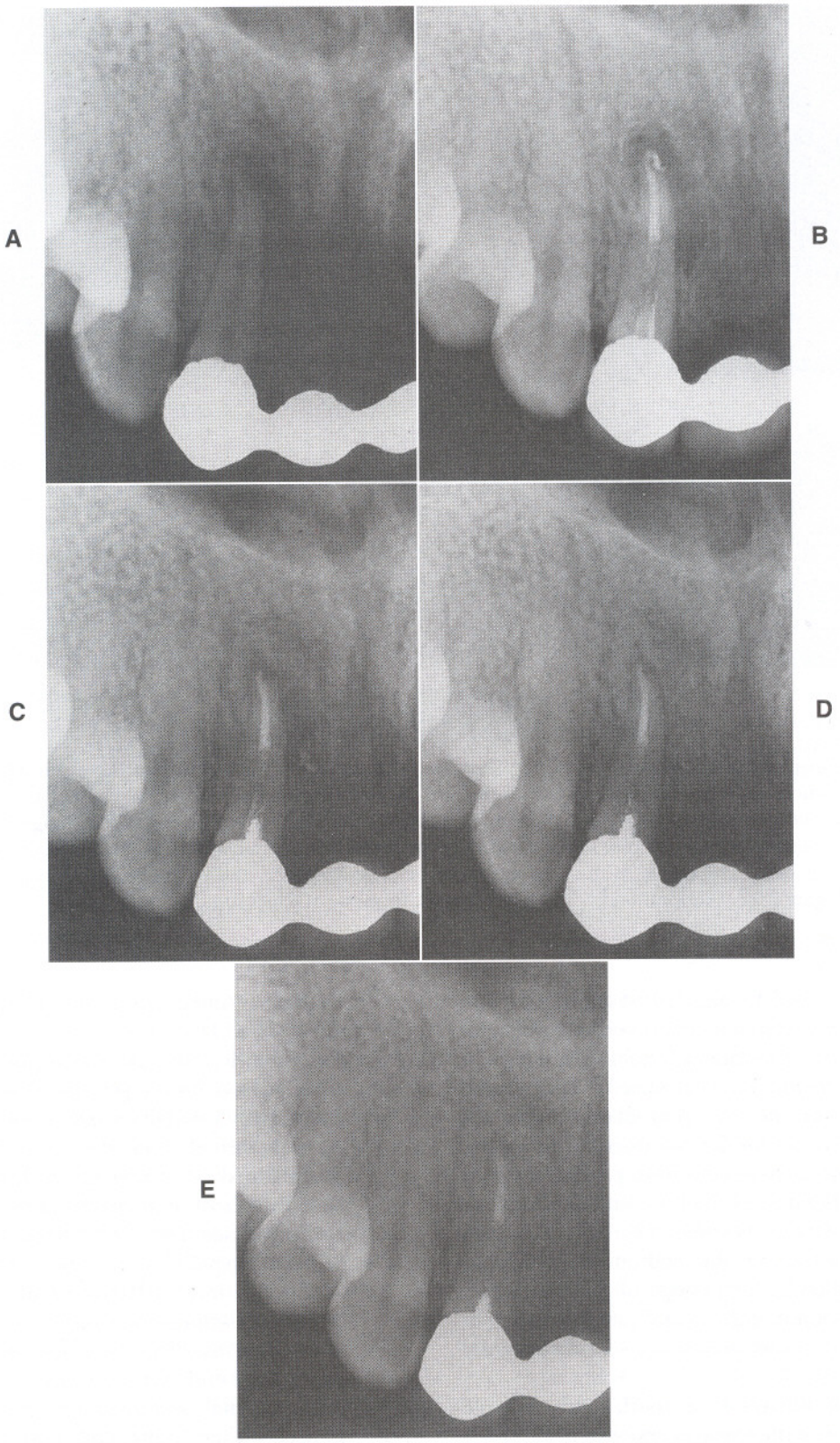


FIGURE 2-16 **A,** Maxillary lateral incisor with periapical radiolucency that has extended along mesial surface of the root. Note similarity of this lesion to those shown in Figures 2-14, *A,* and 2-15, *A.* **B,** Canal filling with laterally condensed gutta-percha and Wach's paste as sealer. No sealer was expressed to the lateral radiolucency, although some sealer was expressed beyond apex. **C,** Six months later, area has decreased in size. Excess sealer from apex has moved down lateral radiolucency, probably by phagocytic action. If this view only were seen without **B,** it could be assumed that a lateral radiolucency with demonstrable lateral canal was present. **D,** One year after treatment, area has almost healed. **E,** Two years after treatment, healing is complete. Some sealer is still present within the bone of mesial surface of treated tooth.

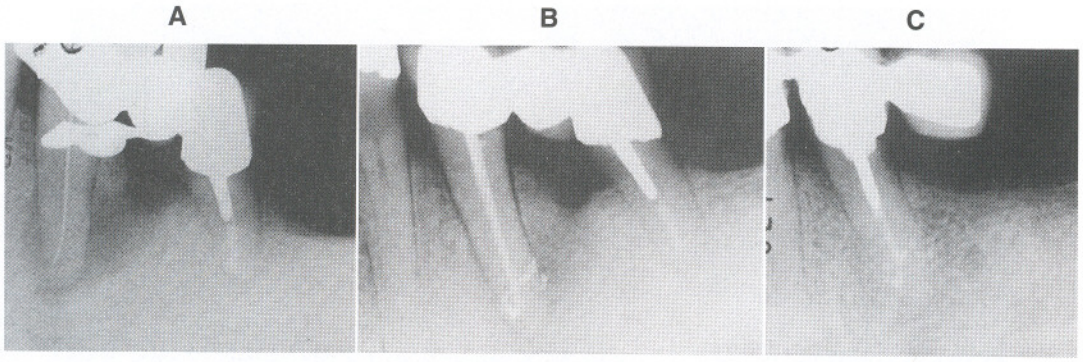


FIGURE 2-17 "Wraparound" lateral canal. A, Radiograph of file in place on mandibular second bicuspid, indicating canal exiting mesially. A sinus tract was present to the distal portion of the tooth, and the film indicates the lesion exiting distally. **B,** Immediate postfilling film after laterally condensed gutta-percha and Kerr's Antiseptic Root Canal Sealer. Several lateral canals are present, with the sealer wrapping around from the mesial to the distal either on the buccal or lingual portion of the root. **C,** Posterior abutment has been lost due to periodontal disease, but 11 years after treatment, the periapical lesion has healed perfectly whereas the path of sealer, although slightly resorbed, is still apparent. (Restorations by Dr. Maurice Slivnick, formerly of Skokie, Ill.)

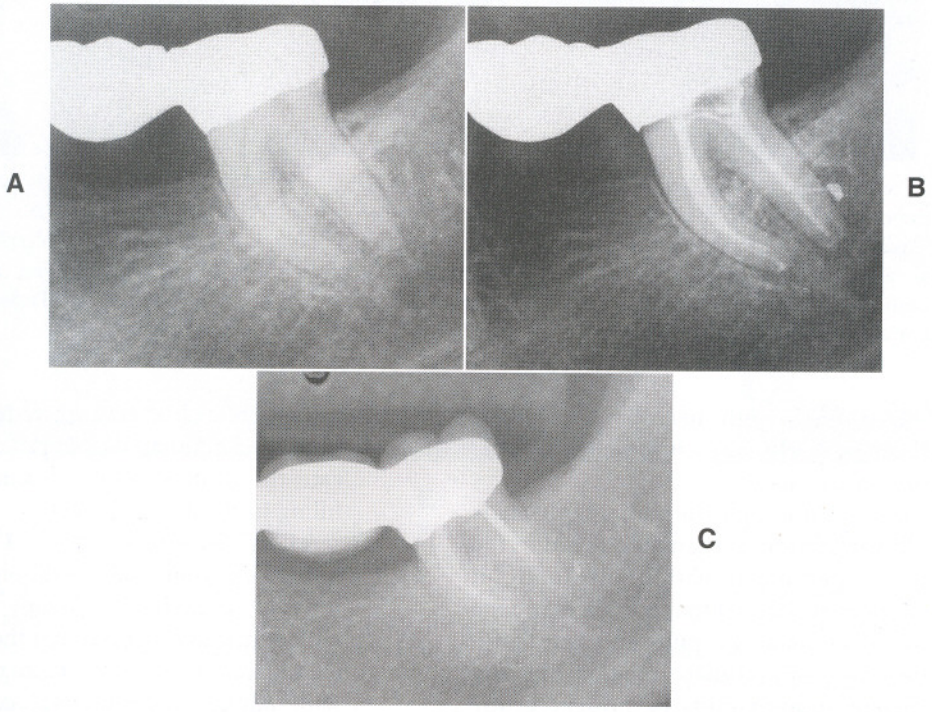


FIGURE 2-18 A, Preoperative film of mandibular second molar, with clinical symptoms of pulpitis thought to be caused by large restoration. No periapical or lateral lesions were seen in association with the tooth. An access cavity was prepared at an emergency appointment, the pulp extirpated, and all symptoms disappeared. The patient had been very pleasant and cooperative for several other endodontic cases, but for various reasons, it took almost 6 months to complete treatment for this tooth. **B,** Viewing this film after filling with laterally condensed gutta-percha and Kerr's Antiseptic Root Canal Sealer indicated two large lateral canals, both in association with lateral lesions, that were quite unexpected. The lateral lesions apparently had developed during the long period that it had taken to complete treatment. A possible cause for the pulpitis is now apparent as the caries on the mesial side. **C,** Nine years after treatment, perfect healing of the lateral areas has occurred. (Restoration in *C* by Dr. Kerry Voit, Chicago.)

the canal yielded a filling with sealer entering the lateral lesion (Figure 2-21, *E*). Excellent healing followed (Figure 2-21, *F* and *G*).

When a sinus tract is traced with a gutta-percha cone and the marker goes to a lateral surface of the root (see Figure 2-28, *A* and *B*), it probably indicates a lateral canal lesion, a root perforation, or a cracked tooth.

In summary, lateral canal lesions are interesting, may have several types of configurations, and can be indicated by a variety of filling techniques. In my opinion, they are much more likely to be

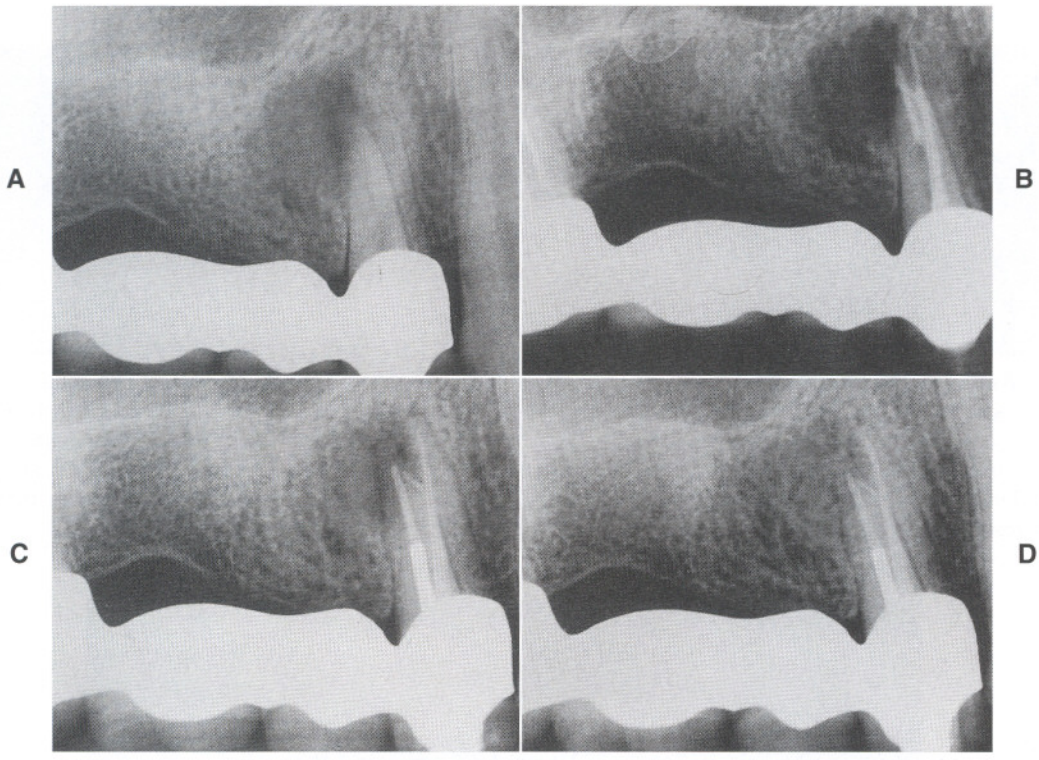


FIGURE 2-19 **A,** Preoperative film of maxillary first bicuspid, indicating large periapical radiolucency with considerable distal extension of the lesion, a condition often seen with lateral canal lesions (see also Figures 2-15 and 2-20). **B,** Although I did not anticipate a lateral canal for this case, when I filled the canals with laterally condensed gutta-percha and Kerr's Antiseptic Root Canal Sealer, a large lateral canal was demonstrated, branching off several millimeters from the tip of the palatal root (root to the right) to the buccal area. Post room was prepared in the buccal canal. **C,** Excellent healing 1 year after treatment. **D,** Perfect healing 5 years after treatment, with material in the lateral canal still visible. (Restoration by Dr. Morton Rosen, Chicago.)

demonstrated in teeth with necrotic pulps and, although occurring rarely, may cause problems after seemingly correct treatment.

9. *Periodontal defects.* Although the radiograph made before endodontic therapy is examined to aid in the treatment to be performed within the tooth, it should always be remembered that the alveolar bone holds the tooth. Because the pulp and the periodontal tissues have an intimate relationship and because sufficient support must be present before endodontic therapy is performed, the periodontal condition must always be evaluated.

   The finding of a periodontal pocket, even an extensive one, does not necessarily indicate that endodontic therapy will be fruitless on the tooth. It is not only important to examine the tooth to be considered for treatment, but also to evaluate the periodontal condition of the other teeth. Figure 2-22 illustrates a case in which the mandibular molar, which had already received endodontic treatment, had a pocket in the furcation that could be probed from the labial direction. The patient was young, and no other areas of even moderate periodontal disease were present. Because the endodontic treatment did not appear adequate (see Figure 2-22, *A-C*), it was decided to attempt re-treatment. The subsequent radiographs (see Figure 2-22, *F* and *H*) indicate the desired result obtained, bone completely filling in the area of defect.

   Many cases in Chapter 11 illustrate seemingly hopeless periodontal conditions alleviated successfully by endodontic therapy alone or combined endodontic and periodontal therapy. This statement should not be misconstrued to suggest that teeth with advanced periodontal conditions should be treated endodontically on a routine basis. Teeth with obvious periodontal defects and no indication of pulpal involvement would not gain in longevity if the canals were cleaned and filled. However, the suggestions for proper evaluation of periodontally involved teeth stated in Chapter 11 must be considered always.

The mesial and/or distal angulation view should add the following information.

1. *Number of roots present.* Although the straight-on view normally indicates the number of roots present in molars, the angle view is the one that discloses unanticipated root bifurcations. The additional roots are superimposed in the direct view and would lead

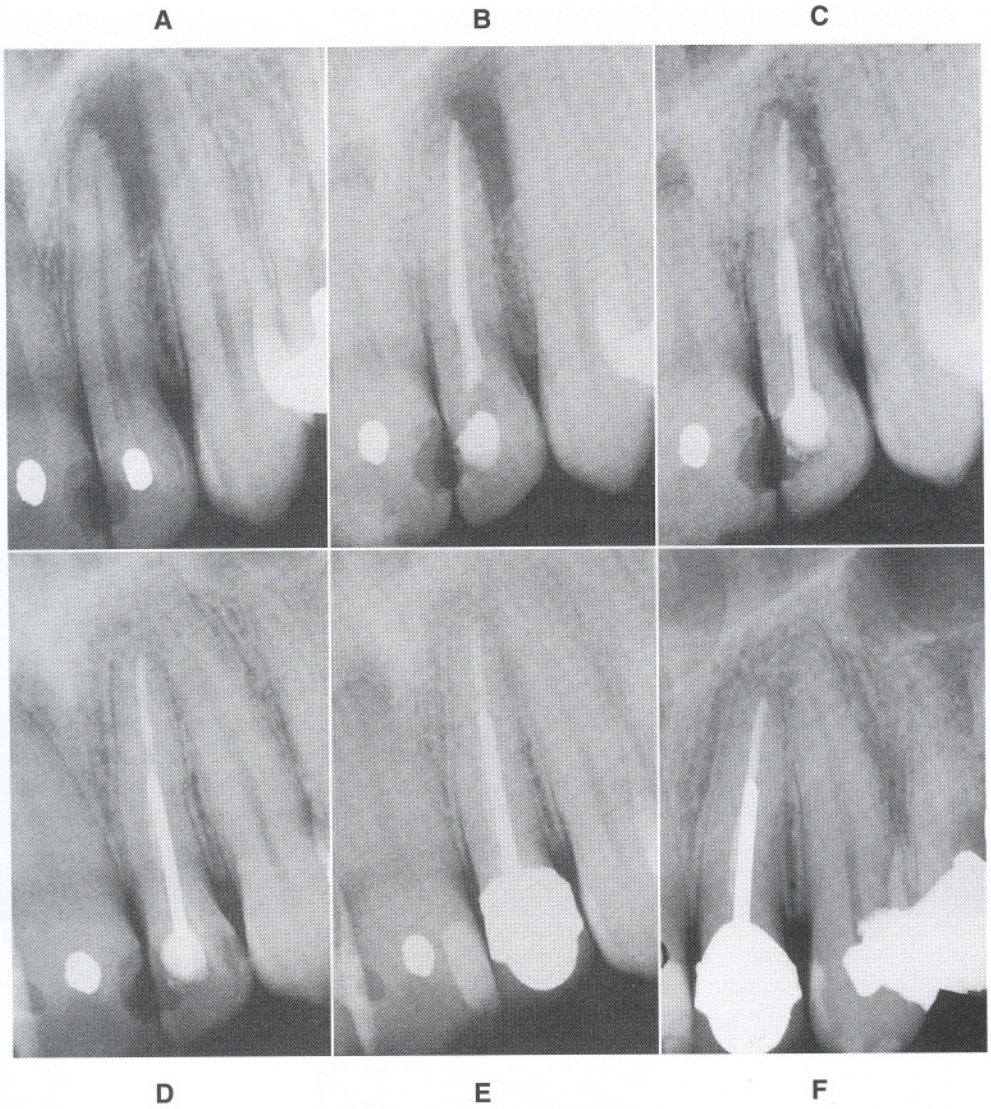


FIGURE 2-20 Lateral lesion deflecting adjacent tooth. A, Preoperative film of maxillary lateral incisor, with lesion extending slightly apically but considerably distally, a sign often indicative of a lateral canal lesion. **B,** Immediately after filling with laterally condensed gutta-percha and Wach's paste, a lateral canal is demonstrated, coursing exactly to the distal portion of the lesion. **C,** After 1 year, lesion has decreased considerably, and it appears that the distance between the lateral and adjacent cuspid has decreased. Note that the contact areas on both the mesial and the distal are identical to those shown on film *A*. **D,** Two years after treatment, with complete healing. Lateral incisor and cuspid are very close to each other at their apices. **E,** Six years after treatment. **F,** Twenty-two years after treatment, still perfect healing. Note continued proximity of apices of lateral incisor and cuspid. (Restoration by Dr. Arnold Wax, Chicago.)

to false information if no additional views were taken (Figure 2-23).

2. *Number of canals present.* The presence of a tooth with a single root does not necessarily indicate a single root canal. A bifurcated canal or separate canals may be present in any root, with the possible exception of maxillary incisors. Such an occurrence is certainly not infrequent in single-rooted bicuspids (both mandibular and maxillary), distal roots of mandibular molars, and mesiobuccal roots of maxillary molars. They may be found in mandibular anterior teeth as well. Because of superimposition in the straight-on radiograph, the angle view is most important in this determination (Figure 2-24, *A* and *B*).
3. *Presence of buccal or lingual root or canal curvature.* These conditions may not be seen in the direct view, but indications are seen in the angle film.

All the intraoral views should show the apices of the tooth and some degree of the surrounding periapical tissue. If a radiolucency is present, one of the views must reveal the complete limits of the

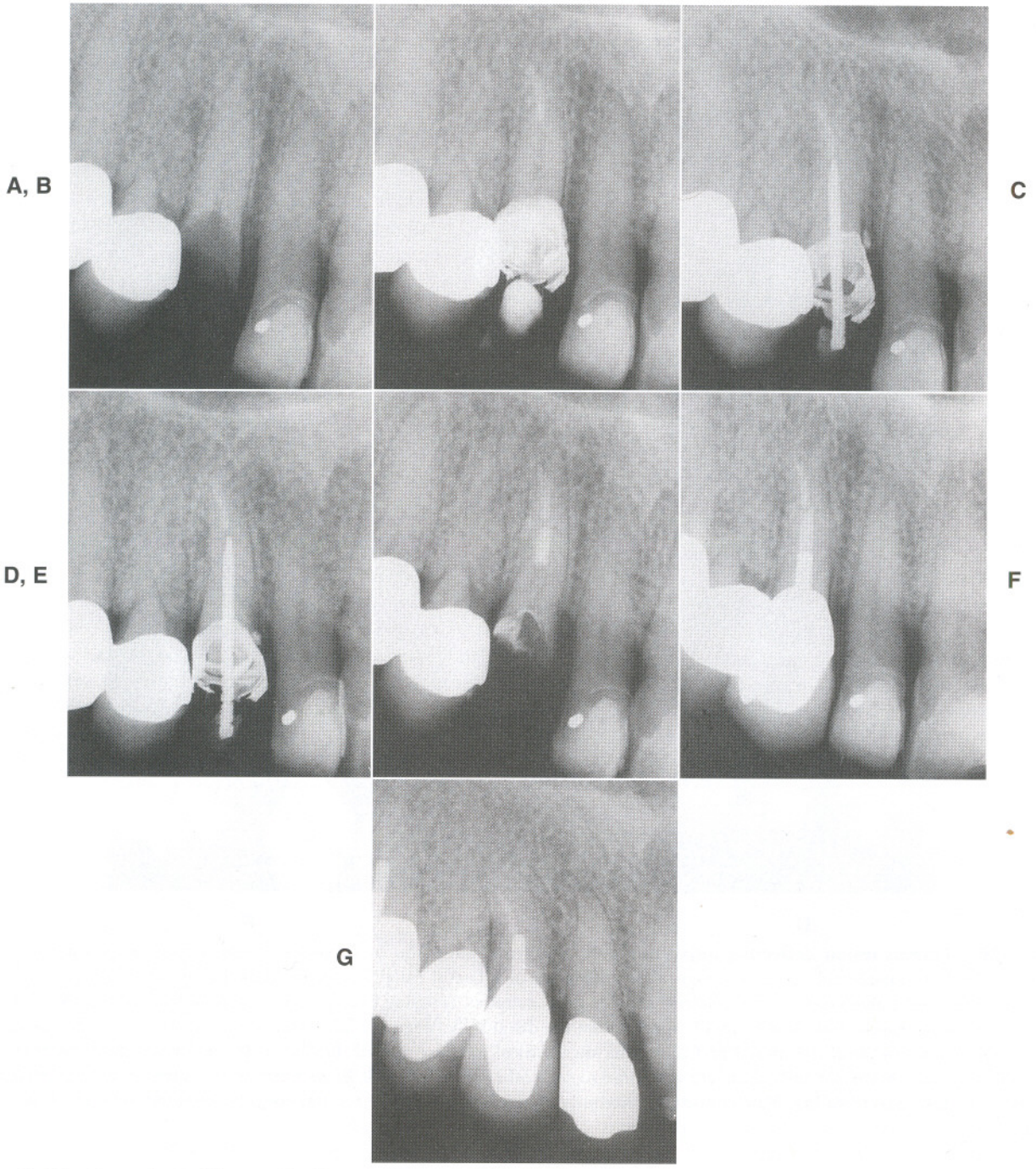


FIGURE 2-21 Lateral canal lesion developing after canal filling and post room preparation. A, Preoperative film of maxillary cuspid. Considerable decay beneath the gingival margin is apparent. No periapical or lateral lesions are present, and the pulp was vital. **B,** Cooperative referring dentist constructed a temporary crown with a contoured metal band and acrylic, allowing me to treat the tooth with a well-adapted rubber dam to maintain asepsis. Canal filled with laterally condensed gutta-percha and Wach's paste, with post room prepared as long as possible due to necessarily considerable length of the anticipated clinical crown. **C,** Crown could not be completed because the patient became quite ill. This film, taken 6 months later, indicated possible development of a lateral lesion adjacent to the post space. **D,** Patient was forced to undergo cardiac surgery, further setting back restoration. This film was taken 1 year after completion of endodontic treatment, and now there is an obvious lateral lesion. The root is tender to palpation in the proximity of the lesion. **E,** Small portion of the canal filling apical to the post room was removed. The apical segment of the post room was reprepared and filled with laterally condensed gutta-percha and Kerr's Antiseptic Root Canal Sealer. This film was taken 3 months later, indicating healing of the lesion. The root is no longer tender to palpation. **F,** Eighteen months later, a post/core system and crown have been constructed, lesion has healed, and area looks excellent. **G,** Eleven years after original treatment, another post/core and crown were constructed, but area continues to look excellent. (Restoration by Dr. Steve Potashnick, Chicago.)

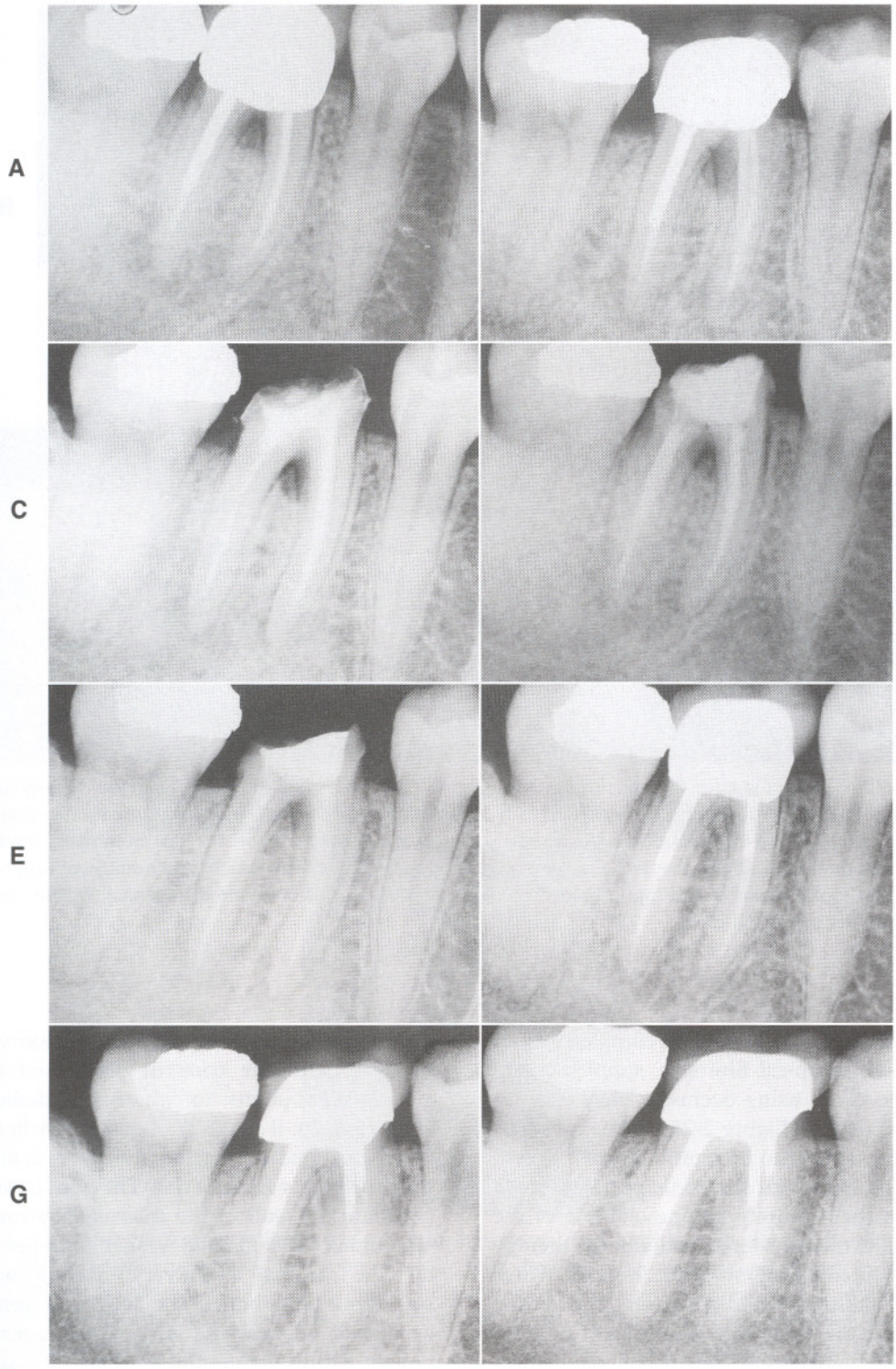


FIGURE 2-22 **A,** Preoperative view, straight, and **B,** angled view of mandibular first molar. Tooth had received endodontic treatment, but periapical lesions were present on both roots. Even worse, a pocket could be probed into the furca, and some mobility was present. **C,** Crown and post were removed, and floor of the chamber was examined to see if any perforations or other causes for furcal involvement were present. There were none. Patient was otherwise free of periodontal problems. Accordingly, the existing canal fillings were removed. The distal canal could be instrumented to a desirable site, but not much length could be gained in the mesial canals. **D** and **E,** Straight and angled views after canal fillings with laterally condensed gutta-percha and Wach's paste as sealer. The furca was no longer probeable. **F** and **G,** Straight and angled views 2 years after treatment. The periapical areas healed, the pocket in the furca could not be probed, and the tooth was tight. **H,** Ten years after original treatment, furcation area remains normal, with periapical lesions healed. (Restoration by Dr. Doug Shindollar, Chicago.)

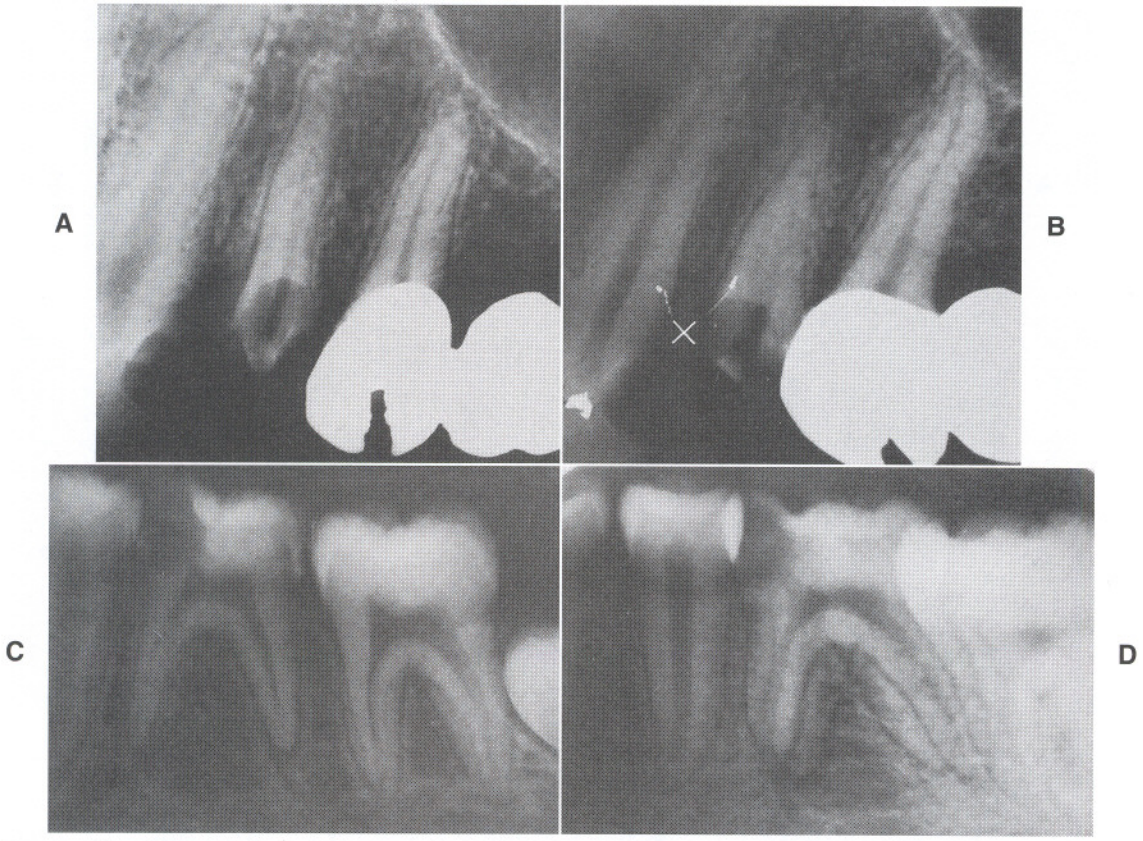


FIGURE 2-23 Maxillary bicuspids have the greatest variation in root and canal configuration. Therefore radiographs from straight and angled positions are necessary to clarify the condition to be treated. **A,** Straight-on view gives information concerning the relative size and shape of the canal, but no information on the number of roots and canals present. **B,** View from distal toward mesial aspect (identified by the x placed on film) shows that two roots are present. Mandibular molars may have a number of variants, too. **C,** Direct view of mandibular first molar seems to indicate presence of two mesial canals but only one distal canal. **D,** View toward distal side shows two separate and distinct distal roots.

defect. If the defect is too large to be completely seen in one view of periapical film size, supplementary films must be taken using occlusal, lateral jaw, or panoramic exposures (Figure 2-25). Certain lesions of the jaws may appear to be typical of those due to pulpal pathosis, except for size or shape. Unless they are viewed in their entirety by one or more of the supplemental extraoral views, endodontic therapy might be instituted on a tooth unnecessarily. Worse yet, the true condition would not receive the needed treatment until the error was determined. Because some of these conditions are potentially dangerous, loss of time might be extremely serious.

Radiographs for Tracing

The dentist should take supplemental radiographs whenever a chronic draining sinus (fistula) is found, to be certain as to the source of the tract. A gutta-percha cone of approximately size 30 is gently placed into the tract with cotton forceps until a solid stop is felt (Figure 2-26). This is usually performed without any need for anesthesia, but in rare cases an injection is necessary. A radiograph is taken with the cone in place, and the tip of the gutta-percha points to where the drainage originates (Figures 2-26, *B* and 2-27, *A* and *B*). Orthodontic wire has been suggested for tracing a chronic draining sinus, but gutta-percha is far superior. The wire is sharp enough to perforate the wall of the tract and burrow into another site, which the softer and weaker gutta-percha is unable to do. The tract may take a very tortuous route through the soft tissue and bone. The wire will penetrate and go erratically, whereas the gutta-percha cone will probably remain within the confines of the tract (see Figure 2-27, *B*). This is most useful in determining whether the sinus is from a pulpal or a periodontal condition, which tooth is involved, or which root of a multirooted tooth is responsible. It is surprising how frequently the cause of the draining is found to differ from the apparent culprit.

Periodontal lesions may also be traced radiographically to determine their depth and extent. A silver point of approximately size 30 is placed into the tract until it is stopped by the sulcus depth or bone and is then

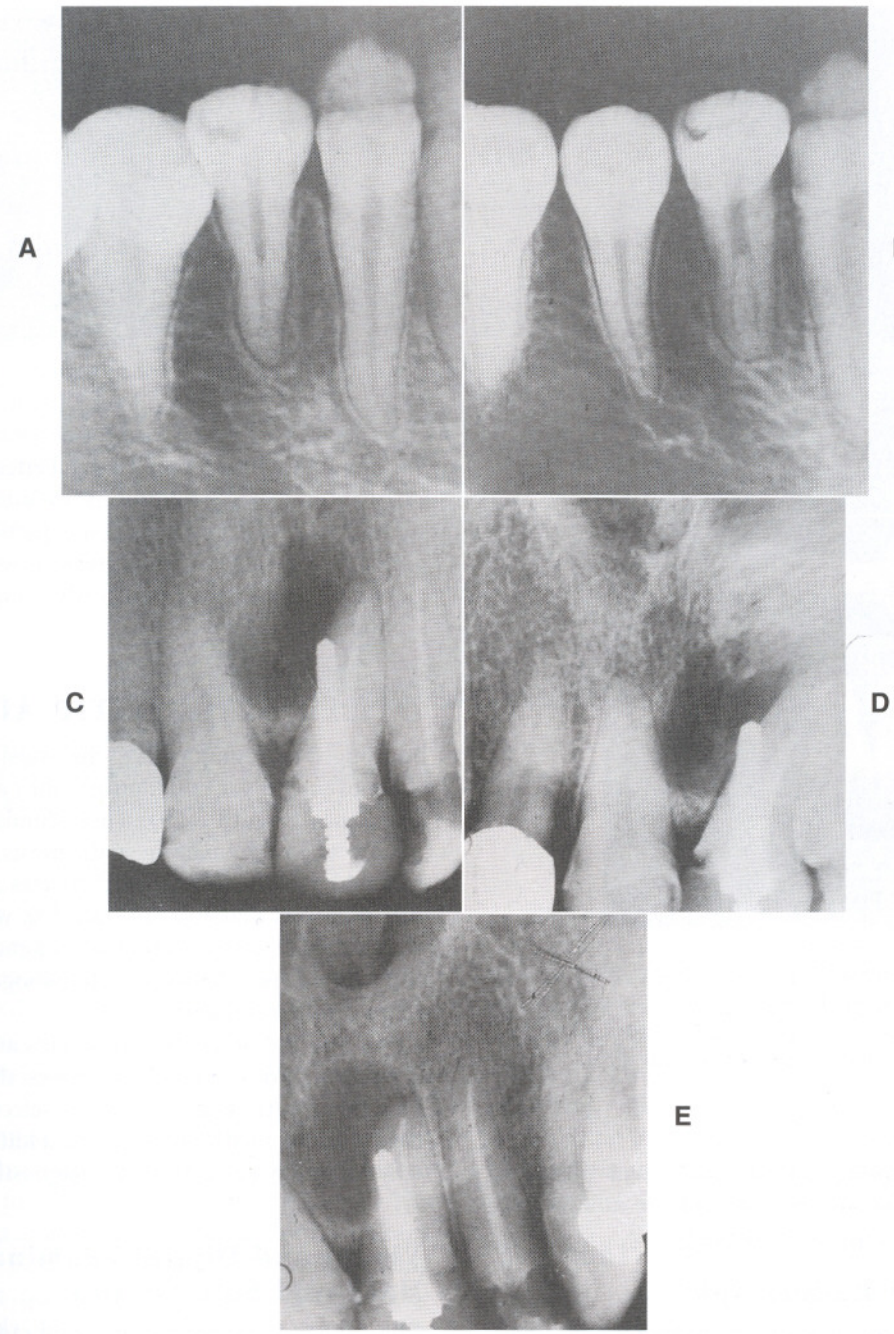


FIGURE 2-24 **A,** Straight-on view of mandibular first bicuspid shows canal with large lateral canal or bifurcation in apical third. **B,** Angled view shows accurate configuration of bifurcation in middle third, leading to two separate and distinct canals. **C,** Routine direct view discloses mesial root perforation by post. As additional information for setting up treatment plan, it would be helpful to know whether perforation is toward labial or palatal surface. Therefore both mesial, **D,** and distal, **E,** views are taken. For identification in later viewing, an x is placed on the distal view film. By using the buccal object rule (Chapter 4), the dentist can determine that perforation is toward the palatal side.

radiographed. The relation of the pocket depth to the root or apex is now apparent. This method is useful in determining factors such as the depth of a pocket, the amount of supporting bone on a periodontally involved tooth, which root of a multirooted tooth should be amputated or treated with periodontal surgery (Figure 2-28).

The size 30 silver point is stiff enough to place but small enough to trace a tortuous pocket and light enough to remain in place while a radiograph is taken. For diagnostic differentiation, when radiographs are reviewed or projected at a later date, it is always obvious where the radiopaque material was placed because gutta-percha is

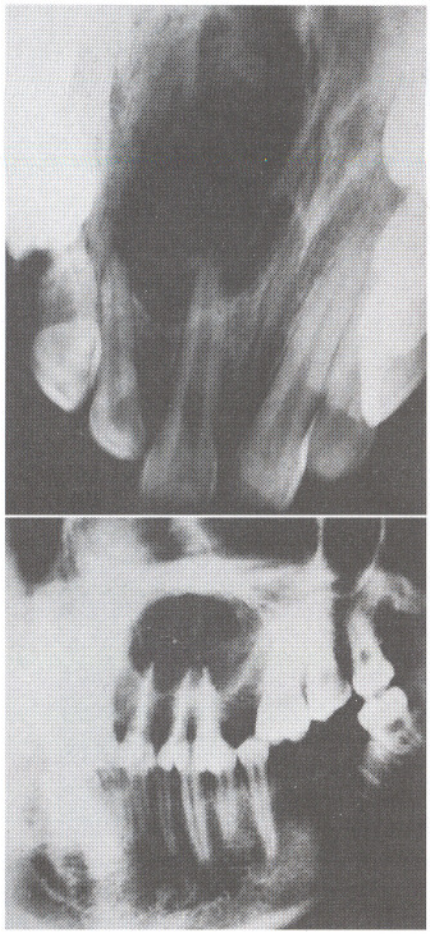


FIGURE 2-25 **A,** Occlusal film gives complete view of large radiolucency that could not be completely visualized on any periapical film. **B,** Panoramic exposure gives excellent view of structures not usually seen on routine periapical films.

used in chronic draining sinuses and silver points in pockets. Both materials are readily available in any office where endodontic therapy is performed.

Newer Types of Radiography

Over the past 20 years, many improvements and innovations have occurred in the field of radiology. There is no segment of dentistry in which radiographs are more important than in endodontics, so any improvement in this area will have a direct and positive effect during root canal therapy.

Several years ago, aspects for using xerography were applied to endodontics. Unfortunately, this was soon abandoned. Applications of video-type screens, with and without computers, have expanded interest in this area recently, and one of the areas of effort and promise has been radiovisiography (RVG).

RVG combines a conventional x-ray generator to a solid-state sensor with a scintillation screen to provide instant imaging. This created image may be enhanced for contrast and density, enlarged several times, and may focus in on specific portions of the image, such as apices or lateral root surfaces. Printing capabilities are also present, and storage in a computer system of charts is possible.

Calculation of working length or fitting of trial cones are obvious uses in addition to preoperative films. One of the major advantages of RVG is that approximately 80% less radiation is required for each exposure compared with current conventional machines.

With instant imaging, time is saved during treatment. Decreasing the hazards of radiation is certainly a valuable feature for the product. Being able to focus on a specific area, such as root tips, lateral lesions, or potential canal divisions, certainly would lead to better endodontic results.

Such interesting additions to our armamentaria for endodontics are always welcome, particularly when it may improve our results and decrease possible damage to our patients. I would hope that further improvements are also on the horizon.

OTHER DIAGNOSTIC AIDS

Although radiographs are the most important of the diagnostic aids for endodontics, they are by no means the only ones (Figure 2-29). They should never be the sole source used for making a diagnosis, but instead, they should be evaluated with other tests and determinations before a final diagnosis is made. As will be illustrated in the section on differential diagnosis of periapical radiolucencies, reliance on the radiograph may only lead to an erroneous diagnosis.

Among the other diagnostic aids are visual and digital examination of soft and hard tissues, thermal pulp testing, electric pulp testing, percussion, selective anesthesia, test cavity, and transillumination. In addition, certain laboratory tests may be required in diagnostic procedures.

Visual and Digital Examination of Hard and Soft Tissues

The danger of too great reliance on radiographs is that the use of the eyes and fingers is overlooked, although often they are of prime diagnostic value.

Severe discoloration of the crown of a tooth, particularly after a traumatic injury, usually indicates severed apical vessels leading to a nonvital pulp. In addition to aiding in the diagnosis, the existence of discoloration also suggests methods involved in treatment. In making the access cavity, the dentist should remove the discolored dentin with a large round bur or a prepared-tip fissure bur. Chlorinated soda used as canal irrigant should be allowed to remain within the crown during canal preparation to help in bleaching out the blood pigments.

Of course, severe carious lesions are usually obvious, and large lesions often cause pulpal involvement. Such

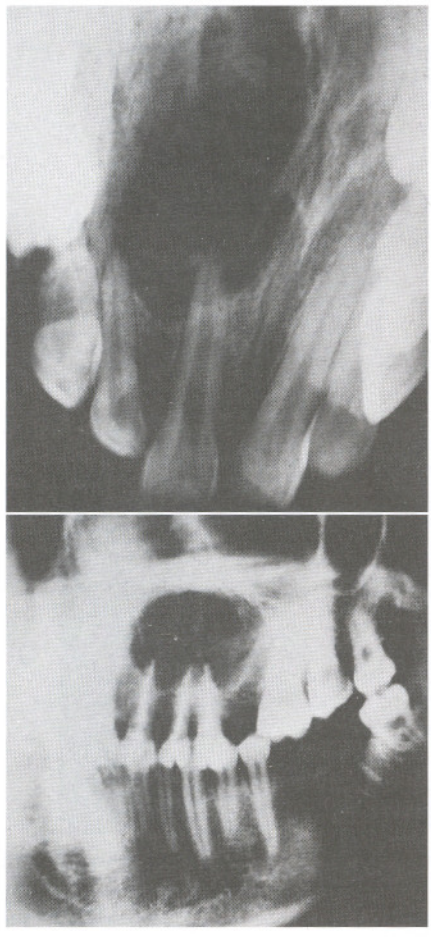


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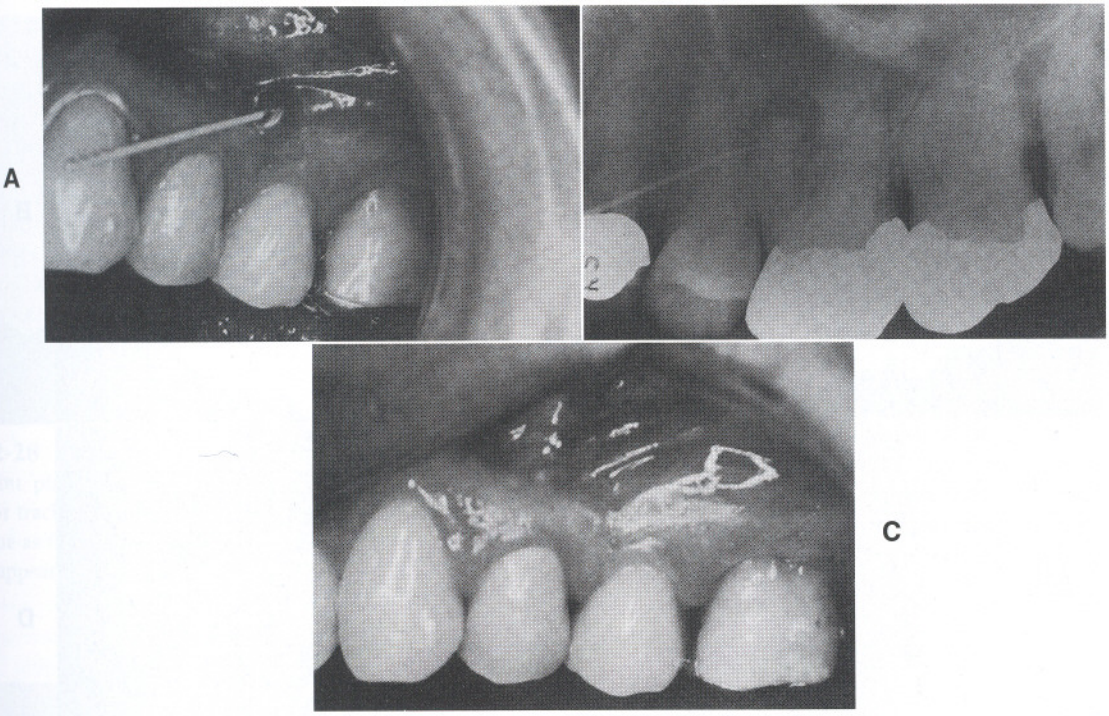


FIGURE 2-26 **A,** Gutta-percha cone placed in chronic draining sinus tract between first and second bicuspids. **B,** Film taken with cone in place indicates that mesiobuccal root of first molar is the culprit rather than either bicuspid. **C,** After canal preparation of molar, the sinus tract heals within a few days. This is a constant finding when endodontic treatment is performed on teeth with sinus tracts.

lesions may occur through buccal or lingual areas and thus are difficult to ascertain from radiographs but are apparent to visual examination. Crown fractures are similarly rarely revealed by x-ray examination, particularly when they occur in a mesiodistal direction. Visual examination and probing with a sharp explorer clarify the condition.

Chronic draining sinus tracts (fistulas) are important aids in diagnosis. As stated previously, they must be traced with gutta-percha to identify the site of origination. The existence of a tract is also of importance during therapy because it is some insurance that an exacerbation during treatment will not occur. Any buildup of pressures or exudates will simply "blow out" through the communication of apex and soft tissue.

The appearance of soft tissue may also be noted visually and may aid in diagnosis. If a patient is in pain, the pulp is the most obvious and frequent site of discomfort. However, an incipient lateral periodontal abscess or necrotizing gingivitis may be similarly painful and may thus be recognized. Before endodontic therapy on any tooth is started, the gingival sulcus must be probed with an endodontic explorer and/or a pocket probe to determine if a periodontal condition is present. This aids in determining the type of treatment plan to be used, the need for coordination with other areas of therapy, the possible etiology of the pulpal problem, and the prognosis (Chapter 11).

Palpation of the soft tissues overlying the buccal plate may induce pain in certain areas, indicative of a possible site of damage, or reveal hard or soft swelling. Complete examination of the tooth with this problem is warranted, including further radiographs and pulp and percussion testing. Existence of swelling in the apical area of a tooth requiring endodontic therapy may indicate that a destruction of the apical foramen is needed to gain successful drainage in the area, that apical surgery may be needed, or that an incipient alveolar abscess is present.

Thermal Pulp Testing

Thermal pulp testing may not be as sophisticated a procedure as electric pulp testing but is often a much more reliable and easily performed diagnostic procedure. The equipment required is inexpensive and easy to use, and the result is usually conclusive (Figure 2-30).

One of the main reasons why thermal pulp testing is a valuable diagnostic tool is that certain painful conditions of the pulp may be brought on or relieved by sudden, severe temperature changes. Therefore the patient's reaction after application of heat or cold to specific teeth not only pinpoints the involved tooth, but also strongly suggests the condition present.

For teeth without crowns or deep restorations, baseplate gutta-percha is used to elicit a response to heat. As in all pulp testing, the teeth to be treated are dried and walled off with cotton rolls, and a saliva ejector is placed.

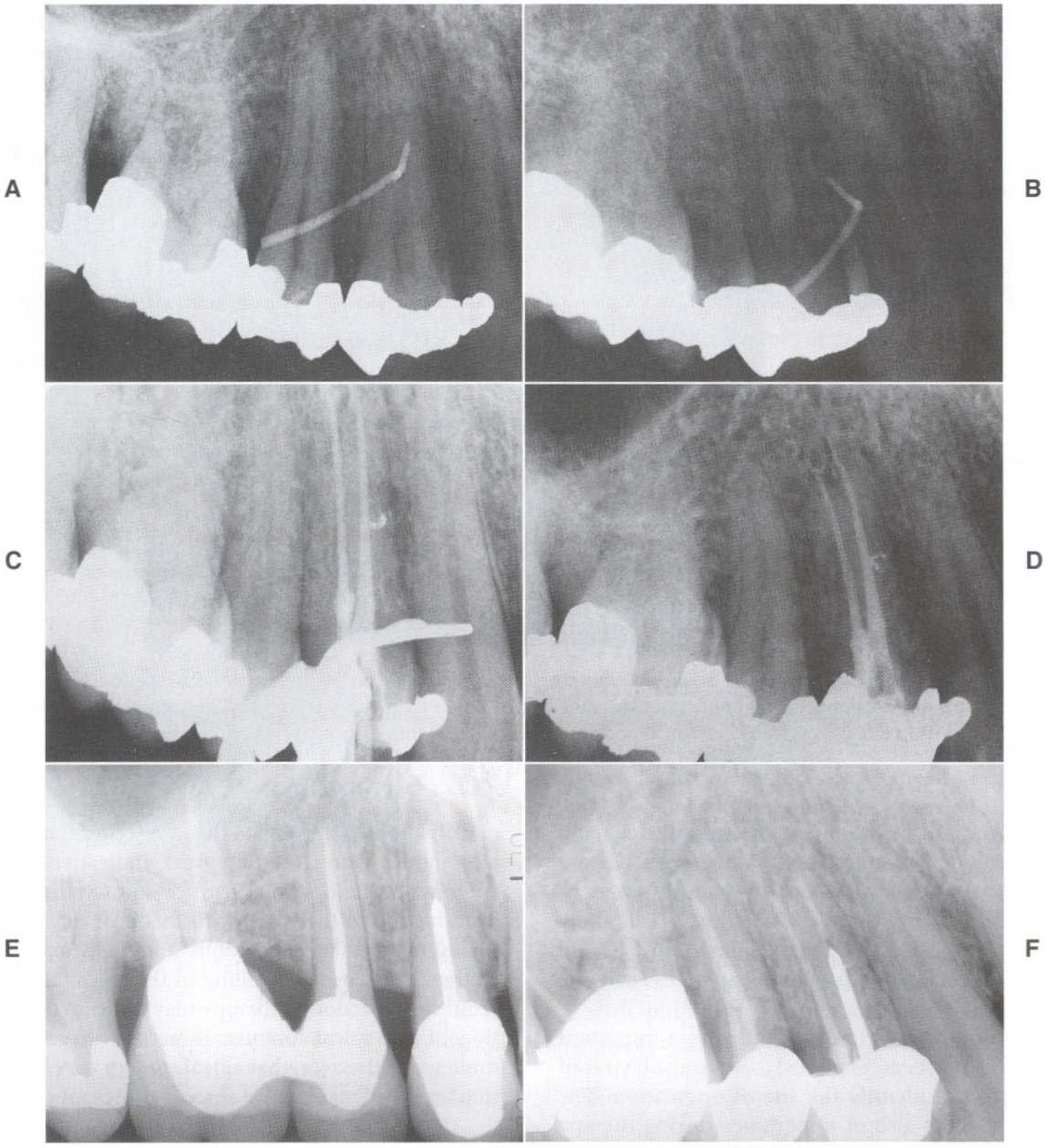


FIGURE 2-27 Radiographs of long-term follow-ups of lateral canal lesion and root amputation. A, Chronic draining sinus tract on the palate is traced with a gutta-percha cone to the lateral surface of a first bicuspid root, straight-on film. **B,** Angled view demonstrating tortuous route these tracts may take. **C,** Angled view taken during canal filling. Sealer is exiting exactly to site of traced sinus tract. **D,** Final film. **E** and **F,** Straight and angled films taken 22 years after original treatment. First bicuspid is very firm, with no sinus tract or radiolucent lesions. First molar had amputation of mesiobuccal root 16 earlier by vertical cut method (see Chapter 10) and two remaining roots have helped stabilize arch. (Periodontal therapy by Dr. Harry Staffileno, Evanston, Ill.)

A strip of the material (7 × 7 mm) is cut and, while being held in a cotton pliers, is heated to just short of smoking and applied to the cervical area of the tooth. A temperature greater than 65.5° C (150° F) is developed, sufficient to elicit a response from a normal or hyperemic pulp. To keep the patient unaware that a hot material is being applied, the heating must be done away from the patient's area of vision; otherwise, when the hot gutta-percha is brought to the tooth, the patient may recoil or react to what he or she thinks is going to happen, rather than to what is felt.

Cast crowns are too thick to allow the heated gutta-percha to raise the temperature of the underlying tooth structure sufficiently to react. Therefore an alternative method of producing heat must be used if a hot test is needed on a tooth with full coverage. Sufficient heat is

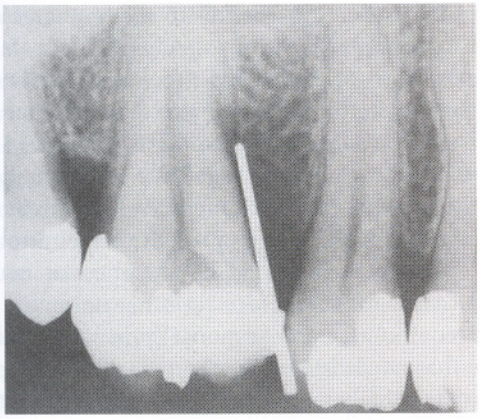


FIGURE 2-28 Periodontal pocket is traced by radiograph of silver point placement along the mesial surface of maxillary molar. For tracing of periodontal defects, x-ray cone angulation is the same as that used for a bite-wing view; thus apex of tooth may not appear on the film.

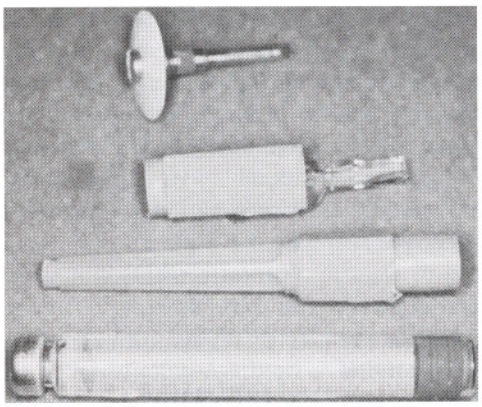


FIGURE 2-30 For thermal testing, a rubber wheel *(top)* against a gold crown provides an excellent hot test. Disposable anesthetic needle holders *(middle)* or empty anesthetic Carpules *(bottom)* filled with water and placed in freezer compartment of refrigerator give sticks of ice, excellent for application to teeth for a cold test.

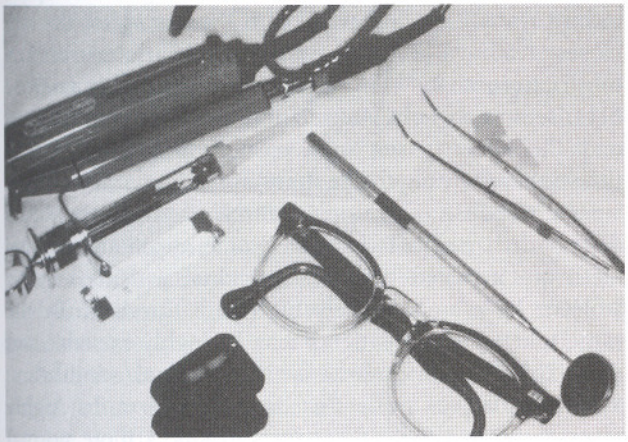


FIGURE 2-29 Diagnostic tests useful in endodontic evaluaion include *(upper left)* electric pulp tester and syringe with anesthetic Carpules for selective anesthesia; *(lower left to right)* radiographs, glasses representing eyes for visual examination of hard and soft tissues, mouth mirror for examination of teeth and butt end for percussion test, and cotton forceps with gutta-percha for hot test.

produced by using a rubber wheel mounted on a mandrel revolving at a polishing speed against the precious metal. Anyone who has had a casting polished in the mouth or who has held an inlay during rubber wheeling will attest to the heat generated.

The rubber wheel is best used on a lingual area of the crown where the polishing will not materially affect the shape of the casting yet will be close enough to the more sensitive areas of the tooth.

Cold tests are easily performed with ice or ethyl chloride spray. The latter is useful if no refrigerator is in the office. The spray is directed at a cotton pellet held in pliers until a frosting is noted on the fibers. The pellet is then placed at the cervical area of the dried tooth and the response noted.

For testing with ice, cubes from an ice tray are unwieldy because of their bulk. As the ice melts from a large cube, cold water may drip on the gingival tissues, and the patient may react to that cold sensation rather than to an application against the tooth. Therefore a thin rod of ice is better for application. This may be obtained by filling with water the plastic containers that have held disposable needles and then placing them in the refrigerator's freezer compartment. When needed, the top of the container is removed, leaving a sharply pointed stick of ice that can be directly applied to the tooth to be tested.

Electric Pulp Testing

The electric pulp tester is an instrument that uses gradations of electric current to excite a response from susceptible elements of the pulpal tissues. The use of an electric tester for evaluation of the condition of the pulp is widespread and is valuable in many instances yet frequently misunderstood. It is important to emphasize that the results of electric pulp testing are always subject to the error of human interpretation and should be evaluated along with results from the other diagnostic aids before a final diagnosis is made.

Pulp testers are available with cords that plug into electric outlets for a power source and also as battery-operated portable instruments. Each type has possible electrical deficiencies. The pulp testers of the future may be operated by transistors, which would let them be smaller in size, able to deliver the expected current routinely, and able to supply many minutes more of use than battery-powered equipment. On the other hand,

future instruments may be developed to determine the degree of blood supply rather than nerve supply to the pulp. Because the vascularity rather than the innervation determines the vitality of pulp, such a test would be infinitely more descriptive of the pulp condition. It has been shown that a considerable loss of blood supply may occur before sufficient degeneration of nerve supply to alter an electrical response takes place.

The use of electric pulp testers has dubious value on youngsters, in general, up to the age of older teens. It has been shown that the electric charges disseminated by the tester are responded to by the A-delta fibers of the nerve tissues in the pulp. These A-delta fibers do not fully develop until late adolescence, and thus may not respond at less than that age, even in the presence of a perfectly vital pulp.

Before the use of an electric pulp tester, the tooth or teeth to be evaluated should be surrounded by cotton rolls and air dried. Saliva present on the teeth may conduct to adjacent gingival tissue and yield a reaction from that source, rather than from the underlying pulp. Removal of supragingival calculus may be needed, particularly in mandibular anterior teeth, to gain access to the cervical areas.

All pulp testers require an electrolyte to transmit the current from the machine to the hard structures of the tooth, and toothpaste is frequently used with good results. The jelly used for electrocardiography is superior for transmission, however, and its viscosity ensures that it will remain where placed. The tooth electrode is lightly dipped into a mound of jelly and placed as close to the cervical portion of the tooth as possible without contacting the gingiva.

The enamel covering the crown acts as a protective barrier and buffer to any of the influences attempting to reach the more susceptible dentin, including electric current. No reaction will take place until sufficient intensity is developed to reach the dentin. However, near the cementodentinal junction, the enamel decreases in thickness, making this the more desired area of testing. If sufficient soft tissue recession has taken place, the electrode may be applied to the cementum covering the root surface. This is an excellent site for gaining a true response because only a very thin layer of cementum separates the electrode and the dentin.

For most pulp testers of the plug-in type, the circuit must be completed by having the operator keep one finger in contact with the patient while current is applied to the tooth. This procedure is not necessary in battery-operated machines.

With the electrode contacting the tooth, an electric charge is applied by pressing the rheostat button, a small charge being given initially and gradually increased until a response is felt. The patient experiences a sense of heat or tingling in the tooth when the nerve tissue is excited. All testers have rheostats that indicate on a scale of 1 to 10 or 1 to 15 estimating the relative amount of current applied. It is important to go slowly up the scale from a small amount of current. Going too rapidly may cause a painful feeling in the tooth being tested before the patient is able to indicate that a response has been felt.

If the vitality of a particular pulp is in question, the pulp tester should be used on adjacent teeth and on the contralateral tooth, when present, as controls. The amount of current indicated by the rheostat is used to make a comparison in determining normalcy. If the current required to gain a response from a test tooth is the same as that needed to excite the control, the pulp of the test tooth is considered normal. The pulp of a test tooth is considered degenerating when much more current is required to gain a response compared with the control. If much less current is required for a response on the tooth in question, it is considered hyperactive. Lack of response indicates pulpal necrosis.

A single test on any individual tooth is insufficient for comparison. Two readings should be taken for each tooth and an average recorded. If the two readings are far apart, a third test should be taken, with the average of the two closest readings accepted. Using an electric test on any tooth more than four times may defeat the purpose because some of the stimulation may become additive, and the nerve tissue may react at a lower-than-true threshold according to the rheostat reading.

The response of multiple nonreactive teeth should be disregarded, particularly when some apparently normal teeth are involved because individual patients may be stoic or have an extremely high pain threshold. By the same token, certain patients may be highly excitable and react quickly to minimal or subminimal stimulation. When testing a tooth that is expected to be highly reactive, as in a severely acute pulpitis, a more normal tooth should be tested first to give the patient a basis for judgment.

Potential Deficiencies of Pulp Testers. Because both battery and plug-in pulp testers may have electrical deficiencies, the output of current on a given reading may vary from time to time, or even from tooth to tooth. Batteries may run down and not deliver the full current expected by the operating dial. On plug-in models, the drain by other electricity-requiring appliances or equipment may alter the true current level.

Large restorations or bases may prevent the current from reaching dentinal tubules attached to processes extending to the pulp. This is particularly true for teeth restored with crowns or with pulpotomy dressings.

Molars may give readings not indicative of the true pulpal condition because some combination of vital and nonvital canals may be present. If the canal in proximity to the tooth electrode is vital, a relatively normal reading will be recorded even if the other canals are necrotic.

As mentioned earlier, reactivity of the nerves to electrical stimulation is not synonymous with normalcy. The nerve tissue, being highly resistant to inflammation, might remain reactive long after the surrounding tissues have degenerated. However, Mullaney et al examined histologically 48 dental pulps that gave a painful response when extirpated, although they had obtained nonvital responses with electric pulp testing. Only two pulps had normal-appearing nerve fibers.

One must remember, when making a comparison between a tooth in question and the contralateral tooth, that the pulp of the control tooth itself may not be normal or that a large restoration or a pulpotomy dressing may be present. The validity of comparing a test tooth with a control holds only when the control tooth gives every indication of normalcy.

Reports have stated that teeth involved in an acute alveolar abscess responded positively to electric pulp tests. Because the pulp must be necrotic for an acute alveolar abscess to occur, it must be assumed that the gaseous or liquefied elements within the pulp canal transmitted the electric charge to the periapical tissues. This would appear to be a relatively rare occurrence.

Teeth involved in splints or bridges may test positive to electric current by virtue of transferring the stimulus to adjacent vital abutments for a reaction. This may happen with hot or cold tests as well. If it becomes necessary to test the pulp of a tooth involved in a nonremovable appliance, temporary stopping may be placed around the pontics or abutments adjacent to the test tooth to prevent any transference. The results of the tests still may be inaccurate.

Teeth are usually nonresponsive to electric pulp testing shortly after eruption and, as noted earlier, until late teenage. At the other end of the spectrum, "older" teeth, despite the patient's age, may be similarly unresponsive. The term *older* is used here to mean teeth in which deep erosion or abrasion has produced heavy areas of sclerotic dentin. Also, teeth with many restorations on multiple areas of the tooth may be unresponsive or difficult to test with an electric tester because no available sites exist where the current can be applied.

Ideal Situations for Electric Pulp Testing. In certain instances, electric pulp testing has a high degree of accuracy and gives excellent essential information. In general, such testing on anterior teeth has a high degree of reliability because these teeth are single rooted, are easy to isolate, have large restorations less frequently than do posterior teeth, and have good access to reach cervical, responsive areas.

Excellent evaluation of teeth involved in traumatic accidents is available with an electric pulp tester. Usually, anterior teeth are affected, frequently teeth with no prior restorations or pulpal damage. The cervical areas are easily accessible on these teeth, and the results of pulp testing are reliable. In the initial few days after an injury, a temporary paresthesia of the nerves may occur and make them unresponsive to testing. However, if the pulp retains its vitality, it will respond within normal limits after 30 to 60 days. Teeth adjacent to the direct site of trauma should also be tested. These teeth may respond normally at the initial examination but later require greater current for stimulation and eventually become nonresponsive due to the presence of a chronic pulpitis.

The electric pulp test may be an important aid in determining when a problem is caused by pulpal or by periodontal damage. The clinical symptoms of an acute alveolar and an acute periodontal abscess are similar. It is a mistake to assume that the frequency of the abscess due to pulpal death compared with that of a periodontal problem justifies opening the pulp chamber for relief. An evaluation of the pulp by either electric or thermal testing would suggest the origin of the swelling. Pulp evaluation is a necessary adjunct in periodontal diagnosis to determine the correct course of treatment for lesions possibly requiring endodontic therapy in addition to periodontics. However, one should remember that pulp vitality does not necessarily mean pulp normalcy (Chapter 11).

A periapical radiolucency does not necessarily indicate pulpal death. Anatomic landmarks, inflammatory lesions, and neoplasms may produce radiolucencies adjacent to teeth, suggestive of the typical periapical granuloma or cyst. Pulp testing should precede institution of endodontic therapy on teeth with periapical radiolucencies, particularly when any question exists as to the etiology of the pulpal death (see Figures 2-7, *B*, and 2-10).

The death of a single pulp may produce a radiolucency that involves the apices of adjacent teeth and suggest endodontic therapy for multiple members of the arch. This is particularly true in the lower anterior area, where the apices are in proximity. Electric pulp testing can indicate which teeth are responsible for the lesion and prevent the treatment of those that are uninvolved. Even if the diseased tissue surrounds the apex of a tooth, vital blood and nerve vessels may penetrate the lesion and retain the tooth in a normal condition (Figure 2-31).

Carbon Dioxide Snow. This method of pulp testing is used in Europe and is very popular with Australian dentists because of the efforts of Ehrmann. It is virtually unheard of in the United States, where ethyl chloride sprayed onto a cotton pellet and ice have been recommended as the preferred cold tests. The apparatus for using carbon dioxide (CO_2) is much more expensive than ethyl chloride or ice, but it does overcome some inherent problems found in the more routine cold tests.

The principle for use involves passing compressed liquid CO_2 through a small orifice in a holding cylinder onto a Plexiglas tube to create a dry ice "pencil." Some CO_2 evaporates when it reaches an atmospheric pressure, accounting for its conversion to dry ice at a temperature

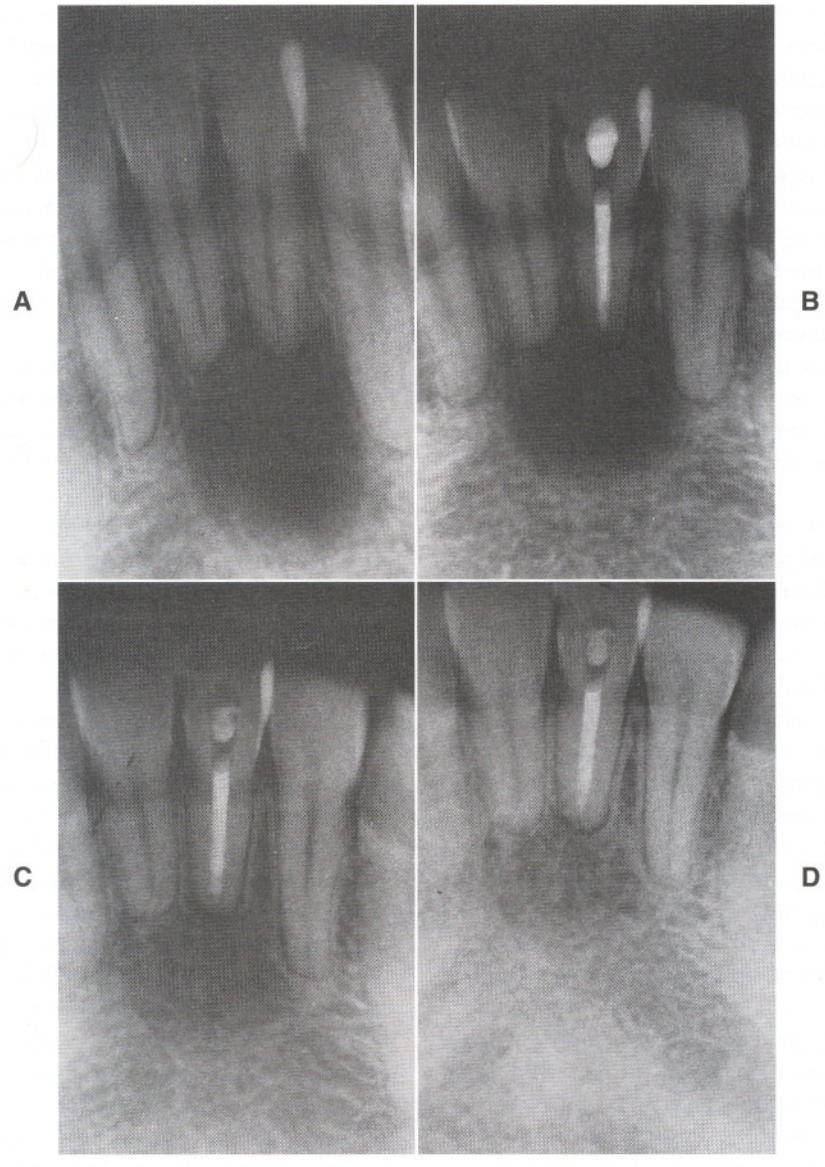


FIGURE 2-31 Excellent indication for electric pulp testing. A, Periapical lesion seems to involve both mandibular central incisors. However, the central to the left on the film responded within normal limits to the electric pulp tester, whereas the central to the right gave no response. **B,** Accordingly, only the nonresponsive tooth was treated. **C,** Six months later, lesion is healing well. **D,** One year after treatment, verifying electric pulp tester results as accurate.

of –78° C (–108° F). This is much colder and remains at a more reliable temperature than the other cold tests, according to Ehrmann.

A major advantage to this method is that it can be used on teeth with metal restorations and, supposedly, on individual teeth under splinted abutments. Possible disadvantages also have been stated. The intense cold of the CO_2 may cause cracks in the enamel, but Ehrmann has stated that if it does occur, it will not be of clinical significance. Cryosurgery involves using extreme cold to remove soft tissue, and some might be concerned that the dry ice stick will cause damage if it touches gingiva, the floor of the mouth, or other oral tissues. However, no damage seems to occur because cryosurgery requires pressure for effectiveness in addition to the low temperatures.

Percussion

The use of percussion as a diagnostic aid gives valuable information as it discloses the existence of an acute periapical inflammation. Because some of the diseases of the pulp and periapical tissues often cause apical periodontitis, such a determination is important in making the correct diagnosis and leads to a correct plan of treatment.

The test is simple to perform, requiring only the butt end of a dental mirror handle used to tap gently the crown

of the tooth. Some dentists claim that the type of noise or "thud" of a percussed tooth indicates the condition of the periapical tissues, but this has not been proven reliable.

Hard percussion of teeth known to be involved in a severely acute periapical condition is cruel. However, the test may be performed on adjacent teeth to rule out multiple etiologic agents when such a finding is determined.

It is important to mention that a normal tooth and one involved in a chronic periapical inflammation respond the same to percussion. Only when the condition becomes acute is the test reliable. If a certain tooth has been bothering the patient when biting, and a sharp response to percussion is anticipated, it is better not to tap that tooth first when using this type of test. It is better to start with a tooth several teeth away, which should induce a normal response. Then the tooth adjacent to the suspected member is tapped. This might induce a slight response or no response. Then it is appropriate to tap the assumed offending tooth, which should give obvious discomfort.

Test Cavity

The use of a test cavity preparation is the final and unquestionably the most accurate of the pulp vitality tests. It involves the removal of dentin by a bur in a handpiece without the use of a local anesthetic to determine the vitality of an underlying pulp. Because it removes sound tooth structure, plus in most instances some portion of a restoration, this test should be performed only as a last resort. When thermal and electric tests have been inconclusive or impossible to perform and yet a determination of pulp vitality is mandatory, the test cavity will supply the answer.

One example of this situation might be the finding of a radiolucency near the apex of an incisor restored with a porcelain jacket crown. Another example might be an acute swelling of the mandible where teeth in the area are splinted together with gold or bonded porcelain restorations.

For producing a test cavity, the preparation is placed in the lingual or palatal surface of an anterior tooth or the occlusal area of a posterior tooth. It is then relatively simple to restore the preparation without causing unesthetic damage to the tooth.

The cavity is best produced by using an airotor without water spray to give the most possible heat production to elicit a pulpal response. If a restoration is present, it may be penetrated with water spray until the underlying dentin is reached. Pain to the patient when penetrating the casting of a splint or bridge abutment is meaningless because it might be reflected by the pulps of adjacent teeth.

When the dentin is drilled, the patient will know in no uncertain terms if the pulp is vital, even if he or she has a high enough threshold of pain to have routine cavity preparation without anesthetic. Once a vital response is elicited, no further heat-producing work should be performed lest pulpal damage be caused that might require endodontic therapy.

After the response is noted, the cavity may be temporarily restored with ZOE before permanent restoration with foil, a casting, or amalgam. If the pulp is nonvital, the preparation may be enlarged to accommodate the normal access opening and the tooth then treated according to the condition present.

Selective Anesthesia

Selective anesthesia refers to administration of a local anesthetic to facilitate identification of the tooth causing a painful episode. Other diagnostic aids may be able to eliminate all but two teeth as possible etiologic agents but be unable to make the final choice. If each tooth is in a separate arch or if both are maxillary teeth and at least one tooth intervenes between them, selective anesthesia may be used to pinpoint the culprit.

If a maxillary tooth and a mandibular tooth are the possible causes, the correct local anesthetic injections (including a palatal injection) necessary to extirpate a vital pulp of the maxillary tooth are administered. If the pain vanishes, the maxillary tooth is identified as the causative agent. If pain has been brought on or intensified previously by thermal changes, the patient is instructed to rinse with water of the type that earlier produced the discomfort to test further that the correct tooth has been found.

If pain is not diminished by anesthesia of the maxillary tooth, the suspect mandibular tooth is indicated as the source of the problem and appropriate treatment administered to it. The maxillary tooth is selected for the initial injections because of the greater degree of deep anesthesia normally obtainable in the maxillary arch. The likelihood of missing a mandibular block injection is always present. If the mandibular injection was given first but did not take completely and pain persisted, the maxillary tooth might be wrongly treated.

If two maxillary posterior teeth are involved, the more anterior tooth is given the selective anesthetic, and observation is made for change in degree of pain. Should the pain disappear, the anterior tooth is responsible; the posterior tooth is indicated for treatment if the pain remains. The more anterior tooth is tested first because innervation of the palatal root for posterior teeth is from the more posterior portion of the palate by way of the greater palatine foramen, adjacent to the second molar. If a palatal injection were given, an inflamed pulp in the palatal canal of any tooth anterior to the site would be anesthetized.

Transillumination

Emergence of the fiberoptic as a dental instrument has been a great aid in the use of transillumination for diagnosis. The test requires shining a bright light from the

lingual or palatal surface of a tooth, with viewing in a darkened room.

In teeth with necrotic pulps the shadow of the pulp canal space appears darker than the rest of the tooth because of the breakdown of the blood cells. In teeth with vital pulps, no differentiation is noted. Periapical tissue may be similarly transilluminated if the plates of bone are close to each other, as in mandibular anterior teeth. Teeth with radiolucencies reveal a shadow around the apex, whereas normal teeth show no difference in the area.

Transillumination may be helpful in diagnosing the presence of a vertical fracture. With the fiberoptic shining at right angles to the fracture line, the segment of the tooth on the side of the crack illuminates, whereas the segment on the far side remains dark.

VERTICAL FRACTURES OF POSTERIOR TEETH

James A. Dewberry, Jr.

One of the most puzzling and frustrating diagnostic problems encountered by the dental practitioner is the vertical fracture. Symptoms of this condition are often characterized by a sharp but brief pain during mastication. The conditions required to elicit this pain may be so unique that it can be extremely difficult for the patient or the dentist to reproduce and therefore to locate. The type and degree of pain can run a broad gamut. It may be sharp but only momentary so that the patient does not seek advice or treatment because total relief comes by abstinence from mastication in the affected area. Usually that type of pain comes from a specific type of vertical fracture—a tiny crack extending into the dentin but not yet intersecting the pulp space. The sharp pain probably comes from exposing, stretching, and rupturing odontoblastic processes in the fracture plane. Eventually this type of fracture will progress farther apically, possibly intersecting the pulp space and infecting its contents.

A tiny crack that just intersects the pulp space or is a close tangent to it may cause a pulpal inflammation that can result in spontaneous pain referred throughout any or all of the areas served by the fifth cranial nerve. The source of pain may be impossible to locate because pulp tissue has no proprioceptive (location sense) capability. This can lead to bizarre medical treks by the patient from the otolaryngologist to the neurologist to the psychiatrist. These patients do not belong in psychiatric therapy, whereas those with seemingly similar (but occasionally bilateral) pain arising from spasm of musculature of the head and neck may benefit from such treatment. Once this subtle fracture progresses to the pulp space, resulting in pulp necrosis, the inflammation extends to the periodontal ligament and periapical bone. Both the ligament and the bone have proprioceptive fibers so that the resultant tenderness to percussion reveals the pain source. With the inflammation confined to the pulp tissue before extension periapically, localization is difficult unless the pain responds to thermal stimuli or the stick-bite test. The latter is virtually the only viable test for early cracks not involving the pulp. Often they can be seen on a visual examination, but many enamel cracks are of no clinical significance.

Radiographic Evidence

Radiographic examination seldom reveals the fracture because it is usually parallel to the film. However, a vertical fracture is often suspected in the absence of an apparent cause for pulpal involvement (Figure 2-32). For example, if symptoms, radiographs, and/or clinical tests show the presence of pulpal pathosis in a posterior tooth, and if the radiograph shows no caries or restoration near the pulp, this is virtually pathognomonic of a vertical fracture. Whereas horizontal root fractures or buccolingual crown fractures may occasionally be demonstrated radiographically, a mesiodistal vertical fracture is impossible to reveal because the line of fracture is not in the plane of the radiograph even in a deep and separated split. When these teeth are extracted and radiographed in a mesiodistal plane, multiple fracture lines are frequently seen (Figure 2-33). An advanced fracture may show what appears to be a periodontal pocket (see Figure 2-32, *B*). It is an area of bone loss caused by the necrosis of periodontal bone in the fracture line.

External Evidence

The external clinical evidence of a cracked tooth is usually a fractured marginal ridge extending into a prominent fissure (Figure 2-34) or a single, uniformly poor margin of a restoration. Cracks and fractures of the enamel may have no clinical significance; however, they may be suggestive of deeper dentin involvement. Frank separation or movement in the fracture line is proof of a fracture of the dentinal body of the tooth. If the tooth has a large, temporary restoration across the occlusal surface with a crack from mesial to distal, this is very often indicative of a similar crack in the tooth structure beneath.

To locate the tooth and cusp(s) involved, the dentist has the patient bite on an orangewood stick or a cotton-tipped applicator. Noting the cusps that occlude when the pain occurs aids in the location of the fracture site.

Once the tooth is located, a window in the dentin in the plane of fracture should reveal it. This window is usually in the form of a Class I cavity (Figure 2-35). Caries does not seem to invade these fractures, although some are black, whereas others show no discoloration. Because the cracks often barely can be seen with the naked eye, a magnifying lens in the two-power range with a good direct light followed by transilluminating light in a darkened room are important diagnostic aids. Dyes such as methylene blue or washable ink are of little value. The

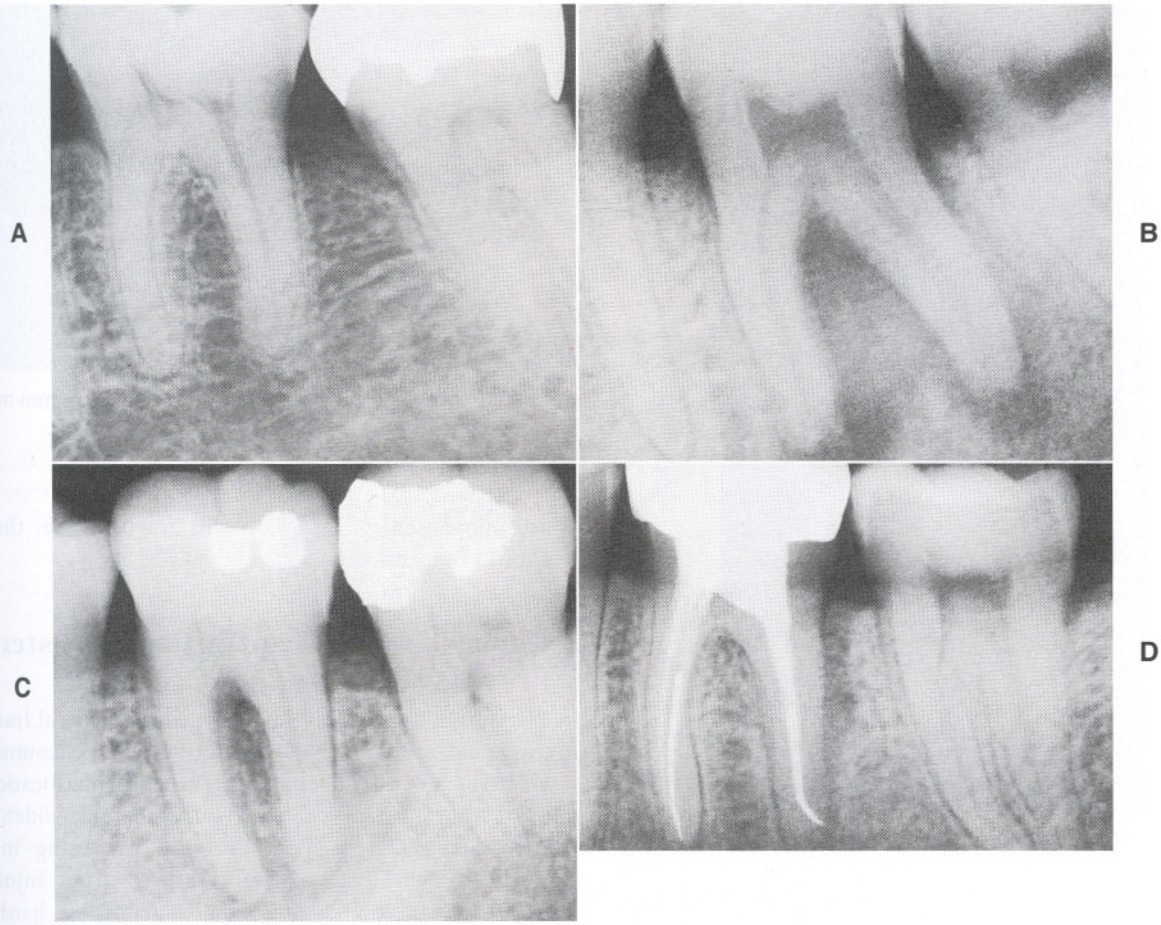


FIGURE 2-32 Four mandibular first molars with diagnosed vertical fractures verified after extraction. Note that no restorations are present in **A** and **B,** and only two small occlusal amalgams are in **C.** Because the fractures are parallel to the film, no routine intraoral view will disclose the defect. **D,** If endodontic treatment is attempted on such teeth, failure will result. Seemingly excellent therapy was performed on this tooth 3 months earlier at the patient's insistence despite the fracture. Note the diffuse radiolucency extending the entire root length of the distal portion of the distal root, pathognomic of a vertical fracture.

floor of the preparation of the exploratory window should be smoothened as much as possible to avoid linear marks on the cavity floor that might be difficult to distinguish from a subtle crack.

In some cases it is tempting to remove dentin in the fracture line until it is no longer visible and place a restoration. This only creates a wedge into the fracture plane that worsens the problem rather than relieves it.

Occasionally, if a crack encircles a single cusp, that cusp may be reduced severely from occlusion, relieving symptoms. If a coronal fracture's apical terminus traverses the epithelial attachment, it creates a defect in the attachment, the periodontal ligament, and the adjacent alveolar bone. This results in an infrabony pocket that will remain until the tooth is extracted (Figure 2-36). These pockets may be tolerable for a time but are never reversible.

Fractures of Anterior Teeth

When an anterior tooth fractures, it generally occurs in a more horizontal plane, and the cause is accidental trauma of extraoral origin. Aspects of treatment are discussed in Chapters 3 and 9. It should be noted here that many untreated horizontal fractures of the roots of anterior teeth heal uneventfully without stabilization or treatment, provided sufficient root length remains on the coronal segment.

Prognosis

There are many variables in the evaluation and prognosis of vertical fractures. Among them are the direction and depth of the fracture plane, separation or movement in the fracture line, evidence of pulpal involvement, and the occlusal dimension or length of the fracture. One must remember that even after removing all restorations, only the occlusal cross-sectional aspect of a vertical fracture can be seen unless the pulp chamber is entered. Even then, placing the apical terminus of the fracture is guesswork, despite the use of a transilluminating light and a magnifying lens. However, with this limited information a predictive clinical judgment of the salvage prospects for

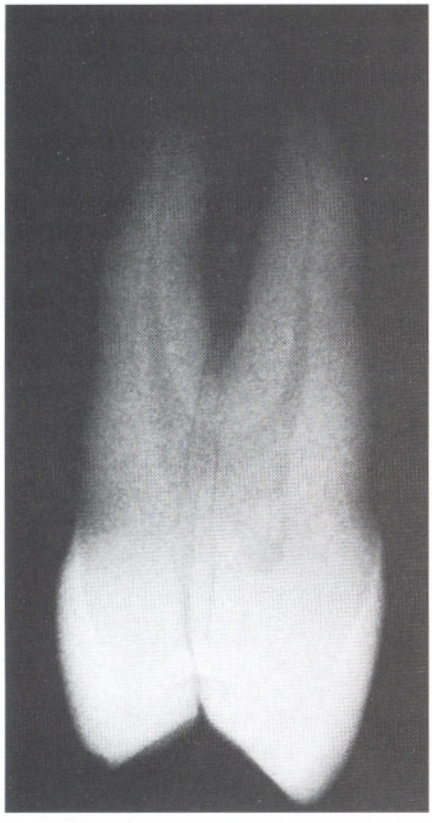


FIGURE 2-33 Proximal view of extracted two-rooted maxillary first bicuspid demonstrating multiple mesiodistal fracture lines. Routine intraoral radiograph showed no crack.

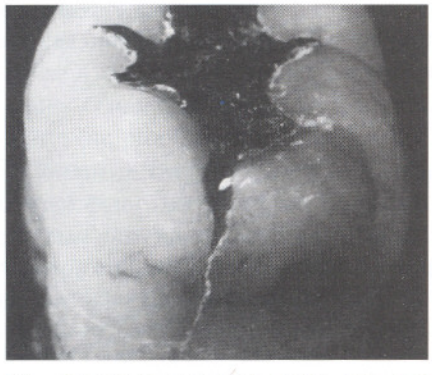


FIGURE 2-34 Fractured marginal ridge was only external evidence of a crack on this mandibular second molar. No cavity was present, and no fracture line was discernible on a routine radiograph.

the tooth must be made. Other factors that play a role in the decision are the strategic value of the tooth, the economics of treatment (the endodontic therapy must be followed by a full-coverage crown), and the patient's commitment or lack of it to attempt to retain the tooth. Generally it can be said that a fracture traceable all the way from mesial to distal offers a very poor prognosis. If

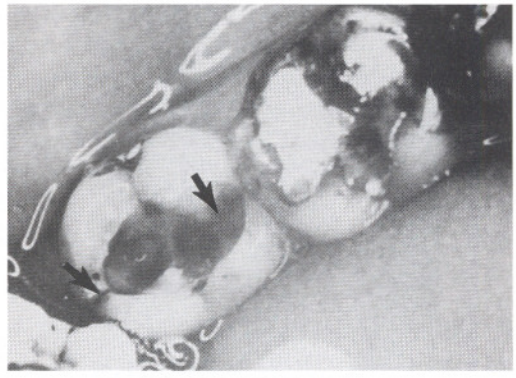


FIGURE 2-35 Occlusal amalgam was removed from mandibular first molar to trace down fracture line *(arrows)*.

any movement is noted in this fracture line, the tooth should be condemned.

Causes and Susceptibility of Posterior Fractures

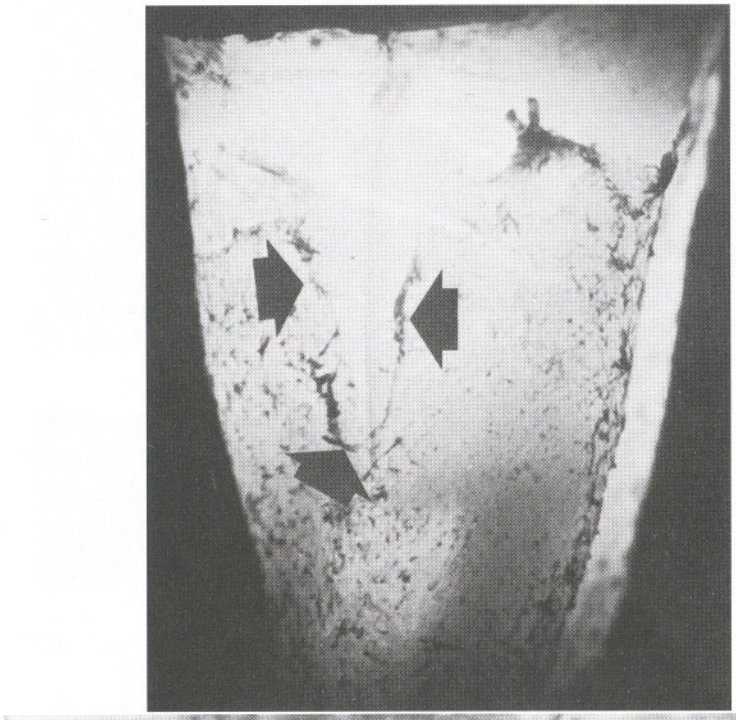
The single most common cause of the vertical fracture is the masticatory accident—an unexpected encounter with a hard object during confident, crushing mastication. The most common history of a remembered incident is an encounter with a piece of bone remaining in meat. Although many teeth are fractured from injudicious voluntary mastication on objects such as ice, hard candy, or nuts, usually caution reigns in chewing these. The unexpected encounter of the masticatory accident seems to be the most destructive.

Patients with cracked teeth are most often healthy. It is unusual to see supporting bone in any condition but excellent in the patient with a cracked tooth. Even more unusual is a cracked tooth opposing a denture or even a bridge pontic. When this happens, or in any fracture with a large restoration, an iatrogenic cause may be considered, such as the overzealous effort to seat a poorly fitting casting or the injudicious use of a mechanical amalgam condenser. The plane of most compound restorations in posterior teeth (i.e., mesial to distal) coincides with the most common fracture plane, creating a metallic wedge through the enamel cap and a major portion of the dentinal body of the crown. Much of the remainder of the crown is pulp space almost to the furcation area, leaving little dentin available to protect against a split.

The use of molar teeth as crushers and grinders subjects them to incredible pressures. Anthropologists examining lead balls found bitten out of shape by prisoners during beatings at Fort Ticonderoga determined that 1600 pounds of pressure were required to reproduce the distortion in a similar ball. The morphology of posterior teeth, with their deep grooves, bifurcations, high cusps, and cuspal interrelationships, also creates susceptibility to fracture.

Table 2-1 lists the breakdown of 475 fractured teeth according to anatomic distribution. A strong majority (58%) was found in mandibular molars, with a slight preference for the first molar (31%) over the second (27%). This reflects not only the extremely heavy work of the molars but the potentially divisive force of a prominent palatal cusp of the maxillary molar driving far down into the central fossa of the opponent. This force tends to divide the mandibular molar vertically and laterally. If a masticatory accident is an additional mechanical component, the result is often a vertical fracture.

The maxillary molars follow far behind their mandibular opponents in incidence of fractures, with much greater occurrence in the first molar (21%) than in the second (6%). Maxillary first and second bicuspids



A



B

FIGURE 2-36 **A,** As a fracture extends toward the apex, it creates a defect in the periodontal ligament space to cause an irreversible pocket. Note that the epithelial attachment divides as the fracture line progresses apically *(arrows)*. *Continued*