thesia or intraosseous injection. I have never found these to be necessary. Rarely do maxillary or mandibular anterior teeth cause any problem, although for certain patients, additional solution may be required.

Special Comments about Mandibular Block Injections

Being able to extirpate a pulp from a mandibular first molar tender to percussion and sensitive to hot in a painless manner is the most demanding anesthetic test in dentistry. The depth of anesthesia required for this procedure transcends any other dental procedure for this tooth, including preparation for a crown, periodontal surgery, or even extraction.

A precisely placed mandibular block injection, more correctly referred to as an *inferior alveolar nerve (IAN) block*, is required for this procedure. The patient should experience lip paresthesia after injection within 90 seconds for the dentist to feel relatively safe in attempting to start the access preparation and expect to complete the extirpation totally and painlessly. When the patient requires 10, 15, or more minutes to gain numbness in the lip, usually more injections (intraligamentary and intrapulpal) are needed.

Methods are available to increase an operator's ability to gain a high percentage of lip paresthesia from IAN injections within this 90-second window. Generally it is accepted that if a dentist can obtain paresthesia in 90 seconds in 85% or more of IAN blocks administered, the technique being used is excellent and cannot be improved. However, many dentists do not reach this 85% level, and the following remarks should be helpful in attaining this degree of effectiveness.

Administer Correct Amount of Solution. Malamed has stated that the IAN injection may require as much as 1.5 to 3.0 ml of solution to be effective. Assuming that 1.8 ml is available in each injection and that some solution will be deposited during penetration to the site of the nerve, one can easily see that injection of one Carpule of local anesthetic may not be enough solution to attain acceptable pulpal anesthesia. Therefore, for these complicated cases, two Carpules of anesthetic should be injected for best results. If the patient has cardiovascular problems and two Carpules may contribute a greater amount of vasoconstrictor than desired, it is a simple matter to give one Carpule with a low amount of vasoconstrictor and a second Carpule of the same or another anesthetic agent without any vasoconstrictor.

Use of the Short Needle. The long needle has been recommended for dental injections for many years. The basic reason for its use originally was that in cases where the needle broke during the injection, more metal was available to grasp for removal. Also, because the most vulnerable site for needle breakage was at the hub, the longer needles would have less chance of being placed into the tissue to the hub and thus less chance of being broken. These are good and logical reasons, and to this day, most dentists use a long needle (28.9 to 41.5 mm in length, averaging about 36.0 mm) to deliver the IAN block.

However, when this view became prevalent, dental needles were much different than they are now, both in manufacture and use. The former needles were cut from a long tube and were more susceptible to breakage than the rolled metal needles of today. Forty years ago it was common practice to reuse needles dozens of times, with boiling the usual method for sterilization. Today, and for many years now, needles are disposable and are reused only at the same appointment for the same patient. Sterilization usually is by gas. Needle breakage in the last few years has been minuscule. Choice of needle length should be based on more significant conditions.

Many dentists think that the use of the long needle is predicated on the distance between the pterygomandibular raphe and the lingula being longer than a short needle (19.9 to 25.5 mm, averaging about 22 mm). Menke and Gowgiel, using cadaver material rather than dried specimens, measured this distance. Although previous literature had suggested that the penetration distance was as short as 12 mm to as long as 38 mm, they found the range to be 12 to 19 mm, with an average of 16 mm, all well within the length of 22 mm, the most popular length of the short needle.

Having the maximal penetration distance only a few millimeters from the total length of the needle allows for the anesthetist to visualize that distance easily when using a short needle, which would be nearly impossible when using a long needle, where the exposed metal would be approximately 20+ mm. Furthermore, the long needle has much more *drift*, or needle deviation, to its tip. This fact and because many more anatomically important sites are found past the site of injection than before it make a miss being too long an undesirable error in administering the IAN block. The shorter miss, although still being an anesthetic failure, probably will not cause an untoward reaction or enter an undesirable position.

Use Care When Giving an IAN Block with a Short Needle. Malamed still discourages the use of the short needle because he believes that it is more apt to break than a long needle. He has stated that the weak point, the hub, may be reached with a short but is unreachable with a long needle. The answer to this problem is to always use a needle length of 19 mm or longer. Furthermore, with virtually every short needle, if you approach within 1 or 2 mm of the hub, the needle has gone too far already.

Remove it carefully and reinject. Never go to the hub with any needle, regardless of length!

If, however, one still insists on using a long needle but understands the advantage of knowing when penetration of 16 mm has been reached, I advise placing a sterile endodontic stop (see Figure 5-18) on the long needle at 16 mm. Then, as the IAN block is being given, the operator knows when the ideal penetration site has been reached.

Intraligamentary Anesthesia

Intraligamentary injections (ILIs) are neither new nor intraligamentary. They were used in the early 1920s, were reintroduced in Italy by Colombo in 1972, and have gained popularity in the last few years since specialized syringes were manufactured. Even though early users and manufacturers claim that anesthesia is gained by the solution filtering down through the periodontal ligament to the apical vessels, there can be no question that the injection is effective by being intraosseous.

Many other misconceptions and incorrect applications surround the so-called ILI. The injection works best with an anesthetic solution containing epinephrine because the vasoconstriction evidently has effect on the apical vessels. According to Pashley, this effect goes farther systemically than merely the local site of the injection, so I prefer an epinephrine level no greater than 1:100,000. Because of the local ischemia produced in the pulp by such an injection, ILI is well used when endodontic procedures or extractions are performed, but according to Kim, should not be used for operative dentistry when the pulp is to be conserved.

Because the injection is intraosseous rather than intraligamentary, the bevel of the needle must be pointed away from, not toward, the tooth being anesthetized. The injection is given into the interproximal space to the mesial and distal of the tooth; buccal or lingual injections do not seem to have any effect on the pulp. The injector must feel that pressure is needed to obtain the desired anesthesia, and only a few drops need to be expressed. If a large amount of solution enters the tissues easily, the injection will probably have little effect because it is not being forced into the bone. Specialized injection syringes need not be used, but a standard injection syringe is perfectly acceptable, as long as pressure can be built up. The ordinary syringe should have a plastic, metal, or glass sleeve to protect the Carpule of anesthetic solution because in some cases the pressure built up can break the glass, thus causing an explosion of flying glass and solution that might cause injury to the patient or the dentist. I have found that 30-gauge and ultrashort (quarter-inch) needles seem to work best.

Dye distribution studies by Walton have demonstrated that the solutions pass into the teeth adjacent to the one being injected. Therefore the ILI cannot inject single teeth to isolate an individual tooth as the cause of pain. Erroneous results may occur if an attempt is made to affect only a single tooth and keep an adjacent tooth unanesthetized.

The patient will experience some pain in the area after the injection but probably very little more than in any other site of needle insertion. The injection should be used with great care in patients with periodontal disease, unless the tooth is to be extracted at that visit. The forceful injection into a diseased, septic area may cause a periodontal abscess to fulminate.

Not all clinicians are in agreement concerning the effectiveness of this injection, even though Kim reported as high as 88% full anesthesia on inflamed mandibular molars. My own experience is that ILIs provide an effective supplementary anesthetic choice when performing pulp extirpations on inflamed mandibular molars. They generally allow the dentist to gain access into the pulp itself relatively painlessly. Then an intrapulpal injection allows for the comfortable completion of the extirpation.

An ILI will not give pulpal anesthesia in mandibular molars for any extended time and may be useful for only 8 minutes or less. In a typical scenario, a dentist may attempt a mandibular block for a painful mandibular molar, but the patient does not feel symptoms of paresthesia quickly. After 10 to 15 minutes, lip paresthesia seems adequate and the dentist starts access preparation. After some painless preparation, the patient starts to become uncomfortable, indicating lack of full effect from the block.

At this point the dentist administers the ILIs. Because it took over 10 minutes for the block to start to work, the dentist decides to allow that much time for the ILIs to work. This is a serious mistake. By that time, even if they were effective initially, the ILIs will have lost their anesthetic quality and the patient will again be in pain.

If ILIs are administered, the operator should wait only a minute or two and then continue preparation. Hopefully the hard tissue to the pulp will be uncovered relatively painlessly, and then the intrapulpal injection can be given to ensure total anesthesia for the extirpation.

Application of Rubber Dam for Severely Broken-Down Teeth

Some teeth with severe loss of tooth structure may present problems for the application of a rubber dam. Because the use of the dam is mandatory, certain procedures performed before access preparation is begun will aid in holding the clamp.

If sufficient tooth structure is present above the alveolar bone, an alveoloplasty procedure is required to expose sufficient portions of the root face. This may be accomplished with tapered diamond stones and water spray to remove the bone covering the root. After the

endodontic appointment, a large amount of zinc oxide–eugenol (ZOE) may be used to cover the entire root face, rather than merely the access cavity, and to act as a pack because ZOE is a major constituent of most periodontal dressings. This will prevent pain and keep the exposed bone covered until sufficient new soft tissue develops.

If only soft tissue covers the tooth to be treated, gingivoplasty procedures will be needed. These may be rapidly and bloodlessly accomplished by the use of an electrosurgery unit. Gingivoplasty may be performed also by applying a sharp rubber dam clamp on the gingiva at the position of gingivectomy depth. The clamp pinches off the tissue, and the latter is easily trimmed and removed with a scalpel or surgical knife (Figure 4-60). The oversized temporary-pack dressing is also used.

Use of Bands. If a badly broken-down tooth requires endodontic therapy and sufficient crown length is present, a cemented preformed band may be useful to allow for rubber dam application and to retain the intertreatment dressing.

Several companies have these preformed bands (Figure 4-61) available in many widths to accommodate every possible size and shape. They are contoured to resemble the gingival shape, thereby lessening the chance for soft tissue damage and aiding in retention of the band. Some authors suggest the use of a copper band. However, these bands take much longer to festoon and apply, are not precontoured to lessen gingival inflammation, and are not as sturdy.

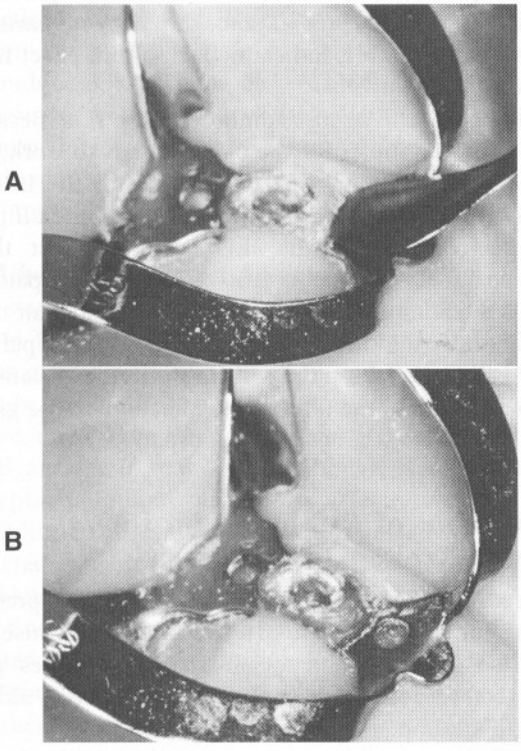


FIGURE 4-60 **A,** Mandibular incisor has broken beneath gingiva but requires rubber dam application. Clamp is placed on tissue, and a periodontal knife is used to trim pinched tissue easily and bloodlessly. **B,** Root face is now completely exposed for performance of necessary endodontic treatment and to simplify the post, core, and crown preparation that will follow.

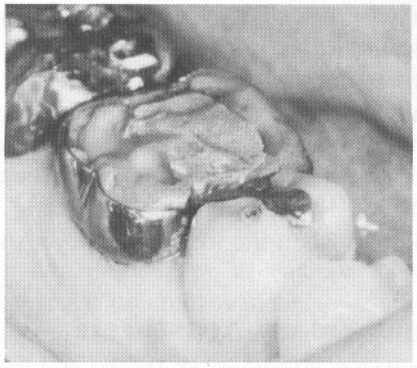


FIGURE 4-61 **Preformed band placed on mandibular first molar that was so badly broken down on buccal aspect that no rubber dam clamp could hold satisfactorily.** Metal band will impinge minimally on gingiva, is relatively simple to place compared with a festooned copper band, and will support direct clamp placement.

Access When Deep Gingival Decay is Present. When deep gingival decay is present, using a preformed band may not seal off the area, and contamination of the canal would result. The correct procedure is to prepare the normal access through the occlusal (or lingual) surface. Contents of the canal are removed past the decay, and the cavity is excavated to sound dentin with sufficient retention to hold a temporary seal. A file or silver point is placed into each canal through the access, well past the gingival preparation. Silver amalgam is the material of choice to seal the preparation, particularly if the area must hold a rubber dam clamp at a succeeding appointment. ZOE, thickly mixed, is also acceptable but may tend to crumble under the pressure of clamp placement. Once the temporary seal has attained initial set, the file or point that was used to keep material from being pushed into the canal is removed, and patency of the canal is verified.

Aid for a Leaky Rubber Dam. In some instances the rubber dam fails to control seepage of saliva, resulting in constant contamination of the chamber of the tooth being treated. This condition may arise during treatment of splint or bridge abutments, where the series of castings prevents the dam from being tucked into the interproximal spaces around the treated tooth or when the normal shape of the crown is lacking because of caries, loss of restoration, or abnormal axial inclination.

To avoid fighting saliva all during the appointment, the practitioner may use Ward's Tempak or other similar temporary cement to halt the seepage. A medium mix is prepared and packed around the rubber dam clamp. Because ZOE cements normally set faster when in contact with moisture, in a few minutes the leakage will be halted, and treatment may continue normally (Figure 4-62).

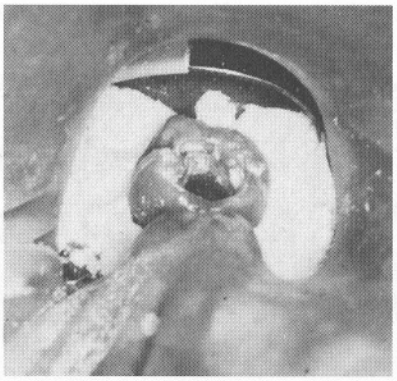


FIGURE 4-62 Rubber dam seal was incomplete, and saliva continued to seep during appointment. A thick mixture of Ward's Tempak is placed around clamp to seal off area.

BIBLIOGRAPHY

Canal Configuration

Baisden MK, Kulild JC, Weller RN: Root canal configuration of the mandibular first premolar, *J Endod* 18:505, 1992.

Carns EJ, Skidmore AE: Configurations and deviations of root canals of maxillary first premolars, *Oral Surg* 36:880, 1973.

Cooke HG, Cox FL: C-shaped canal configurations in mandibular molars, *J Am Dent Assoc* 99:836, 1979.

Eskoz N, Weine FS: Canal configuration of the mesiobuccal root of the maxillary second molar, *J Endod* 21:38, 1995.

Evenot M: *Contribution a la connaissance des systemes endodontiques complexes la racine mesio vestibulaire de la premiere molaire maxillaire, approche, instrumentale, clinique et pedagogique,* doctor's thesis, Paris, 1980, Academie de Paris, Universite Rene Descartes.

Gorduysus MO, Gorduysus M, Friedman S: Operating microscope improves negotiation of second mesiobuccal canals in maxillary molar, *J Endod* 27:683, 2001

Green D: Double canals in single roots, *Oral Surg* 35:689, 1973.

Hartwell G, Bellizzi R: Clinical investigation of in vivo endodontically treated mandibular and maxillary molars, *J Endod* 8:555, 1982.

Ibarrola JL, Knowles KI, Ludlow MO, McKinley IB: Factors affecting the negotiability of second mesiobuccal canals in maxillary molars, *J Endod* 23:236, 1997.

Kulild JC, Peters DD: Incidence and configuration of canal systems in the mesiobuccal root of the maxillary first and second molars, *J Endod* 16:311, 1990.

Nosonowitz DM, Brenner MR: The major canals of the mesiobuccal root of the maxillary 1st and 2nd molars, *NY J Dent* 43:12, 1973.

Peikoff MD, Christie WH, Fogel HM: The maxillary second molar: variations in the number of roots and canals, *Int Endod J* 29:265, 1996.

Pineda F: Roentgenographic investigation of the mesiobuccal root of the maxillary first molar, *Oral Surg* 36:253, 1973.

Pomeranz HH, Fishelberg G: The second mesiobuccal canal of the maxillary molars, *J Am Dent Assoc* 88:119, 1974.

Rankine-Wilson RW, Henry P: The bifurcated root canal in lower anterior teeth, *J Am Dent Assoc* 70:1162, 1965.

Seidberg BH, Altman M, Guttuso J, Suson M: Frequency of two root canals in maxillary permanent first molars, *J Am Dent Assoc* 87:852, 1973.

Skidmore AE, Bjorndal AM: Root canal morphology of the human mandibular first molar, *Oral Surg* 32:778, 1971.

Stropko JJ: Canal morphology of maxillary molars: clinical observations in the number of roots and canals, *J Endod* 25:446, 1999.

Vertucci FJ: Root canal anatomy of the human permanent teeth, *Oral Surg* 58:589, 1984.

Weine FS: Initiating endodontic therapy in posterior teeth. Part I. General considerations and starting treatment of bicuspids, *Compend Contin Educ Dent* 3:377, 1982.

Weine FS: Initiating endodontic therapy in posterior teeth. Part II. Maxillary molars, *Compend Contin Educ Dent* 3:455, 1982.

Weine FS: Initiating endodontic therapy in posterior teeth. Part III. Mandibular molars, *Compend Contin Educ Dent* 4:153, 1983.

Weine FS, Healey HJ, Gerstein H, Evanson L: Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance, *Oral Surg* 28:419, 1969.

Weine FS, Pasiewicz R, Rice RT: Canal configuration of the mandibular second molar using a clinically oriented in vitro method, *J Endod* 14:207, 1988.

Weine FS, Members of the Arizona Endodontic Association: The C-shaped mandibular second molar: incidence and other considerations, *J Endod* 24:372, 1998.

Weine FS, Hayami S, Hata G, Toda T: Canal configuration of the mesiobuccal root of the maxillary first molar of a Japanese subpopulation, *Int Endod J* 32:79, 1999.

Weller RN, Hartwell G: The impact of improved access and searching techniques on detection of the mesiolingual canal in maxillary molars, *J Endod* 15:82, 1989.

Wolcott J, Ishley D, Kennedy W, Johnson S, Minich S: Clinical investigation of second mesiobuccal canals in endodontically treated maxillary molars, *J Endod* 28:477, 2002.

Zillich R, Dawson J: Root canal morphology of the mandibular first and second premolars, *Oral Surg* 36:738, 1973.

Local Anesthesia

Farsakian LR, Weine FS: The significance of needle gauge in dental injections, *Compend Contin Educ Dent* 12:262, 1991.

Kim S: Ligamental injection: a physiological explanation of its efficacy, *J Endod* 12:486, 1986.

Malamed SF: *Handbook of local anesthesia*, ed 6, St Louis, Mosby (in press).

Menke RA, Gowgiel JM: Short-needle block anesthesia at the mandibular foramen, *J Am Dent Assoc* 99:27, 1979.

Pashley DH: Systemic effects of intraligamentary injections, *J Endod* 12:501, 1986.

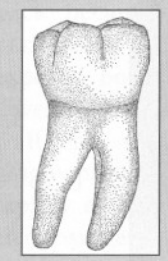
Walton RE, Abbott BJ: Periodontal ligament injection: a clinical evaluation, *J Am Dent Assoc* 103:571, 1981.

Walton RE: Distribution of solutions with the periodontal ligament injection: clinical, anatomical, and histological evidence, *J Endod* 12:492, 1986.

White JJ, Reader A, Beck M, Meyers WJ: The periodontal ligament injection: a comparison of the efficacy in human maxillary and mandibular teeth, *J Endod* 14:508, 1988.

Wittrock JW, Fischer WE: The aspiration of blood through small-gauge needles, *J Am Dent Assoc* 76:79, 1986.

CHAPTER 5



Intracanal Treatment Procedures, Basic and Advanced Topics

CHAPTER OUTLINE

Basic Intracanal Instruments
- Broaches
- Methods for using reamers and files
- Reamers
- Files
- Styles of instruments
- Standardization

Rules for Canal Preparation

Determination of Correct Width for Canal Preparation
- Minimal instrumentation at any appointment—to reach size 25
- Determination of apical width
- Gaining sufficient enlargement for using gutta-percha—the flared preparation
- Canal enlargement in moderately wide and/or straight canals
- Canal enlargement in smaller, relatively straight, canals
- Importance of using MAF as final instrument after using flaring files short of the working length
- Overuse and abuse of flaring
- Final test for completion of canal preparation—placement of the finger spreader

Aids for Preparing Difficult Canals
- Problems encountered in canal preparation
- Precurving of files
- Incremental instrumentation
- New instruments with intermediate sizes
- Need for remeasurement when preparing curved canals

Preparation in Extremely Curved Canals
- Determination of canal curvature
- Observations that canal shape changes
- Plastic block studies
- Standard preparation in the sharply curved canal
- Applications on extracted teeth
- Avoiding the apical zip and the elbow
- Application to clinical cases by using customized files
- Theories for flaring in complex cases versus crown-down preparation
- Rules governing the use of non-ISO tapered instruments
- Effect of the non-ISO tapers on canal curvature and resultant changes in canal shape
- Typical cases

New File Systems for Preparation of Curved Canals
- Effects of increased flexibility on final canal shape
- Flexible file systems
- Nickel-titanium files
- Minimizing zipping by flute removal and modification of tips
- Disadvantages of flexible files
- Non-ISO taper file for penetration

Preparation of Type II Canal Systems

Complete Endodontic Treatment of Primary Teeth

Ultrasonics
- History of ultrasonics in dentistry
- Method for action
- Techniques for use
- Canal preparation
- Related uses for ultrasonics

Irrigants and Chelating Agents
- Functions of irrigants
- Useful irrigants
- Method of irrigation
- Recent studies concerning irrigants and their clinical implications
- Function of chelating agents

Intracanal Medicaments
- Function of intracanal medicaments
- Phenol and related volatile compounds
- Calcium hydroxide as a medicament for "weeping" cases

Sealing Agents for Intertreatment Dressings
- Need for sealing agents
- Types of available sealing agents

Treatment of Operative Perforations
- General rules for treating operative perforations

Treatment of furcation perforations by packing the chamber
Treatment of perforations by enlargement and filling as an additional canal
Perforations treated surgically or orthodontically
New materials for perforation repair
Noninstrumentation Technology (NIT)

The major objective of the intracanal treatment procedures is to remove the contents of the canal and adjacent tissues in such a way that the filling procedures that follow will be facilitated. This means not only that the pulp tissue, necrotic debris, microorganisms, and affected dentin must be removed from the treated tooth, but also that the canal walls must be prepared to receive a filling material that will seal the apical foramen.

To describe this aspect of treatment lucidly, Schilder has dubbed these procedures *cleansing and shaping* in emphasis of the need for debridement and development of a specific receptacle for the filling material. I prefer the term *canal preparation* but certainly acknowledge that cleansing and shaping must be performed to reach the desired goal. *Canal enlargement* should not be used; merely widening the diameter of the canal may not produce the correct shape that must be developed, neither does it always remove undesired contents from the canal.

The importance of canal preparation cannot be overemphasized. It is these intracanal procedures that allow for the initiation of healing by removing the irritants to periapical tissue that have been harbored within the canal. When for some reason a longer than routine period of time has elapsed between the start and the completion of therapy, it is not unusual to note radiographic evidence of healing of a periapical lesion on an x-ray film before canal filling (Figure 5-1).

This chapter will discuss the instruments necessary to accomplish the desired objective, the procedures designed to produce results effectively and rapidly, and the adjuncts needed to retain the tooth in a desirable condition until the canals are filled. The treatment of teeth with complex problems will also be described.

The calculation of working length is often included in the discussion of canal preparation, as it was in the first four editions of this book. Because of its importance, this subject now has a chapter of its own, Chapter 6. Working length calculation may be an object of controversy, and I wanted to give sufficient space to each of the several techniques. Popularity of several types of apex locators also has increased recently.

Because aspects of working length are necessarily involved in canal preparation, it is my hope that this subject does not become disorienting to the reader, who notes references to working length while reading Chapter 5, but has not yet read the basis for its calculation. Perhaps this should be viewed as are some aspects of intricate spy novels, where characters and events are referred to but have not yet been introduced fully in the prose.

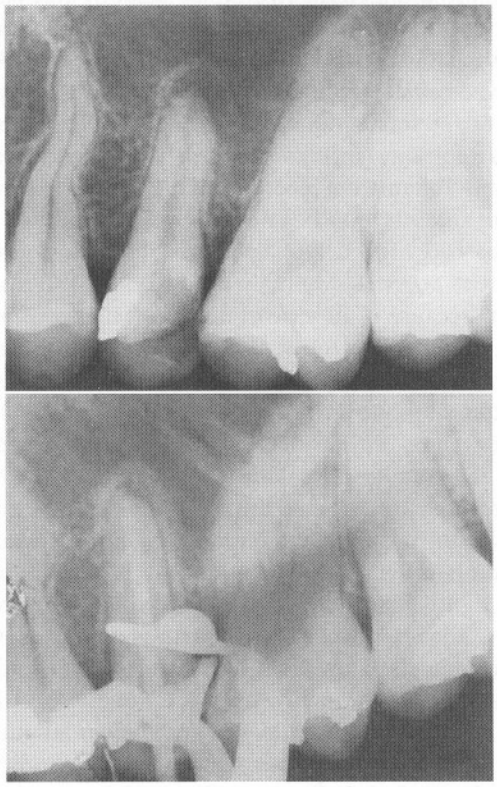


FIGURE 5-1 **A,** Preoperative radiograph of maxillary second bicuspid with large periapical radiolucency. Patient was a college student, home only for school vacations. Canal was debrided during Thanksgiving holiday with heavy irrigation of NaOCl, and second appointment was scheduled for Christmas recess. **B,** The tooth received no further treatment until five weeks later, when radiograph was taken for verification of fit for master cone, radiolucency had already healed without canal being filled. Poor fixing and scratches on this film have occurred because it is an intratreatment film developed ultrafast and generally is discarded at the conclusion of the fill appointment. The significance of this radiograph was not realized until later that day.

BASIC INTRACANAL INSTRUMENTS

The basic endodontic instruments used within the root canal are broaches, files (K-type and Hedstrom), and reamers. Although many engine-driven handpieces have been found to be of dubious value, particularly in the

more difficult curved canals, recently the introduction of some rotary instruments have been found to be very useful. Because of their specific use for providing enlargement in the more coronal portion of the preparation, these systems will be reviewed a bit later in this chapter.

Broaches

Broaches are available in two types: smooth and barbed. The smooth broach had been used by some practitioners as an initial instrument to explore the patency and the walls of the canal. Most practitioners no longer follow this procedure, preferring to remove tissue bulk before the placement of any instrument near the apex to avoid forcing any inflamed or necrotic tissue through the apex. Therefore smooth broaches now are rarely used.

The barbed broach has been used for many years in endodontics and was originally used in canal preparation. However, because of its ease of breakage, it is confined to removal of soft tissue only. It is a tapered instrument of soft steel that is notched by a shredder to produce sharp barbs extending outward from the shaft (Figure 5-2).

This design is responsible for the frequency of breakage because the notching weakens the shaft by providing a place for fracture if stress or torque is applied. In addition, misuse within the canal may lead to disastrous results. If the operator attempts to force apically a barbed broach within a tightly fitting canal, the barbs will be bent toward the shaft, allowing for deeper insertion. However, when the instrument is withdrawn, the barbs will extend and engage the adjacent dentin. As more force is exerted in removal, the barbs will dig deeper, and further fatigue may result in snapping of the instruments. **Therefore, once the hard surface of the dentin walls is felt, the barbed broach must not be inserted any farther.**

Correct use of the instrument involves its careful insertion through the access cavity until the dentin walls are felt or the approximate length of the canal is reached. The broach is slightly withdrawn, then rotated a few revolutions, and removed. Vital or necrotic pulp tissue and debris become ensnared on the barbs and removed so that much of the bulky content of the canal is debrided before files are placed toward the apical foramen. The barbed broach is similarly used to remove the paper points or cotton pellets of intertreatment dressings, which may defy removal by excavator or explorer.

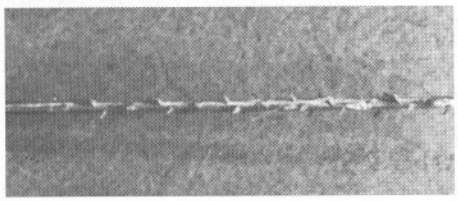


FIGURE 5-2 Broach has small barbs protruding from shaft notched by a shredder, highly susceptible to breakage when locked in canal.

The smallest-sized broach available has approximately the width of a size 20 instrument. Because broaches should not be used until the canal is wide enough for comfortable accommodation, they are not used initially in narrow buccal canals of maxillary molars and mesial canals of mandibular molars. Once these canals have been enlarged to size 20 or larger, broaches should be used to remove the bulky tissue that has been packed into the apical portion of the preparation.

Methods for Using Reamers and Files

Some confusion exists as to the actions for using enlarging instruments and the instruments themselves. Both reamers and files may be used with either a reaming or a filing motion.

Reaming. Reaming involves placement of the instrument toward the apex until some binding is felt and then turning the handle more than a full revolution. Clockwise turning will remove material from the canal by way of the flutes' revolution, whereas counterclockwise turning will force material apically. The major effectiveness of hard tissue removal by reaming is in the insertion of the instrument by shaving the dentin walls.

Filing. Filing involves placement of the instrument toward the apex until some binding is felt and then removing the instrument by scraping against a side of the dentin wall with little or no revolution of the handle. This dragging against the side of the wall is also referred to as *rasping* action. The major effectiveness of hard tissue removal by filing is in the outstroke or withdrawal of the instrument by dragging the flutes on the dentin walls.

Considerable difference exists between using filing action and pistoning the canal. *Pistoning* involves going up and down forcefully. This push/pull motion tends to pack dentinal filings at the apex and alter canal shape in small, curved canals to create ledges and short fills. Filing involves a passive placement of the instrument to its working length and a heavier drag motion against the canal wall.

Circumferential Filing. Circumferential filing is a method of filing whereby the instrument is moved first toward the buccal (or the labial) side of the canal, then reinserted and removed slightly mesially. This continues around the preparation to the lingual aspect and then to the distal until all the dentin walls have received rasping (Figure 5-3). This technique enhances preparation when a flaring method is used by widening the orifice of the canal considerably, whereas the apical portion is kept relatively small.

Most roots are oval in cross section and are wider buccolingually than mesiodistally (the sole exception being the palatal root of the maxillary molar). If such a root contains only one canal, which many but not all do,

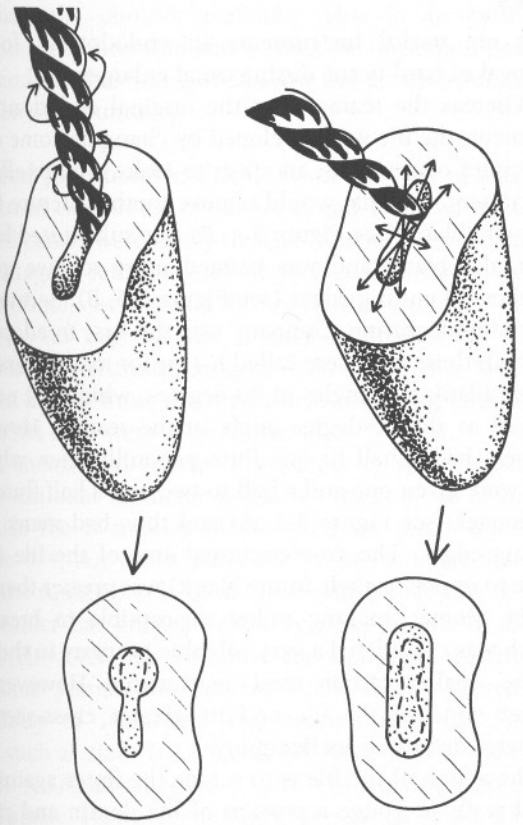


FIGURE 5-3 Many roots are oval in cross section, and yet may have a single oval canal. If the dentist attempts to prepare such a canal with reaming action *(top left)*, the result will be a canal with a keyhole shape *(bottom left)*. This canal is overprepared in one segment *(the upper pole)* and hardly prepared through the remainder of the canal—an undesirable situation. However, circumferential filing *(top right)* involves placement of the file and dragging it out against peripheral walls, emphasizing buccolingual directions. The result *(bottom right)* is a wider oval that is enlarged in all dimensions and may be filled with compressible materials. This method also enhances making the orifice portion as wide as possible without gutting the crown. Circumferential filing is modified in some canals by anticurvature filing (see Figure 5-14, *E*).

it will be wider buccolingually as well. In these cases the circumferential filing is emphasized in the buccolingual direction. The oval canal is made into a wider and larger oval. This permits easier placement of precurved instruments, gutta-percha cones, and finger spreaders.

Circumferential filing is modified by anticurvature filing (see Figure 5-14, *E*) when flaring the mesial canals of maxillary and mandibular molars and some other curved canals. This alteration will be addressed later in this chapter in response to avoiding strip perforations.

Studies have shown that the action of using the instrument, rather than the instrument used, determines the general shape of the canal preparation. Therefore reaming action produces a canal that is relatively round in shape. The use of filing action develops a preparation that is irregular, usually increasing any eccentricities in the original canal shape.

Reamers

Reamers were the original intracanal instruments, used since the nineteenth century for removal of the contents of the pulp canal and for widening and smoothing the canal walls. They are manufactured by twisting triangular blanks (Figure 5-4, *A*) to produce cutting edges (Figure 5-5, *A*). Because each angle of the blank is approximately 60 degrees, a sharp knifelike edge is available to shave and reduce canal walls. The cross-sectional area of the blank is not excessively wide, so the instrument has a high degree of flexibility.

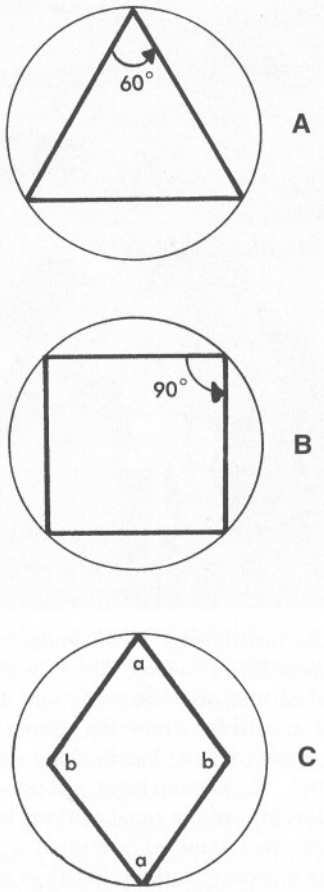


FIGURE 5-4 Shapes of blanks for basic instrument systems, which are twisted to give a different type of instrument. A, Triangular blank, as classically used for the reamer but now used in some files, has three angles of 60° each to provide cutting efficiency and a moderate cross-sectional diameter for flexibility. **B,** Square blank, as classically used for the file, has four angles of 90° each, not as sharp as those of the triangular blank, with a wide cross-sectional diameter that decreases flexibility. **C,** Diamond blank, as used for the K-Flex file, has opposite angles equal. Angle *a* is less than 90°, sharper than those of the square blank, but these are the only two cutting angles. The cross-sectional diameter is narrower than the square blanks of the same size, so this instrument has greater flexibility. Angle *a* plus angle *b* always equals 180°.

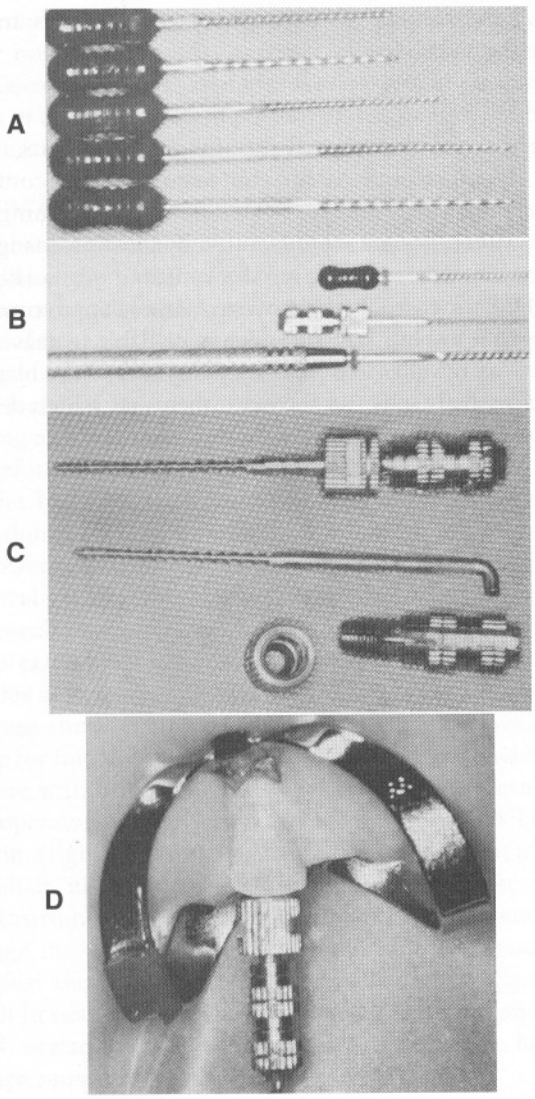


FIGURE 5-5 **A,** Instruments are manufactured in different lengths as well as widths. *From top,* File, 21 mm; reamer, 21 mm; two files, 25 and 31 mm; and reamer, 31 mm. **B,** Different types of handles are available. *From top,* Short plastic handle, measurement control (or test) handle, long metal handle (very rarely used now). **C,** Measurement control handle *(top)* is adjustable to allow for varying canal working lengths. Assembly consists of a file shaft *(middle)* placed in a handle and bolt *(bottom)*. **D,** Once correct working length is set, bulky handle prevents overinstrumentation of apex by being physically stopped by incisal edge of tooth.

Reamers are used during canal preparation to shave dentin. When used with a rasping action, they are less efficient than a file. They remove intracanal debris with clockwise reaming action and are used in this manner to remove old gutta-percha canal fillings that have been softened with chloroform or xylene. By turning reamers counterclockwise, the dentist can place materials such as root canal sealer and creamy medicaments in the apical portion of the canal.

Files

Files are useful instruments in endodontics for the removal of hard tissue during canal enlargement.

Whereas the reamer was the original endodontic instrument, the file was developed by changing some of the principles of design in an effort to make a more efficient instrument, one that would remove tooth structure faster. A square blank (see Figure 5-4, *B*) was substituted for the triangular blank and was twisted more to give greater numbers of cutting edges (see Figure 5-5, *B*). Because the Kerr Manufacturing Company was the first to adopt this method, these files were called *K-type* for many years. The square blank had angles of 90 degrees, which did not cut as well as the 60-degree angle of the reamer. However, reamers had a half to one flute per millimeter, whereas files were given one and a half to two and a half flutes per millimeter (see Figure 5-5, *A*) and thus had many more cutting edges. The cross-sectional area of the file (from angle to opposite angle in the blank) was greater than that of the reamer, making it less susceptible to breakage, which was considered a very valuable property in the days of the weaker carbon steel instruments. However, the tighter wind of the file and its greater cross-sectional diameter decreased its flexibility.

The action of the file is to scrape the flutes against the canal walls to gouge a portion of the dentin and pull it from the canal. This action requires periodic cleaning of the instrument by the operator so the dentin shavings do not clog the flutes.

Files are efficient removers of tooth structure in any one of three techniques because of the multiplicity of cutting edges. They may be used with rasping or pure filing action only, in which they are placed in the apical portion of the canal carefully and dragged against one wall of the canal during removal. They may be used with quarter-turn filing, in which the instrument is carefully placed, rotated 90 degrees, and dragged out at the same time. They also may be used with pure reaming action and turned as they enter the canal.

Files alone may be adequately used in canal preparation. Some techniques suggest the use of reamers first and then files of the same size before going to the next greater width. The rationale for such a method is that the reamer used clockwise removes debris remaining within the canal and that, because reamers may be slightly smaller than files, enlargement is facilitated. I have not found this necessary. Heavy and frequent canal irrigation followed by aspiration of excess lavage fluid will satisfactorily remove canal debris and dentin filings. Also, some companies manufacture reamers larger than files, or this difference may occur because of inaccurate quality control of instrument width.

Virtually no innovations in instrument design occurred since Kerr began making files early in the 1900s. Then, suddenly, in a year's time, several startling changes occurred in instrument manufacturing that tremendously

widened the choices available. This is an extremely advantageous situation and verifies the important position that endodontics has gained with the general public and the dental community.

Need for Flexible Files. From the start of this century until the 1970s, molar teeth and teeth with sharply curved canals were rarely treated. When they were, a high percentage of failures resulted. In fact, Grossman wrote in his textbooks as late as 1967 that teeth with canal curvatures of 45 degrees and greater could not be treated successfully without surgery. Although this was not known at that time, the reason was that most endodontic files used then were rather inflexible.

As mentioned in the discussion of files, increasing cross-sectional diameter decreases instrument flexibility. Because the triangular blank, used for the reamer (see Figure 5-4, *A*), has a narrower cross-sectional diameter than the square blank, used for the file (see Figure 5-4, *B*), the reamer has greater flexibility than the file in similar sizes. However, files became the dominant instrument for canal preparation, and as such, a total decrease in flexibility of intracanal instruments resulted. Smaller files, such as sizes 10, 15, and 20, have narrow diameters (Table 5-1) and thus have sufficient flexibility to retain canal shape. However, in larger sizes, such as 30, 35, and 40, the files lose their flexibility very quickly, and alterations of canal shape may be devastating (see Figure 5-23).



TABLE 5-1 Diameters of Standardized (.02 taper) and .04 Taper Instruments

	Diameter (mm) at		
Instrument no.	D_0 (original D_1)	D_{16} (original D_2)	.04 D_{16}
08	0.08	0.40	NA
10	0.10	0.42	0.74
15	0.15	0.47	0.79
20	0.20	0.52	0.84
25	0.25	0.57	0.89
30	0.30	0.62	0.94
35	0.35	0.67	0.99
40	0.40	0.72	1.04
45	0.45	0.77	1.09
50	0.50	0.82	1.14
55	0.55	0.87	1.19
60	0.60	0.92	1.24
70	0.70	1.02	1.34
80	0.80	1.12	1.44
90	0.90	1.22	1.54
100	1.00	1.32	1.64
110	1.10	1.42	NA
120	1.20	1.52	NA
130	1.30	1.62	NA
140	1.40	1.72	NA

NA: Not available.

To maintain shape in these curved systems, operators decided to keep canal preparation minimal, which may not have allowed for sufficient cleaning. Also, it was difficult to use a good condensation system to fill these minimally enlarged canals, so failures from inadequate filling were common. The result was that as an increased demand for treatment of these more complicated teeth occurred, it was necessary to develop new file systems.

In its first design change in more than 60 years, the Kerr Manufacturing Company modified its basic blank to develop the K-Flex file (see Figure 5-4, *C*). Rather than using a square or triangular blank, a diamond-shape blank was employed (see Figure 5-4, *C*) to decrease the cross-sectional diameter (the distance between the two *b*s in Figure 5-4, *C*) and impart greater flexibility to the instrument. Because of this shape, only two angles of the K-Flex would cut into the dentin (angles *a* in Figure 5-4, *C*). However, because these working angles were approximately 80 degrees, sharper than the 90-degree angles of the file, their cutting ability was compensated somewhat, even though only two angles were present. Once the blank was twisted, there was an increased space between the working edges so more debris could be removed per outstroke.

The implication of instrument flexibility and other designs for flexible file systems will be discussed later in this chapter, dealing with preparation of curved canals. Because of the improvement in final canal shape provided by flexible files, many other manufacturers developed their own file systems with these properties.

Hedstrom Files. Hedstrom files have flutes that resemble successively smaller triangles set one on another (Figure 5-6). They are manufactured by means of a sharp, rotating cutter that gouges triangular segments out of a round blank shaft in the same manner that wood screws are made. This produces a sharp edge that will cut on the removing stroke only. This process differs from that used for the standard reamers and files, which are made by twisting blades of triangular, square, or other shaped blanks. Several new designs have also been made by gouging, including the U-file and the Triocut.

The Hedstrom file, also called the *H-file,* has two serious drawbacks. It is weakened at each position of gouging during manufacture, resulting in a place for fracture if the flutes bind in dentin and the handle is rotated. Also, if it is handled incorrectly and rotated clockwise after binding in dentin, its screwlike configuration may further drive the instrument apically and crack the weakened and stressed root.

However, the Hedstrom file is an extremely effective cutting instrument because of the sharpness of the flutes. If used carefully, with filing action only, it will successfully plane the dentin walls much faster than the K-type of files or reamers. The Hedstrom files are especially indicated in the instrumentation of immature teeth, where the walls

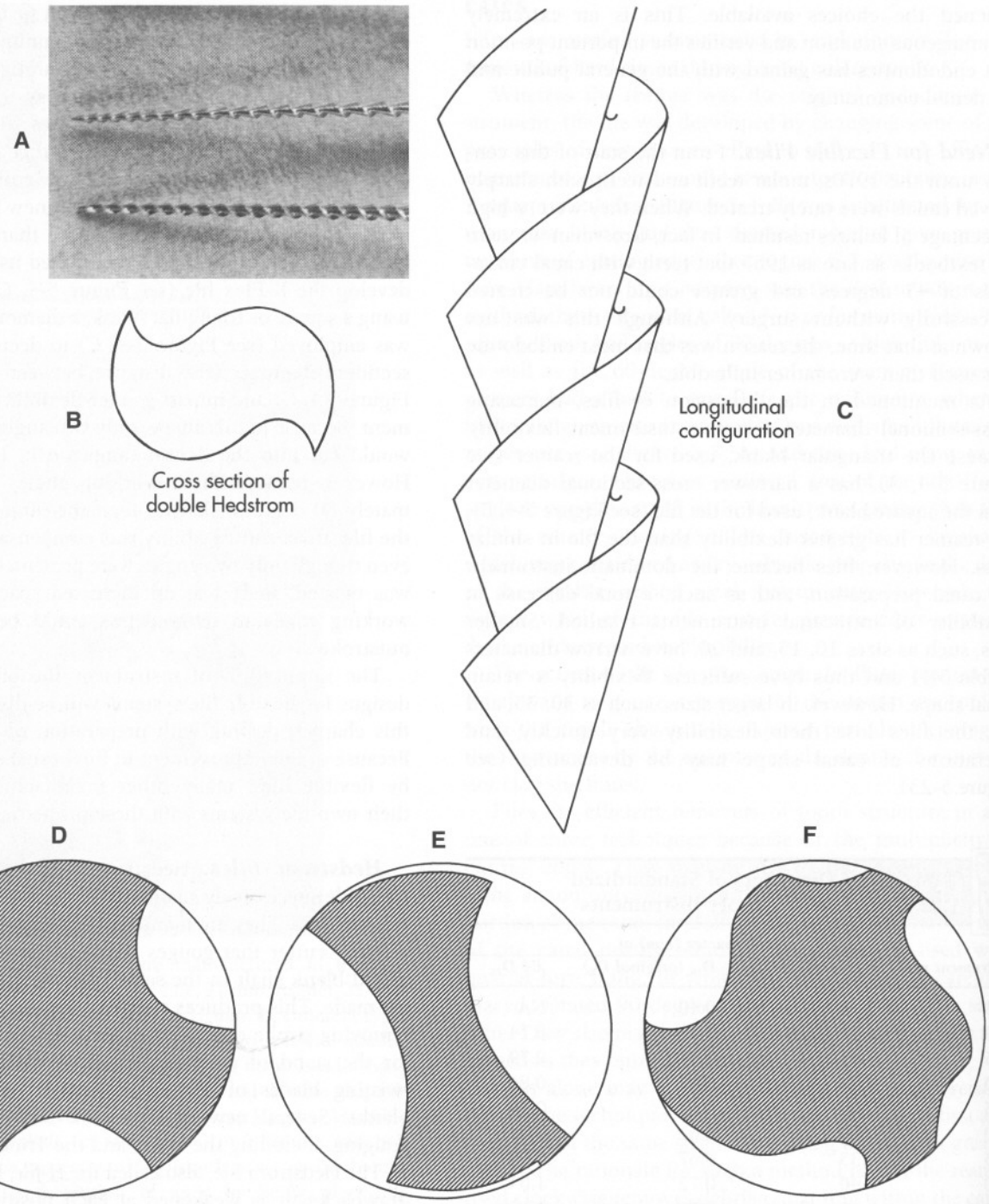


FIGURE 5-6 Types of file systems that are ground, not made from twisted blanks. A, *Top,* Hedstrom file (also called the *H-file*), and, *bottom,* double Hedstrom design, originally called "Burns Uni-File," now called *S-File* because of cross-sectional shape, **B,** indicating two rake angles for increased cutting ability. Wide cross-sectional diameter results in decreased flexibility for the S-File compared with the Hedstrom. **C,** Longitudinal configuration of the S-File demonstrates the design that allows it to cut deeply on the outstroke, minimizing packing of dentin into the apical portion of the preparation. **D,** Cross section of file referred to as *U-file,* because of the three U-shaped cuts ground from a circular blank. This shape is used in the .04 tapered instruments manufactured by Dentsply/Tulsa Dental (see Figure 5-12, *A*) and Dentsply/Maillefer (see Figure 5-12, *B*). **E,** Cross section of file type used in some of the Quantec series now manufactured by Sybron/Kerr. **F,** Cross section of K-3 file, also manufactured by Sybron/Kerr. This is a departure from most other ground blanks in that the segments of the instrument are asymmetrical. Because of the relatively large cross-sectional diameter, this instrument probably is more resistant to fracture but is much less flexible than the other instruments shown.

are irregular and may harbor considerable debris. These instruments are also useful in removing silver points or loose broken instruments from canals. The file is placed alongside the material to be removed, then rotated, and pulled toward the occlusal (or incisal) surface. If successful, the file flutes will hook into the point or broken instrument, break any retention within the canal, and deliver it. When the file is used to remove silver points, canal irrigation with chloroform to dissolve the root canal sealer should precede an attempt at dislodgement.

The Hedstrom and the other gouged instruments are strong, aggressive cutters. As such, they are potentially hazardous in the medium sizes of the apical portion of curved canals. For the same reason, however, they are excellent in widening straight canals or the straight, more coronal portion of curved canals. These files are well suited for performing preflaring or early flaring procedures, widening the orifices of any canals for easier placement of smaller instruments.

Additional Gouged Instruments Recently Developed. Because of the sharpness and the speed afforded by the Hedstrom file, other gouged blank instruments have been introduced in the past 10 years. The U-file is a radial-landed instrument with three grooves in a "U" shape, cut out of the blank. The edge where the groove is cut and the circumference of the file is quite sharp and cuts dentin in either direction when the file is rotated (see Figure 5-6, *D*). This shape is used in the .04 and greater tapered instruments manufactured by Dentsply/Tulsa Dental and Denstply/Maillefer (see Table 5-4) and will be discussed later in this chapter.

The Quantec file system was also created by gouging blanks, but for some of these instruments only two wider grooves were cut and raised edges produce sharp cutting areas (see Figure 5-6, *E*). A very recent entry into this field has been the K-3 file system that has three radial-landed cutting areas, each of a different, or asymmetrical, shape (see Figure 5-6, *F*). This instrument has a wider cross sectional diameter than any of the other ground instruments, so it probably is more resistant to fracture. However, this same increase in diameter means that it also is less flexible. Although the asymmetrical shape makes for an interesting design, it is difficult to see its value when used in a rotating handpiece that delivers the flutes equally around the periphery of its cutting with each complete turn.

Styles of Instruments

Files and reamers come in different lengths and widths and with various types of handles (see Figure 5-5). The shorter instruments are excellent for use in posterior teeth, but extremely long teeth, particularly maxillary cuspids, require those with the longest shaft.

The measurement control handle (or test handle) may appear to be bulky and uncomfortable to use but is extremely useful for the dentist who confines endodontic efforts to single-rooted teeth. The length of instrument is governed by the handle, which physically stops the tip from penetrating too far past the cusp or incisal edge (see Figure 5-5, *C* and *D*). Once the working length of the tooth is correctly established, the files may be set and instrumentation carried out without fear of unintentional overinstrumentation due to misreading of the stop.

For many years it was common practice for any dentist, even a specialist, to use one type of endodontic file system. Whatever type or condition of canal was encountered, that one system had to do the job. Recent studies have indicated that if a large variety of teeth are to be treated, several types of file systems will be necessary, perhaps even including both hand and mechanical instruments. The more flexible files are best used in curved canals but take too long for work in wider, straight canals. Aggressive files or mechanical instruments are well suited for flaring but are dangerous at the tips of curved canals.

Standardization

One of the most significant advances in endodontics has been the installation of a standardized system for intracanal instruments. As originally suggested by Ingle, this logical but long-overlooked development has been one of the greatest aids in bringing endodontic procedures within the scope and ability of the average dentist.

Prestandardization Instruments. Before the establishment of standardization, endodontic instruments were numbered from 1 to 12. There was no system for determining instrument taper. The larger files and reamers usually had a greater taper than the smaller sizes, thereby causing great difficulty in uniformly enlarging the entire extent of the canal.

Gutta-percha cones and silver points similarly differed among manufacturers as to taper and length. Although the same numbering system was used for silver points as for files and reamers, these numbers did not necessarily correspond, even with the same manufacturer. Gutta-percha was identified by complicated descriptive terms—fine-fine, extra-fine, fine-medium, medium, fine, coarse, etc.—that in no way really defined anything about the dimensions of the material.

Landmarks of Standardized Instruments, Original and Revised. In 1957, Ingle established a logical nomenclature for a standardized instrument so that all manufacturers could conform in length, width, and taper to a specific standard. In the instruments of sizes 1 through 12, the numbers themselves meant very little. A size 3 meant that this instrument was larger than a size 2 and smaller than a size 4. The same number did not apply to different manufacturers, and in different years a specific manufacturer could alter any instrument size. Although