completion of the next stage. A case treated with the appliance is presented with the pre-treatment (Fig. 42.17), during (Figs 42.18A and B) and post-treatment (Fig. 42.19) photographs.

A retention sequence follows, once all corrections have been achieved to satisfaction. Retention appliances are a must whatever the appliance chosen for treatment *(Retention appliances are discussed in detail in Chapter on Retention and Relapse).*



Fig. 42.17: Pre-treatment photographs



Fig. 42.18A: Initial alignment using the flexible NiTi wires

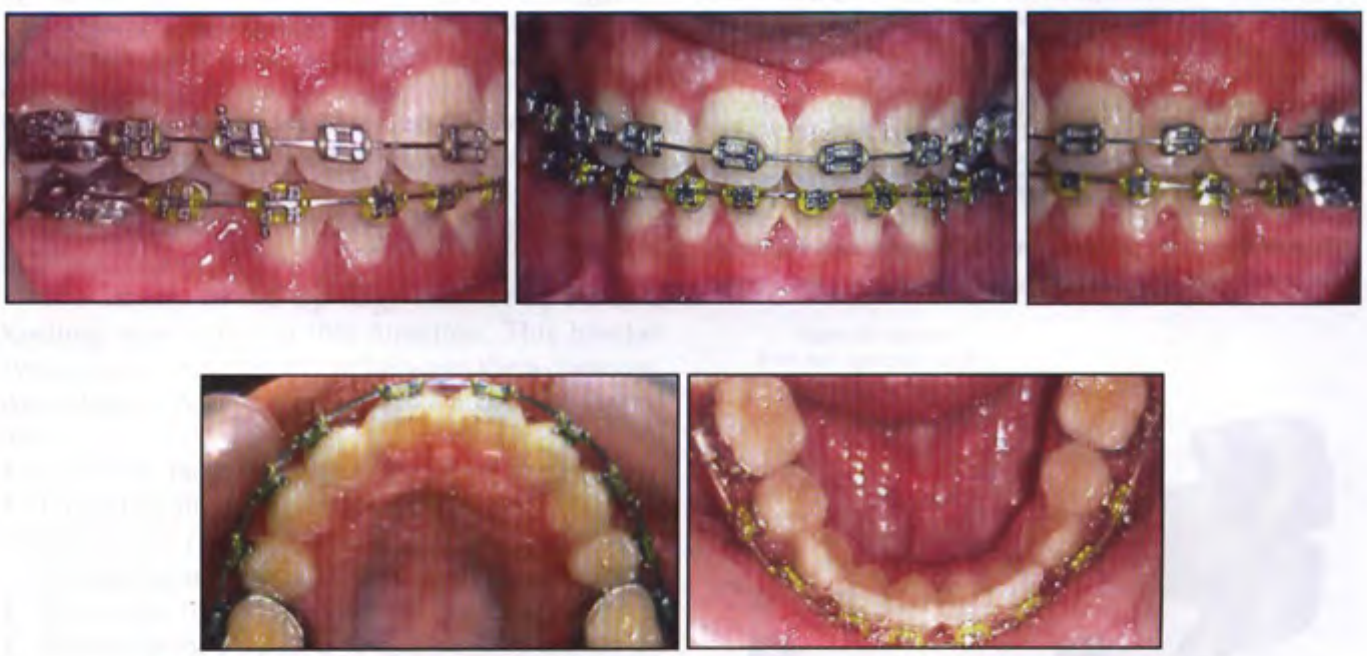


Fig. 42.18B: Space closure and finishing is done using the stiffer stainless steel rectangular wires



Fig. 42.19: Post-treatment photographs

FURTHER READING

1. Andrew LF. Straight wire appliance explained and compared, J Clin Othod 1976;10:174-95.
2. Andrew LF. Straight wire appliance origin , controvercy, commentary, J Clin Othod 1976;10:99-114.
3. Andrews LF. Straight wire appliance Case histories, Nonextraction treatment, J Clin Orthod 1976;10:283-303.
4. Andrews LF. Straight wire appliance, Extraction bracket and classification of treatment, J Clin Orthod 1976;10:360-79.
5. Andrews LF. Straight wire: the concept and appliance, San Diego, 1989 LA Wells.
6. Bennett JE, Melaughlin RP. Controlled space closure with pre-adjusted appliance systm, J Clin Orthod 1990;24:251-60.
7. Dellinger EL. Scientific assessment of straight wire appliance, Am J Orthod Dentofacial Orthop 1978;73:290-9.
8. McLaughlin RP, Bennett JC. The transition from standard edgewise to preadjusted appliance systems, J Clin Ortho 1989;23:142-53.
9. Roth RH. Straight wire appliance 17 years later, J Clin Orthod 1987;21:632-42.

43 The Tip Edge Appliance

Gurkeerat Singh

- Introduction
- Tip edge bracket design
- Advantages of the tip edge brackets
- Placement of tip edge attachments
- Auxiliaries
- Treatment stages

INTRODUCTION

With the advent of the so called straight wire technique, the clinicians who were practicing the Begg technique felt the need to reduce the amount of precision wire bending and the need of the various uprightening and torquing auxiliaries used with the technique. Also, the edgewise practitioners had by now realized the advantages of light forces and differential anchorage, i.e. segregation of forces used to move the tooth crowns, by tipping, and root moving forces. There was also a heightened awareness of the advantages of the rectangular wire finish which provided the three-dimensional control of each individual tooth.

The advent of the tip edge bracket by Peter C Kesling, was a step in this direction. This bracket system provided a interlucor between the techniques. According to Peter C Kesling an ideal bracket should have

- A labially facing wire slot
- Ease of ligation with elastomeric rings
- Provision for root torquing and mesiodistal uprighting using auxiliaries
- First order (in-out) bends built into the bracket
- Predetermined tip and torque control should be available.

Keeping the above in mind, Kesling designed the tip edge bracket. It makes all the above possible and permits differential tooth movement with straight archwires, therefore, the name Differential Straight-Arch Technique.

TIP EDGE BRACKET DESIGN

The tip edge bracket has basically been created by removing the diagonally opposing corners of the conventional edgewise archwire slot (Fig. 43.1). In addition, rotational wings are provided along with a vertical rectangular (0.20″× 0.20″) slot to facilitate the insertion of auxiliaries from either direction (Fig. 43.2).

ADVANTAGES OF THE TIP EDGE BRACKETS

As compared to the Standard edgewise bracket—eliminates the undesired couples and moments which

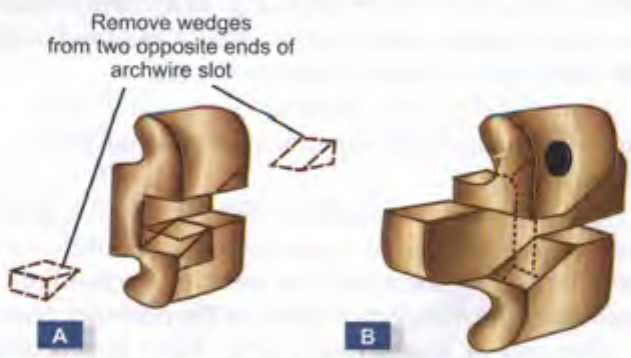


Fig. 43.1: (A) Diagonally opposed corners of a conventional edgewise archwire slot were removed to create the basic tip edge bracket. (B) Additional rotation wings and a vertical slot were provided

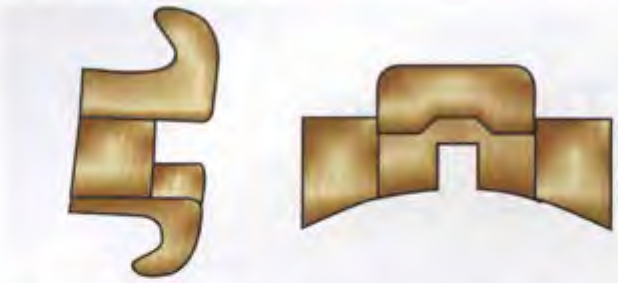


Fig. 43.2: Distal and incisal view of upper right canine bracket. Vertical slot accepts many auxiliaries. Lateral extensions provide rotational control



Figs 43.3A and B: (A) Conventional edgewise bracket on upper anterior tooth tipped at start of treatment. Undesired forces (arrows) are created which interfere with bite opening, (B) Tip-edge bracket on same tooth eliminates couples to permit desired bite opening using light forces

were produced in the standard edgewise bracket allowing light forces to be used for anterior retraction and bite opening (Figs 43.3A and B). This results in diminished anchorage demands and increase in vertical control. In other word, extraoral anchorage is generally not required.

As compared to the Begg bracket—in-out compensation is built into the bracket (Fig. 43.4), hence molar (or other) offsets which are normally required with the ribbon arch bracket were eliminated.

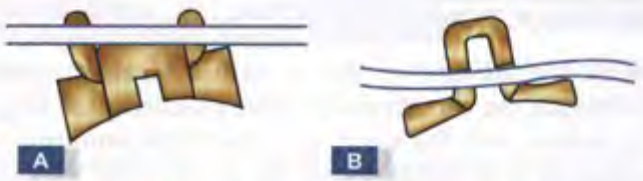
Horizontally facing archwire slots facilitate initial archwire engagement, especially on rotated teeth (Figs 43.5A and B).

The preangulated archwire slot (Table 43.1) stops free crown tipping at a predetermined angle and simultaneously increases the anterior anchorage to encourage the mesial movement of the posterior teeth.

The use of elastomerics (Fig. 43.6) is possible throughout the treatment, which are easier to replace and also more comfortable for the patient than lock pins.



Fig. 43.4: Tip edge brackets are cast with built-in in/out compensation to eliminate the need for lateral, bicuspid or molar offsets



Figs 43.5A and B: (A) Horizontally facing archwire slot in tip-edge bracket with a straight archwire when the tooth is rotated (B) Engaging the same archwire in a vertically facing slot of ribbon arch type bracket produces excessive forces

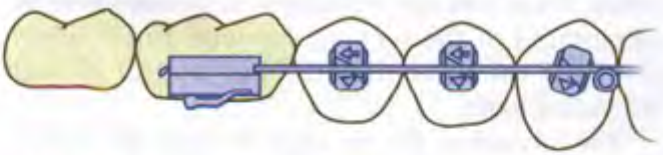


Fig. 43.6: Elastomerics can be used for wire engagement

PLACEMENT OF TIP EDGE ATTACHMENTS

Tip edge brackets are bonded with sides parallel to long axis of crown (Fig. 43.7) Bracket heights can be accurately controlled by using positioning jigs (Fig. 43.8).

The brackets are centered mesiodistally (Fig. 43.9).

The molar tubes (Fig. 43.10) are designed to keep the molars upright and yet permit free sliding of the archwire. The round tubes have .036" inside diameters and length of .250". The rectangular tube is at the same

Table 43.1: Tip edge bracket archwire slot angulations (Slot size .022")

	Crown tipping permissible	*Final crown tip*	*Final root torque*
Maxillary			
Central incisor	20° distal	5°	12°
Lateral incisor	20° distal	9°	8°
Canines	25° distal	11°	– 4°
First premolar	20° distal or mesial	0°	– 7°
Second premolar	20° distal or mesial	0°	– 7°
Mandibular			
Central incisor	20° distal	2°	– 1°
Lateral incisor	20° distal	5°	– 1°
Canine	20° distal	5°	– 11°
First premolar	20° distal or mesial	0°	– 20°
Second premolar	20° distal or mesial	0°	– 20°

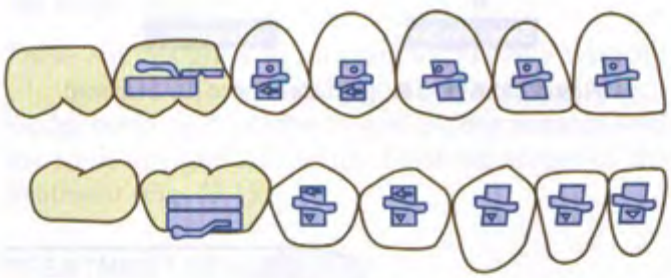


Fig. 43.7: Tip edge brackets bonded with sides parallel to long axes of crowns. Bracket heights can be accurately controlled by using positioning jigs



Fig. 43.8: Normal jig heights/colors

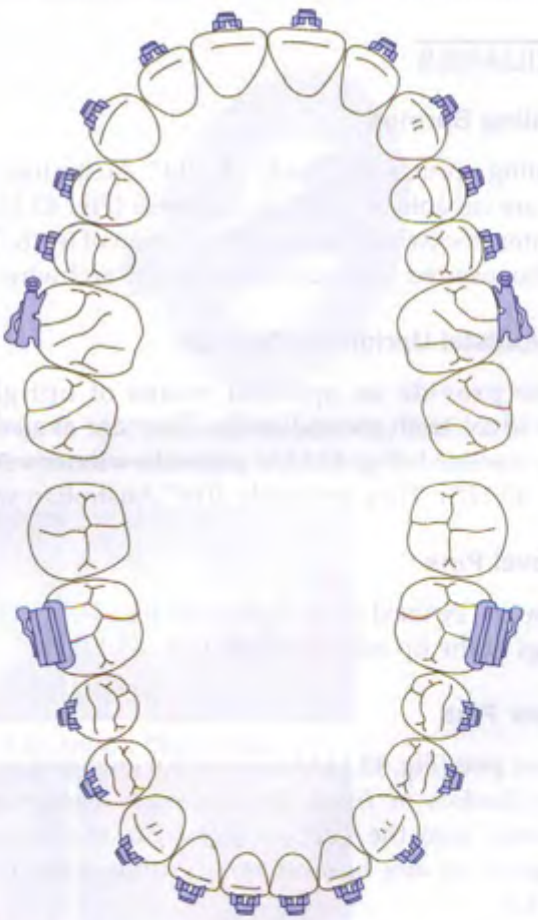


Fig. 43.9: Brackets are centered mesiodistally on the labial and buccal tooth surfaces

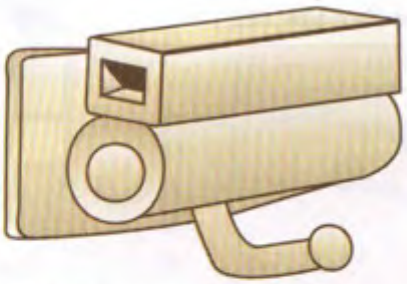
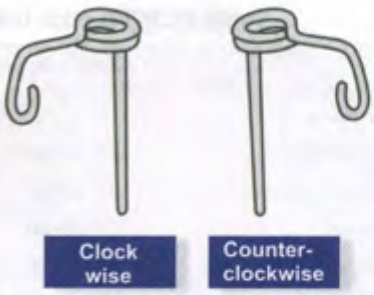


Fig. 43.10: Combination edgewise and round tube for lower left molar



Figs 43.11A and B: Rotating springs: (A) Clockwise, (B) Counter-clockwise

level as the archwire slots in the brackets on the premolars.

Molar tubes are placed parallel with the occlusal surface of the anchor molars. The round .36" round tubes are positioned gingivally to help prevent the archwire from being distorted from occlusal forces.

AUXILIARIES

Rotating Springs

Rotating springs are made of .014" Australian wire, and are capable of causing clockwise (Fig. 43.11A) or counter clockwise (Fig. 43.11B) rotation of teeth. These can be inserted without removing the archwire.

Mesiodistal Uprighting Springs

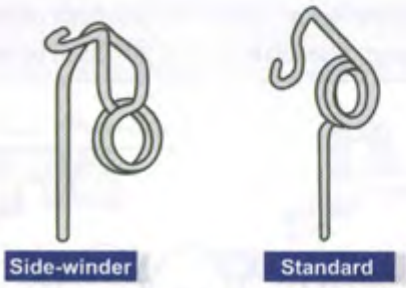
These provide an optional means of uprighting individual teeth mesiodistally. They are available in both standard (Fig. 43.12A) and side-winder versions (Fig. 43.12B). They are made .014" Australian wire.

Bi-level Pins

These can be used to capture auxiliaries behind the tie wings of the tip edge brackets (Fig. 43.13).

Power Pins

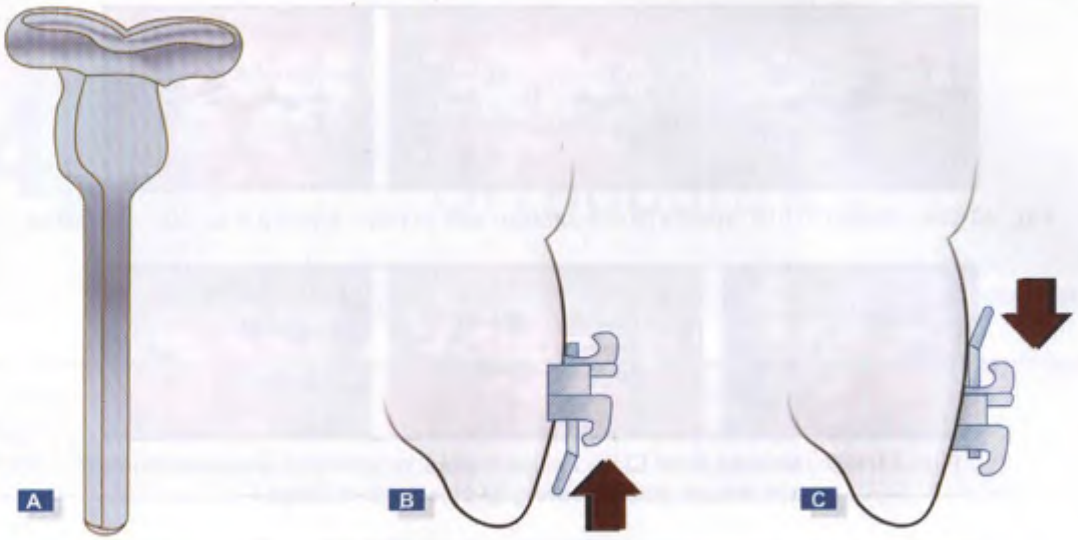
Power pins (Fig. 43.14A) are used for engaging removable elastics or fixed elastomerics. These can be inserted into the vertical slot from the incisal or gingival on any bracket at any time (Figs 43.14 B and C).



Figs 43.12A and B: (A) Side-winder (B) Standard



Fig. 43.13: Bi-level pins



Figs 43.14A to C: When power pin is (A) inserted from the gingival (B) the head is inclined labially, when from the incisal (C) it leans lingually

Tip Edge Rings

These are designed to function exclusively with tip edge brackets. They have lingually facing lugs which wedge between the archwire and the bracket and hold the teeth upright during the finishing stages of the treatment (Fig. 43.15).



Fig. 43.15: Elastomeric tip edge ring retains arch wire while preventing mesiodistal free tipping

TREATMENT STAGES

The basic treatment with differential straight arch appliances is the same as with differential light wire appliance (Figs 43.16A to F). The only difference being



Fig. 43.16A: Pretreatment photographs of an Angle's Class I case

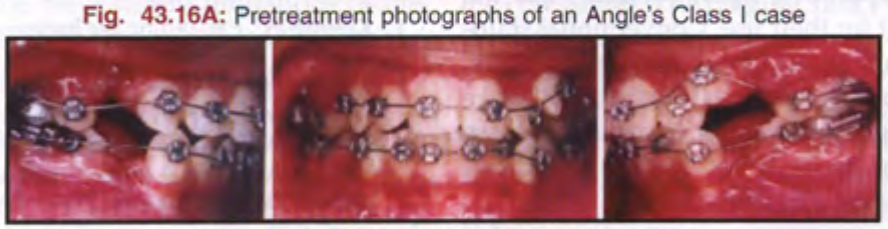


Fig. 43.16B: Initial alignment using NiTi wires



Fig. 43.16C: Stage I, 0.016" special plus Australian wire in place with 2-2.5 oz Class II elastics



Fig. 43.16D: Medium force Class I elastics used for retraction and extraction space closure after achieving all objectives of Stage I



Fig. 43.16E: Round wire used for finishing along with uprightening and torquing auxiliaries



Fig. 43.16F: Case immediately following debanding

in the use of rectangular wires in the finishing or stage IV of this technique. All the objectives of stages I, II and III are the same and should be achieved before proceeding to the next state of treatment.

Stage IV allows for precision finishing using rectangular wires. The rectangular wires may or may not be required depending upon the case, but the provision does exist for their use. Conventional stainless steel wires should be used, beginning with a 0.019" × 0.025" size and progressing to 0.021"× 0.028" wire for total control. These rectangular wires should pass through rectangular molar tubes and are used with special tip edge elastomeric rings.

The tip edge appliance may not be the most popular appliance today but it has certainly provided an opportunity to both Begg and edgewise practitioners to come closer, to a common more versatile appliance system.

FURTHER READING

1. Kesling PC. Expanding the horizons of the edgewise arch wire slot, Am J Orthod Dentofac Orthop, 1988;94:26-37.
2. Kesling PC. Tip-edge Guide and the differential straight arch technique, 2 Swan Advertising Agency, 1988.
3. Kesling PC, Rocke RT, Lesling CK. Treatment with Tip-Edge brackets and differential tooth movement, Am J Orthod Dentofac Orthop 1991;99:387-401.

44 Lingual Orthodontics

Gurkeerat Singh

- Introduction
- History
- Difficulties encountered and their solutions
- Indications for lingual appliances
  - The edgewise lingual appliance
  - The light wire lingual appliance

INTRODUCTION

The lingual orthodontic appliances were conceived with the simple objective of making orthodontic treatment esthetic. The concept of these appliances was developed before the development of esthetic brackets—brackets made of plastic, composites and ceramic, which matched the color of the tooth crowns. Clinicians all over the world have tried to modify their appliances to match the changing demands of their patients. Dr Craven Kurz can be credited with the development of an edgewise lingual appliance and Dr K Fujita of Japan for the development of a light wire lingual appliance.

HISTORY

Even before the development of a true lingual appliance the orthodontic material company Ormco in conjunction with Dr Jim Wildman, had attempted to develop a system to align the dentition using the lingual approach. This system consisted of a pedicle positioner, rather than a multibracketed system. Although innovative, the inherent limitations of this system prevented it from gaining widespread popularity in the orthodontic community.

It was only in the early 1970s that Dr Craven Kurz, an assistant professor at UCLA School of Dentistry, realized that a major portion of his private orthodontic practice was dominated by adult patients. Since many of his patients were public figures, esthetics became a major concern. This led to the development of the concept for the lingually bonded appliance. Dr Kurz developed the first true lingual appliance, consisting of plastic Lee Fisher brackets bonded to the lingual aspect of the anterior dentition and metal brackets bonded to the lingual aspect of the posterior dentition. The plastic brackets were used for the inherent ease of recontouring and reshaping them to avoid direct contact with the opposing teeth.

Around the same time Dr K Fujita of Japan published cases treated with his modification of the Begg light wire appliance. He had bonded the Begg brackets lingually and used the same Australian AJ Wilcock wires contoured to the lingual aspect of the teeth. He explained the arch form which resembled a mushroom (when viewed occluasally) and advocated the same basic steps as in the conventional Begg technique to be used with the Begg bracket with a modified base.

Further research was carried out by individuals and groups of individuals associated together, with financial funding from the orthodontics manufacturing companies. The Lingual Task Force was set-up (by the orthodontic material company Ormco) to develop a commercially viable lingual appliance.

The lingual appliance is the most esthetic orthodontic appliance. Along with this major advantage that it has over other appliances the lingual appliance had some inherent shortfalls (Table 44.1).

Table 44.1: Disadvantages of the initial lingual appliances

1. Indirect vision hampered accurate bracket placement
2. Occlusal interferences caused frequent bond failures and at times restricted tooth movement
3. Speech distortion
4.. The sharp edges hurt/lacerated the tongue
5. Gingival irritation due to plague accumulation
6. Increased chair-side time due to difficulty in insertation and ligation of archwire

The most irritating problem associated with the initial appliances was of frequent bond failures. The turning point in the development of the appliance was the addition of an anterior inclined plane as an integral part of the maxillary anterior brackets (Fig. 44.1). This inclined plane converted the shearing forces produced by the mandibular incisors, which caused the bond failures, to compressive forces applied in an intrusive and labial direction. This modification decreased the bond failures and also assisted in the initial bite opening.

The Lingual Task Force pioneers Drs Kurz, Gorman and Smith were the first to conduct courses on the edgewise lingual appliance. Dr Vince Kelly of Oklahoma and Dr. Steve Paige of Florida were the first to start giving courses using a Begg appliance lingually.

Dr Dilier Fillion of France is the only orthodontist to have restricted his practice to lingual orthodontics exclusively. It would be pertinent to mention that the first textbook on lingual orthodontics was published by Dr Rafi Romano in 1998.

DIFFICULTIES ENCOUNTERED DURING THE DEVELOPMENT OF LINGUAL ORTHODONTIC THERAPY AND THEIR CURRENT SOLUTIONS

Bond Failures

The bracket base was better contoured and the introduction of the indirect bonding technique helped to reduce frequent bond failures.

Occlusal Interferences

Occlusal interferences restricted tooth movement beyond a certain limit (Fig. 44.2). An inclined or bite plane strategically placed to redirect the vertical shearing forces to a horizontal seating force helped not only in reducing frequent bracket failures but also helped in bite opening and correcting teeth in cross bite.

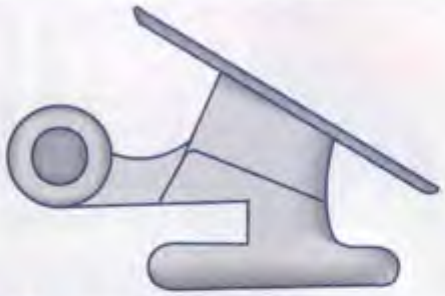


Fig. 44.1: Lingual bracket with anterior bite plane



Fig. 44.2: Maxillary canine bracket preventing mandibular canine retraction

Tissue Irritation and Speech Difficulties

Brackets were redesigned with smooth exterior surfaces and a low profile. This increased comfort allowed normal tongue activity; thereby preventing any significant speech impairment.

Gingival Impingement

The bracket base was redesigned to be more self-cleansing, it now extends more incisally and mesio-distally, providing adequate bond strength, yet retaining hygienic qualities. Also, the bracket hooks have been redesigned with a lower profile and are located several millimeters from the gingival margin.

Appliance Control

Transpalatal bars are now used for additional stability. They can be attached to either the first or second molar.

Appliance Placement and Bonding

Working with a prefabricated appliance is not always easy. Since the appliance has the tip, torque and in-out bends built into the bracket, these values change with even a slight change in the lingual contour of the teeth. To avoid this, the custom lingual appliance set up service was created (CLASS). It involves indirect bonding set up on a diagnostic or ideal model of the teeth.

Ligation

The Light wire bracket is used in the ribbon arch mode with the wire sliding in from the occlusal or incisal aspect and all edgewise lingual brackets have deep locking grooves. Also most brackets have an accessory vertical groove to simplify matters even further. The latest is a self-ligating lingual bracket—a very flexible lid engages the wire in the bracket slot. Self ligating 2-D brackets are now available (Fig. 44.3). They make wire changes very easy and convenient both are the patient and the clinician.



Fig. 44.3: Self ligating lingual brackets

INDICATIONS FOR LINGUAL APPLIANCES

Five distinct situations exist where lingual appliances may be more effective than labial appliances because of their unique mechanical characteristics. These include

1. Intrusion of anterior teeth
2. Maxillary arch expansion
3. Combining mandibular repositioning therapy with orthodontic movements
4. Distalization of maxillary molars
5. Treatment of cases with case complicated with an existent tongue thrust habit.

TREATMENT STAGES OF THE PRE-ADJUSTED EDGEWISE LINGUAL APPLIANCE

Stage I: Diagnosis and Treatment Planning

Step 1: Diagnosis and setting up of treatment objectives.
Step 2: Selection of appliance (tip, torque and in-out values)
Step 3: Direct or indirect bonding (preferred) of brackets.

Stage II: Alignment and Consolidation of Spaces

Step 1: First initial archwires: 0.016 Ni-Ti (Fig. 44.4). (Rarely 0.0155 or 0.0175 Respond).
Step 2: Second initial archwire: 0.016 Special-Plus Wilcocks (Australian) heat-treated stainless steel (Fig. 44.5).
Step 3: Intermediate wires: 0.17 × 0.025 TMA (Fig. 44.6).

Stage III: Finishing and Detailing

Step 1: Finishing wires—0.017 × 0.025 or 0.016 × 0.022 SS.
Step 2: Detailing wires—Wilcocks (Australian) 0.016 or 0.018 Special-Plus.

Stage IV: Retention

Fixed permanent retention preferable (Fig. 44.7).

TREATMENT STAGES OF THE LIGHT WIRE LINGUAL APPLIANCE

Stage I: Diagnosis and Treatment Planning

Step 1: Diagnosis and setting up of treatment objectives.
Step 2: Selection of appliance and placement heights.
Step 3: Direct or indirect bonding (preferred) of brackets.



Fig. 44.4A: Pre-treatment photograph



Fig. 44.4B: Initial alignment using 0.016" x 0.016" Cu NiTi wire



Fig. 44.5: Maxillary arch with initial round 0.016" Australian AJ Wilcock wire (photograph courtesy Dr Vinod Verma, New Delhi)



Fig. 44.6: Retraction carried out in rectangular TMA wires (photograph courtesy Dr Vinod Verma, New Delhi)



Fig. 44.7: Fixed permanent retainer in place lingually (finished case of Fig. 44.3)

Stage 2: Alignment and Consolidation of Space

Step 1: 0.012" Australian AJ Wilcock or NiTi wires used for initial alignment.

Step 2: Space consolidation is done on 0.014" Australian AJ Wilcock wires (Fig. 44.8).

Stage 3: Torquing and Uprightening

Step 1: 0.016"Australian AJ Wilcock basewire with 0.012" wires for torquing and uprightening auxiliaries (Fig. 44.9).

Stage 4: Retention

Fixed permanent retention preferable.



Fig. 44.8: Space consolidation done using e-chains



Fig. 44.9: Lower torquing auxiliary

FURTHER READING

1. Berke JB. Lingual orthodontics treatment. J am Dent Assoc 1989;118:150.
2. Creekmore T. Lingual orthodontics-its renaissance, Am J Orthod Dentofacial Orthop 1989;96:120-37.
3. Fujita K. Multi lingual bracket and mushroom arch wire technique, Am J Orthod 1982;82:120-40.
4. Fujita K. New orthodontic treatment with lingual bracket and mushroom arch wire appliance, Am J Orthod 1979;76:57-675.
5. Gorman JC. Treatment of adults with lingual appliances, Dent Clin North Am 1988;32:589-620.
6. Kurz C, Gorman JC. Lingual orthodontics: a status report: part 7a case reports-nonexraction, J Clin Orthod 1983;83:310-21.
7. Kurz C, Swartz ML, Andreiko C. Lingual orthodontics: a status report: part 2; research and development, J Clin Orthod 1982;16:735-40.
8. Muir JC. Lingual orthodontic appliances: invisible braces, N Z dent J 1991;87:57-59.
9. Paige SF. A lingual light –wire technique, J Clin Orthod 1982;16:534-44.
10. Rafi Romano. Lingual Orthodontics, BC Decker, Hamilton, London, 1998.
11. Schlz RP, Swartz ML. Lingual orthodontics: a status report, part 3: indirect bonding- laboratory and clinical procedures. J Clin Orthod 1982;16:812-20.
12. Shetty VS, Singh Gurkeerat. Lingual Begg Appliance in a Case of Tongue Thrust- A Case Report, J Ind Orthod Soc,Vol.32,20-23.
13. Sirianni AA, Graziano JP, Epstein MB. invisible lingual orthodontic appliance. NY State Dent J 1985;51:480-1.

45 Orthopedic Appliances

Tapasya Juneja, Gurkeerat Singh

- Introduction
- The philosophy of extraoral force
- Basis for orthopedic appliances
- Orthopedic appliances
  - Headgear
  - Facemask
  - Chin cup

INTRODUCTION

According to Sassouni (1972), 'orthodontic therapy' is aimed at the correction of dentoalveolar malocclusion, without any skeletal deviation, i.e. cases in which tooth movement alone is desired. Whereas *'orthopedic therapy' is aimed at the correction of skeletal imbalance with the correction of any dentoalveolar malocclusion being of less importance,* in which little or no tooth movement is desired. Therefore, orthopedic forces are heavier (= 400 gm) when compared to orthodontic forces (50-100 gm).

THE PHILOSOPHY OF EXTRAORAL FORCE

A disproportion in the size or position of the jaws result in a skeletal discrepancy in either the sagittal, coronal or transverse plane. The three approaches to management of a skeletal problem are:

a. Growth modification
b. Camouflage treatment
c. Surgical correction

Growth modification is, by far, the best option if possible. Growth modification helps in altering the expression, direction and magnitude of growth, thus bringing about favorable jaw growth.

BASIS FOR ORTHOPEDIC APPLIANCES

Orthopedic appliances make use of the teeth as a "handle" to transmit forces to the underlying skeletal structures. Forces in excess of 400 gm. should be applied to bring about favorable skeletal change. The treatment result depends on the following.

Amount of Force

The force magnitude should be high i.e. at least greater than 400 gm (400-600 gm) per side to a maximum total of 2-3 lb to make sure that only skeletal and no dental movement takes place. Such high forces produce hyalinization leading to undermining resorption, which prevents tooth movement and thus only an orthopedic movement is seen.

Duration of Force

According to most authors, intermittent forces produce skeletal change whereas continuous forces produce dental movement. Extraoral appliances should be worn for about 12-14 hours/day to bring about the desired effect. Increasing the duration beyond the optimum range increases the dental effects. An intermittent heavy force is less harmful to the teeth and periodontium than a continuous heavy force.

Direction of Force

The direction of force application should be such as to maximize the skeletal effect. A favorable skeletal affect is seen when a force is directed posteriorly and superiorly through the center of resistance of the maxilla. The extraoral anchor unit can be cervical or

occipital to produce a low or high force vector. The length of the outer bow can also be altered to change the force vector. A cervical headgear produces extrusion of the molars along with distalization, whereas an occipital attachment produces intrusion, which is favorable in Class II correction.

Age of the Patient

Orthopedic appliances are most effective during the mixed dentition period as it takes advantage of the prepubertal growth spurt. However, treatment should be maintained till growth is complete as these appliances change only the expression of growth and not the underlying growth pattern, which may later reassert.

Timing of Force Application

There is evidence that there is an increase in the release of growth hormones more during the evening and night and is associated with the sleep onset. Therefore, it is advisable for the child to wear the headgear in the evening and throughout the night. Generally the child is more likely to wear the appliance at night.

ORTHOPEDIC APPLIANCES

1. Headgear
2. Facemask
3. Chin cup

HEADGEAR

Headgears are the most common among all the orthopedic appliances (Fig. 45.1). They are ideally indicated in patients with excessive horizontal growth of the maxilla with or without vertical changes along with some protrusion of the maxillary teeth, reasonably good mandibular dental and skeletal morphology. They are most effective in the prepubertal period. Headgears can also be used to distalize the maxillary dentition along with the maxilla. They are an important adjunct to gain or maintain anchorage.

Components

1. Force delivering unit—face bow, J hook.
2. Force generating unit.
3. Anchor unit—head cap, neck strap.

Face Bow

One of the most important components, which help in delivering extraoral force to the posterior teeth (Fig. 45.2A). The face bow consists of the following.

Outer Bow/Whisker Bow

It is made up of round stainless steel wire 0.051" or 0.062" in dimension and is contoured around the face. The outer bow may be:

i. Short—outer bow is shorter than inner bow (Fig. 45.2B).
ii. Medium—outer bow is the same length as the inner bow (Fig. 45.2A).
iii. Long—outer bow is longer than inner bow (Fig. 45.2C).

Inner Bow

It is made up of 0.045" or 0.052" round stainless steel wire and inserts into the round buccal tube on the maxillary first molars. The inner bow is adapted according to the shape of the arch. 'stops' in the form of 'U' loop, bayonet bends and friction stops are placed in the bow mesial to the buccal tube to prevent it from sliding too far distally through the tube.

Junction

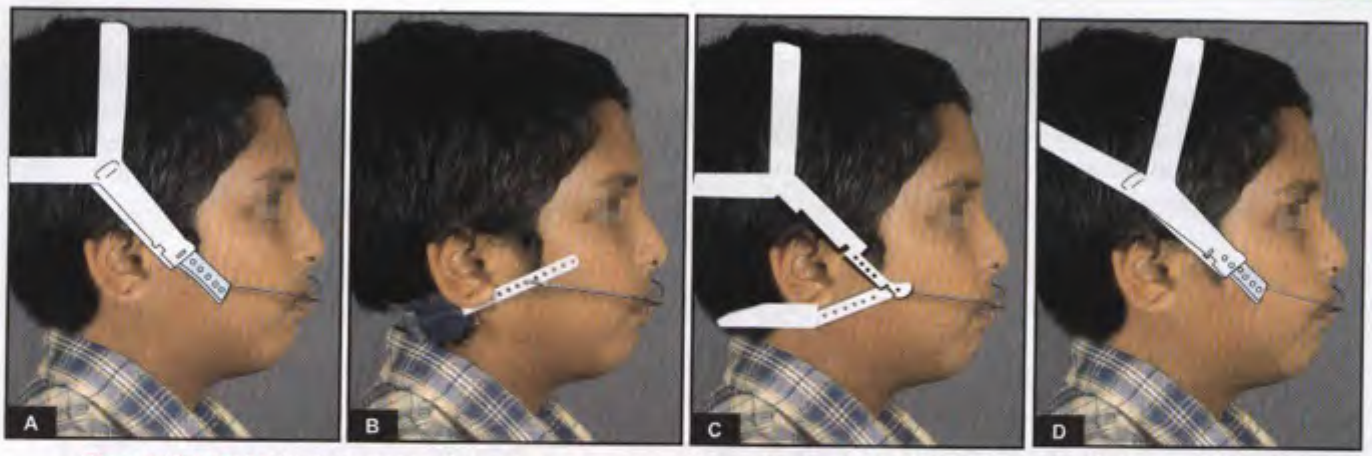
It is the point of attachment of the inner and outer bow, which may be soldered or welded. It is usually positioned at the midline of the two bows, however, it may be shifted to one side in case of asymmetric face bows.

Force Generating Unit

This connects the face bow to the anchor unit and delivers the force to the teeth and the underlying skeletal structures. The force element may be springs (Fig. 45.3) or elastics. Springs are preferred as they provide a constant force whereas elastics undergo force decay.

Anchor Unit

This is in the form of a head cap or a neck strap, which makes use of anchorage from the skull or back of the neck respectively (Fig. 45.1). A combination of the two may also be used.



Figs 45.1A to D: Various types of headgears provide different directions of force for different clinical situations. (A) Occipital headgear, (B) Cervical headgear, (C) The combination headgear, (D) High pull headgear

Headgears

They can be divided as follows

i. According to direction of force:
   - Distal force
   - Mesial force

ii. According to location of anchor unit:
   - Cervical pull
   - Occipital pull
   - High pull (Parietal)
   - Combination pull

Cervical Headgear

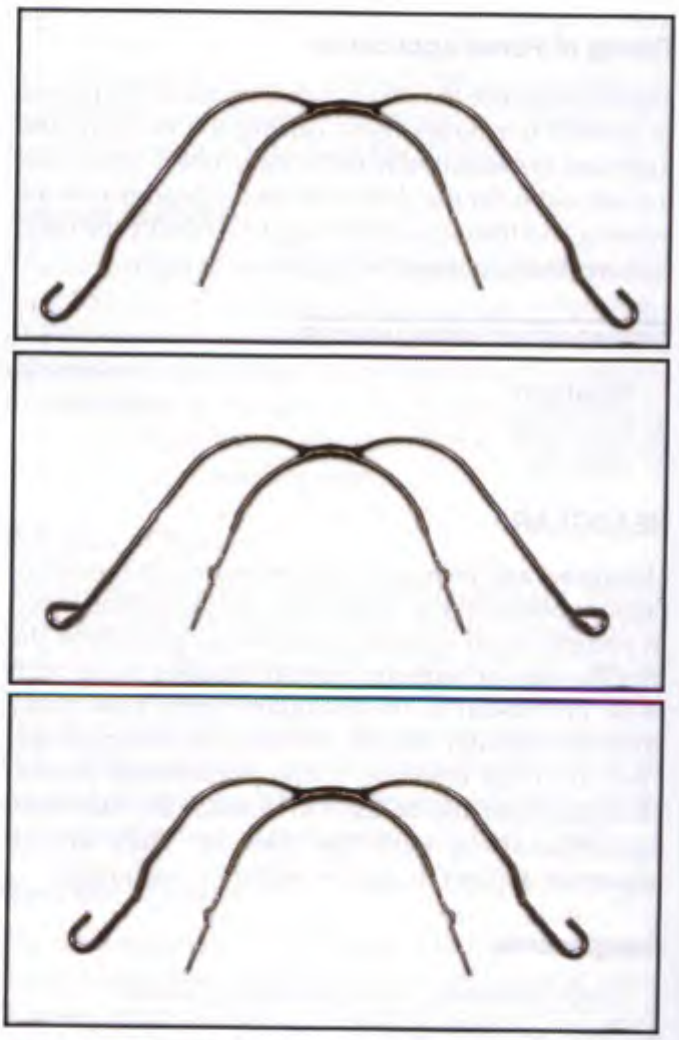
The anchor unit in this headgear is the nape of the neck (Fig. 45.1B). It causes extrusion and distalization of the molars along with distal movement of the maxilla.

Indications

1. Short face, Class II maxillary protrusive cases with a low mandibular plane angle and deep bite (true).
2. Anchorage conservation. The forward movement can be resisted better if the anchor molars are supported further using the forces generated by the cervical headgear.
3. Early treatment of Class II malocclusion as it helps to distalize the maxilla and correct Class II molar relationship.

Contraindications

1. Open bite cases
2. High mandibular plane angle
3. Long face cases with an increase in lower anterior face height.



Figs 45.2A to C: (A) Standard face bow, (B) Loop style face bow, (C) Loop style, short outer bow

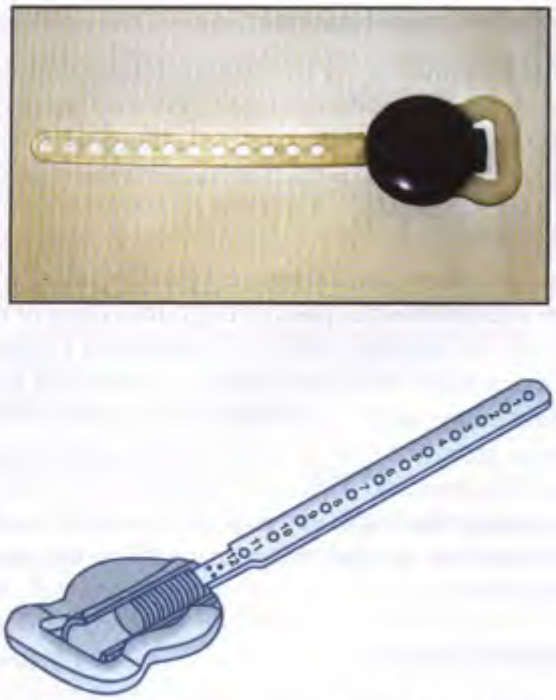


Fig 45.3: Coil spring incorporated into the force modules provide a more constant force over time

Occipital Headgears

Derives anchorage from the occipital region, i.e. back of the head (Fig. 45.1A). It produces distal translation of the molar. Sometimes a slight superior component of force may also be seen.

High Pull Headgear

Derives anchorage from the parietal region, i.e. front of the head (Fig 45.1D). It produces intrusion and distalization of teeth.

Combination Pull headgear

Derives anchorage from at least two regions, i.e. the neck and occiput (Fig 45.1C). It causes a distal and slightly superior force on the maxilla and dentition.

Principles of Force Application in Headgear Therapy

Force

Force is that which changes or tends to change the position of rest of a body or its uniform motion in a straight line. A headgear applies force by means of springs or elastics to move the dentition and the maxilla in all three planes of space.

Point of Origin of Force

This is the anchor site of the headgear. It may be the neck (cervical) or occipital region (occipital) or both. The type of tooth or skeletal movement determines which point of origin would bring about the desired effect.

Point of Attachment of Force

The point of attachment is the point of the outer bow to which the force element is attached. By altering the length or angulation of the outer bow, it is possible to alter the line of action of force.

Center of Resistance

Center of resistance is the point through which the resultant of the forces acting upon a body would produce a translatory movement (Fig. 45.4). A force passing through the center of resistance of a tooth would cause it to translate.

a. The center of resistance of the maxillary first molar lies at the furcation area. To bring about movement translation force should be directed through the center of resistance of molar (Fig. 45.5). Alternatively to bring about distal crown tipping or distal root tipping force should be directed below or above the center of resistance respectively.

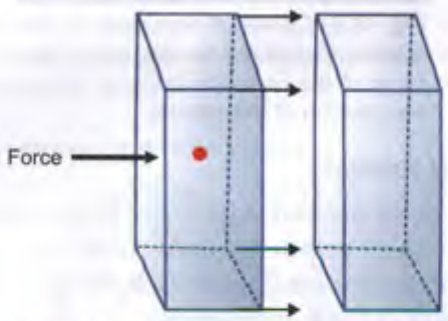


Fig 45.4: Force exerted through the center of resistance (red dot) of a body causes bodily movement

b. Center of resistance of maxilla is usually located between the roots of the two premolars. Therefore, to bring about translation line of action of force should pass through its center of resistance (Fig. 45.6).



Fig 45.5: Center of resistance (red dot) of a multi-rooted tooth lies 1 to 2 mm apical to its furcation (approx.)



Fig. 45.6: Center of resistance of the maxilla is roughly a located above the roots of the premolar teeth, at about the location of the red dot

Center of Rotation

It is the point around which the tooth rotates/tips when force is applied away from the center of resistance of the tooth (Fig. 45.7). It changes according to the point of force application.



Fig. 45.7: Center of rotation (A) At the incisal edge during torquing, (B) At the root apex during controlled tipping, (C) Away from the root apex during uncontrolled tipping, and (D) Outside the tooth during instrusion or extrusion

Biomechanics of Headgear

An understanding of the biomechanics helps the clinician to determine the force systems that need to be applied to produce the desired clinical effects. The line of action of force is the direction in which the force acts. The relationship of the line of force action to the center of resistance of the maxilla or first molar determines whether translation or rotation takes place. When a force does not pass through the center of resistance of the maxilla/molar, a moment is produced. The magnitude of the moment is determined by the product of the force magnitude and the perpendicular distance from the line of force to the center of resistance. The direction of the line of force can be changed by adjusting the length of the center bow or by bending the outer bow up and down to produce the desired clinical effect.

Treatment Effects

Skeletal Effect

The maxillary sutures namely the frontomaxillary, zygomaticotemporal, zygomaticomaxillary and pterygopalatine sutures are the most important growth sites for development of maxilla. Therefore, to alter the maxillary growth, the headgears act by compressing the sutures thus restricting the normal downward and forward growth of the maxilla, while at the same time the mandible is allowed to grow normally.

Dental Effect

Headgear being a tooth-borne appliance, produces certain dental effects along with a skeletal change. Headgears usually cause distalization of the maxillary molars. Along with this, extrusion or intrusion of the molar may also be seen if the extraoral attachment is cervical or occipital respectively. In most skeletal Class II problems a cervical headgear is not desired as the extrusion of the maxillary molar caused by the inferiorly directed force which causes downward and backward mandibular rotation, thus worsening the problem.

Uses of Headgears

1. To restrain the forward and downward growth of the maxilla and redirectioning maxillary growth.

2. Molar distalization: Headgear may be used to distalize the maxillary molar to correct the Class II molar relationship or to gain space for relief of crowding.
3. Headgears can be used to reinforce molar anchorage in high anchorage cases. Headgears should be worn for at least 10 hr/day with a minimum force of 300 gm per side.
4. Headgear is an effective means of maintaining arch length by preventing mesial migration of molars.
5. Molar rotation can also be brought about with the inner bow of the headgear.

Limitations of Headgear Therapy

1. Headgears cannot apply force directly to the maxillary sutures. The orthopedic forces have to be applied through the dentition and therefore, dental changes are inevitably seen along with skeletal effects.
2. Patient compliance is mandatory for headgear therapy to be successful.
3. An adequate amount of mandibular growth is required to "catch up" while maxilla is restrained. However, this may not always be seen clinically.

FACEMASK

Class III malocclusion is usually a result of a combination of maxillary deficiency and mandibular excess. Growth modification for Class III problems is the reverse of Class II, i.e. treatment involves restriction of mandibular growth along with downward and forward maxillary growth. When headgear applies a distal force to the maxilla, compression of the maxillary sutures can inhibit forward maxillary growth. Likewise, pulling the maxilla forward and separating the sutures should stimulate forward growth of the maxilla. Headgears which cause a forward pull on the maxilla are, therefore, called reverse pull headgear. Facemask, (Fig. 45.8) popularized by Delaire in 1970s is one of the most common reverse pull headgears in use today. A facemask works on the principle of pulling the maxillary structures forward with the help of anchorage from the chin or forehead or usually both. A forward maxillary pull is applied with the help of heavy elastics that are attached to hooks on the rigid framework.

Indications

1. Mild to moderate Class II skeletal malocclusion due to maxillary retrusion, reverse pull headgear works best in young, growing children (around 8 years).
2. Ideal patients for facemask should have:
   - Normal or retrusive but not protrusive maxillary teeth as facemask causes forward movement of the maxillary teeth relative to the maxilla.
   - Short or normal, but not long, anterior vertical facial dimensions, i.e. a hypodivergent growth pattern.
3. Correction of postsurgical relapse after osteotomies.
4. Selective rearrangement of palatal shelves in cleft patients.

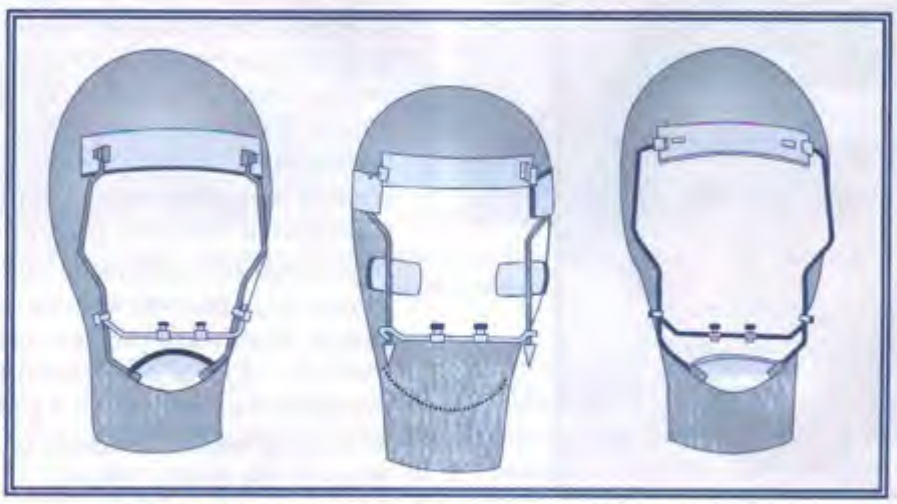


Fig 45.8: Various types of facemasks available commercially

Parts of a Facemask (Fig. 45.9)

Usually, a facemask is made up of the following components:

1. Metal framework
2. Chin cup/pad
3. Forehead cap
4. Intraoral appliance
5. Heavy elastics

The reverse pull headgear is made up of a rigid extraoral framework connecting two pads that contact the soft tissues in the forehead and chin regions. The pads are usually adjustable through the use of screws. The elastics are attached to an adjustable anterior wire with hooks which is connected to the framework. Anchorage is usually derived from both chin and forehead, however, some forms of reverse pull headgears derive anchorage from only chin or forehead. Two sites of anchorage have the advantage that anchorage is spread over a larger area thus reducing the amount of force exerted. Along with the facemask, banded or bonded palatal expansion appliance may also be used to correct cross bites (Fig. 45.10). To resist tooth movement, it is better to splint the maxillary teeth together as a single unit. Whatever the maxillary appliance, it should have hooks in the canine-primary molar region above the occlusal level for attachment of elastics (Fig. 45.10). This places the force vector closer to the center of resistance of the maxilla and helps in pure forward translation (Figs 45.11 and 12).



Fig. 45.9: Parts of a facemask



Fig. 45.10: RME incorporated with a posterior bite planes and hooks placed above the occlusal plane in the canine-premolar region

The heavy elastics apply a forward traction on the upper arch. Elastics attached from the vertical posts of the chin cup to the molar tubes or soldered hooks can bring about tooth movement.

Biomechanical Considerations

The maxilla can be advanced 2-4 mm forward over a period of 8-12 months. The amount of maxillary movement is influenced by a number of factors like:

a. *Amount of force* Successful maxillary protraction can be brought about by 300-500 gm of force per side in the primary or mixed dentition.
b. *Direction of force* According to most authors, a 15-20° downward pull to the occlusal plane is required to produce forward maxillary movement (Figs 45.11 and 12). In most cases of maxillary deficiency, maxilla is deficient in the vertical plane as well, therefore, a slight downward, direction of force is usually desirable. The line of force passes below the center of resistance of the maxilla producing a counter-clockwise moment on the maxilla and dentition. This results in a possible extrusion of maxillary posterior teeth leading to a downward and backward rotation of the mandible. However, in patients with increased anterior facial height, downward pull is contradicted.
c. *Duration of force* A review of literature shows duration to vary between 3 and 16 months. On an average at least 8-12 months of wear is required to produce the desired effect.
d. *Frequency of use* 12-14 hrs/day

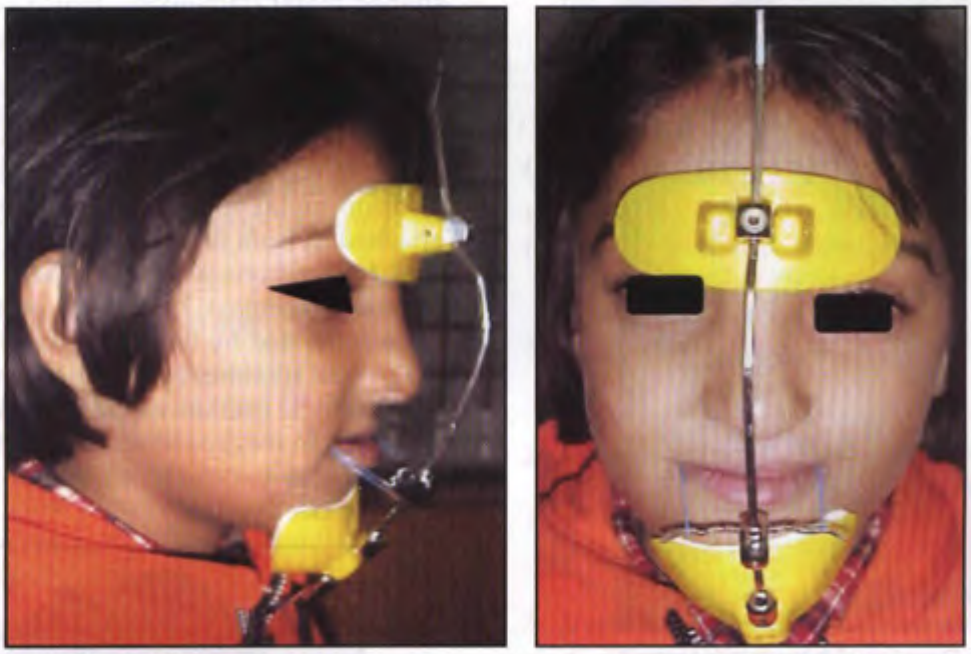


Fig. 45.11A: Patient wearing a Petit type of facemask with the elastics directed 15-20° inferior to the occlusal plane

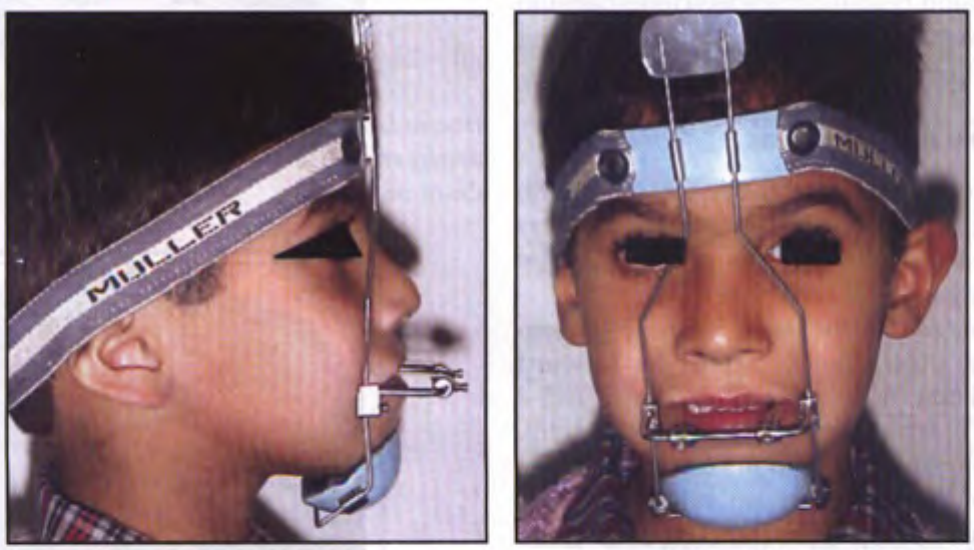


Fig. 45.11B: Patient wearing a facemask with the elastics directed 15-20° inferior to the occlusal plane

e. *Age of patient* Optimal results are seen when facemask is used in the primary or early mixed dentition period. An optimal time to intervene an early Class III malocclusion is at the time of eruption of permanent maxillary central incisors. The anchor molars are also erupted by this time.

f. *Anchorage systems* Palatal arches or palatal expansion appliances may be used as anchorage for

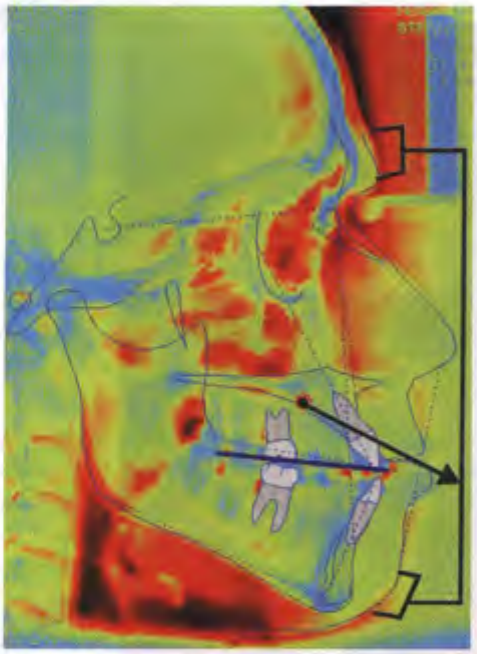


Fig 45.12: Direction of force in a facemask (15-20 degrees) (*Courtesy: Dolt Ceph*)

maxillary protraction. Various authors recommend palatal expansion before protraction as expansion is supposed to "disarticulate" the maxilla making it favorable to respond to protraction forces.

Types of Reverse Pull Headgear

Though Oppenheim was one of the earlier authors to suggest forward maxillary traction, various authors since then have given different modifications of the reverse pull headgear.

1. *Protraction headgear* In the early 1960's, Hickham developed the protraction headgear for forward maxillary traction. It is made up of 2 long and 2 short arms all of which originate from the chin cup. The long arms run parallel to the lower border of the mandible and then bend up vertically at the angle of the mandible to end behind the ears. These ends give attachment to an elastic strap which encircles the head. The short arms are used to engage the elastics. The advantage of this appliance is its ability to apply unilateral force, better aesthetics and comfort.
2. *Delaire facemask* (Fig. 45.13): Delaire is well known for reviving interest in the facemask in the 1960's. Delaire's facemask is made up of a rigid, square-shaped metal framework, which connects a chin up to the forehead pad and has a wire for elastic attachment.
3. *Tubinger model of facemask* (Fig. 45.11B) It is a modified version of facemask in which the forehead cap and chip cup are connected with the help of two midline metal rods. An adjustable crossbar is attached in front of the mouth to engage elastics.
4. *Petit type of facemask* (Fig. 45.11A) Petit modified Delaire's facemask by increasing the amount of force generated by the appliance, thus decreasing the overall treatment time. The appliance is made up of a single midline rod connecting the forehead and chin. In this appliance the forehead cap, chin cup and crossbar can be adjusted according to the patient's needs.



Fig 45.13: Delaire type facemask

CHIN CUP

It is an extraoral orthopedic device (Fig. 45.14), which is useful in the treatment of Class III malocclusions that occurs due to a protrusive mandible but a relatively normal maxilla. Chin cup therapy attempts to retard or redirect the growth of the mandible in order to obtain a better anteroposterior relation between the two jaws.

Philosophy of Chin Cup Therapy

Mandible grows by apposition of bone at the condyle and along its free posterior border. Condyle is not a growth center and condylar growth is largely a response to translation of surrounding tissues. This contemporary view offers a more optimistic view of the possibilities for growth restraint of the mandible, as with chin cup therapy.

Basic Chin Cup Appliance Design

The chin cup is an extraoral appliance that utilizes a head cap, which is firmly fitted/seated on the posterosuperior aspects of the cranium as anchorage and has attachments for the placement and activation of the chin cup. It consists of the following:

- *Force module* Elastic/metal spring that provides the desired tension levels on the chin cup.
- *Chin cup* Custom made or preformed, hard or soft. A hard chin cup can be custom made from plastic using a chin impression. A soft cup can be made from a football helmet chinstrap. A commercial metal or plastic cup can be used if it fits well enough. Soft cups produce more tooth movement than hard ones.



Fig 45.14: The chin cup assembly

Line of Direction of Force

There are two ways to use the chin cup:

1. Line of force acting directly through the condyle (Fig. 45.15A) with the intent of impeding mandibular growth in the same way that extraoral force against the maxilla impedes its growth. This method causes no opening of the mandibular plane angle.
2. Line of force acting below the condyle (Fig. 45.15B):
   - Chin is rotated downward and backward
   - Less force is required
   - Increase in facial height is achieved for a decrease in the prominence of the chin.
3. Vertical force on the chin:
   - Decrease in mandibular plane angle
   - Decrease in gonial angle
   - Increase in posterior facial height.

Magnitude of Force

Most authors recommend a force of 300-600 gm/side. Initially a lower force level (about 150 gm) may be advised for the patient to get used to the appliance.

Duration of Wear

A maximum of 12-14 hr/day of chin cup wear is recommended.

Effects of Chin cup

Extraoral force of the chin cup, directed against the mandibular growth. However, most human studies have failed to conclusively prove that chin cup inhabits mandibular growth. However, the following effects are seen.

a. Redirection of mandibular growth in a downward and backward direction.
b. Remodeling of the mandible and a decrease in mandibular plane angle and gonial angle
c. Lingual tipping of lower incisors.
d. Improvement in skeletal and soft tissue profile.

Therefore, chin cup works well in patients with reduced or normal lower anterior face height but is contradicted in long face patients.



Fig 45.15A: Line of force acting through the condyle



Fig 45.15B: Line of force acting below the condyle

According to TM Graber, ideal patients for chin cup therapy are those suffering from:

- A mild skeletal problem with the ability to bring the incisors end-to-end or nearly so.
- Short vertical face height
- Normally positioned or protrusive, but not retrusive lower incisors.

Types of Chin Cup

1. Occipital pull chin cup derives anchorage from the occiput region. This is used in Class III cases with mild to moderate mandibular prognathism, who can bring their incisors in an edge-to-edge position at centric relation. Patients with short anterior facial height also benefit from this type of chin cup. This is the more commonly used chin up.
2. Vertical pull chin cup (Fig. 45.16) derives anchorage from the parietal region. It is indicated in high angle cases or long face patients as it helps to close the angle of the mandible and increase the posterior facial height.



Fig 45.16: Vertical pull chin cup

Commercially Available

- Soft Elastic appliance
- Hickham-type appliance
- Unitek design
- Summit design.

FURTHER READING

1. Bowden DE. Theoretical considerations of headgear therapy: A literature review-1 Mechanical principle, Brit J Ortho, 1978;85:145-52.
2. Bowden DE. Theoretical considerations of headgear therapy: A literature review-2 Clinical response and usage, Brit J Ortho, 1978;5:173-81.
3. da Silva Filho OG, Magro AC, Capelozza Filho L. Early treatment of the Class III malocclusion with rapid maxillary expansion and maxillary protraction, Am J Orthod Dentofac Orthop 1998;113:196-203.
4. Firouz M, et al. Dental and orthopedic effects of high-pull headgear in treatment of Class II Division 1 malocclusion, Am J Orthod Dentofac Orthop 1992;104:277-84.

5. Grabber LW. Chin cup therapy for mandibular prognathism. Am J Orthod 1977;72:23-41.
6. Hagg U, Panchez H. Dentofacial orthopaedics in relation to chronological age, growth period and skeletal development: an analysis of 72 male patients with Class II Division 1 malocclusion treated with the Herbst appliance. Eur J Orthod 1988;10:169-76.
7. Sakamoto T, Iwase I, Uka A, et al. A roentgeno-cephalometric study of skeletal changes during and after chin cap treatment, Am J Orthod 1984;85:341-50.
8. Sugawara J, Mitani H. Facial growth of skeletal Class III malocclusion and the effects, limitations, and long-term dentofacial adaptations to chin cap therapy, Sem Orthod 1997;3:244-54.

46 Functional Appliances

Ankur Kaul, Ashish Gupta, Gurkeerat Singh

- Introduction
- Basis for functional appliances
- Classification of functional appliances
- Cephalometric analysis
- Activator
- Bionator
- Frankel appliance (functional regulator)
- Twin-block
- Fixed functional appliances
- Conclusion

INTRODUCTION

Conventional orthodontic appliances use mechanical force to alter the position of tooth/teeth into a more favorable position. However, the scope of these fixed appliances is greatly limited by certain morphological conditions which are caused due to aberrations in the developmental process or the neuromuscular capsule surrounding the orofacial skeleton. To over come this limitation, functional appliances came into being.

These appliances are considered to be primarily orthopedic tools to influence the facial skeleton of the growing child. The uniqueness of these appliances lies in the fact that instead of applying active forces, they transmit, eliminate and guide the natural forces (e.g. muscle activity, growth, tooth eruption) to eliminate the morphological aberrations and try to create conditions for the harmonious development of the stomatognathic system

Most of the functional appliances are intraoral devices, and nearly all of them are tooth borne or supported by teeth. With a few exceptions, these appliances are removable, consisting primarily of acrylic with wire components for retention and support.

Most of the functional appliances are used to correct early Class II malocclusions and some cases of Class III malocclusion. About 40 percent of all malocclusions treated belong to the Class II category. This preponderance of the Class II malocclusions seen in orthodontic practice is partly a result of public awareness of aberrant characteristics associated with the malocclusion and education of the public by the concerned dental practitioners.

Too often, Class II malocclusions have been treated with extra-oral forces directed against the maxilla. However, abundant research has shown that much of the problem lies in the mandible, which is retrognathic (small) or retro-positioned (backwardly placed) or a combination of both. Nevertheless the past 30 years have seen an increasing awareness regarding the potential of functional appliances as a valuable tool in the armamentarium of an orthodontist.

BASIS FOR FUNCTIONAL APPLIANCES

Although functional appliances have been in use for over two centuries, their scope and potential has been realized only recently with the recognition of inter-relationship between form and function and the realization that neuro-muscular involvement is vital in treatment.

Graber described the 'Three Ms' Muscles, Malformation and Malocclusion in 1963. Melvin Moss, again validated the concept of form and function through his theory 'The Functional Matrix Hypothesis'.

Another factor that gave impetus to the use of functional appliances (especially mandibular hyperpropulsers) was the identification of certain cartilages in the body as 'Secondary cartilages'

Secondary cartilage is that cartilage which is not of developmental origin but rather differentiates from the bony periosteum in response to the needs of the body, e.g. condylar cartilage.

Among the other features of the secondary cartilages (Table 46.1) the characteristics which make it useful for functional appliance therapy is its adaptive growth response to the local intrinsic and extrinsic stimuli, unlike the primary cartilages which are minimally responsive to local factors/stimuli.

Other factors / theories have also been proposed in favor of the use of Functional appliances which include – hyperactivity of the lateral pterygoid and the Cybernetic growth theory (proposed by Petrovic and associates) and more recently the 'Growth Relativity Theory' (Vodouris & associates) which was proposed after extensive research and shows that significant remodeling in the glenoid fossa and the mandibular condyle takes place in response to the mandibular hyperpropulsers.

However, one question that still looms large is whether the functional appliance therapy actually causes growth modification (beyond genetic potential) or just growth re-direction.

Although answers to these questions are still at large, one thing is clear that growth modification and growth re-direction both take place to varying degrees depending on various factors like the age of the patient, diagnosis and skill of the clinician, etc.

CLASSIFICATION OF FUNCTIONAL APPLIANCES

Myofunctional appliances are classified as:

1. Classification put forth by Tom Graber when functional appliances were removable:
   1. Group A—Teeth supported appliances, e.g. catlans appliance, inclined planes, etc.
   2. Group B—Teeth/tissue supported, e.g. activator, bionator, etc.

Table 46.1: Differences between primary and secondary cartilage

Biological criteria	*Epiphyseal growth plate or primary cartilage*	*Condyles or secondary cartilage*
Origin	Derivative of primordial cartilage (chondroblasts)	Secondary cartilages form on original membrane bone.
Growth	Interstitial, three dimensional, in hyaline cartilage	Peripheral in Fibro-cartilage covering; proliferating cells are not cartilage cells but rather resemble undifferentiated mesenchymal cells.
Maturation	Secondary ossification center, final fusion, disappearance of all cartilage. Only the degenerative zone is mineralizing. Primary spongiosa	Conversion from hypertrophic to non-hypertrophic state, but no complete conversion into bone. Whole hypertrophic area in a state of mineralization. No primary spongiosa.
Histology	Well arranged histologic features	Haphazard arrangement
Hormonal control	Marked response to thyroxine deficiency. After final fusion; no further response to growth hormones.	Minimal response to thyroxine deficiency. Mature condyle can be awakened by growth hormone
Vitamin response	Ascorbic acid deficiency leads to Gerustmark zone; Vitamin D deficiency results in classic picture of Rickets.	Vitamin C deficiency elicits minimal response; Vitamin D deficiency causes reversion to more immature state.
Mechanical stimuli	Unresponsive	Responsive
Antigenic difference	Possesses antigenic determinants common to condylar cartilage and nasal septum.	Possesses one or more unique antigenic determinants distinct from the epiphyseal cartilages and the nasal septum.

3. Group C—Vestibular positioned appliances with isolated support from tooth/tissue, e.g. Frankel appliance, lip bumpers.

II. With advent of fixed functional appliances, a new classification evolved:
1. Removable functionals, e.g. activator, bionator, frankel, etc.
2. Semi-fixed functional appliances, e.g. Den Holtz, Bass appliances, etc.
3. Fixed functional appliances, e.g. Herbst, Jasper jumper, Churro jumper, Saif springs, adjustable corrector, Eureka spring, mandibular anterior repositioning appliance, (MARA), Klapper super spring, Sabbagh universal spring (SUS).

III. With concept of hybridization by Peter Vig, functionals were classified as:
1. Classical functional appliances, e.g. activator, Frankels appliance, etc.
2. Hybrid appliances, e.g. propulsor, double oral screen, hybrid bionators, Bass appliance.

IV. Classification put forth by Profitt
1. Teeth borne passive appliances—myotonic appliances, e.g. Andresen/Haupl activator, Herren activator, Woodside, activator, Balter's bionator etc.
2. Tooth borne active appliances—myodynamic appliances, e.g. elastic open activator (EOA), Bimler's appliance, modified bionator, stockfish appliance, etc.
3. Tissue borne passive appliance, e.g. oral screen, lip bumpers, etc.
4. Tissue borne active appliances, e.g. Frankel appliances.
5. Functional orthopedic magnetic appliances (FOMA)

CEPHALOMETRIC DIAGNOSIS FOR FUNCTIONAL APPLIANCE THERAPY

Cephalometric analysis attempts to define normal/abnormal craniofacial pattern by examining the angular and linear relationships of clearly defined skeletal landmarks.

However, as far as patients for functional appliance therapy are concerned, this seemingly simple approach is complicated by the unpredictability in the nature, dimension, rate and direction of growth. Therefore, cephalometric diagnostic assessment for functional appliance patient include 4 areas of emphasis:

1. Increment of growth direction vector
2. Assessment of magnitude of growth change
3. Assessment of constantly changing inclination of upper and lower incisors
4. Radiographic cephalometrics

The various cephalometric analysis for functional appliance therapy for patients can be divided into 3 groups
1. Facial skeleton
2. Jaw bases
3. Dentoalveolar relationships

ANALYSIS OF FACIAL SKELETON

This includes three angular measurements
1. Saddle angle
2. Articular angle
3. Gonial angle

and four linear measurements
- Anterior and posterior facial height
- Anterior and posterior cranial base length

Saddle Angle (N-S-Ar) (Fig. 46.1)

Formed by joining these 3 points. A large saddle angle signifies posterior condylar position and a mandible which is posteriorly placed with respect to cranial base and maxilla. However, it has been seen that the posterior positioning of the fossa is sometimes compensated by the articular angle and the ramal length. Nevertheless, a non-compensated posterior positioning of mandible caused by a large saddle angle is difficult to influence with functional therapy.

Articular Angle (S-Ar-Go) (Fig. 46.2)

It is the constructed angle between Sella, Articulare and Gonion. It is large if mandible is retrognathic and small if mandible is prognathic. Can be influenced by orthodontic and orthopedic therapy. A decrease in the articular angle can be seen in the following conditions:
- Anterior positioning of the mandible
- Closing of the bite
- Mesial migration of posterior segment.

An increase in the articular angle is seen in:
- Posterior relocation of mandible
- Opening of the bite
- Distal driving of posterior teeth

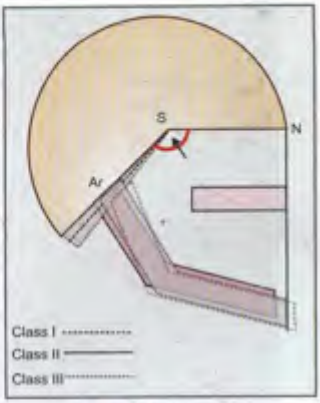


Fig. 46.1: Saddle angle

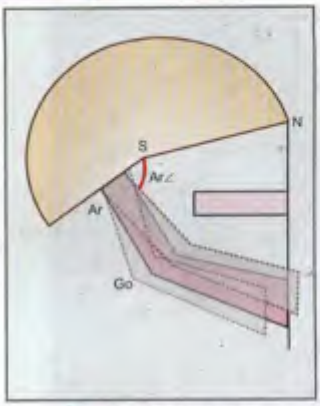


Fig. 46.2: Articular angle

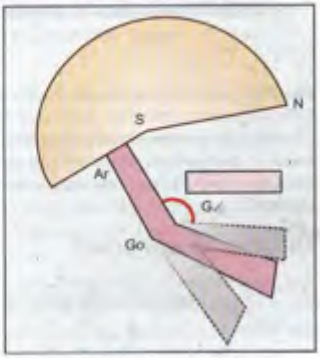


Fig. 46.3: Gonial angle

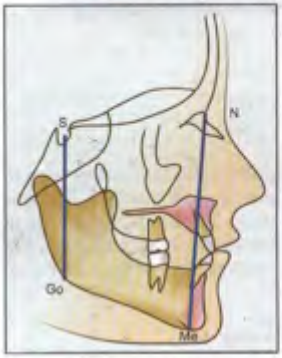


Fig. 46.4: Anterior and posterior face height

Gonial Angle (Ar-Go-Me) (Fig. 46.3)

An angle formed by tangents to the body of the mandible and posterior body of the ramus. Acute or small angle, signifies the horizontal growth direction, a condition favorable for functional appliance therapy/anterior positioning of mandible. Large gonial angle signifies vertical growth direction. Functional appliance treatment in such cases is generally contraindicated, and if attempted should be directed towards reducing the vertical facial growth of the patient.

Anterior and Posterior Face Height (Fig. 46.4)

These are linear millimetric measurements:

Anterior facial height (AFH) Nasion to menton

Posterior facial height (PFH) Sella to gonion

The measurement should be done with teeth in habitual occlusion.

The ratio of PFH/AFH was described by Jarbak in 1972 and is known as Jarbak's ratio. It gives an idea about the growth direction of the patient—

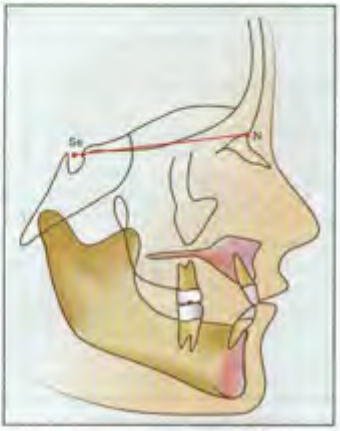


Fig. 46.5A: Anterior cranial base length

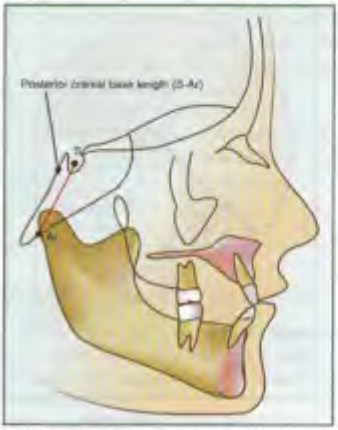


Fig. 46.5B: Posterior cranial base length

$$\text{Jarbak's ratio} = \frac{\text{PFH}}{\text{AFH}} \times 100$$

A ratio less than 62% indicates vertical growth pattern whereas, a ratio of more than 65% indicates more horizontal pattern of growth. This growth direction, as explained earlier, is very important in planning the functional appliance therapy for an individual.

Cranial Base Length (Fig. 46.5)

Cranial base length can be divided into:

1. Anterior cranial base length—Se to N
2. Posterior cranial base length—S to Ar

Anterior cranial base length (Se-N) (Fig. 46.5A)
Here center of superior entrance to sella turcica (Se) is used as reference point. The correlation of this criteria with the length of jaw bases enables the assessment of proportional averages of these bases.

For example, in one of the longitudinal study groups, average length of anterior cranial base in 9 years children was 68.8 mm for horizontal growth pattern and 63.8 mm for vertical growth pattern.

Posterior cranial base length (S-Ar) (Fig. 46.5B)
This depends upon the posterior face height and position of the fossa. Short posterior cranial bases that occur in vertical growth patterns and skeletal open bite, give poor prognosis for functional appliance therapy.

ANALYSIS OF JAW BONES

It is done to assess the sagittal and vertical relationships of jaw bones to each other as well as to the cranium.

SNA (Fig. 46.6)

Indicates the position of maxillary apical base with respect to the anterior cranial base.

A large angle signifies a prognathic maxilla whereas, a small angle signifies a retrognathic maxilla. However, a great variation in this angle must be viewed with caution because of possible variations in the anterior cranial base itself.

Nevertheless, a Class II Division 1 malocclusion caused by a prognathic maxilla is not a good case for functional appliance therapy. However, a large decrease in overjet is possible with the twin block appliance.



Fig. 46.6: SNA – angle

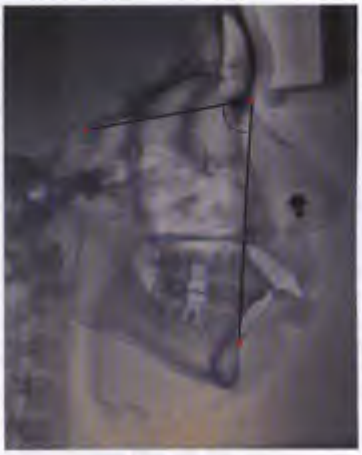


Fig. 46.7: SNB – angle

SNB (Fig. 46.7)

Relationship between the mandibular apical base and anterior cranial base. The angle is increased in cases with prognathic mandible and is small in retrognathic mandible. Retrognathic mandible (with small SNB) are generally cases indicated for functional appliance therapy.

Base Plane Angle (Pal-Mp) (Fig. 46.8)

Another parameter used for the assessment of the inclination/the growth direction of the mandible.

In horizontal growth patterns, the angle is small (23.4° at 9 years) whereas in vertical growth pattern, it is larger (32.9° at 9 years).

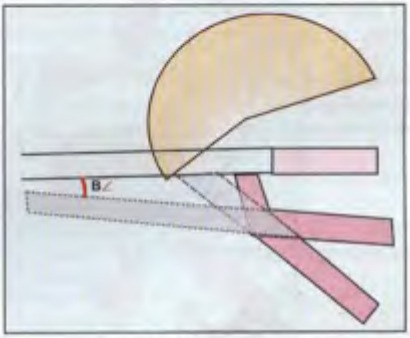


Fig. 46.8: Base plane angle

Inclination Angle (Fig. 46.9)

Gives an indication of the inclination of palatal plane with respect to anterior cranial base.

The angle is formed by PN line (perpendicular line dropped from N-Se at N') and palatal plane (Fig. 46.9A).

A large angle indicates an upward and forward inclination whereas small angle indicates downward tipping of the anterior end of palatal plane and the maxillary base (Fig. 46.9B). Although, this angle does not correlate with growth pattern or facial type, the functional and therapeutic influences can alter the angle.

Rotation of Jaw Bases (Figs 46.10A to D)

The craniofacial skeleton is a dynamic entity wherein no cephalometric landmark can be taken as a standard.

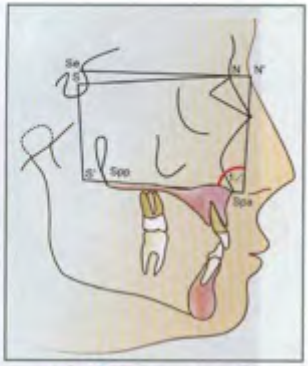


Fig. 46.9A: Inclination angle

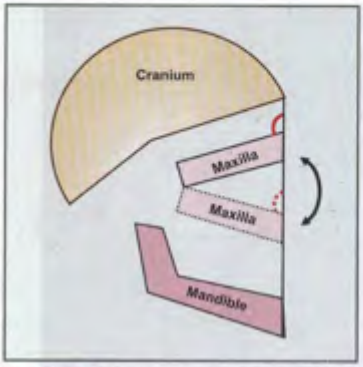
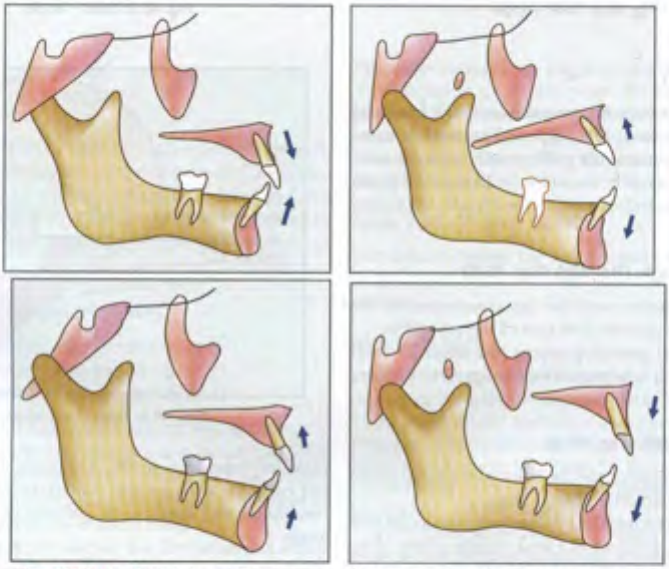


Fig. 46.9B: Variation in the inclination angle with the rotation of the maxillary base. Note an increased angle with upward tipping and decreased angle with downward tipping of the maxilla



Figs 46.10 A to D: Rotation of the jaw bases. (A) Convergent rotation of the jaw bases. (B) Divergent rotation of the jaw bases. (C) Cranial rotation of the jaw bases. (D) Caudal rotation of the jaw bases

Hence, a composite view of all the previously described cephalometric measurements should be taken into consideration before arriving at any conclusion. This is particularly true in cases with rotation of the jaw bases or the cranial base towards or away from each other, which leads to a great variation in the cephalometric angular measurements that may or may not correlate well with the clinical findings.

EVALUATION OF THE LENGTH OF JAW BASES

Not only the position, but also the length of jaw bases is an important consideration in the etiology and therapy of functional appliance cases. Hence, the length of maxillary and mandibular bases and the ascending ramus is measured relative to Se-N

The ideal dimensions as proposed by Schwarz (1958) are:

1. Se-N: Mandibular base 20:21
2. Ascending ramus: Mandibular base 5:7
3. Maxillary base: Mandibular base 2:3

Mandibular Base (Fig. 46.11)

It is the distance Co-Pog projected perpendicularly on to the mandibular plane.

The growth changes of the mandibular base in relation to anterior cranial base (Se-N) have been shown in the Table 46.2:

Table 46.2: Growth changes in the mandibular base in relation to the anterior cranial base.

Age	*Mandibular base*
upto 12 years	3 mm longer than Se-N
After 12 years	1.5 mm longer than Se-N
A length of 5 mm less than average is considered within normal range upto 7 years	
5mm > average-Normal limits upto 15 years	

Correlation between the length and position of the mandible should also be examined. A retrognathic mandible may either have a long base or short base. If base is short, cause of retrognathism is possibly a growth deficiency. If a favorable growth direction is present, prognosis for functional appliance therapy is good.

A mandibular base that is long and retrognathic can result from mandible that is functionally retruded because of overclosure and occlusal guidance. Treatment consists of elimination of forced guidance.

Mandible which is morphogenetically built into the facial skeleton in a posterior position, shows poor prognosis for functional therapy.

Maxillary Base (Fig. 46.11)

Length of maxillary base is measured between PNS and point A projected perpendicularly onto the palatal plane.

Assessment of the length of the maxillary base has two ideal values—one related to the distance N-Se, the other to the length of the mandibular base. A deviation from the mandibular base-related norm indicates that the maxillary base is too long or too short. If the maxillary base corresponds to the mandibular base-related norms, the facial skeleton is proportionally developed.

Ascending Ramus (Fig. 46.12)

Length of ascending ramus is measured between gonion and condylion.

This length is important in determining the posterior facial height and consequently the growth pattern of an individual.

Evaluation of ramal length should also be done in relation to other proportions so as to be able to predict the possible growth increments and consequently the efficacy of the functional therapy

Morphology of the Mandible

Morphology of the mandible varies according to different facial types. The various facial types seen are:

- Orthognathic
- Retrognathic
- Prognathic

In orthognathic type—Ramus and body of mandible are fully developed, width of ascending ramus is equal to height of the body of mandible, including height of the alveolar process and incisors. Condylar and coronoid process are almost on the same plane. Symphysis is well developed (Fig. 46.13A).

In the retrognathic type—Corpus is narrow particularly in the molar region, symphysis is narrow and long. Ramus is short and narrow. Coronoid process is shorter than condylar process. Gonial angle is obtuse or large (Fig. 46.13B).

In prognathic type—Corpus is well developed and wide in molar region. Symphysis is wider in the sagittal plane. Ramus is wide and long. Gonial angle is acute or small (Fig. 46.13C).

The prognathic mandible grows horizontally. Even if an average or slightly vertical growth direction is evident in mixed detention, it shifts to horizontal pattern in following years.

In retrognathic mandible, shifting of the growth pattern in opposite direction is unlikely.

ANALYSIS OF DENTOALVEOLAR RELATIONSHIPS

An assessment of constantly changing inclination and position of incisors with respect to anterior cranial base, their apical bases, and each other is an important factor in deciding the type and construction of functional appliance for a patient.

Axial Inclination of the Incisors (Fig 46.14)

Upper incisor: The posterior angle between the long axis of upper incisor and SN line is measured (Fig. 46.14A). The measurement averages 94°-100° uptil the age of 7 years. However, the angle increases slightly to an average of 102° after the eruption of permanent teeth.

A large angle indicates proclined incisors, a smaller angle indicates incisor retrusion

Lower incisor: Posterior angle between the long axis of lower incisor and mandibular plane (Fig. 46.14A).

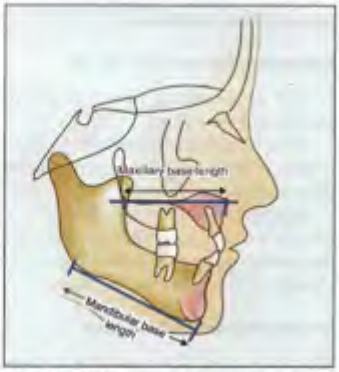


Fig. 46.11: Maxillary and mandibular base lengths

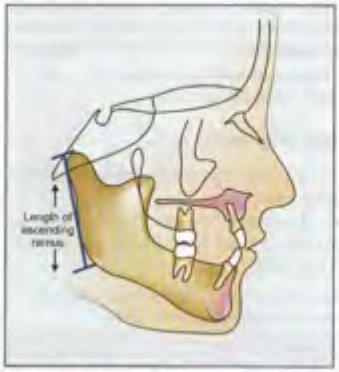


Fig. 46.12: Length of ascending ramus

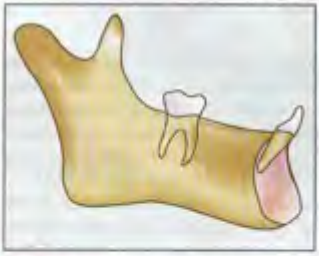


Fig. 46.13A: Morphology of orthognathic type of mandible



Fig. 46.13B: Morphology of retrognathic type of mandible



Fig. 46.13C: Morphology of prognathic type of mandible



Fig. 46.14A: Axial inclination of the upper and lower incisors

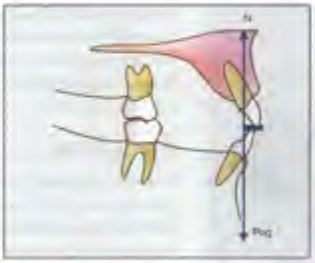


Fig. 46.14B: Linear measurement to assess the horizontal position of the upper incisors

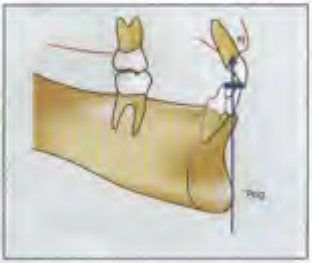


Fig. 46.14C: Linear measurement to assess the horizontal position of the lower incisors



Fig. 46.14D: A girl child showing a positive VTO

Average measurement is 90°-95°. Larger angle indicates labially tipped incisors which makes the functional appliance therapy difficult. Smaller angle indicates retroclined incisors which is advantageous for functional appliance therapy.

Position of incisors This is the linear measurement and is done between the incisal edges of the incisors to N–Pog line. Ideal position of maxillary incisors is 2-4 mm anterior to N-Pog Line (Fig. 46.14B)and lower incisors 2 mm anterior/posterior to N-Pog line (Fig. 46.14C). However, the reliability of these measurements in growing individuals is questionable because of the constantly changing reference points, i.e. nasion and pogonion, themselves.

VISUAL TREATMENT OBJECTIVE (VTO) (FIG. 46.14D)

One of the important criteria in case selection for the functional appliance therapy is eliciting a positive VTO. VTO is said to be positive if, the profile of the patient improves noticeably when the patient advances the mandible voluntarily to correct the overjet. A negative VTO, i.e. patient whose profile does not improve/ worsens on voluntary forward posturing of the mandible, are not good candidates for the functional appliance therapy.

ACTIVATOR (FIGS 46.15A TO C)

Activator is a loose fitting appliance which was designed by Andreasen and Haupl to correct retrognathic mandible. The present form of the appliance came through various stages of development starting with the concept of 'bite jumping' introduced by Norman Kingsley (1879). He used a vulcanite palatal plate consisting of an anterior inclined plane, which guided the mandible into a forward position when the patient closed on it.

This was followed by Hotz's Vorbissplatte which was a modification of Kingsley's plate and was used to correct retrognathic mandible with deep bite.

Monobloc which was made up of a single block of vulcanite, was used by Pierre Robin to correct the airway obstruction in patients with micrognathia.

Later in 1908 Viggo Andreasen, modified the Hawley's type of retainer, on the maxillary arch, to which he added a lower lingual horse shoe shaped



Fig. 46.15A: The activator (frontal view)



Fig. 46.15B: The activator (superior view)

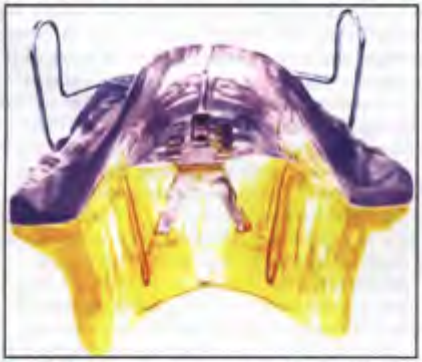


Fig. 46.15C: The activator (lingual view) showing the jack screw (*Photograph courtesy: Dentaurum Germany*)

flange which helped to position the mandible forward. He called it the biomechanical working retainer. Later he teamed with Karl Haupl, and developed an appliance which they called as Norwegian appliance and later came to be known as the activator.

INDICATIONS

Actively growing individual with favorable growth pattern are good candidates for the activator therapy. Various types of activators have been devised for the treatment of various conditions like:

- Class II division 1 malocclusion
- Class II division 2 malocclusion
- Class III malocclusion
- Class I open bite malocclusion
- Class I deep bite malocclusion
- For post-treatment *retension*
- Children with decreased facial height

CONTRAINDICATIONS

- Cannot be used in correction of Class I problems of crowded teeth where there is disharmony between tooth size and jaw size
- Cannot be used in children with excess lower facial height
- Cannot be given in cases with lower *proclination*
- In case of nasal stenosis
- In non-growing individuals

ADVANTAGES

- Uses existing growth
- Minimal oral hygiene problems
- Appointments usually short

DISADVANTAGES

- Requires good patient co-operation
- Cannot produce precise detailing and finishing of occlusion.

PHILOSOPHY OF ACTIVATOR

Various views have been put forward to explain the mode of action of the activator. Some implicate the reflex myotactic activity and isometric contractions while others attribute the results to the viscoelastic properties and stretching of the muscles and soft tissues.

However the basic fact remains that most of the changes are induced by holding the mandible forward and the ensuing reaction of the stretched muscles and soft tissues, transmitted to the periosteum, bones and the teeth.

A restraining effect on the growth of the maxilla and the maxillary dentoalveolar complex is also seen along with the stimulation of mandibular growth and mandibular alveolar adaptation.

Research has also shown favorable changes in the TMJ region.

COMPONENTS OF THE ACTIVATOR

It consists of the following elements (Figs 46.15 A to C):

1. *Labial bow* The wire used is spring hardened 0.9 mm stainless steel. The primary wire element of the activator consists of an upper and/or lower labial bow. It consist of horizontal middle sections, two vertical loops and wire extensions through the canine-deciduous first molar embrasure into the acrylic body.
2. *Jack screw* Optional (fitted to maxillary arch).
3. *Acrylic portion* This can be fabricated in cold cure acrylic directly on the models or a wax matrix can be made first and then invested in the flask.

CONSTRUCTION BITE

It is an intermaxillary wax record used to relate the mandible to the maxilla. This is done to improve the skeletal inter-jaw relationship. In most cases bite opening is by 2-3 mm and advancement is by 4-5 mm.

General considerations for construction bite

1. In case the overjet is too large, forward positioning is done in 2-3 stages
2. In case of forward positioning of the mandible by 7-8 mm, the vertical opening should be slight to moderate i.e. 2-4 mm.
3. If the forward positioning is not more than 3-5 mm then the vertical opening can be 4-6 mm

Lower construction bite with marked mandibular forward positioning

This kind of construction bite is characterized by marked forward positioning of the mandible with minimum vertical opening. As a rule of the thumb the anterior advancement should not exceed more than 70% of the most protrusive position, and vertically it should be within the limits of inter occlusal clearance. This kind of an activator with marked sagittal advancement with minimal bite opening is called H-activator and is indicated in persons with Class II Division 1 malocclusion with horizontal growth pattern.

High construction bite with slight anterior mandibular positioning

Here mandible is positioned anteriorly by 3-5 mm only and the bite is opened vertically by 4-6 mm. This kind of activator constructed with minimal sagittal advancement but marked vertical opening is called a 'V' activator and is indicated in Class II Division 1 malocclusion with vertical growth pattern.

Construction bite without forward positioning of mandible

It is done in cases with deep bite, and open bite

Construction bite with opening and posterior positioning of the mandible

In Class III cases bite is taken after retruding the mandible to a more posterior position. In this a vertical opening of 5 mm and a posterior positioning of 2 mm is required.

FABRICATION

Impressions

Impressions of upper and lower arches are made to construct 2 pairs of models - study models, working models

Bite Registration

- Amount of sagittal and vertical advancement is planned
- Horse-shoe shaped wax block is prepared. It should be 2-3 mm more than the vertical opening planned
- Patient is asked to practice placement of mandible at the desired position
- Horse-shoe shaped wax block is placed on the occlusal surface of one of the cast, maxillary or mandibular (maxillary preferred) and is pressed gently to form indentation of the teeth on the wax.
- It is then removed and placed in the patients mouth and the patient is asked to bite in the proposed sagittal position
- If found all right it is chilled and once again tried on the cast and then checked again in the patients mouth

Articulation of the Model

Upper and lower casts are articulated with the construction bite in place. The upper and lower casts are articulated in a reverse direction facing the hinge. This is to get easy access to the palatal surface of the upper and lingual surface of the lower casts.

Preparation of Wire Elements

A labial bow is prepared with 0.8 or 0.9 mm wire. The ends of the wire enter the acrylic body. The labial bow can be active or passive.

Fabrication of Acrylic Portions

Appliance consists of three parts (Figs 46.15A and B)

- Maxillary part
- Mandibular part
- Interocclusal part

The maxillary and mandibular parts are same as the acrylic portions of upper and lower Hawley's plate, but these are joined by an interocclusal part which makes this appliance into a single block. The inter occlusal portion has the indentations of upper and lower teeth and caps the lower anteriors, which controls their supra-eruption and proclination.

Trimming of the Activator

Activator therapy aims at providing a good skeletal as well as dentoalveolar relationship of upper and lower arches. However, this is not possible by simply holding/posturing the mandible forward, in a predetermined position, without appropriate guidance for the erupting teeth. Therefore, to achieve a proper three dimensional relationship of teeth, selective trimming of the activator is carried out. Trimming can be done at the time of appliance insertion or as some clinicians suggest, it can be done after about a week's time.

Trimming for Sagittal Control

a. Class II correction: Trimming is done so as to encourage the mesial movement of the lower molar and distal movement of the upper molar. Therefore, the distopalatal surface in the maxillary and mesio lingual surface in the mandibular posterior segments are trimmed. This pattern of trimming is particularly useful in horizontally growing patients as it tends to open the bite due to molar eruption (Fig. 46.15D).



Fig. 46.15D: Trimming of the activator for Class II correction. Note the lower posterior segment is free to erupt vertically and mesially, thus helping in the correction of deep overbite and Class II relation

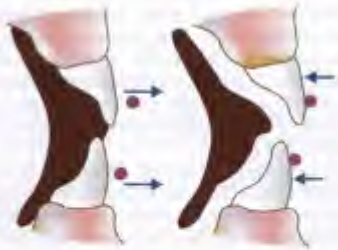


Fig. 46.15E(i): Activator design for protrusion of incisors. Note the loading of the entire lingual surface and labial bow away from the incisors to encourage labial movement of the incisors

Fig. 46.15E(ii): Activator design for retrusion of incisors. The labial bow here is active and the lingual surfaces of the incisors are relieved for lingual movement of the teeth



Fig. 46.15F: Activator design for intrusion of teeth (for anterior intrusion the labial bow is placed below the greatest convexity in the upper and above the greatest convexity in the lower)

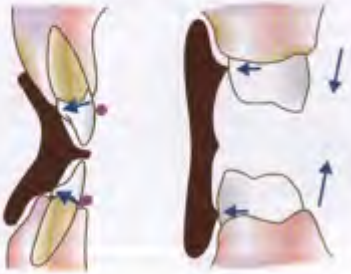


Fig. 46.15G: Activator design for extrusion of teeth. (i) Anteriors. (ii) Posteriors

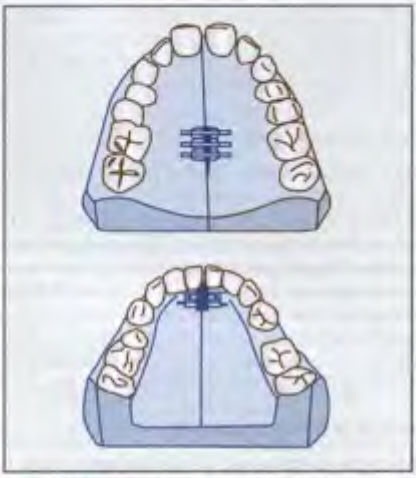


Fig. 46.15H: Activator with jack screw, for transverse control

b. Protrusion of incisors
   - In this case lingual surfaces of teeth are loaded with acrylic and a passive labial bow is given (Fig. 46.15E i).

c. Retrusion of incisors
   - Here the lingual surface is made totally free of acrylic and an active labial bow is given (Fig. 46.15E ii).

Trimming for Vertical Control

a. Intrusion of teeth (Fig. 46.15F)
   - For this the incisal area is loaded with acrylic
   - Labial bow is placed below the greatest convexity at the incisal area for intrusion
   - In case of intrusion of posteriors load the surfaces of the teeth with acrylic

b. Extrusion of teeth (Figs 46.15Gi and ii)
   - Here the lingual surface is loaded above the area of greatest convexity in the maxilla and below the area of greatest convexity in the mandible
   - Also the labial bow can be placed at the gingival 1/3 i.e. below the greatest convexity
   - In case of posterior extrusion the lingual surfaces below the greatest convexity are loaded.

For Transverse Control (Fig. 46.15H)

Jack screw is incorporated into the activator for expansion (trasnverse control) as and when required.

MANAGEMENT OF THE APPLIANCE

The patient is demonstrated to place and remove the appliance in mouth. The appliance is to be worn 2 to 3 hours during the day for the first week.

During the second week the patient sleeps with the appliance in mouth and wears it for 1-3 hours each day.

The appliance is checked during the third week to evaluate the trimming.

If the patient is wearing the appliance without any difficulty and following the instructions, checkup appointments are scheduled every 6 weeks.

BIONATOR (FIGS 46.16A AND B)

INTRODUCTION

The bulkiness of the activator and its limitation to night-time wear was a major deterrent in its greater use by clinicians to obtain maximum potential of functional growth guidance. The appliance was too

bulky for day-time wear. Moreover, during sleep, the function is minimized or virtually nonexistent.

This led to the development of the **BIONATOR**, a less bulky appliance. Its lower portion is narrow, and its upper component has only lateral extensions, with a crosspalatal stabilizing bar. The palate is free for proprioceptive contact with the tongue and the buccinator wire loops hold away the potentially deforming muscles.

The appliance developed by **BALTERS** in 1960, can be worn all the time, except during meals.

PHILOSOPHY OF BIONATOR

According to Balters, "the equilibrium between the tongue and the circumoral muscles is responsible for the shape of the dental arches and that the functional space for the tongue is essential for the normal development of the orofacial system" e.g. posterior displacement of the tongue could cause Class II malocclusion. Taking into consideration the dominant role of the tongue, Balters designed an appliance, which could take advantage of tongue posture. Thus he constructed an appliance whereby the mandible was positioned anteriorly, with the incisors in an edge to edge position. This forward positioning brought the dorsum of the tongue in contact with the soft palate and helped accomplish lip closure.

Thus the principle of bionator is not to activate the muscles but to modulate muscle activity, thereby enhancing the normal development of the inherent growth pattern and eliminate abnormal and potentially deforming environmental factors.

BIONATOR TYPES

Three basic constructions are common in bionator

- Standard appliance
- Open-bite appliance
- Class III or reverse bionator

Standard Appliance (Figs 46.16A to C)

It consists of a lower horse-shoe shaped acrylic lingual plate extending from the distal of the last erupted molar to the corresponding point on the other side. For the upper arch the appliance has only posterior lingual extensions that cover the molar and premolar regions. The anterior portion is open from canine to canine (Fig. 46.16A). The upper and lower parts, which are joined interocclusally, extend 2 mm above the upper gingival margin and 2 mm below the lower gingival margin.

The palatal bar is formed of 1.2 mm hard stainless steel wire extending from the top edges of the lingual acrylic flanges in the middle area of the deciduous first molars (Fig. 46.16B). The palatal bar forms an oval, posteriorly directed loop that orients the tongue and mandible anteriorly to achieve a Class I relationship.

The labial bow is made from 0.9 mm hard stainless steel. It starts above the contact point between the canine and deciduous upper first molar/ premolar. It then extends vertically, making a rounded 90° bend to the distal along the middle of the crowns of the posterior teeth and extends as far as the embrasure between deciduous 2nd molar and permanent 1st molar. It then makes a gentle downward and forward curve running anteriorly till the lower canine. From there, it forms a sharp curve extending obliquely till the upper canine, bends to a level at approximately the incisal third of the incisors and extends to the canine on the opposite side (Fig. 46.16C).

Open Bite Appliance

This is used to inhibit abnormal posture and function of the tongue. The construction bite is kept as low as possible with acrylic bite blocks between the posterior teeth to prevent their extrusion. The acrylic portion of the lower lingual part extends onto /upto the upper incisor region as lingual shield, to prevent tongue movements. The palatal bar has the same configuration. The labial bow is quite similar with the exception that the wire runs approximately between the incisal edges (Fig. 46.16D).

Class III or Reverse Bionator

This type of appliance is used to encourage the development of maxilla. The bite is taken in most possible retruded position, to allow labial movement of the maxillary incisors and reciprocally a slight restrictive effect on the lower arch. The bite is opened about 2 mm only in the interincisal region.

The palatal bar configuration runs forward instead of posteriorly, with the loop extending as far as the deciduous 1st molar or premolar.



Fig. 46.16A: The bionator (standard appliance)



Fig. 46.16B: Bionator (lateral view). Note that the palatal acrylic coverage has been replaced by the palatal bow and the buccal extensions of the labial bow which keep the deforming cheek muscles away

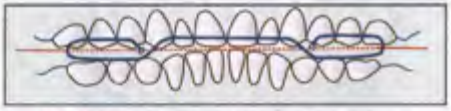


Fig. 46.16C: Labial bow for the standard appliance



Fig. 46.16D: Labial bow for the open bite appliance

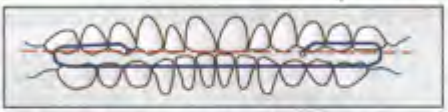


Fig. 46.16E: Labial bow for the Class III appliance

The labial bow runs in front of the lower incisors rather than in front of the upper incisors (Fig. 46.16E).

INDICATIONS FOR BIONATOR THERAPY

Bionator is indicated for the treatment of Class II Division 1 malocclusion in the mixed dentition using the standard bionator under the following conditions:

- Well aligned dental arches.
- Functional retrusion
- Mild to moderate skeletal discrepancy
- No evidence of labial tipping seen

CONTRAINDICATIONS

- Class II relationship caused by maxillary prognathism
- Vertical growth pattern
- Labially tipped lower incisors.

ADVANTAGES OF BIONATOR

1. Appliance is less bulky.
2. Can be worn full time, except during meals.
3. Appliance exerts a constant influence on the tongue and perioral muscles.

DISADVANTAGE OF APPLIANCE

The main disadvantage lies in the difficulty of correctly managing it.

THE FRANKEL FUNCTION REGULATOR

Function regulator appliances were developed by Rolf Frankel (Germany). Frankel believed that the active muscle and tissue mass i.e., the buccinator mechanism and the orbicularis oris complex have a major role in the development of skeletal and dentofacial deformities.

Hence he developed function regulators as orthopedic exercise devices, to aid in the maturation, training and reprogramming of the orofacial neuromuscular system.

FRANKEL PHILOSOPHY

1. *Vestibular area of operation*
   - Shields of the appliance extend to the vestibule and this prevents the abnormal muscle function.
2. *Sagittal correction via tooth borne maxillary anchorage*
   - Appliance is fixed on the upper arch by grooves mesial to the 1st permanent molar and distal to the canine in the mixed dentition period.
   - Presence of the lingual pad acts as proprioceptive stimulus and helps in the forward posturing of the mandible.
3. *Differential eruption guidance*
   - Frankel is placed on the upper teeth.
   - Mandibular posterior teeth are free to erupt and their unrestricted upward and forward movement contributes to both vertical as well as horizontal correction of the malocclusion.
4. *Periosteal pull by buccal shields and lip pad*
   - Presence of buccal shields and lip pads exert the periosteal pull which helps in bone formation and lateral expansion of the maxillary apical base.
5. *Minimal maxillary basal effect*
   - Downward and forward growth of maxilla seems to be restricted, even though lateral maxillary expansion in seen.

MODE OF ACTION OF FR

1. *Increase in transverse sagittal direction*
   - by use of buccal shields and lip pads
2. *Increase in vertical direction*
   - by allowing the lower molar to erupt freely because appliance is fixed to the upper arch
3. *Muscle adaptation*
   - The form and extension of the buccal shields and lip pads along with the prescribed excercises corrects the abnormal peri-oral muscle activity.

ORAL EXERCISES WITH FRANKEL

- Frankel—full time wear appliance.
- Lips to be closed at all times or keep a paper between the lips
- Swallowing, speaking, etc. with the appliance in mouth, itself serves as an exercise

TYPES OF FUNCTION REGULATORS

1. FRI—used for Class I and Class II, Division 1.
   FRIa —used for Class I, moderate crowding and deep bite.
   FRIb—used for Class II Division 1 overjet less than 7 mm.
   FRIc—used for Class II Division 1 overjet more than 7 mm.
2. FR II—used for Class II Division 2 and Division 1 (Figs 46.17A and B)
3. FR III—used for Class III (Figs 46.17C to E)
4. FR IV—used for cases with open bite and bimaxillary protrusion.
5. FR V—FR with headgear.

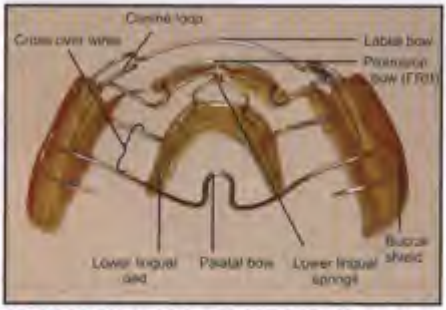


Fig. 46.17A: Frankel II (superior view showing parts of the appliance)

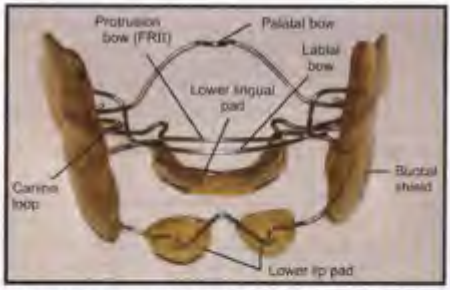


Fig. 46.17B: Frankel II (frontal view showing parts of the appliance)

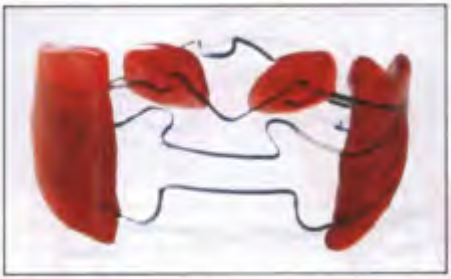


Fig. 46.17C: Frankel III (for Class III cases)



Fig. 46.17D: Frankel III in mouth



Fig. 46.17E: Patient with Frankel III

FABRICATION OF FUNCTION REGULATOR

PARTS OF THE APPLIANCE (FIGS 46.17A,B AND F TO I)

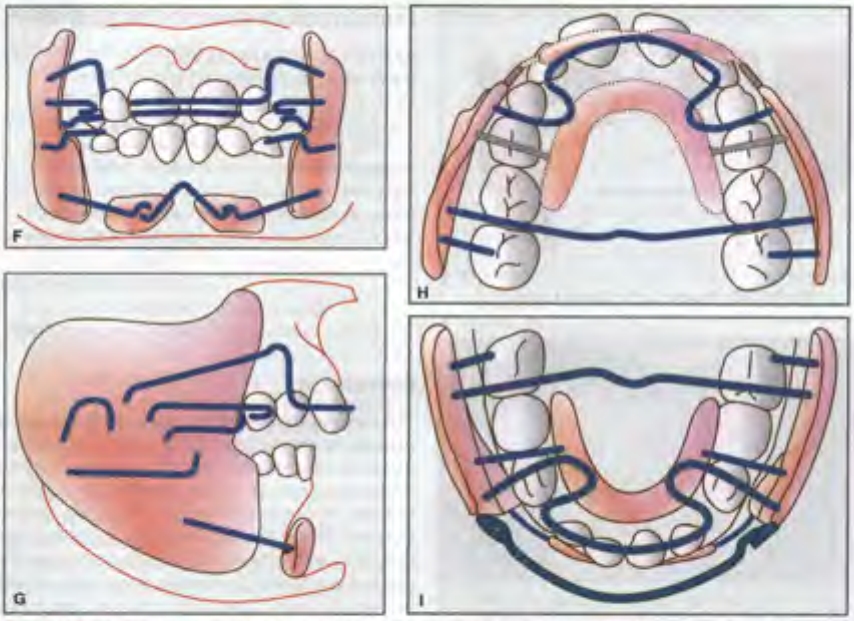
Acrylic part	*Wire parts*
Buccal shields	Palatal bow
Lip pads	Labial bow
Lower lingual pads	Canine extensions
	Upper lingual wire (only in FR II)
	Lingual cross over wire
	Lip pads
	Lower lingual springs

IMPRESSIONS

The impressions should reproduce the whole alveolar process to the depths of the sulci, including the maxillary tuberosities. The soft tissues and the muscle attachments should not be distorted. A custom tray can also be fabricated based on the study models, if desired. Since the appliance is anchored in the maxillary arch between the deciduous second molar and the permanent first molar, separators should be placed between these teeth prior to impressions; otherwise, disking of the distal surface of the primary second molar, can also be done after fabrication of appliance.

WORKING MODEL POURING AND TRIMMING

- Model base must extend away from alveolar process by at least 5 mm
- Correct model trimming is necessary before appliance fabrication
- The desired amount of stone to be cut is outlined with a pencil before trimming.
- Then it should be cut with a round bur
- Final detailing is done with plaster knife.
- No trimming required for buccal shields on mandible.
- But trimming is required in the maxillary buccal shield area and lower lip pad area.
- Care must be taken not to disturb the muscle attachments.



Figs 46.17F to I: Basic components as described for a FR II appliance. (F) Buccal shields, lip pads, labial wire, (G)Buccal shields, lip pads, canine clasp, labial arch, and labial arch loop, (H) Appliance on the maxillary cast, (I) Lingual acrylic pad, lingual wires and lingual springs

TRIMMING FOR LIP PADS

- 5 mm from greatest curvature of alveolar base to ensure optimum extension.
- Lower relief should be 12 mm below gingival margin.

TRIMMING FOR BUCCAL SHIELD

- Sulcular depth must be 10-12 mm above the gingival margin of posterior teeth.
- Region next to the muscle attachment over the deciduous 1st molar and the superior limit of the lateral incisor depression must be well defined.
- This allows optimal extension of buccal shields for deposition of bone.

CONSTRUCTION BITE (FIG. 46.17J)

For minor sagittal problems, the construction bite is taken at and end-to-end incisor relationship, with the mandible position forward not more than 2.5 to 3 mm. A clearance of at least 2.5 to 3.5 mm in the buccal segments is necessary to allow the crossover wires to pass through in the Frankel appliance.

Dental midline discrepancies should not be corrected in the bite by manipulation during forward posturing. The construction bite should be checked on the casts and the cases should be mounted with the bite.

WAX RELIEF (FIGS 46.17K TO M)

Relief is placed such that the buccal shields and lip pads stay away from teeth and tissues to achieve the



Fig. 46.17J: Construction bite for FR II. Note that the dental midline deviation should not be corrected in the construction bite unless the skeletal midlines are deviating as well



Fig. 46.17K: Wax relief in the maxillary arch. Note the configuration of the palatal bow as well



Fig. 46.17L: Wax relief on the mandibular cast

desired expansion. Thickness of wax depends on the expansion required but should not exceed 4-5 mm in the tooth area and 2.5-3 mm in the alveolar area in the maxilla (Fig. 46.17K). In the mandible, only 0.5 mm of relief is given (Fig. 46.17L). Thickness of relief wax is greater in maxilla because of arch narrowing in case of Class II Division 1 malocclusions.



Fig. 46.17M: Complete wax up of the Frankel. Ready for the fabrication of the buccal shields in cold cure acrylic

WIRE COMPONENTS (FR Ib) (FIGS 46.17A,B AND F TO I)

Consists of:

- Stabilizing wires
- Tooth moving wires

Lower Lingual Support Wire

- Made of 1.25 mm wire
- Can be one unit or 3 separate parts
- Horizontal reinforcing wire element contours to the lingual apical base 1-2 mm away from the mucosa and 3-4 mm below the gingival margin so as to permit adding acrylic to the pad.
- Cross over wire pass between deciduous first and 2nd molar
- Ends are then bent at 90° to insert into the buccal shields.

The ends must be parallel to each other and the occlusal plane to allow for advancement of the anterior section later if needed.

Lower Lingual Springs

- Made of 0.8 mm wire.
- Right above the cingula the wire is curved about 3 mm below the incisal margin
- Function—is to prevent extrusion of lower incision
- Should not be active only passive
- If tooth movement is required the spring is made active.

Lower Labial Wires

- Made of .9 mm wire
- Acts as a skeleton for lower lip pads
- It can be one piece or three piece
- It should be 1 mm away from the tissue.
- Wire frame-work should be 7 mm below the gingival margin
- Middle part should be inverted 'V' shaped for labial frenum relief.

Palatal Bow (Figs 46.17K and M)

- Made of 1 mm wire
- Should have a curve in the center for lateral expansion
- Wire should pass into the groove between deciduous 2nd and 1st permanent molar
- Wire emerges out of wax relief makes a loop in the buccal shield and lies between maxillary 1st molar buccal cusp ending in the fossa as an occlusal rest.
- This provides a positive seat to the FR as well as prevents eruption of the upper 1st permanent molar.

Labial Bow

- Made of 0.9 mm wire
- Originates in buccal shield curves upwards and lies in the depression between canine and lateral. It is in the middle of labial surface of incisors and leaves the acrylic with slight bend towards the sulcus.
- Should be 2 mm away from mucosa
- Permits canine eruption and expansion without contacting the labial wire
- Loops should be wide enough to allow activation later to close anterior space if required.

Canine Loops (For FR Ia)

- Made of 0.9 mm.
- Embedded in buccal shield at occlusal plane level
- Turned sharply towards gingival margin of upper deciduous 1st molar and fit in embrasure between deciduous first molar and canines.
- Wire wraps around the lingual surface of the canine emerges labially at the canine-lateral embrasure curves distally over the canine cusps. Free ends can be bent occlusally if required.

Canine Loops (For FR II)

- Made of 0.8 mm wire.
- Originate in buccal shield
- Contact canines on buccal surface as recurved loop.
- Serves as extension of buccal shield in the canine area which is normally narrowed by the peri-oral muscles.
- Should be 2-3 mm away from canines to prevent restrictive muscle function.

Upper Lingual Wire (Protrusion Bow)

- Made of 0.8 mm wire
- Mostly seen in FR II and FR III.
- Lingual bow behind the maxillary incisors serves to maintain pre-functional appliance alignment achieved and also stabilizes the FR by locking it on to the maxillary arch
- 0.8 wire is used if the centrals are retroclined, but if the anterior alignment is already achieved a stiffer wire can be used i.e. 0.9 mm wire.
- It originates in the vestibular shield and passes to the lingual through the canine-deciduous 1st molar embrasure.
- Wire forms loops at the palatal mucosa and curve vertically to contact the incisor at the embrasure between canine and lateral incisor.

ACRYLIC PARTS

- After the wires are fabricated and adapted they are secured in place with sticky wax.
- The lip pad, buccal shields, lower lingual pads are fabricated in cold cure acrylic.
- Total thickness of the acrylic should not exceed 2.5 mm
- Lip pads look like parallelogram (tear drop shape in longitudinal cross-section)
- Lip pads should be 5 mm from the gingival margin
- Presence of lip pads eliminates mentalis hyper-activity and abnormal functional lip trap, thereby helps correcting the overjet.
- Buccal shields should extend past the canine deciduous first molar embrasure to the middle of the canine.

COMPONENTS OF VARIOUS FR APPLIANCES

FR Ia

Not popular. Replaced by FRIb

- Used for Class I moderate crowding and deep bite
- Lingual wire loops are given instead of acrylic lingual pads to posture the mandible forwards
- The cross over wire (passing between upper and lower occlusal surface) is an extension of the lingual loops.

FR Ic

- used in Class II Division 1 with over jet greater than 7 mm
- It has been observed that posturing the mandible forward into a Class I relationship and eliminating excessive overjet in one step for a Frankel appliance is neither feasible nor necessary. Because tissue response is less favorable and there is increased patient discomfort or compliance.
- So mandibular protraction is done in 2 or 3 steps.
- Horizontal and vertical cuts are made on the buccal shield and then made to slide along the hanger (Fig. 46.17N)
- The cuts are then filled with cold cure acrylic.
- FRIc is seldom used because FRIb and FRII can be modified in the same way.

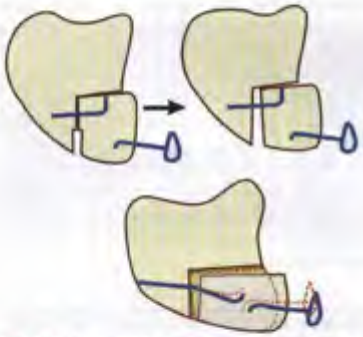


Fig. 46.17N: Mandibular advancement done in stages. Horizontal and vertical cuts are made in the acrylic and the lower lingual pad and lip pads are advanced. The gap is later filled with acrylic

FR II

- Used for Class II Division 2 and Division 1
- Protrusion bow is made unlike in FRI
- Canine loops
  - It is only a recurved loop
  - It originates in the buccal shield and contacts the buccal surface of the canine as a recurved loop.
  - It shields the canine against the buccinator action.
  - It is placed 2-3 mm away from the deciduous canines

FR III (Figs 46.17C to E)

- Used for Class III correction
- Lip pads are in the maxillary arch
- Labial bow resting against mandibular teeth. Protrusion bow is on the upper teeth and is made of 0.8 mm wire for forward movement of maxillary incisiors if desired.
- The occlusal rest is on the mandibular molar unlike in FRII where it is on the maxillary molar.

FR IV

- Used for open bite and bimaxillary protrusion
- Has no canine loops
- Has no protrusion bow
- Four occlusal rests present i.e. on deciduous 1st molar and permanent 1st molar on each side to prevent eruption of posterior teeth.
- Palatal bar resembles FR III i.e. it does not contact the teeth
- The buccal shield in FR IV should be wafer thin to enable lip closure and exercise without which the appliance will be a failure.

FR V

- Frankel appliance used along with head gear.

TREATMENT TIMING

The best therapeutic effect of the Frankel appliance is achieved during the late mixed and transitional dentition period, when both the soft and hard tissues are undergoing their greatest transitional changes.

Treatment for Class III and open bite cases should usually start sooner than for Class II problems.

TWIN-BLOCK

EVOLUTION OF TWIN-BLOCK

Introduction

The twin block appliance was developed by Clark in 1977, and it consists of an upper and lower device with simple bite blocks that engage on occlusal inclined planes.

The appliance became popular due to a number of advantages over other functional appliances namely:

1. The functional mechanism is very similar to that of the natural dentition.
2. The occlusal inclined planes give greater freedom of movement in lateral and anterior excursion and cause less interference with normal function.
3. Appearance is noticeably improved.
4. Less bulk, therefore, better patient compliance.
5. Can be used in later stages of growth (late mixed dentition/early permanent dentition)
6. The appliance can be cemented in mouth, without disrupting the normal oral functions, to improve patient compliance.
7. Absence of lip pads and buccal shields, allow patient a much better comfort, however, modifications containing lip pads can be incorporated as and when required.

DEVELOPMENT OF TWIN-BLOCK

The twin block appliance evolved in response to a clinical problem that presented when a young patient, the son of a dental colleague, fell and completely luxated an upper central incisor. The incisor was reimplanted and a temporary splint was constructed to hold the tooth in position.

After 6 months with a stabilizing splint, the tooth had partially reattached, but there was evidence of severe root resorption and the long-term prognosis for the reimplanted incisor was poor.

The occlusal relationship was Class II Division 1 with an overjet of 9 mm and lower lip was trapped lingual to the upper incisors. Adverse lip action on the reimplanted incisor was causing mobility, and root resorption. To prevent the lip from trapping in the overjet it was necessary to design an appliance that could be worn full time to posture the mandible forward. At that time no such appliance was available and simple bite blocks were therefore, designed to achieve this objective. The appliance mechanism was designed to harness, the forces of occlusion to correct the distal occlusion and also reduce the overjet without applying direct pressure to the upper incisors. The first twin block appliances were fitted on 7th September 1977. The upper and lower bite blocks engaged mesial to the 1st permanent molar at 90° to the occlusal plane, when the mandible postured forward. This positioned the incisors edge-to-edge with 2 mm vertical separation to hold the incisors out of occlusion. The patient had to make a positive effort to posture the mandible forward to occlude the bite blocks in protrusive bite.

CASE SELECTION FOR TWIN-BLOCK APPLIANCE

Case selection for clinical use of twin-block should, display the following criteria:

1. Angle's Class II Division 1 malocclusion with good arch form.
2. A lower arch that is uncrowded or decrowded and aligned.
3. An upper arch that is aligned or can be easily aligned.
4. An overjet of 10-12 mm and a deep overbite.
5. A full unit distal occlusion in the buccal segments.
6. On examination of models in occlusion with the lower model advanced to correct the increased overjet, the distal occlusion is also corrected and it can be seen that a potentially good occlusion of the buccal teeth will result.
7. On clinical examination the profile should be noticeably improved when the patient advances the mandible voluntarily to correct the overjet (Fig. 46.14D).
8. To achieve a favorable skeletal change, during treatment, patient should be actively growing. A more rapid growth response may be observed when the treatment coincides with the potential growth spurt.

APPLIANCE DESIGN AND CONSTRUCTION

EVOLUTION OF THE APPLIANCE DESIGN (FIGS 46.18A TO C)

The present form of the appliance evolved over a period following clinical experience with the

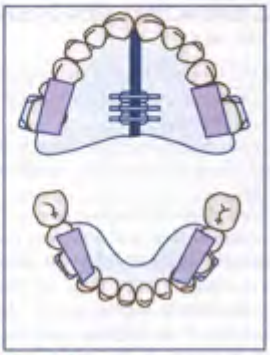


Fig. 46.18 A: The twin block appliance

4. Clasps on lower premolars and incisors.
5. Springs to move the individual teeth
6. Provision for extra-oral traction in some cases. (esp. maxillary protrusion cases)

DELTA CLASPS (FIG. 46.18D)

After initial use of the Adams' clasp, Clark introduced the delta clasp in 1985. The basic premise was to reduce the incidence of breakages (as seen with the Adams' clasp) due to repeated adjustments and consequent metal fatigue.

LABIAL BOW

The use of labial bow in the upper plate was discontinued after it was noticed that it causes unwanted retroclination of upper incisors with consequent deepening of the bite. This is turn, limited the scope of mandibular correction possible. However, in certain cases with severe upper proclination, labial bow in the upper arch may be placed.

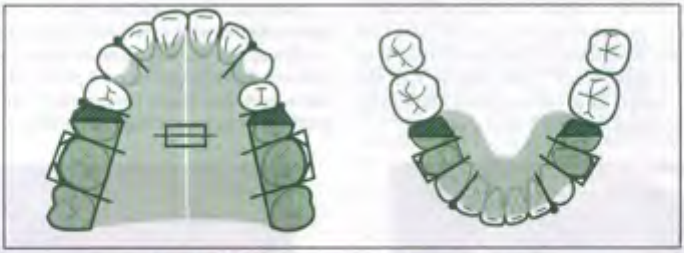


Fig. 46.18 B: Clark's standard twin block appliance



Fig. 46.18 C: Patient with a twin block

appliance. The earliest design of the twin-block consisted of:

1. A midline screw to expand the upper arch
2. Occlusal bite block (at 90° to occlusal plane)
3. Clasps on upper molars and premolars (Adams' clasp)

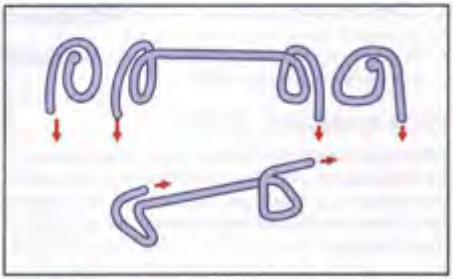


Fig. 46.18 D: Delta clasp – construction and design

BASE PLATE (FIGS 46.18E i AND ii)

The design is similar to upper and lower Hawley's plate and can be prepared in heat cure or cold cure acrylic. The main advantage of heat cure acrylic is its additional strength. Cold cure acrylic has the advantage of speed and convenience, however, strength and accuracy is slightly compromised.

OCCLUSAL BITE BLOCKS WITH INCLINED PLANES (FIG. 46.18F)

Position of the bite blocks and the angulation of its inclined planes are important factors in the success of the twin-block therapy.

The position of the inclined plane is determined by the lower block and is critical in the treatment of deep overbite.

The inclined plane on the lower bite-block is angled from the mesial surface of the second pre-molar or second deciduous molar at 70° to the occlusal plane. This places the leading edge of the inclined plane on the upper appliance mesial to the lower first permanent molar, thus keeping a provision for the unhindered eruption of the lower 1st permanent molar.

Mesially, the lower bite block extends upto the canine region with a flat occlusal surface.

The upper inclined plane is angled from the mesial surface of the upper second premolar to the mesial surface of the upper first molar. The flat occlusal portion then passes distally over the remaining upper



Fig. 46.18 E (i): Maxillary portion of the twin block – similar to upper Hawleys' plate with bite blocks



Fig. 46.18 E (ii): Mandibular portion of the twin block – similar to lower Hawleys' plate with bite blocks



Fig. 46.18 F: Bite blocks with the incline.The lower bite block does not extend beyond half of the primary second molar/ 2nd premolar, which allows free eruption of the lower molar for the correction of Class II occlusion and deep over bite. Also note the angulation of the inclined planes

posterior teeth in a wedge shape, reducing in thicken as it extends distally.

The height of the bite blocks is determined by the vertical opening planned and recorded in the construction bite. For a twin block therapy, it is recommended that the vertical opening in the construction bite be beyond the free way space. This implies that the height of the bite block should be 4-6 mm so that the mandible does not go back even in physiologic rest position.

ANGULATION OF THE INCLINED PLANES (FIG. 46.18F)

Initially, inclined planes were at 90° to occlusal plane. However, adjustment to this sort of inclined plane was difficult for a lot of patients.

Therefore, for patient convenience inclined planes were reduced to 45° but since, this angulation caused equal vertical and horizontal movement, the angulation was further changed to 70°, so that more horizontal vector of force would be produced.

Nevertheless, the inclined plane angulation can vary between 45° and 70° depending upon the patient comfort levels.

CONSTRUCTION BITE

BITE REGISTRATION FOR CONSTRUCTION OF TWIN-BLOCKS FOR CLASS II DIVISION 1 MALOCCLUSION

Construction bite for twin-block can be taken is the conventional manner, by means of an inter-occlusal wax bite, as described earlier, for the activator, or by the use of an '**Exactobite**'

Exactobite or project-bite gauge is a horse-shoe shaped device with an anterior handle with various grooves, designed for accurate control in registering a protrusive bite for construction of twin block. The blue bite gauge registers 2 mm vertical clearance between the incisal edges of the upper and lower incisors, which are in appropriate interincisal clearance for bite registration in most Class II Division 1 malocclusions with increased overbite.

In a Class II Division 1 malocclusion a protrusive bite is registered to reduce the overjet and distal occlusion on average 5-10 mm on initial activation, depending on the freedom of movement in protrusive functions. The length of the patient's protrusive path is determined by recording the overjet in centric occlusion and fully protrusive occlusion. The activation should not exceed 70% of the maximum protrusive path.

In growing child, with an overjet of up to 10 mm, provided the patient can posture comfortably forwards, bite may be activated up to edge-to-edge on the incisors with a 2 mm interincisal clearance. Larger overjet requires partial correction.

It is best, first to rehearse the procedure of bite registration with the patient using a mirror. The patient is instructed to close correctly into the bite gauge before applying the wax. Once the patient understands, what is required, softened wax is applied to the bite gauge from a hot water bath.

The clinician can then place the bite gauge in the patient's mouth to register the bite. Midlines should be coincident, however, if dental midlines are deviating, skeletal midlines should be taken into consideration.

One important aspect of the construction bite for the twin-block appliance is to establish the correct vertical dimension. The bite should be open slightly beyond the clearance of the free way space to encourage the patient to close into the appliance rather than allow the mandible to drop out of contact into rest position.

Hence, an inter-incisal clearance of about 2-3 mm is established, which is equivalent to an approximately 5-6 mm clearance in the 1st premolar region and about 3 mm clearance distally in the molar region.

This amount of vertical clearance ensures that the mandible does not drop back at rest and that enough space is available for the vertical development of the posterior teeth to reduce the over bite.

ESTABLISHING THE CORRECT VERTICAL DIMENSIONS—THE INTERGINGIVAL HEIGHT

A simple guide is used to establish the correct vertical dimension during the twin block phase of treatment. The intergingival height is measured from the gingival margin of the upper incisor to the gingival margin of the lower incisor when the teeth are in occlusion.

The 'comfort zone' for intergingival height for adult patients is about 17-19 mm. This is equivalent to combined heights of the upper and lower incisors minus an overbite within the range of normal. Patients whose intergingival height varies significantly from comfort zone are at a greater risk of developing TMD. This applies both to the patients with a deep overbite

whose intergingival height is reduced, and to patients with an anterior open bite who have an increased intergingival height.

The intergingival height is a useful guideline to check progress and to establish the correct vertical dimensions during treatment. Measurement of intergingival height is done by using a mm ruler and divider or with a Vernier scale to measure the distance between the upper and lower gingival margins.

In twin block treatment the correct intergingival height is achieved with great consistency. Deep overbite may be corrected to an intergingival height of 20 mm to allow for a slight settling in with a resultant overbite increase after treatment.

In the younger patient's a range of 15-17 mm is normal and allowance should be made for the diminutive height of the clinical crowns.

FITTING TWIN-BLOCKS: INSTRUCTIONS TO PATIENT

Patient motivation is an important factor in all removable appliance therapy. The process of patient education and motivation continues when the patient attends to have twin block fitted. It is often helpful to the patient if the clinician demonstrates twin blocks on models to confirm that it is a simple appliance system and is easy to wear with no visible anterior wires.

Simply biting the blocks together guides the lower jaw forward to correct the bite. The appliance system is easily understood even by young patients, who see that biting the blocks together corrects the jaw position. It is important to emphasize positive factors and to motivate the patient before treatment.

The patient is shown how to insert the twin blocks with the help of a mirror, pointing out the immediate improvement in facial appearance when the twin blocks is inserted and explaining that the appliance will produce this change, in a few months, provided they are worn full time. A removable appliance only corrects the teeth when it is in mouth, and not in the pocket. Both appliances must be worn full time, especially during eating with sole exception being removed for cleaning and during swimming and contact sports.

At first the appliance may feel large in the mouth, but within a few days, it will be very comfortable and easy to wear. Twin blocks cause much less interference with speech than other, one piece functional appliances. For a first few days, speech will be affected, but will improve and should return to normal within a week.

As with any new appliances it is normal to expect a little initial discomfort. But it is important to encourage the patient to preserve and keep the appliance in mouth at all times except for hygiene process.

The patient should be advised to remove the appliance during eating for first few days. Then it is important to learn to eat with the appliance. The force of biting on the appliance corrects the jaw position, and learning to eat with the appliance is important to accelerate the treatment. In a few days patient should be eating with the twin block and within a week should be more comfortable with the appliance in the mouth than they are without it.

It is necessary to check the initial activation and confirm that the patient closes consistently on the inclined plane with the mandible protruded in new position. The overjet is marked with a mandible fully retruded and this measurement should be recorded and checked at every visit to monitor progress.

Stages of Treatment (Figs 46.19A and B)

Twin-block treatment is described in two stages. Twin blocks are used in the active phase to correct the anteroposterior relationship and establish the correct vertical dimension. Once this phase is completed, the twin-blocks are replaced with an upper Hawley's type of appliance with an anterior inclined plane which is then used to support the corrected position as the posterior teeth settled fully into the occlusion.

Stage I—Active Phase

Twin-blocks achieve rapid functional correction of mandibular position from a skeletal retruded Class II to Class I occlusion using occlusal inclined planes over the posterior teeth to guide mandible into correct relationship with the maxilla. In all functional therapy, sagittal correction is achieved before vertical development of posterior teeth is complete.

The upper block is trimmed occlusodistally to leave the lower molars 1-2 mm clear of the occlusion to encourage lower molars to erupt and reduce the overbite. By maintaining a minimal clearance between the upper bite block and the lower molars, the tongue is prevented from spreading laterally between the teeth. This allows molars to erupt more quickly. At



Fig. 46.19A: Twin block in patient's mouth



Fig. 46.19B: Pre and post twin blocks photographs



Fig. 46.20 A: Banded Herbst appliance (Photograph courtesy Dentaurum, Germany)

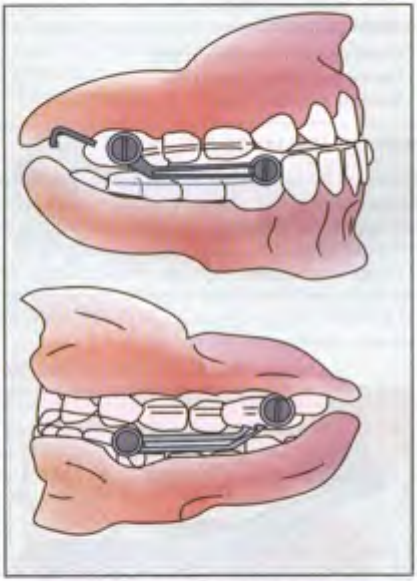


Fig. 46.20 B: Acrylic splint Herbst appliance

Disadvantages

- Appliance is prone to breakage.
- Lateral movement is restricted

JASPER JUMPER (FIGS 46.21A AND B)

The Jasper Jumper (American Orthodontics) consists consists of a heavy coil spring encased in vinyl coating. The flexible springs are attached to the maxillary 1st molar posteriorly and distal to the mandibular canine, either directly onto the lower arch wire or by means of an out-rigger.



Fig. 46.21 A: Jasper Jumper in mouth



Fig. 46.21 B: Pre and post-treatment photographs following treatment with Jasper Jumper

Indications

- Dental Class II malocclusion
- Deep bite with retroclined mandibular incisors.

Contraindications

- Dental and skeletal open bites.
- Minimum buccal vestibular space.
- Vertical growth pattern with increased lower facial height.
- Cases prone to root resorption.

Advantages

- Ease of insertion and activation
- Generation of intrusive forces on molars and incisors.

Disadvantages (Figs 46.21C and D)

- Frequent breakages
- Compromised oral hygiene
- Externally perceivable bulge in the cheeks



Fig. 46.21 C: Compromised oral hygiene due to Jasper Jumper. Also note the tearing off of the vinyl sleeve of the Jasper Jumper



Fig. 46.21D: Externally perceivable bulge in the cheeks due to Jasper Jumper

THE MANDIBULAR ANTERIOR REPOSITIONING APPLIANCE (MARA) (FIG. 46.22)

The MARA consists of cams made from 0.060 square wire attached to tubes (0.062 square) on upper first molar bands or stainless steel crown. A lower first molar crown has a 0.059 arm projecting perpendicular to its buccal surface, which engages the cam of the upper molar (Fig. 46.28).

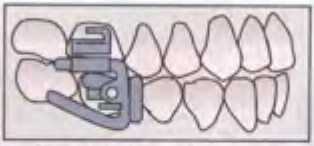


Fig. 46.22: The mandibular anterior positioning appliance

The appliance is adjusted so that when patient closes the mouth, the cam on upper molar guides and repositions the mandible into a Class I relationship.

Its main disadvantage is that temporary stainless steel crowns are needed on all first molars.

Indication

Skeletal Class II with mandibular deficiency.

Contraindications

- Cases prone to root resorption
- Dental and skeletal open bite
- Vertical growth pattern.

BIOPEDIC APPLIANCE (FIG. 46.23)

Developed by Jay Collins in 1997 consists of buccal attachment on upper and lower molar crowns which includes the standard edge wise tubes and a large .070 inch molar tube.

Large rods pass through these tubes. The mandibular rod insert from mesial of the molar tube and is fixed at the distal by its screw clamp. Activation is done by moving the rod mesially.

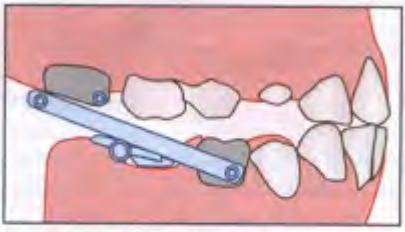


Fig. 46.23: The biopedic appliance

Maxillary rod inserts from distal of the tube and is fixed at the mesial by screw clamp. Two rods are connected by a rigid shaft and have pivotal regions at their ends (Fig. 17.6, Grab and V 3rd ed. Pg 782.)

EUREKA SPRING (FIG. 46.24)

Developed by De-vincenzo in 1996. One of the first inter arch appliances to utilize the compressive forces.

Advantages

- Good patient acceptance
- Can be used for Class II and Class III correction as well as in conjunction with extraoral force.
- Possibility of alteration in the amount and direction of force during treatment.
- Components are available separately
- Significantly less expensive than other appliances.

Disadvantages

- Technique sensitive insertion procedure
- Frequent breakages of interval spring
- Less force levels than forsus and twin force corrector.
- Tissue irritation.

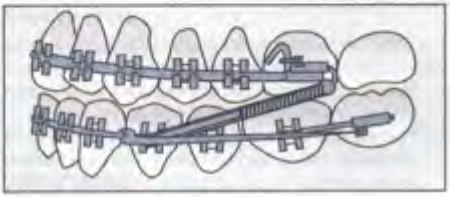


Fig. 46.24: Eureka spring

SAIF SPRING (FIG. 46.25)

Introduced by Armstrong, consists of two Ni-Ti coil springs, one inside the other with soldered loops on both ends. Used for Class II and Class III correction and available in 2 lengths: 7 and 10 mm. Delivers the force of 200-400 gm.



Fig. 46.25: Saif spring

Disadvantage

- Bulky, therefore oral hygiene maintenance is problem.
- Large inventory
- Oral hygiene is compromised
- Breakages are often seen.

THE KLAPPER SUPER SPRING (FIG. 46.26)

Introduced by Lewis Klapper in 1997. Resembles Jasper Jumper except that instead of coil spring, cable is used. In 1998, the cable was wrapped with a coil and Klapper super spring II came into being.

Advantages

- More vertical force vector, therefore useful for intrusion.

Disadvantages

- Unlike, Jasper Jumper it enters the molar tube from mesial and requires special molar tube for engagement.

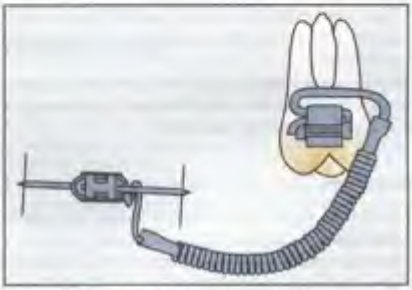


Fig. 46.26: Klapper super spring

FORSUS FATIGUE RESISTANT DEVICE (FIGS 46.27A AND B)

The appliance consists of:

- Spring module
- L ball pin
- Push rod installation. The push rods are available in following sizes 25, 29, 32 and 35 mm which are available for right and left side.



Fig. 46.27 A: Forsus fatigue resistance device



Fig. 46.27 B: Forsus flat spring

- The L pin with the spring module is attached to upper first molar after selecting the appropriate push rod.

Its loop is attached to archwire between the cuspid and first bicuspid and the other end is inserted into the compressed spring module.

Advantages

- Unequal push rods can be used for midline correction
- Spring can be reactivated by placing crimp split ring bushings on push rod
- Relative ease of installation and removal.

SABBAGH UNIVERSAL SPRING (SUS) (FIGS 46.28A TO C)

It is the latest interarch compressive spring to be introduced and has a number of unique features as:

- Slotted screw for partial adjustment of distal aspect of the plunger assembly (upto 4 mm)
- The second coil spring inserted at the time of placement which in combination with the internal spring permits a greater active extension of force than any other appliance.
- Available in one standard link
- No difference in appliance for the right and left sides.



Fig. 46.28 A: Sabbagh universal spring (Photograph courtesy Dentaurum, Germany)



Fig. 46.28 B: SUS – 1 in patient's mouth



Fig. 46.28 C: SUS – 2 in patient's mouth

- Lateral mandibular movement possible.
- More resistant to fatigue fracture

Disadvantages

- Unsuitability for Class III treatment
- Limitations in patients with maximum opening of less than 48 mm.
- Increased force levels
- Considerably greater cost

CONCLUSION

The purpose of this chapter was to discuss the biological basis and clinical management of the various functional appliances.

Today, with this important tool in the hands of the orthodontist, the speciality has truly evolved from just the ability to move teeth to the ability of influencing and transforming the dentofacial structures, thus, permitting the attainment of the achievable optimum.

However, as with any other speciality of medicine, the importance of proper diagnosis and treatment planning in the success of the functional therapy cannot be over emphasized. One must not forget the importance of correct timing for achieving the best results with functional appliances.

FURTHER READING

1. Bishara SE, Ziaja RR. Functional appliances: A review, Am J Orthod Dentofac Orthop 1989;95:250-6.
2. Clark WJ. The twin block technique. A functional orthopedic appliance system, Am J Orthod Dentofacial Orthop 1988;93:1-18.
3. Clark WJ. The twin block technique: A functional orthopedic appliance, Am J Orthod Dentofac Orthop 1988;93:1-18.
4. Delaire J. Maxillary development revisited: Relevance of the orthopaedic treatment of Class III malocclusion, Eur J Orthod 1997;19:289-311.
5. Devincenzo J. The Eureka Spring: A new interarch delivery system, J Clin Ortho 1997;32:454-67.
6. Eirew HL. The Bionator, Brit J Ortho 1981;8:33-36.
7. Frankel R. A functional approach to orofacial orthopedics, Brit J Ortho 1980;7:41-51.
8. Gianelly AA, et al. The use of magnets to move molars distally, Am J Orthod Dentofac Orthop 1989;96:161-7.
9. Gianelly AA. Japanese Ni-Ti coils used to move molars distally, Am J Orthod dentofac Orthop 1991;99:564-71.
10. Gottfried PF, Schmuth GP. Milestones in the development and practical applications of functional appliances. Am J Orthod 1983;84:48-53.

11. Hilgers JJ. The pendulum appliance for Class II non-compliance therapy, J Clin Orthod 1992;16:706-14.
12. Keeling SD, Wheeler TT, King GJ, et al. Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear, Am J Orthod Dentofac Orthop 1998;113:40-50.
13. McNamara JA, Howe RP. Clinical management of the acrylic splint Herbst appliance, Am J Orthod Dentofac Orthop 1988;94:142-9.
14. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a Cephalometric study, Am J Orthod Dentofac Orthop 1998;114:15-24.
15. Orton HS. Functional appliances in orthodontic treatment: an atlas of clinical prescription and laboratory construction, 1990, Quintessence Publishing Company.
16. Pancherz H. The effects, limitations and long-term dentofacial adaptations to treatment with the Herbst appliance, Sem Orthod 1997;3:232-43.
17. Pancherz H. The Herbst appliance: its biological effects and clinical use. Am J Orthod 1985;87:1-20.
18. Singh Gurkeerat. "V" Bend stopper for the Jasper Jumper, J Ind Orthod Soc, 1998;31(II):38.
19. Stucki N, Ingervall B. The use of the Jasper Jumper for correction of Class II malocclusion in the young permanent dentition, Eur J Orthod 1998;20:271-81.
20. Vardimon AD, Stutzmann JJ, Graber TM, Voss LR, Petrovic AG. Functional orthopedic magnetic appliance (FOMA) II— Modus operandi. Am J Orthod Dentofacial Orthop 1989;95:371-87.
21. Woodside DG, Metaxas A, Altuna G. The influence of functional appliance therapy on glenoid fossa remodeling. Am J Orthod Dentofacial Orthop 1987;92:181-98.
22. Woodside DG, Metaxas A, Altuna G. The influence of functional appliance therapy on glenoid fossa remodeling. Am J Orthod Dentofacial Orthop 1987;92:181-98.

Section Six

MANAGEMENT OF MALOCCLUSION

47. Preventive Orthodontic Procedures
48. Interceptive Orthodontic Procedures
49. Oral Habits and their Management
50. Etiology and Management of Class I Malocclusion
51. Etiology and Management of Class II Malocclusion
52. Etiology and Management of Class III Malocclusion
53. Correction of Midline Diastema
54. Management of Open Bite
55. Management of Cross Bite
56. Orthodontics for Adults
57. Management of Cleft Lip and Palate

47 Preventive Orthodontic Procedures

Rajesh Ahal, Gurkeerat Singh

- Introduction
- Preventive measures undertaken
  - Caries control
  - Parental counseling
  - Space maintenance
  - Exfoliation of deciduous teeth
  - Abnormal frenal attachments
  - Locked permanent first molars
  - Abnormal oral musculature
- Space maintenance

INTRODUCTION

Prevention is not only better than cure but more stable and cheaper as well. Begg in 1977 stated that "the proper time to begin treatment is as near the beginning of the variation from the normal, in the process of development of the dental apparatus, as possible". Kesling in 1960 stated that "some cases should be referred as early as 3 or 4 years of age and all cases by the age of 8 or 9 years", thereby, laying the foundation of preventive and interceptive orthodontics.

Graber (1966)—has defined *preventive orthodontics as the action taken to preserve the integrity of what appears to be a normal occlusion at a specific time.*

Profitt and Ackermann (1980)—has defined it as *prevention of potential interference with occlusal development.*

Preventive orthodontics generally shows results over a period of time. The right time to initiate preventive orthodontics would be ideally during prenatal counseling.

In our society, the deciduous dentition is given the least importance, with the promise that the deciduous teeth have to exfoliate eventually. However, maintaining the integrity of deciduous teeth and occlusion leads to their preservation up to exfoliation, which in turn forms one of the most important steps in preventive orthodontics. Therefore, this is largely the responsibility of the pedodontist and where such specialists are unavailable, of the general dentist. The general dentist's view of initiating treatment should be as early as possible instead of the now impregnated view that it should be initiated after all the permanent teeth have erupted. There is a fundamental need for a shift in this thought process among the general dentists.

Some of the procedures and concepts of preventive and interceptive orthodontics are common but the time of application pertaining to the stage of dental development are different. These procedures not only prevent or intercept a developing malocclusion, but also allow proper mastication to develop along with speech, which in turn leads to the development of an individual with good esthetics and has a positive psychological effect apart from guiding dental growth and development positively.

PREVENTIVE MEASURES UNDERTAKEN

1. Caries control
2. Parent counseling
3. Space maintenance
4. Exfoliation of deciduous teeth
5. Abnormal frenal attachments
6. Treatment of locked permanent first molars
7. Abnormal oral musculature and related habits.



Fig. 47.1: Loss of arch length due to carious deciduous teeth



Fig. 47.2: Stainless steel crown on deciduous first molar

CARIES CONTROL

Caries involving the deciduous teeth (Fig. 47.1), especially the proximal caries is the main cause of development of a malocclusion. There has been a sudden spurt in nursing and rampant caries, involving the deciduous and the mixed dentition generally, which has resulted in a sudden demand for preventive and interceptive orthodontics. The importance of maintaining and preserving the deciduous dentition should be counseled to the parents and pediatricians. Most of the parents first seek the opinion of their pediatrician regarding their child's decayed teeth. In case of proximal decay, the adjacent tooth tends to tilt into the proximally decayed area resulting in the loss of arch length, thereby resulting in lesser space for the succedaneous tooth to erupt in their rightful place and position. Therefore, the proximal decay should be restored accurately at the earliest and much problems may not arise provided arch length loss is equal to or less than the Leeway Space of Nance. In case of pulpal involvement due to caries, partial pulpectomy or pulpotomy is done followed by the placement of stainless steel crown (Fig. 47.2).

Caries initiation can be prevented by diet counseling, topical fluoride application, pit and fissure sealants and educating parents (prenatal counseling and postnatal counseling).

PARENTAL COUNSELING

Parent counseling though the most neglected, is the most effective way to practice preventive orthodontics. Parental counseling may be divided into:

a. Prenatal counseling
b. Postnatal counseling—which in turn can be associated with the clinical examination of the child at
   i. Six months to 1 year of age
   ii. Two years of age
   iii. Three years of age
   iv. Five to six years of age.

Prenatal Counseling

This is the most effective time to get across to the expecting parents. They are open to ideas and receive the suggestions regarding better welfare of the child's well being. The gynecologists would benefit immensely on having their patients counseled on dental health. Prenatal counseling may involve the following:

i. The importance of oral hygiene maintenance by the mother.
ii. How irregular eating and hunger pangs by the mother can result in her developing decayed teeth, which can be quite painful on pulpal involvement, especially during the third trimester of pregnancy.
iii. Recent studies have indicated a possible co-relationship between the mothers' poor oral hygiene and premature births.
iv. A mother suffering from pregnancy induced diabetes mellitus, would be more difficult to manage during the pregnancy period especially if her oral hygiene is poor.
v. The increased risk of a mother suffering from poor oral hygiene transmitting the strains of caries

inducing bacteria to the baby on sharing the same feeding spoon or on tasting the food with the same are high.

vi. To have natural foods containing calcium and phosphorus, e.g. milk, milk products, egg, etc. especially during the third trimester, as they would allow adequate formation of deciduous teeth crowns.

Postnatal Counseling

Postnatal counseling should be advocated along with the clinical examination of the child. The same can be divided into:

Six months to One-year of Age

This is the most important period of counseling. The parents are made aware of:

i. Teething and the associated irritation, slight loose motions are possible in mildly elevated febrile condition.

ii. Most of the parents are appalled on seeing the deciduous teeth erupting in rotated positions. Awareness to be brought about as to how they are in that position and that they would eventually straighten out on erupting fully.

iii. No sugar addition to bottle milk, however mothers' milk is preferred and the best for the TMJ development as well as for non- development of tongue thrusting habits.

iv. Brushing with the help of a finger brush during bathing should be introduced. Cleaning of the deciduous dentition with a clean, soft cotton cloth dipped in warm saline is also recommended, to prevent the initiation of nursing or rampant caries (Fig. 47.3).

v. Child should be initiated to drinking from a glass by one year of age.

Two years of Age

i. Bottle-feeding if previously initiated should never be given during the passage to sleep. Bottle-feeding to be withdrawn completely by 18 to 24 months of age. These would decrease the chances of initiation of decay and the potential for nursing caries.

ii. Brushing to be initiated post-breakfast and post dinner.



Fig. 47.3A: Nursing bottle caries



Fig. 47.3B: Advanced nursing bottle caries

iii. Clinical examination to assess any incipient decay and eruption status of teeth.

Three years of Age

i. Clinical examination—generally the full compliment of deciduous dentition should have erupted by now. To assess the occlusion, molar and canine relationships and if there is the presence of any discrepancies away from the normal, e.g. unilateral cross bite (Fig. 47.4), supernumerary teeth (Fig. 47.5), missing teeth (Fig. 47.6), fused teeth (Fig. 47.7), etc.

ii. The child should be on 3 square meals a day.

iii. Oral habits such as thumb sucking, lip sucking, oral breathing, etc. and their effects on the development of occlusion should be considered. Parents to be informed accordingly. The use of muscle training appliances to be considered (Fig. 47.8).



Fig. 47.4: Cross-bite



Fig. 47.5A: Supernumerary deciduous lateral incisors



Fig. 47.5B: Mesiodens



Fig. 47.6: Congenitally missing deciduous mandibular lateral incisors



Fig. 47.7: Fused mandibular deciduous incisors



Fig. 47.8: Commercially available infant trainer

iv. To assess clinically for incomplete eruption of deciduous second molars/pericoronal flaps—may lead to decay on the same.
v. Child to be encouraged to begin brushing on his own at least once a day—preferably post-breakfast.

Five to Six years of Age

i. Parents to be informed about the initiation of exfoliation of deciduous teeth and that it would go up to 12 to 13 years of age.
ii. Clinical examination.
iii. The need for constant review and recall on a regular basis.
iv. In case of extraction of deciduous teeth due to decay, etc. the need, advantages and importance of space maintainers should be explained.

SPACE MAINTENANCE

Space maintainers in different forms may be required to maintain spaces in case of premature loss of teeth (to be discussed later in this chapter).

EXFOLIATION OF DECIDUOUS TEETH

Generally the deciduous teeth should exfoliate in about 3 months of exfoliation of the one in the contralateral arch. Any delay more than that should be considered with suspicion and the following should be ruled out:

a. Over-retained deciduous/root stumps.
b. Fibrous gingivae.
c. Ankylosed/submerged deciduous teeth to be assessed radiographically.
d. Restoration overhangs of the adjacent tooth.
e. Presence of any supernumerary tooth.

ABNORMAL FRENAL ATTACHMENTS

May cause the development of diastemas/excess spacing between the teeth, which in turn may not allow the eruption of succedaneous teeth. Surgical correction of the high frenal attachments is therefore advised (Fig. 47.9A). The tongue should also be assessed for ankyloglossia/ tongue-tie (Fig. 47.9B).

LOCKED PERMANENT FIRST MOLARS

The permanent first molars may get locked distal to the deciduous second molars, at times. Slight distal (proximal) stripping of the deciduous second molar allows the permanent first molar to erupt in their proper place.

ABNORMAL ORAL MUSCULATURE

Abnormal oral musculature can be prevented:

a. Tongue thrusting habits or retained infantile swallow patterns are related to prolonged breast feeding or bottle feeding by the mother. The same should be withdrawn by 18-24 months of age.
b. Hyperactive mentalis action results in the lingual inclination of mandibular incisors resulting in decreased arch length and an increased chance for the developing anterior crowding. Oral habits such as:
    i. Thumb/digit/lip sucking (Figs 47.10A and B)—the child can be distracted from indulging in the same.



Fig. 47.9A: Thick maxillary labial frenum



Fig. 47.9B: Tongue tie



Fig. 47.10A: Abnormal nail biting habit



Fig. 47.10B: Abnormal thumb sucking habit



Fig. 47.11A: Oral screen



Fig. 47.11B: Pre-orthodontic trainer in place

ii. Mouth breathing—the child can be given adequate medical attention, regarding recurrent upper respiratory tract infection. Oral screens (Fig. 47.11A) and the recently introduced myofunctional appliances such as the pre-orthodontic trainers, (Fig. 47.11B) train the child to breathe through the nose, thus allowing the proper development of nasal passage, regression of adenoid mass and the development of a shallow, broad palate.

SPACE MAINTENANCE (IN THE DECIDUOUS AND THE MIXED DENTITION)

Space maintenance *is defined as the measures or procedures that are brought into use due to premature loss of deciduous tooth / teeth, to prevent loss of arch development.*

Space maintainers *are defined as the appliances that prevent loss of arch length and which in turn guide the permanent teeth into a correct position, in the dental arch.*

Premature loss of deciduous tooth/teeth in the anterior or posterior quadrant results in the adjacent tooth to tip or migrate into the edentulous space. This in turn results in a decrease in the arch length, which if greater than the Leeway space of Nance, would lead to lesser space for the premolars to erupt. The premolars would then be impacted or erupt buccally or lingually, resulting in a malocclusion.

The likelihood of a child requiring corrective orthodontic treatment tends to increase on premature loss of deciduous teeth, irrespective of it being deciduous first or second molars.

FACTORS TO BE CONSIDERED FOR SPACE MAINTENANCE

1. *Time elapsed since loss of tooth* Maximum loss of space occurs within 2 weeks to 6 months of the premature loss of deciduous tooth. In the majority of cases, patients do not come back for space maintainers post-extraction despite being informed of the same. Therefore, it is recommended to fabricate the space maintainer before the extraction and to be inserted at the time of extraction.
2. *Dental age of the patient* The dental age is more important than the chronological age of the patient. Several studies have indicated that the premature loss of a deciduous molar less than 7 years of chronological age generally leads to a delayed eruption by more than a year but the loss after 7 years of chronological age may lead to premature eruption. However, this is not true for many cases and the dental age is a more reliable parameter.
3. *Amount of bone covering the developing succedaneous tooth bud* The developing premolars usually require 3-5 months to move through 1 mm of covering alveolar bone, as observed on a bitewing radiograph. However, the eruption could be earlier provided the alveolar bone covering the developing tooth bud has been destroyed by the periapical/furcation involvement of the deciduous tooth.
4. *Stage of root formation* The developing tooth buds begins to erupt actively if the root is three- fourth formed.
5. *Sequence of teeth eruption* The status of the developing and erupting tooth buds adjacent to the space created by the premature loss of the deciduous tooth is important. Two clinical conditions are of importance:
   - The first one being—premature loss of deciduous second molar. If the level of eruption of the second permanent molar is at a level higher than that of the second premolar, then

there is a likelihood of permanent first molar to tip mesially and impact the eruption of the second premolar.
- The second scenario is that of premature loss of deciduous first molar and an erupting permanent lateral incisor, which tends to distally ditch the deciduous canine thus effecting the eruption of permanent first premolar. This also results in the lingual inclination of the anteriors especially in the mandible thus resulting in the collapse of the anterior segment.

6. *Congenitally missing teeth* If detected before the tooth distal to them erupts, it is advisable to extract their precursor deciduous tooth. This would permit the tooth present distal to the congenitally missing tooth to move bodily and erupt in its place. And, if the space has been created as the congenitally missing tooth was detected later on, the edentulous area can be rehabilitated prosthetically.
7. *Eruption of the permanent tooth in the opposite arch* If the permanent tooth in the opposing arch to the prematurely lost tooth has erupted, then an occlusal stop should be placed on the planned space maintainer so as to prevent the supra-eruption of the opposing permanent tooth, which in turn would maintain an acceptable curve of Spee.

IDEAL REQUIREMENTS OF SPACE MAINTAINERS

1. Should maintain the desired mesiodistal dimensions of the space.
2. Should not interfere with the eruption of the permanent teeth.
3. Maintenance of functional movement (physiological) of the teeth.
4. Should allow for space regainence—mesiodistally, when required.

Fixed space maintainers require lesser maintenance and cooperation as compared to removable space maintainers. All types of appliances tend to break. Lingual arch on the mandible appears to fracture/disfigure the most.

CLASSIFICATION OF SPACE MAINTAINERS

1. According to Raymond C Throw
   a. Removable.
   b. Complete arch
      - Lingual arch
      - Extraoral anchorage.
   c. Individual tooth space maintainer.
2. According to Heinrichsen
   a. Fixed space maintainers:
      Class I I. Nonfunctional:
         i. Bar type—no longer in use
         ii. Loop type.
      II. Functional type:
         i. Pontic type
         ii. Lingual arch type.
      Class II—Cantilever type (distal shoe, band and loop).
   b. Removable type space maintainers: Acrylic space maintainers.
3. According to Hitchcock:
   a. Removable, fixed or semi-fixed.
   b. With bands or without bands.
   c. Functional or nonfunctional.
   d. Active or passive.
   e. Certain combinations of the above.
4. According to Prof Shobha Tandon: The classification is simpler and pertains to space maintainers more in use today:
   a. Removable:
      i. Cast partial or wrought metal
      ii. Passive or active
      iii. Functional or nonfunctional.
   b. Fixed:
      i. Banded or bonded
      ii. Passive or active
      iii. Functional or nonfunctional.

SPACE MAINTENANCE FOR PREMATURE LOSS OF DECIDUOUS FIRST MOLAR

Sequelae

1. If the deciduous first molar is lost during the active eruption of permanent first molar—the deciduous second molar may move/ tilt mesially resulting in decreased space for the eruption of first premolar.
2. If deciduous first molar is lost during the active eruption of permanent lateral incisor—leads to distal ditching of deciduous canine and it may at times lead to shifting of midline towards the effected side and an eventual overbite.
3. Permanent canine may get blocked out on premature loss of deciduous maxillary first molars. Timely placement of a space maintainer will prevent the above.

In case of unilateral loss: Band and loop—Nonfunctional passive space maintainer—where the deciduous second molar is the abutment (Fig. 47.12A).

Advantages

1. Is economical
2. Requires less chair time
3. Allows transverse growth of the jaws.

Disadvantages

1. Is nonfunctional—therefore does not restore mastication.
2. Does not prevent supraeruption of opposing permanent tooth.
3. May lead to slight mesial tipping if the loop slips below the contact area. Therefore, the loop fabrication and adaptation has to be precise.

Modifications

1. Crown and loop space maintainers—post-pulp therapies and or if the tooth is having extensive caries.
2. Band pinched on a stainless steel crown on to which the loop is fabricated.
3. Band and loop space maintainer with occlusal stop to prevent supraeruption of opposing permanent teeth. But, this may not allow the premolar to erupt fully, which would erupt between the loops at a later date. Therefore, requires a constant recall and review regimen.
4. Extended band and loop space maintainer with a reinforcement.
5. Bonded band and loop- though requires the least chair time as it uses the advantages of adhesive dentistry. But it also has a higher failure rate clinically.

In case of bilateral loss: Permanent first molars are the first choice as abutments followed by deciduous second molars. If placed on the deciduous second molars, the space maintainers may be lost due to exfoliation even before they need to discarded.

For Maxilla:

1. Nance palatal holding arch (Fig. 47.12B).
2. Trans palatal arch (Fig. 47.12C).
3. Bilaterally placed band and loop space maintainers.

For Mandible:

1. Lingual arch (Fig. 47.12D)
2. Bilaterally placed band and loop space maintainers.



Fig. 47.12A: Band and loop space maintainer



Fig. 47.12B: Nance palatal holding arch



Fig. 47.12C: Transpalatal arch, given along with a fixed tongue rake



Fig. 47.12D: Lower lingual arch

NANCE PALATAL HOLDING ARCH

Advantages

1. Is economical as compared to 2 band and loop space maintainers being placed.
2. Allows growth transversely in the inter-canine areas.
3. If deciduous second molars are used as abutments—allows transverse growth in inter-molar (permanent) areas.

Disadvantages

1. Requires more clinical skills and dexterity.
2. Palatal button may cause food accumulation leading to an inflammatory soft tissue response in the palate.
3. If permanent molars are used as abutments does not allow inter-molar transverse growth.

TRANSPALATAL ARCH

Advantages

1. No inflammatory changes in the palate.
2. Is more effective if there is bilateral premature loss of deciduous first molars.

Disadvantages

1. Some patients report of food debris getting entrapped between the transpalatal wire and the palate.

LINGUAL ARCH

Advantages

1. Is economical as compared to 2 bilaterally placed band and loop space maintainers.
2. Is less irritating to the tongue if well fabricated.

Disadvantages

1. The child may disfigure the wire in an attempt to remove any entrapped food debris, with his finger.

Modifications

1. Lingual arch with U-loops—which when activated can bring about distalization of the molars by 1 to 2 mm.

SPACE MAINTENANCE FOR PREMATURE LOSS OF DECIDUOUS SECOND MOLARS

Sequelae

1. Premature loss of deciduous second molars leads to mesial tipping of the permanent first molar, which in turn would impact the second premolar later on, during the late mixed dentition period.
2. In case of the maxilla, the maxillary first molars would also mesially rotate along their palatal root as the axis.
3. Have more effects on the posterior segments leading to the development of irregularity in molar relationships.
4. Space loss is generally more in the maxilla than the mandible.

In case of unilateral loss: Band and loop space maintainer.

Modifications

Same as discussed earlier also.

- Reverse band and loop space maintainer—is specifically given where the distal aspect of permanent first molar has not erupted fully or there is a large pericoronal flap. The reverse band and loop may not have long-term utility as compared to the conventional band and loop space maintainer, as the deciduous first molars would exfoliate. Therefore, it should be changed to the conventional band and loop space maintainer as soon as the permanent first molar has fully erupted.

In case of bilateral loss:

For maxilla

1. *Nance palatal holding arch* is the appliance of choice, which also holds the Leeway space of Nance.
2. *Transpalatal arch* is not indicated as the maxillary first permanent molars may tilt mesially, bilaterally.
3. Bilateral band and loops are indicated.

For mandible: Lingual arch is the appliance of choice and also to hold leeway space, even if there is no premature loss of deciduous molars, so as to allow sufficient space for the permanent teeth to erupt.

SPACE MAINTENANCE ON PREMATURE LOSS OF DECIDUOUS SECOND MOLARS BUT PRIOR TO ERUPTION OF PERMANENT FIRST MOLARS

Premature loss of deciduous second molar prior to eruption of permanent first molar is one of the most difficult clinical conditions to treat, as it may lead to mesial tilting or migration of permanent first molar.

Methods of space maintenance in such conditions are:

- Distal shoe (Figs 47.13A and B)

Synonyms:

- Intra-alveolar space maintainer.
- Eruption guidance space maintainer.

Introduced by Willets (1932) with bar type gingival extension and modified by Roche (1942) with a 'V' shaped gingival extension.



Fig. 47.13A: Pre-extraction radiograph furcation involvement and bone resorption of 85



Fig. 47.13B: Distal shoe following extraction of 85

It has (1) A horizontal component, which bridges the mesiodistal divide left over by the premature loss of deciduous second molar and, (2) vertical component, which generally lies 1 to 1.5 mm below the mesial marginal ridge of the unerupted permanent first molar.

Disadvantages

1. Small metallic tattoo may form at the space, where the vertical component enters the gingivae.
2. Controversy exists regarding the healing at the site of invagination of the vertical component. Clinically, a good healing exists at the site whereas; histologically it may lead to the formation of tissue with incomplete epithelial lining and a chronic inflammatory response.

Contraindications

1. If several teeth are missing in the same quadrant as there is lack of adequate abutment.
2. Medically compromised patients, such as:
   i. Blood dyscrasias.
   ii. Congenital heart defects.
   iii. Previous history of rheumatic fever.
   iv. Diabetes mellitus.
   v. Generalized debilitation.
   vi. Immunosuppression.
3. Poor oral hygiene.
4. Lack of patient or parental cooperation.

In patients which are medically compromised, alternatives available are:

1. Use of pressure appliances, where pressure is applied on the area immediately mesial to the pre-eruptive bulge. This also acts as a guidance plane, e.g. guidance removable appliance.
2. To allow the permanent first molar to erupt in the mesial tilt and then regain space and upright the same later on but prior to eruptive phase of the permanent second molars (12-year molars).

SPACE MAINTENANCE FOR PREMATURE LOSS OF DECIDUOUS INCISORS

Appliances advised are:

1. Bands cemented on the molars/stainless steel crowns on molars onto which a wire framework is soldered on the palatal aspect and combined with acrylic prosthesis (see Figs 47.14A to E).
2. Removable partial dentures (Fig. 47.15).



Fig. 47.14A: Missing / lost maxillary incisiors



Fig. 47.14B: Frontal view



Fig. 47.14C: Occlusal view



Fig. 47.14D: Acrylic prosthesis



Fig. 47.14E: Space maintainer modified to permit eruption of II

Advantages

1. Allows the speech and phonetics to develop well.
2. Aesthetics.
3. Stimulates the edentulous area for eruption of permanent incisors.
4. Does not allow mesial drifting.
5. Does not allow shift in the midline.

Disadvantages

1. Have to remove the acrylic areas for the permanent tooth eruption.
2. Removable partial dentures should be remade every 6 months so as to allow for transverse growth.



Fig. 47.15: Removable space maintainer

SPACE MAINTENANCE FOR PREMATURE LOSS OF DECIDUOUS CANINES

Sequelae

1. Premature loss of deciduous canines may lead to delayed eruption of the permanent canine. This may allow the permanent incisors to tilt lingually and/or ditch distally leading to impaction of canine.

In case of unilateral loss:

1. Band and loop—where the deciduous first molar acts as the abutment.

In case of bilateral loss:

For Maxilla:

1. Nance palatal holding arch (Fig. 47.16A).

For Mandible:

1. Lingual arch (Fig. 47.16B).

REMOVABLE PARTIAL DENTURES

Advantages

1. They are the most economical of the space maintainers.



Fig. 47.16A: Nance palatal holding arch



Fig. 47.16B: Lingual arch

2. Are functional passive space maintainers.
3. Enable to prevent development of abnormal speech or tongue movement habits.

Disadvantages

1. Children tend to play with the removable space maintainers in the mouth. Therefore, are not useful in those children who are noncooperative and show a lack of interest.
2. Uncontrollable dental caries- nursing or rampant caries.
3. Poor oral hygiene maintenance.
4. Lateral jaw growth is restricted, if clasps are incorporated.

FURTHER READING

1. Ackerman JL, Proffit WR: Preventive and interceptive orthodontics: A strong theory proves weak in practice. Angle Orthod 1980;50:75-86.
2. Ackerman JL, Proffit WR: Preventive and interceptive orthodontics: A strong theory proves weak in practice. Angle Orthod 1980;50:75-86.
3. Bjerregaard J, Bundgaard AM, Melsen B: The effect of the mandibular lip bumper and maxillary bite plane on tooth movement, occlusion, and space conditions in the lower dental arch. Eur J Orthod, 1962;48:504-29.
4. Bolton, WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod 1958;28:113-130.
5. Fränkel R. Decrowding during eruption under the screeing influence of vestibular shields. Am J Orthod 1974;65:372-406.
6. Ghafari JA: A lip activated appliance in early orthodontic treatment, J Am Dent Assoc 1985;11:771-4.
7. Subtenly JD, Sakuda M: Muscle function, oral malformation, and growth changes, Am J Orthod, 1966;52:495-517.
8. Valentine F, Howitt JW: Implications of early anterior crossbite correction, J Dent Child 1970;37:420-7.

48 Interceptive Orthodontic Procedures

Rajesh Ahal, Gurkeerat Singh

- Introduction
- Space regaining
- Correction of anterior and posterior cross bites
- Elimination of oral habits leading to interception
- Muscle exercises
- Removal of soft or hard tissue impediments in the pathway of eruption
- Resolution of crowding
- Management of crowding
- Serial extraction and guidance of eruption
- Definition
- Historical review
- Diagnosis and treatment planning
- Procedure
- Interception of developing skeletal malocclusions
- Classification
- Interception of Class II malocclusion
- Interception of Class III malocclusion

INTRODUCTION

A malocclusion, if detected as soon as possible, can be eliminated or made less severe, by initiation of interceptive orthodontic procedures. Preventive orthodontic procedures are also interceptive in nature if undertaken soon after the development of the malocclusion.

An interceptive procedure undertaken at the right time can, therefore, either eliminate a developing malocclusion or make it less severe, so as to allow corrective orthodontics to deliver a stable and conservative result, in the shortest treatment time possible with least discomfort to the patient.

An interceptive orthodontic procedure will ensure that an oral habit does not become fixed and its deleterious effects do not affect the normal growth and development of the patient. It will also ensure that there is no loss of arch length due to the premature loss of deciduous tooth / teeth or due to rotated teeth or on crowding of teeth and guide the growth of mandible by using myofunctional appliances so as to deliver greater benefits to the patient.

Council on Orthodontic Education of the American Association of Orthodontists—Orthodontics: Principles and Policies—has defined *'Interceptive Orthodontics as that phase of the science and art of orthodontics employed to recognize and eliminate potential irregularities and malpositions in the developing dentofacial complex'*. It implies that corrective measures may be necessary to prevent a potential irregularity from progressing into a more severe malocclusion.

The basic interceptive procedures that are undertaken by the interceptive pedodontist are:

1. Space regaining
2. Correction of anterior and posterior cross bites
3. Elimination of oral habits
4. Muscle exercises
5. Removal of soft or hard tissue impediments in the pathway of eruption
6. Resolution of crowding
7. Interception of developing skeletal malocclusions.

SPACE REGAINING

If space maintenance is not carried out on the premature loss of a deciduous second molar, the permanent first molar may tip or move mesially resulting in the loss of the arch length. The loss of the arch length may impede the second premolar to erupt.

Causes of the mesial tipping/drifting of molars are:
1. Extensive carious lesions (Fig. 48.1A)
2. Ectopic eruption (Fig. 48.1B)
3. Premature extraction of primary molars—without any space maintenance (Fig. 48.1C)



Fig. 48.1A: Space loss due to decayed deciduous teeth



Fig. 48.1B(i): Mesial migration of the maxillary posterior segment due to the ectopic eruption of the canine



Fig. 48.1B(ii): Mesial migration of the maxillary right posterior segment due to a congenitally missing maxillary right lateral incisor



Fig. 48.1C: Space lost due to early loss of deciduous teeth and no space maintainer

ESTIMATION OF SPACE LOST

Mixed dentition analysis (discussed in detail in Chapter on Study Models).

TIMING OF DISTALIZATION OF 6 YEARS MOLARS

Timing of distalization is important. If the child is treated before the age of 9 years the root of the first permanent molar to be moved has not completed its growth and the orthodontic tipping or bodily movement to normalize its position is easier. If however, the treatment is delayed too long and the second molar begins to erupt distal to the mesially drifted 6 years molar, the clinician has the problem of moving two molars distally, which requires greater force, therefore, requiring extraoral anchorage or corrective orthodontics.

For most children, the age range between 7-10 years proves to be the best for tipping or bodily movement of 6 years molars distally, to recover lost arch space. If properly timed and executed, these movements can prevent the extraction of many bicuspids and subsequent disruption in developing occlusion among children.

It is feasible to regain the lost space by distal movement of the permanent first molar. The earlier the distalization is done the better the results. The methods of space regaining are divided into two broad groups:

1. Fixed appliances
2. Removable appliances.

Fixed Appliances

Open Coil Space Regainer (Herbst Space Regainer)

In this the band is adapted and pinched on the tooth, generally the permanent first molar, which is distalized to regain space. The buccal and lingual tubes are soldered to the adapted band with the help of a spot welder. These tubes about 0.25 inches long have flanges for spot welding. The tubes should be parallel to one another in all planes and their lumen should be aimed at the junction of crown and the gingiva of the first premolar. An impression of the band and tubes is taken with the band seated on the tooth and the band is then removed. The holes in the tube are plugged with carding wax to prevent them from getting blocked by dental plaster. The band is then seated in the impression and dental plaster is poured after stabilizing the same.

A 0.7 mm stainless steel wire is then bent to a U shape, which will fit passively in both the buccal and lingual tubes. The anterior part of the 'U' shaped wire should have a reverse bend where it contacts the distal outline of the first premolar. If the tubes have been aimed and soldered correctly, then the wire will contact the distal surface of the first premolar below its greatest convexity. A rectangular tube if used should easily accommodate a 0.0215 × 0.025 rectangular wire. A rectangular wire, however, is harder to bend.

At the junction of the straight part and the curved part of the wire, both buccally and lingually, flow enough solder to make a stop. Then cut enough spaced open coil spring so as to extend from the stop to a point about 2 mm distal to the anterior limit of the tube on the molar band. The band is then removed from the model by heating the stone inside the band, plunging the model into water and carefully cutting away the resulting softened residue. The coil spring is slipped on the wire. The wire is then put in the tubes and the band with the wire and compressed springs is cemented on the molar. The compressed spring will try to become passive and exert reciprocal pressure mesially to the premolar and distally to the permanent molar. The seating pressure is applied on the band from the buccal in case of the mandibular molar and both buccal and palatal in case of the maxillary molar (Fig. 48.2).

Jackscrew Space Regainer

The jackscrew space regainer is used to recover the loss of space caused by tooth drift into an edentulous area. It uses 2 banded adjacent teeth and a threaded shaft with a screw and a locknut. This is activated regularly to exert a consistent force against the banded teeth. A bilateral version of this appliance consists of a coiled loaded lingual arch that passes through tubes soldered lingually to molar bands. This appliance produces rapid results.

The cast is poured after transferring the bands on the impressions made. A 0.036 inch buccal tube is soldered or welded to the molar band. The tube should be centered in the middle one-third of the band and aligned with the other banded abutment tooth.



Fig. 48.2A: Space loss due to mesial migration of permanent left first molar



Fig. 48.2B: Open coiled space regainer



Fig. 48.2C: Space regained after 6 weeks, open coil removed, converted into space maintainer

A jackscrew unit as received from the manufacturers consists of one adjustment nut and one lock nut on a threaded shaft. Slide the threaded end of the shaft into the molar tube. The proper alignment of the shaft between the abutment teeth should be kept in consideration. The mesial end of the shaft is trimmed and contoured to the premolar band surface. A liberal amount of the flux is applied and soldered onto the premolar band. End of the shaft should be trimmed so that it extends 2 mm from the distal end of the tube. It is then cemented into the patient's mouth.

Gerber Space Regainer

This type of appliance may be fabricated directly in the mouth during one relatively short appointment and requires no laboratory work. In this a U shaped assembly is used into which the U shaped wire can be fitted. This in turn is soldered onto the mesial aspect of the band and the coiled spring is fitted onto the U shaped wire, which in turn is fitted into the U assembly and finally cemented.

Removable Space Maintainer

The different removable space maintainers are:

Upper or Lower Hawley's Appliance with Helical Spring

These can be used for both mandibular and maxillary molars. It consists of the following:

- Short labial bow, as it gives more anchorage.
- Adam's clasps on contralateral molars.
- 0.6 mm wire helical spring with the active arm towards the tissue.

Helical spring is in 2 configurations; single or double, depending upon the dentist's experience. Double helical spring requires slightly more time to bend but is kinder to the periodontium of the tooth being repositioned. These helical springs should be adjusted with little or no pressure exerted distally against the molar during the first week of treatment. At the second visit and thereafter at intervals of 2 weeks, the springs should be adjusted to produce a slight distal pressure against the permanent first molar.

Constant measurement of the child's arch with the modified Boley gauge during treatment gives the dentist an exact indication of progress in moving the molar distally. Usually it takes about 2-4 months to move a mandibular molar distally by a distance of 2 mm. To increase the spring pressure excessively

against the tooth in an attempt to lessen treatment time is to invite a sore tooth and possible tissue necrosis in the periodontium of the molar under treatment. The active arm of the helical spring lies in the mesial undercut of the molar. Placing the spring in an undercut also aids in retention of the appliance, whereas a spring not held in position tends to displace itself and the appliance.

Hawley's Appliance with Split Acrylic Dumb-bell Spring

Hawley's appliance on the mandibular arch is constructed with a split acrylic dumb-bell spring (Fig. 48.3A). It is used to regain up to 2 mm of lost space by tipping one of the permanent first molars distally. It is an effective and comfortable appliance during treatment.

Dumb-bell spring allows easy adjustments (Fig. 48.3B) to add distalizing force to the lower molar, and the limit of possible spring opening is at least 3 mm, which is beyond the necessity of the usual movement of this tooth. The spring should be adjusted twice a month, creating an increment of opening in the split acrylic area of 0.5 mm at a time. Any larger adjustments may not allow the appliance to be seated firmly into the area immediately mesial to the molar being moved distally.

Hawley's Appliance with Slingshot Elastic

Instead of especially contoured wire springs that transmits a force against the molar to be distalized, a wire elastic holder with hooks may be used. Also known as a slingshot appliance, since the distalizing force is produced by the elastic stretched between the



Fig. 48.3A: Split acrylic space regainer with split saddle

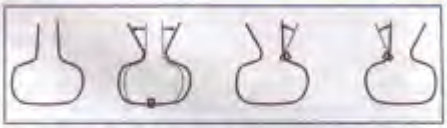


Fig. 48.3B: Dumb-bell spring adjusted by broadening the base of the dumb-bell

2 hooks. One hook is located on the middle one-third of the lingual aspect of the molar to be distalized and the other is arranged in the same position on the buccal aspect of the molar.

Hawley's Appliance with Palatal Spring

It is made up of 0.5 mm stainless steel wire. The active arm of the palatal spring is placed mesial to the permanent molar to be distalized. The activation is 2 mm by opening of the spring. It is important that the active arm should not be too long and that the helix diameter should be 2 mm.

Hawley's Appliance with Expansion Screws

Fischer's one-point screws are less bulky and the two point screws are more bulky. It was Schwartz in 1938 who first introduced the expansion screws. Expansion screws are basically divided into 2 types depending on their incorporation:

i. Encased type—are sturdy and resist stress. The spiral part may however sometime turn back. These have also been known to be incorporated with a spring.
ii. Skeleton type—have a part of the spiral embedded in the acrylic and are therefore superior and generally more preferred now. Such screws are available in various sizes—broader for the maxillary plates and narrower for the mandibular plates. The smaller size also is effective for the distalization of teeth. Generally, one full turn of the screw brings about 0.4 or 0.8 mm expansion (Skeleton-Fischer type) that is one-fourth turn would bring about 0.1/0.25 mm expansion.

The other kind of expansion screws is the rapid maxillary expansion (RME). The use, indications and contraindications will be discussed in the Chapter on Space Creation. Recently, certain companies—Leone (Italy) and Dentaurum (Germany) have introduced the

microscrews, which require less space, as they are smaller than the conventional screws. These are again available in different types and configurations. Today, there are more than 300 different types of expansion screws available for different kinds of applications.

CORRECTION OF ANTERIOR AND POSTERIOR CROSS BITES

Cross bites—anterior or posterior should be corrected as soon as they are detected. Some authors believe that the same should be treated during the deciduous dentition. However, it may be better to treat them as the permanent teeth begin to erupt into the oral cavity. The child may be too young and uncooperative at the deciduous dentition stage. Moreover, it is easier to bring about changes in the mixed dentition stage. Cross bites can be unilateral or bilateral. These can also be true or functional in nature or a combination of the two.

If the cross bite is not treated in time it could lead to a skeletal malocclusion, which would require corrective orthodontic treatment later on. Some of the common appliances used in the correction of cross bites are—tongue blade therapy, inclined planes (Figs 48.4Ai to Aiii), composite inclines, Hawley's appliance with Z-spring (Fig. 48.4B), quad helix appliance (Fig. 48.4C), medium (Fig. 48.4Di and Dii), mini (Fig. 48.4E) and microscrews (Fig. 48.4F) embedded in acrylic appliances, etc. which will be extensively discussed in a chapter exclusively on the same.



Fig. 48.4A(i): 11 in cross bite



Fig. 48.4A(ii): Anterior incline plane cemented



Fig. 48.4A(iii): Occlusal view following correction of cross bite after 3 weeks of inclined plane use



Fig. 48.4B: Appliance incorporating 'Z'-springs



Fig. 48.4C: The quad helix appliance



Fig. 48.4D(i): Unilateral cross bite



Fig. 48.4D(ii): Correcting cross bite with medium expansion screw



Fig. 48.4E: Appliance incorporating a miniscrew



Fig. 48.4F: Appliance incorporating microscrews

ELIMINATION OF ORAL HABITS LEADING TO INTERCEPTION

Oral habits—such as thumb/digit sucking (Figs 48.5A to F), mouth breathing, tongue thrusting, lip sucking, etc. tend to cause malocclusions. Clinical studies have linked the development of Class II malocclusions to these oral habits. All the oral habits lead to an imbalance in the forces acting on the teeth, causing the development of dental malocclusions and if left



Fig. 48.5A: Thumb sucking habit



Fig. 48.5B: Midline diastema has developed due to thumb sucking and anti-clockwise growth of the pre-maxillary segment



Fig. 48.5C: Tongue thrust has developed



Fig. 48.5D: Maxillary view



Fig. 48.5E: Palatal crib-fixed, maxillary occlusal view



Fig. 48.5F: Resolution of the diastema, and correct overjet and overbite attained, after 3 months

untreated over a longer period of time these definitely cause skeletal malocclusions. Oral habits also lead towards abnormal positioning of the tongue, aberrant lip and perioral musculature, development of unfavorable V shaped and high palatal arches as well. The effects, detection, complexities, diagnosis and treatment of oral habits are not in the purview of this chapter and will be dealt in depth and complete details in a chapter devoted exclusively on the same.

MUSCLE EXERCISES

The normal development of the occlusion depends on the nature of the muscles of the face. If the oro-maxillofacial musculature were in a state of balance, a good occlusion would develop and if any of the muscle groups were aberrant it would result in a malocclusion in some form or the other. Muscle exercises allow a clinician to bring such aberrant muscular functions into normal functioning, to create normal health and function, as they are important elements in aiding growth and development of normal occlusion.

USES

1. To guide the development of occlusion.
2. To allow optimal growth patterns.
3. To provide retention and stability in post-corrective (mechanical) orthodontic cases.

EXERCISES

Exercises of orbicularis and circumoral group of muscles:

A. Upper lip is stretched in the posteroinferior direction by overlapping the lower lip. Such muscular exercises allow the hypotonic lips to form an oral seal labially.
B. Hypotonic lips can also be exercised by holding a piece of paper between the lips.
C. Parents can stretch the lips of the child in the posteroinferior direction at regular intervals.
D. Swishing of water between the lips until they get tired.
E. Massaging of the lips.
F. Playing a reed musical instrument—produces fine lip tonicity.
G. Placement of scotch tape over the lips helps to train them to remain sealed.
H. Use of an oral screen with a holder—to exercise the lips.
I. Button pull exercise—a 1½ inch diameter button is taken through which a thread is passed. The patient is asked to place the button behind the lips and pull the thread while the lips try to resist the same.
J. Tug of war exercise—is similar to the button pull exercise, where the difference is that 2 buttons are used and another individual pulls the thread gently while the same movement is resisted, by the patient.

Exercises of the Tongue

Exercises of the tongue are done to correct any aberrant tongue swallow patterns:

a. *One elastic swallow* An orthodontic elastic, usually 5/16th of an inch, is placed on the tip of the tongue and the patient is asked to raise the same to rugae area and swallow.

b. *Two elastic swallow* $2^{5}/_{16}$th inch elastics are used and one is placed on the tip of the tongue whereas the other is placed on the dorsum of the tongue in the midline and asked to swallow.
c. *Tongue hold exercise* A 5/16th inch elastic is used and the patient is asked to place the same on a designated spot over a definite period of time with the lips closed. The patient is asked to swallow with the elastic in the designated position and lips apart.
d. *Hold pull exercise* The tip of the tongue is made to contact the palate in the midline and the mandible is gradually opened. This allows the stretching of the frenum to relieve a mild tongue-tie.

Exercises of Masseter Muscles

At times it is advised to strengthen the masseter muscles. The patient is asked to clench his teeth, count up to 10 in his mind and then relax them. This has to be repeated over a period of time, until the masseter muscles feel tired.

Exercises of Pterygoid Muscles

In case of disto-occlusion cases the patient is asked to protrude the mandible as much as possible and then retracted. Repeat the exercises until the muscles feel tired. The ability to keep the mandible in correct position gradually improves.

Limitations of Muscle Exercises

1. Exercises are not known to drastically alter any bone growth pattern.
2. They are not a substitute for corrective orthodontic treatment.
3. Patient compliance is extremely important.
4. If not done correctly, can be counter productive.

REMOVAL OF SOFT OR HARD TISSUE IMPEDIMENTS IN THE PATHWAY OF ERUPTION

The clinical conditions in which the hard and soft tissue acts as an impediment in the natural pathway of tooth eruption are:

Retained deciduous tooth/teeth: A clinical manifestation, which has become more common today due to the shift from hard, detergent diet to a soft diet. Generally, retained deciduous teeth are observed in the mandibular anterior region, with the permanent teeth erupting lingually or in the maxillary anterior and buccal regions, with the permanent teeth erupting labially/buccally (Fig. 48.6A). The unilateral presence of such retained teeth also results in a midline shift thus compounding an arch space deficiency in a quadrant. Interception by extraction of the retained deciduous teeth would resolve the malocclusion completely or decrease its severity, thus allowing easier management of the same.



Fig. 48.6A: Retained deciduous teeth



Fig. 48.6B: Mesiodens obstructing the eruption of 21 may cause midline shift if not removed

Supernumerary teeth: Presence of supernumerary teeth and mesiodens would impede the eruption of the permanent teeth in their rightful place (Fig. 48.6B). Therefore, timely extraction of the same would go a long way in interception of a developing malocclusion.

Fibrous/bony obstruction of the erupting toothbud: If the contralateral tooth fails to erupt even after 3 months, there should be a cause for concern and a radiographic assessment, therefore, becomes mandatory. Surgical intervention may be required. Wherein, the excision of the fibrous soft tissues is done or removal of any overlying bone over the unerupted crown is done. The soft or hard tissue excision is done in such a way so as to expose the greatest diameter of the unerupted tooth crown or slightly larger. A zinc oxide eugenol dressing is recommended for a period of 2 weeks postsurgically.

RESOLUTION OF CROWDING

Crowding of teeth is one of the primary reasons that a parent tends to bring a child for a pediatric dental consultation. Crowding is present at different stages and of variable severity during the mixed dentition stage. Normally, in the anterior segment the incisal liability plays an active role whereas in the posteriors the Leeway space of Nance helps in the resolution of any crowding.

Incisal liability in the anteriors occurs due to the greater mesiodistal dimensions required by the permanent incisors as compared to their deciduous predecessors. Due to the same the crowding may further accentuate, especially in a non-spaced dentition and where primate spaces are absent. In such clinical conditions the mandibular lateral incisors may erupt more lingually and the maxillary lateral incisors may erupt more palatally or labially. The deciduous-permanent tooth size differential averages 6 to 7 mm even when there is no crowding. Mayne in 1965 listed the mechanisms by which *incisal liability* is resolved by the growth and development of occlusion:

1. *Interdental spacing* Presence of interdental spaces and primate spaces during the deciduous and the early mixed dentition provide space for the accommodation of larger permanent incisors (Leighton) as they erupt. This is generally 2 to 3 mm. As the lateral incisors erupt they bring about a lateral shift of the deciduous canines in the mandible only, into the primate spaces if present, resulting in a further resolution of crowding.
2. *Intercanine arch growth* Resolution of crowding occurs to some extent also due to the attainment of optimal intercanine width as the individual grows. The space provided by the same is generally 3 to 4 mm, which is greater in the maxilla. This would get affected on premature loss of a deciduous canine or on developing of a deep bite.
3. *Labial positioning of the incisors* Also provide more space for the correct alignment of the incisors as they erupt. Generally, the space available is about 1 to 2 mm.

Holding of the Leeway space of Nance would also allow more space so as to allow adjustments for anterior crowding. The space that can be obtained by holding the Leeway space is 0.9 mm in the maxilla and 1.7 mm in the mandible per quadrant.

MANAGEMENT OF CROWDING

The stepwise management of crowding involves the following steps:

1. Observation
2. Disking of primary teeth
3. Extractions and serial extraction
4. Corrective orthodontic referral.

1. *Observation* Clinical observation of the spaces in the deciduous dentition reveals 50 percent chances of resolution of crowding in permanent dentition if the physiological spaces are between 2 to 3 mm, and no crowding occurs if these spaces are > 6 mm. If the crowded permanent incisors require 2 mm spaces for resolution, then there is a greater chance that no interception would be required. Therefore, a regular recall and review regimen is a must.
2. *Disking of primary teeth* It is again an effective mechanism to resolve anterior crowding. This procedure is generally done if the space required for the resolution of anterior crowding is not > 4 mm. Disking is done of the mesial surfaces of the deciduous canines, followed by that of the distal surfaces of deciduous canines, if more space is required. If still more space is required after recall and review, then mesial surfaces of the deciduous first molars can be disked. Topical fluoride application after disking is a must to ensure that child does not suffer from any sensitivity.

   The combination of observation and disking allows the interceptive pedodontist to treat a larger proportion of anterior crowding cases, provided the cases are referred on time and that they seek review as and when advised.
3. *Extractions and serial extraction:* Retained deciduous teeth should be extracted if their successors have erupted and submerged deciduous teeth should be extracted on radiographic and clinical evaluation. Serial extractions will be discussed in deep depth and details in the same chapter.
4. *Corrective orthodontic referral:* Cases treated by serial extraction as well as severe crowding cases and those having severe dentoskeletal malocclusions should be referred to the corrective orthodontists for the needful.

Fixed orthodontics might be required in some cases even in the mixed dentition case (Figs 48.7A and B). Intervention should be of a short duration and only



Fig. 48.7A: Fixed appliance therapy in ectopically erupting 11



Fig. 48.7B: Fixed mechanotherapy used in a case of rotated 11

undertaken in selective cases. A retention appliance is a must following removal of the appliance.

SERIAL EXTRACTION AND GUIDANCE OF ERUPTION

It is logical to intercept a malocclusion as early as possible and to reduce or, in rare instances, avoid banded or bonded corrective therapy at the sensitive teenage period.

Serial extraction, if done properly in carefully selected patients reduces time, the cost of the treatment, discomfort to the patient and time lost by the patient and the parents. These days more stress is being put on lingual correction system as well as ceramic and invisible corrective orthodontic treatment systems, serial extraction becomes more important, as the best way to hide the appliances is to not to use them at all or use them for a limited period of time.

One of the most crucial decisions that the clinicians are required to make is whether to extract teeth for the correction of the malocclusion. To do this, they need all the intelligence, training and experience they can muster. Adding the dimension of time, complicating the clinical situation as growth and development proceeds, the treatment by serial extraction procedures make it even more demanding. Serial extraction therefore should never be initiated without a comprehensive diagnosis, which is established by a thorough evaluation of the diagnostic records.

DEFINITION

Tweed has defined it as *the planned and sequential removal of the primary and permanent teeth to intercept and reduce dental crowding problems.* Dental crowding exists where there is an excess of tooth material in relation to the amount of basal and alveolar bone that supports the teeth.

Tandon has defined it as *the correctly timed, planned removal of certain deciduous and permanent teeth in mixed dentition cases with dentoalveolar disproportion,* i.e. teeth to supporting bone imbalance, in order to:

a. Alleviate crowding of the incisor teeth.

   For example, to provide space for spontaneous alignment of incisors, when lateral incisors erupting at 7-8 years, deciduous canines may be extracted.

b. Allow unerupted teeth to guide themselves into improved positions.

For example, deciduous first molar is extracted to speed up the eruption of first premolar, when its root development is halfway.

c. Lessen the period of active appliance therapy or eliminate it.

It has also been defined as *an interceptive orthodontic procedure usually initiated in the early mixed dentition, to avoid development of a fully matured malocclusion in the permanent dentition.* Serial extraction increases the amount of space available for the erupting permanent teeth and thereby enables them to assume a more normal position and occlusal and spatial relationship.

HISTORICAL REVIEW

Robert Bunon (1743) made the first reference to the extraction of deciduous teeth to achieve a better alignment of permanent teeth in his publication titled Diseases of Teeth. Lecluse in 1754, Bourdet in 1757, Hunter in 1771, Duval in 1817, Robinson in 1846, Harris in 1855 and Joseph Fox (England) in 1814 recommended removal of primary cuspids and bicuspids when the permanent incisors are irregular.

Serial extraction was a term coined by Kjellgren (1929), which has become popular. However, it was Nance (1940) who actually popularized the same on presenting clinics on his technique of progressive extraction and is considered the father of serial extraction technique practised today. The term serial extraction, however, is misleading as it does not indicate the depth of understanding required and the importance of studyang diagnostic and investigative records for undertaking serialized extraction. It is mosily understood as simply extraction of teeth.

Hotz in 1970 preferred to term it as, ' Guidance of Eruption'. It would be still better to term the same as Guidance of Occlusion.

RATIONALE

The acceptance of expansion of the dental arches to eliminate tooth irregularities has always dogged the practice of serial extraction. Most of the clinicians prefer the expansion route on ignoring the interrelationship between the tooth, nerve, muscle and bone system, resulting in an ultimate relapse post-corrective treatment.

In Class I malocclusion, though there is tooth size-arch length deficiency the neuromuscular activity is within normal limits and expansion of the arches would make the positioning of teeth unstable. Therefore, the guidance of occlusion would be the best treatment option.

In case of Class II malocclusion, there is a definite change in the muscular function away from the normal; a change in position of teeth on expansion may be a more valid treatment so as to bring about the restoration of normal function.

Serial extractions are advocated when there exists a definite and excessive tooth material-arch length discrepancy—a large arch length deficiency of 10 mm or more indicates serial extraction.

INDICATIONS

1. Class I malocclusion with an arch size—tooth size deficiency of 5 mm or more per quadrant, normal eruption sequence as assessed radiographically and a skeletal growth pattern within normal limits.
2. Arch length deficiency, which could be unilateral or bilateral, is indicated by:
   a. *Non-pathologic*
      i. Midline shift of mandibular incisors due to displaced lateral incisors.
      ii. Premature loss of deciduous canine.
      iii. Abnormal canine root resorption.
      iv. Canine being blocked out labially.
      v. Mandibular and maxillary anterior teeth that are proclined (bimaxillary protrusion), could be associated with crowding.
      vi. Gingival recession on the labial aspect of mandibular anterior.
      vii. Ectopic eruption.
   b. *Pathologic*
      i. Extensive proximal caries and subsequent mesial migration of the teeth distal to the carious lesion.
      ii. Premature loss of deciduous tooth and lack of subsequent space maintenance.
      iii. Deleterious oral habits.
      iv. Improper proximal restorations.
      v. Tooth ankylosis.

CONTRAINDICATIONS

1. Mild to moderate crowding—tooth size arch length deficiency < 5 mm per quadrant.

2. Class II division 2 and Class III malocclusions.
3. Spaced dentition.
4. Congenital absence—anodontia/oligodontia.
5. Extensive caries involving permanent first molars, which cannot be conserved.
6. Open bite and deep bite, which should be corrected first.

DIAGNOSIS AND TREATMENT PLANNING

DIAGNOSIS

The primary step is to assess that a malocclusion exists on a clinical examination and the need for investigations and collection of diagnostic records. The investigations recommended are:

a. Study models
b. Radiographs
c. Photographs.

Study Models

Study models are made. These provide us the following information:

i. Assess the dental anatomy of teeth.
ii. Assess the intercuspation of teeth.
iii. Assess the arch form and curve of occlusion.
iv. Evaluate occlusion.
v. Undertake model analysis—Carey's analysis, arch perimeter analysis and mixed dentition analysis.
vi. Between and post-treatment assessments.

Radiographs

The different radiographs recommended are:

- Intraoral periapical radiographs.
- Lateral cephalograms for cephalometric analysis.
- Orthopantomogram.

These provide us the following informations:

i. Detection of congenitally missing teeth, supernumerary teeth.
ii. Detection of any bony pathosis.
iii. Enable to undertake radiographic mixed dentition analysis, which is more accurate.
iv. To assess the stage of root development and the possible eruption pattern.
v. To determine the dental age of the patient.
vi. To assess the different relationships between craniofacial structures using cephalometric analysis.
vii. To assess facial patterns.
viii. To assess soft tissue matrix.
ix. To assess changes in mid- and post-treatment relationships cephalometrically, as well as monitor treatment progress.

Photographs

The photographs taken pre- and post-treatment are extraoral and intraoral. They provide the following information:

i. These are important for self-evaluation of the case pre, mid and post-treatment.
ii. Are useful for showing the patient the progress in treatment as well as for patient motivation.
iii. To observe for any changes extraorally in front, right lateral and left lateral aspects mid and post-treatment.
iv. To assess any muscular hypo- or hyperactivity.

These diagnostic records can also be used to present to the patient and the parent the conditions intraorally and the need for dental treatment.

PROCEDURE

Different authors have given different sequences for following guidance of occlusion. Some of the most common and accepted sequences are:

a. Tweed's method
b. Dewel's method
c. Nance's method
d. Grewe's method.

It is important that before each step of extraction, the sequence should be re-evaluated.

TWEED'S METHOD (1966)

Proposed the extraction sequence DC4.

The deciduous first molars are extracted at 8 years of age. The deciduous canines are maintained to slow down the eruption of permanent canines. As soon as the first premolars are in the advanced eruptive stage wherein their crowns are above the alveolar bone—radiographically, the deciduous canines along with the first premolars are extracted.

DEWEL'S METHOD (1978)

Proposed the extraction sequence CD4.

At about 8½ years of age the deciduous canines are extracted so as to create space for the self-alignment

of crowded anteriors. At about 9½ years of age, as the incisor crowding would have got resolved and the first premolar would have had their roots developed up to their half level or more radiographically, the deciduous first molars are extracted so as to allow the first premolar to erupt prematurely into the oral cavity. The first premolars are then extracted to allow the permanent canines to erupt in their place and in alignment.

Modified Dewel's techniques involves the enucleation of the developing first premolar crown at the time of extraction of deciduous first molar, if the level of eruption of permanent canine is at a level higher than that of the first premolar, on radiographic evaluation. Another modification advised in such clinical conditions is to extract the deciduous second molars instead of first premolar enucleation after placement of a lingual holding arch, so as to allow the first premolar to erupt distally. On eruption of permanent canines the first premolars are extracted.

NANCE'S METHOD

Proposed the extraction sequence of D4C.

Is basically a modified Tweed's method. It involves the extraction of deciduous first molars at about 8 years of age, which is followed by the extraction of the first premolars and deciduous canines.

GREWE'S METHOD

Has described the planning of extraction sequence for different clinical conditions:

i. *Class I malocclusion with premature loss of a mandibular deciduous canine:* Has a midline shift to the side of the premature loss of deciduous canine and where the arch length discrepancy is 5 to 10 mm per arch, then the remaining deciduous canines should be extracted. The deciduous first molars should be extracted next, if the first premolars have their roots more than half developed. If the roots of the first premolars are not developed more than half then one should delay the extraction of deciduous first molar. The first premolars should be extracted as they emerge. If the development pattern from left side to right side and from maxilla to mandible is not symmetric, a successful serial extraction would be difficult to achieve.

ii. *Class I malocclusion with severe mandibular anterior crowding:* Along with an arch-length deficiency in excess of 5 mm per quadrant, extract the deciduous canines. The deciduous first molars are extracted next on completion of at least half of first premolar root formation and the extraction of first premolars follow as they erupt into the oral cavity.

iii. *Class I malocclusion where minimal mandibular anterior crowding is 6 to 10 mm arch deficiency:* This type of problem is observed where the crowding is in canine-premolar region or there is bimaxillary protrusion. The objective in such cases is to eliminate the first premolar as early as possible. The deciduous primary first molars are extracted when the roots of first premolars are more than half formed, as this would in turn result in premature eruption of the first premolar. As soon as the first premolars erupt into the oral cavity, these are extracted followed by deciduous canines. If there is bound to be eruption of permanent canine before that of the first premolar, then the deciduous canine is extracted first, followed by the extraction of the deciduous first molar and enucleation of the first premolar.

Grewe, however, suggested the serial extraction technique for in certain types of Class II malocclusions. Some of the malocclusions are:

- *Dental Class II with normal overjet:* When there is no crowding in the mandibular arch but, there is crowding in the maxillary arch, which can be eliminated. The deciduous maxillary canines are extracted followed by the deciduous first molars. This is followed by the extraction of maxillary first premolars as they erupt. The deciduous second molars are kept under review so that they may be extracted to allow buccal interdigitation.
- *Dental or skeletal Class II with slight but minimal overjet:* If crowding is present in both the maxillary and mandibular arches, the following sequence may be considered. Extraction of maxillary deciduous first molars and mandibular deciduous second molars and then enucleation of mandibular second premolars. The maxillary first premolar and maxillary deciduous canine are extracted when the maxillary first premolars emerge into the oral cavity. Some form of corrective orthodontic intervention is required.

The serial extraction procedure will not be a successful one if there is lack of patient cooperation or delay in review visits. However, despite different authors presenting different extraction sequences for undertaking the guidance of occlusion, it is always prudent to formulate an individualized extraction sequence for each individual depending upon the assessments from their diagnostic records (Figs 48.8 to 48.24 for case report).

Advantages

1. More physiologic treatment as teeth are guided into normal positions using physiologic forces.
2. Duration of fixed treatment is reduced.
3. Health of investing tissues is preserved.
4. Lesser retention period is required.
5. Results are more stable.

Disadvantages

1. Good clinical judgment is required. No single approach can be universally applied.
2. Treatment time is prolonged over 2-3 years.
3. Patient cooperation is very important.
4. Tendency to develop tongue thrust as extraction spaces close gradually.
5. Extraction of buccal teeth causes deepening of the bite.
6. Residual spaces can remain between the canine and second premolar.
7. Some amount of fixed appliance therapy is usually required at the end of serial extraction.

INTERCEPTION OF DEVELOPING SKELETAL MALOCCLUSIONS

A developing skeletal malocclusion if detected at an earlier stage can be intercepted so as to decrease its severity and at times even resulting in a normal occlusion. These changes are brought about by myofunctional therapy, which more appropriately is known as Functional Jaw Orthopedics today.

Mills (1991) has defined *a functional appliance as a removable or fixed appliance, which changes the position of the mandible so as to transmit forces generated by the stretching of the muscles, fascia and/or periosteum, through the acrylic and wirework to the dentition and the underlying skeletal structures.*



Fig. 48.8: Serial extraction—pre-treatment



Fig. 48.9: Pre-treatment, maxillary view



Fig. 48.10: Pre-treatment mandibular view, lingual holding arch. 74, 34, 84, 44 post-extraction



Fig. 48.11: 63,54 and 24 extracted, Nance palatal holding arch cemented



Fig. 48.12: 53, 54 and 14 extracted. Healing progressing



Fig. 48.13: Labial view. 22 is more palatally placed



Fig. 48.14: Maxillary occlusal view of the same



Fig. 48.15: Mandibular occlusal view of the same



Fig. 48.16: Intraoral view after 5 months, 22 less proclined



Fig. 48.17: Maxillary occlusal view of the same



Fig. 48.18: Mandibular occlusal view showing erupting 33 and 43



Fig. 48.19: Labial view, another 3 months later



Fig. 48.20: Maxillary view, 22 almost in the arch



Fig. 48.21: 33 and 43 have erupted, lingual holding arch removed



Fig. 48.22: One year later, labial view, severity of crowding had decreased drastically



Fig. 48.23: Maxillary occlusal view 13, 14, 23, 24 have erupted



Fig. 48.24: Mandibular view, resolution of crowding, corrective orthodontic referral

CLASSIFICATION

Functional appliances have been traditionally classified as:

1. Tooth-borne passive
2. Tooth-borne active
3. Tissue-borne.

INTERCEPTION OF CLASS II MALOCCLUSION

A Class II malocclusion generally occurs as result of either increased maxillary growth or decreased mandibular growth or a combination of the same. Face bow along with the headgear retards excessive growth of the maxilla, whereas functional appliances bring about the anterior positioning of the mandible.

Functional appliances have not been well accepted by the patients as these have been found to be hard or stiff as well as bulky, which has resulted in a poor cooperation by the patient. Newer softer appliances have been introduced in recent times, which are as effective and softer, as well as immensely accepted by the patient. These are the product of modern CAD/CAM techniques and will be discussed in depth and detail shortly. The other appliances such as bionator, activator, oral screen and Frankel's appliances as well as their functioning are to be discussed in great detail in the chapter on functional appliances.

INTERCEPTION OF CLASS III MALOCCLUSION

Class III malocclusion generally results due to a deficiency in maxillary growth or excessive mandibular growth or a combination of the same. The Frankel's III appliance is used for promoting growth of the deficient maxilla and a chin cup is generally used to restrict mandibular clockwise growth.

CAD/CAM MYOFUNCTIONAL APPLIANCES

The concept of myofunctional appliances, which developed in Scandinavian countries, shifted to Germany before the World War II, got stagnated there and finally spread to Europe, in the post-wartime. It became accepted over a period of time. It however, did not become popular as most of the myofunctional appliances were difficult to fabricate, had frequent breakages and were hard.

Farrell (Myofunctional Research Company) in Australia using CAD/CAM techniques and the flexibility as well as inherent memory effects of silicone/non-thermoplastic polyurethane produced myofunctional appliances. The appliance was developed to bring about tooth guidance effects as well as have a functional effect too.

DESIGN

The appliance has been designed using CAD/CAM techniques. The appliances are soft and are shaped in the form of the normal parabolic shape of the dental arches. It has channels for the maxillary and mandibular teeth. The labial/buccal screen has premolded condensations of the material, which act as labial bow, thereby having an effect similar to the arch wire in corrective (fixed) treatment. This allows the irregular teeth to get aligned and the tooth channels further guide the teeth into the normal arch form.

The oral screen like structure enveloping the teeth buccally/labially help in treating the mouth breathing or thumb sucking habits. This allows for the child to shift from oral to nasal breathing, which in turn allows the nasal passages to develop and the palate to descend. The maxillary arch therefore tends to develop into a shallow arch and a U shaped arch develops due to the parabolic natural like shape of the appliance. Promotion of development of a U shaped arch allows an increase in the inter-canine dimensions of the maxilla, which in turn allows an increase in the inter-canine dimensions of the mandible, thereby allowing resolution of mandibular anterior crowding.

Small projections on the labial aspect of the oral screen like structure in the region relating to the mandibular anteriors, behaves as a lip bumper or mentalis stretcher, which in turn deactivates an over-active mentalis muscle, thereby allowing a mandibular anterior flat arch to develop into a rounded one and thereby increasing arch perimeter. It also allows the perioral group of muscles to become normotonic thereby ensuring a lip seal. A tongue tag has also been incorporated in the maxillary palatal aspect, which is used to train aberrant tongue habits such as retained infantile or tongue thrust cases. Thus, the imbalance of forces acting on the developing arches if any from the lingual aspect are also taken care of.

The tooth channels are designed in such a way so as behave like an activator guiding the teeth into the occlusion.

These are used in 2 phases—the softer blue pre-orthodontic trainer first, which allows for correction of aberrant muscle movements and mild tooth movements. This is generally worn for about 6 months or until one finds that the aberrant movement of the groups of muscles have ceased considerably followed by the firmer pink pre-orthodontic trainer, which exerts slightly greater forces for the alignment of teeth. The CAD/CAM process has allowed the appliance to be developed in such a way that a single size is applicable to all the patients. The only adjustments required are in case of the distal aspects, which can be easily trimmed. In case of open bite cases the appliances may need to be trimmed distally so that the maxillary anterior teeth get to lie below the maxillary labial bow like premolded area so that the appliance exerts the corrective forces.

Indications

1. Mandibular anterior crowding
2. Class II Division 1 and 2
3. Anterior open bite
4. Deep bite
5. Mild Class III/ Pseudo Class III
6. Tongue thrusters, thumb sucking and oral breathing habits.

Contraindications

1. Posterior cross bite—which is uncorrected.
2. Severe Class III
3. Complete nasal obstruction
4. Non-cooperative child/parent.

The appliance should be inserted for a minimum of one hour daily during the day and also be worn while sleeping. Initially, the appliance may fall out while sleeping at night, this would decrease over a couple of weeks and finally the appliance would not fall out in sleep, as the aberrant muscular forces become normal. The daily one hour wearing is important so as to unlearn the old habits and learn the correct

habits at the conscious levels, e.g. in case of aberrant tongue swallow patterns and the night time wear during sleep is equally important so as to convert the same into a subconscious habit. The blue trainer is made to be worn for 6-8 months followed by the pink trainer for 12 months or so until the treatment objectives are achieved. Alignment of teeth will begin to occur in 3-6 months time. A clinical review once every month is important to review as well as motivate the child to wear the appliance regularly and for the parents to see the changes and regulate the child use of the appliance at home. The appliance is kept clean by brushing the same with lukewarm soft soapy water everyday.

Adjustment Required

Generally the appliance does not require to be adjusted, except for a few cases such as:

1. Narrow mouths may require 2-3 mm of the distal ends of the appliance to be trimmed, if the patient finds the appliance to be long or the lips do not close over the appliance.
2. If the tongue tag area hurts the V cuts on either side of the appliance needs to deepen.
3. If there is an exacerbated mouth opening or in extreme Class II cases, where the maxillary anterior teeth do not come into the tooth guidance system, 2-3 mm of the distal ends are trimmed to correct the same. If the maxillary anterior teeth still do not fit into the appliance well, then the trimming of the upper labial bow of the appliance is indicated.
4. In children less than 6 years of age, where the permanent first molars have not erupted, 4-6 mm of the distal ends are trimmed off.
5. Upper labial bow is removed in case of Class III cases so as to allow the maxillary arch to advance anteriorly over the mandibular arch.
6. The lower labial bow is removed to have an enhanced lip bumper effect so as to increased arch length. This is more effective in the pink pre-orthodontic trainer.
7. A more compliant patient with the use of the appliance may result in an edge-to-edge bite; this can be corrected by removing the upper labial bow to allow an overjet and overbite to develop.

This way the treatment is not only more economical, but also more stable, with an improvement in facial profile and features, decrease in the need for extractions and decreased corrective orthodontic treatment time, if required.

The pre-orthodontic trainer can also be used with the Farrel Bent Wire system, so as to bring about arch development by lateral expansion forces once the appliance is activated. These can be placed on both the maxillary and mandibular arches in a phased manner, starting from the maxilla. It along with the pre-orthodontic trainer corrects the tongue positioning, which in turn brings about a slight anterior tipping of the anteriors thus increasing the arch perimeter. Thus, arch length deficiency including lost canine space can be regained without the opening of the bite. This generally should take about 6 to 9 months if the patient wears the appliance properly.

Certain other appliances have also been introduced which allows the aberrant muscular forces to be corrected along with the use of corrective fixed appliances (Figs 48.25A to 48.27H).



Fig. 48.25A: Cut section of the pre-orthodontic trainer
1. Tooth channels. 2. Labial bows



Fig. 48.25B: Parts of the pre-orthodontic trainer
3. Tongue tag, 4. Tongue guard, 5. Lip bumpers and 6. Enables jaw positioning into edge-to-edge Class I occlusion



Fig. 48.26A: Labial view, excess overjet



Fig. 48.26B: Occlusal view of the mandibular arch, 36-Band and loop and 42 rotated



Fig. 48.26C: Occlusal view of the maxillary arch pre-treatment



Fig. 48.26D: Lateral view of study model-Class II Division 2-12 mm overjet



Fig. 48.26E: Anterior view-12 mm overjet



Fig. 48.26F: Blue pre-orthodontic trainer on insertion

Case II Figures 48.27A to H: Case treated using pre-orthodontic trainer.



Fig. 48.26G: Pink pre-orthodontic trainer after 8 months



Fig. 48.27A: Maxillary and mandibular anterior crowding



Fig. 48.26H: Class I edge-to-edge bite achieved



Fig. 48.27B: Pre-treatment occlusal view mandibular arch



Fig. 48.26I: Intraoral view: From Class II Division 2 to Class I



Fig. 48.27C: Pre-treatment occlusal view maxillary arch



Fig. 48.27D: Blue pre-orthodontic appliance in place



Fig. 48.27G: Maxillary occlusal view after alignment



Fig. 48.27E: Pink pre-orthodontic appliance in place following 7 months of treatment

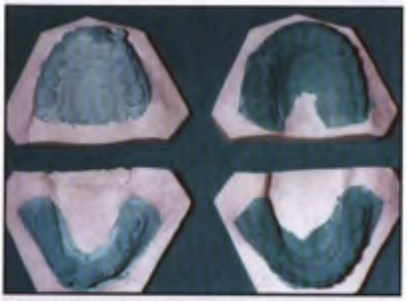


Fig. 48.27H: Pre-and post-correction patient models



Fig. 48.27F: Mandibular occlusal view following alignment

Case III Figures 48.28A to F: Case treated using pre-orthodontic trainer.



Fig. 48.28A: Pre-treatment occlusal view of the maxillary arch



Fig. 48.28B: Pre-treatment intraoral view



Fig. 48.28C: Pre-treatment occlusal view of the mandibular arch



Fig. 48.28D: Post-correction intraoral view



Fig. 48.28E: Post-correction occlusal view of the maxillary arch



Fig. 48.28F: Post-correction occlusal view of the mandibular arch

In conclusion, the interceptive and preventive orthodontic procedures enable the clinician to treat and/or make a developing malocclusion less severe so as to allow the corrective orthodontist to deliver a stable and more conservative (non-extraction) treatment plan benefiting the patient. Certain patients may need to undergo a 2 phase treatment plan but, the end results are more rewarding. Therefore, the interceptive orthodontic procedures should not be made controversial as being done at present by a section of the dental specialists and instead there should be a team approach towards early detection of malocclusion, patient and parent counseling towards the long-term benefits of the same, cross referral as well as treatment of the malocclusion.

FURTHER READING

1. Ackerman JL, Proffit WR. Preventive and interceptive orthodontics: A strong theory proves weak in practice. Angle Orthod 1980;50:75-86.
2. Bjerregaard J, Bundgaard AM, Melsen B. The effect of the mandibular lip bumper and maxillary bite plate on tooth movement, occlusion and space conditions in the lower dental arch. Eur J Orthod 1980;2:257-65.
3. Bjerregaard, J, AM Bundgaard, B Melsen. The effect of the mandibular lip bumper and maxillary bite plate on tooth movement, occlusion, and space conditions in the lower dental arch. Europ J Orthod 1983;84:147-55.
4. Bolton, WA. Disharmony in tooth size and its relation to the analysis and treatment of malocclusion. Angle Orthod 1958;28:113-30.
5. Dewel BF. A critical analysis of serial extraction in orthodontic treatment. Am J Orthod 1959;45:424-55.

6. Dewel BF. Serial extraction, its limitations and contraindications in orthodontic treatment. Am J Orthod 1967;53:904-21.
7. Dewel BF. Serial extractions in orthodontics; Indications, objections, objections, and treatment procedures, Int J Orthod 1954;40:906-26.
8. Fränkel R, Decrowding during eruption under the screeing influence of vestibular shields. Am J Orthod 1974;65:372-406.
9. Heath J, Serial extraction. New Zeal Dent J 1953;49:77-88.
10. Hotz R. Active supervision of the eruption of teeth by extraction. Trans Eruop Orthod Soc 1948;134-60.
11. Jarvis RG. Interproximal reduction: A restorative adjunct to orthodontic procedures. Austral Prosthodont J 1989;3:51-62.
12. Kjellgren B. Serial extraction as a corrective procedure in dental orthopedic therapy. Acta Odont Scand 1948;8:17-43.
13. Richardson A. Interceptive Orthodontics, 2nd edn, BDJ Publications, 1989.
14. Schroder U, Granath L. A new interceptive treatment of cases with missing maxillary lateral incisors. Swed Dent J 1981;5:155-58.
15. Terwilliger KF. Treatment in the mixed dentition. Angle Orthod 1950;20:109-13.
16. Thilander B, et al. The effect of early interceptive treatment in children with posterior cross-bite, Eur J Ortho 1984;6:25-34.
17. Wieslander K. Early or later cervical traction therapy in the mixed dentition. Am J Orthod 1975;67:432-9.

49 Oral Habits and their Management

Tapasya Juneja, Gurkeerat Singh

- Introduction
- Definitions
- Classifications
- Maturation of oral functions
- Development of a habit
- Etiological agents in the development of oral habits
- Treatment philosophy and considerations
- Digit-sucking habit
- Tongue thrusting habit
- Mouth breathing habit
- Bruxism
- Lip habits
- Lip-wetting
- Lip-biting
- Cheek-biting
- Masochistic habit
- Postural habit

INTRODUCTION

Oral habits in children are a prime concern for the dentist, be it an orthodontist, pedodontist or a general practitioner (Fig. 49.1).

The neonate uses its mouth as a primary device for exploring the environment and his survival depends on instinctive sucking when his lips and tongue are stimulated. By random movements, infants discover their hands and toes, and use these to continue stimulation of the mouth and related structures. Normal habits grow out of these early developmental stages smoothly. Occasionally, a retained infantile pattern can cause an evident oral habit.

Finn says that habits cause concern because they cause.

i. *Oral structural changes* Harmful, unbalanced pressures bear upon the immature, highly malleable alveolar ridges and bring about potential changes in position of teeth and occlusion.
ii. *Behavioral problems*
iii. *Socially unacceptable act.*



Fig. 49.1: Confluence of specialists

DEFINITIONS OF HABITS

1. **Dorland** (1963): Fixed or constant practice established by frequent repetition.
2. **William James**: A new pathway of discharge formed in the brain by which certain incoming currents lead to escape.
3. **Maslow** (1949): A habit is a formed reaction that is resistant to change, whether useful or harmful, depending on the degree to which it interferes with the child's physical, emotional and social functions.
4. **Moyers**: Habits are learned patterns of muscle contraction, which are complex in nature.

5. **Johnson** (1938): A habit is an inclination or aptitude for some action acquired by frequent repetition and showing itself in increased facility to performance and reduced power of resistance.
6. **Stedman**: Habit is an act, behavioral response, practice or custom established in one's repertoire by frequent repetitions of the same act.
7. *Habit is an automomic response to a situation acquired normally as the result of repetition and learning, strictly applicable only to motor responses. At each repetition the act becomes less conscious and can lead on to a unconscious habit.*

CLASSIFICATION OF HABITS

Over time various authors have classified habits in differing ways:

WILLIAM JAMES (1923)

William James (1923) classified habits into.

Useful Habits

Include habits of normal function, e.g. correct tongue posture, respiration and deglutition.

Harmful Habits

Includes all habits which exert pressures/stresses against teeth and dental arches and also mouth breathing, lip biting and lip sucking.

KINGSLEY (1956)

Based on the nature of the habits, **Kingsley** (1956) classified habits as:

a. *Functional oral habit*, e.g. mouth breathing.
b. *Muscular habits* Tongue thrusting, cheek/lip biting.
c. *Combined muscular habits* Thumb and finger sucking.
d. *Postural habits*
   Chin-propping
   - Face leaning on hand
   - Abnormal pillowing.

EARNEST KLEIN (1971)

Intentional/Meaningful Habits

Intentional/meaningful habits are caused by a definite underlying psychological disturbance.

Unintentional/Empty Habits

A meaningless habit, has no need for support. They can be easily treated by reminder appliances.

GRABER (1976)

Graber included all habits under extrinsic factors of general causes of malocclusion.

1. Thumb/digit sucking
2. Tongue thrusting
3. Lip/nail biting, bobby pin opening
4. Mouth breathing
5. Abnormal swallow
6. Speech defects
7. Postural defects
8. Psychogenic habits-bruxism
9. Defective occlusal habits.

FINN AND SIM (1975)

Habits

- Compulsive oral habits
- Non-compulsive oral habits.

Compulsive Habits

An oral habit is compulsive when it has acquired a fixation in the child to the extent that he retreats to the practice of this habit whenever his security is threatened by events which occur in his world. They express deep-seated emotional need and attempts to correct them may cause increased anxiety. The act serves as a bulwark against society or a safety valve when emotional pressures are too much to bear. Various etiologies often implicated are:

- Rapid feeding patterns
- Too little feeding at a time
- Too much tension during feeding
- Bottle-feeding
- Insecurity brought by a lack of love and tenderness by the mother.

Non-compulsive Habits

Non-compulsive habits are the ones that are easily added or dropped from the child's behavior pattern as he matures. Continual behavior modification causes release of undesirable habits and addition of new socially acceptable ones. No abnormal response results from attempts to retrain the child to form a pattern of behavior consistent with his increased level of maturity.

JOHNSON AND LARSON (1993)

Classification of Non-nutritive Sucking (NNS) Habits

Level	*Description*
Level I (+/-)	Boy/girl of any age with a habit that occurs during sleep
Level II (+/-)	Boy under 8 years with a habit that occurs at one sitting during waking hours
Level III (+/-)	Boy under 8 years with a habit that occurs across multiple sittings during waking hours
Level IV (+/-)	Girl under 8 years/boy over 8 years with habits that occur at one sitting during waking hours
Level V (+/-)	Girl under 8 years/boy over 8 years with habits across multiple sittings during waking hours
Level VI (+/-)	Girls over 8 years with habits during waking hours

+/- designates willingness of patient to participate in treatment level. Increased level designates increased habit severity.

Some of the other common classifications of habits are as follows:

HABITS CAN BE CLASSIFIED ACCORDING TO THE CAUSE OF THE HABIT

Physiologic Habits

Those required for normal physiologic functioning, e.g. nasal breathing, sucking during infancy.

Pathologic Habits

Those that are pursued due to pathologic reasons e.g. mouth breathing due to deviated nasal septum (DNS)/ enlarge adenoids.

CLASSIFICATION BASED ON THE ORIGIN OF THE HABIT

Retained Habits

Those that are carried over from childhood into adulthood.

Cultivated Habits

Those that are cultivated during socioactive life of an individual.

CLASSIFICATION BASED ON THE PATIENT AWARENESS TO THE HABIT

Unconscious Habits

Unconscious habits are sustained by unconscious behavior. Simple attenuation of sensory feedback mechanism aid in cessation.

Conscious Habits

Involve choice or need, making treatment more difficult and complex.

MATURATION OF ORAL FUNCTIONS

Principle physiologic functions of oral cavity are respiration, swallowing, mastication and speech. Respiration needs are the primary determinants of the posture of the mandible and tongue.

FETAL LIFE

Respirative movements are seen in utero but lungs do not inflate. Swallowing occurs during the last months of fetal life.

At Birth

Newborn infants are obligatory nasal breathers. Thus, to open the airway, mandible is positioned downward and tongue is moved downward and forward away from the posterior pharyngeal wall. Breathing through the mouth becomes physiologically possible later. The next physiologic priority of the newborn is to obtain milk and transfer it to the gastrointestinal tract by sucking and swallowing.

SUCKLING

Milk ducts of lactating mammals are surrounded by smooth muscles and the infant stimulates their contraction by suckling, i.e. small nibbling movements of lips. This causes squirting of milk into the mouth. Infant grooves the tongue to allow milk to flow posteriorly. This sequence of events is called an *infantile swallow*, which later on matures to an adult swallow.

At Birth

Maturation of oral function is characterized as a gradient from anterior to posterior. Hence, at birth, we see that lips are more mature as compared to the

tongue and greater activity by posterior parts of the tongue and complex motion of pharyngeal structures is seen as time passes and maturation proceeds.

Acquisition of speech takes place with development of pharyngeal structures.

After sucking habits are extinguished, a complete transition into adult swallow requires some months. Delay can occur in the presence of an anterior open bite (due to a habit) due to the physiologic need to seal the anterior space.

DEVELOPMENT OF A HABIT

A newborn instinctively develops certain habits essential for his survival in the state of neuromuscular immaturity.

There are 5 sources of unconscious mental patterns in childhood which may lead to the development of a habit:-

1. Instinct
2. Insufficient outlet for energy
3. Pain/discomfort or insecurity
4. Abnormal physical size of parts
5. Limitation/imposition by parents or others.

ETIOLOGICAL AGENTS IN THE DEVELOPMENT OF ORAL HABITS

ANATOMICAL

For example, posture of the tongue. Infantile swallow occurs due to a large tongue in a small oral cavity coupled with anterior open bite of gum pads (Fig. 49.2).

MECHANICAL INTERFERENCES

Mechanical interferences lead to undesirable oral habits, e.g. in a child with normal breathing and swallowing, if permanent incisors erupt ectopically (Fig. 49.3), then to achieve a proper anterior seal/vacuum when swallowing, the child must thrust the tongue and resultant mouth breathing occurs due to loss of lip seal. Again if the succedaneous teeth are missing (Fig. 49.4), an abnormal habit can develop.

PATHOLOGICAL

Certain conditions of oral and perioral structures can cause an undesirable oral habit, e.g. tonsillitis, DNS, hypertrophy of inferior nasal turbinates (can cause mouth breathing) (Fig. 49.5).



Fig. 49.2: Infantile swallow; note the placement of the tongue at rest and its position just before the act of swallowing. The tongue comes in between the gum pads to obtain the vacuum required to suck



Fig. 49.3: Ectopically erupting central incisor resulting in the tongue being placed at the sight



Fig. 49.4: Anterior tongue thrust habit due to the congenitally missing permanent maxillary lateral incisors



Fig. 49.5: Nasal blockage as seen on an OPG

EMOTIONAL

Upset children regress towards infancy, assume infantile postures, e.g. digit sucking which gives the child a feeling of security.

IMITATION

Young children are extremely observant and sensitive to environment and highly affected by parents and siblings. The child may imitate jaw positions/speech disorders of parents.

RANDOM BEHAVIOR

Behavior appears purposeless if not completely accidental.

EQUILIBRIUM THEORY

Weinstein *et al* (1963) observed: "An object subjected to an unequal force will get accelerated and thereby will move to a different position in space. Hence, any object subjected to a set of forces remains in place if forces are balanced".

In dentition, small imbalance of forces maintained for a long time (6 yrs) can upset the equilibrium. This depends upon the duration of the habit.

TREATMENT PHILOSOPHY AND CONSIDERATIONS

Three main variables need to be considered.

1. Emotional significance of a habit for the child in relation to family and peer group.
2. Age.
3. Existing or potential malocclusions associated with a force exerting habit.

It should be kept in mind that:

a. Active intervention before 3 years, other than ignoring the habit is unadvisable. Contingency behavior modification should be done.
b. A 3-year-old child with a skeletal Class II may not be correctable by any measure.
c. A 5-year-old with Class I and anterior open bite correction is expected only if the habit is stopped before eruption of the permanent incision.
d. Malocclusion development and correction are most dramatic during active eruption of permanent dentition.

RESTRAINING HABIT

Process of progressive elimination of an undesirable oral habit from a child's behavior pattern involves use of various approches:

Psychologic Methods/Approach

Examine duration, frequency, osteogenic development, genetic endowment, state of health of the child.

It is a clinical rule of thumb - A habit can be overcome only by the conscious efforts of the child himself guided by the dentist and parent. This is possible only if a child is ready psychologically and wants to break the habit.

Parents should cooperate by:

a. Setting a short term goal for dropping the habit
b. Do not criticize the child if the habit continues
c. Offer a small reward if the habit is extinguished.

Extra-oral Methods

- Painting the child's finger/thumb with an unpleasant tasting substance (Fig. 49.6).
- Arranging for offending digit to be taped or glove taped at the wrist to hold it in place (Fig. 49.7).
- Rewarding a child for growing out of the habit during a procedure, makes a deep impression and orients him towards the goal.
- Parents must not demand perfection, with which a child cannot comply.

Intra-oral Methods

Appliances fabricated by the dentist and placed in the child's mouth with or without his overt permission.



Fig. 49.6: Commercially available bitter material for application on the digit that is put in the mouth



Fig. 49.7: Patient wearing a boxing glove to prevent digit sucking

DIGIT-SUCKING HABIT (THUMB/FINGER-SUCKING—Fig. 49.8)

DEFINITIONS

Gellin (1978): Defines digit-sucking as placement of thumb or one or more fingers in varying depths into the mouth.

Moyers: Repeated and forceful sucking of thumb with associated strong buccal and lip contractions.

Practically all children take up this habit, but eventually discontinue it spontaneously with age and maturation, as growth unfolds.

SUCKING REFLEX

Anatomy and Physiology of Sucking

Engel on direct observation of infants during the first year of life revealed their organization to be an oral and clinging one. At birth, the child has a reflex pattern of neuromuscular functions such as sucking.



Fig. 49.8: Digit-sucking habit

The habit of sucking is a reflex occurring in the oral stage of development and disappears during normal growth between 1-3½ years. Even before birth, oral contractions and other reflexes have been observed. This early neural organization allows the infant to nurse and cling to the mother as evidenced by the sucking and the grasping reflexes. With hearing and vision development, the baby tries to reach and transport to its mouth, what it has seen and heard at a distance. The baby tends to persist until all possible objects are carried into his mouth.

There are two forms of sucking:

The Nutritive Form

Breast and bottle-feeding, which provides essential nutrients.

Breast-feeding Flow of milk is regulated by biting and releasing the lacteal glands. Rapid mandibular protrusive movement and buccinator mechanism alternately contracts and relaxes during breast-feeding. Infantile swallowing exerts a progressive pressure towards the rear to drain milk. Gum pads are apart; tongue and lower lip are in constant contact.

Bottle-feeding Warmth of association with mother's body is lacking.

Two types of nipples are available

- Non-physiologic nipple
- Physiologic nipple.

Non-physiologic/conventional nipple (Fig. 49.9A)

- End of the nipple is almost against the posterior pharyngeal wall.

- Milk is directly released into the digestive tract reducing the period of predigestion.
- Flow of milk may be too rapid.
- Mouth is held wide open.
- Greater demand on buccinator mechanism. Suckling is now converted to sucking.

Physiologic nipple (Fig. 49.9B)

- Forward movement of tongue under the flat surface of nipple.
- Nipple is drawn upward and backward towards the palate.
- Child has to work and exercise the lower jaw.
- Posterior part of the tongue awaits milk and pushes it into esophageal area.
- Milk flows down by the peristaltic action of the tongue and cheeks.
- Flat shape of the nipple improves lip seal, e.g. functionally designed latex nuk sauger nipple.

Hence physiologic nipple serves better adapted to anatomy and physiology of sucking.



Fig. 49.9A: The conventional nipple



Fig. 49.9B: The Nuk Sauger nipple

The Non-nutritive Form

Larsson (1993) described non-nutritive sucking (NNS) to be the earliest sucking habit adopted by infants in response to frustration and to satisfy their urge and need for contact. Children who neither receive unrestricted breast feeding nor have access to a pacifier may satisfy their need with habits like thumb sucking which ensures a feeling of warmth and sense of security but may be detrimental to their dentofacial development.

PSYCHOLOGY OF NON-NUTRITIVE DIGITAL-SUCKING (NNS)

Developmental psychologists have produced numerous theories regarding digit sucking.

1. *Psychoanalytical theory of psychosexual development (Sigmund Freud)* NNS arises from an inherent psychosexual drive. It is a pleasurable, erotic structuralization of lips and mouth. Orality in an infant is related to pregenital organizations thus, the object of thumb sucking is nursing. Abrupt interference with such a basic mechanism is likely to lead to stuttering and other antisocial tendencies. Thumb sucking may be the only manifestation of insecurity maladjustment/deep-seated internal conflicts.
2. *Learning theory-Palermo (1956)* NNS stems from an adaptive response. Infants associate sucking with such pleasurable feelings as hunger, satiety and being held.
   Eric Johnson and Brent Larsson (1993) Origin of NNS is a combination of psychoanalytical and learning theories.
3. At will feeding causes less digit sucking when compared to widely separate feeding.
4. *Oral drive theory—Sears and Wise (1960)* Strength of oral drive is, in part, a function of how long a child continues to feed by sucking. The oral drive is strengthened by prolongation of nursing, this is the cause and not frustration of weaning.
5. *Benjamin (1962)* Thumb sucking is an expression of a need to suck that arises simply from rooting and placing reflexes. These reflexes are maximal during the 1st three months of life.
6. *Oral gratification theory-Sheldon (1932)* If a child is not satisfied with sucking during the feeding period, it will persist as a symptom of an emotional disturbance by digit sucking.

Maintenance of habit as explained jointly by Freudian and the learning theory. Prolonged NNS is a learned habit in most children. In fewer children, it may represent some underlying psychological disturbance caused by an acute increase in the level of anxiety.

CLASSIFICATION OF THUMB SUCKING

Cook (1958) 3 patterns of thumb sucking:

1. α Group: Pushed palate in a vertical direction and displayed only little buccal wall contractions (Fig. 49.10A).
2. β Group: Registered strong buccal wall contractions and a negative pressure in the oral cavity show posterior cross bite (Figs 49.10B and C).
4. γ Group: Alternate positive and negative pressure; least effect on anterior occlusion.

Subtleny *et al* (1973)

Four types of thumb-sucking

Group I Thumb was inserted into the mouth considerably beyond the first joint. The thumb occupies a large area of hard palate vault pressing against the palatal mucosa and alveolar tissue. Lower incisors press out the thumb and contact it beyond the first joint. This type was seen in 50 percent of children.

Group II The thumb extended into mouth around the first joint or just anterior to it. No palatal contact, contacts only maxillary and mandibular anteriors (24%).

Group III Thumb placed fully into mouth in contact with the palate as in group I; without any contact with the mandibular incisors (18%).

Group IV Thumb did not progress appreciably into the mouth. The lower incisors made contact approximately at the level of thumb nail (8%).

Index finger may be curled over the bridge of the nose or rolled into a fist with other fingers.

CLINICAL ASPECTS OF DIGIT-SUCKING

Moyers divided the thumb sucking habit into 3 distinct stages:

Phase I

Normal and subclinically significant sucking:

- From birth to 3 yrs of age depending on the child's social development.
- Most infants exhibit digit sucking especially during weaning. Usually sucking is resolved towards the end of phase I.



Fig. 49.10A: Vertical placement of the digit in the palate only causes anterior tooth dearrangements



Fig. 49.10B: Horizontal placement of the digit in the palate and sucking on it can cause bilateral posterior cross-bites



Fig. 49.10C: Anterior open-bite caused due to a digit-sucking habit

- If vigorous sucking persists at the end of phase I, then a definite prophylactic approach is to be taken due to possible occlusal harm, e.g. pacifier (oval, flat shape) is less harmful.

Phase II

Clinically significant sucking:
Features:
- From 3 - 6/7 years
- More serious attention required for purposeful digit sucking because:
  a. Possibility of clinically significant anxiety.
  b. Best time to solve dental problems related to digit sucking.
- Firm and definite corrective program is indicated.

Phase III

Intractable-sucking

Persistence of thumb-sucking till phase III is a symptom of significant problem that can be associated with a malocclusion.

Finger Sucking from Birth to 4 Years

The newborn child exhibits a well developed circumoral and intraoral muscular activity. It is the most important means of his exchange with the outside world. During the first few days of life, apart from sucking at meal times, child attempts to suck his fingers or a dummy.

Weaning to the cup is postponed to at least the first birthday. For the first 3 years, damage due to thumb sucking is largely confined to the anterior segment. Usually it is temporary, provided the child starts with a normal occlusion.

Finger-sucking After Age 4

If habit continues beyond the time it would have been automatically dropped, the child normally comes from homes where ineffectual badgering attempts by the family to break the habit is carried out.

INCIDENCE OF FINGER-SUCKING HABIT

Literature surveys of last 40 years show that incidence of digit sucking is highly age dependent.
- Fifty two to sixty seven percent—Incidence in newborn.
- Thirty percent—1 year old rate of occurrence.
- Twelve percent—by 9 years number of new cases/year.
- Two percent—12 years or beyond.

EFFECT OF DIGIT-SUCKING

Dentofacial changes associated with NNS can affect:
i. Maxilla
ii. Mandible
iii. Inter-arch relationship
iv. Lip placement and function
iv. Other effects.

Effects on Maxilla (Fig. 49.11)

1. Proclination of maxillary incisors: When a child places a thumb/finger between the teeth, it is usually positioned at an angle so that it presses against the lingual palatal surface of the upper incisors and the lingual surface of the lower incisors. This direct pressure causes displacement of incisors.
2. Increased arch length

3. Increased anterior placement of apical base of maxilla: Maxillary teeth experience a labial and apical force resulting in flared and labially inclined anteriors with or without a diastema.
4. Increase in SNA angle
5. Increased clinical crown length of maxillary incisors.
6. Increased counter clockwise rotation of occlusal plane.
7. Decreased width of palate. Left/right side of anterior maxillary arch is usually deformed with deformation related to whether the right or left thumb is sucked.
8. Atypical root resorption of primary central incisors.
9. Trauma to maxillary central incisors (Primarily due to their prominance).

Effects on Mandible (Fig. 49.11A)

1. Proclination of mandibular incisors.
2. Increased mandibular inter-molar width.
3. More distal position of point B. Mandible is more distally placed relative to the maxilla.
4. Mandibular incisors experience a lingual and apical force.

Inter-arch Relationship (Fig. 49.11B)

1. Decreased inter-incisal angle
2. Increased overjet
3. Decreased overbite
4. Posterior cross-bite (Fig. 49.10B) If the thumb is placed between the upper and lower teeth, tongue



Fig. 49.11A: The maxillary and mandibular arches in the vertical and horizontally placed digit suckers



Fig. 49.11B: Inter-arch relationship in vertical and horizontally placed digit suckers

is lowered, which decreases the pressure exerted by the tongue against the lingual aspect of upper posterior teeth, at the same time, cheek pressure against these teeth is increased as buccinator contracts during sucking. Cheek pressures are greatest at the corner of the mouth, therefore, maxillary arch tends to become V-shaped with more constriction across the canines than molars. Hence, the maxillary arch becomes narrower than the mandibular arch.

5. Anterior open-bite (Fig. 49.10C) Arises by a combination of interference to normal eruption of incisors and excessive eruption of posterior teeth. When a thumb or a finger is placed between the jaws the mandible must be positioned downward to accommodate it. The interposed thumb directly impedes incisor eruption. With the separation of jaws, there is an alteration in the vertical equilibrium, which causes more eruption of posterior teeth; about 1 mm supraeruption posteriorly, opens the bite about 2 mm anteriorly resulting in an open bite.
6. Narrow nasal floor and high palatal vault results from loss of equilibrium in the force system in and around the maxillary complex, it is possible for the nasal floor to drop down vertically from its expected position during growth.

These are commonly seen and is dependent on the position and pressure exerted by the digit during sucking.

EFFECT ON LIP PLACEMENT AND FUNCTION

1. Lip incompetence
2. Hypotonic upper lip
3. Hyperactive lower lip: Since it must be elevated by contractions of orbicularis oris and mentalis muscle to a position between malposed incisors during swallowing.

EFFECT ON TONGUE PLACEMENT AND FUNCTION

1. Tongue thrust
2. Lip to-tongue rest position
3. Lower tongue position: Tongue is displaced inferiorly towards the floor of mouth and laterally between posterior teeth.

Other Effects

1. Affects psychological health
2. Risk of malpositioning of the teeth and jaws
3. Deformation of digits
4. Speech defects (lisping).

DIAGNOSIS

According to Nanda and Sorokohit (1989) the type of malocclusion that may develop in a thumb sucker is dependent on a number of variables. These include:

1. Position of digit
2. Associated orofacial muscle contractions
3. Position of the mandible during sucking
4. The facial skeletal morphology
5. Duration of sucking.

The diagnosis of thumb sucking consists of the following diagnostic procedures:

History of Digit Sucking

Information on whether the child has had a history of digit sucking is obtained from the parents. When there is a positive answer, one should inquire about:

i. Frequency: Number of times/day habit is practiced.
ii. Duration: Amount of time spent on habit.
iii. Intensity: Amount of force applied to the teeth during sucking.

More damage occurs to the child with a constant sucking habit, also if sucking can be heard loudly and visible perioral muscle functions and facial contortions are seen, it is more harmful.

Extra-oral Examination

Casual examination of the upper extremities can reveal considerable information about the digit used for NNS habit.

a. Cleaner digit
b. Redness, wrinkling or chapped and blistered due to regular sucking.
c. Dishpan thumb—clean thumb with short nails.
d. Fibrous/roughened wart like callus on superior aspect of the digit, ulceration, corn formation.
e. Rarely finger deformity seen.
f. Short upper lip
g. Higher incidence of middle ear infections, blocked eustachian tubes, enlarged tonsils and mouth breathing.

Intraoral Examination

As discussed in the effects of digit sucking.

TREATMENT OF DIGIT SUCKING

Pretreatment Screening

a. Social background: Inquire into the family status of the child, whether the parents are married/single, lack of jobs, family stress, evidence of child abuse, etc. All factors causing turbulent home environments are ruled out before eliminating the habit.
b. School and peer relationship: Poor school performance and self image diminishes chances for success.

Dental Consultation

Confirm habit, its etiology, duration, frequency, intensity and direction of force as well as the presence of other habits.

Clinical Treatment

The child, parent and dentist will be amalgamated together to form a team to assist the child in stopping the habit.

According to **Pinkham** there are three categories of treatment

1. Reminder therapy
2. Reward system
3. Appliance therapy.

Younger than 3 years

i. No active intervention regardless of type and severity of malocclusion because of general emotional immaturity.
ii. Most children out grow the habit by 5 years of age.
iii. Malocclusion is self-correcting if ceased by the time of eruption of permanent teeth.
iv. Parents are advised to ignore habit.
v. Give more attention to the child when not sucking.
vi. If occlusion Class II, advise need for future orthodontic treatment.

3-7 year old More concern about finger sucking than thumb sucking due to anterior orthopedic force vectors associated with finger sucking leverage.

Watching and counseling Working with parent on contingent behavior modification.

7 years and older Anterior open bite will not close by itself due to established functional patterns. Therefore, orthodontic intervention is needed.

Psychologic Approach

Dunlap's theory "Beta hypothesis" states that the best way to break a habit is by conscious, purposeful repetitions, i.e. the subject should sit in front of a large mirror and suck observing as he does so. The timing of sucking should conflict with some pleasurable activity the child enjoys. By practicing the bad habit with the intent to stop it, one learns not to perform that undesirable act. This is especially practiced in older children (8 yrs and over).

Reminder Therapy: Appliance

An appliance may be used to control a habit only in the capacity of a psychologic reminder.

Appliances must be used after trying psychologic non-appliance approach. Appliances act as reminders for control of habit to break the chain of association with tactile gratification.

A number of factors should be considered before giving the appliance to the child. The patient should be at least 7 years old to reason and understand the need for an appliance. The child should understand the problem and have a desire to correct it. Support and encouragement is necessary from the parents to help the child through the treatment period.

Graber explained the working of these appliances. The appliances:

1. Render finger habit meaningless by breaking suction.
2. Prevents finger pressure from displacing maxillary central incisors thus, avoids/labially from creating worse a malocclusion.
3. Forces tongue backwards changing its postural rest position, thus exerting more lateral pressures.

Reminder Therapy: Non-appliance

Best suited for those patients who desire to stop the habit but need assistance to do so.

Includes adhesive tapes, bandages to offending digits, mittens, socks, or distasteful liquid/ointments (Figs 49.6 and 49.7). These serve as reminders for child to remove the finger from the mouth.

Norton and Gellin (1968): Proposed a 3-alarm system often effective in children between 3-7 yrs (Mature children).

1. Offending digit is taped and when the child feels the tape in the mouth it serves as the first alarm.
2. Bandage tied on the elbow of the arm with the offending digit, a safety pin is placed lengthwise. When child flexes the elbow, the closed pin mildly jabs indicating a second alarm.
3. Bandage tightens if the child persists serving as a third alarm.

Chemical Approach to Habit Control

Recommends the use of hot flavored, bitter tasting or foul smelling preparations, placed on the thumb or fingers that are sucked. The chemical therapy uses cayenne (red) pepper dissolved in a volatile liquid medium. Quinine and Asafoetida, which have a bitter taste and an offensive odour respectively, also may be used. This should be done only when the patient has a positive attitude and wants treatment to break the habit.

Corrective therapy Appliances are indicated only when the child wants to discontinue habit and needs only a reminder.

Classification of appliances for thumb-sucking

1. *Removable appliances* These are passive appliances which are retained in the oral cavity by means of clasps and usually have one of the following additional components:
   a. Tongue spikes (Fig. 49.12A)
   b. Tongue guard (Fig. 49.12B)
   c. Spurs/rake (Fig. 49.12C).
2. *Fixed appliances*
   a. Quad helix (Fig. 49.13A)
   b. Hay rakes(Fig. 49.13B)
   c. Maxillary lingual arch with palatal crib (Fig. 49.13C).

One of the best appliances is a lingual archwire with a short spur soldered at strategic locations, i.e. maxillary lingual arch with anterior crib device to remind the thumb to keep out. It should be well adapted, out of the way of normal oral functioning and contain sufficient sharp, short spurs to provide mild afferent signals of discomfort each time the thumb is inserted.

A clear signal of discomfort or mild pain reminds the neuromuscular system, even when the child is asleep, that the thumb best not be inserted.

This appliance consists of molar bands/crowns on 1st permanent molars with a palatal assembly and soldered spurs made of 0.040" nickel-chrome/S.S. wire. This appliance serves as a reminder and not punishment if its understood by the child as a "helping hand", treatment will be successful and psychologic problems will not result. When sucking ceases, appliance should be retained for approximately 3 months to ensure that the habit has truly stopped.

Time of therapy Four to six months. A period of 3 months of total absence of finger sucking is convincing evidence of absence of relapse.

The ideal appliance for correction of posterior cross-bite due to a digit sucking habit is the **Quad Helix** (Fig. 49.13A). It is an adjustable lingual arch that requires little patient cooperation as it is fixed and is reliable and easy to use. Constructed with 38 mil steel wire shaped in the form of a 'W', consisting of 2 anterior and 2 posterior helices. These helices increase the range and springiness of the appliance. The helices



Fig. 49.12A: Tongue spike



Fig. 49.12B: Tongue guard



Fig. 49.12C: Removable tongue crib



Fig. 49.13B: Fixed tongue rake with and without Nance palatal button



Fig. 49.13A: Quad helix appliance



Fig. 49.13C: Maxillary lingual arch with palatal crib

in the anterior palate are bulky, which can effectively serve as reminders to aid in stopping the habit. Quad helix is activated by opening the helices. The activation of anterior helices produces posterior expansion and activation of posterior helices produce causes anterior expansion. Three months of retention are recommended with this appliance.

Figure 49.14 demonstrates the sequence to be followed in treating NNS in patients who are able to understand their condition.

TONGUE THRUSTING HABIT

Tongue thrusting is the most controversial of all oral habits. Considerable attention has been paid at various times to the tongue and tongue habits as possible factors in malocclusion.

Proffit defined **Tongue Thrust Swallowing** *as placement of the tongue tip forward between incisors during swallowing* (Fig 49.15A). This anterior tongue position may be termed as tongue thrust, deviate swallow, visual swallow or infantile swallow. Tongue thrust is actually a 'misnomer' as it means that tongue is forcefully thrusted forward whereas actually, The tongue is only placed forward.

Some of the other definitions are **Norton** and **Gellin** (1978): *Condition in which the tongue protrudes between anterior and posterior teeth during swallowing with or without affecting tooth position.*

Humans show 2 types of swallow patterns:

1. Infantile and neonates swallow
2. Mature/adult swallow.

Infantile swallow (Fig. 49.15B) is characterized by:

- Active contractions of the lip muscles.
- Tongue is placed between the gum pads and tongue tip is brought forward into contact with the lower lip.
- Little posterior tongue activity/ pharyngeal muscle activity.
- Tongue-to-lower lip posture adopted by infants at rest.
- Contraction of lips and facial muscles helps to stabilize the mandible.
- Vigorous mandibular thrust.

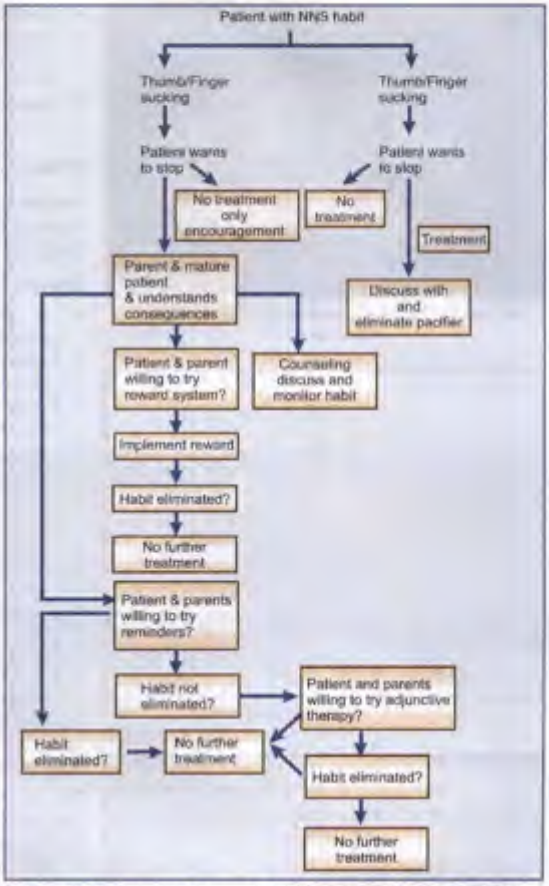


Fig. 49.14: Sequence followed in NNS patients who can understand their condition

Physiologic transition of swallow begins during the 1st year of life and continues for several years. Mature swallow is seen usually by 4-5 years. Maturation of swallow pattern occurs with the addition of semisolid and solid food to the diet. Increasing activation of the elevator muscles of mandible is seen. When sucking activity stops, a continued transition of swallow leads to acquisition of adult pattern of swallow (Fig. 49.15C). This swallow is characterized by:

- Cessation of lip activity, i.e. lips relaxed.
- Placement of tongue tip against the palate and behind upper incisors.



Fig. 49.15A: Abnormal placement of the tongue/tongue thrust swallow

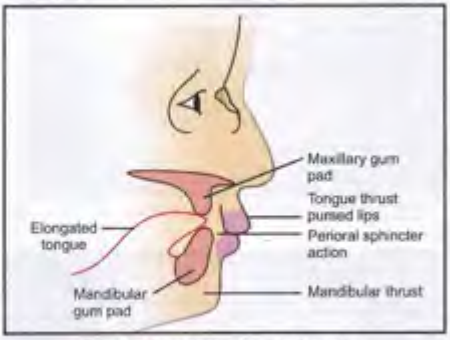


Fig. 49.15B: Infantile (visceral) swallow

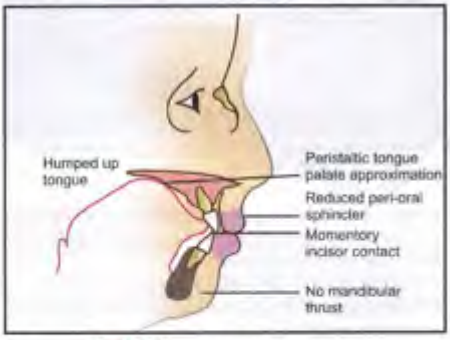


Fig. 49.15C: Mature (somatic) swallow

- Posterior teeth into occlusion during swallow.
- Downward and forward mandibular growth increases intraoral volume and vertical growth of the alveolar process changes tongue posture.
- Mandible stabilized by contraction of muscles of mastication.

ETIOLOGY OF TONGUE THRUSTING

Various factors have been proposed for tongue thrust. Fletcher (1975) reviewed the etiological factors in tongue thrust as follows:

Genetic Factors

- An inherited variation in oro-facial form that precipitates a tongue thrust pattern.
- Inherited anatomic configuration and neuromuscular interplay generating a tongue thrust.
- Genetically predetermined pattern of mouth behavior.

Learned Behavior

Improper bottle feeding which results in abnormal functional pattern.

- Protracted period of soreness/tenderness of gum tissue or teeth thereby keeping teeth apart during swallowing.
- Prolonged thumb sucking.
- Tongue held in open spaces during natural exfoliation/extractions.
- Prolonged tonsillar/upper respiratory tract infection which cause adaptive patterns that are retained even after the infection subsides.

Maturational Factors

Tongue thrust presents as a part of normal childhood oral behavior pattern that is gradually modified as the lingual space and suspensory system change.

- Late maturation from infantile swallow patterns
- Late maturation from immature patterns of general oral behavior.

Mechanical Restriction

Constricted arches which cause tongue to function in a lower than usual position.

- *Macroglossia:* Limits space in the oral cavity and forces a forward thrust (Figs 49.16A and B).
- *Enlarged tonsils and adenoids:* Reduce space available for lingual movement.



Fig. 49.16A: Abnormally large tongue causing a tongue thrust

1. Younger children with reasonably normal occlusion: It is a transitional stage in normal physiologic maturation.
2. Individuals of any age with displaced teeth (incisors): It is an adaptation to the space between teeth (overjet and anterior open bite) since correcting tooth position should cause change in swallowing pattern.

CLASSIFICATION OF TONGUE THRUST

Backlund 1963

Anterior tongue thrust (Fig. 49.17A) Forceful anterior thrust.

Posterior tongue thrust (Fig. 49.17B) Lateral thrusting in case of missing teeth.



Fig. 49.16B: Abnormally large tongue causing a tongue thrust

Neurological Disturbances

Hypersensitive palate which precipitates crude patterns of food manipulation and swallowing.

- Disruption in tactile sensory control and coordination of swallowing.
- Moderate motor disability and loss of precision in oral function.

Psychogenic Factors

- Substitution of tongue thrust for forcibly discontinued thumb sucking.
- Exaggerated motor image of tongue.

Modern View

Tongue thrust is seen in 2 circumstances:

Pickett's 1966

Adaptive tongue thrust-Tongue adapts to an open bite caused by missing teeth/thumb sucking.

Transitory Tongue is put forward only for a short period. Forceful and rapid.

Habitual Due to postural problem, a habit or presence of open bite.

Moyers, 1970

Simple tongue thrust (Fig. 49.18A) Teeth are together.

Complex tongue thrust (Fig. 49.18B) Teeth are apart and buccal occlusion is deranged.

Retained Infantile swallow Persistence of infantile swallow even after permanent teeth appear.



Fig. 49.17A: Anterior tongue thrust in an adult



Fig. 49.17B: Lateral tongue thrust



Fig. 49.18A: Simple tongue thrust



Fig. 49.18B: Complex tongue thrust

James Braner and Holt

Type I Non-deforming tongue thrust.

Type II Deforming anterior tongue thrust
- Sub-group 1 : Anterior open-bite
- Sub-group 2: Anterior proclination
- Sub-group 3: Posterior cross-bite.

Type III Deforming lateral tongue thrust:
- Sub-group 1: Posterior open-bite
- Sub-group 2: Posterior cross-bite
- Sub-group 3: Deep over-bite.

Type IV Deforming anterior and lateral tongue thrust.
Sub-group 1: Anterior and posterior open-bite
Sub-group 2 : Proclination of anterior teeth
Sub-group 3 : Posterior cross-bite.

CLINICAL FEATURES/ EFFECTS OF TONGUE THRUST ON DENTO-FACIAL STRUCTURES (Figs 49.19A and B)

1. Open-bite—anterior and posterior (lateral tongue thrust)
2. Proclination of upper anterior teeth.
3. Protrusion of anterior segments of both arches with spaces between incisors and canines.
4. Narrow and constricted maxillary arch—posterior cross-bite.

DIAGNOSIS

Extra-oral Examination

The facial profile is examined to confirm favorable/ unfavorable growth pattern, steepness of mandibular plane angle, anterior facial height

Examination of Tongue

- Tongue posture
- Tongue function.

Tongue Posture

Tongue posture is examined when the mandible is in a postural rest position either using a cephalogram or with the patient seated upright. During rest, dorsum of tongue touches the palate, while the tip rests against the cingula or fossa of mandibular incisors.



Fig. 49.19A: Features of anterior tongue thrust



Fig. 49.19B: Flattening of the mandibular segment

Differential Diagnosis

Abnormal tongue posture is related to malocclusion and skeletal morphology. In Class III—tongue lies below occlusal plane and in Class II—tongue is positioned forward.

Two significant variations may be seen in tongue posture.

Retracted

Tip is withdrawn behind all the incisors, seen in 10 percent children.

- Associated with posterior open bite because of edentulous/multiple loss of posteriors.
- Loss of positional sense due to removal of periodontal ligament, tongue retracts to establish contact with the alveolus and used to obtain a seal when swallowing.

Protracted

- Resting tongue is between the upper incisors.
- Serious, since it results in an anterior open bite.

Two forms:

1. *Endogenous protracted:* Retention of infantile swallow pattern.
   - Mild open bite.
   - No certain treatment—surgery caused relapse due to failure of tongue to adapt to the new posture.
2. *Acquired adaptive* Transitory adaptation to enlarged tonsils and pharyngitis.

Differences between simple and complex tongue thrust have been tabulated in Table 49.1.

RETAINED INFANTILE SWALLOW

Retained infantile swallow is defined as predominant persistence of the infantile swallowing reflex after the eruption of permanent teeth (Fig. 49.20).

CLINICAL FEATURES

- Strong contractions of lips and facial musculature especially buccinator.
- Massive grimace
- Anterior and lateral thrusting

Table 49.1: Differences between simple and complex tongue thrust

Simple tongue thrust (Fig. 49.18A)	*Complex tongue thrust (Fig. 49.18B)*
1. Displays contractions of lips, mentalis and mandibular elevators.	1. Combined contractions of lip, facial and mentalis muscles. Lack of contraction of mandibular elevators
2. Teeth are in occlusion as tongue protrudes into open bite, i.e. normal teeth together swallow but tongue thrust is present to seal open-bite.	2. Teeth apart during tongue thrust i.e. tongue thrust with teeth apart swallow
3. History of digit sucking adaptive mechanism to maintain open bite created by thumb-sucking	3. History of breathing or chronic nasorespiratory diseases and allergies
4. Well circumscribed open-bite	4. More diffuse open-bite
5. Also found with hypertrophy of tonsils which are not enlarged enough to prompt a tooth apart swallow.	5. Seen in cases where tonsils are so inflamed as to cause teeth apart swallow
6. Precise, secure intercuspation, reinforced by simple thrust swallow	6. Poor occlusal fit and instability of intercuspation, not reinforced by swallow
7. Diminishes with age	7. Does not diminish with age.
8. Treatment is simple; prognosis certain	8. Poor prognosis.



Fig. 49.20: Infantile swallow

- Inexpressive face due to use of facial muscles for swallowing.
- Difficulty in mastication since they normally occlude on only one molar in each quadrant.
- Low gag threshold
- Poor prognosis
- Usually associated with skeletal craniofacial developmental syndromes and neural deficits.

MANAGEMENT OF TONGUE THRUSTING

The management of tongue thrust involves interception of the habit followed by treatment of the malocclusion

Since tongue thrust decreases with age, treatment must be based on age.

1. *3-11 years* Normal occurrence, not to be concerned, reassure parents.
   If child is under 7 yrs, there is no need to be concerned since speech sound that elicits a lisp are not matured until 7-8 years of age.
   Conservative approach Demonstrate correct swallow and observe the child.
2. *11 yrs or older* Tongue thrust is not a normal pattern.

MANAGEMENT OF SIMPLE TONGUE THRUST

Three phases (Moyers):

1. Conscious learning of new reflex—cognitive approach
2. Transferring to subconscious level—reflexive approach
3. Reinforcement of new reflex.

Cognitive Approach

Functional therapy.

Myofunctional Therapy

It is based on the fact that form of the occlusion adapts to function. The sum total of forces exerted by the muscles through well motivated, controlled tongue function, and lip exercises, child can be trained to develop a new swallowing pattern and through this altered tongue and lip function correct a malocclusion or for orthodontically treated patients, prevent relapse. Functional therapy is attempted before appliance treatment.

Advantages of postponing tongue therapy until treatment of malocclusion is begun include:

1. In absence of obvious predisposing factors, correction of malocclusion results in disappearance of habit.
2. Gives maximum opportunity for transition to mature adult swallow.
3. Therapy is most effective when carried out with orthodontic treatment.

Muscle Exercises

1. Barnet's tongue positioning exercises
   a. Identify the incisal papilla as the spot behind front teeth.
   b. Practice touching spot with the tongue tip.
   c. Swallow with lips and teeth closed and tongue tip touching the incisal papilla.
   d. Have patient practice this with lips apart.
2. Andrews recommends practice of swallow correctly 20 times before meals with water in the mouth and mirror in hand. Each practice is followed by relaxation of muscles until the swallowing progress smoothly.
3. *Use of sugarless mint* Held against roof of the mouth stimulates saliva and makes it necessary to swallow.
4. Single elastic swallow of gardiner

   Using orthodontic elastic band of 1/4 " or 5/16" placed on the tip of the tongue plus speech exercises – 'D' 't'.
5. *Double elastic swallow*
   - Place 1 elastic each at tip and middle of tongue contact with tip and mid part of palate.
   - Lips open with buccal teeth together
   - Speech exercises 'C', 'h', 'g'.
6. *Peanuts and elastic band* Patient chews peanuts but not to swallow it. The chewed peanuts are placed in the middle of the tongue.
   - Place elastic at tip of tongue.
   - Instruct the practice of swallow.
   - Speech exercises – 'C', 'g', 'k'.
7. *Lip exercises*
   a. Lip pull exercises – to strengthen lips
   b. Lip over lip exercises – to strengthen lips.

Reflective Approach

When new swallowing pattern has been learned at a conscious level, it is necessary to transfer it to the subconscious level. At the second appointment, the patient should be able to swallow correctly at will.

Neuromuscular facilitation: Subcortical method of affecting swallowing act. Sensory input is correlated with motor activities on a subconscious level.

REINFORCEMENT OF NEW REFLEX

This is achieved by means of mechanical restraints which may be removable or fixed. Cribs or rakes are valuable in breaking the habit (Figs 49.12 and 49.13). Oral screen also may be used (Fig. 49.21).



Fig. 49.21: Vestibular screen. Small airholes may be drilled to aid breathing

TREATMENT OF COMPLEX TONGUE—THRUST

1. Treat the occlusion first.
2. When orthodontic treatment is in its retentive stages, careful occlusal equilibration is completed.

3. The muscle training is begun similar to simple tongue-thrust with minor modifications.

MOUTH BREATHING HABIT

ORAL VEGETATIVE RESPIRATION

Naso-respiratory function and its relation to craniofacial growth is of great interest today, not only as an example of the basic biologic relationship of form and function, but also is of great concern for orthodontists, pedodontist, pediatricians, otorhinolaryngologists, allergists and speech pathologists for varying reasons.

Infants are obligatory nasal breathers. Everyone breathes partially through the mouth under physiological conditions, the most important being the need for increased air, i.e. physical exertion during strenuous activity and exercise.

During normal mechanism of respiration, the efforts to breathe through the nose is greater. The mouth does not normally participate in respiration. The tortuous nasal passages introduce an element of resistance to airflow as they perform their function of warming and humidifying the inspired air. This modest resistance present in the system makes respiration more efficient.

DEFINITIONS

CHOPRA RB (1951) *Defined mouth breathing as habitual respiration through the mouth instead of the nose.*

CHACKER FM (1961) *Defined mouth breathing as a prolonged or continued exposure of the tissues of anterior areas of mouth to the drying effects of inspired air.*

Sassouni (1971) *Defined it as, habitual respiration through the mouth instead of the nose.*

Merle (1980) *Used the term oro-nasal breathing instead of mouth breathing.*

CLASSIFICATION OF MOUTH BREATHING

SIM and FINN

SIM and FINN classified mouth breathing as:

1. Obstructive
2. Habitual
3. Anatomic

1. *Obstructive* Children with an increased resistance to or a complete obstruction of the normal flow of air through the nasal passages.
   Seen in ectomorphous individuals with long narrow faces and nasopharyngeal passages
2. *Habitual* Child who continually breathes through the mouth by force of habit, although the obstruction has been removed.
3. *Anatomical* Short upper lip does not permit closure without undue effort.
   a. *Total blockage:* Nasal passages are completely blocked.
   b. *Partial blockage.*

FUNCTIONS OF NASAL BREATHING

An important function of the nose is to prepare and modify inspired air to a more physiologic state before it enters the lungs.

The nasal passages are so designed that inspired air is cleaned, warmed and humidified prior to its entry into the lungs, since the quality of air required by the lungs may influence the health and function of the lungs.

ETIOLOGY OF MOUTH BREATHING

Mouth breathing usually results when nasal passage is obstructed or is inadequate for respiratory exchange. Causes of mouth breathing are:

Nasal Obstruction

1. *Enlarged turbinates* Infection and increase blood supply produces hypertrophy of the mucosa causing obstruction of the nasal passage unilaterally/bilaterally. This may be due to allergies, chronic infections of mucous membrane, atrophic rhinitis, hot and dry climatic conditions, and polluted air.
2. *Hypertrophy of pharyngeal lymphoid tissue (adenoids)* Repeated infection resulting in the overgrowth of lymphoid masses blocks the posterior nares, rendering mouth breathing necessary. Enlarged tonsils will cause the soft palate to rest on their upper pole instead of the dorsum of the tongue and further displace the dorsum downward and forward contributing to an open mouth posture, possible nocturnal snoring and sleep apnea.

3. Intranasal defects:
   - Deviated nasal septum
   - Subluxation of septum
   - Thickness of septum
   - Bony spurs
   - Polyps
4. *Allergic rhinitis* Continuous infections and toxins of the bacteria may sensitize the tissue to develop allergic reactions.

Facial Type

Seen more in ectomorphs, long-faced, tall, slender persons with long narrow pharyngeal space (Fig. 49.22).

RESPIRATORY PATTERN (PROFFIT)

Respiratory needs are the primary determinant of the posture of the jaws and tongue. Thus, an altered respiratory pattern, e.g. in mouth breathing could alter the posture of the head, jaw and tongue. This, in turn, could alter the equilibrium of pressure on the jaws and teeth thus, affect, jaw growth and tooth position. To breathe through the mouth, it is necessary to extend lower the mandible and tongue and the head. If these postural changes were maintained:

- Face height would increase.
- Posterior teeth would supra-erupt
- Mandible would rotate down and back
- Open-bite develops anteriorly, increased overjet
- Narrower maxillary arch-increased pressure from stretched cheeks
- 'Adenoid Facies' appearance (Fig. 49.23).

EFFECTS OF MOUTH BREATHING

1. *Associated structures and nose* When air is inspired through the mouth, it is not cleaned, warmed and moistened, secretion of mucus is stopped gradually. The irritants accumulate resulting in local inflammation discomfort and pain.
2. *General health and growth* The child is usually restless and is affected by repeated cold, cough, glandular fever etc., loss of general body resistance to other diseases.
3. *Growth and development of the face and jaws*

On Face (Fig. 49.23)

1. Lips slack and stay open
2. Short upper lip
3. Moulding action of upper lip on incisors is lost thereby resulting in proclination and spacing.
4. Lower lip: heavy and everted.
5. Tongue is suspended between upper and lower arches resulting in constriction of buccal segment (V shape arch).



Fig. 49.22: Long face patient



Fig. 49.23: Adenoid Facies' appearance

EFFECT ON OCCLUSION OF TEETH

- Proclination of anteriors
- Distal relation of mandible to maxilla
- Lower anteriors elongate and touch the palatal tissues.
- *Upon gingival tissues* Constant wetting and drying of the gingiva causes irritation, saliva about the exposed gingiva tends to accumulate debris resulting in an increase in bacterial population.

Hypertrophic Mouth Breathing Gingivitis

Gingival hypertrophy is seen as mouth breathing line/gum ridge at the junction of edematous and normal tissues (Fig. 49.24). This line marks the limit of the area exposed to air.



Fig. 49.24: Effect of mouth breathing on gums and occlusion

Non-hypertrophic Mouth Breathing Gingivitis

Non-hypertrophic mouth breathing gingivitis is a marginal gingivitis without edema which develops on the palatal tissues of upper anterior region in mouth breathers even in the presence of good oral hygiene.

DIAGNOSIS OF MOUTH BREATHING

Diagnose the habit by looking for the following symptoms.

Subjective Symptoms

1. *History* A good history should be recorded from patients and parents also, as children may deny the habit.
2. Clues about nasal stiffness, nasal discharge, sore throat, repeated attacks of cold.
3. Posterior nasal defects.

Objective Symptoms

1. Hoarseness of voice
2. Mouth breathing malocclusion (clinical features)
3. Restlessness at night, feeling thirsty.
4. Mouth breathing gingivitis.
5. Association with other habits.

Cephalometrics

Cephalometric examination helps in establishing the amount of nasopharyngeal space, size of adenoids, and also helps in diagnosing the long face associated with mouth breathing.

Rhinomanometry

It is the study of nasal air flow characteristics using devices consisting of flow meters and pressure gauges. These devices help in estimation of air flow through the nasal passage and nasal resistance.

Methods of Examination

1. Study the patient's breathing unobserved: Nasal breather's lips touch lightly during relaxed breathing whereas mouth breathers keep the lips parted.
2. Ask the patient to take a deep breath: Most mouth breathers respond to this request by inspiring through the mouth. The nose, does not change the size or shape of external nares occasionally contracts the nasal orifices while inspiring.

Other Tests

a. *Mirror test* A double sided mirror is held between the nose and mouth. Fogging on the nasal side of the mirror indicates nasal breathing while fogging on oral side – mouth breathing.
b. *Cotton test/Massler's butterfly test* Butterfly shaped cotton strands is placed over the upper lip below nostrils. If the cotton flutters down it is a sign of nasal breathing. This test can be used to determine unilateral nasal blockage.
c. *Water test* The patient is asked to fill the mouth with water and retain it for a period of time. Mouth breathers find this task difficult.

MANAGEMENT

1. *ENT referral* For management of nasopharyngeal obstruction.
2. *Prevention and interception* It usually ceases at puberty or after it due to increase in size of passage during period of rapid growth. Mouth breathing can be intercepted by use of an oral screen.
3. *Myofunctional therapy*
   - During day time – hold pencil between the lips.
   - During night time – tape the lips together with surgical tape in habitual mouth breathing.
   - Hold a sheet of paper between the lips.
   - Piece of card 1 × 1½" held between the lips.
   - Patients with short hypotonic upper lip stretch the upper lip to maintain lip seal or stretch in downward direction towards the chin.
   - ***Button pull exercise*** A button of 1½" diameter is taken and a thread is passed through the button hold. The patient is asked to place the button behind the lip and pull the thread, while restricting it from being pulled out by using lip pressure.
   - ***Tug of war exercise*** This involves 2 buttons, with one placed behind the lips while the other button is held by another person to pull the thread.
   - Blow under the upper lip and hold under tension to a slow count of 4 repeat 25 times a day.
   - Draw upper lip over the upper incisors and hold under tension for a count of 10.

ORAL SCREEN/VESTIBULAR SCREEN/ORAL SHIELD

The oral screen (Fig. 49.21) is a device fitting in the vestibule which shuts off the ingress of air through the mouth and directs contraction of lips against any anterior teeth in labioversion. It is used to retrain the lips

1. Corrects simple labioversion of the maxillary anterior teeth.
2. Habit correcting appliance – as it helps retrain and strengthen lip action.

It should not be used if the child has naso-respiratory distress or nasal obstruction. It is of no use for correction of Class II malocclusion.

Breathing holes can be bored initially. This allows passage of some amount of air into the mouth. As the child learns to breathe through nose, fill some holes with acrylic so that less and less air enters through the mouth and finally close all the holes.

Rapid Maxillary Expansion

Patients with narrow, constricted maxillary arches benefit from RME procedures aimed at widening of the arch. It is found to increase nasal air flow and decrease nasal air resistance. Following RME an increase in intranasal space occurs due to outer walls of nasal cavity moving apart. This increase in nasal cavity width is maximum in the anterior and inferior region and gradually decreases towards superior and posterior aspect respiratively.

BRUXISM

Bruxism was first described in 1907 by Marie and ever since, it has been a subject of intense investigation.

DEFINITIONS

1. **Rubina (1986)** Bruxism is the term used to indicate the non functional contact of the teeth which may include clenching, grinding and tapping of the teeth.
2. **Ramjford (1961)** Bruxism usually refers to a nocturnal, subconscious activity but can occur during the day or night and may be performed consciously or subconsciously. It is a conscious activity when parafunctional activities are included in it.

ETIOLOGY OF BRUXISM

Nadler (1957) gave the following causes of Bruxism.

1. Local factors
2. Systemic factors
3. Psychological factors
4. Occupational factors.

Local Factors

Within the stomatognathic system are prime factors of importance in development of bruxism.

i. Faulty restorations
ii. Calculus and periodontitis

iii. Traumatic occlusal relationship: Occlusal interferences/deflective occlusal contacts elicit bruxism.
iv. Functionally incorrect occlusion
v. Malocclusions—it is unclear whether clenching and bruxism cause malocclusion or are the results of malocclusion. The cause and effect relationship is not clear. Malocclusion interferes with proper occlusion of teeth thus resulting in Bruxism.
vi. Dentigerous cysts
vii. Faulty eruption of deciduous or permanent teeth.

Systemic Factors

Etiologically significant but difficult to evaluate.
i. Nutritional deficiencies
ii. Calcium and vitamin deficiencies
iii. Intestinal parasite infection.
iv. Gastrointestinal disturbances from food allergy.
v. Enzymatic imbalances in digestion causing chronic abdominal distress.
vi. Persistent, recurrent urologic dysfunction.
vii. Endocrine disorders, e.g. hyperthyroidism.
viii. Hyperkinetic children. Nadler believed that histamine released during stress may act as an exciting agent in the irritation of Bruxism.
ix. Pubertal growth spurt peak in boys and start of spurt in girls sees increase in bruxism.
x. Hereditary factors are important to genesis and pattern of Bruxism (Lindquist).
xi. Allergy: Nocturnal Bruxism may be initiated reflexly by increased negative pressures in the tympanic cavities from intermittent allergic edema of the mucosa of the eustachian tubes. Chronic middle ear disturbances may promote reflex action to the jaws by stimulating the trigeminal nuclei in the brain.
xii. CNS disturbances, e.g. Cortical brain lesions, disturbances in medulla and pons, epilepsy, tuberculous meningitis.

Psychological Factors

Most dominant factor. Nervous tension finds a most gratifying release in clenching and bruxism. Research studies show a positive relationship between tooth grinding and repressed aggression, unconscious and conscious anxiety, unconscious expressions of oral gratification.

Childhood bruxism may be related to other oral habits, such as, chronic biting and chewing of toys and pencils, digit sucking, tongue thrusting and mouth breathing.

Occupational Factors

- Athletes, indulge in bruxism because of a great desire to excel.
- Over anxious students/compulsive over achievers.

NEUROPHYSIOLOGY OF BRUXISM

Bruxism occurs during sleep from disruption of normal physiologic rest position of mandible resulting from the forceful rhythmic contractions of masseter, temporalis and lateral pterygoid. In awakened state, bruxism results from abnormal stimuli from the oral structures, e.g. periodontal proprioceptors causing central disturbances; Increased reflex activity in jaw closing muscles. Forces of bruxism are transmitted to structures of masticatory apparatus and depending on the resistance of individual structures, certain amount of forces are absorbed and rest are passed to others.

The direction of forces to stomatognathic system which, in children may lead to maladaptive growth or structural destruction.

SIGNS AND SYMPTOMS

On Teeth (Figs 49.25A and B)

1. *Tooth mobility* Seen due to occlusal trauma of bruxism. Spread of gingivitis to deeper structure and alveolar bone loss.
2. Dull percussion sounds.
3. Soreness to biting stress
4. Non functional pattern of occlusal wear
5. Increased sensitivity from excessive abrasion of enamel.
6. Atypical facets—Shiny, uneven, occlusal wear with sharp edges, abrasion on incisal edges of upper and lower incisors.
7. Other features—Pulp exposure and abscess.
   - Fractures of crown/restorations
   - Root fractures

Tooth wear from bruxism can be found in both primary and permanent dentitions. During grinding some forces are directed laterally, thus loading the tooth horizontally rather than axially. This encourages



Fig. 49.25A: Generalized attrition following bruxism



Fig. 49.25B: Gross attrition

cusp fracture and tooth mobility. The occlusal surfaces may be worn to a level below the interproximal contact area resulting in spacing and food impaction. The sharp edges of the flattened teeth are often irritating to the lips, cheek and tongue.

Musculature and TMJ

The effects of bruxism on the muscles, ligaments and joints of the masticatory system are not as easily identified as on the teeth but they are often painful and have serious long-term consequences.

Noctural bruxism is considered an important etiological factor in several muscular and TMJ conditions like.

- Muscular facial pain.
- Muscle tiredness or tightness and fatigue on rising in morning.
- Tenderness of jaw muscles to palpation.
- Compensatory hypertrophy of muscles
- Muscular incoordination.
- Locking of jaws
- Difficulty in opening mouth for a long time.

Order of muscle sensitivity Lateral pterygoid > medial pterygoid > masseter.

TMJ

Pain, osteoarthritis, crepitus/clicking, restricted jaw movements, jaw deviations. The disc may become worn or perforated and wear patterns are often correlated with condylar remodeling. Extreme wear of posterior teeth is correlated with severe flattening of the condylar articular surface.

Diagnosis of Nocturnal Bruxism

History and clinical examination is usually sufficient to diagnose bruxism. The consistent and most direct method of examination is.

Provocation Test

Ask the patient to move the mandible in lateral and/or protrusive positions until wear facets on mandibular and maxillary arches correspond. Then ask the patient to purposely clench/grind the maxillary teeth until symptoms, similar to patients complaints are noted.

Nocturnal bruxism is more influenced by emotional stress level and sleep patterns rather than tooth contacts. Thus, it responds poorly to patient education, relaxation and biofeedback techniques, and occlusal alterations. It can be effectively reduced with occlusal appliance therapy, e.g. muscle relaxation appliance.

The muscle relaxation appliance is used to treat muscle hyperactivity and conditions associated with it like bruxism. It is fabricated for the maxillary arch and provides an occlusal relationship considered optimal for the patient when it is in place, condyles are in their most musculoskeletally stable position at the time the teeth are contacting evenly and simultaneously.

MANAGEMENT

1. Determine the underlying cause and eliminate it.
2. Psychotherapy includes counselling, hypnosis, conditioning, relaxation exercises, and biofeedback (patient is made aware of tension level in their jaw muscles and are trained to relax these muscles).
3. Drugs like vapocoolants (ethyl chloride) for pain in the TMJ area, local anaesthetic injections into TMJ for muscles, tranquilizers and sedatives, muscle relaxants are used.
4. *Occlusal adjustments* to bring the jaws to normal relaxed state of physiologic movements. Bite planes also help.
   Bite planes/occlusal splints/ bite guards An occlusal guard (Fig. 49.26) is usually made of acrylic resin and is designed to cover the occlusal surface and/or incisal edges of teeth. They are therapeutic because of their "bite raising" effects, i.e. passive stretching of painful muscle fibres.
   In bruxers, it may minimize tooth wear and reduce tooth contacts that act as trigger factors eliciting bruxism. If muscle splinting occurs in combination with bruxism, it may decrease after the pain is relieved with the wearing of an occlusal guard.
5. Restoration of lost vertical dimension—cast crowns/stainless steel crowns (Fig. 49.27).
6. Electrogalvanic stimulation for muscle relaxation.
7. *Ultrasound* Provides analgesic effect for masticatory pain.
8. *TENS* Transcutaneous electrical nerve stimulation: Local analgesic for pain related to temporomandibular joint. Transcutaneous electrical stimulation of skin over major sensory nerves is sometimes undertaken.
9. *Acupressure* For relaxation.
10. *Other methods* Oral exercises.
    - Desensitizing agents
    - Occlusal correction
    - Counseling on nutrition
    - Supplement deficiencies.



Fig. 49.26: A commercially available occlusal guard





Fig. 49.27: Fixed prosthetic replacements to prevent further attrition

LIP HABITS

Lips play an important role in deglutition, speech and maintenance of normal occlusion.

Three lip habits:

1. Lip-sucking (Figs 49.28A and B)
2. Lip-wetting
3. Lip-biting (Fig. 49.28C)



Fig. 49.28A: Lip-sucking habit



Fig. 49.28B: Notice the increased over-jet and upright mandibular incisors



Fig. 49.28C: Lip-biting habit

LIP-SUCKING

In many instances, lip-sucking (Fig. 49.28) is a compensatory activity that results from an excessive overjet and the relative difficulty of closing the lips properly during deglutition. It is easy for the child to cushion the lip to the lingual side of maxillary incisors. To achieve this position, mentalis muscle extends the lower lip upwards.

The patient may exhibit the following features:

i. When the habit has become pernicious, a marked flattening and crowding of lower anterior segment occurs.
ii. Retraction of teeth occurs which depends upon whether the upper or lower lip is sucked.
iii. Maxillary incisors may be forced upward and forward into a protrusive relationship (Fig. 49.28B) in lower lip-sucking.

In severe cases, the lip itself shows the effects of abnormal habit.

- The vermilion border becomes hypertrophic and redundant during rest.
- Reddening below vermilion border is seen.
- Flaccid lip due to lengthening caused by frequent practise.
- Mento-labial sulcus becomes accentuated .
- Chronic herpes with areas of irritation and cracking of lip appears sometimes.

Mentalis Muscle Habit

It is a variation of lip-sucking. Lip-sucking will involve the whole lip, whereas in mentalis habit, the lower lip is everted and only involves the vermilion border. An area of contraction between lips and chin will result in protrusion of maxillary incisors and collapse of mandibular incisors.

MANAGEMENT

- Lip over lip exercises
- Playing bass instruments.
- Lips bumper/shield (Fig. 49.28D)
- Oral screen (Fig. 49.21)

LIP-WETTING

Tongue constantly wets the lips due to dryness/irritation which later becomes a habit.



Fig. 49.28D: The lip bumper appliance used to prevent lip sucking/biting

LIP-BITING

May involve either of the lips (Fig. 49.28C), features seen are cuts and abrasions, marks of incisors on lips along with reddening of lips.

CHEEK-BITING

Biting the cheeks, if unchecked may contribute to ulceration, pain, discomfort or malignancy.

ETIOLOGY

Buccoversion of erupting third molar
- Flabby cheeks
- Lack of proper coverage of lower teeth by upper teeth buccally.
- Atrophy of muscles seen in paralysis.

TREATMENT

- Identify the cause
- Analgesics
- Appliance therapy - oral screen
- Oral screen (Fig. 49.21).

FRENUM-THRUSTING

Rarely seen
- Patient has spaced upper permanent incisors.
- Child holds the labial frenum between teeth for several hours.
- Starts as idle play and develops into a tooth displacing habit by keeping centrals apart.

Treatment

Orthodontic correction for spacing.

Bobby Pin Opening

Habitual opening of pins with incisors (Fig. 49.29A).

Features:
Notched incisors
Teeth derided of labial enamel.
Treatment involves counseling and restoration of the defect with light cure composites (Fig. 49.29B).



Fig. 49.29A: Defect caused by a bobby pin opening habit



Fig. 49.29B: Defect restored with light cure composites

MASOCHISTIC HABIT

It is a prevention in which the sufferer derives pleasure from his own pain. It is the enjoyment of what appears to be painful to others. **Ayer and Levin 1974**: Based on the etiology divided this self destructive habit into:

ORGANIC

Includes various syndromes it is seen in 19-20 percent of mentally retarded population.

FUNCTIONAL

a. Injuries superimposed on preexisting lesion
b. Injuries secondary to another established habit
c. Injuries of unknown and complex etiology with more of a psychological component.

POSTURAL HABIT

CHIN-PROPPING HABIT

It is an extrinsic pressure, unintentional habit which causes a deep anterior closed bite. It may cause retraction of mandible.

FACE LEANING

Lateral pressure from face leaning which is an unintentional, extrinsic pressure habit, may cause lingual movement of maxillary teeth on that side. The mandible is less affected as it does not have a rigid attachment and can slide away from the pressure.

ABNORMAL PILLOWING/HABITUAL SLEEPING ON RIGHT OR LEFT SIDE OF FACE

Normally children do not lie in one position during sleep. The movements are largely involuntary and are produced by nervous reflexes in order to prevent pressure interferences with circulation. Pillowing habits may cause flattening of the skull, facial asymmetry in infants.

FURTHER READING

1. Christensen JR, Fields HW, Adair SM: Oral habits. In Pinkham AJ (editor): Pediatric dentistry: infancy to adolescence, ed 3, Philadelphia, 1999, W.B.Saunders.
2. Graber TM. the finger sucking habit and associated problems. J Dent Children, 1958;25:145-51.
3. Graber TM. The three "M's": muscles, malformation and malocclusion. Am J Orthod, 1963;49:418-50.
4. Graber TM. Thumb and fingersucking. Am J Orthod, 1959;45:258-64.
5. Harvold Egil P. The role of function in the etiology and treatment of malocclusions. Am J Orthod, 1968;54(12):883-93.
6. Hotz RP. Guidance of eruption Vc serial extraction. Am J Ortho 1970;58:1-20.
7. Johnson ED, Larson BE. Thumbsucking classification and treatment Journal of Dentistry for Children (ASDC) 1993;60:392-8.
8. Johnson ED, Larson BE. Thumbsucking: Literative review journal of dentistry for dentistry (ASDC) 1993;60:385-91.
9. Klein Pressure habits, etiological factors in malocclusion. Am J of Ortho 1952;38(8):569-87.
10. Larsson EF, Dalhlin KG. The prevalence of finger and dummy- sucking habits in European and primitive population groups, Am J Orthod 1985;87:432-5.
11. Levin RS. Briefing paper: Oral aspects of dummy and digit sucking. British Dental Journal 1999;186:108.
12. Moore MB. Digits dummies and malocclusions Dental Update 1996;415-22.
13. Moss JP. The soft tissue environment of teeth and jaws. An experimental and clinical study. Part-I. Brit J Orthod, 1980;7:127-37.
14. Moss JP. The soft tissue environment of teeth and jaws Experimental malocclusions. Part-2 and 3. Brit J Orthod, 1980;7:205-16.
15. O'Brien H, et al. Nutritive and non-nutritive sucking habits: A review: Journal of dentistry for children (ASDC) 1996;63(5):321-7.
16. Palermo DS. Thumbsucking: a learned response. Pediatrics 1956;17:392-9.
17. Popovich. Study of habits in 1258 children for evaluation of preventive and interceptive orthodontic treatment between 3-18 years of age, Am J Orthod 1973;63:149-55.
18. Rasmas R, Jacobs R. Mouthbreathing and malocclusion: quantitative techniques for measurements or oral and nasal air flow velocities. Angle orthodontics 1969;39(4):296-300.
19. Rubin R. The effects of nasal airway obstruction J of Pedodontics 1983;8:3-26.
20. Vanders. Relationship b/w malocclusion and bruxism in children and adolescents: A review Pediatric Dentistry 1995;17(1):7-12.
21. Vig PS, Vig KW. Hybrid appliance: A component approach to dentofacial orthopaedics. Am J Ortho & Dentofac Orthop 1990;90:293-85.
22. Wright 92, Kenedy DB. Space control in the primary and mixed dentition. DCNA 1978;22(4):579-602.

50 Etiology and Management of Class I Malocclusion

Gurkeerat Singh

- Introduction
- Associated problems
- Features of Class I malocclusion
- Correction of Class I malocclusion

INTRODUCTION

Class I malocclusion, as defined by Angle, incorporates a normal inter-arch relationship. Class I malocclusion is said to exist when there a harmonious relationship of the underlying skeletal structures and the malocclusion component is restricted to the dental malrelations only.

These malocclusions may typically include individual tooth malalignments and/or malocclusions in the vertical or transverse planes. The most commonly encountered malocclusions in this group are the bimaxillary protrusion/proclination cases (Fig. 50.1) and cases involving crowding in the maxillary and mandibular arches (Fig.50.2).

ASSOCIATED PROBLEMS

The problems associated with Class I malocclusions are primarily dental in nature, i.e. associated with the teeth or the surrounding soft tissue. If protrusion or crowding is present, the aesthetics are compromised (Fig. 50.3). Such malocclusions are often also referred to the orthodontists due to a lack of oral hygiene maintenance. Hence, periodontal complications are very frequently seen.

The primary concern of the patients is generally facial aesthetics.

FEATURES OF CLASS I MALOCCLUSION (TABLE 50.1)

These malocclusions are typically characterized by a harmonious profile. Unless the malocclusion is a skeletal bimaxillary protrusion, the profile is usually straight or slightly convex. The lips may be competent or incompetent depending upon the protrusion of the jaws/teeth.

Table 50.1: Features of Class I malocclusion

Features of Bimaxillary Protrusion:

Skeletal features

- Prognathic jaws
- Increased ANB angle
- Convex profile
- More everted lips
- May have smaller upper and posterior face height with consequent divergent facial planes

Dental features

- Dental bimaxillary proclination
- Increased interincisal angles
- Spacing between teeth may be seen
- Normal molar and canine relationship
- Steep mandibular plane angles may be present

Features of Class I Skeletal Malocclusion:

Skeletal features

- Harmonious face
- Straight to convex profile
- Nothing really abnormal



Dental features

- Molar relation is Angles Class I
- Individual tooth malocclusions may be seen with varying degree of severity
- Malocclusion may be present in the vertical and transverse planes
- Lip competence is dependent on the degree of anterior proclination



Fig. 50.1: Class I bimaxillary proclination treated using all four first premolar extraction

The teeth may show all kinds of individual malpositions. The two most common forms seen are the bimaxillary proclination and crowding. Bimaxillary proclination cases are most frequently seen in the Afro-Caribbeans and the oriental populations. In India the highest incidence is seen in the population of Kerala.

CORRECTION OF CLASS I MALOCCLUSION

Treatment for Class I malocclusions is generally undertaken in the adolescent age group or sometimes even in adults. These kind of malocclusions generally require to be treated using fixed appliances. The choice of appliance and the need for extractions should be assessed based on the individual case.

Class I skeletal cases that are diagnosed as having a severe arch length discrepancy may be treated in the pre-adolescent stages with the serial extraction protocol. For the alignment of mild crowding, space may be created by expansion of the arch (Fig. 50.4), proclining the anterior teeth (Fig. 50.5), proximal stripping (Fig. 50.6) or derotation of adjacent posterior teeth (Fig. 50.7). Bimaxillary proclination (Fig. 50.1) and severe crowding (Fig. 50.2) cases may require the extraction of all-first or second pre-molars depending upon the space and anchorage requirements.

Surgical correction can be undertaken for patient with a true skeletal protrusion. Sub-apical osteotomy with concomitant extractions of the first premolars is the preferred procedure.



Fig. 50.2: Class I crowding case with proclination, treatment with fixed orthodontic appliance and all first premolar extractions



Fig. 50.3A: Class I bimaxillary protrusion case compromising esthetics





Fig. 50.3B: Compromised esthetics due to anterior crowding



Pre-treatment photographs



Post-treatment photographs

Fig. 50.4: Intraoral photographs of a case treated using fixed orthodontic appliances and expansion of the dental arches for gaining space



Fig. 50.5: Case treated with fixed appliances and space gained by proclining the adjacent anterior teeth



Fig. 50.6: Pre- and post-treatment photographs of a case treated with fixed orthodontic appliance and proximal stripping in the canine region to gain space



Fig. 50.7: Treatment done using segmental fixed appliances and derotation of adjacent posterior teeth for gaining space

FURTHER READING

1. Cetlin NM, A Ten Hoeve. Non-extraction treatment. J Clin Orthod 1983;17:396-413.
2. Hammond BA. Treatment of a Class I crowded malocclusion. Am J Orthod Dentofacial Orthop 2002;411-8.
3. Motohashi K, et al. Maxillary protrusion cases treated by the Begg technique, Odontology 1966;52:232-59.
4. Motohashi K, Hioki M, Sato M. Five cases of crowded teeth treated by Begg's technique, J Jap Orhtod Soc 1966;25:89-105.
5. Motohashi K. Five cases of maxillary protrusion treated by Begg's technique, J Jap Orthod Soc 1965;24:72-94.
6. Rocke RA. Management of a severe Class I Division I mal-occlusion, Begg J Orthod Theory and Treat 1963;2:37-47.

51 Etiology and Management of Class II Malocclusion

Gurkeerat Singh

- Introduction
- Classification of Class II malocclusion
- Clinical features of Class II malocclusion Div. 1 and Div. 2
- Etiologic considerations of Class II malocclusion
- Management of Class II malocclusion
  - Management of functional disturbances
  - Management of Class II malocclusion during mixed dentition period
  - Management of Class II malocclusion with maxillary prognathism with normal mandible
  - Management of mandibular deficiency
  - Management of dentoalveolar Class II malocclusion with normal skeletal relationship
  - Management of Class II malocclusion in adults
  - Management of Class II malocclusion by orthognathic surgery
  - Surgical approach for mandibular retrognathism
  - Management of Class II Div. 2 cases

INTRODUCTION

The term Class II is an unfortunate generalization which groups together morphologies of wide ranging varieties often with one common trait—their abnormal molar relationship.

Unfortunately there is as yet no one standard method for identifying and classifying the types of Class II malocclusion. Angle's classification, which is the most frequently used, has inherent flaws, as it does not comment upon the etiology or the underlying skeletal makeup. Class II is the most common and difficult to treat malocclusion as compared to other malocclusions, due to its wide ranging varieties and interplay of various types of etiological factors.

It is important for every orthodontist to have adequate knowledge and correct understanding of the various types of Class II malocclusions before instituting a treatment plan. There is no universal method of managing the condition. It is essential to have an adequate knowledge of normal growth pattern and various cephalometric analysis for proper diagnosis and treatment planning.

CLASSIFICATION OF CLASS II MALOCCLUSION

The Angle's classification of Class II mainly indicates the distal relationship of the mandible to the maxilla, which is purely based on molar relationship of the first permanent molar, i.e. the disto-buccal cusp of upper first permanent molar occludes with the buccal groove of the lower first permanent molar.

Angle has further subdivided the Class II malocclusion into two types:

Class II Division 1—the molar relationship is Class II with the upper anteriors proclined (Figs 51.1A to D).

Class II Division 2—the molar relationship is Class II and the upper central incisors are retroclined and overlapped by the lateral incisors (Figs 51.2A to C).

Class II subdivision—is said to exist when the molar relationship is Class II only on one side, i.e. unilaterally (Figs 51.3A to C).

Further Van der Linden has classified the Class II Division 2 into three types depending on the severity:

Type A—the upper central and lateral incisors are retroclined. It is less severe in nature (Fig. 51.4).



Fig. 51.1A: Angle's Class II Division 1 intraoral photographs



Fig. 51.1B: Intraoral view highlighting the increased overjet and trauma caused due to the deep bite



Fig. 51.1C: Occlusal views, note the 'V' shaped maxillary arch





Fig. 51.1D: Profile and close up of the lower half of the face, highlighting the averted lower lip, convex profile and the retropositioned mandible



Fig. 51.2A: Intraoral photographs of Angle's Class II Division 2 case



Fig. 51.2B: Occlusal views, highlighting the retroclined maxillary central incisors



Fig. 51.2C: Frontal and profile photographs of the same patient



Fig. 51.3A: Intraoral views of Class II subdivision malocclusion. Right side molar is in Calss II molar relation where as the left side molars are in full Class I relation



Fig. 51.3B: Intraoral occlusal views of Class II subdivision malocclusion



Fig. 51.3C: Extraoral photographs of the same patient



Fig. 51.4: The maxillary central and lateral incisors are retroclined



Fig. 51.5: The maxillary central and lateral incisors are retroclined and the canines overlap them

Type B—the central incisors are retroclined and are overlapped by the lateral incisors (Fig. 51.2A).

Type C—the central and lateral incisors are retroclined and are overlapped by the canines (Fig. 51.5).

CLINICAL FEATURES OF CLASS II MALOCCLUSION

	Class II Division 1	*Class II Division 2*
Extraoral features		
1.	In frontal view, face is usually oval (mesocephalic to dolichocephalic).	Squarish face (brachycephalic).
2.	In profile view, exhibits a convex profile.	Usually straight to mildly convex profile because of less skeletal discrepancy and the retroclined incisors.
3.	Posteriorly divergent face.	Usually straight face.
4.	Incompetent and stretched upper lip due to proclined incisors.	Upper lip is invariably short and positioned high with respect to upper anteriors.
5.	Lower lip is invariably everted and placed behind the upper incisors exhibiting a deep mento-labial sulcus.	Lower lip is thick flabby covering the upper incisors and exhibiting a shallow sulcus.
6.	There is lack of lip seal.	Adequate lip seal is present.
Intraoral characteristics	*Class II Division 1*	*Class II Division 2*
1.	Class II molar relationship indicating distal relationship of mandible to maxilla.	Class II molar relationship indicating distal relationship of mandible to maxilla.
2.	Upper incisors are proclined increasing the overjet.	Upper incisors retroclined exhibiting a decreased overjet and an increased overbite.
3.	There is a deep bite which may be traumatic in nature.	Deep bite usually traumatic.
4.	An exaggerated curve of Spee.	An exaggerated curve of Spee.
5.	Upper arch is usually narrow, 'V' shaped.	The upper arch is usually broad, 'U' shaped.
6.	The palatal vault is usually deep but may be average.	The palatal vault is usually deep.
7.	Other characteristics such as anterior open-bites or posterior cross-bites may be present depending upon the persistence of deleterious habits.	Other characteristics are rarely seen but may be present occasionally.

ETIOLOGICAL CONSIDERATIONS OF CLASS II MALOCCLUSION

Though it may be difficult to know the precise etiological factor for any given type of malocclusion, the possible contributing factors related to the presence of Class II malocclusion are:

Prenatal Factors

1. Genetic and congenital : Studies done on parents and children having the same type of malocclusion indicate that the facial dimension are principally determined by heredity through genes. Hence, the dimensions of the basal bones which can contribute to skeletal Class II malocclusion can be inherited.

2. Certain drugs when administered during pregnancy have a potential of producing abnormal development, leading to Class II malocclusions. Such drugs which have teratogenic potential are called teratogens.
3. Irradiation therapy during fetal life can also be a causative factor for the Class II malocclusion.
4. Intrauterine fetal posture like hands placed across the face also seems to influence the craniofacial growth especially that of the mandible.

Natal Factors

Improper forceps application during delivery can lead to condylar damage/fracture thereby causing internal hemorrhage into the joint area. The joint area may later become ankylosed or fibrosed leading to under development of mandible.

Postnatal Factors

Certain conditions that can influence the normal development of the craniofacial skeleton are:

1. Sleeping habits (e.g. stomach way), can affect the normal growth of the jaws. A retarded mandibular growth as compared to the maxillary growth can manifest as Class II malocclusion.
2. Traumatic injuries during play. Any injury to the mandible with potential damage to the condylar region has the potential to retard mandibular growth.
3. Long term irradiation therapy has similar potential and can affect normal growth of the jaws.
4. Certain infectious conditions like rheumatoid arthritis, can also adversely influence the growth of the mandible.
5. Other infectious conditions that predispose and may alter the normal growth pattern include acute tonsillitis, allergic rhinitis, nasal polyp.
6. Pernicious habits such as mouth breathing, digit sucking or lower lip biting are capable of causing a Class II malocclusion (Fig. 51.6).
7. Anomalies of the dentition can contribute towards establishing a Class II malocclusion. These include:
   a. Congenitally missing teeth; most commonly lateral incisors can allow the upper molars to migrate mesially (Fig. 51.7).
   b. Malformed teeth like peg laterals have a reduced mesiodistal dimension can also allow the buccal upper segment to migrate mesially.
   c. Premature extraction in the upper buccal segment can produce a similar effect.
   d. Over retention of lower deciduous teeth, ectopic eruption, supernumerary teeth can also produce a Class II malocclusion.
8. In Class II Division 2 condition mandible is completely imprisoned due to retrocline upper incisors and thereby preventing the further mandibular growth (lid effect).

FUNCTIONAL ASPECT AS A CONTRIBUTING FACTOR FOR CLASS II MALOCCLUSION

Functional matrix theory by Melvyn Moss, proposed that there is a relationship between anatomic form and physiologic function and if there is any derangement in this form-function relationship especially during growth period, it would certainly be a contributing factor for any type of malocclusion.

If there is any derangement in the normal functions like nasal respiration, swallowing pattern, tongue position and position of the lips; it can contribute to the production of the malocclusion.

Certain abnormal habits like thumb sucking, lip biting, cheek biting, hyperactive mentalis can also influence the normal development.

Other factors like wearing of millwakee braces, playing of wind instruments may also aggravate the condition.

MANAGEMENT OF CLASS II MALOCCLUSION

Coming to the management of Class II malocclusion our treatment principles depends on three important factors.

1. The age at which the patient is seen.
2. The nature and severity of the problem.
3. The underlying etiologic factors as seen from the diagnostic aids clinical and functional examination.

So accordingly, we can have three approaches: one, which intend to prevent the malocclusion from occurring, two, intercept the developing malocclusion or three, correct an already developed malocclusion.

1. Management by preventing the possible etiological factors like functional disturbances, abnormal habits, etc. that would have contributed or exaggerated the Class II malocclusion.



Fig. 51.6: Intra-and extra-oral photographs of a thumb sucker



Fig. 51.7: Class II malocclusion due to congenitally missing maxillary lateral incisors

2. Management by modifying the growth either by restricting the maxillary growth or enhancing the mandibular growth.
3. If the patient is seen after the growth period then camouflaging of skeletal jaw discrepancy by orthodontic tooth movement by fixed mechanotherapy is the treatment of choice. It is just a compromised treatment for mild to moderate skeletal discrepancy.
4. If the skeletal discrepancy is severe, then surgical intervention is the only alternative choice and should be undertaken after the cessation of growth.

MANAGEMENT OF FUNCTIONAL DISTURBANCES

Mouth Breathing

Any condition like chronic nasal infections, allergic rhinitis, cold, deviated nasal septum, enlarged tonsils and adenoids, should be looked for and managed. Habit breaking appliances such as an oral shield can be made use of.

Abnormal Tongue Position and Swallowing Patterns

Adequate motivation of the patient, by explaining the deleterious effect is tried and if they fail then habit-breaking appliances (fixed or removable) may be indicated. Any other secondary causes, leading to nasal airway obstruction, should be looked for and eliminated. An abnormally large tongue should be considered for surgical reduction.

Lip Posture and Activity

Following exercises are suggested

a. In Class II Division 1 cases patient should try to take the lower lip over the labial surface and try to exert a backward pressure.
b. Extending the lower lip over the upper lip or the reverse way and holding it as long as possible (lip massage exercises).
c. Holding an ice-cream stick between the lips and holding it as long as possible.
d. Button pull exercises or tug of war exercises.
e. Lip exercises by holding paper between the lips as long as possible and/or trying to pull it out are suggested.

All the above exercises should be done for a minimum of 30 minutes in divided periods of 5 minutes, which would restrain and correct the abnormal muscular activity.

Management of Abnormal Habits like Thumb Sucking and Finger Sucking Habits

a. No intervention is needed until deciduous teeth are erupted because they usually tend to stop by then.
b. Giving dummies which are less deleterious in nature.
c. Adult approach, by giving a mature talk.
d. Reward system and remainder systems are also suggested.
e. The offending digit can be painted with a pungent substance.

If all the above fails, then treatment by fixed or removable habit breaking appliances is the treatment of choice.

MANAGEMENT OF CLASS II MALOCCLUSION DURING MIXED DENTITION PERIOD (TAKING ADVANTAGE OF THE GROWTH)

Before instituting a treatment, three important things should be considered.

a. Age of the patient.
b. Location of the fault (maxilla, mandible or combination)
c. Type of growth pattern (horizontal or vertical).

MANAGEMENT OF CLASS II MALOCCLUSION WITH MAXILLARY PROGNATHISM WITH NORMAL MANDIBLE

Here the primary goal is mainly to restrict the excessively growing maxilla. Management by extraoral force using headgears is the most effective approach. A maxillary splint can be used (Figs 51.8A and B).

MANAGEMENT OF MANDIBULAR DEFICIENCY

Here the primary goal is to enhance mandibular growth rather than restricting the maxillary growth. The various functional appliance used for the purpose are: activator, frankel, herbst and various other bite jumping devices which may be modification of the earlier mentioned. These are thought to work by unloading the mandibular condyle from the glenoid fossa (with the help of the construction bite) to a more forward position inducing an altered muscular



Fig. 51.8A: Maxillary splint appliance with the head gear attached on the cast



Fig. 51.8B: The patient with the maxillary splint appliance

activity. This tends to enhance the growth in the condylar region. The profile changes of patients treated at the right time with the right appliance can be very noticeable (Fig. 51.9).

MANAGEMENT OF DENTOALVEOLAR CLASS II MALOCCLUSION WITH NORMAL SKELETAL RELATIONSHIP

Management is mainly based on the etiological factors.

1. Avoiding premature extraction and if necessary space should be maintained to prevent the mesial drift of molars (especially in the maxillary arch).
2. In premature exfoliated cases or extracted cases where mesial drift has already occurred, space-regaining devices like springs, screws or extra-oral appliances for distalization of the upper buccal segment can be done (Fig. 51.10).
3. In cases where the upper and lower anteriors are proclined with spacing and deep bite, persistence of any abnormal habit like thumb sucking, cheek bites, etc. should be looked for and eliminated before retracting.

MANAGEMENT OF CLASS II MALOCCLUSION IN ADULTS

Since the patient has surpassed the stage when growth could be harnessed to correct skeletal malrelationships, skeletal correction is over ruled. So dentoalveolar compensation for the skeletal defect through reduction of tooth material is the treatment of choice.



Fig. 51.9: Pre-and post-treatment profile photographs treated using a fixed bite jumping appliance. The change in profile is very evident



Fig. 51.10A: Pre-and post-treatment photographs of a patient treated with the extraction of the maxillary right first premolar



Fig. 51.10B: Pre-and post treatment photographs of a patient treated with the extraction of the maxillary first premolars

The dentoalveolar correction is brought about by various multibanded appliance therapies. The technique of choice is left for the operator to decide.

For the reduction of tooth material, a proper treatment planning with the help of cephalometric analysis and model analysis are done prior to extraction. Generally maxillary first premolars can be extracted and the maxillary anterior segment retracted in the space so created (Figs 51.10A and B). The case can be finished with molars in full Class II relationship. A camouflage of the underlying skeletal malocclusion can be achieved in certain cases with the reduction of tooth material in the maxillary arch. The results so achieved may be acceptable but are definitely not ideal (Fig. 51.11).

MANAGEMENT OF CLASS II MALOCCLUSION BY ORTHOGNATHIC SURGERY

Any type of orthognathic surgery should be undertaken only after cessation of growth. This is especially true for boys, who tend to have their postpubertal growth extending up to 18 years.

Presurgical orthodontics should be considered in all cases which require the repositioning of jaw segments



Fig. 51.11: Pre-and post-treatment extraoral photographs of a case in which camouflage treatment was peformed to mask the existing skeletal deformity

and cases with an exaggerated curve of Spee. Without proper interdigitation surgical results are very difficult to maintain.

Surgical procedure should be oriented to the defect.

There are two surgical approaches for the correction of maxillary prognathism:

1. Total maxillary retro-positioning is thought to be a difficult procedure. The various attachments, skeletal and muscular, of the maxillary complex to other craniofacial regions complicates its reattachment. It might also cause a reduction of the pharyngeal space. This procedure is seldom used for the correction of skeletal Class II malocclusion due to prognathic maxilla unless specifically indicated for.
2. Partial maxillary retro-positioning is currently the most commonly used procedure (Figs 51.12A and B). It is relatively simple and involves the extraction of upper first premolars and the retro-positioning of maxilla in the extracted area.

SURGICAL APPROACH FOR MANDIBULAR RETROGNATHISM

Though there are several techniques that have been followed example inverted L—osteotomy (intraoral



Fig. 51.12A: Profile shows prominent maxilla



Fig. 51.12B: Profile shows maxillary subapical set back

approach), C—osteotomy (extraoral approach), subapical surgical procedure etc. The procedure that is most frequently used currently is the intraoral bilateral, sagittal split osteotomy. The main advantage for this procedure is a good post-treatment stability (because of bony interfaces in the split area allows a larger area for bone apposition). The main drawback of this surgical procedure is damage to the long buccal nerve and/or lingual nerve. This may lead to paresthesia for a period of 5-6 months, till regeneration takes place.

MANAGEMENT OF CLASS II DIV. 2 CASES

Mandible is usually guided posteriorly due to premature contact from the retroclined incisors and thereby restricting its growth. The treatment sequence remains the same except that for any form of treatment modality to be instituted the retroclined teeth have to be aligned in a proper labio-lingual direction. Correction of the exaggerated curve of Spee, may also pose some problems.

If the patient comes during the mixed dentition phase functional appliances can be made use of, after proclining the maxillary anteriors. The results are good even after the eruption of all permanent teeth. The maxillary first premolars are generally extracted to creat space for aligning the crowded maxillary anterior segment. Anterior bite-planes, reverse curve of Spee wires and anchor bend in arch wires may be used to correct the anterior deep bite.

The malocclusion is more difficult to treat following cessation of all growth. The need for orthognathic surgery increases with the increase in the severity of symptoms. The surgical procedures are also the same but the use of presurgical orthodontics becomes imperative to achieve stable results. Postsurgical orthodontics might also be required for final finishing and detailing. Over all the treatment results are better after the resolution of Class II Division 2 malocclusion as compared to Class II Division 1 malocclusion.

FURTHER READING

1. Bowman SJ. Class II combination therapy. J Clin Orthod 1998;32:611-20.
2. Cetlin NM, A TenHoeve. Non-extraction treatment. J Clin. Orthod 1983;17:396-413.
3. Craig CE. The skeletal patterns characteristics of Class I and Class II, division 1 malocclusions, in normalateralis. Angle Orthod 1951;21:44-56.
4. Di Biase AT, Sandler PJ. Malocclusion, orthodontics and bullying. Dent Update 2001;28:464-66.
5. Dyer FM, McKeown HF, Sandler PJ. The modified twin block appliance in the treatment of Class III Division 2 malocclusions. J Orthod 2001;28:271-80.
6. Firouz M, et al. Dental and orthopedic effects of high-pull headgear in treatment of Class II Division 1 malocclusion. Am J Orthod Dentofac Orthop 1992;104:277-84.
7. Ghosh J, Nanda RS. Evaluation of an intra-oral maxillary molar distalization technique. Am J Orthod Dentofacial Orthop, 1996;110:639-46.
8. Kalra JPS, Khairwarda OP, Sidhu SS, Gulati S. Maxillary molar distalization using intra-oral methods. J Ind Orthod Soc 1994;25:64-9.
9. Keeling SD, Wheeler TT, King GJ, et al. Anteroposterior skeletal and dental changes after early Class II treatment with bionators and headgear. Am J Orthod Dentofac Orthop 1998;113:40-50.
10. Kim T-W, Little RM. Postretention assessment of deep overbite correction in Class II Division 2 malocclusion. Angle Orthod 1999;69:175-186.
11. King GJ, Keeling SD, Hocevar RA, Wheeler TT. The timing treatment for Class II malocclusions in children: a literature review. Angle Orthod 1990;60:87-97.
12. Lapatki BS, Mager AS, Schute-Moenting, Jones IE. The importance of the level of the lip line and resting lip pressure in Class II Division 2 malocclusion. J Dent Res 2002;81:323-28.
13. Mills CM, McCulloch KJ. Treatment effects of the twin block appliance: a Cephalometric study. Am J Orthod Dentofac Orthop 1998;114:15-24.
14. Moyers RE Riolo ML, Guire KE, et al. Differential diagnosis of Class II malocclusions. Part 1. Facial types associated with Class II malocclusions. Am J Orthod, 1980;78:477-94.
15. O'Brien KH, et al. Effectiveness of early orthodontic treatment with the Twin-block appliance: a multicentre, randomized controlled tria. Part 1: Dental and skeletal effects. Am J Orthod Dentofacial Orthop 2003;124:234-43.
16. Pancherz H. The effects, limitations and long-term dentofacial adaptations to treatment with the Herbst appliance. Sem Orthod 1997;3:232-43.
17. Pfeiffer JP, Gribety D. The Class II malocclusion: differential diagnosis and clinical application of activators, extra-oral traction and fixed appliances. Am J Orthod, 1975;68(5):499-514.
18. Prescott MA. Class II extraction treatment using ACCO appliance and Begg technique. L Pract Orthod. 1969;3:590-3.
19. Rocke RA. Management of severe Class II Division 1 malocclusion. Begg J Orthod. Theory and Treat. 1963;2:37-47.
20. Selwyn-Barnett BJ. Class II division 2 malocclusion: a method of planning and treatment. Br J Orthod 1996;23:29-36.

52 Etiology and Management of Class III Malocclusion

Gurkeerat Singh

- Introduction
- Clinical features
- Etiologic considerations
- Correction of the Class III malocclusion
- Treatment of the pre-adolescent child
- Treatment of the adolescent child
- Treatment during adulthood

INTRODUCTION

A Class III malocclusion is rare as compared to other type of malocclusions, with an incidence of possibly less than 5 percent. It is of special interest to the orthodontist because it offers a therapeutic challenge. It is usually a progressive type of malocclusion, which makes it difficult for the clinician to predict the future growth of such patients both in magnitude and direction. Even after achieving good results and following the cessation of active treatment these patients have a high tendency for relapse (Fig. 52.1). This has been attributed to the reappearance of the adverse growth vectors causing the mandible to grow further forward than it would grow normally.

Class III malocclusion was recognized as early as the 18th century. In the year 1978, John Hunter in his book the natural history of the human teeth stated, "It is not uncommon to find the lower jaw projecting too far forward". The use of restraining device to reduce mandibular prognathism were reported even in the early 1800s.

As the concept of growth and its prediction became more clear, treatment for Class III malocclusion also improved. Still, the treatment of Class III malocclusion is challenging.

Although various treatment modalities are available, which aim at the correction of a Class III malocclusion during the growth period, these have proved unsuccessful in maintaining the results for a long time. Retention appliances are required to be worn until growth is complete. And relying on the patient to cooperate over long and extent treatment protocols is a potential problem in achieving successful, stable treatment results. Surgical intervention may be still needed in a few cases. The newer and more advanced treatment procedures available to us today offer hope for patients so that psychological and morphological setbacks are avoided and lessened during the formative years of life.

CLINICAL FEATURES

A Class III malocclusion on clinical examination may have the following features.



Fig. 52.1: Relapse seen in an adolescent patient following orthodontic treatment when the patient was 12 years old



Fig. 52.2A: Extraoral profile photograph of a typical Class III patient; note the straight profile



Fig. 52.2C: Extraoral frontal photograph of a typical Class III patient; note the long tapering face with the protruded chin



Fig. 52.2B: Anteriorly divergent profile



Fig. 52.2D: Obtuse gonial angle

Extraoral Features

- A straight to concave profile (Fig. 52.2A).
- Anteriorly divergent profile (Fig. 52.2B).
- Long face (increased lower face height), which may be pointed at the chin (Figs 52.2B and C).
- Mandible appears to be well developed (with an obtuse gonial angle) (Fig. 52.2D).

Intraoral Features

- A Class III molar relationship (Fig. 52.3A).
- A Class III canine relationship (Fig. 52.3B).
- A reverse overjet (Fig. 52.3C) with possibly labially inclined lower incisors and lingually inclined upper incisions.
- A posterior cross-bite unilateral or bilateral (or functional) due to a constricted maxillary arch or a



Fig. 52.3A: A Class III molar relationship; the black lines are drawn indicating the mesio-buccal cusp tip of the maxillary first molar and the buccal groove of the mandibular first permanent molar



Fig. 52.3B: A 'super'—Class III canine relationship



Fig. 52.3C: Negative overjet along with a posterior cross-bite

more forward positioned lower arch (Fig. 52.3C).

The soft tissue profile differs depending on the soft tissue thickness and compensations. The lower lip may be full and pendulous.

A Class III skeletal imbalance is usually attributable to one or more of the following component variables:

1. The mandible may be larger in reality as compared to the maxilla.
2. Mandible may be positioned too far forward relative to the maxilla (cases with an acute cranial base angle).
3. The maxilla may be too small relative to the normal mandible.
4. Maxilla may be retro-positioned relative to the mandible.
5. A forward rotation of the mandible relative to the cranium will cause the chin point to move into a more protruded position horizontally.
6. A normal position and size of the mandible and maxilla with lingually inclined upper anteriors.
7. Prematurities in the developing occlusion causing a functional shift in the growing mandible.

ETIOLOGIC CONSIDERATIONS

Heredity is considered to be the main etiologic factor in a Class III skeletal dysplasia.

Functional factors and soft tissue can also have some influence on malocclusion pattern. A flat, low, anteriorly positioned tongue, which lies low in the oral cavity, is to be a local epigenetic factor in Class III malocclusion. The posture of the tongue has to be corrected if possible or a macroglossia corrected by surgery. It has been postulated that enlarged adenoids or any other respiratory problem may lead to the tongue posturing more anteriorly. Whether tongue posture is compensatory to Class III or it's a primary etiologic factor is not clear and it is not clear whether this is inherited as the Class III skeletal structure.

Subjects who have the compulsive habit of protruding the mandible, seem to support the development of a Class III with mandibular prognathism.

A unilateral or bilateral hyperplasia of mandibular condyle can cause the Class III malocclusion. Such cases are extremely rare.

Occlusal forces created by the abnormal eruption may produce unfavorable incisal guidance and promote a Class III relationship. This may present

initially as a pseudo Class III but if unattended can lead to a true skeletal Class III dysplasia.

Premature loss of deciduous molars may also cause mandibular displacement with an occlusal guidance from teeth that are not in proper occlusion or favor a Class III malocclusion. If the mandible looses its posterior proprioceptive and functional support in habitual occlusion it is often positioned anteriorly in an attempt to establish full occlusal contact during chewing.

Lack of eruption of buccal segments due to lateral tongue thrust or postural nativity of tongue permits the mandible to close through an excessive inter-occlusal space autorotating into a Class III relationship because of this abnormal vertical development.

A vertical as well as anteroposterior deficiency of the maxilla can occur in cases of cleft lip and palate with a normal mandible (Fig. 52.4). The same is true in cases of trauma to the mid-face during the growth phase (Fig. 52.5).



Fig. 52.4: Underdeveloped maxilla in a case of cleft lip and palate causing a Class III malocclusion



Fig. 52.5: Class III features in a patient who suffered trauma to the mid-face at the age of 9 years

CORRECTION OF THE CLASS III MALOCCLUSION

Approximately 40-50 percent are due to a prognathic mandible and about one-fourth due to a retrognathic maxilla. Nearly 75 percent have a hereditary component associated with the condition. The treatment is generally initiated as soon as the condition is diagnosed. It is recommended that children of parents who have been diagnosed to suffer from the condition be put on periodic recall, so that the treatment can be initiated as soon as the child shows any sign of the condition.

TREATMENT OF THE PRE-ADOLESCENT CHILD

FRANKEL III APPLIANCE

The Frankel III appliance can be very effective if the case is diagnosed early. The biggest problem is of patient cooperation.

The Frankel III appliance stretches the soft tissue envelop around the maxilla in an attempt to stimulate the forward growth of the maxilla. At the same time it does not allow the mandible to advance forward. The vertical opening of the appliance is used to enhance the downward and forward eruption of the maxillary posterior teeth.

THE CHIN CUP

Chin cup is used to apply forces, which are directed along the direction of growth of the condyle. This inhibits the forward growth of the mandible. It can also be used, with far greater success to change the direction of growth of the mandible. The appliance is capable of rotating the mandible downward and backward, moving the chin down and back. It may also be used with a relatively vertical pull to prevent the mandible from growing downwards (Fig. 52.6A). The lower anterior facial height tends to increase and the patient may end up with a skeletal open bite following treatment. The pressure from the cup tends to tip the mandibular incisors lingually (Fig. 52.6B).



Fig. 52.6A: Vertical pull chin cup with the line of action passing through the condyles is used to prevent worsening of the malocclusion



Fig. 52.6B: Lingually inclined mandibular incisors due to the pressure from the chin cup

ANTERIOR FACEMASK

An anterior facemask can be used to help provide the impetus for the maxilla to grow anteriorly and/or rotate downwards. This causes a reciprocal downward and backward rotation of the mandible. It is a very effective appliance if the patient is cooperative (Figs 52.7A to C).

RME WITH ANTERIOR FACEMASK

A rapid maxillary expansion (RME) by splitting of the mid-palatal suture causes a downward and forward movement of the maxilla. If at this time, when the sutures are split and the teeth are disoccluded, a facemask is used to pull the maxilla further forward, a synergistic action is seen (Fig. 52.8).

3-D SCREWS

3-D screws are capable of expanding the maxilla in all the three directions. Appliances, both removable (Fig. 52.9A) and cemented (Fig. 52.9B) can be used to correct pseudo Class III malocclusions (Fig. 52.9C) and thus prevent their progression to a full-fledged malocclusion (Fig. 52.9D).

TREATMENT OF THE ADOLESCENT CHILD

Treatment in the adolescent phase is limited to orthodontic camouflage or orthodontic decompensation in an effort to prepare the patient for surgery.

Camouflage can be achieved by proclining the maxillary anteriors and tipping the mandibular



Fig. 52.7A: Pre-treatment photographs



Fig. 52.7C: Patient following cessation of facemask therapy



Fig. 52.7B: Patient with facemask



Fig. 52.8: Pre-, during, and post-treatment profile photographs of a patient treated with an RME and anterior facemask appliance



Fig. 52.9A: 3-D screw incorporated in a removable appliance



Fig. 52.9C: Pre-treatment photographs of a male patient with a pseudo Class III malocclusion



Fig. 52.9B: 3-D screw appliance with a posterior bite plane cemented in the patient's mouth. Additional 'C' clasps are provided on the 1st permanent molars for retention in case of cementation failure



Fig. 52.9D: Post-treatment photographs of the patient following treatment with an appliance incorporating the 3-D screw



Fig. 52.10: Pre- and post-treatment photographs of a case involving the proclination of the maxillary anterior and the lingual crown tipping of the mandibular anteriors



Fig. 52.11: Pre-and post-treatment photographs of a patient treated with extractions in the mandibular arch only



Fig. 52.12: Class III yellow elastics in use

incisors lingually (Fig. 52.10). Single arch extractions, extraction only in the mandibular arch, are frequently done to create space for the retraction of the mandibular anterior segment (Fig. 52.11). Class III elastics are frequently used in an effort to tip/retract the mandibular incisors (Fig. 52.12).



Fig. 52.13: Case treated with a bilateral sagittal split osteotomy



Fig. 52.14: Case treated with a Le-Fort I down fracture (Surgery done by Dr Dilip Shukla, New Delhi)

TREATMENT DURING ADULTHOOD

Treatment during adulthood is similar to that during the adolescent age group except that the emphasis is more on orthognathic surgery. Orthodontic camouflage is possible only within a range and over ambitious treatment plans shouldn't be attempted.

The two commonly used procedures are the bilateral sagittal split osteotomy with retraction of the mandible (Fig. 52.13). Segmental retraction may be attempted in certain cases. In cases with maxillary deficiency a Le-Fort I down fracture may be attempted (Fig. 52.14).

FURTHER READING

1. Baccetti T, et al. Skeletal effects of early treatment of Class III malocclusions with maxillary expansion and face-mask therapy. Am J Orthod Dentofac Orthop 1998;113:333-43.
2. Battagel JM. The aetiological factors in Class III malocclusion. Eur J Orthod 1993;15:347-70.
3. Craig CE. The skeletal patterns characteristics of Class I and Class II, division 1 malocclusions, in normalateralis. Angle Orthod 1951;21:44-56.
4. Delaire J. Maxillary development revisited: Relevance of the orthopaedic treatment of Class III malocclusion. Eur J Orthod 1997;19:289-311.
5. Grabber LW. Chin cup therapy for mandibular prognathism. Am J Orthod 1977;72:23-41.
6. Gravely JF. A study of the mandibular closure path in Angle Class III relationship. Br J Orthod 1984;11:85-91.
7. Jacobson A, Evans WG, Preston CB, et al. Mandibular prognathism. Am J Orhtod, 1974;66:140-71.
8. Kondo E. Non surgical and nonextraction treatment of a skeletal Class III patient with severe prognathic mandible,World J Orthod, 2001;2:115-26.
9. McNamara JA Jr. An orthopedic approach to the treatment of Class III malocclusion in young patients, J Clin Ortho 1987;21:598-608.
10. Miethke RR, Lindenau S, Dietrich K. The effect of Fänkel's function regulator type III on the apical base. Eur J Orthod 2002;25:11-318.
11. Motohashi K, et al. Class III malocclusion cases treated by the Begg technique, J Jap Orthod, 1969;27:414-32.
12. Rodesano AJ. Treatment of Class III malocclusion with the Begg light wire technique, am J Orthod, 1974;65:237-45.
13. rodesano AJ. Treatment of Class III malocclusion with the Begg light wire technique, Am J Orthod, 1974;65:237-45.
14. Thlander B. Treatment of angle Class III malocclusion with chin cap, TEOS, 1963;384-97.
15. Ülgen M, Firatli A. The effects of the Fränkel's function regulator on the Class III malocclusion. Am J Orthod Dentofacial Orthop 1994;105:561-67.

53 Correction of Midline Diastema

Rajesh Ahal, Gurkeerat Singh

- Introduction
- Etiology
- Diagnosis
- Treatment planning
- Use of removable appliances
- Fixed orthodontic appliances
- Role of cosmetic restorations/prosthesis
- Retention

INTRODUCTION

The term midline diastema refers to any spacing or gaps existing in the midline of the dental arch. It is generally used in reference to the maxillary arch, even though midline spacing can be present in the mandibular arch.

ETIOLOGY

Before any treatment is undertaken it is essential to find out the etiology of the particular condition.

Midline diastemas are seen in various conditions summarized in Table 53.1.

Table 53.1: Various conditions leading to the presence of a midline diastema

1.	Deciduous dentition
2.	Ugly duckling stage, before the eruption of the permanent canines
3.	Abnormal frenal attachments
4.	Microdontia (peg-lateral incisors)
5.	Presence of a mesiodens
6.	Congenitally missing teeth
7.	Abnormal pressure habits (tongue thrust, digit sucking, etc.)
8.	Trauma, leading to tooth loss in the incisor region
9.	Hereditary
10.	Racial predisposition, negroids

Midline diastema is present in the deciduous dentition (Fig. 53.1). This is a healthy sign and indicates the presence of adequate amount of space for the eruption of the succedaneous teeth.



Fig. 53.1: Midline diastema seen in the deciduous dentition

Transient midline diastemas may appear during the age groups of 9-11 years during the ugly duckling stages (Figs 53.2A and B) or the mixed dentition stage (Fig. 53.3). The eruption of the maxillary canines lead to their automatic closure (Fig. 53.2B). The presence of midline diastemas has a familial and at times racial predisposition. The Negroid population shows the highest incidence of midline diastemas (Fig. 53.4). It may also be seen as a familial trait, its presence noticeable in one or both of the parents as well as in their children.

A midline diastema may also be seen due to the presence of tooth material arch length discrepancy. This may be manifested as true microdontia (rarely seen), relative microdontia (Fig. 53.5), localized



Fig. 53.2A: Midline diastema present in the ugly-duckling stage



Fig. 53.2B: Closure of the midline diastema following the eruption of the canines



Fig. 53.3: Transient midline diastema seen during the mixed dentition



Fig. 53.4: Midline diastema in a negroid male patient

microdontia (Fig. 53.6), most commonly associated with "peg-shaped laterals", congenital absence of the lateral incisors (Figs 53.7A and B), presence of supernumerary teeth in the midline (mesiodens) (Fig. 53.8) or other midline pathologies. A Bolton's tooth material excess in the lower arch as compared to maxillary arch may also lead to midline diastema (Fig. 53.9).

Abnormal frenal attachment; a high attachment of the maxillary labial frenum, which may or may not be thick and fibrous, can prevent the approximation of the two central incisors (Fig. 53.10). A high frenal attachment, where fibers from the labial frenum may be imbedded into the incisive papilla is invariably associated with a gap in the midline.

Abnormal pressure habits have also been implicated in the occurrence of midline diastemas. Thumb/finger sucking and the abnormal anterior tongue thrust habits (Fig. 53.11) have been often associated with midline diastemas. Mouth breathers may also present with a gap between their central incisors. A combination of the above mentioned causes might be present (Fig. 53.12).



Fig. 53.5: Relative microdontia



Fig. 53.6: Peg-shaped lateral incisors leading to a midline diastema



Fig. 53.7A: Midline diastema in a case with congenitally missing lateral incisors



Fig. 53.7B: Midline diastema present due to the congenital absence of the right lateral incisor and peg shaped left maxillary lateral incisor



Fig. 53.8: Midline diastema appearing following the extraction of mesiodens

DIAGNOSIS

It is important to pinpoint the cause. Once the cause has been established treatment can be started, first towards alleviating the causative factor especially if it is due to a neuromuscular imbalance or a pernicious habit. If the midline diastema is due to a high frenal attachment, the Blanch test (Table 53.2) may be used



Fig. 53.9: Midline diastema due to tooth material excess in the mandibular arch and high frenal attachment



Fig. 53.10: Abnormal frenal attachments



Fig. 53.11: Midline diastema present with a tongue thrust habit

to confirm the diagnosis. Notching in the interdental region between the central incisors may also be seen in IOPAs of the region, in such cases.

Often a multitude of causative factors may be involved, e.g. a missing lateral incisor along with tongue thrust habit (Fig. 53.12) or a true tooth material deficiency in the maxillary anterior segment complicated by the presence of a tongue thrust habit. The combinations can change, but the clinician should be aware of and should be able to identify all the etiologic factors.



Fig. 53.12: Congenitally missing maxillary lateral incisors along with an anterior tongue thrust

Table 53.2: The blanch test

Step 1:	The lip is pulled superiorly and anteriorly
Step 2:	Any blanching in the interdental region is indicative of the fibers of the frenum crossing the alveolar ridge
Step 3:	The blanch test can be collaborated with an IOPA of the region which shows a slight radiolucent wedging/notching in the interdental alveolar ridge region

TREATMENT PLANNING

Once the causative factors have been established, treatment planning can be undertaken. Adequate allowances should be made before undertaking appliance therapy for the removal of the etiologic factors involved (Table 53.3).

Both, fixed as well as removable appliances can be used to close midline diastemas. It is essential to assess the amount of control actually required of the adjacent teeth and accordingly the appliance should be selected.

USE OF REMOVABLE APPLIANCES

HAWLEY'S APPLIANCE INCORPORATING FINGER SPRINGS

A simple Hawley appliance incorporating two finger springs distal to the central incisors can close small

Table 53.3: Treatment of etiologic factor

	Etiologic factor	*Timing of treatment*	*Treatment*
1.	Tongue thrust	Start before and continue during orthodontic treatment proper	Tongue rake (fixed or removable)
2.	Thumb sucking	Start before and continue during orthodontic treatment proper	Tongue rake (fixed or removable)
3.	High frenal attachment	During treatment	Frenectomy with or without gingivoplasty
4.	Supernumerary	Before starting	Extract
5.	Peg-shaped lateral	After orthodontic treatment or sometimes before	Composite build up, crowns
6.	Tooth material deficiency	After orthodontic treatment	Veneers (procelain/composite), crowns
7.	Missing lateral incisors	After orthodontic treatment	Implants crowns/bridges



Fig. 53.13: Finger springs for closure of midline diastema

diastemas in 3 to 6 months. The finger springs are usually made of 0.5 or 0.6 mm diameter wire (Fig. 53.13).

Split labial bow appliance—removable appliance incorporating a split labial bow along with retentive components (Adams' clasps and/or 'C' clasp, and/or ball clasps) may be used to close midline diastemas (Fig. 53.14) 0.7 mm SS wire is used to fabricate the split labial bows.

FIXED ORTHODONTIC APPLIANCES

Fixed orthodontic appliances used to treat midline diastemas:

- M' spring (Fig. 53.15): A simple appliance with fixed attachments on the labial or palatal surfaces of the centrals with a 'M' or 'W' shaped springs can easily close midline diastemas.



Fig. 53.14: Split-labial bow used to close the mid-line diastema

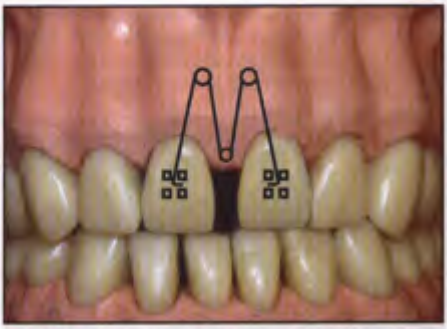


Fig. 53.15: Treatment of midline diastema using 'M' spring



Fig. 53.16: Elastic thread used to close a midline diastema



Fig. 53.17A: Midline diastema present due to an abnormal frenal attachment



Fig. 53.17B: Fixed orthodontic appliance used to close the midline diastema. Frenectomy was performed after closure of the diastema



Fig. 53.17C: Post-treatment photograph

- Elastic thread stretched in a figure of eight fashion is used frequently with fixed appliances (Fig. 53.16).
- Elastic chains (Figs 53.17A to C) are also stretched to exert forces, which are capable of closing midline diastemas.
- Closed coil springs can be used for the same purpose (Fig. 53.18).

Space has to be maintained for any enhancement of the tooth material, e.g. in cases with missing laterals or peg-shaped laterals.

ROLE OF COSMETIC RESTORATIONS/PROSTHESIS

Composite buildups are recommended only in cases where there is a tooth material deficiency (Fig. 53.19).



Fig. 53.18: Treatment of midline diastema using closed coil spring





Fig. 53.19: Composite build-up of the central incisors for the closure of the midline diastema

Crowns can be used to make peg-shaped laterals look more natural and esthetic. Implants may be recommended for the replacement of missing teeth.

RETENTION

Retention is usually long-term and hence, fixed retainers (Figs 53.20A to D) are generally recommended. Composite buildups might be used as a form of retention appliance (Figs 53.21A and B). The build up of the central incisors is joined in the midline to prevent the opening up of the diastema.



Fig. 53.20A: Co-axial wire bonded lingually as a fixed lingual retainer



Fig. 53.20B: Mesh bonded palatally to prevent the midline diastema from reopening



Fig. 53.20C: Fixed bonded retainer



Fig. 53.20D: Fixed bonded co-axial wire retainer



Fig. 53.21A: Pre-treatment mid-line diastema



Fig. 53.21B: Post-treatment composite buildup

FURTHER READING

1. Cetlin NM, A Ten Hoeve. Non-extraction treatment. J Clin Orthod 1983;17:396-413.
2. Edwards JG. The diastema, the frenum, the frenectomy: A clinical study, Am J Ortho 1977;71:489-08.
3. Hammond BA. Treatment of a Class I crowded malocclusion. Am J Orthod Dentofacial Orthop 2002;411-8.
4. Motohashi K, et al. Maxillary protrusion cases treated by the Begg technique, Odontology 1966;52:232-59.
5. Motohashi K, Hioki M, Sato M. Five cases of crowded teeth treated by Begg's technique, J Jap Orhtod Soc 1966;25:89-105.
6. Motohashi K. Five cases of maxillary protrusion treated by Begg's technique, J Jap Orthod Soc 1965;24:72-94.
7. Rocke RA. Management of a severe Class I Division I malocclusion, Begg J Orthod Theory and Treat 1963;2:37-47.

54 Management of Open Bite

Gurkeerat Singh

- Introduction
- Classification of open bite
- Etiology of anterior open bite
- Anterior open bite
- Correction of anterior open bite
- Posterior open bite
- Correction of posterior open bite

INTRODUCTION

An open bite is said to exist when there is a lack of vertical overlap between the maxillary and mandibular teeth. In normal circumstances the mandibular dental arch is contained within the maxillary arch. In other words the maxillary teeth overlap the mandibular teeth labially and buccally. Depending upon the lack of this overlap an open bite is said to exist.

Open bites can exist in the anterior as well as the posterior region. Extent can vary from being simply dental in nature to involving the underlying skeletal structures. The classification and treatment will depend mainly on the location, etiology and the extent of the open bite.

An open bite present in the anterior segment is the most unesthetic, as the patient has to bring his tongue anteriorly between the teeth and the lips during speech and while swallowing. Posterior open bites may hamper mastication and are more difficult to treat.

CLASSIFICATION OF OPEN BITE

i. Based on the location of the open bite, they may be classified as:
   - Anterior open bite
   - Posterior open bite.

ii. Based on the dental or skeletal components involved, open bites can be classified as:
   - Skeletal open bite, or
   - Dental open bite.

ETIOLOGY OF ANTERIOR OPEN BITE

Etiologic factors that are responsible for the appearance of open bites (Table 54.1) include inherited traits such as—abnormal skeletal growth pattern (short mandibular ramus or an increased gonial angle) and abnormally large tongue size. Habits such as digit sucking, mouth breathing and tongue thrusting are more commonly implicated in the etiology of open bites.

With majority of these habits the patient disoccludes his/her jaw, in other words keeps his mouth perpetually open. This over a period of time either causes the posterior teeth to supra-erupt and/or flaring and infra-occlusion of the anterior teeth.

Table 54.1: Etiology of anterior open bite

Habits • Anterior tongue thrust • Digit sucking habits • Mouth breathing
Abnormally increased tongue size
Inherited or acquired, abnormal growth pattern

ANTERIOR OPEN BITE

Anterior open bite is the most commonly encountered severity of open bite. Even though the extent and of its appearance may vary greatly (Figs 54.1A to E). Majority of the anterior open bites encountered in day-



Fig. 54.1A: Anterior open bite seen unilaterally in the mixed dentition period (the most probable cause here being the habit of placing the tongue in the space left after the loss of a deciduous tooth)



Fig. 54.1D: Anterior open bite accompanied by a unilateral posterior cross bite



Fig. 54.1B: Anterior open bite seen in the mixed dentition period accompanied with a mid line shift



Fig. 54.1E: Moderate anterior open bite in a young adolescent patient



Fig. 54.1C: An anterior open bite seen in an adolescent patient, affected teeth are the maxillary and mandibular incisors (their flaring is quite evident)



Fig. 54.1F: Severe anterior open bite seen in a 31-year-old male patient



Fig. 54.1G: Extremely severe anterior open bite caused by an anterior tongue thrust habit (has caused not only flaring of the teeth but also the loss of a mandibular incisor)

to-day clinical practice are dental in nature (Table 54.2). They are usually associated with a local cause, which has to be removed for the correction of the malocclusion (Table 54.3). The persistence of pernicious habit can lead to the malocclusion acquiring a skeletal component or it could be the result of a hereditary skeletal pattern (Table 54.4 and Figs 54.2A to E). Skeletal anterior open bite can occur if there is incoherent growth of the maxilla and/or mandible and/or anterior cranial base (Fig. 54.3).

CORRECTION OF ANTERIOR OPEN BITE

The appliances used for the corrections of anterior open bites are usually used in conjunction with the habit breaking appliances used for the elevation of the underlying etiologic cause.

Unless the treatment of the underlying etiologic factor is delayed and the patient is seen as an adolescent or an adult, anterior open bites have a tendency to regress spontaneously with the removal of the underlying cause (Fig. 54.4). In cases with a minor skeletal component or where the correction is not seen spontaneously, fixed appliances should be used in conjunction with a removable or fixed habit-breaking appliance (Fig. 54.5). Box elastics of medium to heavy forces may be used for the correction of mild to moderate open bites (Fig. 54.6).

Table 54.2: Features of dental anterior open bites

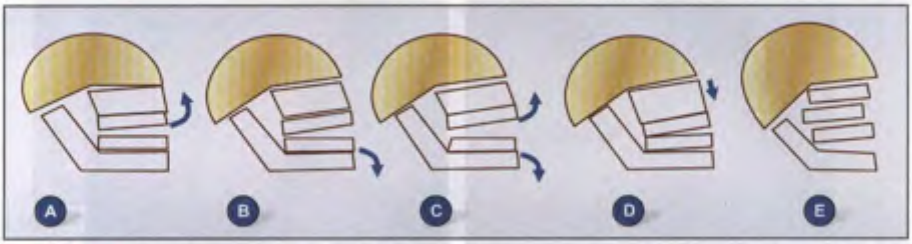
Intraoral features:
1. Open bite limited to the anterior segment, often asymmetrical.
2. Proclined maxillary and/or mandibular incisors
3. Spacing between maxillary and/or mandibular anteriors
4. Narrow maxillary arch is a possibility.
5. "Fish mouth" appearance
Extraoral features:
No unusual features.

Table 54.3: Appliances used to remove the etiology of anterior open bites

Etiology	*Age of the patient*	*Appliance used for correction*
Tongue thrust	Pre-adolescent	Fixed tongue crib/rake
Tongue thrust	Adolescent or adult	Fixed or removable tongue crib/rake
Digit sucking	Pre-adolescent	Motivation and/or medicaments Acrylic digit caps Fixed tongue crib/rake
Digit sucking	Adolescents (rarely seen)	Fixed tongue crib/rake
Mouth breathing	Pre-adolescents	ENT check-up followed by • Breathing exercises • Mouth shield
Mouth breathing	Adolescents and adults	ENT checkup followed by • Breathing exercises • Orthodontic trainers

Table 54.4: Features of skeletal anterior open bites

Extraoral features:
1. Long face due to increased lower anterior face height
2. Incompetent lips
3. An increased mandibular plane angle
4. An increased gonial angle
5. Marked antegonial notch
6. A short mandible is a possibility
7. Maxillary base may be more inferiorly placed (vertical maxillary excess)
8. The angle formed by the mandibular and maxillary planes is also increased
Intraoral features:
1. Mild crowding with upright incisors
2. Gingival hypertrophy
3. Maxillary, occlusal and palatal planes tilt upwards
4. Mandibular occlusal plane canted downwards



Figs 54.2A to E: Skeletal anterior open bite (A) Due to upward maxillary rotation, (B) Due to downward mandibular rotation, (C) Due to combination of downward rotation of mandible and upward rotation of maxilla, (D) Due to vertical maxillary excess, (E) Due to an increased flexure angle



Fig. 54.3A: Cephalogram and profile photographs of a patient with a skeletal anterior open bite



Fig. 54.3B: Intraoral frontal photograph of the same patient with a skeletal anterior open bite



Fig. 54.4A: Spontaneous correction of a mild anterior open bite with the wearing of a removable habit breaking appliance



Fig. 54.4B: Spontaneous correction of a mild anterior open bite with the wearing of a removable habit breaking appliance



Fig. 54.5: Fixed appliances used along with a fixed tongue crib for the correction of anterior open bite



Fig. 54.6: Moderates force box elastics used to close the anterior open bit along with fixed appliances

A chin cup with a vertical pull head cap (Fig. 54.7) may be used for the correction of anterior open bites in the pre-adolescent age group. Skeletal open bites in adults should be treated surgically after the correction of the existing habit. Surgery generally involves the Le-Fort I osteotomy to impact the maxilla posteriorly. Muscle-retraining exercises may be required following the surgical correction.



Fig. 54.7A: Pre-adolescent patient with skeletal anterior open bite



Fig. 54.7B: Patient wearing the chin cup with a vertical pull head cap



Fig. 54.8: Posterior open bite caused by a lateral tongue thrust habit

POSTERIOR OPEN BITE

Posterior open bites are characterized by a lack of contact between the posterior teeth when the teeth are brought in occlusion (Fig. 54.8). Posterior open bites are relatively rare and are caused mainly because of a lateral tongue thrust habit or submerged/ankylosed posterior teeth.

CORRECTION OF POSTERIOR OPEN BITE

The elevation of the etiology remains the main stay of treatment. Since lateral tongue thrust is the most frequently encountered etiologic factor, the use of lateral tongue spikes either fixed or incorporated in a removable appliance, form the first line of treatment (Fig. 54.9).

Vertical elastics used along with fixed orthodontic appliances can be used once the lateral tongue thrust habit has been controlled. It has been noted that, most of the posterior open bites close spontaneously following the cessation of the tongue thrust habit. Fixed appliances are the most frequently used means for the correction of submerged and impacted teeth.



Fig. 54.9: Lateral tongue spicker incorporated in an acrylic appliance

FURTHER READING

1. Johnson NCL, Sandy JR. Tooth position and speech—is there a relationship? Angle Orthod 1999;69:306-10.
2. Kim YH. Anterior open bite and its treatment by means of multiloop edgewise archwire. Angle Orthod 1987;57:290-21.
3. Lopez-Gavito G, Wallen TR, Little RM, Joondeph DR. Anterior open bite malocclusion: A longitudinal 10-years post-retention evaluation of orthodontically treated patients. Am J Orthod 1985;87:175-86.
4. Mizrahi E. A review of anterior open bite. Br J Orthod 1978;5:21-7.
5. Ngan P, Fields H. Open bite: A review of etiology and management, Pediatr Dent 19:91-98,19.
6. Worms F, Meskin L, Issacson R. Open bite, Am J Orthod 1967;59:589-95.

55 Management of Cross Bite

Gurkeerat Singh

- Introduction
- Classification of cross bites
- Correction of anterior cross bites
- Correction of anterior cross bite in the preadolescent age group

INTRODUCTION

Cross bites are a deviation of the normal bucco-lingual relationship of the teeth of one arch with those of the opposing arch. *Graber defined cross bites as a condition where one or more teeth may be malposed abnormally, buccally or lingually or labially with reference to the opposing tooth or teeth.*

Under normal circumstances the maxillary arch overlaps the mandibular arch both labially and buccally. But when the mandibular teeth, single tooth or a segment of teeth, overlap the opposing maxillary teeth labially or buccally, depending upon their location in the arch, a cross bite is said to exist.

CLASSIFICATION OF CROSS BITES

Cross bites can be classified according to their location in the arch as

- Anterior cross bites (Fig. 55.1) and
- Posterior cross bites (Fig. 55.2).

Anterior cross bites is basically a condition where a reverse overjet is seen. Anterior cross bites can be further classified according to the number of teeth involved as

— Single tooth cross bite (Fig. 55.1A), or
— Segmental cross bite (Fig. 55.1B).

Posterior cross bites can also be further classified according to the number of teeth involved as

— Single tooth cross bite (Fig. 55.2A), and
— Segmental cross bite (Fig. 55.2B).



Fig. 55.1A: Single tooth anterior cross bite



Fig. 55.1B: Segmental anterior cross bite

Posterior cross bites may be further classified according to the existence of the cross bite on one side or both the sides of the arch as

- Unilateral cross bite (Fig. 55.2C), and
- Bilateral cross bite (Fig. 55.2D).

Posterior cross bites can also be classified according to the extent of the cross bite as





Fig. 55.2A: Single tooth posterior cross bite (maxillary right first molar)



Fig. 55.2B: Segmental posterior cross bite





Fig. 55.2C: Unilateral cross bite



Fig. 55.2D: Bilateral posterior cross bite



Fig. 55.2E: Simple posterior cross bite



Fig. 55.2F: Scissors bite (maxillary left first pre-molar)

- *Simple posterior cross bite:* This type of cross bite is seen most frequently in clinical practice. Here the buccal cusps of one or more posterior teeth occlude lingual to the buccal cusps of the mandibular teeth (Fig. 55.2E).
- *Buccal non-occlusion:* Here the maxillary teeth palatal cusp of the occlusion and are placed buccal to the buccal cusp of the mandibular posterior teeth. The condition is also known as *scissors bite* (Fig. 55.2F).
- *Lingual non-occlusion:* Here the maxillary posterior tooth or teeth are placed completely palatal to the lingual aspect of the mandibular posterior teeth, i.e. the buccal cusp of the maxillary tooth is palatal/lingual to the lingual cusp of the mandibular posterior teeth (Fig. 55.2G).

Based on the location of the etiologic factors the cross bites can be classified as

- Dental cross bite
- Skeletal cross bite
- Functional cross bite.

Dental cross bites are generally single tooth or sometimes-segmental cross bites. These usually result from (Table 55.1) arch length discrepancy or an abnormal path of eruption. These are usually not accompanied by any threat to general health of the patient, the problems arising due to such cross bites are periodontal or esthetic in nature (Fig. 55.3).

Skeletal cross bite These include those cross bites, which are primarily due to mal-positioning or malformation of the jaws (Fig. 55.4). These can be inherited (e.g. Cross



Fig. 55.2G: Lingual/palatal non-occlusion (maxillary left second premolar)

Table 55.1: Etiology of dental cross bites

1. Anomalies of number:
   i. Supernumerary teeth
   ii. Missing teeth
2. Anomalies of tooth size
3. Anomalies of tooth shape
4. Premature loss of deciduous and / or permanent teeth
5. Prolonged retention of deciduous teeth
6. Delayed eruption of permanent teeth
7. Abnormal eruptive path
8. Ankylosis

bites seen in patients with Class III skeletal pattern), congenital (e.g. cleft lip and palate cases) or arising due to trauma at the time of birth (e.g. unilateral ankylosis of the TMJ) or later in life (Table 55.2). They are capable of causing appreciable damage to a person's health and personality as the appearance may be compromised to a larger extent.

Functional cross bites These cross bites are usually caused due to the presence of occlusal interferences during the act of bringing the jaws into occlusion. These can be caused by the early loss of deciduous teeth, decayed teeth or ectopically erupting teeth. If not corrected early, these can ultimately lead to skeletal cross bites.



Fig. 55.3: Dental cross bite leading to compromised esthetics



Fig. 55.4: Skeletal cross bite causing facial asymmetry

Table 55.2: Etiology of skeletal cross bites

- Hereditary (Class III skeletal structure).
- Congenital (cleft lip and palate).
- Trauma at birth (forcep injury causing ankylosis of the TMJ).
- Trauma during growth (ankylosis of the TMJ of retardation of growth in the traumatized bone).
- Trauma after completion of growth (malunion of fracture segments).
- Habits (if not corrected during growth can cause).

CORRECTION OF ANTERIOR CROSS BITES

Depending upon the age of the patient, the eruption status of the teeth and the space availability various appliances have been designed to correct anterior cross bites. For the selection of an appliance it is essential to give consideration to these factors. At times two appliances might be able to achieve the same function, at such time the cost affordability of the patient should be taken into consideration as well as the ability of the clinician to handle the particular appliance.

CORRECTION OF ANTERIOR CROSS BITE IN THE PREADOLESCENT AGE GROUP

Use of Tongue Blade

If a cross bite is seen at the time the permanent teeth are making an appearance in the oral cavity (Fig. 55.5A), a simple appliance like a tongue blade (Fig. 55.5B) can correct the developing cross bite. A tongue blade resembles a flat ice-cream stick. It should be



Fig. 55.5A: Ideal case for tongue blade therapy



Fig. 55.5B: Tongue blade used to treat developing anterior cross bite

placed inside the mouth, contacting the erupting tooth in cross bite on its palatal aspect. Upon slight closure of the jaw the opposing side of the stick comes in contact with the labial aspect of the opposing mandibular tooth. This point acts as a fulcrum and if light forces are exerted over a couple of weeks the erupting tooth can be easily made to attain a better position. Force can be generated by rotating the oral part of the blade labially or holding the blade stiffly and closing the jaw slightly (till it is tolerable).

The appliance is most effective till the clinical crown is not completely visible in the oral cavity and is to be used only if sufficient space is available for the correction. The only drawback is that the patient has to be cooperative for any correction to be achievable.

CATALANS APPLIANCE OR LOWER ANTERIOR INCLINED PLANE

Catlan's appliance basically consists of an inclined plane cemented on the mandibular incisors. The name Catlan's appliance is generally associated with appliances which are cemented, hence, not removable in nature. The lower inclined plane is constructed at an angle of 45° to the maxillary occlusal plane. It may be constructed for a single tooth or a group of teeth and can be made of acrylic (Figs 55.6A and B) or cast metal.

Prerequisites for the use of a mandibular anterior inclined plane include:

- Enough space in the maxillary arch to align the tooth/teeth.





Fig. 55.6A: Acrylic inclined plane made on the mandibular incisors



Fig. 55.6B: Side view of Catlan's appliance

- The maxillary tooth/teeth to be corrected should be retroclined or erupting posterior to actual tooth position.
- The developmental status of the mandibular incisors should be such that they can tolerate the forces generated.
- The mandibular incisors should be relatively well aligned to allow appliance fabrication.
- The patient should be cooperative.

The disadvantages associated with the appliance are:

1. The patient has difficulty with speech and chewing. The appliance acts as an anterior bite-plane and prevents the posterior teeth from coming into contact.

2. The appliance cannot be given if the mandibular incisors are periodontally compromised.
3. The appliance cannot be fabricated if the mandibular incisors are maligned.
4. Wearing the appliance for a long duration can affect the periodontal status of the teeth on which the appliance is retained and/or the tooth being corrected.
5. Prolonged usage of the appliance can also lead to and anterior open-bite (because of posterior supraeruption).
6. The appliance may need to be recemented frequently.

DOUBLE CANTILEVER SPRING/'Z' SPRING

The double cantilever spring or the 'Z' spring (Fig. 55.7A), as it is more frequently called, is one of the most frequently used appliance to correct anterior tooth/ teeth cross bites. The spring consists of a double helix between two parallel arms and the inferior arm extends as the retentive component in the acrylic base plate. The parallel arms can be activated as per the requirement to either push the entire tooth labially or just the mesial or distal aspect of the tooth to correct a mesio-palatal/lingual or disto-palatal/lingual rotation of the tooth respectively.

The spring is effective only when there is enough space for aligning the teeth. It is advisable to use the spring along with a posterior bite-plane when the teeth in cross bite and show an overbite of more than 2 mm (Figs 55.7B and C) or the opposing teeth are periodontally compromised. The use of a posterior bite plane decreases or at times even eliminates the forces exerted on the teeth in the opposing arch.

Screw Appliances

Acrylic appliances incorporating various size screws can be used to correct either individual tooth or segmental cross bites. *Micro-screws* (Fig. 55.8A) are the most comfortable for the patient and can be used on individual teeth. Multiple micro-screws can be used to correct individual teeth in a segmental cross bite.

Mini-screws (Fig. 55.8B) are also used for the same purpose but are capable of moving up to two teeth.

Medium screws (Fig. 55.8C) are used to correct segmental cross bites. They are larger and are capable of moving 4-6 teeth in a segment.

3-D (three dimensional) screws (Fig. 55.8D) are capable of correcting posterior as well as anterior cross bites simultaneously. Appliances incorporating a 3-D screw, achieve an overall increase in the circumference of the maxillary arch. They are ideal to treat the anterior cross bites associated with pseudo-Class III malocclusions (Fig. 55.8E).

Face Mask or Face Mask Along with RME

In cases of anterior cross bite due to an actual skeletal deficiency of the maxilla, at times it is possible to



Fig. 55.7A: Double cantilever spring or 'Z' spring



Fig. 55.7B: Pre-treatment, during treatment and post-treatment photographs of a patient treated with an appliance incorporating 'Z' springs



Fig. 55.7C: Mesio-palatally rotation of 21, leading to a crossbite treated using an appliance incorporating a 'Z' spring

mesialize the maxilla using a protraction facemask (reverse head gear). If the maxilla is narrow a rapid maxillary expansion screw may be employed simultaneously (Fig. 55.9) to aid in the transverse expansion of the maxilla.

Frankel III Appliance

A Frankel III appliance may be used to correct a developing Class III skeletal jaw structure. The appliance stretches the soft tissue envelop around the



Fig. 55.8A: Micro-screws incorporated in a Hawley's appliance. The screw will push the tooth in the direction of the arrows



Fig. 55.8B: Correction achieved using a mini-screw



Fig. 55.8C: Correction achieved using a medium screw



Fig. 55.12A: Pre- and post-treatment photographs of a case treated with fixed appliances



Fig. 55.12B: Multiple cross bites corrected using a fixed orthodontic appliance



Fig. 55.13: Coffin spring



Fig. 55.14: The quad helix appliance

activate the screw or at least get it activated at regular intervals.

Coffin Spring

This omega shaped wire appliance (Fig. 55.13) is capable of correcting cross bites in the young developing dentition. The appliance is removable and usually well tolerated by the patients of this age group. The expansion produced is slow, and bilaterally symmetrical.

When used in the mixed dentition stage and with better retention than the usually used Adam's clasps, the appliance is capable of producing skeletal changes.

Quad Helix Appliance

The quad helix evolved from the coffin spring and overcomes the short comings of the former appliance. It is a fixed appliance (Fig. 55.14), soldered to molar bands cemented generally on the first permanent maxillary molars. Reactivation using the three pong pliers, without having to is done remove the appliance. The forces generated can be increased or decreased depending upon the amount of activation. It is a versatile appliance and can be used along with the usual fixed appliance therapy.

The appliance can produce slow expansion in adolescent and adult patients and skeletal effects in the preadolescents. Since it can be reactivated, the force levels can be adjusted depending upon the requirement.

The RME Appliance

The rapid maxillary expansion (RME) involves a hyrax screw type of appliance which produces high forces capable of splitting the mid-palatine suture and bringing about skeletal changes within a matter of days (0.2-0.5 mm/day). The RME screw can be incorporated in two type of appliances—one, the banded RME, and the second kind, the cemented RME.

In the banded RME the expansion screw is soldered to bands which are cemented on to the first premolar and the first permanent molar in the maxillary arch (Fig. 55.15A). The cemented RME has a meshwork of wires which are incorporated in acrylic or cast metal splints which are cemented to the posterior segment (Fig. 55.15B).

The appliance produces rapid expansion over 3-4 weeks.

Surgically assisted expansion using the RME can be achieved in adults. Generally used procedure is the buccal corticotomy or Le-Fort I osteotomy and/or mid-palatal splits. The benefits of postsurgical results following RME use are still debatable.

NiTi Expanders

These are nickel titanium wire shapes which can be attached to lingual sheath that are welded to molar bands cemented to the maxillary first permanent molars (Fig. 55.16). Various sizes are available and need to be selected depending upon the amount of expansion desired and the pretreatment width of the



Fig. 55.15A: Treatment results after 3 weeks of banded RME use



Fig. 55.15B: Pre-and post-expansion occlusal view photographs of a patient with a acrylic splint type appliance incorporating a hyrax screw

palate. Bring about slow expansion (dental changes) in the adolescent and adult patients.



Fig. 55.16: A NiTi expander brings about slow expansion



Fig. 55.17A: Fixed appliances used for the correction of posterior cross bites



Fig. 55.17B: Red cross bite elastics worn for the correction of cross bite in the molar region

Fixed Orthodontic Appliances

Fixed orthodontic appliance can be used for correction of posterior cross bites (Fig. 55.17A). The arches can kept slightly expanded or constricted depending upon the movement required.

Cross-elastics can be used to bring about correction of individual tooth cross bites in the posterior segment (Fig. 55.17B). Fixed orthodontic appliances are ideal for the accurate placement of teeth in a dental arch as they provide a three dimensional control over the tooth.

FURTHER READING

1. Adkins MD, Nanda RS, Currier GF. Arch perimeter changes on rapid palatal expansion, Am J Orthod 1990;97:10-19.
2. Clifford F. Crossbite corrections in the deciduous dentition: princiles and procedures. Am J Orthod 1971;59:343.
3. Frank SW, Engel GA. Effects of maxillary Quad-Helix appliance expansion on cephalometric measurements in growing patients, Am J Orthod 1982;81:378-89.
4. Harrison J, Ashby D. Orthodontic treatment for posterior crossbites. Cochrane Review. The Cochrane Library. Issue 24 John Wiley, Chichester, 2004.
5. Hermanson H, Kurol J, Ronnerman A. Treatment of unilateral posterior crossbites with quadhelix and removable plates. A retrospective study. Eur J Orthod 1985;7:97-102.
6. Kutlin G, Harves RR. Posterior crossbites in the deciduous and mixed dentitions, Am J Orthod 1969;55:491-504.
7. Menezes AE. Begg light wire treatment of a severe Class II crossbite malocclusion, Am J Orthod, 1975;68:420-5.
8. Payne RC, Mueller Bh, Thomas HF. Anterior crossbites in the primary dentition. J Pedodontics, 1981;5:281-94.
9. Ranta R. Treatment of unilateral posterior crossbite: comparison of the quad-helix and removable plate, J dent Child 1988;55:102-4.
10. Sandikcioglu M, Hazar S. Skeletal and dental changes after maxillary expansion in the mixed dentition, Am J Orthod Dentofac Orthop 1997;111:321-7.
11. Shivapuja Prasanna Kumar, Lepczyk J, Finn L. Transverse maxillary asymmetry treated with unilateral surgically assisted rapid maxillary palatal expansion- a case report, J Ind Orthod Soc 2006;39:176-88.

56 Orthodontics for Adults

Gurkeerat Singh

- Introduction
- Indications for orthodontic treatment in adults
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  - Periodontal
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  - Esthetics
- Contraindications for orthodontic treatment in adults
  - Medical
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- Difference between adolescent and adults
- Biomechanical considerations when treating adults
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INTRODUCTION

At one time, orthodontic treatment was limited to the adolescent age group. But today, with the development of newer techniques and better understanding of the biologic basis of tooth movement, the age up to which orthodontic treatment is considered possible has increased considerably. Today more and more adult patients are visiting orthodontic clinics.

The reasons why more and more adults are visiting orthodontic clinics are many and varied (Table 56.1). But one thing that stands out is that it is the increased awareness about dental health that motivates the patients to visit dentists and/or orthodontists. Since orthodontic treatment is easily available and acceptable to the patients, the general dentists are also recommending orthodontic intervention more frequently than ever before. The prevalence of periodontal problems and their established association with malaligned teeth has also helped advocate the case for orthodontics.

For all practical purposes, an adult is defined as a person who has ceased to grow. Biologically, this happens at around 18 years of age. For orthodontic purposes, it is better to classify adult patients as:

Table 56.1: Reasons why adults seek orthodontic treatment

1.	Did not want orthodontic treatment as children
2.	Parents or they themselves did not know about orthodontics as children
3.	Orthodontist was not available in the vicinity
4.	Dentist did not advise orthodontic treatment when younger
5.	Parents could not afford orthodontic treatment
6.	Incomplete or relapsed orthodontic treatment as children.
7.	Gum (periodontal) problems because of the malocclusion present
8.	Concerned about appearance
9.	Can afford orthodontic treatment now
10.	Malocclusions like spacing/crowding becoming more prominent with age
11.	Advised by prosthodontist, prior to fixed replacement of teeth
12.	Advised by periodontist, to prevent further deterioration of periodontal condition
13.	TMJ problems arising due to the malocclusion
14.	Overall heightened concern about dental health

Group I : 18 to 25 years of age
Group II : 26 to 35 years of age
Group III : 36 years and older

The first group patients are generally treated as other adolescent patients. They may exhibit heigh-

tened concerns for esthetics, but otherwise they are periodontally healthy. The second group exhibits more periodontal and restorative problems. Whereas, the third group will invariably present prosthodontic complications and may lack a full complement of teeth.

INDICATIONS FOR ORTHODONTIC TREATMENT IN ADULTS

Why undertake orthodontic treatment in adults? Is it only to improve the esthetic demands of the patient or just because we have better techniques today? Indications for orthodontic treatment can be broadly classified into four categories:

1. Prosthodontic
2. Periodontal
3. Temporomandibular joint (TMJ)
4. Esthetic.

PROSTHODONTIC INDICATIONS FOR ORTHODONTIC TREATMENT OF ADULTS

Prosthodontists are advocating fixed prosthesis in more and more patients. Certain criteria need to be fulfilled before teeth can be used as abutments, these relate to parallelism of abutment teeth, redistribution and redirection of occlusal and incisal forces, improvement of crown/root ratio, etc. (Table 56.2).

Orthodontic appliances can *upright teeth that have tilted into extraction spaces*. They are even more frequently used to achieve *parallelism of abutment teeth* (Fig. 56.1). They are also used to *distribute teeth more favorably both inter-and intra-arch*. Teeth that have supra-erupted and prevent the placement of prosthesis in the opposing arch can be intruded (Fig. 56.2). Orthodontic appliances can act as space re-gainers, and can help *achieve regain lost space* into which prosthesis may be placed (Fig. 56.3).

Table 56.2: Prosthodontic indications of orthodontic treatment

- Parallelism of abutment teeth
- Uprighting of tilted teeth
- Regaining lost extraction spaces
- Derotation of abutment teeth
- Intrusion of supra-erupted teeth
- Distribute abutment teeth more favorably

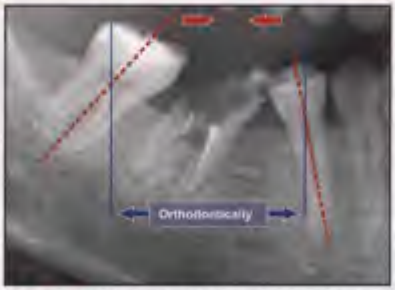


Fig. 56.1: Parallelism of tipped abutment teeth can be achieved



Fig. 56.2: Maxillary right first molar supra-erupted in the mandibular right first molar extraction site



Fig. 56.3: Mesial tilting of the right mandibular 3rd molar into the extraction site of the 2nd molar, leading to the decrease in the extraction space

PERIODONTAL INDICATIONS FOR ORTHODONTIC TREATMENT IN ADULTS

Crowding of teeth: It is a proven fact that crowding of teeth leads to accumulation of plaque, which if not removed can cause subsequent periodontal breakdown. Crowded teeth are difficult to clean (Fig. 56.4) as the bristles of the routinely used toothbrushes cannot reach the embrasures so created. Once these teeth become well aligned, oral hygiene procedures can be carried out more easily and efficiently.

Spacing between teeth is not only unsightly but also provides an ideal location for food lodging. This can lead to the formation of periodontal pockets and associated loss of bone. Spacing in the anterior segment is often associated with periodontal breakdown following pregnancy in middle-aged women (Fig. 56.5). An orthodontist can close these gaps and help to maintain the results.

TEMPOROMANDIBULAR JOINT DYSFUNCTION

The term is a symptom and encompasses a varied number of underlying causes. It can often be the result of over-closure, caused due to an early loss of posterior teeth or/and decrease in the lower facial height. Orthodontist can elevate symptoms and use of splints can be beneficial before any prosthetic rehabilitation.

ESTHETICS

This remains and will remain the most important motivation for a patient to seek orthodontic treatment. An incisor drifting anteriorly (Fig. 56.6), or a cross bite



Fig. 56.4: Crowding associated with poor oral hygiene



Fig. 56.5: Periodontal breakdown following childbirth causing spacing and proclination of the maxillary anterior teeth

(Fig. 56.7) which was acceptable for 30 years suddenly becomes unsightly as the malocclusion starts worsening following a generalized loss of periodontal health.

CONTRAINDICATIONS FOR ORTHODONTIC TREATMENT IN ADULTS

The buzz word is—'don't over do it'. Yes, science has progressed, but the bottom line remains that do not try it if you think it is not possible. The situation may arise because of four main reasons:

a. *Medical:* The patient is medically compromised to an extent that bone formation itself is likely to be compromised. Especially in diseases like diabetes mellitus, the healing capacity of the tissues is much below normal and treatment should be avoided.
b. *Periodontal condition* of the patient is poor, with multiple mobile teeth. Patients who do not maintain good oral hygiene are poor candidates for orthodontic treatment irrespective of the age of the patient.
c. *Skeletal malocclusions*, which require surgical intervention, also might not be undertaken because of the extent of medical and for physical condition of the patient.
d. *Motivation of the patient* is essential. Do not start treatment, if at the time of evaluation itself it is felt that the patient is skeptical of the procedure being advocated. It is advised not to proceed with the treatment unless the patient is found to be determined to see the therapy through to completion.



Fig. 56.6: Pre- and post-treatment photographs of a 34-year-old female patient treated for a protruding central incisor. Following active treatment, a fixed retainer was bonded lingually

DIFFERENCE BETWEEN ADOLESCENTS AND ADULTS (TABLE 56.3)

Both adolescent and adults, if cooperative can be treated equally well orthodontically. The two differences which can play havoc with any orthodontic appliance therapy are growth and the degree of periodontal breakdown. Growth is a factor that can be ignored for all practical purposes in adults. In a way, this makes it easier for the clinician as he is expected to undertake only dental changes, which are usually simpler to achieve as compared to growth modification procedures. Periodontal disease, which is rarely seen in growing children, becomes a major factor when planning orthodontic treatment for adults. The degree of periodontal breakdown and the

Table 56.3: Differences between adolescent and adult patients

Characteristic	*Adolescent patient*	*Adult patient*
Growth potential	Growth modification may be possible	No growth possible. Correction limited to tooth movement
TMJ adaptability	Adaptable	Frequently shows signs of TMJ dysfunction
Periodontal problems	Rarely show symptoms of periodontal disease	Periodontal problems are frequently encountered
General health	Rarely a consideration	Might be of major concern, especially if surgery is planned
Appliance esthetics	Rarely of concern	Of major concern to the patient
Retention planning	Usually short-term and with removable appliances	Long-term and usually fixed
Appliance tolerance	Will usually tolerate and get used to all orthodontic appliances soon	More time is required to get accustomed to the appliance
Speech	Adjusts quickly	Adjustment takes time and effort
Motivation and cooperation	Ranges from poor to excellent	Usually good
Treatment appreciation	Ranges from hardly concerned to very appreciative	Usually very appreciative



Fig. 56.7: An anterior cross bite that the patient started perceiving as unsightly after he turned 30

resultant bone loss around teeth might determine and at times even dictate the course of treatment for adults.

Generally, adult patients are better motivated and will standby their commitments on oral hygiene and appliance maintenance. Adults definitely take longer to get used to the appliance, but they appreciate results better and hence, it is a more satisfying experience treating adult patients.

BIOMECHANICAL CONSIDERATIONS WHEN TREATING ADULTS

Orthodontic appliances should always be chosen depending upon the malocclusion and in the case of adults—the patient's expectations. Expectations can be with regards to the esthetics of the appliance or the results desired. The capability of the orthodontist to treat cases with different appliances also plays a major role here.

The most esthetic appliance is the lingual appliance (Fig. 56.8) but labially placed esthetic brackets (Fig. 56.9) might be more commonly used. This is because very few orthodontists are trained in the lingual technique. Also, a lingual orthodontic treatment will be much more expensive as compared to treatment with any other appliance.

The traditional adolescent treatment objectives are toned down without necessarily compromising treatment results to incorporate minimal dental manipulation appropriate for the individual case. In other words, move only those teeth that are essential to achieve acceptable results. At times, space may be created by proclining teeth (Fig. 56.10) or extracting a single tooth (Figs 56.11A and B) or single arch



Fig. 56.8: The lingual appliance.
(Photograph courtesy: Dr Vinod Verma)



Fig. 56.9: Patient being treated with ceramic brackets. A ceramic-coated wire and transparent elastomerics can also be seen



Fig. 56.10: Space created for alignment by proclining the anterior teeth. Permanent retention is a must for the retention of such cases



Fig. 56.11A: Pretreatment photographs of a case treated with the extraction of only the maxillary right 1st premolar



Fig. 56.11B: Post-treatment photographs of the case treated with the extraction of only the maxillary right 1st premolar

extractions are more commonly done, rather than the routine all first premolar extraction. The scope for segmental treatment is increased in adult patients (Figs 56.12A to C).

With advancing age, certain changes take place in the oral tissues which have a bearing on orthodontic tooth movement. Some such changes are seen in all adult patients treated. These are as follows.



Fig. 56.12A: Pretreatment photographs of a patient treated with segmental lingual appliance



Fig. 56.12B: Photographs of the patient with the segmental lingual appliance in place

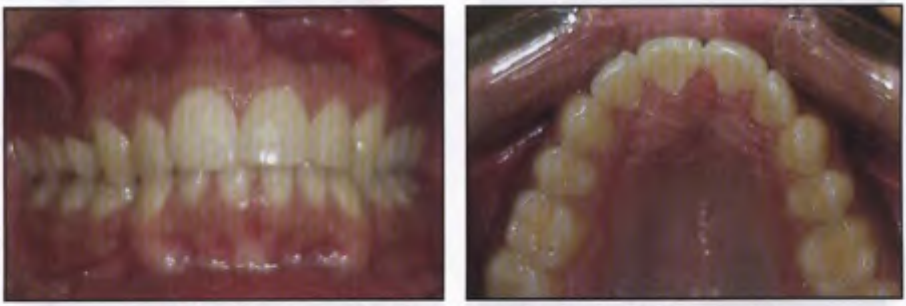


Fig. 56.12C: Posttreatment photographs of the patient after completion of active treatment

CHANGES IN THE TOOTH STRUCTURE

Occlusal Facets

Occlusal facets are more common in adults as compared to adolescent (Fig. 56.13). These might cause resistance to movement, as the teeth tend to interdigitate better and more perfectly.

Dental Caries

Adults are most susceptible to recurrent dental caries, and these might increase the chances of the tooth being root canal treated. Root canal treated teeth might show more root resorption as compared to normal healthy teeth.

Restorative Failures

As the patient's age progresses, so do the chances of him/her having dental restorations.

Restoration with:

1. Improper contours leading to the loss of proper contacts;
2. Proximal overhangs—causing formation of periodontal pockets;
3. Deficient occlusal carving may cause loss of occlusal contacts, decreasing the chewing capability of the patient.
4. Teeth restored with ceramic crowns or laminates may also pose problems while bonding of orthodontic attachments.



Fig. 56.13: Pronounced occlusal facets in an adult patient

CHANGES IN THE 'U'

As the age advances, the periodontism is weakened and its reparative capacity is reduced.

Adults exhibit higher susceptibility to periodontal bone loss as compared to adolescent. Decrease in the alveolar bone height of teeth tends to decrease periodontal support. Forces have to be accordingly decreased to move such compromised teeth. Also, this causes a change in the center of resistance which shifts more apically (Fig. 56.14). Hence, not only the magnitude of the force has to be decreased but bracket placement might have to be altered. The further away the point of application of force from the center of resistance, the more the chances for the tooth to tip. Tipping movement is the easiest to achieve.



Fig. 56.14: Changes in the center of resistance with alveolar bone loss

The adult bone is more dense and less vascular. Also, as age progresses, the overall rates at which cells are produced decreases. And this in turn might lead to decrease in the rate at which adult teeth move and stabilize. The more slowly the bone forms the longer and more critical the retentive phase becomes.

MISSING TEETH

Premature Loss

Premature loss of teeth might cause:

1. If replaced in time—presence of removal or fixed prosthesis in the patient's mouth or
2. If not replaced within a reasonable period of time—(a) supra-eruption of the tooth in the opposing arch; (b) tipping of the tooth distal to the extraction site. This often leads to narrowing of the bone at the site of extraction—moving a tooth into such a site is usually difficult and might lead to loss of attachment and mobility.

TEMPOROMANDIBULAR JOINT (TMJ)

The temporomandibular joint is one thing that is often not considered important while treating adolescent. This is mainly because they exhibit high degree of adaptability and rarely any symptoms of TMJ dysfunction. It is exactly the opposite with adults and the joint should be evaluated not only while diagnosing the case but also monitored during and after treatment.

TYPES OF TREATMENT IN ADULTS

Adults present with multiple problems and these need not be only classified as simple malocclusions. Orthodontic treatment needs to take into consideration the periodontal and/or prosthodontic rehabilitation of the patient, depending upon the intensity of malocclusion and the amount of orthodontic correction required.

Profitt has classified adult orthodontic treatment procedures as:

1. Adjunctive orthodontic treatment
2. Comprehensive orthodontic treatment
3. Surgical orthodontic treatment

ADJUNCTIVE ORTHODONTIC TREATMENT

These are procedures which are done as precursors or in conjunction with other dental procedures. These are generally done to facilitate further prosthodontic or periodontal rehabilitation of the patient. These are the most commonly undertaken procedures in the patients who fall in the Group II and III age groups.

The goals of adjunctive orthodontic treatment include:

1. Parallelism and/or derotation of abutment teeth (Fig. 56.15).
2. Elimination of crowding (Fig. 56.10)
3. Elimination of anterior spacing (Fig. 56.16), which might be causing frequent food lodgment or esthetic problems.
4. Establishing a more favorable distribution of teeth (Fig. 56.17)
   a. Inter-arch
   b. Intra-arch, to facilitate prosthetic rehabilitation.
5. Establishing a more favorable crown-to-root ratios and/or intrusion of specific teeth.

All the above mentioned treatments may or may not require the placement of full jaw orthodontic appliances. Most of these procedures can be accomplished by using segmental treatment (Figs 56.12 and



Fig. 56.15A: Pretreatment photographs malaligned abutment teeth (mandibular lateral incisors)



Fig. 56.15B: Segmental appliance in place to align mandibular lateral incisors



Fig. 56.15C: Posttreatment photographs with the mandibular lateral incisors in ideal position to serve as abutments for a fixed prosthetic appliance



Fig. 56.16A: Unsightly anterior spacing pre and post-treatment photographs

56.15). In other words, the appliance is limited to only a portion of the dental arch and does not alter the occlusion *per se*. The treatment duration is less as compared to a comprehensive treatment plan.

COMPREHENSIVE ORTHODONTIC TREATMENT FOR ADULTS

Comprehensive treatment is similar to treatment undertaken in adolescent and is most frequently



Fig. 56.16B: Midline diastema treated using segmental lingual arch appliance in a 56-year-old female patient. Note the fixed fiber splint in place palatal to the maxillary incisors for retention

undertaken in the Group I patients. It involves full fledged treatment with or without extraction of teeth. The orthodontic appliance is usually the bonded kind and esthetic brackets are frequently used (Figs 56.11 and 56.16).

The treatment objectives of comprehensive orthodontic treatment for adults are the same as for adults, namely:

1. Dentofacial esthetics
2. Stomatognathic function, and
3. Stability

Comprehensive treatment patients are orthodontic patients in the true sense. They approach or are referred to orthodontists for the malocclusion that is inflicting them and not because of any preprosthetic or periodontal treatment that may be required. Even



Fig. 56.17A: Pretreatment photographs of a 65-year-old man with retroclined maxillary incisors



Fig. 56.17B: Patient with appliance in place, flexible NiTi wire



Fig. 56.17C: Patient with appliance in place, stainless steel wire

though, the malocclusion may ultimately lead to such treatment. For example, if anterior crowding is left untreated, it might cause accumulation of plaque; and if proper oral hygiene is not maintained—periodontal breakdown.

According to Profitt, comprehensive orthodontic treatment would last for a duration of more than 6 months. Generally, fixed appliance therapy may last from 1 to 1½ years.



Fig. 56.17D: Post-prosthodontic rehabilitation photographs of the patient
(Prosthetic rehabilitation Courtesy Dr Abhay Lamba)

Comprehensive treatment may or may not be combined with surgical orthognathic treatment.

SURGICAL ORTHODONTIC TREATMENT IN ADULTS

Orthognathic surgery is a distinct identity in itself and has been discussed separately. But it is pertinent to mention here that after the cessation of growth, the only way to correct true skeletal malocclusion has to involve surgery. This branch of dentofacial surgery has come far in the past decade. Our knowledge of anatomy and the advent of newer surgical aids have helped its cause.

A team approach is essential to carry out surgical orthodontic procedures. Here, three procedures are involved in sequence:

1. Presurgical orthodontics
2. Orthognathic surgery proper
3. Postsurgical orthodontics.

Presurgical orthodontics helps in achieving a proper alignment and levelling of arches individually. Orthognathic surgical procedures are used to establish a proper skeletal relationship. This involves the planned skeletal fracturing of individual skeletal bones—maxilla, mandible, etc. and their repositioning with the help of bone plates or wiring as required. Jaw discrepancies in all three planes of space can be corrected. Postsurgical orthodontics then helps to achieve proper inter-digitations and final positions of teeth for balance, stability and esthetics.

RETENTION AND RELAPSE IN ADULTS

Retention mechanics are planned as part of the original treatment plan itself. In adults, fixed retention is made use of most frequently as relapse is more common.

Generally, in the adult age groups bonded retainers are used (Fig. 56.18). Now with the advent of better splinting materials, these are being extensively used to splint the periodontally compromised adult teeth.



Fig. 56.18: A fixed bonded coaxial wire retainer in place





Fig. 56.19: Composite build-up of the maxillary incisors to compensate the tooth material arch length discrepancy

Table 56.4: Considerations to be kept in mind while treating adult patients

Existing oral diseases
1. *Dental caries*
• Recurrent decay can cause restorative failures
• Pulpal involvement can lead to root canal treated teeth that are more prone for root resorption during orthodontic tooth movement
• Large restorations might prevent bonding of attachments
2. *Periodontal disease*
• Higher susceptibility for periodontal bone loss
3. *Faulty restoration*
• Problems associated with improper interproximal contouring can lead to improper contacts
• Proximal overhangs may cause periodontal pockets
• Insufficient occlusal carving might prevent proper interdigitation
4. *TMJ adaptability*
• Adults frequently show symptoms of TMJ dysfunction
5. *Occlusal awareness is heightened with enamel wear and adverse changes in the supporting tissues*
Skeletal and neuromuscular considerations
6. *Growth factor*
• No growth possible with minimal skeletal adaptability. Surgical procedures like surgically assisted RME may be required
• Dental camouflage for mild to moderate skeletal disharmonies
7. *Dentofacial esthetics*
• Concern is occasionally disproportionate to the degree of existing problem
8. *Neuromuscular maturity*
• There is a general lack of neuromuscular adaptability, which may lead to a tendency towards iatrogenic transitional occlusal trauma

This not only acts as a splint and causes more uniform distribution of forces but also maintains the achieved orthodontic relationship.

Sometimes prosthetic rehabilitation will help and function as a retention appliance. Tooth material discrepancies can be overcome by reducing the size of the teeth by proximal stripping or building teeth mesiodistally using composite materials (Fig. 56.19).

Overall adult orthodontic treatment is a reality and more and more patients are going to require it. It is for the clinician to learn the latest and provide the adult patients with the desired results (Table 56.4).

FURTHER READING

1. Graber TM. Cranio-facial morphology in cleft palate and cleft lip deformities. Surg Gynec Obstet 1949;88:359-69.
2. Gustke CJ. Treatment of periodontitis in the diabetic patient. A critical review. J Clin Periodontal 1999;26:133-37.
3. Huddaart AG, North JF, Davis MEH. Observations on the treatment of cleft lip and palte, Dent Prac, 1966;16:265-74.
4. Nattrass C, Sandy JR. Adult orthodontics—a review. Br J Orthod 1995;22:331-37.
5. Pruzansky S, Aduss H. Prevalence of arch collapse and malocclusion in complete unilateral cleft lip and palate. Trans Europ Ortho Soc, 1967;1-18.
6. Rosenstein SW. New concept in early orthopedic treatment of cleft lip and palate. Am J Orthod, 1969;55:765-74.
7. Shaw WC, Semb G. Current approaches to the orthodontic management of cleft lip and palate, J R Soc Med, 1990;83:30-3.
8. Tessier P. Anatomical classification of facial, craniofacial and latero-facial clefts, J Maxillofac Surg 1976;4:69-92.

57 Management of Cleft Lip and Palate

Gurkeerat Singh

- Introduction
- Historical review
- Incidence
- Factors influencing incidence
- Etiology
- Embryological background
- Possible mechanisms for formation of isolated cleft palate
- Classifications
- Problems associated with cleft lip and palate
- Management of cleft lip and palate

INTRODUCTION

Cleft palate can be defined as *'a furrow in the palatal vault'*. It may be defined as *'breach in continuity of palate'*. Cleft lip or hare lip (Fig. 57.1), as it is commonly called, along with the cleft palate are the most commonly seen congenital deformities at the time of birth. Clefts of lip and palate can occur individually or together in various combinations and/or along with other congenital deformities. The management of cleft palate is not limited to any one of the specialties but involves a number of specialists of medical science in order to get a composite, esthetic and functional result. This chapter is aimed at providing the dental student an overview of the topic with emphasis on the role of the dental surgeon and the orthodontist.

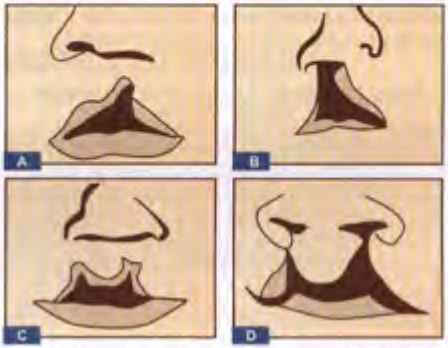


Fig. 57.1: Various presentations of cleft lip and palate (A) Partial unilateral involving lip (B) Complete unilateral involving lip (C) Partial bilateral involving lip (D) Complete bilateral involving lip

HISTORICAL REVIEW

Records suggest that hare lip was reported as far back as 1000 AD. *Paren*, a French surgeon in 1561 was the first who try to put an obturator to fill the cavity produced by a cleft in order to facilitate eating and speech. *Le Monnier* a French dentist in 1764 tried to repair cleft palate surgically. Many attempts were made to close the cleft palate surgically, but failed due to the tension developed at the median suture. In 1826, *Diffenbach* suggested the separation of soft tissues of the palate from the underlying bone. He also recommended the use of lateral relaxation incisions in the soft tissues of the hard palate to close clefts of velum and hard palate.

Fergusson in 1844 and *Von Langenback* in 1862 emphasized the need to elevate periosteum with the palatal mucosa, thus creating a mucoperiosteal flap.

Surgeons were thus provided with a technique by which hard palate clefts could be closed more successfully than ever before. During the first World War, *Harold Gillies* and *Pomfret Kilner* in London, *Victor Veau* in Paris and so many other surgeons developed their skill to repair the cleft.

INCIDENCE

Incidence of cleft lip and palate has increased from 1 per thousand live births in first third of the century to 1.5 to 2 per thousand. The incidence varies widely and is the least in the Negroids (Table 57.1). The Mongoloids show the highest incidence. The incidence varies widely in the Indian subcontinent.

Unilateral clefts account for nearly 80 percent of all clefts seen, while bilateral clefts account for the remaining 20 percent. Among the unilateral clefts, clefts involving the left side are more common (70% of the cases). Male patients show a higher incidence of cleft lip or palate. Female patients show a higher incidence of cleft palate as compared to cleft lip.

Table 57.1: Incidence of cleft lip and or cleft palate per thousand live births

Caucasians	1
Japanese	1.7
Negroids	0.4
American Indians	3.6
Afghans	4.9
Czechoslovakia (Erstwhile)	1.85
Denmark	1.1
Indians	1.7

FACTOR INFLUENCING INCIDENCE

SEX

Cleft lip and/or palate is more common in males than in females. Around 70 percent of cleft lip and palate is found in males while cleft palate is more common in females.

RACE

Japanese population shows a higher incidence than Caucasians and Negroes.

BIRTH WEIGHT

No significant correlation was found between birth weight and incidence of cleft. However, some investigators have found that babies with isolated cleft palate had lower birth weight than those with isolated cleft lip.

PARENTAL AGE

An increased incidence has been reported with increasing parental age by some investigators. It is possible that frequency does increase somewhat with advancing parental age, particularly the mother's.

SOCIAL STATUS

No variations in frequency of cleft lip or palate have been reported with social class. This suggests that factors such as malnutrition or infectious diseases may not be important in causing cleft lip or palate.

BIRTH RANK

No significant correlations have been found associating birth rank to clefts. Some investigators claim that incidence is more in the first born child. Also if one or both the parents are suffering from some form of cleft the probability rises considerably.

ETIOLOGY

HEREDITARY

According to Fogh and Anderson, less than 40 percent of cases of cleft lip with or without cleft palate are genetic in origin. And less than 20 percent of isolated cleft palates are genetically determined.

According to Bhatia, the two possible modes of transmission are—by a single mutant gene producing a large effect, or by a number of genes (polygenic inheritance) each producing a small effect together creating this condition. More recently, researchers have expanded upon this concept and reiterated that there are two forms of cleft. The most common is hereditary, its nature being most probably polygenic (determined by several different genes acting together). In other words, when the total genetic liability of an individual reaches a certain minimum level, the threshold for expression is reached and cleft occurs. Actually it is presumed that every individual

carries some genetic liability for clefting, but if this is less than the threshold level, there is no cleft. When the individual liabilities of the two parents are added together in their offspring, a cleft occurs if the threshold value is exceeded.

The second form of cleft is monogenic or syndromic and is associated with a variety of other congenital anomalies. Since these are monogenic, they are the high-risk type.

Multifactorial Threshold Hypothesis

Multifactorial inheritance theory implies that many contributory risk genes interact with one another and the environment and collectively determine whether the threshold of abnormalities is breached, resulting in a defect in the developing fetus. This theory explains the transmission of isolated cleft lip or palate, and it is extremely useful in predicting occurrence risks of this anomaly among family members of an affected individual.

CONGENITAL

The word congenital and hereditary differs in meaning. Congenital refers to an anomaly which must be present at birth. It can either be hereditary, genetically determined or induced (environmental teratogens). Hereditary anomalies may or may not be present at birth and may appear in due course of time. Congenital anomalies may be brought about by the following agents/teratogens:

Infections

Infections like Rubella, Influenza, Toxoplasmosis, etc. to the mother during pregnancy may cause formation of the cleft in the fetus.

Drugs

Cases have been reported in which acute hypoxia produced by *carbon monoxide* or *morphine* overdose was followed by a birth of a malformed child. *Aminopterin*, an antifolic drug is occasionally used as an abortifacient. Surviving fetuses of such abortion attempts were grossly malformed. All cytotoxic anticancer drugs such as *alkylating agents* have been blamed for producing clefts. *Cortisone* is a suspected teratogen.

An *alcoholic* mother may give birth to a child with foetal alcoholic syndrome which may be associated with cleft palate. *Thalidomide* may have a similar effect.

Radiation

Today, radiations such as X-rays, gamma rays etc. are used widely in medicine for diagnosis and treatment. These are ionizing radiation and are capable of producing either somatic or genetic effects. Somatic effects are those which become manifested in the exposed individual. Genetic effects are those which are expressed in individual's descendents. The genetic effects include anomalies such as cleft palate, cleft lip, microcephaly and neonatal death. These radiation anomalies are due to the irradiation of the embryo/fetus during pregnancy.

Diets

Dietary deficiency of riboflavin, folic acid and hypervitaminosis A, may act as environmental teratogens.

EMBRYOLOGICAL BACKGROUND

The fusion of various embryonic processes around the stomodeum (the primitive oral cavity), leads to the formation of the nasomaxillary complex.

The mesoderm covering the forebrain proliferates and descends towards the stomodeum. This process is called the fronto-nasal process. As the nasal pits develop, the fronto-nasal process gets divided into the medial nasal process and two lateral nasal processes.

The first branchial arch, called the mandibular arch, is placed lateral to the developing stomodeum. From its dorsal aspect, it gives rise to the maxillary process. The maxillary processes join the lateral and the medial nasal processes to form the future upper lip and maxilla.

The maxillary processes gives rise to the palatal shelves. The palatal shelves grow medially and as the developing tongue descends downward, the palatal shelves fuse with the fronto-nasal process to form the palate. Failure of fusion results in clefts of the palate.

The mandibular process gives rise to the lower lip and jaw. Defective fusion or incomplete fusion between the various processes leads to different types of cleft formations.

POSSIBLE MECHANISM FOR FORMATION OF ISOLATED CLEFT PALATE

1. Agenesis or hypoplasia of the tissues involved.
2. Palatal tissues may be obstructed from moving dorsal to the tongue by lack of intrinsic or extrinsic motivational force or by physical obstruction.
3. Poor adherence of the medial edge epithelium of the palatal process to each other or a delay in transposition, until fusion capacity is lost.
4. Persistence of midline seam due to a failure of cellular degeneration might result in post-fusion breakdown in the midline.
5. Lack of mesenchymal growth in the midline region may result in submucous cleft formation.

CLASSIFICATIONS

DAVIS AND RITCHIE'S CLASSIFICATION (1922)

This was one of the first recognized classifications. The classification was based on the location of the cleft relative to the alveolar process. The classification divided all clefts into three groups as:

Group I

Prealveolar clefts or in other words clefts restricted to the lip region only. The group was subdivided depending on the location of the cleft as:

- Unilateral
- Median
- Bilateral

Group II

Postalveolar clefts, i.e. clefts involving the soft palate only, or clefts involving the soft and hard palates, or a submucous cleft.

Group III

Alveolar clefts, i.e. complete clefts of the palate, alveolar ridge, with subdivisions based on the location as:

- Unilateral
- Median
- Bilateral

VEAU'S CLASSIFICATION (1931)

Veau classified clefts into four broad groups.

Group I

Clefts restricted to the soft palate.

Group II

Clefts involving the hard and the soft palate, but limited up to the incisive foramen.

Group III

Complete unilateral clefts of the soft and hard palate.

Group IV

Complete bilateral clefts of the soft and hard palate, the lip and the alveolar ridge.

CLASSIFICATION BY FOGH ANDERSON (1942)

Group I

Included clefts of the lip; and is subdivided into:

- Single—Unilateral or median clefts
- Double—Bilateral clefts.

Group II

Included cleft restricted to the lip and the palate. They are subdivided as:

- Single—Unilateral clefts
- Double—Bilateral clefts.

Group III

They are clefts of the palate extending up to the incisive foramen.

SCHUCHARDT AND PFEIFER'S SYMBOLIC CLASSIFICATION

This was the first diagrammatic classification. It makes use of a chart made up of a vertical block of three pairs of rectangles with an inverted triangle at the bottom (Fig. 57.2). The inverted triangle represents the soft palate, while the rectangles represent the lip, alveolus and the hard palate as we go down. Areas affected by clefts are shaded on the chart. Partial clefts and total clefts were shaded in different colors.

It is a relatively simple classification and ideal if printed graphs of the proposed chart are available. It was not easy to communicate as writing or typing were not possible.

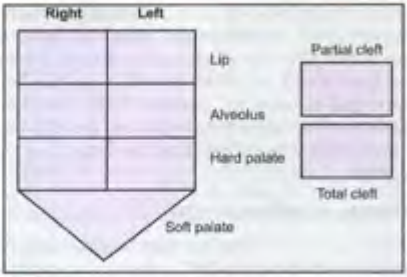


Fig. 57.2: Schuchardt and Pfeifer's symbolic classification

KERNAHAN AND STARK CLASSIFICATION (1958)

This is an embryological classification. The primary palate denotes the lip, alveolar ridge and the premaxilla and the secondary palate refers to the hard and the soft palate which evolves from the maxillary shelves.

A. Clefts of primary palate only
- Unilateral
  - — Complete
  - — Incomplete.
- Median
  - — Complete (premaxilla absent)
  - — Incomplete (premaxilla rudimentary)
- Bilateral
  - — Complete
  - — Incomplete

B. Clefts of secondary palate only
- Complete
- Incomplete, or
- Submucosal

C. Clefts of primary and secondary palate
- Unilateral (right or left)
  - — Complete or incomplete.
- Median
  - — Complete or incomplete.
- Bilateral
  - — Complete or incomplete.

KERNAHAN'S STRIPED 'Y' CLASSIFICATION

This is a symbolic classification put forward by Kernahan (Fig. 57.3).

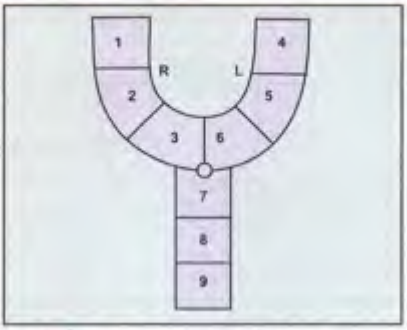


Fig. 57.3: Kernahan's striped 'Y' classification

The classification uses a striped 'Y' having numbered blocks to represent a specific area of the oral cavity.

Block 1 and 4 — Lip
Block 2 and 5 — Alveolus
Block 3 and 6 — Hard palate anterior to the incisive foramen
Block 7 and 8 — Hard palate posterior to incisive foramen
Block 9 — Soft palate

The boxes are shaded in areas where the cleft has occurred.

MILLARD'S MODIFICATION OF THE KERNAHAN'S STRIPED "Y" CLASSIFICATION (FIG. 57.4)

Millard added two triangles over the tip of the "Y" to denote the nasal floor as shown in Figure 57.4.

This increased the number of boxes to 11 as:
- Block 1 and 5—Nasal floor
- Block 2 and 6—Lip
- Block 3 and 7—Alveolus
- Block 4 and 8—Hard palate anterior to the incisive foramen
- Block 9 and 10—Hard palate posterior to the incisive foramen
- Block 11—Soft palate.

The unaffected areas were not shaded and the shading of the triangles denoted the distortion of the nose.

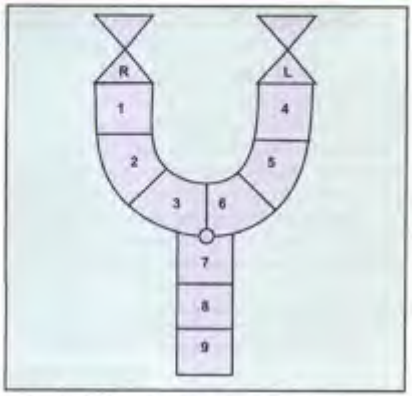


Fig. 57.4: Millard's modification of the Kernahan's striped 'Y' classification

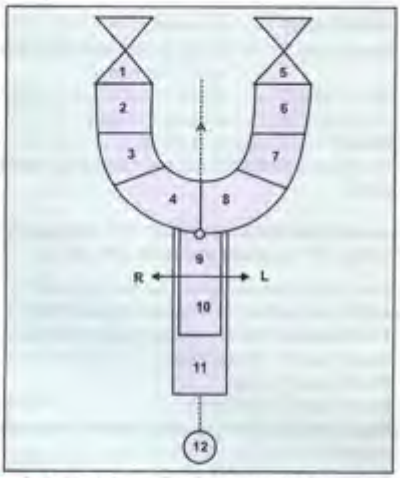


Fig. 57.5: Elsahy's modification of striped 'Y' classification

ELSAHY'S MODIFICATION OF THE KERNAHAN'S STRIPED "Y" CLASSIFICATION (FIG. 57.5)

Elsahy modified the Striped "Y" further by double lining the blocks 9 and 10 in the hard palate area and used arrows to indicate the direction of deflection in complete clefts. He also placed a circle 12 under the stem of the "Y" to represent the pharynx and a dotted line from the Y to circle 12 reflecting the velopharyngeal competence. Another circle 13 was also added to represent the premaxilla, and the amount of its protrusion was indicated by the dotted line with an arrow.

LAHSHAL CLASSIFICATION

This is one of the simplest classifications and was formulated by Okriens in 1987. Lahshal is a paraphrase of the anatomic areas affected by the cleft.

L : Lip
A : Alveolus
H : Hard palate
S : Soft palate
H : Hard palate
A : Alveolus
L : Lip

This classification is based on the premise that clefts of lip, alveolus and hard palate can be bilateral while clefts involving the soft palate are usually unilateral. The areas involved in the cleft are denoted by the specific alphabet standing for it. For example, LAH— stands for cleft of right lip, alveolus and hard palate and LA H S—L stand for cleft of right lip, alveolus, hard palate and soft palate together with left cleft lip.

AMERICAN CLEFT PALATE ASSOCIATION'S CLASSIFICATION (1962)

1. Clefts of Pre-palate

Cleft lip

Unilateral	—	Right, left, extent in thirds
Bilateral	—	Right, left, extent in thirds
Median	—	Extent in thirds
Prolabium	—	Small, medium, large
Congenital scar	—	Right, left, medium Extent in thirds

Clefts of the alveolar process

Unilateral	—	Right, left, extent in thirds
Bilateral	—	Right, left, extent in thirds
Median	—	Extent in thirds, submucous right, left, median

Cleft of pre-palate

Any combination of foregoing type:
Pre-palate protrusion

Pre-palate rotation
Pre-palate arrest (median cleft)

2. **Clefts of Palate**

Cleft soft palate

Extent	—	Posteroanterior in thirds
		Width (maximum in mm)
Palatal shortness	—	None, slight, moderate, marked
Submucous cleft	—	Extent in thirds

Cleft of the hard palate

Extent	—	Posteroanterior in thirds
		Width (maximum in mm)
Vomer attachment	—	Right, left, absent
Submucous cleft	—	Extent in thirds

3. **Cleft of Hard and Soft Palate**

4. **Clefts of Pre-palate and Palate**
Any combination of clefts described under clefts of prepalate and clefts of palate

INTERNATIONAL CONFEDERATION FOR PLASTIC AND RECONSTRUCTIVE SURGERY CLASSIFICATION (1968)

Group I

Cleft of anterior primary palate

a. Lip	—	Right, left, both
b. Alveolus	—	Right, left, both

Group II

Clefts of anterior and posterior palate

a. Lip	—	Right, left, both
b. Alveolus	—	Right, left, both
c. Hard palate	—	Right, left, both

Group III

Clefts of posterior secondary palate

a. Hard palate	—	Right, left
b. Soft palate	—	Median

PROBLEMS ASSOCIATED WITH CLEFT LIP AND PALATE

The lack of awareness and superstition associated with the condition has led the parents/relatives of the child to create unnecessary psychological problems for the child/mother/and at times the family. As it is, the patient is afflicted by a number of problems associated with the functions performed by the oral and nasal cavities. The problems associated with cleft lip and/palate patients are:

PSYCHOLOGICAL

The disfigurement caused by the condition is enough to cause psychological stress for the patient and the family. The child often has to put up with staring, teasing, pity, etc. If this is not enough, due to the frequent visits to the various specialists the education suffers. He also fares badly in academics due to speech and hearing problems often associated with such cases.

DENTAL (FIG. 57.6)

The clefts are generally associated with underdeveloped maxilla and associated structures. The patient may present with some of the following features:

- Multiple missing teeth (most commonly the maxillary lateral incisors).
- Mobile premaxilla.
- Anterior and/or posterior cross bites.
- Ectopically erupting teeth.
- Impacted teeth.
- Supernumeraries.
- Poor alignment often predisposes to poor oral hygiene.
- Multiple decayed teeth.
- Periodontal complications.

ESTHETIC (FIG. 57.7)

The patients with un-repaired clefts are badly disfigured due to the nature of the deformity. Even following the closure of the cleft the maxilla remains underdeveloped and the patient usually has a Class III skeletal profile with compromised esthetics.

SPEECH AND HEARING

Cleft lip and palate have definite speech problems. These are sometimes associated with infections of the middle ear. Since speech is learnt by the art of imitation, if hearing is compromised so is the speech. Also, if the maxilla is underdeveloped the space for maneuverability of the tongue gets decreased and speech is likely to get affected.



Fig. 57.6: Dental problems associated with clefts



Fig. 57.7: Compromised esthetics

MANAGEMENT OF CLEFT LIP AND PALATE

Children born with cleft lip and palate have a number of problems that have to be solved for successful rehabilitation. The complexity of the problem requires that a number of specialists get together at various stages of development for the eventual betterment of the patient.

The treatment of cleft lip and palate involves the total rehabilitation of the patient. It requires the expertise of various specialists at different milestones of life. No single specialist is fully equipped to handle the cleft patient on his own, to attempt such an exercise will lead to grave consequences for the esthetics of the patient and would be an injustice to him/her.

The management of cleft cases requires team work and patience. Each specialist has to be selfless and work within his/her limits, involving specialists from other fields as and when the need arises. Since the orthodontist is involved with the patient from immediately after birth till the permanent teeth have been brought into functional and esthetically acceptable position, he can be the team leader and help coordinate the activities of other specialists.

The management of the patient can be divided into four distinct yet overlapping stages. The stages have been created, based on the dentition of the patient.

Stage I

The first stage extends from birth to 24 months. The orthodontist may be called upon to perform the following two functions:

- Fabrication of a feeding plate or passive maxillary obturator.
- Strapping of the premaxilla or other infant orthopedic procedures.

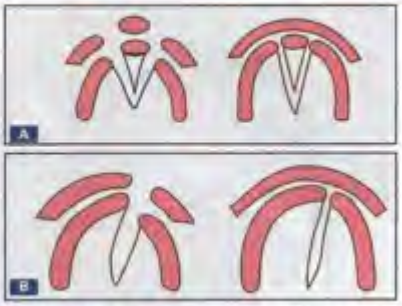
It is important to note that both the procedures are optional and have inherent advantages and disadvantages. The procedures should be undertaken after evaluating the individual case.

The feeding plate or the passive maxillary obturator (Fig. 57.8) is a passive prosthetic appliance that is used to restore the palatal cleft and aid sucking. It also helps in preventing the maxillary arch from collapsing further. The appliance is generally made of cold cure or heat cure acrylic. Extraoral clasps are often used to aid retention of the appliance. These retention clasps or winged extensions can be held in place adjacent to the cheeks using micropore adhesive tape.

Infant orthopedic procedures were popular in late 1950's. They basically made use of removable orthodontic appliances to reposition the maxillary segments in early infancy, before the initial flap closure. In a unilateral cleft, the premaxillary segments are likely to be displaced facially adjacent to the cleft (Fig. 57.9A). Whereas in bilateral clefts, the premaxilla is usually displaced significantly forward, with the posterior segments collapsed medially behind it (Fig. 57.9B). Repositioning the segments before the initial lip surgery made it easier to produce a more esthetic lip with the first operation. This made the patients look much better at an early stage.



Fig. 57.8: Passive maxillary obturator with wings for retention



Figs 57.9A and B: Pre-surgical orthopedics (A) In bilateral clefts the displaced premaxilla is readapted to conform to the arch (B) In unilateral clefts the displaced greater segment is readapted to conform to the arch

The use of such appliances has decreased over the years, because even though they improved the esthetics initially but the results over the years were not that encouraging.

Infants with bilateral cleft need two types of movements of maxillary segment; collapsed maxillary posterior segment must be laterally pushed and pressure exerted against the maxilla to reposition it posteriorly. Repositioning can be done either by an appliance pinned to the segments, which applies a contracting force or by the application of leucoplast over the premaxillary segment (Fig. 57.10). A similar force was also seen to have generated following an early lip repair.

Lip closure: Surgical correction of lip is done in early infancy as it is compatible with a good long-term result. The common guidelines (as advocated by Millard) is age 10 weeks, weight 10 pounds and hemoglobin 10 gm%. Correcting the lip immediately after birth offers only psychological advantage to the parents and was popular in the 1960s. It involves a greater risk of surgical morbidity, and long-term esthetic results were found to be not as good.



Fig. 57.10: Pre-surgical orthopedics by extraoral strapping across the premaxilla

Many surgical techniques have been developed for primary lip and nose closure. The rotation-advancement technique of Millard is most commonly used. A discussion on surgical procedures is beyond the scope of this book.

Surgical palate repair An intact palate aids the acquisition of normal speech. At this time speech is developing rapidly. For ideal speech, therefore palate closure between the age of 12 and 24 months is recommended. Some authors prefer to wait and recommend palatal repair in the age group of 9 to 12 years.

The objectives of palatal surgery are to join the cleftal edges, lengthen the soft palate, and repair the levator palatinii muscle.

Stage II

This stage extends from 24 months to 6 years of age. The period covers the primary dentition. The orthodontist plays the part of an observer and monitors the development of the dentition. Generally no active orthodontic treatment is undertaken during this stage. Adjustments may be made in the obturator to accommodate the erupting deciduous teeth. Cross bites present at this stage can be corrected with either removable (split plate) or fixed (lingual arch) appliances. The correction of cross bites at this stage is debatable, as cross bite problems tend to reappear and will require additional treatment in the mixed and permanent dentition period.

The oral-hygiene instruction may be emphasized upon and procedures undertaken to preserve the existing tooth structures.

Stage III

This stage extends from 6 to 12 years of age, i.e. the mixed dentition stage. The orthodontist plays a major role during this stage.

- Arch expansion can be undertaken.
- Maxillary protraction devices can be made use of.
- Fixed orthodontic treatment can be initiated, which will form the basis of the final alignment and position of the teeth.

Arch expansion can be undertaken using appliances such as the NiTi expander (Fig. 57.11A) or the quad helix (Fig. 57.11B). The NiTi molar rotator (Fig. 57.11C) may be used prior to the use of expansion appliances to correct the rotated first permanent molars. A screw appliance can also be used.

Maxillary protraction appliances as in the reverse pull headgear is often used and has been found to be very effective in cooperative patients (Fig. 57.11D).

Alignment using fixed orthodontic appliances can be initiated. The patient is referred for a bone graft in the palatal region, before the eruption of the permanent maxillary canine. If the canine can be made to erupt through the graft, it adds to its stability.

Stage IV

This stage corresponds to the permanent dentition and final corrections are made during this stage (Fig. 57.12). A reasonable amount of alignment along with esthetics should be achieved. The canine, if not erupted is exposed and brought into alignment. The arches are aligned and the occlusion made to settle. Planning is done regarding the need for orthognathic surgery. Consultation with the oral and maxillofacial and plastic surgeons is a must.

The retention planned should be permanent in nature. Prosthetic rehabilitation can be accommodated in the retention appliance- using fixed bridges or cast partial dentures.



Fig. 57.11A: A NiTi expander



Fig. 57.11B: A quad helix appliance (*Photograph courtsey: Dr Gautam Munjal, Chandigarh)*



Fig. 57.11C: A NiTi molar rotator is used before an expander



Fig. 57.11D: Case treated using a face mask/reverse pull head-gear



Fig. 57.12: Treatment done during stage IV

Lip revision, nasal correction and the restoration of the nasophiltral angle can be undertaken following the completion of all orthodontic treatment.

FURTHER READING

1. Barrer G. The adult orthodontic patient, Am J Orthod 1977; 72:617-40.

2. Bergland O, Semb G, Abyholm FE. Elimination of the residual alveolar cleft by secondary bone grafting and subsequent orthodontic treatment. Cleft palate J 1986;23:175-205.
3. Boyd RL, Leggott PJ, Quinn RS, et al. Periodontal implications of orthodontic treatment in adults with reduced or normal periodontal tissues versus those of adolescents. Am J Orthod Dentofac Orthop 1989;96:191-99.
4. Boyd RL, Miller RJ, Vlaskalic V. The Invisalign system in adult orthodontics: Mild crowding and space closure cases. J Clin Orthod. 2000;34:203-12.
5. Boyd RL, Vlaskalic V. Three-dimensional diagnosis and orthodontic treatment of complex malocclusions with the Invisalign Appliance,. Semin Orthod 2001;7:274-93.
6. Gorman JC. Treatment of adults with lingual appliances. Dent Clin North Am 1988;32:589-620.
7. Graber TM. Cranio-facial morphology in cleft palate and cleft lip deformities. Surg Gynec Obstet 1949;88:359-69.
8. Horn BM, Turley PK. The effect of space closure of the mandibular first molar in adults. Am J Orthod 1984;85:457-69.
9. Huddaart AG, North JF, Davis MEH. Observations on the treatment of cleft lip and palate. Dent Prac 1966;16:265-74.
10. Kokich VG, Spear FM. Guidelines for managing the orthodontic-restorative patient, Sem Orthod 1997;3:3-20.
11. Kondo F: Utilization of wisdom teeth in adult orthodontic treatment, dental Frontier 2003;22:14-32.
12. Mirabella AD, Artun J. Risk factors for apical root resorption of maxillary anterior teeth in adult orthodontic patients. Am J Orthod Dentofac Orthop 1995;108:48-55.
13. Pruzansky S, Aduss H. Prevalence of arch collapse and malocclusion in complete unilateral cleft lip and palate. Trans Europ Ortho Soc 1967;1-18.
14. Rivkin CJ, Keith O, Crawford PJM, Hathorn IS. Dental care for the patient with a cleft lip and palate. Part 1: From birth to the mixed dentition Stage; Part 2: The mixed dentition stage through to adolescence and young adulthood. Br Dent J 2000;118:78-83;131-34.
15. Rosenstein SW. New concept in early orthopedic treatment of cleft lip and palate. Am J Orthod 1969;55:765-74.
16. Shaw WC, Semb G. Current approaches to the orthodontic management of cleft lip and palate. J R Soc Med 1990;83:30-33.
17. Tessier P. Anatomical classification of facial, craniofacial and latero-facial clefts, J Maxillofac Surg 1976;4:69-92.
18. Thilander B. Indications for orthodontic treatment in adults, in Thilander B, Ronning O (Eds), Introduction to Orthodontics. Stockholm, Tandlakarforlaget, 1985.
19. Thom AR. Modern management of the celft lip and palate patient. Dent Update 1990;17:402-08.
20. Wagenburg BD, Eskow RN, Langer B. Orthodontic procedures thet improve the periodontal prognosis, J Am Dent Assoc 1980;100:370-73.
21. Wintner M. Surgically assisted palatal expansion: An important consideration in adult treatment, Am J Orthod Dentofacial Orthop 1991;85-90.
21. Ziskind D, Schmidt A, Hirschfeld Z. Forced eruption technique: rationale and technique, J Pros Dent 1998;79:246-48.

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