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Isolation, Endodontic Access, and Length Determination

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CHAPTER OUTLINE

LEARNING OBJECTIVES

After reading this chapter the student should be able to:

1. Describe the rationale for rubber dam isolation during endodontic procedures.
2. Describe techniques for application of the clamp and rubber dam.
3. Recognize situations in which special isolation approaches are necessary and identify isolation techniques for unusual situations.
4. Identify patients who should be considered for referral.
5. Identify major objectives of endodontic access preparation, including importance of dentin preservation.
6. Relate reasons and indications for removing caries or restorations before access.
7. Describe the technical procedure, materials used, and sequence to properly access all teeth.
8. Demonstrate the step-by-step technique for obtaining estimated and correct working lengths.
9. Describe the practice and accuracy of electronic apex locators.
10. Illustrate the portions of the tooth that must be removed to attain access to the canals.

Chapters 14 and 15 address the technical aspects of nonsurgical root canal treatment. Areas presented include isolation, access, length determination, cleaning and shaping, and obturation. A number of instruments and techniques are advocated for treatment procedures. These chapters introduce concepts and principles that are important for successful treatment. These building blocks are based on the best available evidence and provide a basis for incorporating more complex and alternative techniques.

Rubber Dam Isolation

Application

Application of the rubber dam for isolation during endodontic treatment has many distinct advantages and is mandatory for legal considerations.[1] Expert testimony is not required in cases involving patients who swallowed or aspirated instruments or materials, because juries are considered competent to determine negligence. Failure to use a rubber dam indicates that the clinician does not understand the need to protect the patient from aspiration or swallowing instruments, the protection afforded the dental staff from contaminated aerosols, the microbial nature of the disease process, and the decreased success rate for treatment when strict asepsis is not used.

Evidence exists that many general dentists unnecessarily place themselves at risk by not using the rubber dam when performing endodontic procedures.[2] Although the use of the rubber dam in the United States is considered the standard of care, recent studies have shown that is not universal among general dentists. A survey conducted in 2013 reported that only 44% of general dentists who perform root canal therapy (RCT) use rubber dam isolation. Moreover, 15% reported that they do not use a rubber dam for any of the RCTs that they provide.[2] Considering that the use of rubber dam significantly increases the tooth survival rates after initial

RCT, its constant usage will improve the infection control—and in consequence the outcome—of endodontic treatment.[3]

The rubber dam provides protection for the patient and creates an aseptic environment; it enhances visibility, retracts tissues, and makes treatment more efficient. Soft tissues are protected from laceration by rotary instruments, chemical agents, and medicaments. Irrigating solutions are confined to the operating field. Most important, rubber dam isolation protects the patient from swallowing or aspirating instruments and materials (Fig. 13.1).[4] An additional advantage is that the dentist and auxiliary employees are also protected.[5-7] The risk from aerosols is minimized,[8,9] and the dam provides a barrier against the patient's saliva and oral bacteria. Application of the rubber dam may also reduce the potential for transmission of systemic diseases, such as acquired immunodeficiency syndrome (AIDS), hepatitis, and tuberculosis.[5,9]

The rubber dam is manufactured from latex; however, nonlatex rubber dam material is available for patients with latex allergy and is used exclusively in many institutions (Fig. 13.2).[10] The rubber dam can be obtained in a variety of colors that provide contrast to the tooth. The thickness also varies (light, medium, heavy, and extra heavy). A medium-weight dam is recommended because a lightweight dam is easily torn during the application process. Also, the medium material fits better at the gingival margin and provides good retraction.

The design of the rubber dam frames also varies. For endodontics, plastic frames are recommended; they are radiolucent and do not require complete removal during exposure of interim images, such as the working length and master cone radiographs and digital images (Video 13.1).

Rubber Dam Retainers

Rubber dam clamps fit the various tooth groups. During routine treatment, metal clamps are adequate; however, they may damage tooth structure[11] or existing restorations. Some have serrated edges to enhance retention when minimal coronal tooth structure remains. Plastic clamps are manufactured and have the advantage of being radiolucent. This radiolucency is an advantage in difficult cases in which the pulp chamber and canal cannot be located. When using a plastic clamp, the rubber dam can remain in place. The plastic clamps are less likely than metal ones to damage tooth structure or existing restorations.[12]

Types

Different styles and shapes of rubber dam clamps are available for specific situations. The following selection is recommended: (1) for anterior teeth: Ivory No. 9 or 212; for premolars: No. 0 and 2; and for *molars:* No. 14, 14A, 56, and 205. Clamps that will manage most isolation situations during root canal treatment are shown in Fig. 13.3. Winged clamps permit the application of the rubber dam as a single unit during single-tooth isolation (Fig. 13.4).[13]

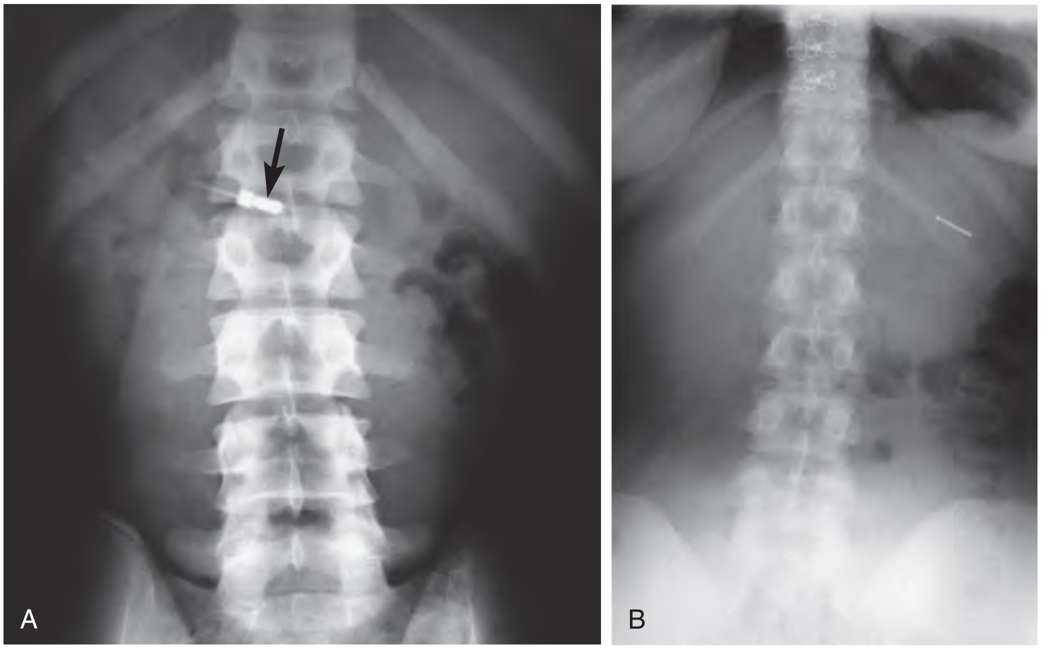
Universal Clamp Designs

Two designs (see Fig. 13.3), the "butterfly" Ivory No. 9 and the Ivory No. 56, are suitable for most isolations. The butterfly design (No. 9) has small beaks, is deep reaching, and can be applied to most anterior and premolar teeth. The No. 56 clamp can isolate most molars.

With teeth that are smaller, reduced by crown preparation, or abnormally shaped, a clamp with smaller radius beaks (No. 0, 9, or 14) is necessary. Small-radius beaks can be positioned farther apically on the root, which stretches the dam cervically in the interproximal space.

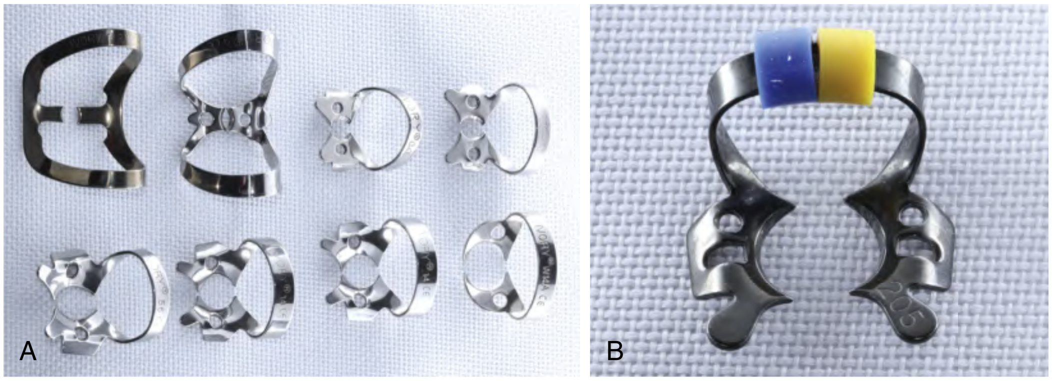
Additional Designs

Clamps that may be most useful when little coronal tooth structure remains have beaks that are inclined apically. These are termed *deep-reaching clamps.* Clamps with serrated edges are also available for cases involving minimal coronal structure. These clamps should not be placed on porcelain surfaces because damage may occur.[11]

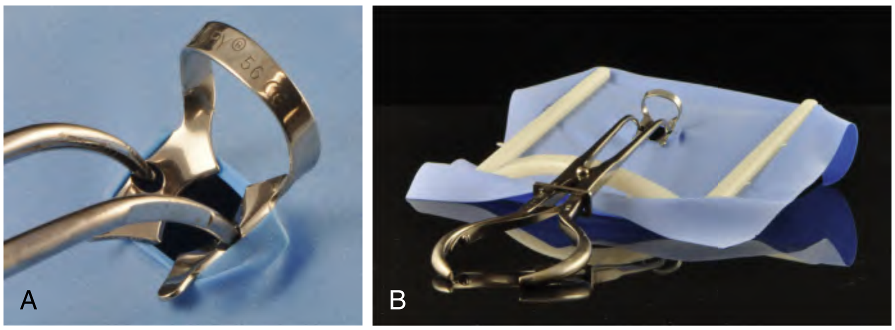


• **Fig. 13.1 A,** A file *(arrow)* that a patient swallowed during endodontic treatment. **B,** A bur that a patient also swallowed due to the lack of proper protection with rubber dam.

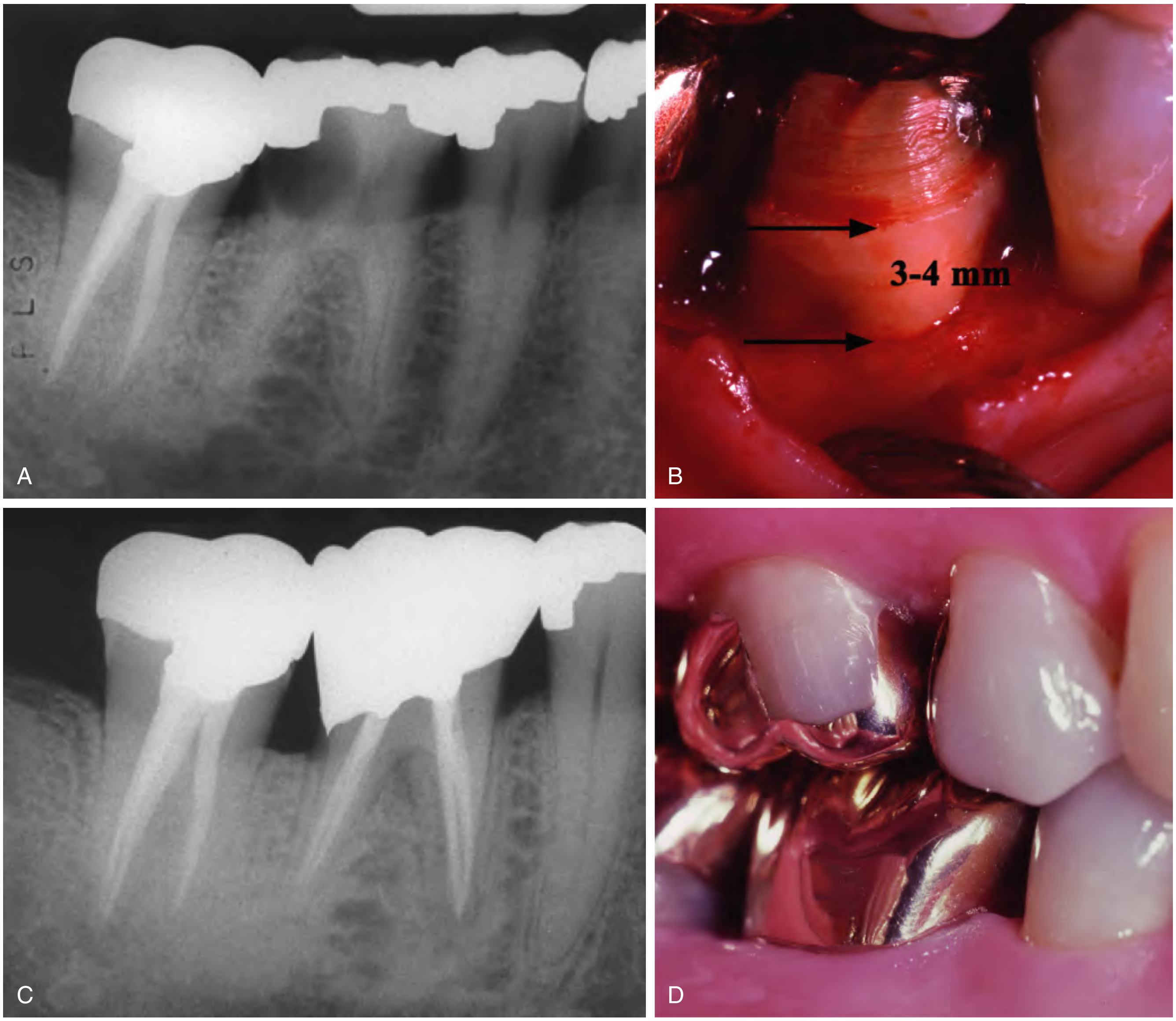
• **Fig. 13.2** **A** and **B,** Disposable rubber dam systems; **C**, OptiDam, a three-dimensional rubber dam.



• **Fig. 13.3** **A**, The retainers in the bottom left (No. 212 and 9) are designed for anterior teeth but are useful for premolars. The two clamps in the bottom right (No. 56 and 14) are for molars and anterior teeth. The upper left clamps (No. 0 and 2) are for premolars. No. W14A and 14 are deeper reaching than the No. 56. **B**, Clamp No. 205 can be used for most of the molars.



• **Fig. 13.4** **A,** Placement of the rubber dam as a single unit requires the use of a winged clamp. A hole is punched in the rubber dam and then stretched over the wings of the appropriate clamp. **B,** The rubber dam is attached to a plastic radiolucent frame, and the rubber dam forceps is then used to carry the unit to the tooth.



• **Fig. 13.5** **A,** The first molar shows extensive caries on the distal extending to the crestal bone. **B,** A full-thickness, mucoperiosteal flap and osseous reduction are performed after caries excavation and preparation for a provisional crown; then, 3 to 4 mm of tooth structure coronal to the osseous crest restores the biologic width. **C,** Root canal treatment and placement of the crown. **D,** The definitive restoration.

For stability, the clamp selected must have four-point contact between the tooth and beaks. Failure to have a stable clamp may result in damage to the gingival attachment and coronal structure,[11,14] or the clamp may be dislodged. Clamps may also be modified by grinding to adapt to unusual situations.[15]

Placement of the rubber dam as a single unit is fast and efficient. Once in place, the dam is flossed through the contacts, and the facial and lingual portions of the dam are flipped under the wings.

Identification of the tooth requiring treatment is usually routine. However, if no caries or restorations are present, the operator may clamp the wrong tooth. This error can be avoided by marking the tooth before rubber dam application or by beginning the access after placement of a throat pack without the rubber dam in place.

Preparation for Rubber Dam Placement

Before treatment is initiated, the degree of difficulty in obtaining adequate isolation must be assessed. Often, teeth requiring root canal treatment have large restorations, caries, or minimal remaining tooth structure that may present complications during isolation and access. Adequate isolation requires that caries, defective restorations, and restorations with leaking margins be removed before treatment. Removal of all existing restorations has been advocated to improve the ability to assess restorability, pathogenesis of disease, and prognosis.[24]

Once the treatment plan has been finalized, it may be necessary to perform ancillary procedures to allow for placement of the rubber dam.[16,17]

Isolation of Teeth with Inadequate Coronal Structure

Ligation, the use of deep-reaching clamps, bonding, or building up before access are the major methods of isolating teeth without adequate coronal tooth structure. Surgical management may also be required (Fig. 13.5).

In the case of inability to obtain appropriate isolation, the patient should be referred to an endodontic specialist.

Ligation

Inadequate coronal structure is not always the cause of lack of retention. In young patients the tooth may not have erupted sufficiently to make the cervical area available for clamp retention. In these cases, ligation with floss or the use of interproximal rubber Wedjets is indicated (see Fig. 13.15, *D*). Another approach is multiple tooth isolation (see Fig. 13.2, *C*, OptiDam 3D rubber dam).

Deep-Reaching Clamps

When the loss of tooth structure extends below the gingival tissues but there is adequate structure above the crestal bone, a deep-reaching clamp is indicated. It may be necessary to use a caulking material or resin around the clamp to provide an adequate seal (Fig. 13.6). Another option is the use of an anterior retainer regardless of the tooth type.

Bonding

When there is missing tooth structure, including the natural height of contour, retention can be increased by bonding resin on the facial and lingual surfaces of the remaining tooth structure.[18] The clamp is placed apical to the resin undercut. After treatment the resin is easily removed. This technique is preferred over the more invasive technique of cutting horizontal grooves in the facial and lingual surfaces for the prongs of the clamp.

Replacement of Coronal Structure

Temporary Restorations

When there is missing tooth structure but adequate retention, missing structure can be restored with reinforced intermediate restorative material (IRM) containing zinc oxide–eugenol, glass ionomers, or resins. These materials provide an adequate coronal seal and are stable until the definitive restoration is placed. Bonded materials provide a better seal with improved strength and esthetics.

Band Placement

Placement of orthodontic bands may be indicated in cases of cracked or fractured teeth to provide protection and support until a definitive restoration can be placed. The bands are available in various sizes and are appropriately contoured. A band can be cemented, and the missing tooth structure replaced with IRM (see Fig. 13.39). During the placement procedure, it is important to protect the canals and pulp chamber.

Provisional Crowns

Placement of temporary crowns is an option; however, they reduce visibility, result in the loss of anatomic landmarks, and may change the orientation for access and canal location. Often temporary crowns are displaced during treatment by the rubber dam clamp. In general, when provisional crowns are placed, they should be removed before endodontic treatment to provide the correct orientation and maintain the remaining tooth structure.

Rubber Dam Placement

Placement as a Unit

Placement of the rubber dam, clamp, and frame as a unit is preferred (see Fig. 13.4). This method is most efficient and is applicable in most cases. A traditional dam and frame can be used, or proprietary disposable systems are available (see Fig. 13.2; Video 13.2). The steps in this process are as follows:

1. The dam is placed on the frame so that it is stretched tightly across the top and bottom but has slack horizontally in the middle.
2. A hole is punched in the dam, and then the clamp wings are attached to the dam.
3. The dam, frame, and clamp are placed as a unit to engage the tooth near the gingival margin.
4. The dam is released apically off the clamp wings to allow it to constrict around the tooth neck. The dam is then flossed through the contacts.

Placement of a Clamp, Followed by the Dam and Then the Frame

Placement of a clamp followed by the dam and frame is seldom used but may be necessary when an unobstructed view is required while the clamp is positioned. The clamp is first placed on the tooth and secured. The rubber dam is then stretched over the clamp and the frame affixed (Video 13.3).[5]

Placement of the Rubber Dam and Frame and Then the Clamp

The preferred method for applying a butterfly clamp that does not have wings (No. 212) is to place the dam and frame and then the clamp. improved visibility is possible when the hole is stretched over the tooth and gingiva first by the operator or dental assistant, and the clamp is then placed. The No. 212 clamp has narrow beaks and is often used in situations in which wing clamps are unstable or cannot be retained.

Rubber Dam Leakage

Several proprietary products are available for placement around the rubber dam at the tooth–dam interface should leakage occur (see Fig. 13.6). These are caulklike materials, putty, or light-cured resins; they are easily applied and removed after treatment and are especially useful for isolation of an abutment for a fixed partial denture or for a tooth that is undergoing active orthodontic treatment.

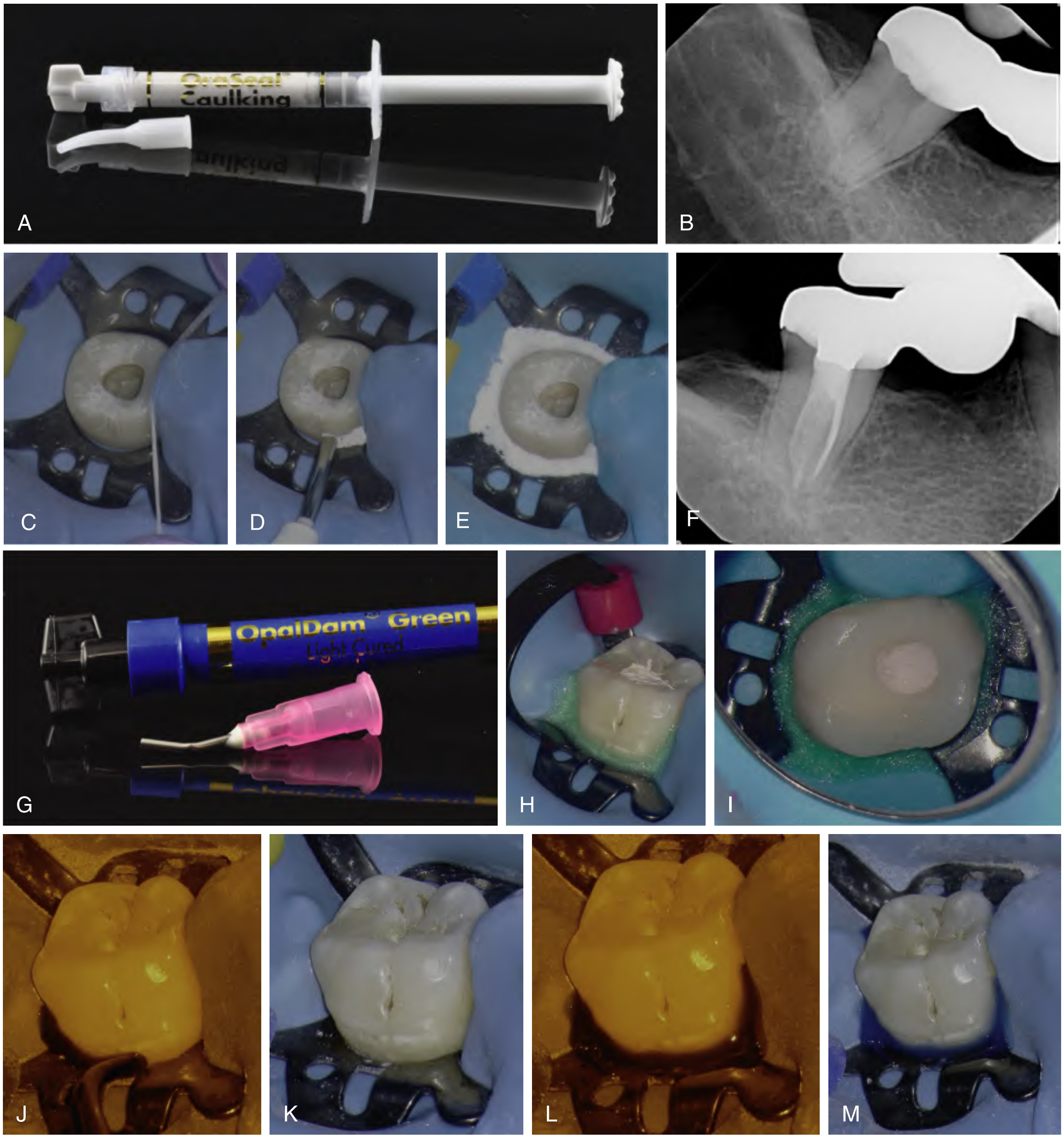
The material can be placed on the gingival tissues at the dam–tooth interface after isolation. The caulking and putty materials adhere to wet surfaces, although the putty has a stiffer consistency.

Disinfection of the Operating Field

Various methods and techniques are used to disinfect the tooth, clamp, and surrounding rubber dam after placement. These disinfectants include alcohol, quaternary ammonium compounds, sodium hypochlorite, organic iodine, mercuric salts, chlorhexidine, and hydrogen peroxide. An effective technique is as follows: (1) plaque is removed by rubber cup and pumice; (2) the rubber dam is placed; (3) the tooth surface, clamp, and surrounding rubber dam are scrubbed with 30% hydrogen peroxide; and (4) the surfaces are swabbed with 5% tincture of iodine or with sodium hypochlorite.[19]

Access Openings

Endodontic access openings are based on the anatomy and morphology of each individual tooth group. In general, the pulp



• **Fig. 13.6** **A,** Caulking and putty materials are available to prevent leakage after rubber dam application. **B,** Preoperative radiograph and **C,** demonstration of lack of isolation with dental floss. **D,** Application of the caulk. **E,** The sealed dam. **F,** Postoperative radiograph. **G,** OpalDam. **H, I,** Two teeth sealed with OpalDam after light curing. **J,** LC Block-Out. **K,** Before the sealing. **L,** Placing the Block-Out under the microscope (yellow filter to avoid the material setting). **M,** Final seal after light curing.

number of root canals dictates the final design of the access preparation. The internal anatomy is projected onto the external surface. Internal pulp chamber morphology varies with the patient's age and secondary or tertiary dentin deposition. In anterior teeth and premolars with a single root, calcification occurs in a coronal to apical direction with the chamber receding. In posterior teeth with bifurcations and trifurcations, secondary dentin is deposited preferentially on the floor of the chamber, decreasing the cervical to apical dimension of the chamber.[20,21] The mesiodistal and buccolingual dimensions remain relatively the same, as does the cusp-to-roof distance. Dystrophic calcifications related to caries, restorations, attrition abrasion, and erosion also can occur. In general, the pulp chamber is located at the cementoenamel junction (CEJ).[22,23] In young teeth, the pulp horns are at approximately the level of the height of contour.

The major objectives of the access openings include (1) removal of the chamber roof and all coronal pulp tissue, (2) locating all canals, (3) unimpeded straight-line access of the instruments in the canals to the apical one third or the first curve (if present), and (4) conservation of tooth structure.

Before initiating treatment, the clinician should assess the existing coronal structure; restorations present; tooth angulation in the arch; and the position, size, depth, and shape of the pulp chamber. A parallel preoperative radiograph or digital image is essential. Additional angled radiographs or digital images may aid the identification of additional canals and roots. Bitewing radiographs and digital images offer the most accurate and distortion-free information on chamber anatomy in posterior teeth. Recent advances in cone beam computed tomography (CBCT) imaging allow three-dimensional (3D) viewing of the pulp chamber and radicular space.[25,26] Conservation of tooth structure is important for subsequent restorative treatment and the long-term prognosis.[27] Maintaining adequate structure in the cervical region is assured by not extending the access preparation beyond the natural external chamber walls. The distance from the surface of the clinical crown to the peripheral vertical wall of the pulp chamber is the same throughout the circumference of the tooth at the level of the CEJ, and the orifices of the root canals are located at the angles in the floor–wall junction (Video 13.4).[28,29]

General Principles

A broad discussion about the preservation of dentin during the endodontic procedures, including the conventional access, has been subjected to debate in the literature.[27] The traditional endodontic access underscores the concept of straight-line preparation to improve the mechanical débridement of root canals and to minimize procedural errors. However, the excessive removal of tooth structure has been associated with the increased risk of fracture and loss of the tooth as consequences. Lately, investigators have associated the survivability of the endodontically treated tooth with conservative approaches such as contracted endodontic cavities.[30] Even though this concept has been questioned and not completely proved to be the predictable treatment method,[31-33] we deem that dentin preservation must be taken in consideration in all procedures to increase the long-term survival rate of endodontically treated teeth.

Contemplating the debate on preservation of tooth structure and the lack of a comprehensive opinion of the straight-line access significance, the general principles for endodontic access remain (1) outline form, (2) convenience form, (3) caries removal, and (4) cleaning the periphery of the preparation to ensure it is free of any debris or objects that could fall into the canals upon access.

Outline form is the recommended shape for access preparation of a normal tooth with radiographic evidence of a pulp chamber and canal space. The outline form ensures the correct shape and location and provides straight-line access to the apical portion of the canal or to the first curvature. The access preparation must remove tooth structure that would impede the cleaning and shaping of the canal or canals. The outline form is a projection of the internal tooth anatomy onto the external root structure. The form can change with time. As an example, in anterior teeth with mesial and distal pulp horns, the access is triangular. In older individuals with chamber calcification, the pulp horns are absent, so the access is ovoid.

Convenience form allows modification of the ideal outline form to facilitate unstrained instrument placement and manipulation. As an example, the use of nickel–titanium rotary instruments requires straight-line access. An access might be modified to permit placement and manipulation of the nickel–titanium instruments. Another example is a premolar exhibiting three roots. The outline form might be made more triangular to facilitate canal location.

Caries removal is essential for several reasons. First, removing caries permits the development of an aseptic environment before entering the pulp chamber and radicular space. Second, it allows assessment of restorability before treatment. Third, caries removal provides sound tooth structure so that an adequate provisional restoration can be placed. Unsupported tooth structure is removed to ensure a coronal seal during and after treatment so that the reference point for length determination is not lost should fracture occur.

Cleaning the periphery involves preventing materials and objects from entering the chamber and canal space. A common error is entering the pulp chamber before the coronal structure or restorative materials have been adequately prepared. As a result, these materials enter the canal space and may block the apical portion of the canal.

Canal Morphologies

Five major canal morphologies have been identified (Fig. 13.7).[34] They include round, ribbon or figure eight, ovoid, bowling pin, kidney bean, and C-shape. With the exception of the round morphologic shape, each presents unique problems for adequate cleaning and shaping.

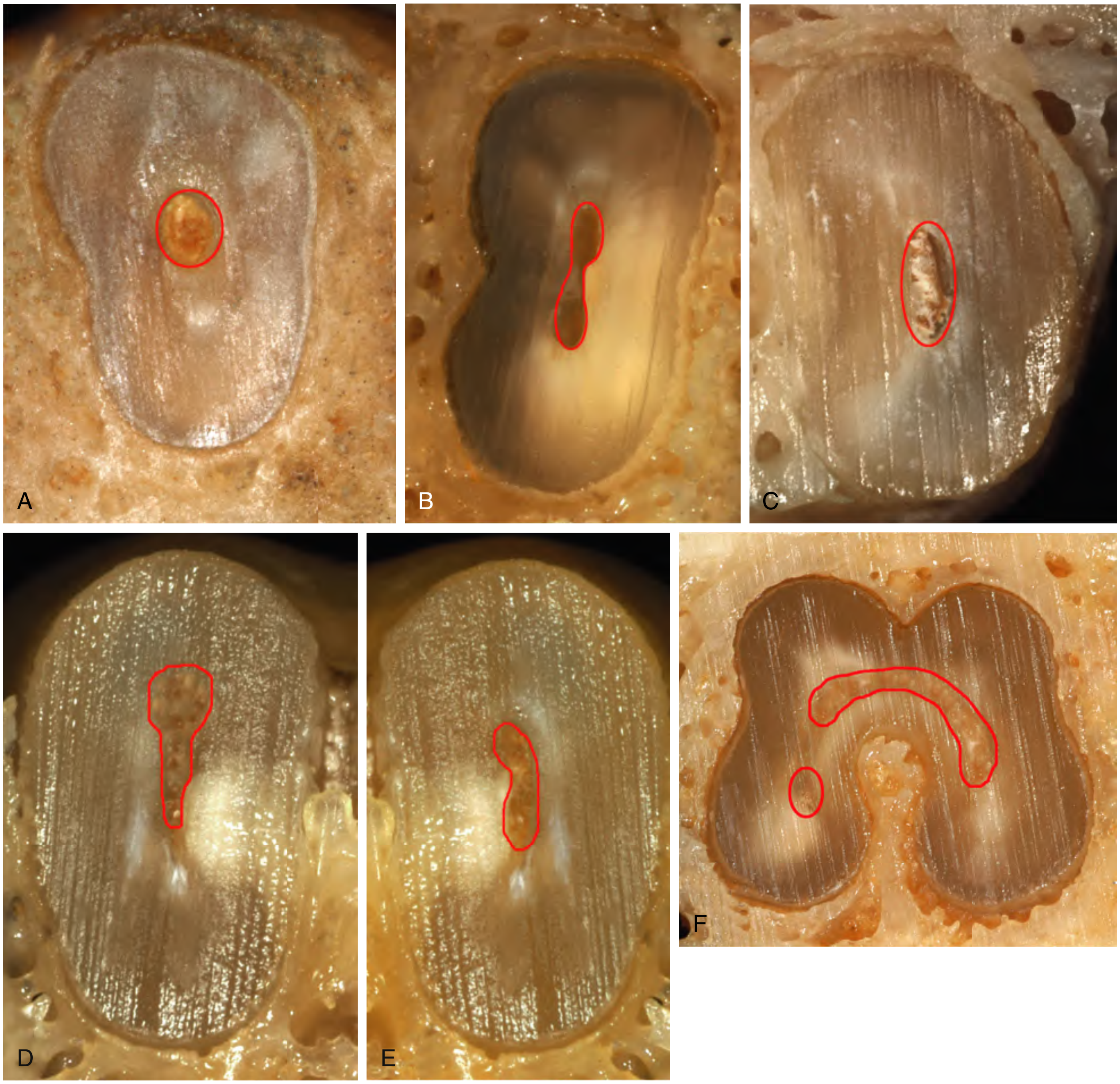
General Considerations

In difficult cases the access can be prepared without the rubber dam in place. This preparation allows visualization of the tooth shape, orientation, and position in the dental arch. When the canal or chamber is located, the rubber dam is applied. *Caution:* Until the rubber dam is in place, broaches and files cannot be used (see Fig. 13.1).

Care must be taken to prevent tooth structure or restorative materials from entering the radicular portion of the root if additional expansion of the access is necessary after the chamber is exposed. When an access is to be enlarged or restorative materials removed after chamber exposure, the radicular space must be protected. The canal orifice and chamber floor can be blocked by placing gutta-percha temporary stopping. The material is heated and then compacted with a plugger. The temporary stopping is removed with heat (preferred) or solvents after completion of the access preparation.

Before beginning the access, the clinician should assess the preoperative images to determine the degree of case difficulty. At this stage the estimated depth of access is calculated. This calculation is a measurement from the incisal edge of anterior teeth and the occlusal surface of posterior teeth to the coronal portion of the pulp chamber. Calculated in millimeters, this information is then transferred to the access bur and provides information on the depth necessary to expose the pulp. If the estimated depth of access is reached and the pulp has not been encountered, the access depth and orientation must be reevaluated. A parallel image exposed with the rubber dam removed helps determine the depth and orientation so that perforations and unnecessary removal of tooth structure can be avoided (see Fig. 13.33).

The estimated depth of access for anterior teeth is similar in different tooth groups.[35] The maxillary central and lateral incisors average 5.5 mm for the central incisor and 5 mm for the lateral incisor. The mandibular central and lateral incisors average 4.5 mm for the central incisor and 5 mm for the lateral incisor. The maxillary canine averages 5.5 mm, and the mandibular canine, with its longer clinical crown, averages 6 mm. In maxillary furcated premolars, the



• **Fig. 13.7** Common canal morphologies. **A,** Round. **B,** Ribbon shaped (hourglass). **C,** Ovoid. **D,** Bowling pin. **E,** Kidney bean shaped. **F,** C-shaped.

average distance from the buccal cusp tip to the roof of the chamber is 7 mm.[35] For maxillary molars, the distance is 6 mm, and for the mandibular molars, it is 6.5 mm. With an average pulp chamber height of 2 mm, the access depth for most molars should not extend beyond 8 mm (the floor of the chamber).[23]

Access openings are best accomplished using fissure burs in the high-speed handpiece. A number of special burs are also available for access. No single bur type is superior. For the clinician with knowledge of anatomy and morphology and the appropriate clinical skills and judgment, bur selection is a personal choice (Figs. 13.8 and 13.9). Regardless of the high-speed bur chosen, the bur is placed in the chamber and removed while rotating. High-speed burs are not used in the canals. Failure to follow these principles can result in breakage (Fig. 13.10).

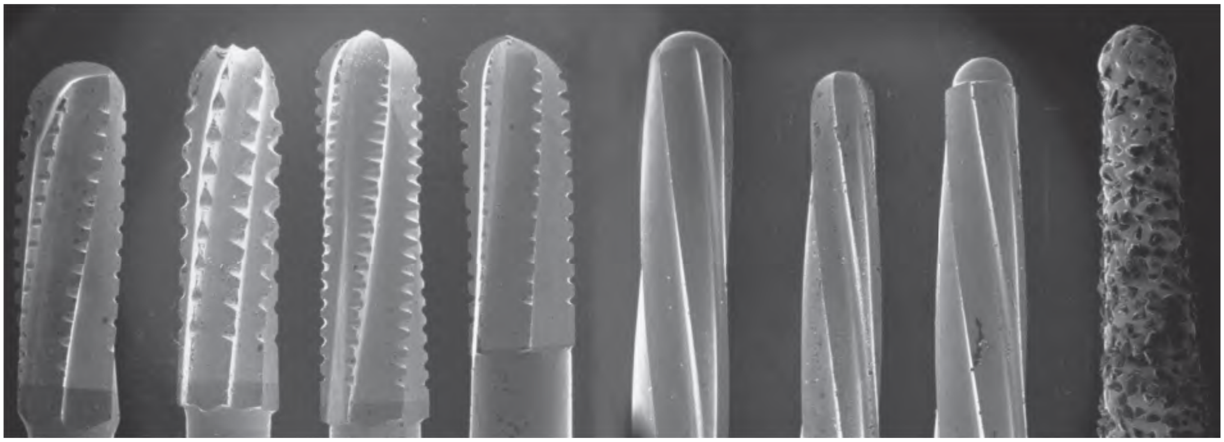
Visualization of the internal anatomy is enhanced during access by using a fiberoptic handpiece and microscopy.[36] Illumination is the key. A sharp endodontic explorer is used to detect the canal orifice or to aggressively dislodge calcifications. When a canal is located, a small file or pathfinding instrument (0.06, 0.08, or 0.10 stainless steel file) is used to explore the canal and determine canal patency close to the apical foramen. Care should be exercised during this process to avoid forcing tissue apically, which might result in canal blockage (Fig. 13.11). This procedure is performed in the presence of irrigant or lubricant.

Removal of restorative materials during access is often indicated, with the knowledge that after treatment a new restoration will be placed. Removal enhances visibility and may reveal undetected canals, caries, or coronal fractures. When difficulties occur with calcifications or extensive restorations, the operator may become disoriented. The discovery of one canal can serve as a reference in locating the remaining canals. A file can be inserted and an angled image exposed to reveal which canal has been located.

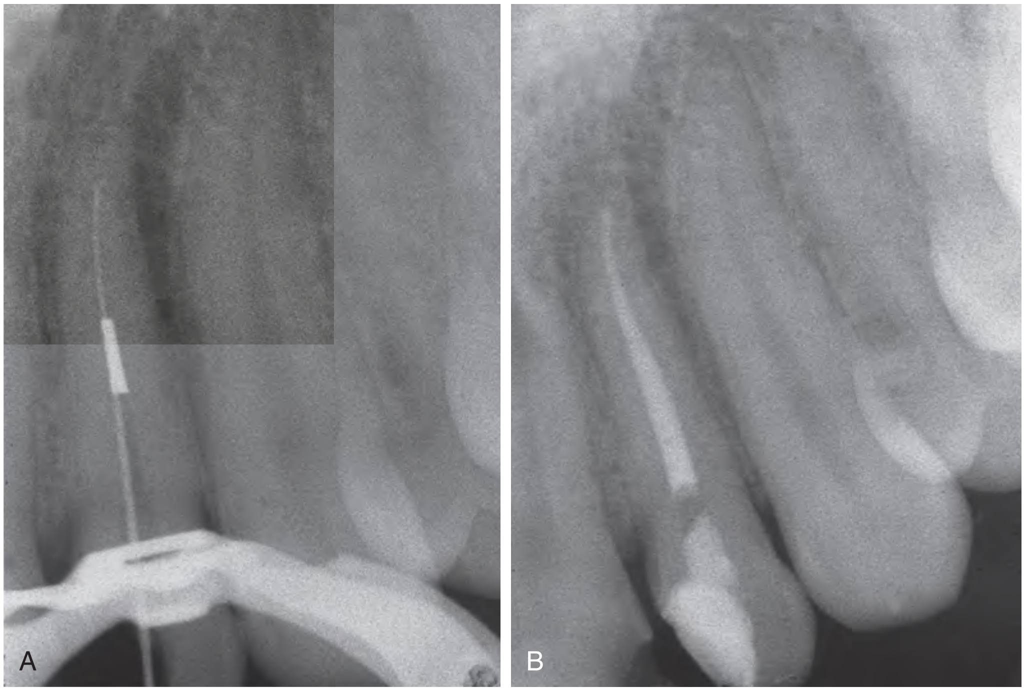
It is important not to violate marginal ridges during access preparation in any of the tooth groups.

Complex restorations, such as crowns and fixed partial dentures, may have changed the coronal landmarks used in canal location. A tipped tooth might be "uprighted" or a rotated tooth "realigned." Loss

• **Fig. 13.8** Examples of access burs. *Left to right,* No. 4 round carbide, No. 557 carbide, Great White, Beaver bur, Transmetal, Multipurpose bur, Endo Z bur, and Endo Access bur.



• **Fig. 13.9** Muller discovery Access burs.



• **Fig. 13.10** **A,** Fractured fissure bur and working length file bypassing the obstruction. **B,** After the bur was removed with files and ultrasonics.

of orientation can result in incorrect identification of a canal, and searching for the other canals in the wrong direction results in excessive removal of tooth structure, perforation, or failure to locate and débride all canals.

Access through crowns with extensive foundations may make visibility difficult. Class V restorations may have induced coronal calcification or could have been placed directly into the pulp space or the canals. In some instances, it may be best to remove restorative materials that interfere with visibility before initiating root canal treatment.

A modification of the armamentarium for teeth restored with crowns has been advocated for all-ceramic crowns. The initial outline and penetration through ceramic (porcelain) restorative material are made with a round diamond bur in the high-speed handpiece with water coolant. After penetration into dentin, a fissure bur is used. In teeth with porcelain-fused-to-metal restorations, a metal cutting bur is recommended. When possible, the access should remain in metal to reduce the potential for fracture in the porcelain. Evidence indicates that with a water coolant and careful instrumentation, diamond and carbide burs are equally effective.[37] The access is restored with amalgam after the root canal treatment. With the introduction of all-ceramic and zirconia crowns, specialized burs have been fabricated to facilitate access through these very hard materials.

In summary, aids in canal location include a knowledge of pulp anatomy and morphology; parallel straight-on and angled radiographs or digital images; a sharp endodontic explorer; interim radiographs or digital images; long-shanked, slow-speed burs (Fig. 13.12); ultrasonic instruments for troughing; dye staining; irrigation; transillumination; and enhanced vision with loupes or microscopy.[38] Additional aids include CBCT imaging.[25,26]

Study Questions

1. Avoidance of rubber dam isolation can place patients and clinicians at unnecessary risk.
   a. True
   b. False
2. Rubber dam isolation serves the following purpose:
   a. Protects patient from instruments
   b. Provides a more aseptic field of work
   c. Enhances visibility
   d. Retracts tissues
   e. All of the above
3. If adequate tooth structure is not remaining for clamp placement, which of the following is not acceptable?
   a. Rubber dam placement may be avoided.
   b. The tooth may require placement of a buildup to enhance remaining structure.
   c. The tooth may require crown lengthening procedure.
   d. Patient may need to be referred to a specialist.
   e. A deep-reaching clamp may be required.
4. What is the best time to assess difficulties and challenges in tooth isolation and placement of a rubber dam?
   a. Before initiation of treatment
   b. At the time of placement of the clamp
   c. After access preparation
   d. After caries removal
5. Which of the following is correct with respect to access preparation?
   a. Endodontic access openings are based on the anatomy and morphology of each tooth.
   b. The pulp number of root canals dictates the final design.
   c. Typically, the internal anatomy is projected onto the external surface.
   d. Age may affect the internal anatomy of the pulp chamber.
   e. All of the above.

Access Openings and Canal Location*

Maxillary Central and Lateral Incisors

The maxillary central incisor has one root and one canal.[41] In young individuals, the prominent pulp horns require a triangular outline form to ensure that tissue and obturation materials, which otherwise might cause coronal discoloration, are removed (Fig. 13.13). Although the canal is centered in the root at the CEJ and when the tooth is viewed from a mesial to distal orientation, it is evident that the crown is not directly in line with the long axis of the root (Fig. 13.14). For this reason, the establishment of the outline form and initial penetration into enamel are made with the bur perpendicular to the lingual surface of the tooth. This outline form is made in the middle third of the lingual surface (Figs. 13.15 and Figs. 13.16). After penetration to the depth of 2 to 3 mm, the bur is reoriented to coincide with the long axis and lingual orientation of the root.

After penetration to a depth of 2 to 3 mm, the bur is reoriented to coincide with the long axis and lingual orientation of the root. This reorientation reduces the risk of a lateral perforation through the facial surface. An additional common error is failure to remove the lingual shelf (see Fig. 13.15, *C*), which results in inadequate access to the entire canal. The canal is located by using a sharp endodontic explorer. When calcification has occurred, long-shanked burs in a slow-speed handpiece can be used (see Figs. 13.12 and 13.24, *D*). These burs move the head of the handpiece away from the tooth and enhance the ability to see exactly where the bur is placed in the tooth.

Access for the maxillary lateral incisor is similar to that for the central incisor. A triangular access is indicated in young patients with pulp horns (Fig. 13.17); as the pulp horns recede, the outline form becomes ovoid (Fig. 13.18).

Dens invaginatus (or dens en dente) is a common developmental defect in the maxillary lateral incisor that results in pulp necrosis.[40-42] Additionally, a lingual groove may be found in maxillary lateral incisors, as evidenced by a narrow probing defect. These developmental defects complicate treatment and affect the prognosis (Video 13.5).

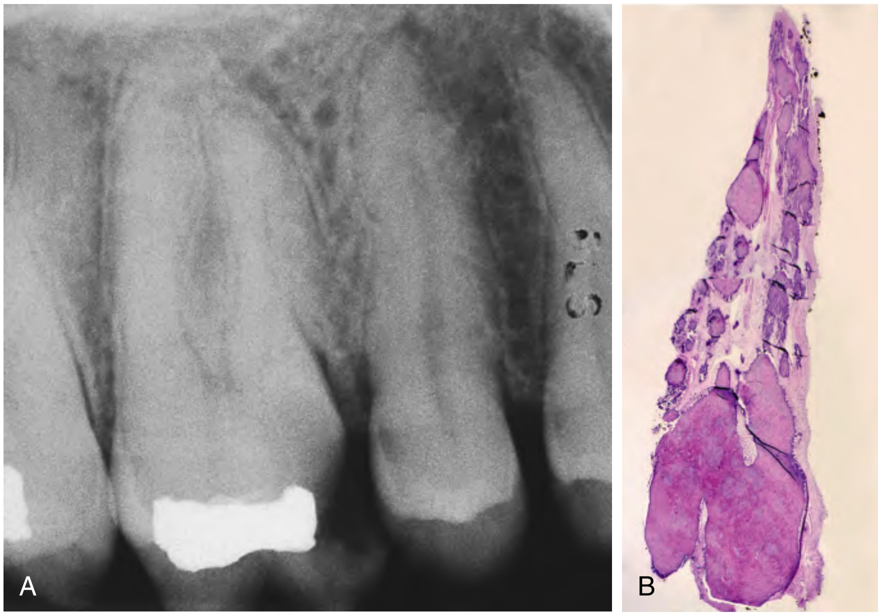
Maxillary Canines

The maxillary canines have one canal in a single root. In general, pulp horns are absent, so the outline form is ovoid in the middle third of the lingual surface (Figs. 13.19 and 13.20). As attrition occurs, the chamber appears to move more incisally because of the loss of structure. In cross-section, the pulp is wide in a faciolingual direction compared with the mesiodistal dimension (Video 13.6).

Maxillary Premolars

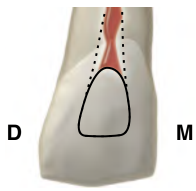
The maxillary first and second premolars have a similar coronal structure; therefore the outline form is similar for these two teeth. It is centered in the crown and has an ovoid shape in the faciolingual direction (Figs. 13.21 and 13.22). An important anatomic consideration with these teeth is the mesial concavity at the CEJ. In this area, a lateral perforation is likely to occur. When two canals are present, the canal orifices are located under the buccal and lingual cusp tips, equidistant from a line drawn through the center of the chamber in a mesial to distal direction. The cross-sectional morphology shows a kidney bean– or ribbon-shaped configuration. In rare instances when three canals are present, the outline form is triangular, with the base to the facial and the apex toward the lingual (Videos 13.7 and 13.8).

*See Appendix, Pulpal Anatomy and Access Preparations, for color illustrations showing the size, shape, and location of the pulp space in each tooth.



• **Fig. 13.11** **A,** Maxillary first molar shows extensive mesial caries. **B,** Histologic section of pulp tissue from the palatal canal reveals extensive calcification. Early canal exploration should be done with small files to avoid forcing the tissue and calcification apically and blocking the canal.

• **Fig. 13.12** Mueller burs have a round cutting head attached to a long shank. The long shank is not designed to drill deep into the root, but rather to extend the head of the slow-speed handpiece away from the tooth and permit better visibility.

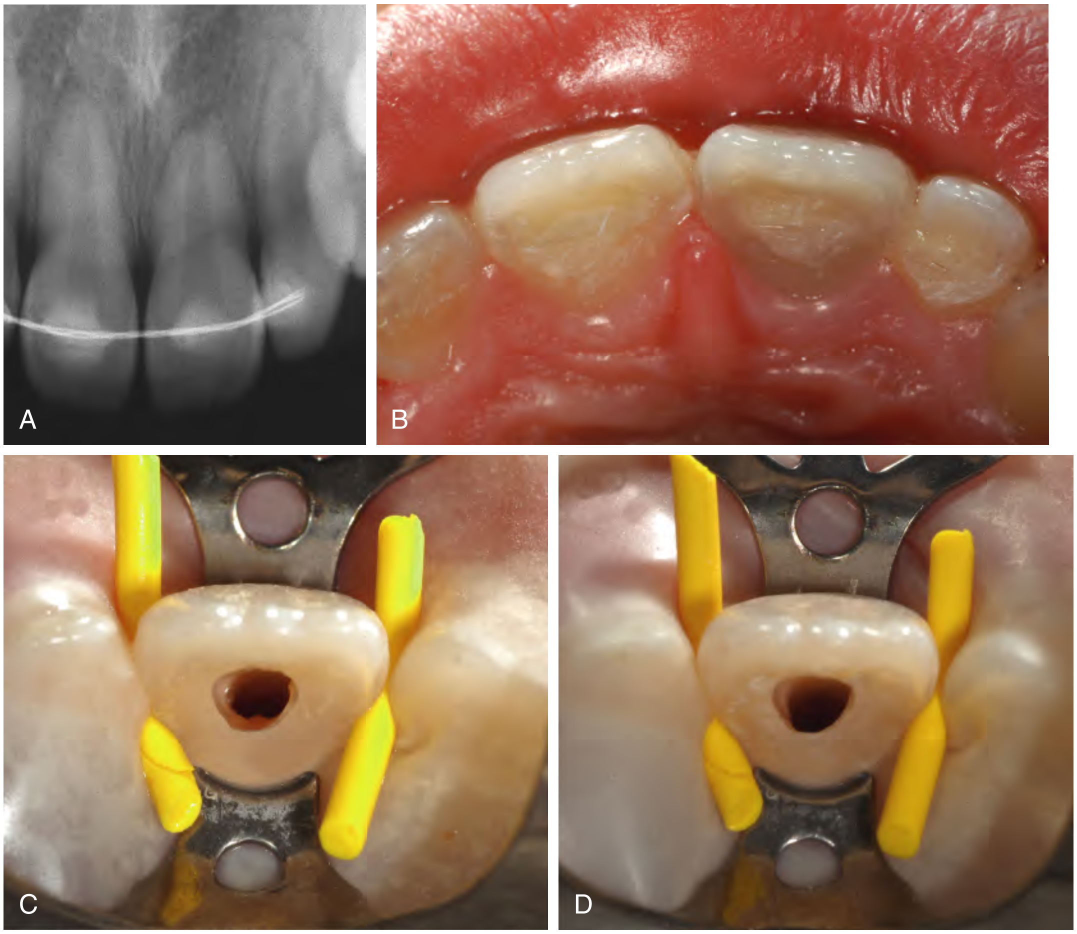


• **Fig. 13.13** A triangular outline form for access of the maxillary central incisor.

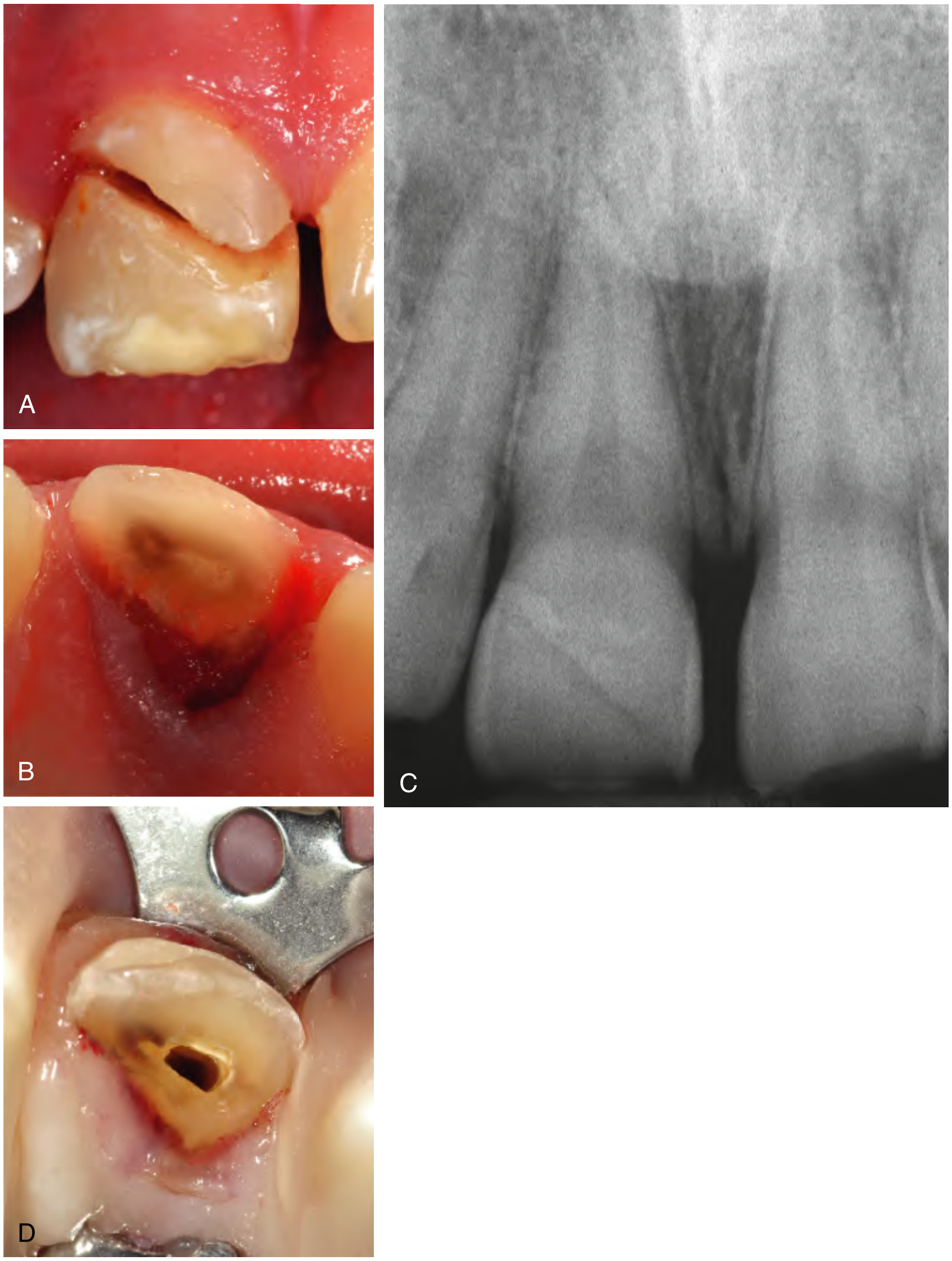
Maxillary Molars

The maxillary first and second molars have similar access outline forms. The outline form is triangular and located in the mesial half of the tooth, with the base to the facial and the apex toward the lingual (Figs. 13.23 and 13.24). The transverse or oblique ridge is left mostly intact. The external references for canal location serve as a guide in developing the outline form. The mesiobuccal canal orifice lies slightly distal to the mesiobuccal cusp tip. The distobuccal canal orifice lies distal and slightly lingual to the main mesiobuccal canal and is in line with the buccal groove. The lingual or palatal canal orifice generally exhibits the largest orifice and lies slightly distal to the mesiolingual cusp tip. The mesiobuccal root is very broad in a buccolingual direction; thus a small second canal is common.[43-47] The mesiolingual canal orifice (commonly referred to as the *MB2 canal*) is located 1 to 3 mm lingual to the main mesiobuccal canal *(MB1 canal)* and is slightly mesial to a line drawn from the mesiobuccal to the lingual or palatal canal. The initial movement of the canal from the chamber is often not toward the apex but laterally toward the mesial (Fig. 13.25).

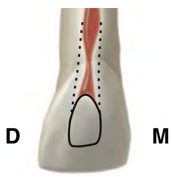
• **Fig. 13.14** Note the lingual inclination of the root in relation to the crown. In addition, the pattern of calcification occurs from the coronal portion of the pulp apically.



• **Fig. 13.15** A maxillary left central incisor showing pulp necrosis. **A,** A large pulp space with pulp horns that requires a triangular access outline. **B,** The lingual surface after removal of the orthodontic retaining wire. Note that tooth #9 is slightly discolored. **C,** The initial triangular access form exposing the chamber. Note that the lingual shelf has not been removed to expose the lingual wall. **D,** Removal of the lingual shelf and completed access.



• **Fig. 13.16** Crown-root fracture. **A,** Initial presentation demonstrating fragment separation. **B,** The lingual surface with the segment removed. **C,** Preoperative radiograph. **D,** The extent of the fracture subgingivally requires a unique approach to isolation. Note that a premolar clamp is placed on the gingival tissues for isolation.

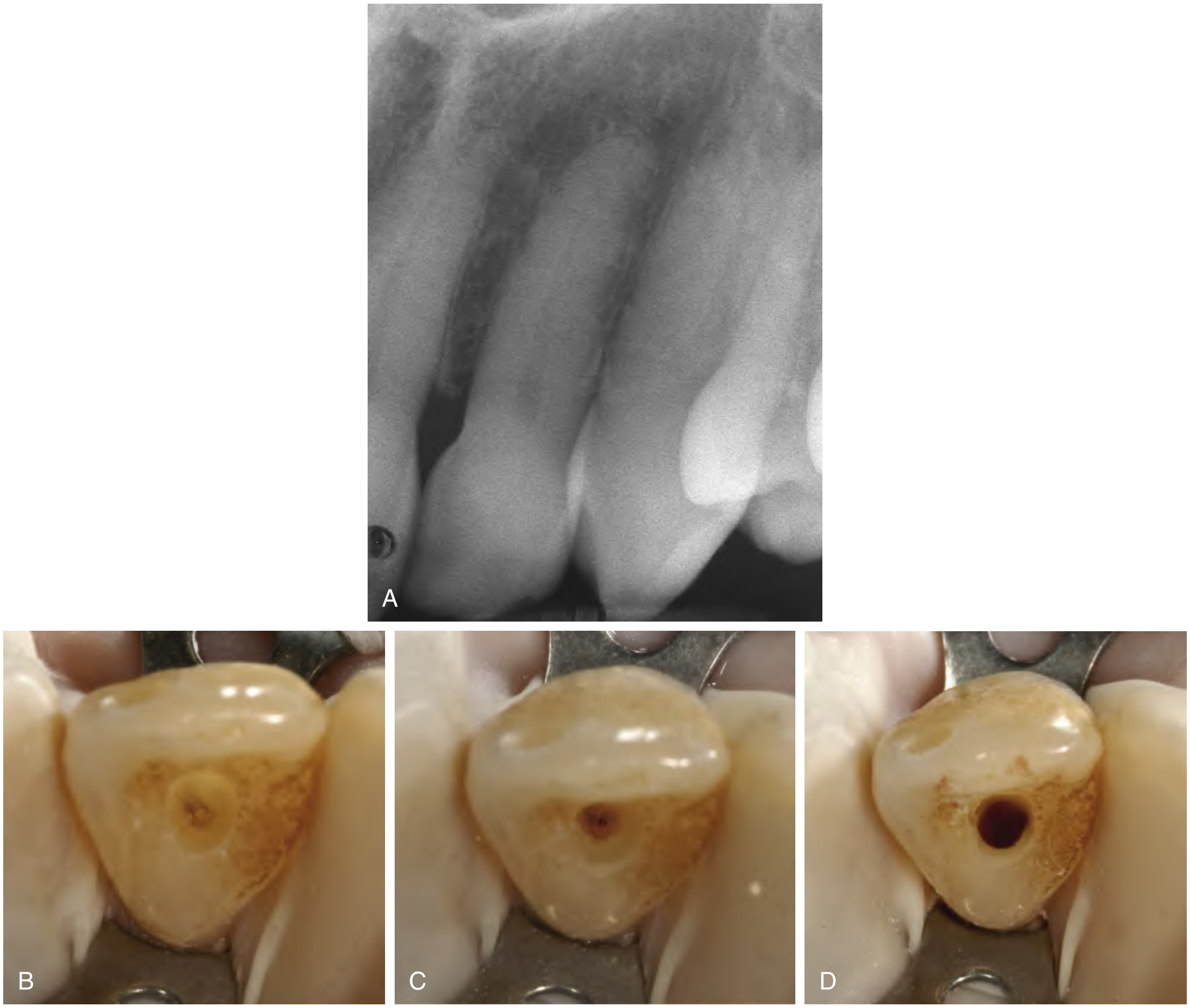


• **Fig. 13.17** Triangular outline form of the maxillary lateral incisor.

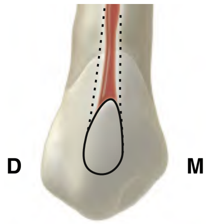
Removal of the coronal dentin (cornice) in this area permits exposure of the canal as it begins to move apically and facilitates negotiation (Figs. 13.26 and 13.27; also see Figs. 13.24 and 13.25).[47] The operating microscope is a valuable aid (Video 13.9).[36,38,39]

Mandibular Central and Lateral Incisors

The mandibular incisors are narrow in the mesiodistal dimension and broad faciolingually. There may be one canal with an ovoid or a ribbon-shaped configuration; often two canals are present. When there are two canals, the facial canal is easier to locate and is generally straighter than the lingual canal, which is often shielded by a lingual



• **Fig. 13.18** **A,** Lateral incisor with a receded pulp chamber. **B,** Initial ovoid outline form is initiated. **C,** Coronal calcification is indicated by the color change. **D,** Completed access.



• **Fig. 13.19** Outline form for the maxillary canine.

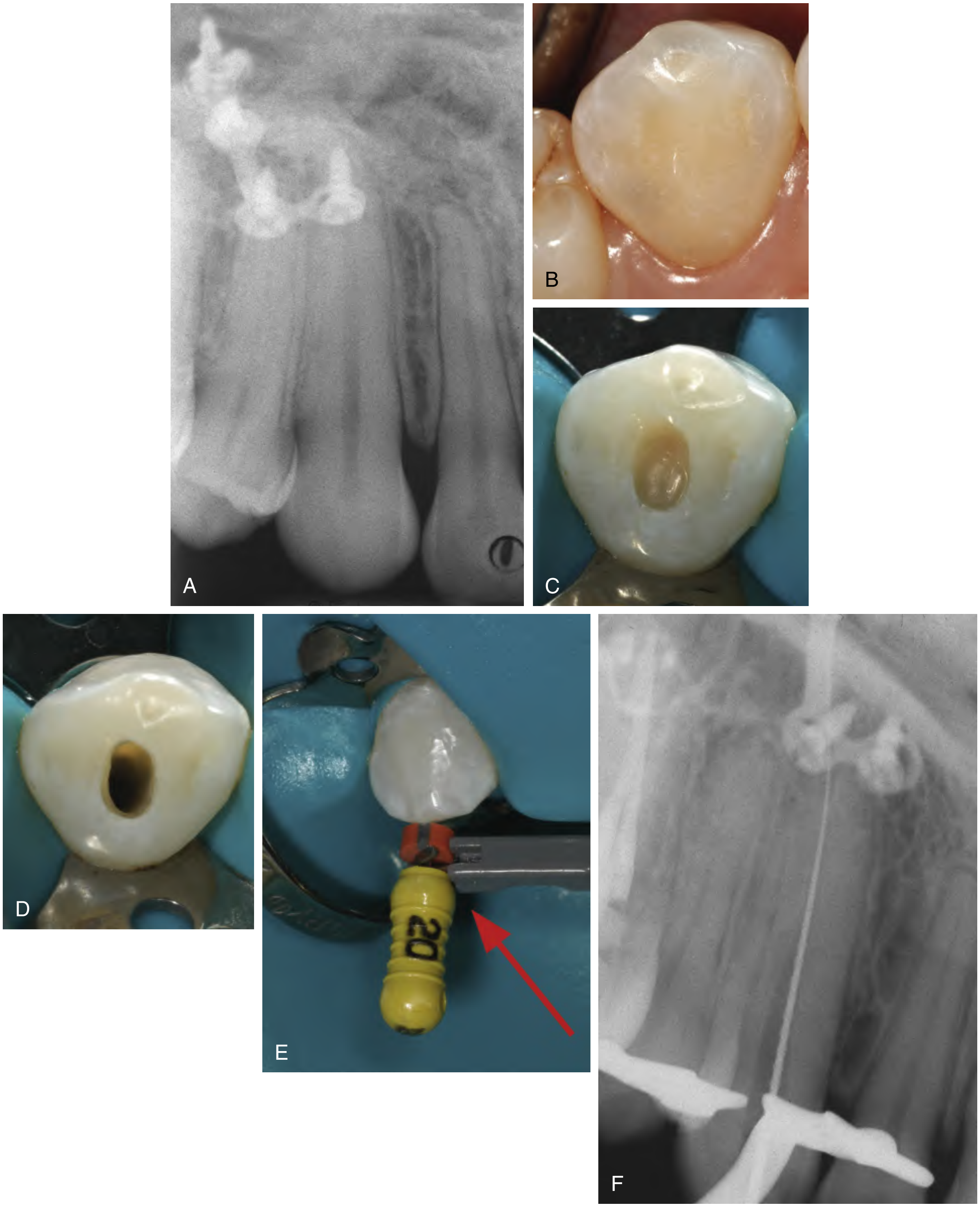
bulge. Because the tooth is often tipped facially, the lingual canal is difficult to locate; perforations primarily occur on the facial surface (Video 13.10).

The narrow mesiodistal dimension of these teeth makes access and canal location difficult. In young patients with mesiodistal pulp horns, the outline form is triangular with the base incisally and the apex gingivally. As the pulp recedes over time and the pulp horns disappear, the shape becomes more ovoid. The access is positioned in the middle third of the lingual surface (Figs. 13.28 and 13.29). Because of the small size of these teeth and the presence of mesiodistal concavities, access must be precisely positioned. The initial outline form is established into dentin with the bur perpendicular to the lingual surface. At a depth of 2 to 3 mm, the bur is reoriented along the long axis of the root. Because the percentage of teeth with two canals is reported to be 25% to 40%,[48,49] the lingual surface of the chamber and canal must be diligently explored with a small, precurved stainless steel file. A Gates Glidden drill or orifice shaper is used on the lingual to remove the dentin bulge.

In cases of attrition, the access moves toward the incisal surface. With the use of nickel–titanium rotary and reciprocating instruments, straight-line access is imperative. A more incisal approach on the lingual or facial surface is justified.[50] A modification of the access for the incisors is a facial approach.[51] This approach provides better visibility and can be used when there is crowding or when the canal is receded below the CEJ (Video 13.11).

Mandibular Canines

The mandibular canines usually have a long, slender crown in comparison with the maxillary canine, which is shorter and wider in a mesiodistal direction. The tooth may have one or two roots. The root is broad in a faciolingual dimension and therefore may

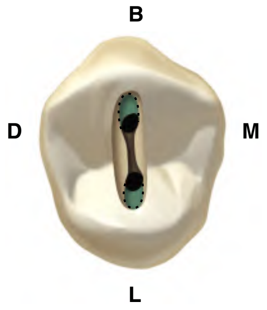


• **Fig. 13.20** **A,** The apex is obscured by the screws placed during a maxillary surgical advancement. **B,** Lingual surface. **C,** Initial access outline into dentin. **D,** Access is finalized. **E,** Apex locator *(arrow).* **F,** Working length.

contain two canals.[49] The outline form is ovoid and positioned in the middle third of the crown on the lingual surface (Figs. 13.30 and 13.31). On access opening into the chamber, the lingual surface should be explored for the presence of a lingual canal. As attrition occurs, the access must be more incisal, and in severe cases it may include the incisal edge of the tooth (Video 13.12).

Mandibular Premolars

The mandibular premolars appear to be easy to treat, but the anatomy may be complex. One, two, or three roots are possible, and canals often divide deep within the root in these complex morphologic configurations.[49,52] The crown of the first premolar has

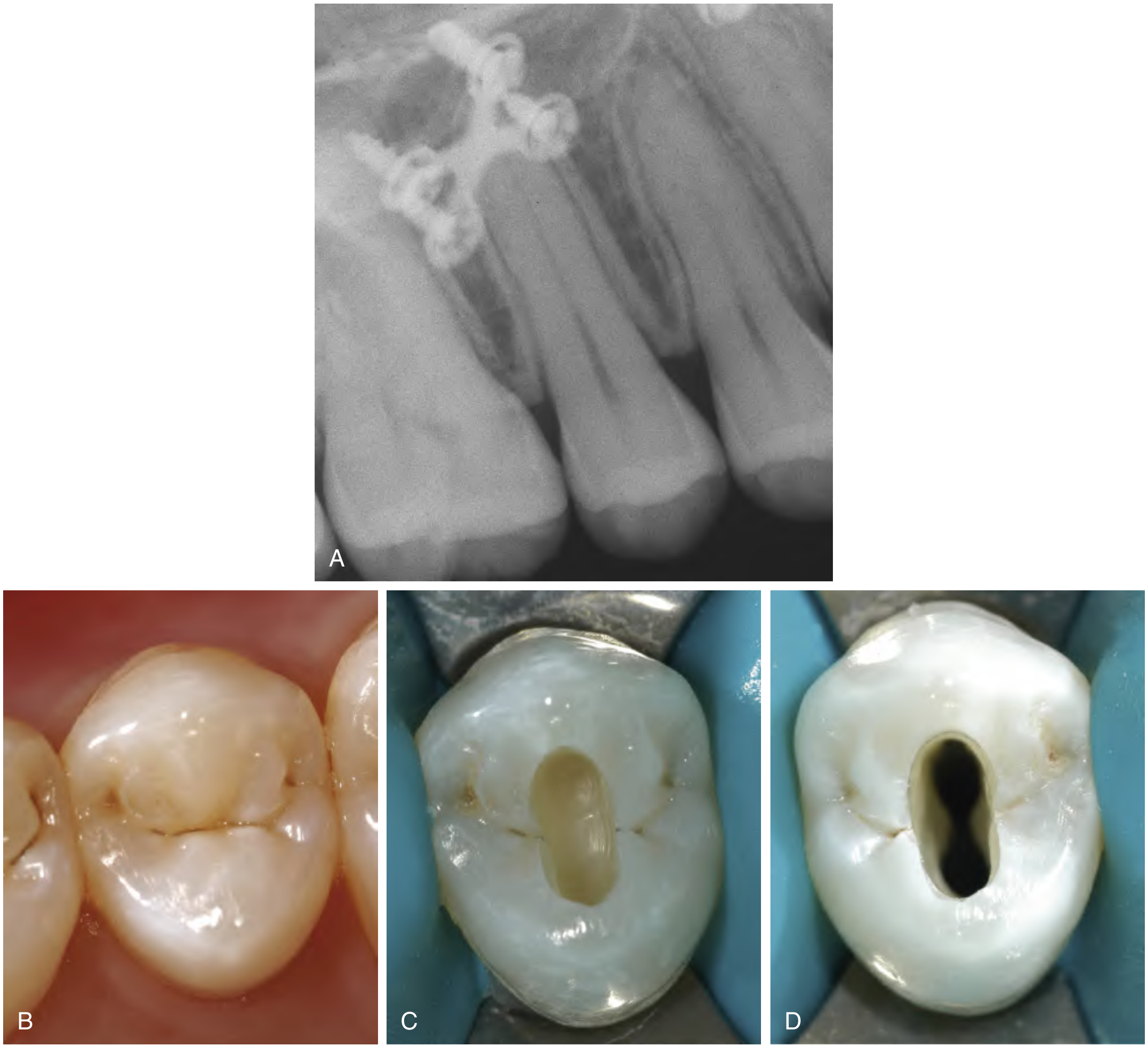


• **Fig. 13.21** Ovoid outline form for the maxillary premolars.

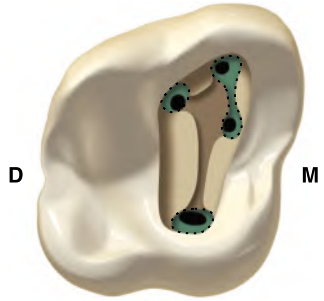
a prominent buccal cusp and a vestigial lingual cusp. In addition, there is a lingual constriction. Mesiodistal projections reveal that the chamber and canal orifice are positioned buccally. The access is therefore ovoid in a buccolingual dimension and positioned buccal to the central groove (Figs. 13.32 and 13.33). It extends just short of the buccal cusp tip. The mandibular second premolar has a prominent buccal cusp, but the lingual cusp can be more prominent than with the first premolar. There is also a lingual constriction, so the outline form is ovoid from buccal to lingual and positioned centrally (Fig. 13.34; Video 13.13).

Mandibular Molars

The mandibular molars are similar in anatomic configuration; however, there are subtle differences. The most common mandibular first molar configuration is two canals in the mesial root, although three have been reported,[53] and one canal in the distal root. A second canal is present in the distal root in 30% to 35% of



• **Fig. 13.22** **A,** Note the obstructed view of the apical region. **B,** Maxillary right second premolar. **C,** The initial outline form prepared into dentin. **D,** The chamber and canals are accessed.



• **Fig. 13.23** Triangular outline form for access of the maxillary molar.

cases (Fig. 13.35).[53,55] The roots often have a kidney bean shape in cross section with the concavity in the furcal region. The most common configuration for the mandibular second molar is two canals in the mesial root and one canal in the distal root. The incidence of four canals is low (Video 13.14).[54]

The coronal reference points for canal location in the mandibular molar roots are influenced by the position of the crown on the root and by the lingual tipping of these teeth in the arch (Fig. 13.36). The mesiobuccal canal orifice is located slightly distal to the mesiobuccal cusp tip. The mesiolingual canal orifice is located in the area of the central groove area and slightly distal compared with the mesiobuccal canal. The distal canal is located near the intersection of the buccal, lingual, and central grooves. When a distobuccal canal is present, the orifice can be found buccal to the main distal canal and often is slightly more mesial. The mandibular first molar may even have a distinct separate extra distal root. Because of these anatomic relationships, the access outline form is rectangular or trapezoidal and positioned in the mesiobuccal portion of the crown (Fig. 13.37). An additional variation in mandibular molars is the presence of a middle mesial canal (Fig. 13.38).

During access preparation, the cervical bulge that overlies the canal orifices of the mesiobuccal and mesiolingual canals is removed (Fig. 13.39), permitting straight-line access to the first curve or apical portion of the root by reducing the emergence profile. This technique also enhances entry into the canals.

Errors in Access

Inadequate Preparation

Errors in access preparations are varied (Fig. 13.40). A common error is inadequate preparation, which has several significant consequences. Direct effects are decreased access and visibility, which prevent the clinician from locating the canals. The ability to remove the coronal pulp tissue and subsequent obturation materials is limited, and straight-line access cannot be achieved. Inadequate straight-line access can indirectly lead to errors during the cleaning and shaping. When files are deflected by coronal interferences, procedural errors, such as loss of working length, apical transportation, ledging, and apical perforation, are likely in curved canals. A No. 25 file or above has a straightening force that overcomes the confining resistance of the dentin wall. The file cuts on the outer surface apical to the curvature and the inner wall coronal to the curve. Adequate straight-line access decreases the canal curvature and reduces the coronal interferences, allowing the instrument to work more freely in the canal.[55]

Excessive Removal of Tooth Structure

The excessive removal of tooth structure has direct consequences and unlike inadequate preparation is irreversible and cannot be corrected. A minimum consequence is weakening of the tooth and subsequent coronal fracture. Evidence indicates that appropriate access and strategic removal of tooth structure that does not involve the marginal ridges do not significantly weaken the remaining coronal structure.[56] The marginal ridges provide the faciolingual strength to the crown[57]; access openings do not require removal of tooth structure in this area.[58]

The ultimate result of removing excessive tooth structure is perforation. Perforations in single-rooted teeth are located on the lateral surface. In multirooted teeth, perforations may be lateral or furcal (see Chapter 18).

Length Determination

Radiographic Evaluation

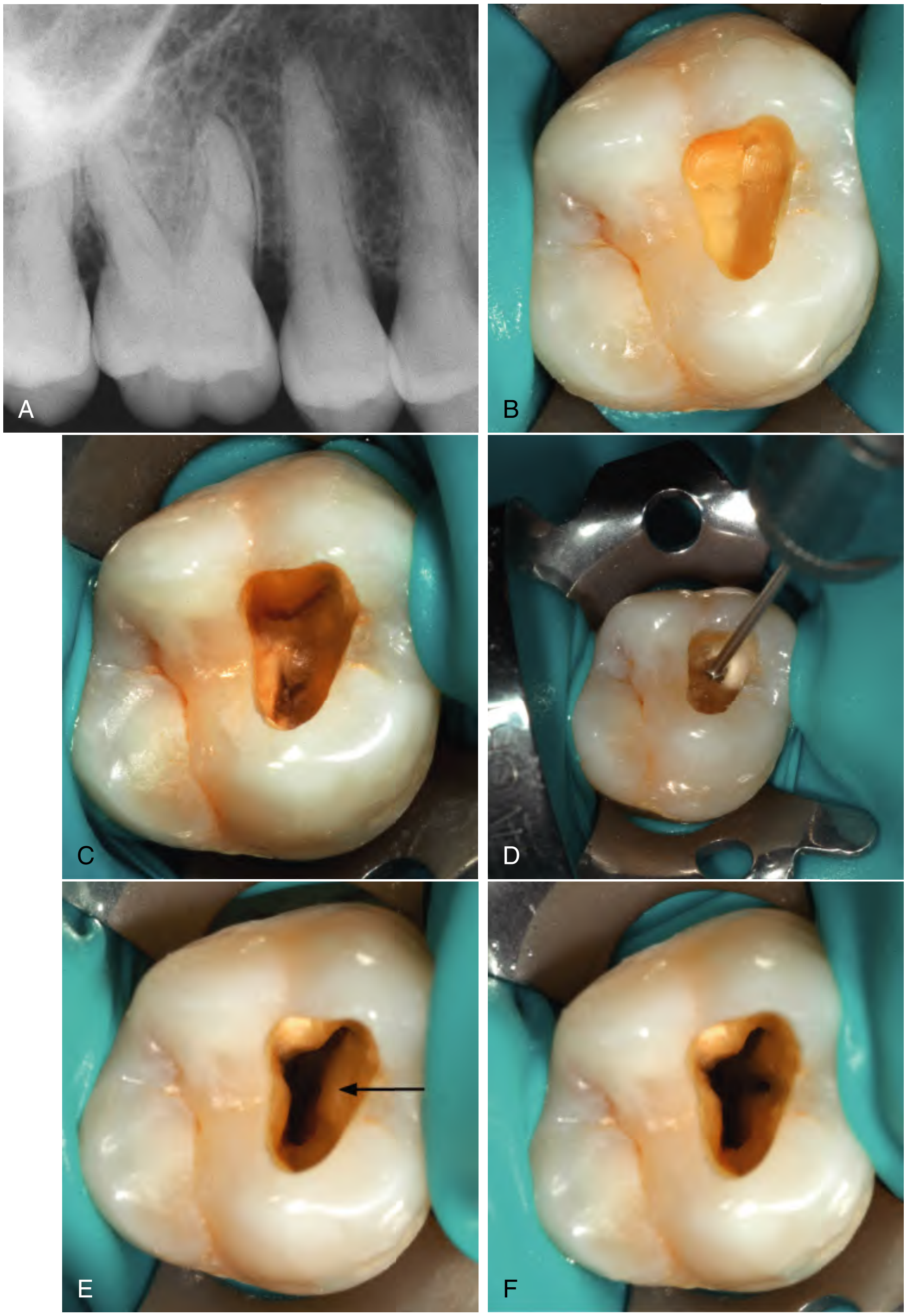
The *working length* is defined as the distance from a predetermined coronal reference point (usually the incisal edge in anterior teeth and a cusp tip in posterior teeth) to the point where the cleaning and shaping and obturation should terminate. The reference point must be stable so that fracture does not occur between visits. Unsupported cusps that are weakened by caries or restorations should be reduced. The point of termination is empirical and based on anatomic studies; it should be 1 mm from the radiographic apex.[59,60] This distance accounts for the deviation of the foramen from the apex, and the distance from the major diameter of the foramen to the area where a dentinal matrix can be established apically.

Before access, an estimated working length is calculated either by measuring the total length of the tooth on the diagnostic parallel radiograph or digital image or with the use of an electronic apex locater. Violation of the apex may result in inoculation of the periapical tissues with necrotic tissue, debris, and bacteria[61] and can lead to extrusion of materials during obturation[62,63] and a less favorable prognosis.[64]

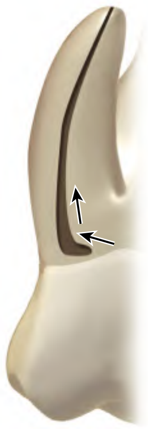
After access preparation, a small file is used to explore the canal and establish patency to the estimated working length. The largest file to bind is then inserted to this estimated length; a file that is loose in the canal may be displaced during film exposure or forced beyond the apex if the patient bites down inadvertently. Millimeter markings on the file shaft or rubber stops on the instrument shaft are used for length control. A sterile millimeter ruler or measuring device can be used to adjust the stops on the file. To ensure accurate measurement and length control during canal preparation, the stop must physically contact the coronal reference point. To obtain an accurate measurement, the minimum size of the working length should be a No. 20 file. With files smaller than No. 20, it is difficult to interpret the location of the file tip on the working length film or digital image. In multirooted teeth, files are placed in all canals before the image is made.

Angled films or digital images are necessary to separate superimposed files and structures (Fig. 13.41),[65] to provide an efficient method of determining the working length, and to reduce radiation to the patient. It is imperative that the rubber dam be left in place during working length determination to ensure an aseptic environment and to protect the patient from swallowing or aspirating instruments. The film/digital sensor can be held with a hemostat or a positioning device (Fig. 13.42).

A modified paralleling technique is used to position the film/digital sensor and the cone; this has been shown to be superior to the bisecting-angle technique.[66,67] With the modified paralleling



• **Fig. 13.24** **A,** Maxillary left first molar. Note the calcification in the chamber. **B,** The outline form established and dentin removed apically in layers. **C,** Exposure of the pulp horns. **D,** Use of a Mueller bur to completely unroof the chamber. Note the visibility and ability for precise removal of dentin. **E,** The completed access. The mesiobuccal canal is evident under the mesiobuccal cusp tip, the distobuccal canal is found opposite the buccal groove and slightly lingual to the main mesiobuccal canal, and the palatal canal is located under the mesiolingual cusp tip. Note the identification of the mesiolingual canal *(arrow).* **F,** Removal of the dentinal cornice that covers the mesiolingual canal to reveal the canal orifice. (See Appendix, Pulpal Anatomy and Access Preparations, for color illustrations showing the size, shape, and location of the pulp space within each tooth.)



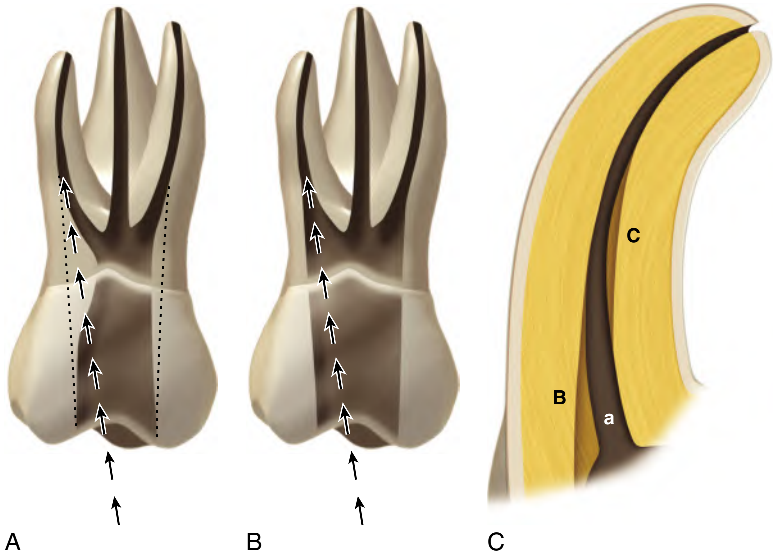
• **Fig. 13.25** The mesiolingual canal as it leaves the pulp chamber. Canals that are not negotiable but detected by an explorer may move laterally before proceeding apically.

technique, the film/digital sensor is positioned by using a hemostat approximately parallel to the long axis of the tooth. The cone is then positioned so that the central beam strikes the film at a 90-degree angle (Fig. 13.43). Although this technique is reliable, it is not foolproof.[68]

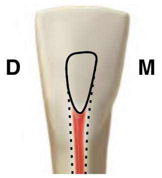
Other clinical factors should be considered in establishing the corrected working length. These include tactile sensation,[69] the patient's response, and hemorrhage. The use of tactile sensation may be valuable in large tapering canals; however, in small cylindrical canals, the rate of taper of the files may exceed the rate of taper of the canal, and binding occurs coronally, giving the false sense of constriction. Preflaring the canal before length determination increases the tactile sensation significantly compared with unflared canals.[70]

After the film or sensor exposure, the corrected working length is calculated. The distance from the file tip to the radiographic apex is determined. If the distance is greater than 1 mm, a calculation is made (adding or subtracting length) so that the file tip is positioned 1 mm from the radiographic apex. If the correction is greater than 3 mm, a second working length radiograph or digital image should be made with the file placed at the adjusted length.

• **Fig. 13.26** **A,** Maxillary left first molar showing calcification. **B** and **C,** Initial access and identification of a pulp stone. Color and a thin line surrounding the periphery identify the hemorrhage. **D,** The pulp chamber with the stone removed. (See Appendix, Pulpal Anatomy and Access Preparations, for color illustrations showing the size, shape, and location of the pulp space within each tooth.)



• **Fig. 13.27** **A,** The dashed lines show where dentin must be removed to achieve straight-line access. **B,** The access completed. **C,** The original canal *(a)* is modified using Gates Glidden burs to remove tooth structure at *(B)* and *(C).*



• **Fig. 13.28** Lingual outline form for the mandibular incisor.

With angled radiographs or digital images, the canal determination is based on the buccal object or SLOB rule (same lingual, opposite buccal; see Chapter 3).[71,72] Because maxillary anterior teeth have only one canal, no angle is necessary. Mesial angles are recommended for premolars and maxillary molars (Fig. 13.44). Distal angulation is recommended for the mandibular incisors and molars (Fig. 13.45). For maxillary posterior teeth, the film should be placed on the opposite side of the midline to facilitate capture of the palatal roots on the film (see Fig. 13.43).

Electronic Apex Locators

Apex locators are also used in determining length.[73,74] Contemporary apex locators are based on the principle that the flow of higher frequencies of alternating current is facilitated in a biologic environment compared with lower frequencies. Passing two differing frequencies through the canal results in the higher frequency impeding the lower frequency (Fig. 13.46). The impedance values that change relative to each other are measured and converted to length information. At the apex, the impedance values are at their maximum differences. Unlike previous models, the impedance apex locator operates accurately in the presence of electrolytes.[75] Apex locators are helpful in length determination but must be confirmed with radiographs. Films or digital images help confirm the appropriate length and can identify missed canals. If the file is not centered in the root, a second canal is likely to be present.

An apex locator is very helpful in patients with structures or objects that obstruct visualization of the apex, patients who have a gag reflex and cannot tolerate films, and patients with medical problems that prohibit the holding of a film or sensor.

The use of apex locators and electric pulp testers in patients with cardiac pacemakers has been questioned.[76-81] In a recent study involving 27 patients with either implanted cardiac pacemakers or cardioverter/defibrillators, two impedance apex locators and one electric pulp tester did not interfere with the functioning of any of the cardiac devices.[82] However, it may be advisable not to use these devices in these patients; other means of length determination and pulp testing are available.

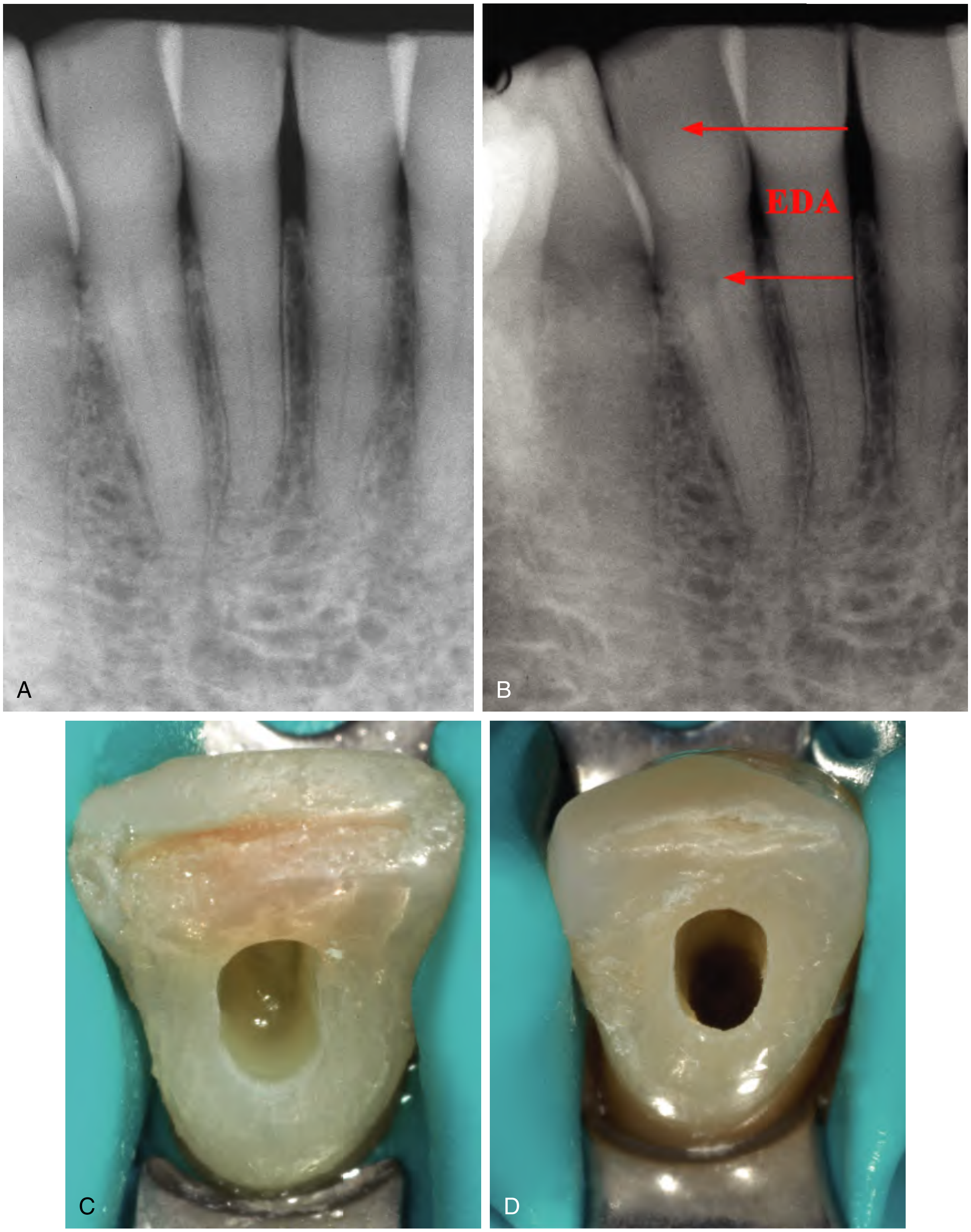
Study Questions

6. Name the potential issues related to inadequate access preparation.
   a. Less visibility
   b. Inability to locate canals
   c. Inability to completely remove pulp tissues from the pulp chamber
   d. Instrumentation errors caused by lack of straight-line access
   e. All of the above
7. The ridges should be preserved during access preparation whenever possible.
   a. True
   b. False
8. Which of the following is correct regarding working length determination?
   a. Placement of the smallest file to the apex
   b. Placement of the largest file that binds at the apex
   c. Removal of the file stopper before placement of the file in the canal
   d. Use of files no larger than #
9. The rubber dam may be removed during radiographic working length determination.
   a. True
   b. False
10. During radiographic working length determination, a new radiograph is required if:
   a. The file is within 1 mm of the apex.
   b. The file is at the apex.
   c. The file is more than 2 mm from the apex.
   d. The file is at the apex.

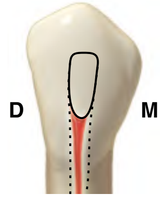
ANSWERS

Answer Box 13

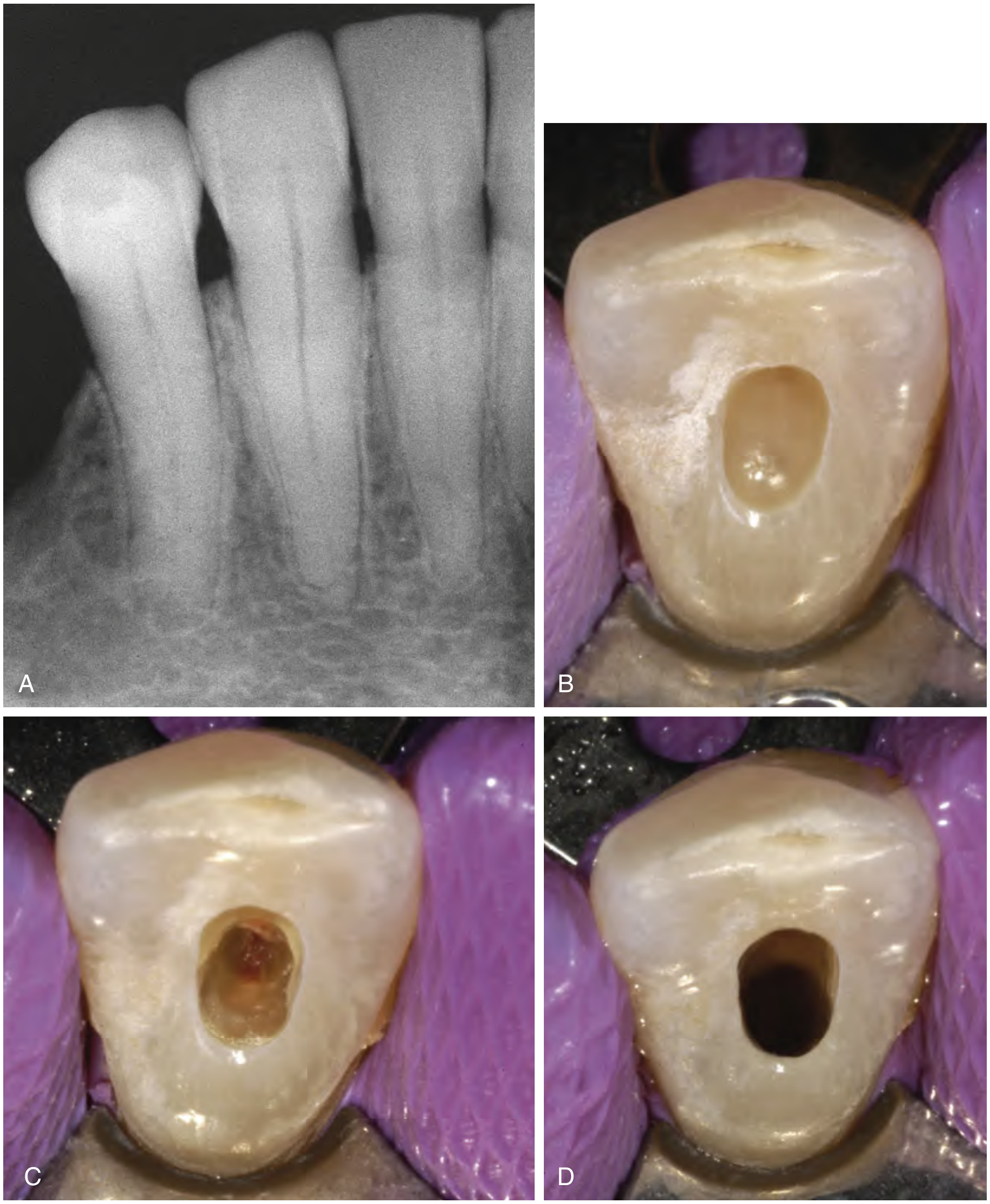
1 a. True
2 e. All of the above.
3 a. Rubber dam placement may be avoided.
4 a. Before initiation of treatment
5 e. All of the above
6 e. All of the above
7 a. Truex
8 b. Placement of the largest file that binds at the apex
9 b. False
10 c. The file is more than 2 mm from the apex.



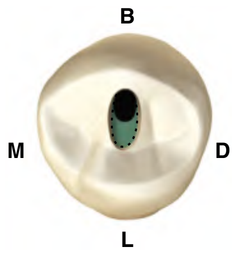
• **Fig. 13.29** **A,** Mandibular lateral incisor. **B,** Calculation of the estimated depth of access from the middle of the lingual surface to the coronal extent of the pulp. **C,** The initial outline form is more oval due to the receded chamber. **D,** Completed access.



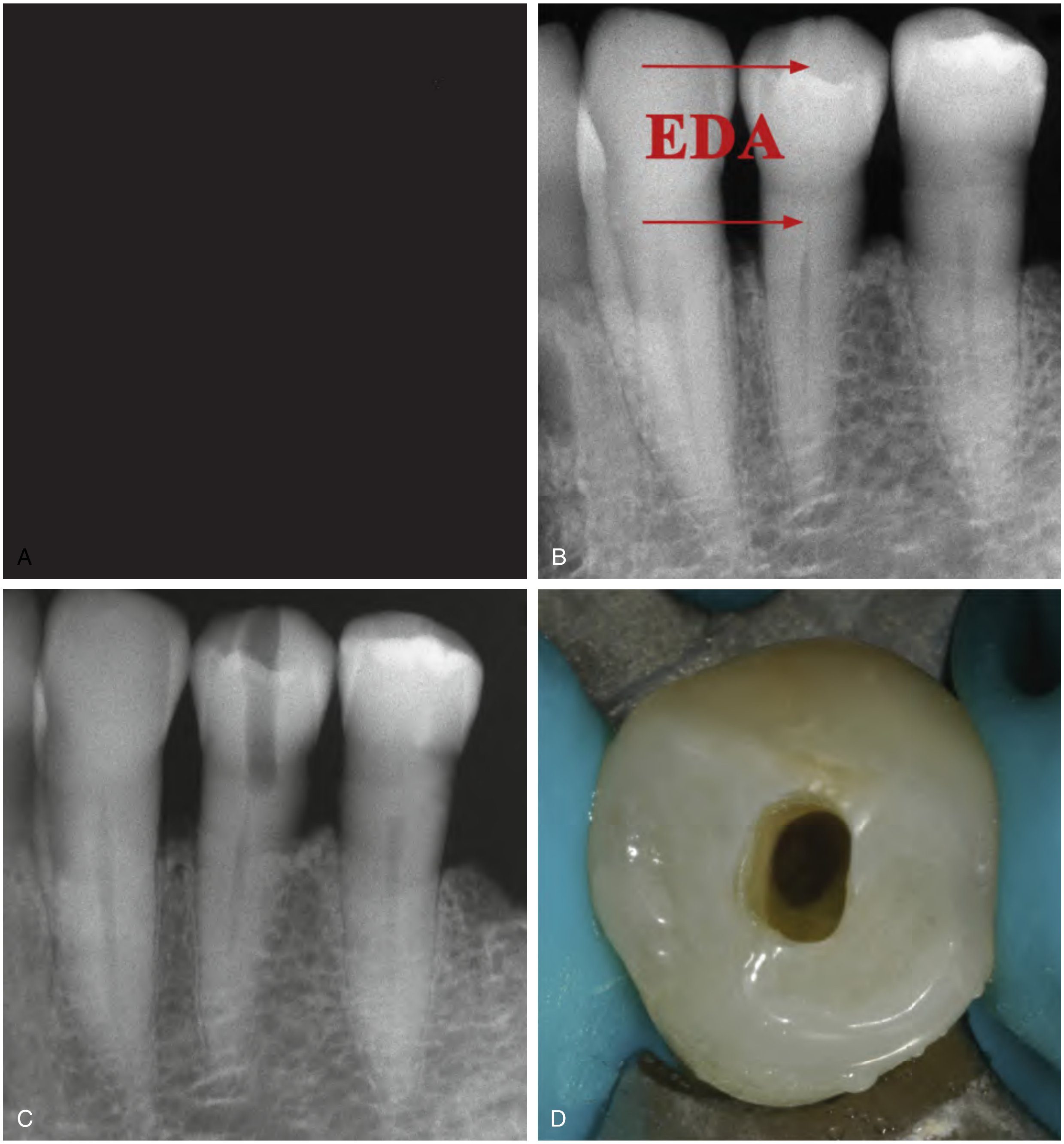
• **Fig. 13.30** Lingual ovoid outline form for the mandibular canine.



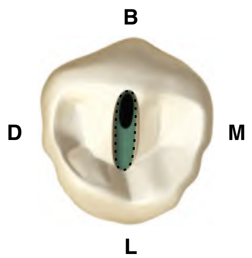
• **Fig. 13.31** **A,** Mandibular canine. **B,** The initial outline form is established into dentin. **C,** Exposure of the coronal pulp. **D,** The completed access opening.



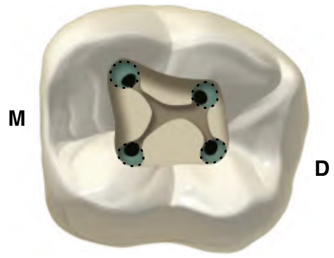
• **Fig. 13.32** Ovoid outline form for the mandibular first premolar. Note that the access is buccal to the central groove.



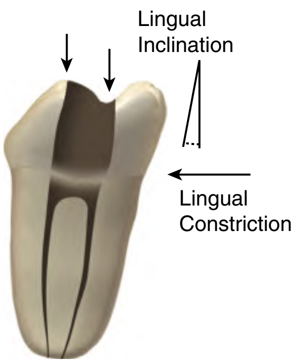
• **Fig. 13.33** **A,** Mandibular right first premolar. Note the receded pulp space. **B,** Calculation of the estimated depth of access. **C,** The estimated depth of access is reached, and the canal is not located. The rubber dam is removed and a straight-on parallel radiograph exposed. The film/digital image indicates that the canal is located mesial to the opening. **D,** The completed access.



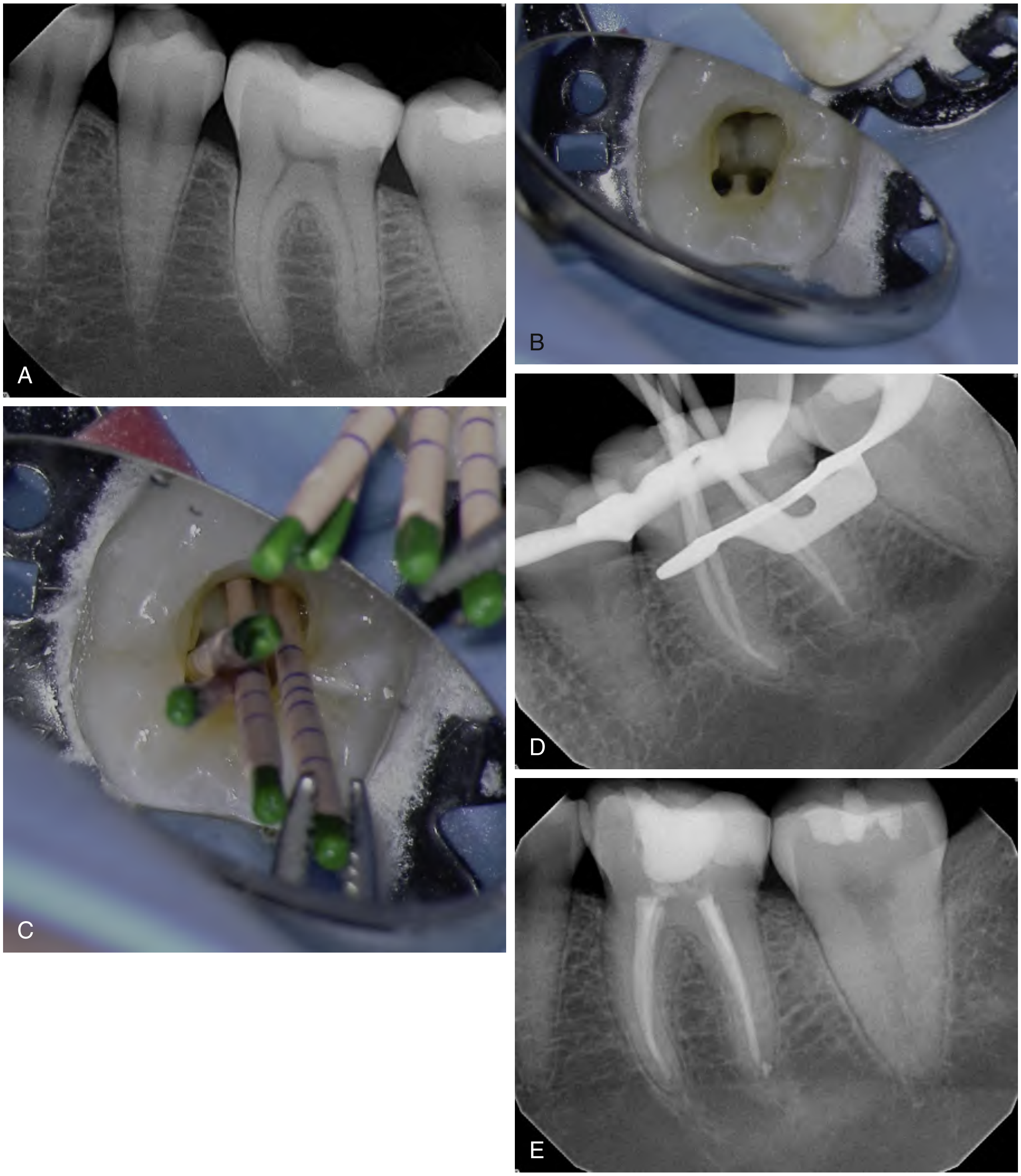
• **Fig. 13.34** Ovoid outline form for the mandibular second premolar.



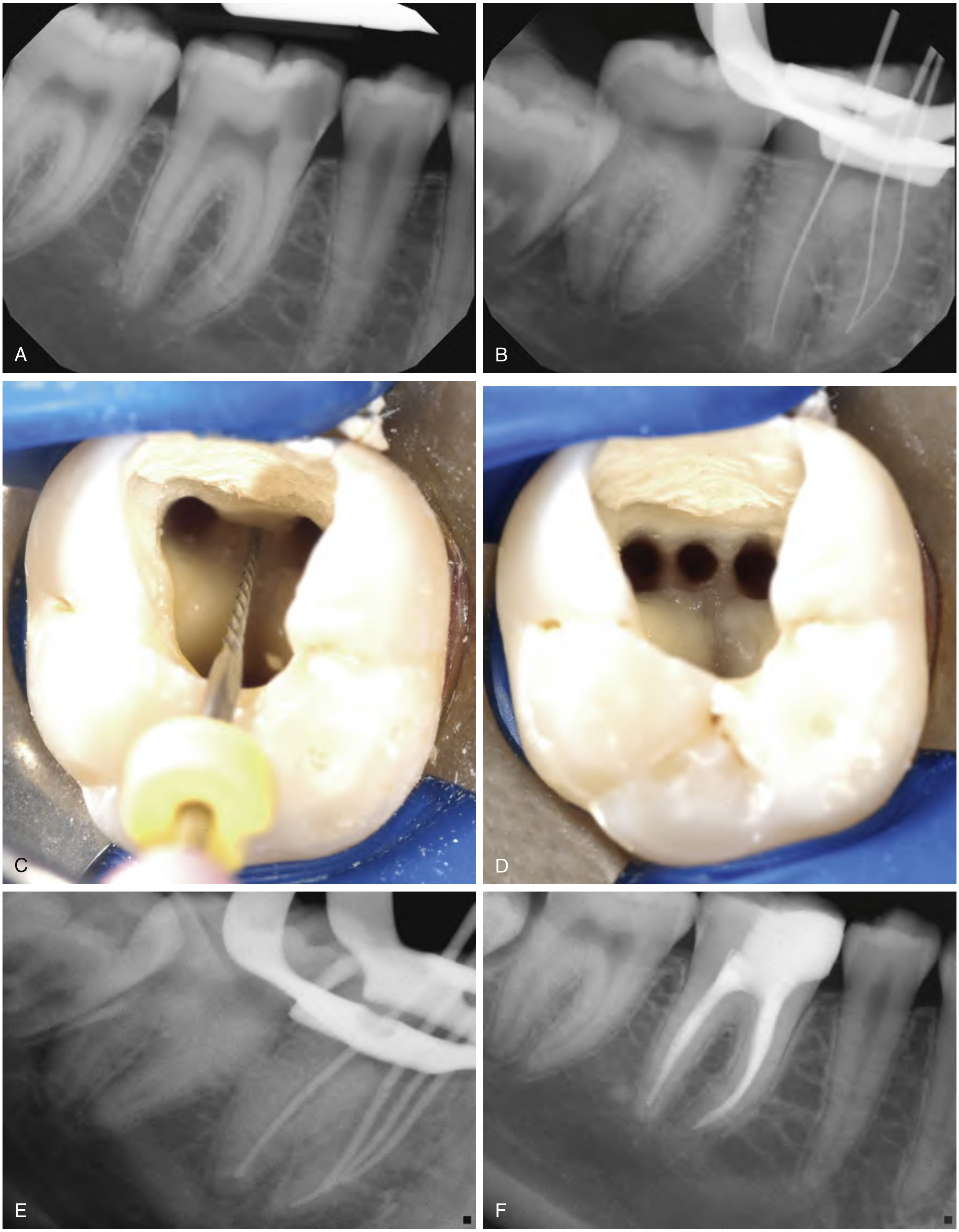
• **Fig. 13.35** Rectangular outline form for the mandibular first molar. Note that the mesiobuccal canal is located under the mesiobuccal cusp, and the mesiolingual canal lies centrally in relation to the crown and slightly to the distal of the mesiobuccal canal. The distolingual canal is located centrally, and the distobuccal canal lies more buccal and mesial to the main canal.



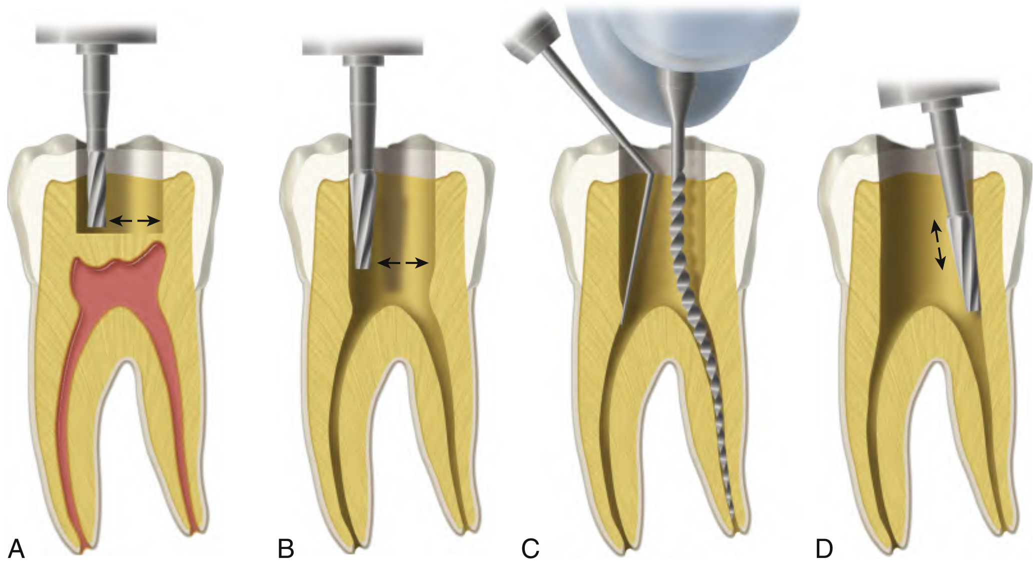
• **Fig. 13.36** Proximal view of a mandibular molar demonstrating the lingual inclination in the dental arch and a lingual constriction of the crown at the cementoenamel junction. Note that the mesiobuccal and mesiolingual canals are uniformly spaced within the root. However, with coronal access, the external reference points for the canal's location are the mesiobuccal cusp tip and the central groove as it crosses the mesial marginal ridge.



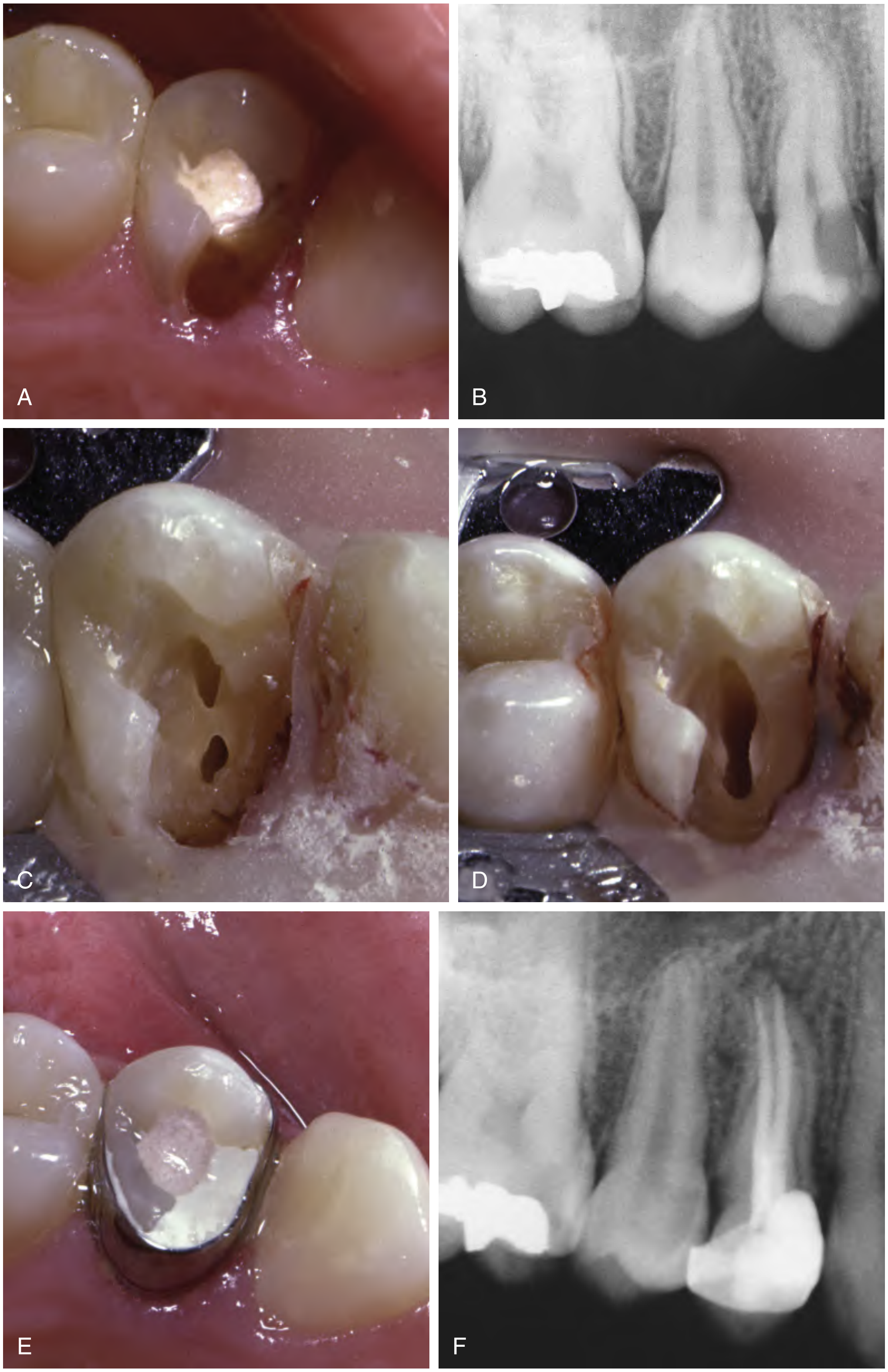
• **Fig. 13.37** **A,** The preoperative radiograph of a mandibular first molar. **B,** The completed access cavity demonstrating the two mesial canals and the single distal canal. **C,** Cone fit. **D,** Cone fit radiograph. **E,** postoperative radiograph. (See Appendix, Pulpal Anatomy and Access Preparations, for color illustrations showing the size, shape, and location of the pulp space within each tooth.)



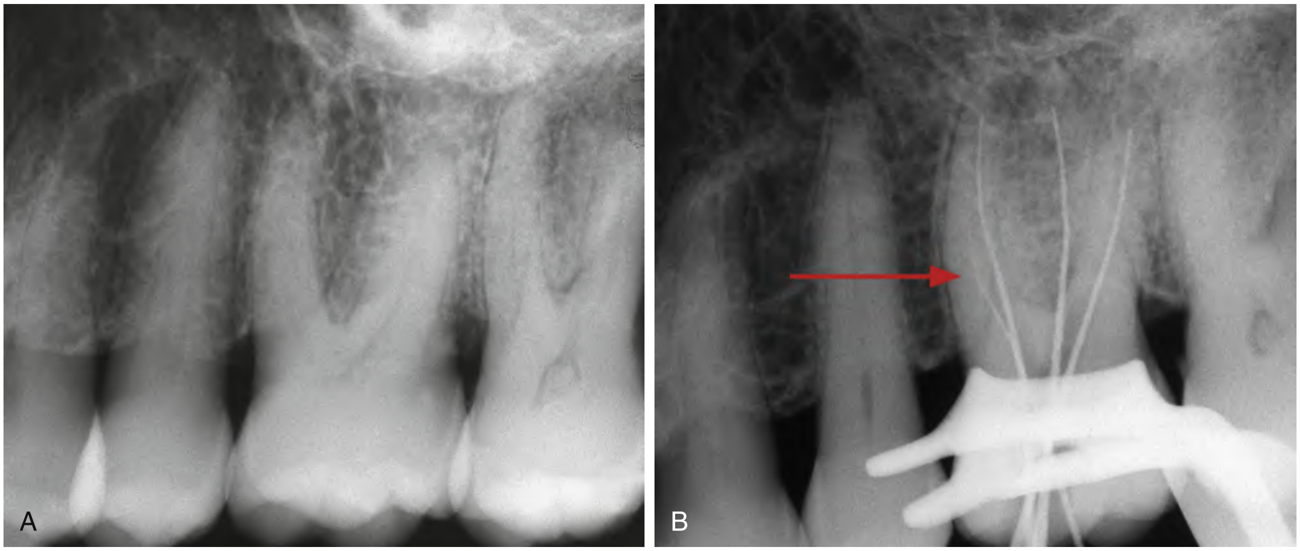
• **Fig. 13.38** **A,** Preoperative radiograph of a mandibular first molar with a middle mesial canal. **B,** Original working length radiographic image. **C,** Middle mesial canal located. **D,** Prepared canal. **E,** Master cone radiographic image. **F,** Postoperative radiographic image of tooth #30.



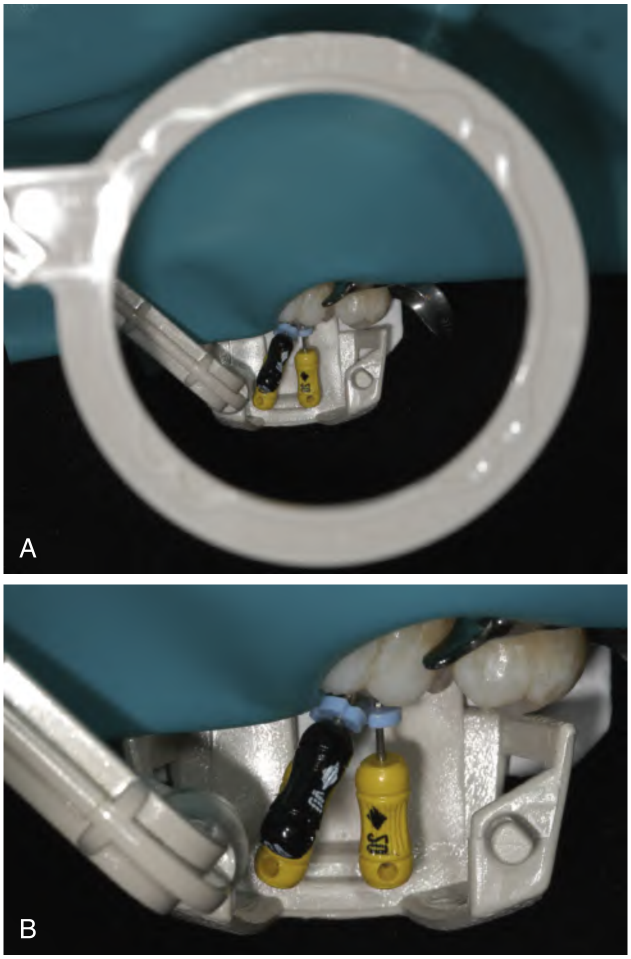
• **Fig. 13.39** Basic steps in access preparation. **A,** The access cavity is outlined deep into dentin and close to the estimated depth of access with the high-speed handpiece. **B,** Penetration and unroofing are achieved by fissure high-speed bur or slow-speed latch-type burs. Other bur configurations are acceptable. **C** and **D,** Canal orifices are located and identified with an endodontic explorer. Small files are used to negotiate to the estimated working length. The dentin shelf that overlies and obscures the orifices is removed.



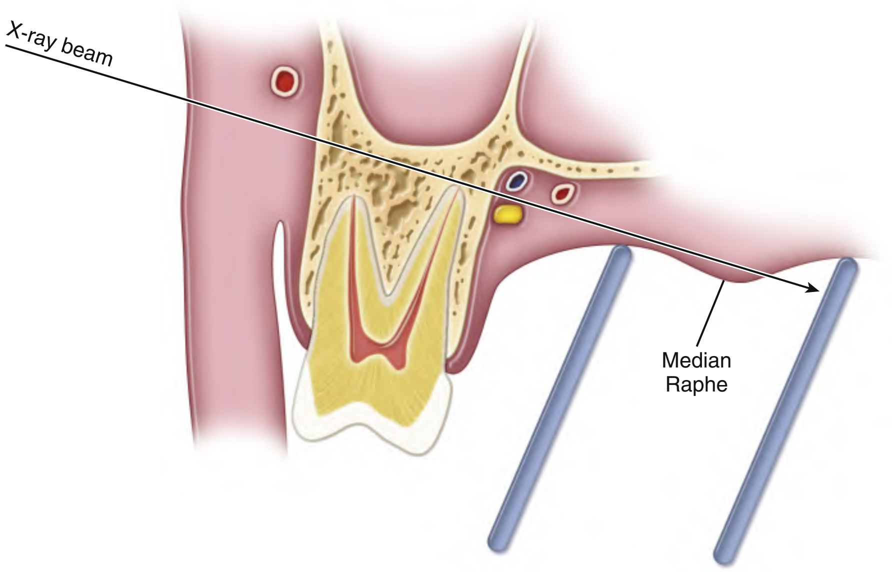
• **Fig. 13.40** **A,** Access made through gross mesial caries. **B,** Caries at the level of the crestal bone. **C,** Caries removal provides an aseptic operating field and allows assessment of restorability. Note that the previous access failed to deroof the chamber. **D,** Appropriate access reveals a ribbon-shaped pulp chamber. **E,** An orthodontic band placed to provide isolation. **F,** Post obturation.



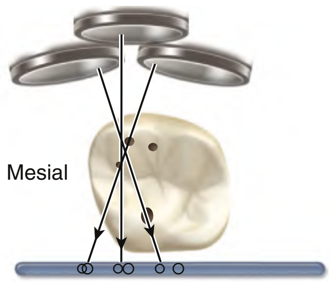
• **Fig. 13.41** **A,** Parallel preoperative radiograph. **B,** The mesial working length film is made correctly. The apices and file tips are clearly visible. Note the mesiolingual canal *(arrow).*



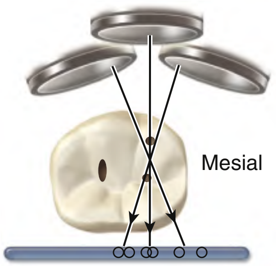
• **Fig. 13.42** **A,** Positioning device for holding working films. The ring assists in cone alignment. **B,** Close-up view of the device in position.



• **Fig. 13.43** Proper positioning of the radiograph when making a working length radiograph. To capture the palatal root, the film should be placed on the opposite side of the midline.



• **Fig. 13.44** Separation of the mesiobuccal and mesiolingual canals achieved by varying the horizontal angle. With maxillary molars, maximum separation occurs with a mesial cone angulation because of the mesial location of the mesiolingual canal in relation to the mesiobuccal canal.



• **Fig. 13.45** Separation of the mesiobuccal and mesiolingual canals achieved by varying the horizontal angle. With mandibular molars, maximum separation occurs with a distal orientation because of the mesial location of the mesiobuccal canal in relation to the mesiolingual canal.

• **Fig. 13.46** **A** and **B,** Two impedance apex locators.

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Video 13.1: Rubber Dam Placement Introduction
Video 13.1A: Placement of Rubber Dam, Clamp, and Frame as a Unit
Video 13.1B: Placement of Clamp, Followed by the Dam and Then the Frame
Video 13.1C: Placement of Rubber Dam and Frame and Then the Clamp
Video 13.2: Access Preparations Introduction
Video 13.2A: Maxillary Incisors
Video 13.2B: Maxillary Canines
Video 13.2C: Maxillary Premolars
Video 13.2D: Finding Additional Canals
Video 13.2E: Maxillary Molars
Video 13.2F: Mandibular Incisors
Video 13.2G: Mandibular Canines
Video 13.2H: Mandibular Premolars
Video 13.2I: Mandibular Molars
Video 13.3: Working Length Determination