18

Procedural Accidents

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CHAPTER OUTLINE

LEARNING OBJECTIVES

After reading this chapter, the student should be able to recognize procedural accidents and describe the causes, prevention, and treatment of the following:

1. Pulp chamber perforation during access preparation
2. Ledging
3. Dental materials or dentin shavings obstructing the canal
4. Coronal or radicular perforation
5. Separated instrument
6. Obturation short of prepared working length
7. Obturation materials extended beyond apex
8. Incomplete obturation
9. Post space preparation mishaps
10. Accidental injections

Introduction

Like other complex disciplines of dentistry, root canal therapy can present unwanted or unforeseen challenges that can affect the prognosis. These mishaps are collectively termed *procedural accidents*. However, fear of procedural accidents should not deter a practitioner from performing root canal treatment if proper case selection and competency issues are observed.

Knowledge of the etiologic factors involved in procedural accidents is essential for their prevention. In addition, methods of recognition and treatment, as well as the effects of such accidents on prognosis, must be learned. Most problems can be avoided by adhering to the basic principles of diagnosis, case selection, treatment planning, access preparation, cleaning and shaping, obturation, and post space preparation.

Examples of procedural accidents include swallowed or aspirated endodontic instruments, crown or root perforation, ledge formation, separated instruments, underfilled or overfilled canals, and vertically fractured roots. A good practitioner uses knowledge, dexterity, intuition, patience, and awareness of personal limitations to minimize these accidents. When an accident occurs during root canal treatment, the patient should be informed about (1) the incident, (2) procedures necessary for correction, (3) alternative treatment modalities, and (4) the effect of this accident on prognosis. Proper medical-legal documentation is mandatory. A successful practitioner learns from past experiences and applies them to future challenges. In addition, the practitioner who knows her/his own limitations will recognize potentially difficult cases and will refer the patient to an endodontist. The beneficiary will be the patient, who will receive the best care.

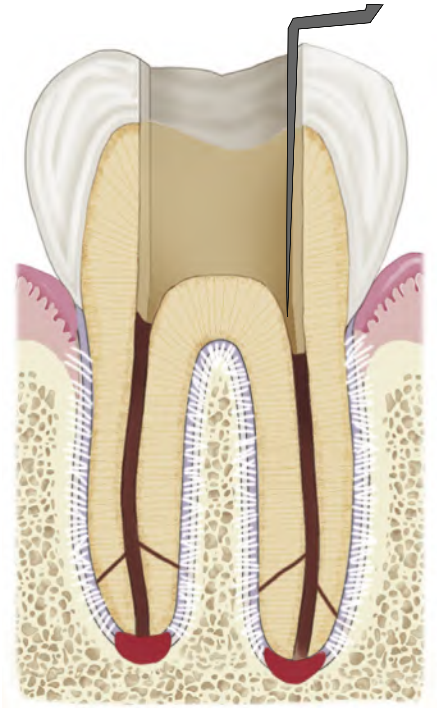
This chapter discusses the causes, prevention, and treatment of several types of procedural accidents that may occur at different phases of root canal treatment (Video 18.1). The effect of these accidents on short- and long-term prognoses will be also described.

Perforations During Access Cavity Preparation

The prime objective of an access cavity is to provide an unobstructed or straight-line pathway to the apical foramen (Fig. 18.1). Accidents, such as excess removal of tooth structure or perforation, may occur during attempts to locate canals. Failure to achieve straight-line access is often the main etiologic factor for other types of intracanal accidents.

Causes

Despite anatomic variations in the configuration of various teeth, the pulp chamber, in most cases, is located in the center of the anatomic crown. The pulp system is located in the long axis of the tooth. Lack of attention to the degree of axial inclination of a tooth



• **Fig. 18.1** Making an unobstructed and straight-line pathway to the apical foramen of root canals prevents accidental procedures.

• **Fig. 18.2** Lack of attention to the degree of axial inclination of central incisor in relation to adjacent teeth and to alveolar bone resulted in severe gouging and near perforation in an otherwise simple access preparation.

in relation to adjacent teeth and to alveolar bone may result in either gouging or perforation of the crown or the root at various levels (Fig. 18.2). After establishing the proper access outline form, failure to direct the bur parallel to the long axis of a tooth will cause gouging or perforation of the crown or root. This problem often occurs when the dentist must use the reflected image from an intraoral mirror to make the access preparation. In these situations, the natural tendency is to direct the bur away from the long axis of the root to improve vision through the mirror. Another reason that can cause failure in directing the bur parallel to the long axis of the root is access cavity preparation under higher magnifications. The clinician may lose "depth perception" when using the microscope at higher magnifications, which can cause deviation from the long axis. Failure to check the orientation of the access opening during preparation may result in a perforation. The dentist should stop periodically to review the bur-tooth relationship. Aids for evaluating progress include transillumination, magnification, and radiographs. Bite-wing radiographs taken during access cavity preparation are useful to adjust the mesiodistal orientation. Shifted periapical radiographs are useful to adjust the buccolingual orientation.

Searching for the pulp chamber or orifices of canals through an underprepared access cavity may also result in accidents. Failing to recognize when the bur passes through a small or flattened (disk-like) pulp chamber in a multirooted tooth may also result in gouging or perforation of the furcation (Fig. 18.3, *A*).

A cast crown often is not aligned in the long axis of the tooth; directing the bur along the misaligned casting may result in a coronal or radicular perforation.

Prevention

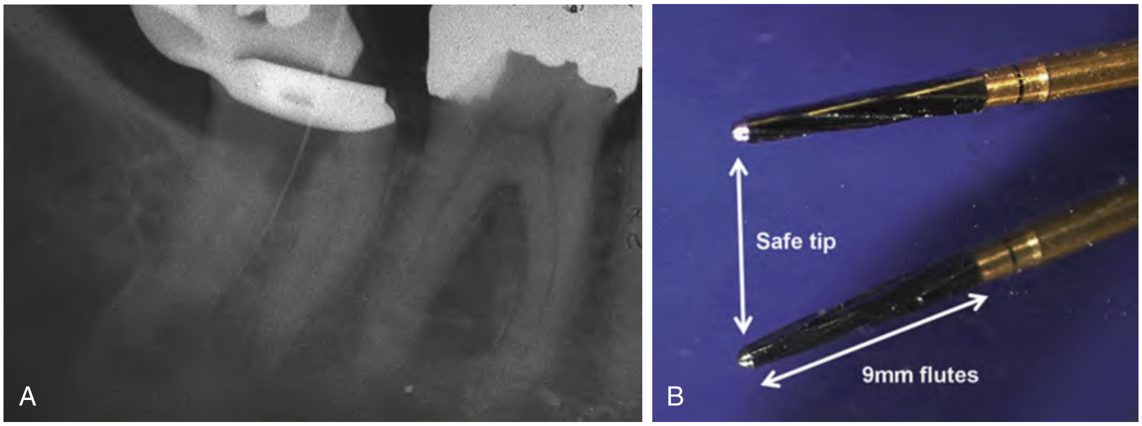
Clinical Examination

Thorough knowledge of tooth morphology, including both surface and internal anatomy and their relationship, is mandatory to prevent pulp chamber perforations. Next, location and angulation of the tooth must be related to adjacent teeth and alveolar bone to avoid a misaligned access preparation. In addition, radiographs of teeth from different angles provide information about the size and extent of the pulp chamber and the presence of internal changes such as calcification or resorption. The radiograph is a two-dimensional projection of a three-dimensional object. Varying the horizontal exposure angle will provide at least a distorted view of the third dimension and may be helpful in supplying additional anatomic information. Cone beam computed tomography (CBCT) can also provide invaluable information in cases with severe calcification or unusual canal anatomy. In complex cases, referral to an endodontist may be indicated.

Operative Procedures

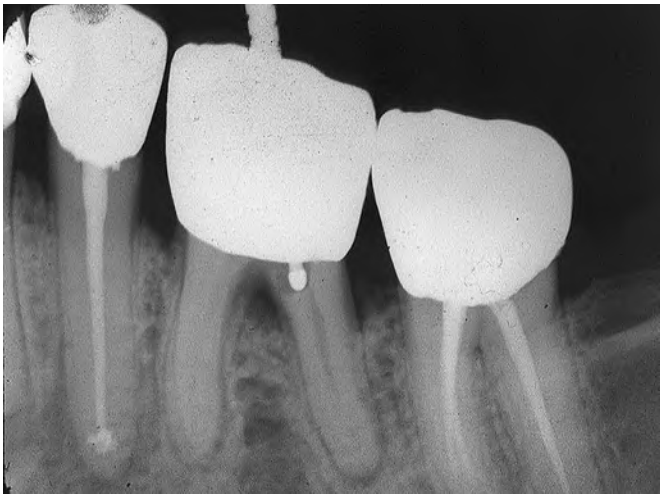
Use of a rubber dam (Fig. 18.4) during root canal treatment is usually indicated.[1,2] However, in situations in which problems are anticipated in locating pulp chambers (e.g., tilted teeth, misoriented castings, or calcified chambers), initiating access without a rubber dam is preferred because it allows better crown-root alignment. However, when access is made without rubber dam placement, no intracanal instruments, such as files, reamers, or broaches, should be used unless they are secured by a piece of floss[6] and a throat pack is placed. Constricted chambers or canals must be sought patiently, with small amounts of dentin removed at a time.

Failure to recognize when the bur passes through the roof of the pulp chamber, if the chamber is calcified, may result in gouging or perforation of the furcation. After penetration of the roof of



• **Fig. 18.3** **(A)** Failure to recognize when the bur passes through the roof of the pulp chamber in a calcified pulp chamber may result in gouging or perforation of the furcation. The use of apex locators and angled radiographs is necessary for early perforation detection. Early detection reduces damage and improves repair. **(B)** Use of a "safe-ended" access bur will prevent perforation of the chamber floor.

• **Fig. 18.4** Rubber dam must be applied in the anterior and posterior teeth. It provides isolation of the target tooth and prevents procedural accidents.



• **Fig. 18.5** A small bur is placed during access preparation when orientation is a problem. This provides information about angulation and depth of bur penetration.

the chamber, using a "safe-ended" access bur, such as the Endo Z (Dentsply/Maillefer, Tulsa, OK) or a pulp shaper bur (Dentsply/Tulsa Dental, Tulsa, OK), will prevent perforation of the chamber floor (Fig. 18.3, *B*).

The use of apex locators and angled radiographs is necessary for early perforation detection. Early detection reduces damage caused by continued treatment (irrigation, cleaning, and shaping) and improves the prognosis for nonsurgical repair.

Another useful method of providing isolation and visualizing the crown-root alignment is the use of a "split" dam. This dam can be applied in the anterior region without a rubber dam clamp (see Chapter 13) or in posterior regions by quadrant isolation if a distal tooth can be clamped. Also, elimination of the metal clamp from the field of operation allows radiographic orientation of coronal access preparation.

To orient the access, a bur may be placed in the preparation hole (secured with cotton pellets) and then radiographed (Fig. 18.5). This provides information about depth of access in relation to canal location. Remember, a single canal is located in the center of the root. A direct facial radiograph will show the mesiodistal relationship; a mesial- or distal-angled film will show the faciolingual location. This procedure is helpful for locating small canals.

Use of a fiberoptic light during access preparation may assist in locating canals. This strong light illuminates the cavity when the beam is directed through the access opening (reflected light) and illuminates the pulp chamber floor (transmitted light). In the latter case, a canal orifice appears as a dark spot. Using magnifying glasses or an operative microscope[3-7] will also aid in locating a small orifice. Magnification loupes (2.5 or greater) are useful especially when combined with transillumination. The ultimate aid in canal location is the operating microscope. Patients with problems requiring significant magnification for canal location should be referred to an endodontist who has this specialized equipment.

CBCT imaging is a useful tool to locate and negotiate the canals, specifically in teeth with complicated or calcified internal anatomy.[8-10] CBCT can be used before and, if needed, during the treatment to prevent perforation and to locate the canals in teeth with calcified pulp chamber. Limited field of view images are preferred over large field of view images as they provide accurate images with higher resolution. The axial cross-sections at the cementoenamel junction (CEJ) level can show the position of the calcified pulp chamber relative to the external surface of the crown. If the clinician cannot find the canals after the access cavity preparation is started, the CBCT can be taken to help locating the canals. The clinician can adjust the depth of troughing as well as the mesiodistal and buccolingual position of the bur using axial, sagittal, and coronal cross-sections, respectively.

Recognition and Treatment

Perforation into the periodontal ligament (PDL) or bone usually (but not always) results in immediate and continuous hemorrhage. The canal or chamber is difficult to dry, and placement of a paper point or cotton pellet may increase or renew the bleeding. Bone is relatively avascular compared with soft tissue. Mechanical perforation may initially produce only hemorrhage equal to that of pulp tissue.

Perforations must be recognized early to avoid subsequent damage to the periodontal tissues with intracanal instruments and irrigants. Early signs of perforation may include one or more of the following: (1) sudden pain during the working length determination when local anesthesia was adequate during access preparation; (2) sudden appearance of hemorrhage; (3) burning pain or a bad taste during irrigation with sodium hypochlorite; or (4) other signs, including a radiographically malpositioned file or a PDL reading from an apex locator that is short of the working length on an initial file entry.

Unusually severe postoperative pain may result from cleaning and shaping procedures performed through an undetected perforation. At a subsequent appointment, the perforation site will be hemorrhagic because of the inflammation of the surrounding tissues. The overall prognosis of the tooth must be evaluated with respect to the strategic value of the tooth, the location and size of the defect, and the potential for repair.

Perforation into the PDL at any location will have a negative effect on long-term prognosis.[11] The dentist must inform the patient of the questionable prognosis[12] and closely monitor the long-term periodontal response to any treatment. In addition, the patient must know what signs or symptoms indicate failure and, if failure occurs, what the subsequent treatment will be.

Perforations during access cavity preparation present a variety of problems. When a perforation occurs or is strongly suspected, the patient should be considered for referral to an endodontist. In general, a specialist is better equipped to manage these patients (Fig. 18.6, *A–C*). Also, after long-term evaluation, other procedures, such as surgery, may be necessary if future failure occurs.

Lateral Root Perforation

The location and size of the perforation during access are important factors in a lateral perforation. If the defect is located above the height of crestal bone, the prognosis for perforation repair is favorable.[13] These defects can be easily "exteriorized" and repaired with standard restorative material such as amalgam, glass ionomer, or composite. Periodontal curettage or a flap procedure is occasionally required to place, remove, or smooth excess repair material. In some cases, the best repair is placement of a full crown with the margin extended apically to cover the defect.

Teeth with perforations at or below the crestal bone in the coronal third of the root generally have the poorest prognosis (Video 18.2).[12,13] Attachment often recedes and a periodontal pocket forms, with attachment loss extending apically to at least the depth of the defect. The treatment goal is to position the apical portion of the defect above the crestal bone. Orthodontic root extrusion is generally the procedure of choice for teeth in the esthetic zone.[14] Surgical crown lengthening may be considered when the esthetic result will not be compromised or when adjacent teeth require surgical periodontal therapy. Internal repair of these perforations by mineral trioxide aggregate (MTA) has been shown to provide an adequate seal compared with other materials.[15] Ideally, repair of these perforations should be done as soon as it happens to prevent the damage to the periodontium. Generally, repair of perforations in the coronal third after attachment loss and pocket formation has a very poor prognosis. However, a recent case report showed calcium-silicate–based materials might have the potential to induce healing in the periodontium even when perforation repair is done after pocket formation.[16]

Furcation Perforation

A perforation of the furcation is generally one of two types: the "direct" or the "stripping" type. Each is created and managed differently, and the prognoses vary. The direct perforation usually occurs during a search for a canal orifice. It is more of a "punched-out" defect into the furcation with a bur and is usually accessible, may be small, and may have walls. This type of perforation should be immediately (if possible) repaired with MTA (Fig. 18.7). If proper conditions exist (dryness), glass ionomer or composite can be used to seal the defect. Prognosis is usually good if the defect is sealed immediately.

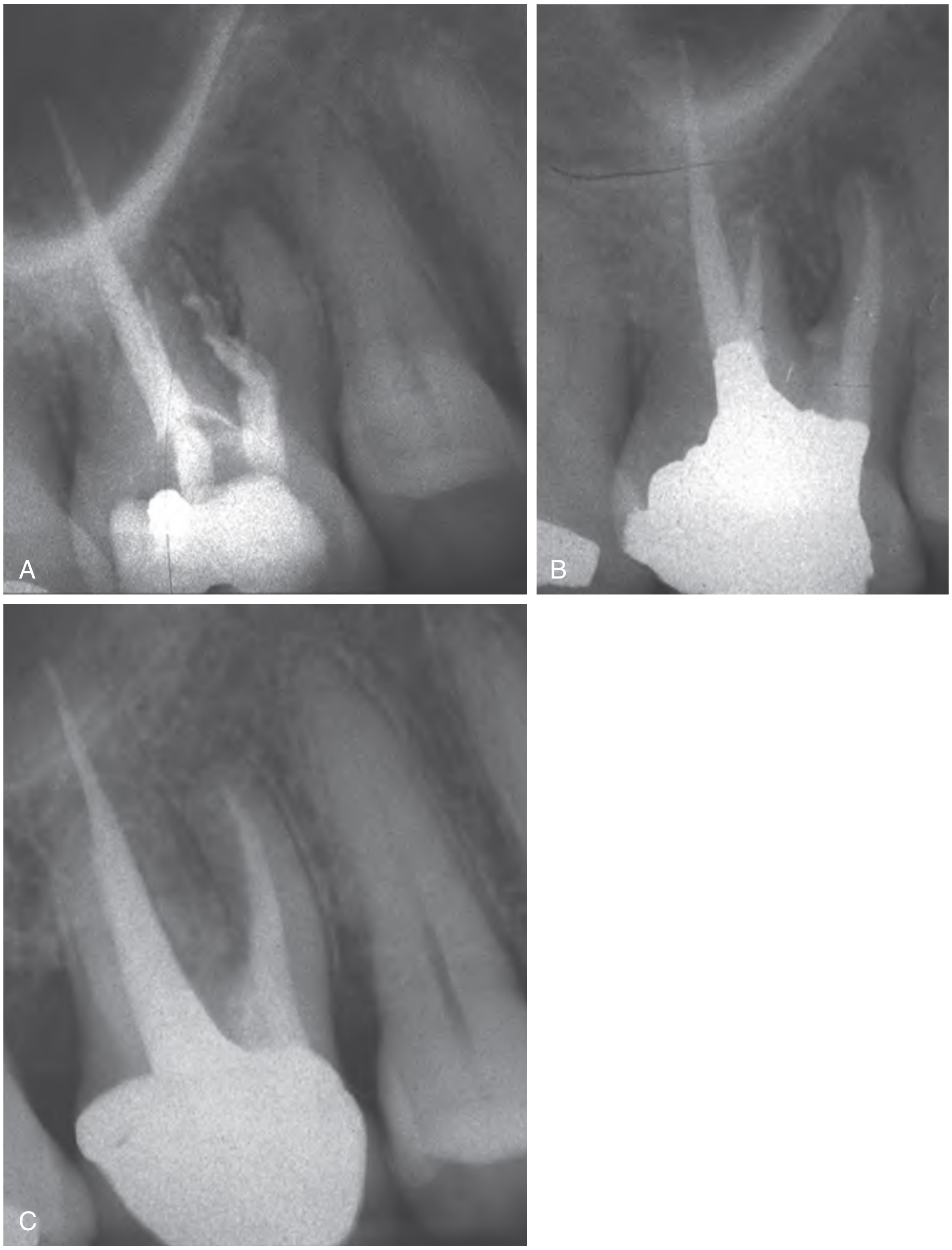
A stripping perforation involves the furcation side of the coronal root surface and results from excessive flaring with files or drills. Whereas direct perforations are usually accessible and therefore can be repaired nonsurgically, stripping perforations are generally inaccessible, requiring more elaborate approaches. The usual consequences of untreated stripping perforations are inflammation followed by development of a periodontal pocket. Long-term failure results from leakage of the repair material, which produces periodontal breakdown with attachment loss. Skillful use of MTA has significantly improved the prognosis of nonsurgical repair of stripping perforations compared with other repair materials (Fig. 18.8, *A–C*).

Nonsurgical Treatment

If feasible, nonsurgical repair (Fig. 18.9) of furcation perforations is preferred over surgical intervention as a result of difficult access and possibility of further damage to the periodontium during the surgery. Traditionally, materials such as amalgam, gutta-percha, zinc oxide–eugenol, Cavit, calcium hydroxide, freeze-dried bone, and indium foil have been used clinically and experimentally to seal these defects.[17,18] Repair is difficult because of potential problems with visibility, hemorrhage control, and management and sealing ability of the repair materials. In general, perforations occurring during access preparation should be sealed immediately, but the patency of the canals must be protected. Immediate repair of the perforations with bioactive materials (i.e., MTA and MTA-like materials[19]) offers the best results for perforation repair (Video 18.3).[12,20-23]

Surgical Treatment

Surgery requires more complex restorative procedures and more demanding oral hygiene from the patient.[24] Surgical alternatives include repair of the perforation with MTA if accessible by a surgical approach. The exact location and size of the perforation, and also the accessibility of the perforation, can be assessed using CBCT images.[25] If the perforation is not repairable or accessible by a surgical approach, hemisection, bicuspidization,

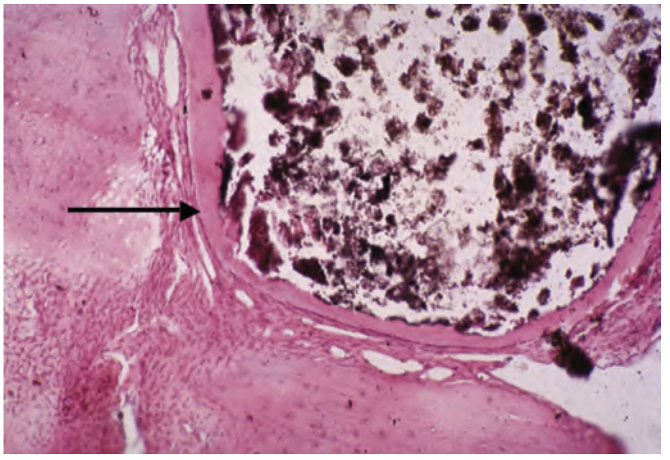


• **Fig. 18.6** **(A)** A search for the MB canal in a partially calcified chamber resulted in a furcation perforation and extrusion of filling materials into the periapical tissues. An apex locator reading, or an angled radiograph, would have detected this type of error. **(B)** The initial treatment was redone and the perforation was sealed with mineral trioxide aggregate (MTA). **(C)** Radiograph (3 years later) shows no evidence of pathosis in the repaired area. (Courtesy Dr. George Bogen.)

root amputation, or intentional replantation should be considered. Teeth with divergent roots and bone levels that allow preparation of adequate crown margins are suitable for either hemisection or bicuspidization (Fig. 18.10). Intentional replantation is indicated when the defect is inaccessible or when multiple problems exist, such as a perforation combined with a separated instrument, or when the prognosis with other surgical procedures is poor. Both the dentist and the patient must recognize that the prognosis for treatment of surgically altered teeth is questionable because of the increased technical difficulty associated with restorative procedures and demanding oral hygiene requirements. The remaining roots are prone to caries, periodontal disease, and vertical root fracture. Treatment planning options, including extraction, should be discussed with the patient when the prognosis is poor.

Prognosis

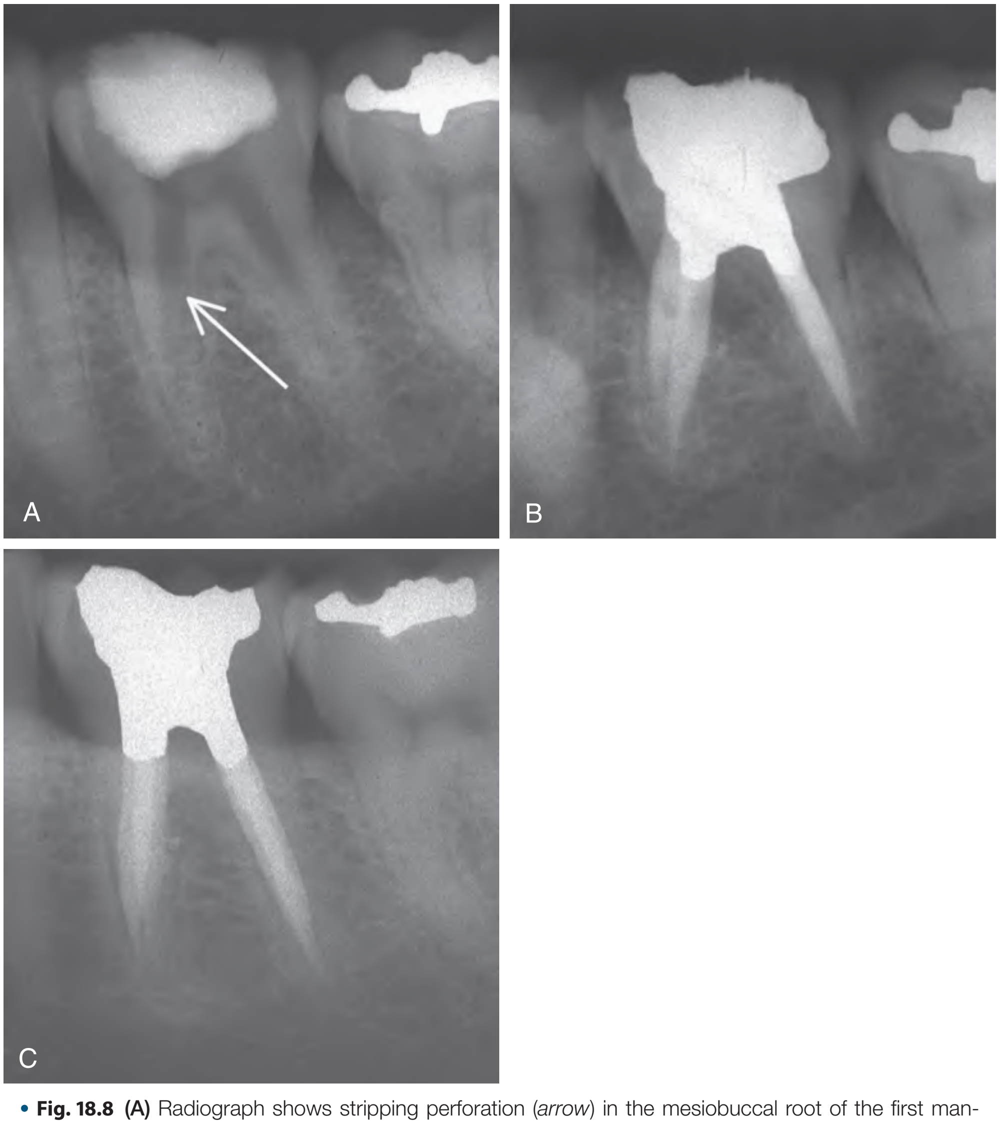
Factors affecting the long-term prognosis of teeth after perforation repair include the location of the defect in relation to the crestal bone, length of the root trunk, accessibility for repair, size of the defect, presence or absence of a periodontal communication to the



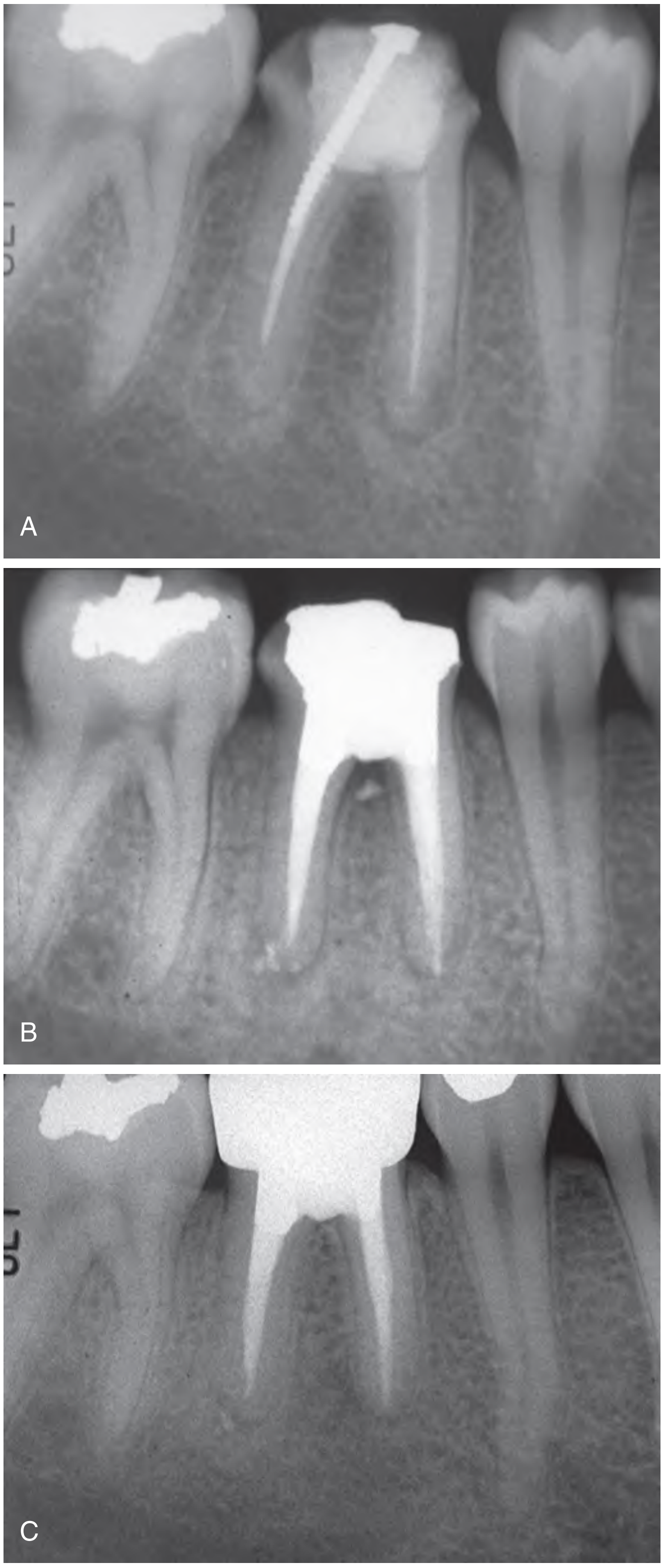
• **Fig. 18.7** Immediate repair of a perforation in the furcation of a dog premolar with mineral trioxide aggregate (MTA) results in the formation of cementum (*arrow*) adjacent to the material.

defect, time lapse between perforation and repair, sealing ability of restorative material, and subjective factors such as the technical competence of the dentist and the attitude and oral hygiene of the patient.[13] Early recognition and repair will improve the prognosis by minimizing damage to the periodontal tissues by bacteria, files, and irrigants. Additionally, a small perforation (less than 1 mm) causes less tissue destruction and is more amenable to repair than a larger perforation. Electronic apex locators or angled radiographs with files in place aid in early detection. Another useful tool to diagnose and locate the perforations is CBCT. CBCT images can help clinicians to understand the spatial position of the perforation and determine a realistic treatment plan (surgical or nonsurgical) to repair the perforation.[26]

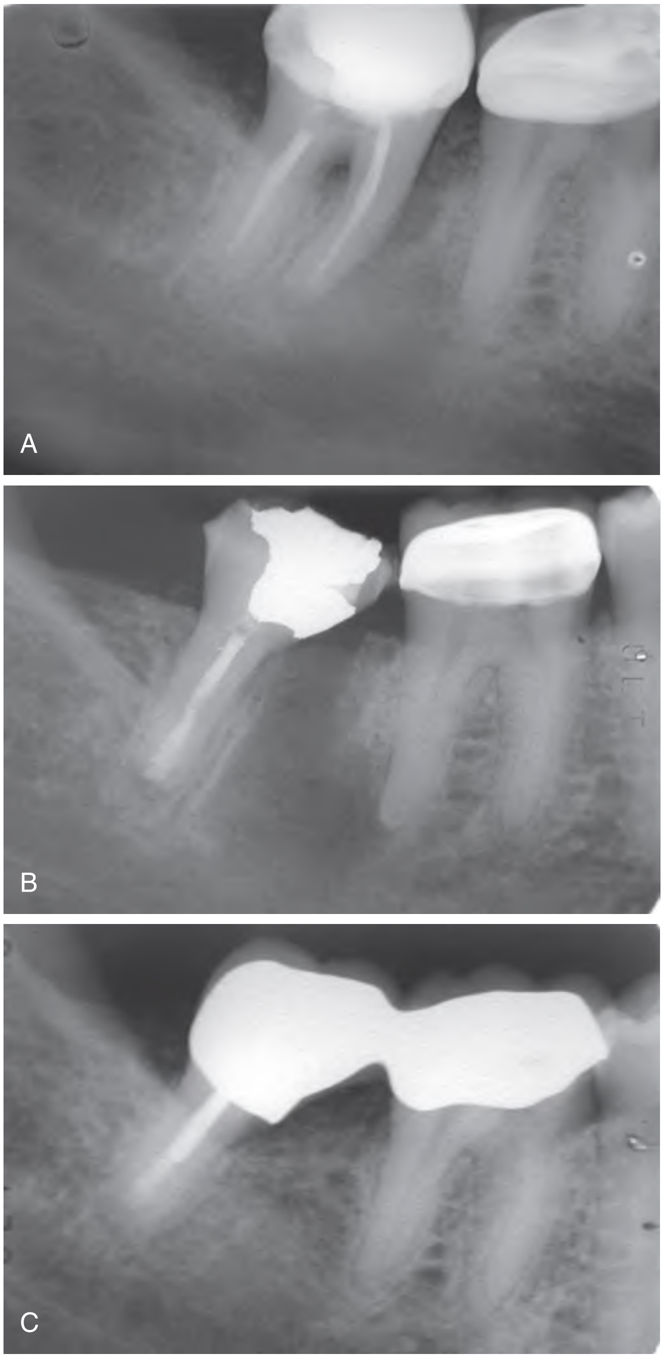
An unrecognized or untreated perforation in the furcation usually results in a periodontal defect that communicates through the gingival sulcus within weeks or sometimes days. A preexisting periodontal communication caused by perforation worsens the prognosis; the time between perforation and repair should be as short as possible.[27,28] Immediate sealing of the defect reduces



• **Fig. 18.8** **(A)** Radiograph shows stripping perforation (*arrow*) in the mesiobuccal root of the first mandibular molar. **(B)** The mesial roots were filled with mineral trioxide aggregate (MTA) and the distal root with gutta-percha and root canal sealer. **(C)** A radiograph taken 1 year later shows no periradicular pathosis.



• **Fig. 18.9** **(A)** Periapical radiograph shows presence of a furcation perforation in the first mandibular molar. **(B)** The root canal was retreated and the perforation was repaired with mineral trioxide aggregate (MTA). **(C)** Radiograph taken 26 months later shows evidence of osseous healing in the furcation.



• **Fig. 18.10** **(A)** Postoperative radiograph of a 58-year-old female after endodontic treatment. The patient is percussion-sensitive, and periapical lesions are present. A 7-mm periodontal pocket exists on the mesiobuccal aspect of the mesial root of the second molar. A fracture is suspected, and extract-replant was performed for diagnostic reasons. The tooth was extracted, and a fracture was noted on the mesial root. **(B)** The mesial root was resected and the tooth was replanted after retrofilling of the distal root with mineral trioxide aggregate (MTA). **(C)** Radiograph 1 year later shows osseous repair and restoration of this tooth. The periodontal pocket healed.

the incidence and severity of periodontal breakdown. To best determine the long-term prognosis, the dentist must monitor the patient's symptoms, radiographic changes, and, most importantly, periodontal status. Radiographs and periodontal probing during recall examination are the best measures of success or failure of the repair procedure. Formation of a periodontal pocket adjacent to the site of perforation is a definitive sign for failure.

Accidents During Cleaning and Shaping

The most common procedural accidents during cleaning and shaping of the root canal system are ledge formation, artificial canal creation, root perforation, instrument separation, and extrusion of irrigating solution periapically. Correction of these accidents is usually difficult, and the patient should be referred to an endodontist.

Ledge Formation

By definition, a ledge has been created when the working length can no longer be negotiated and the original patency of the canal is lost. The major causes of ledge formation include (1) inadequate straight-line access into the canal, (2) failure to precurve the files, (3) forcing large files into curved canals, (4) inadequate irrigation or lubrication, and (5) packing of debris in the apical portion of the canal.

Prevention of a Ledge

Preoperative Evaluation

Prevention of ledging begins with examination of preoperative radiographs taken from different angles and CBCT images for curvatures, length, and initial size.

Curvatures

The incidence of ledge formation was reported to increase significantly when the curvature of the canal was greater than 20 degrees, and when the curvature was greater than 30 degrees more than 50% of the canals were ledged.[29] Most important is the coronal third of the root canal. Severe coronal curvature predisposes the apical canal to ledging. Straight-line access to the orifice of the canal can be achieved during access preparation, but accessibility to the apical third of the canal is achieved only with coronal flaring and using precurved files. Severe apical curvatures require a proper sequence of cleaning and shaping procedures to maintain patency (see Chapter 14).

Length

Longer canals are more prone to ledge formation compared with shorter and larger diameter canals. Careful attention to maintaining patency is required to prevent ledging.

Initial Size

Smaller-diameter canals are more easily ledged than larger-diameter canals.

In summary, the canals most prone to ledging are small, curved, and long. Radiographs are two-dimensional and cannot provide accurate information about the actual shape and curvature of the root canal system. All root canals have some degree of curvature, including faciolingual curves, which may not be apparent on straight facial exposures (Fig. 18.11). CBCT images are the most accurate tools for understanding the presence and degree of curvatures.[8]

Instruments

Instruments with more flexibility cause less apical transportation, resulting in a ledge formation. The flexibility of the instruments depends on several interrelated factors such as the cross-sectional design, core diameter, pitch, metallurgical properties, surface treatment of the instruments, heat treatment, the type of kinematics (continuous rotation, reciprocation, and adaptive motion), the number of contact points with the canal walls, and the type of the alloys used for the instruments (conventional, R-phase, M-Wire, CM-wire, MaxWire, and GOLD Wire).[30,31] The most common way to increase file flexibility is to decrease the metal mass of the file by increasing the number of flutes per unit length; increasing the depth of the flutes; and decreasing the helix angle, the taper, size, and/or core diameter of the file. Thus an increased taper results in the increased cross-sectional area and decreased flexibility.[32] The tip design may also affect the incidence of ledge formation. Instruments with pyramidal tips were reported to form ledges.[33] Flexible files (nickel-titanium) with noncutting tips reduce the chances for ledge formation. Failing to use the instruments in sequential order may also lead to ledge formation.

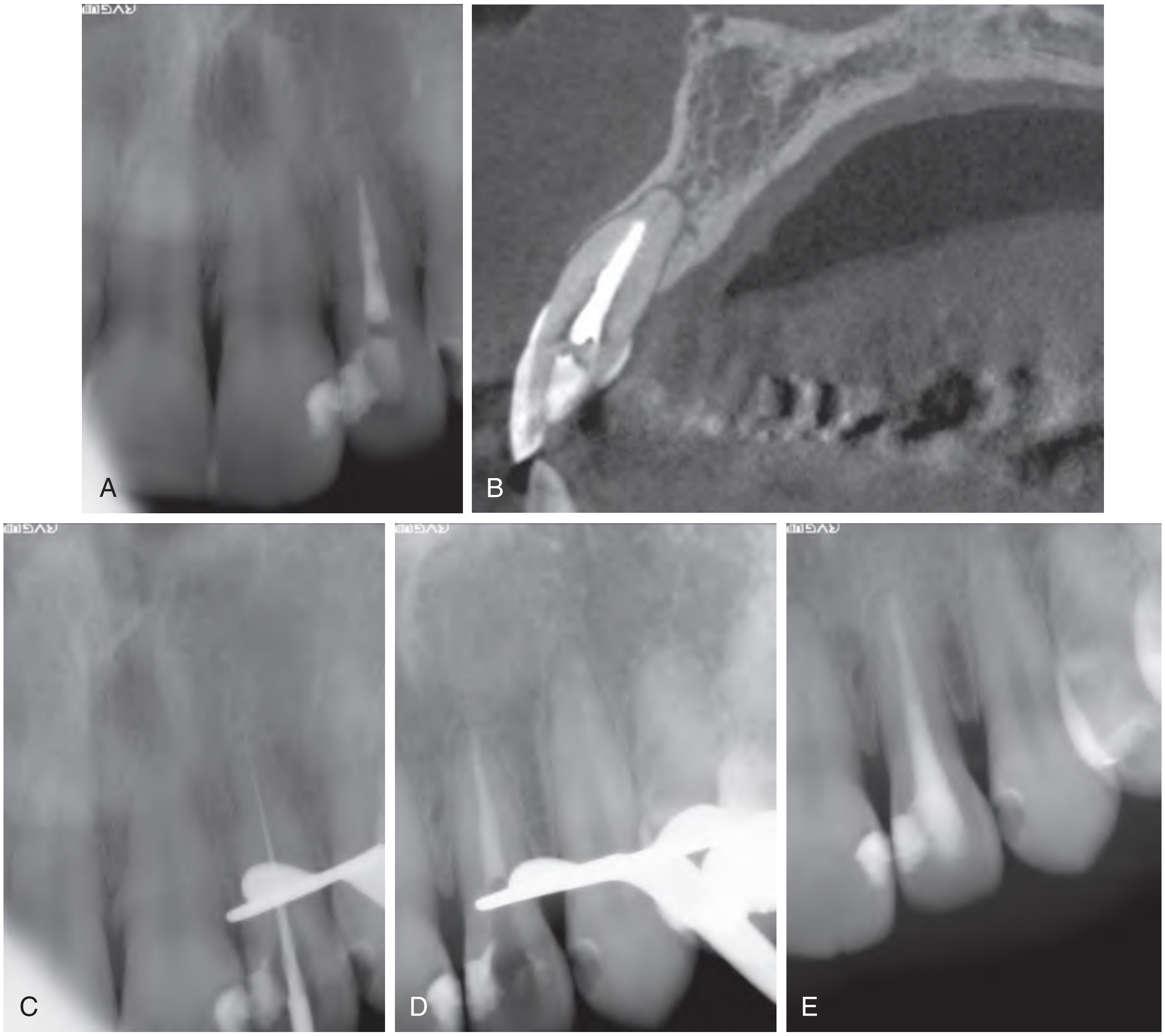
Technical Procedures

Determination of working length in the cleaning and shaping process is a continuation of the access preparation. Optimum straight-line access to the apical third is not achieved until cleaning and shaping have been completed. An accurate working length measurement is a requirement because cleaning and shaping short of the ideal length is a prelude to ledge formation. Frequent recapitulation and irrigation, along with the use of lubricants, are mandatory. Sodium hypochlorite may be used initially for hemorrhage control and removal of debris. However, this agent alone may not be adequate to provide maximum lubrication.

Silicone, glycerine, and wax-based lubricants are commercially available for canal lubrication. Because these materials are viscous, they are carried into the apical regions of the canal with the file. Enhanced lubrication permits easier file insertion, reduces stress to the file, and assists with removal of debris. The lubricant is easily removed with sodium hypochlorite irrigation. Overusing ethylenediaminetetraacetic acid (EDTA)-based lubricants can increase the risk of ledge formation.

Passive step-back and balanced force techniques are two beneficial methods of canal preparation that reduce the chances of ledge formation. Each file is used in sequence with circumferential filing to remove any irregularities before a larger diameter file is placed. The effective use of circumferential filing ensures smoothness of the canal walls and flaring toward the apical end of the canal, which will help to prevent the formation of ledges.

Canals with a severe coronal curvature require a passive step-back cleaning and shaping technique (see Chapter 14). A No. 15 file is used at working length. With maximum irrigation or lubrication, the canal is passively and progressively flared in a step-back fashion. The No. 15 file is recapitulated many times to maintain patency. This preflaring technique reduces the coronal curvature and enlarges the canal. Better control of the files is gained for enlarging and cleaning the apical third of the canal as the last step (see section on Apical Clearing in Chapter 14). Using this technique, the chances of ledge formation are reduced. Rotary files with increased taper will blend and join the shape into a tapering funnel.



• **Fig. 18.11** **(A)** Preoperative radiograph shows the maxillary left lateral incisor is underfilled and the presence of the canal apical to the end of the root filling is present. **(B)** Sagittal view of cone beam computed tomography (CBCT) imaging shows the presence of the ledge formation in relation to the apical one third of the canal with a small sized lesion. **(C)** Ledge was bypassed, and the apical patency was established. **(D)** Mineral trioxide aggregate (MTA) was obturated into the canal. **(E)** Three-month postoperative radiograph showing apical healing.

Management of a Ledge

Once created, a ledge is difficult to correct. If possible, both the original canal and the ledge must be located under the microscope and with the help of CBCT imaging. If the ledge is not clearly located, the canal should be enlarged to the ledge in an anticurvature direction with a No. 3 Gates-Glidden (GG) bur in a brushing motion as a ledge often forms in a straight line. Then the attempt should be made to bypass the ledge and instrument the canal using one of the following techniques: "Hand instruments," "Ultrasonic tips," "Rotary instruments," and "Surgical approach."

Hand Instruments

A small K file such as a No. 10 K file is the key instrument used in bypassing a ledged canal. The file tip (2 to 3 mm) is sharply bent and worked in the canal in the direction of the canal curvature. A "pecking" motion is used to attempt to feel the catch of the original canal space, which is slightly short of the apical extent of the ledge. A microfile designed to be used under the microscope such as the micro-Opener with #10/.06 taper (Dentsply Sirona, Switzerland) and the microexplorer (Dental Engineering laboratories, Seattle, WA) is best to place in the original canal when the original canal is visible under the microscope. Once the file has been placed in the original canal, a short up-and-down movement is repeated to enlarge the entrance to the original canal (see Fig. 18.11). Then a larger file is subsequently placed in the canal until the ledge is reduced to allow any file to be smoothly inserted to working length.

Ultrasonic Tips

The small diameter ultrasonic tips will help improve visibility with the added benefit of reducing the need for sacrificing sound dentin in bypassing or removing the ledge. The use of longer ultrasonic tips may also facilitate bypassing or reducing the ledge in the apical third under the microscope. First, the entrance to the original canal is located under the microscope. Then the ultrasonic tip to be used should be sharpened with a metal polishing bur and precurved to the original canal. The precurved ultrasonic tip is placed is in the original canal and activated to enlarge the entrance to it. Once the entrance to the original pathway has been enlarged for file insertion, negotiating files should be placed into the canal to establish patency and to smooth out the irregularities on the canal walls that may have been created with ultrasonics. Root canal preparation with nickle-titanium (NiTi) rotary or hand files will be followed (see Fig. 18.11).

Rotary Instruments

If a rotary file is used to bypass a ledge, it should be a less tapered instrument such as a #13 PathFile with .02 taper (Dentsply Sirona, Switzerland) or a Race International Organization for Standardization (ISO) 10 with .02 taper (FKG, Switzerland). First the apical portion, "the apical 2 to 3 mm," of the .02 taper rotary file is precurved to 30 to 45 degrees and is rotated at 100 rpm or slower, brought into the canal, and moved apically. If a ledge or sharp apical curvature is encountered, the instrument is withdrawn about 1 mm and immediately reinserted. This allows the precurved tip to move to a different orientation in the canal when reinserted. This may require several withdrawals and reinsertions as the clinician cannot anticipate when to get into the original pathway before fully negotiating the canal. This procedure is followed in sequence by a larger diameter file to preliminarily enlarge the original pathway and reduce the ledge until the root canal preparation with conventional NiTi rotary instruments becomes possible.

Surgical Approach

If a ledge cannot be bypassed with any of the techniques described previously and the periapical lesion persists, then the treatment options are limited to surgical intervention such as periapical surgery and intentional replantation with retrograde endodontic treatment.

Prognosis

Ledge formation does not immediately result in surgery or loss of the tooth. The presence of ledges may affect the prognosis depending on whether the canal apical to the ledge can be adequately cleaned or not. In general, short and cleaned apical ledges have good prognoses. Teeth with vital pulp tissue apical to a ledge, in general, have a better prognosis than teeth with necrotic infected tissues apical to a ledge that has not been previously cleaned before the formation of the ledge. The patient must be informed of the prognosis, the importance of the recall examination, and what signs indicate failure. Future appearance of clinical symptoms or radiographic evidence of failure may require referral for apical surgery or retreatment.

Creating an Artificial Canal

Cause and Prevention

Deviation from the original pathway of the root canal system and creation of an artificial canal cause an exaggerated ledge; it is initiated by the factors that cause ledge formation and transportation. Therefore the recommendations for preventing ledge formation should be followed to avoid creating artificial canals. The unfortunate sequence is as follows: A ledge is created and the proper working length is lost. The operator, eager to regain that length, "bores" apically with each file, thus creating an artificial canal. Used persistently, the file eventually perforates the root surface. Aggressive use of stainless-steel files is the most common cause of this problem. Creation of an artificial canal can be prevented by taking an intraoperative radiograph with the negotiating file placed in the canal as soon as the working length is lost, negotiating the canal under the microscope to locate the original pathway, and using a precurved small file oriented to the original pathway.

Management

Negotiating the original canal with the exaggerated ledge is usually very difficult. However, if the original pathway can be located in the CBCT images and under the microscope, negotiating the original canal should not be as difficult. If a perforation exists in the artificial canal, it needs to be evaluated to manage the artificial canal. If the size of perforation at the apical extent of the artificial canal is larger than 0.5 mm in diameter, it should be sealed with MTA before negotiating the original canal (Fig. 18.12). This allows for easier negotiation of the main canal. The prognosis of the tooth with perforation depends on débridement and sealing ability of both the perforated artificial canal and the original canal.[27,34] For the canal with a perforation sized smaller than 0.5 mm in diameter, both canals should be cleaned, shaped, and obturated with MTA at the same time. If nonsurgical management of the perforation repair is difficult, surgical intervention should be considered (see the section Root Perforations in this chapter).

To obturate the canal without perforation, the original canal should be located, negotiated, cleaned, and shaped along with the artificial canal.

Prognosis

Prognosis depends on the ability of the operator to renegotiate the original canal and the remaining uninstrumented and unfilled portion of the main canal. Unless a perforation exists, teeth in which the original canal can be renegotiated and obturated have a prognosis similar to those without procedural complications. In contrast, when a large portion of the main canal is uninstrumented and unobturated, a poorer prognosis exists, and the tooth must be examined periodically. Perforations at the crestal bone level have the worst prognosis as a result of damage to the periodontal attachment and pocket formation. Failure usually means surgery will be required to resect the uninstrumented and unobturated root.

Root Perforations

Roots may be perforated at different levels during cleaning and shaping. Location (apical, middle, or cervical) of the perforation and the stage of treatment affect prognosis.[27] The periodontal response to the injury is affected by the level and size of the perforation. Also, perforations at the early stages of cleaning and shaping affect prognosis significantly.

Apical Perforations

Apical perforations occur through the apical foramen (overinstrumentation or transportation at the level of apical foramen) or through the body of the root (perforated new canal).

Etiology and Indicators

Instrumentation of the canal beyond the apical constriction results in perforation. Incorrect working length or inability to maintain proper working length causes "zipping"[4] or "blowing out" of the apical foramen. The appearance of fresh hemorrhage in the canal or on instruments, pain during canal preparation

• **Fig. 18.12** **(A)** Preoperative radiograph showing periapical and furcal lesions. **(B)** Axial view of cone beam computed tomography (CBCT) imaging shows a large furcal perforation in the MB canal causing furcal lesions. **(C)** Sagittal view of CBCT imaging shows the MB canal perforated on the distal wall into the furcation and periapical lesions associated with both the mesial and the distal roots. **(D)** Perforation on the distal wall in the MB canal (*arrow pointing*). **(E)** Three-month postoperative radiograph after obturation showing reduced size periapical and furcal lesions. **(F)** Six-month postoperative radiograph showing furcal and periapical healing.

in a previously asymptomatic tooth, and sudden loss of the apical stop are indicators of perforation through apical foramen. Extension of the largest (final) file beyond the radiographic apex is also a sign. An electronic apex locator may also confirm this procedural accident.

Prevention

To prevent apical perforation, proper working lengths must be established and maintained throughout the procedure. In curved canals, the flexibility of files with respect to size and taper must be considered. Cleaning and shaping procedures straighten the canal somewhat and effectively decrease the working length by as much as 1 to 2 mm, thereby requiring compensation. To prevent apical perforation, the working length should be verified with an apex locator before and after completion of cleaning and shaping steps. Using an electrical motor for rotary files with a built-in apex locator is another option.

Treatment

Treatment includes establishing a new working length, creating an apical seat (taper), and obturating the canal to its new length. Depending on the size and location of the apical foramen, a new working length 1 to 2 mm short of the point of perforation should be established. The canal is then cleaned, shaped, and obturated to the new working length. The master cone must have a positive apical stop at the working length before obturation. Placement of MTA as an apical barrier can prevent extrusion of obturation materials.

MTA can also be used for filling the canal and repairing the perforation at the same time. The apical diameter is measured with a series of K files. Then a NiTi rotary file that is one or two sizes smaller than the apical diameter is selected. The selected NiTi rotary file is connected to an apex locator, followed by MTA compaction into the canal as well as the perforation site using the file manually. The working length should be reached once or twice with the NiTi rotary file rotating counterclockwise manually to further condense MTA into the canal space.

Prognosis

The prognosis depends primarily on the size, shape, and location of the defect as well as the material used for perforation repair.[20] An open apex or reverse funnel should be sealed with MTA as it provides adequate seal even when the material is extruded beyond the apical foramen. Although MTA is bioactive[19] and sets in the presence of blood and moisture,[35] it is recommended to prevent the extrusion of MTA[36] and any types of root canal filling material. The surgical accessibility of perforations also are important variables for long-term success. Repair of apical perforations in anterior teeth is easier and more practical than in posterior teeth.

Lateral (Midroot) Perforations

Etiology and Treatment

Lateral (midroot) perforations happen as a result of continued efforts in reaching the working length in an artificial canal that is not diagnosed by the clinician. The reader is referred to the topic of “Creating an Artificial Canal” to find information about causes, prevention, and treatment of the lateral (midroot) perforations (Video 18.2).

Prognosis

The prognosis of teeth with midroot perforations depends on the effectiveness of débridement of the canal, control of hemorrhage, and the ability to obturate the canal apical to the perforation. MTA is the material of choice not only for perforation repair. It can also be used as the obturation material when there is a midroot perforation. Teeth with perforations close to the apex after complete or partial débridement of the canal have a better prognosis than those with perforations that occur earlier. In general, small perforations are easier to seal than large ones.

On recall, both radiographic and periodontal examinations for signs and symptoms are performed. Failure generally requires surgery or other approaches. These approaches depend on the severity of perforation, the strategic importance of the tooth, and the location and accessibility of the perforation. Corrective techniques include repair of the perforation site, root resection to the level of the perforation, root amputation, hemisection, replantation, and extraction.

Coronal Root Perforations

Etiology and Indicators

Coronal root perforations can occur by over-enlarging canals in the cervical portion of a canal by files, GG drills, Orifice openers, or Peeso reamers. Using the methods described earlier in this chapter can minimize perforations during access preparation. Removal of restorations when possible, use of fiberoptic lights for illumination, magnification, CBCT imaging, straight-line access to the orifice of the canals, and cautious exploration for the canal orifice can prevent most problems during access preparation. Careful flaring (step-back) and conservative use of flaring instruments are required during cleaning and shaping procedures.

Treatment and Prognosis

Preventing the communication between the perforation site and the gingival sulcus is very critical in prognosis of teeth with coronal root perforations. Repair of a strip perforation in the coronal third of the root, especially when the perforation is coronal to the crestal bone, has the worst prognosis because of quick periodontal attachment loss. The canal apical to the perforation should be filled with MTA first and subsequently the defect should be repaired with the same material for the optimal seal and healing.

Instrument Separation

Etiology

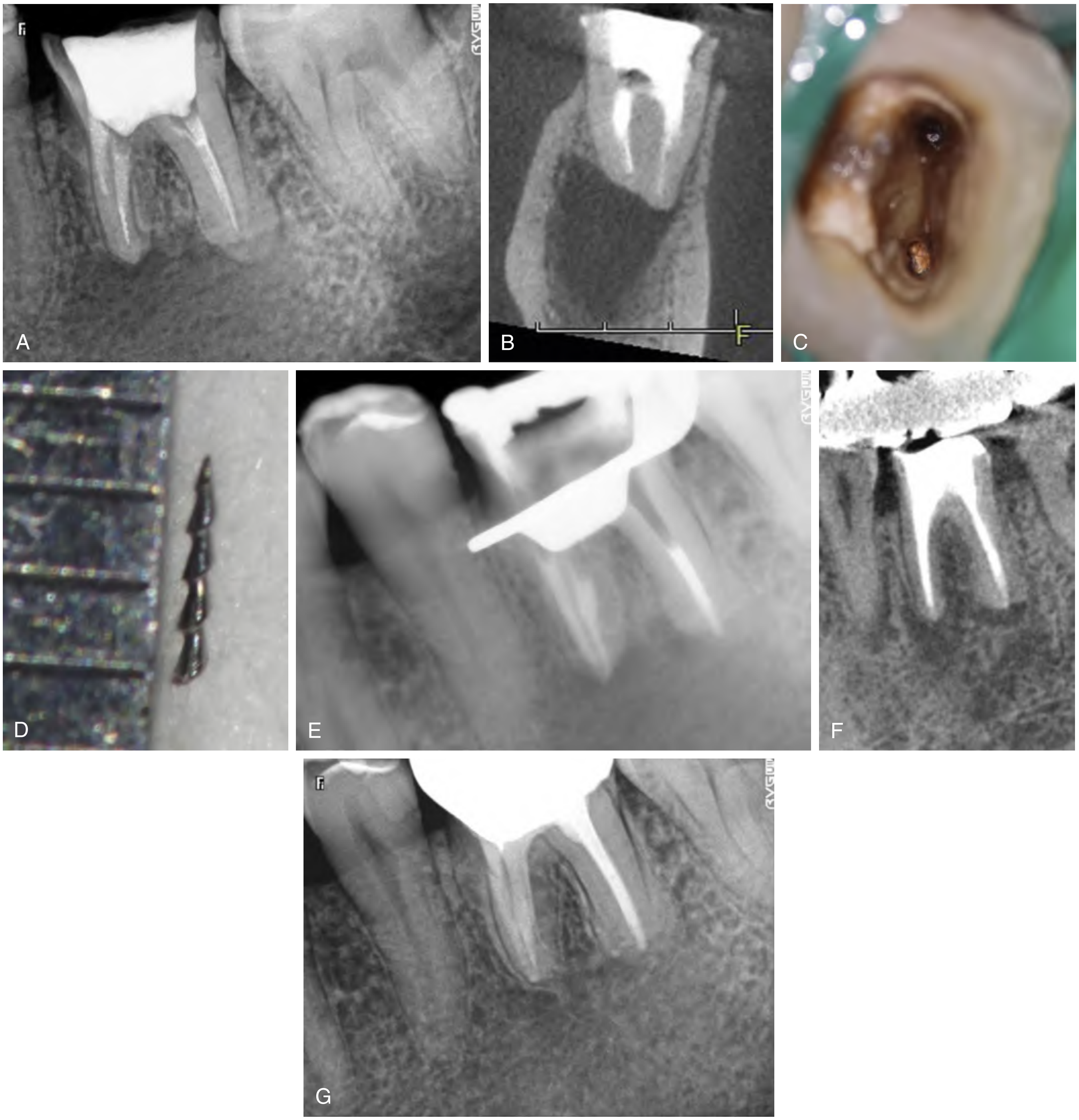
Although an instrument separation does not always reduce the prognosis, it might affect the outcome of endodontic treatment. Studies showed that instrument separation negatively affects the outcome of endodontic treatments only in cases where microbial control is compromised or periapical lesions preexist[37](Fig. 18.13). Instrument separation in endodontics occurs mainly as a result of the metal fatigue (cyclic fatigue and torsional fatigue), manufacturing defects, corrosion of the instrument in the presence of NaOCl,[38,39] or a combination of these factors. Despite the high flexibility, NiTi instruments in general are more susceptible to fracture at a lower force than stainless steel instruments.[40] Other factors associated with instrument separation are as follows: operator experience,[41,42] rotational speed,[43] canal curvature (radius),[44] instrument design and technique,[45] torque setting,[46] manufacturing process,[47] the type of NiTi alloys used,[48] the type of rotational motion (continuous rotations or reciprocating motions),[49] the type of tooth,[50,51] and absence of glide path.[52]

Recognition

A shortened file with a blunt tip and subsequent loss of patency to the original length are the main clues for the presence of a separated instrument. A radiograph is essential for confirmation. It is imperative that the patient be informed of the accident and its effect on prognosis.[1] As with other procedural accidents, detailed documentation is also necessary for medical-legal considerations.

Prevention

Recognition of the physical properties and stress limitations of files is critical. Continual lubrication with either irrigating



• **Fig. 18.13** **(A)** Preoperative radiograph showing a fractured instrument in the apical one third of the mesiobuccal canal with large periapical lesions associated with the mesial and distal roots. **(B)** Preoperative coronal view of cone beam computed tomography (CBCT) imaging showing the fractured instrument in the MB canal with a large periapical lesion. **(C)** Magnified view showing the fractured instrument in the MB canal (*arrow*). (D) Retrieved instrument measuring 2.5 mm. **(E)** Postoperative radiograph mineral trioxide aggregate (MTA) filling in mesial canals, gutta-percha obturation in distal canals. **(F)** Six-month postoperative sagittal view of CBCT imaging showing healing of the periapical lesion. **(G)** Twelve-month postoperative radiograph showing periapical healed.

solution or lubricants is required. Each instrument is examined before use. If an unwound or twisted file is rotated and viewed, reflections from the chairside light will magnify fluting distortions. Rotation of a file with a large diameter in a curved canal increases cyclic fatigue compared with a file with a smaller diameter. To reduce cyclic fatigue of an instrument in a curved canal, a file with a smaller diameter should be used with reduced rotational speed. In the meantime, rotating a small diameter file in a tight canal makes it more susceptible to fracture because of torsional fatigue. To reduce torsional fatigue of an instrument, the rotational speed should be increased, and the file should be used with light apical pressure.

The fatigue life of NiTi instruments is longer in liquid media than in air, which indicates the effect of temperature and environment on the risk of instrument separation.[53] An aqueous medium may be able to serve as an effective heat sink to reduce the risk of instrument separation.

The use of reciprocal motions is reported to extend the lifespan of an instrument[54] and increase cyclic fatigue resistance compared with continuous rotation.[49] It is important to establish a glide path with hand files before rotary files are introduced into the canal.

Treatment

Nonsurgical management of fractured instruments can be categorized into mechanical and chemical methods. The chemical method includes the use of chemical solvents for instrument corrosion and electrochemical process for instrument dissolution, which may be time-consuming because the chemical solvents can only contact the exposed surface of the fractured instrument in the canal to corrode the whole instrument. Therefore the mechanical method for instrument retrieval is solely discussed in this chapter.

There are three approaches to managing an intracanal fractured instrument: (1) attempt to remove the instrument nonsurgically or surgically, (2) attempt to bypass it, or (3) prepare and obturate the canal with the fractured instrument. Using a small file and following the guidelines described for negotiating a ledge, the operator should attempt to bypass the separated instrument. After bypassing the separated instrument, ultrasonic files[55] or Hedstrom files are used to remove the segment (Video 18.3). If removal of the separated piece is unsuccessful, the canal is cleaned, shaped, and obturated to its new working length.

First, a diagnosis and a treatment plan for instrument retrieval should be made by using periapical radiography and CBCT imaging. With CBCT imaging, accurate procedural information about the removal of the separated instrument such as the length of the separated instrument, the degrees of the curve, the thickness of the canal walls, the presence of perforation, and the presence of preoperative lesions, can be obtained.

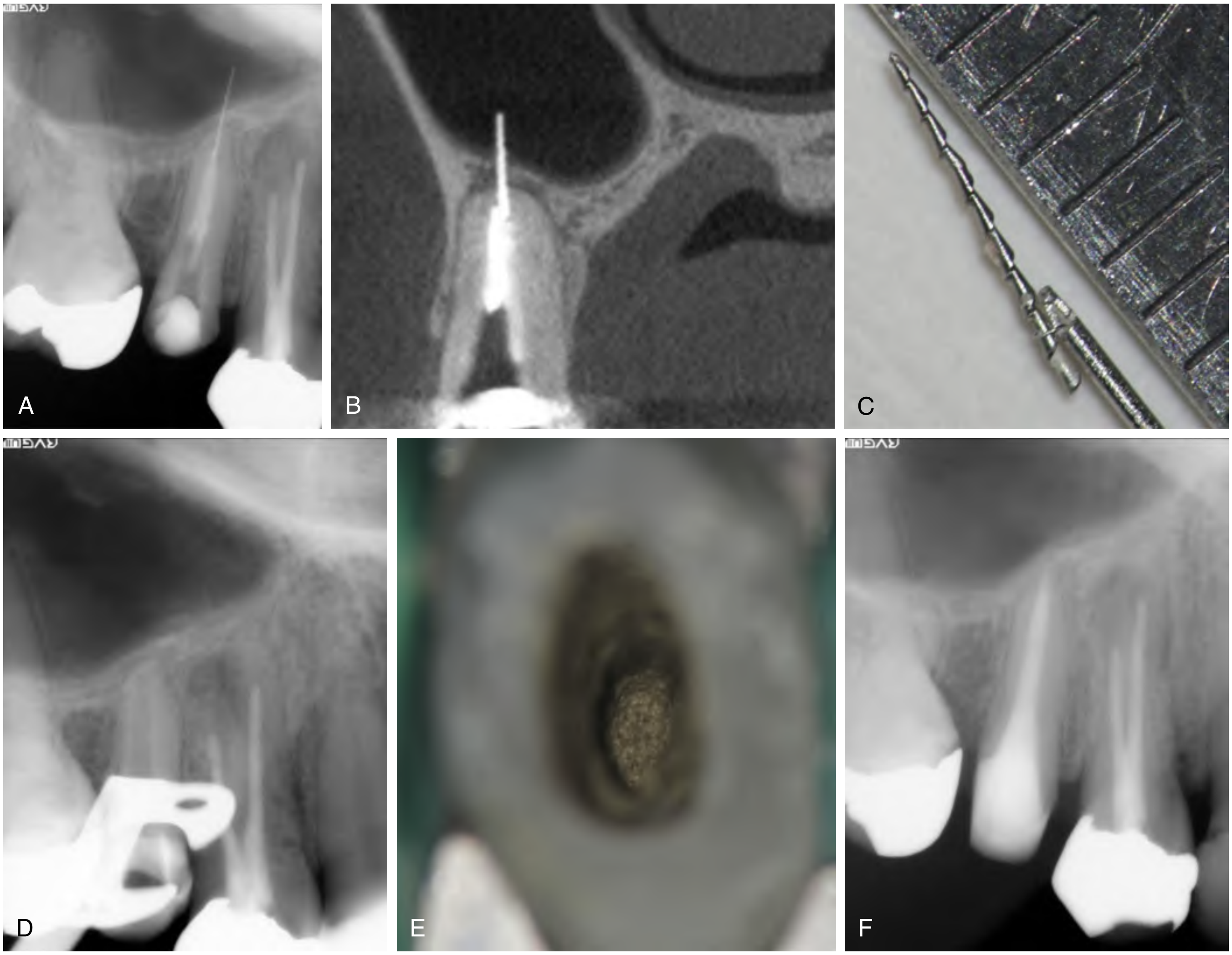
The great majority of NiTi rotary instruments fracture in the apical third of the canals.[56] When a fractured instrument is beyond the curve and extruded mostly beyond the apical foramen, a surgical approach should be considered. A nonsurgical approach should be performed if the amount of dentin removal is minimal and reasonable and does not impose the risk of ledging or perforations.

Predictable instrument retrieval requires precise preparations. First, the canal needs to be enlarged to the level of fractured instrument with a #3 GG bur without the pilot tip (#3 modified GG bur). Then the microtrephine bur (Dental Engineering laboratories, Santa Barbara, CA) is inserted into the canal and rotated counterclockwise at 600 rpm to both loosen the fractured instrument and expose the coronal 1 mm portion of the separated instrument. If the separated instrument is around the curve or beyond the curve, a large diameter NiTi rotary file approximately three sizes larger than the estimated diameter of the separated instrument should be used instead of the GG bur without using the microtrephine bur to prevent ledge formation. Then a sharp ultrasonic tip, such as the Terauchi File Retrieval Kit (TFRK)-12/6 and the TFRK-S (Dental Engineering Laboratories, Santa Barbara, CA), is used to create a thin space in the gap between the fractured instrument and the inner wall or the surrounding wall in the straight portion of the canal where the dentin wall thickness is the largest. When the fractured instrument is ultrasonically oscillated from the inner wall of a curved canal, it will be shifted coronally, whereas ultrasonic oscillation from the outer wall will result in pushing it more apically. The ultrasonic tip used in preparation must be small enough to not only slip into the gap on the inner wall, but also allow for proper visualization in the canal under the microscope. The ultrasonic tip should be activated intermittently (on and off) at the lowest power setting that allows minimal dentin removal to both prevent the temperature rise[57,58] and breakage of the fractured instrument or the ultrasonic tip. The thin space to be created on the inner wall with ultrasonics should be at least longer than one third of the fractured instrument and more than 180 degrees semicircular around it on the inner wall to loosen the fractured instrument. The preparation for instrument retrieval should continue by deepening the space or extending the semicircular space until the fractured instrument is seen moving or "dancing." A longer NiTi fractured instrument tends to be flexing with ultrasonics, which is often misinterpreted as moving or "dancing" under the microscope. After the separated file is loosened, the retrieval process should be attempted. During retrieval by ultrasonics the root canal space should be filled with EDTA. When the sharp ultrasonic tip is placed in the space created on the inner wall and activated continuously in an up-and-down motion within the space, the fractured instrument should come out within 10 seconds. The space between the fractured instrument and the canal wall must be wider than the diameter of the fractured instrument to allow it to flow out of the canal. If the loop device is used to retrieve the fractured instrument, the minimum space required for the placement of the loop is 0.4 mm wide and 0.5 mm long on the side of the coronal portion of the fractured instrument. A #40 plugger should be introduced into the space to see if the space is wide enough to place the loop. The loop size must be adjusted to the size of the fractured instrument with a DG-16 endodontic explorer. The loop should be bent to 45 degrees to facilitate the placement of the loop. Then the loop is placed over the fractured instrument, tightened around it with minimum force, and gently pulled out of the canal as the fractured instrument is already dislodged from the canal walls. If the resistance is felt from pulling the fractured instrument up with the loop, gently swing the loop in several lateral and coronal directions (Fig. 18.14).

If the instrument is separated in an apical curved portion of the canal beyond the straight section of the canal, the use of a staging platform should not be attempted as ledging, perforation, or excessive loss of dentin may result.[59]

If the instrument cannot be bypassed or removed, preparation and obturation should be performed to the coronal level of the fragment.

For most cases involving fractured instruments, the patient should be referred to an endodontist for management (Video 18.4).



• **Fig. 18.14 (A)** Preoperative radiograph showing a fractured file in the root canal with the apical portion extruded into the maxillary sinus. **(B)** Preoperative coronal view of cone beam computed tomography (CBCT) image showing the position of the fractured file. **(C)** Retrieved fractured file measuring 6 mm. **(D)** Radiograph taken immediately after the retrieval. **(E)** Microscopic image showing mineral trioxide aggregate (MTA) obturation. **(F)** Postoperative radiograph showing MTA obturation well adapted to the root canal.

Prognosis

The prognosis is best when separation of a large instrument occurs in the later stages of preparation close to the working length. Prognosis is worse for teeth with undébrided canals in which a small instrument is separated short of the apex early in preparation. For medical-legal reasons, the patient must be informed (with documentation in the record) of an instrument separation. Despite the concern of both the patient and the dentist, clinical reports indicate that the prognosis in most procedures involving fractured instruments is favorable.[60] The most important prognostic factor for teeth with retained fractured instruments is the presence of periapical lesion. The prognosis of endodontically treated teeth with retained instruments remains unchanged.[37,60]

If the tooth remains symptomatic or there is a subsequent failure, the tooth can be treated surgically. Accessible roots are resected with placement of a root-end filling material. Accessibility of the root apex for surgical intervention is critical to the outcome.

Role of 3D Imaging in Prevention

CBCT provides the clinician with a three-dimensional view of the internal anatomy, which helps the clinician to prevent most of the procedural accidents. For instance, if CBCT imaging shows an abrupt apical curvature and an apical foramen on the distal side of the mesial root of a mandibular molar, ledge formation, perforation, and instrument fracture can be prevented during instrumentation directed to the apex of the root. Axial slices typically show the number of canals and the thickness of the canal wall in relation to the long axis of the root to prevent perforation during the access preparation and instrumentation. Sagittal and coronal slices reveal canal curvature in relation to the coronal access to the root canal and the long axis of the root to prevent formation of ledges and instrument fracture. CBCT images reveal periapical lesions better than periapical radiographs, which gives the clinician a better understanding of the prognosis if a procedural accident happens.[61] On the other hand, studies showed that CBCT imaging has no advantage over periapical radiographs in detecting the fractured instruments in root-filled teeth.[62]

Study Questions

1. What type of canal is prone to ledge formation during instrumentation?
   a. Short and curved canal
   b. Short canal with small diameter
   c. Long canal with small diameter and curvature
   d. Long canal with large diameter and curvature
2. What kind of instrument is less likely to ledge the canal?
   a. Large diameter instrument with an increased taper
   b. Small diameter instrument with minimal taper
   c. NiTi instrument with a cutting tip
   d. Stainless steel instrument with a noncutting tip
3. Which side of the canal should a thin space be created with ultrasonics in preparation for instrument retrieval?
   a. Outer wall
   b. Inner wall
   c. Thickest wall
   d. Thinnest wall
4. What is the objective of the root canal preparation for instrument retrieval?
   a. To visualize the fractured instrument
   b. To loosen the fractured instrument
   c. To expose the coronal portion of the fractured instrument
   d. To create a semicircular space in the space on the inner wall
5. What does the axial view of CBCT image show to prevent perforation during the access cavity preparation and instrumentation?
   a. The number of canals and the thickness of the canal wall
   b. Canal curvature and the long axis of the root
   c. The presence of periapical lesions
   d. The presence of a ledge

Accidents During Obturation

Appropriate cleaning and shaping are the keys to preventing obturation problems because these accidents usually result from improper canal preparation. In general, adequately prepared canals are obturated without mishap. However, problems do occur. The quality of obturation reflects the quality of canal preparation.

Underfilling

Etiology

Some causes of underfilling include a natural barrier in the canal, a ledge created during preparation, insufficient flaring, a poorly adapted master cone, and inadequate condensation pressure. Bypassing (if possible) any natural or artificial barrier to create a smooth funnel is one key to avoiding an underfill. The advent of NiTi rotary files of increased taper has greatly improved the predictability of proper funnel and taper.

Treatment and Prognosis

Removal of underfilled gutta-percha and retreatment is preferred. The focus of the retreatment should be on the cause of underfilling. In other words, the clinician should first determine what caused the underfill and then address this issue during retreatment. Forcing gutta-percha apically by increased spreader or plugger pressure is not a solution and can fracture the root. If lateral condensation is the method of obturation, the master cone should be marked to indicate the working length. If displacement of the master cone during condensation is suspected, a radiograph is made before excess gutta-percha is removed. Removal can then be accomplished by pulling the cones in the reverse order of placement. Removal of gutta-percha in canals obturated with lateral condensation is easier than removal with other obturation techniques.

Overfilling

Extruded obturation material causes tissue damage and inflammation. Postoperative discomfort (mastication sensitivity) usually lasts for a few days or weeks.

Etiology

Overfilling is usually the consequence of overinstrumentation through the apical constriction or lack of proper taper in prepared canals. When the apex is open naturally by apical resorption or its constriction is removed during cleaning and shaping, there is no matrix against which to condense; uncontrolled condensation forces extrusion of materials (Fig. 18.15). Other causes include inflammatory resorption and incomplete development of the root.

Prevention

To avoid overfilling, guidelines for preventing apical foramen perforation should be followed. Tapered preparation with an apical "matrix" usually prevents overfill. The largest file and master cone at working length should have a positive stop. If overfilling is suspected, a radiograph should be made before excess gutta-percha is removed. As with underfilling, the gutta-percha mass may be removed if the sealer has not set.

Treatment and Prognosis

When signs or symptoms of endodontic failure appear, apical surgery may be required to remove the material from apical tissues and place root-end filling material. Long-term prognosis is dictated by the quality of the apical seal, the amount and biocompatibility of extruded material, host response, and toxicity and sealing ability of the root-end filling material.

Vertical Root Fracture

Complete vertical root fracture causes untreatable failure. Aspects of vertical root fracture are described in more detail in Chapter 4.

Etiology

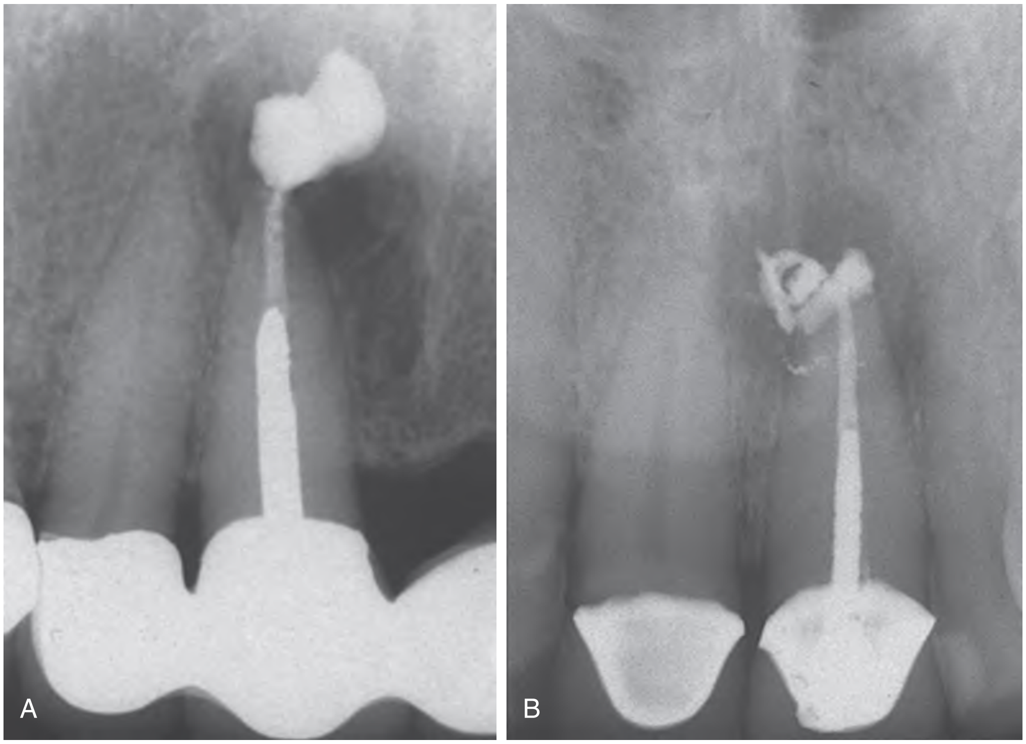
Causative factors include root canal treatment procedures and associated factors such as post placement. A main cause of vertical root fracture is post cementation. The secondary cause is overzealous application of condensation forces to obturate an underprepared or overprepared canal.[63] A study showed that vertical root fracture is associated with two canals in a root, presence of isthmus between the canals in a root, and condensation forces during obturation.[64]

Prevention

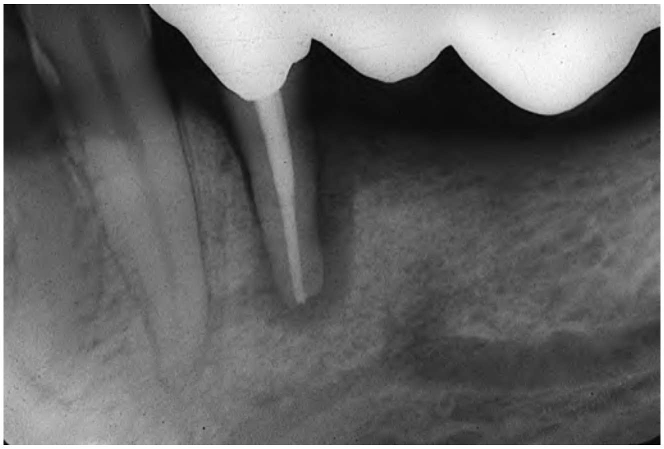
As related to root canal treatment procedures, the best means of preventing vertical root fractures are appropriate canal preparation and use of balanced pressure during obturation. A major reason for flaring canals is to provide space for condensation instruments. Finger spreaders produce less stress and distortion of the root than their hand counterparts.[65] Furthermore, NiTi finger spreaders produce less stress during compaction than stainless-steel finger spreaders.[66]

Indicators

Long-standing vertical root fractures are often associated with a narrow and deep periodontal pocket with or without a sinus



• **Fig. 18.15** **(A)** Lack of proper length measurements can result in overfilling with root canal sealer or **(B)** sealer and gutta-percha.



• **Fig. 18.16** A "tear-drop" lateral radiolucency and a narrow probing defect extend to the apex of a tooth with vertical fracture.

tract stoma, as well as a lateral or a J-shaped radiolucency (Fig. 18.16) extending to the apical portion of the vertical fracture.[67] To confirm the diagnosis, a vertical fracture must be visualized. Exploratory surgery or removal of the restoration is usually necessary to visualize this mishap. More recently, CBCT has been used to confirm or rule out vertical root fractures. However, scatter from posts or root canal filling materials may make interpretation of vertical root fractures difficult in CBCT images.[68]

Prognosis and Treatment

Complete vertical root fracture predicts an unfavorable prognosis. Treatment is removal of the involved root in multirooted teeth or extraction of single-rooted teeth.

Accidents During Post Space Preparation

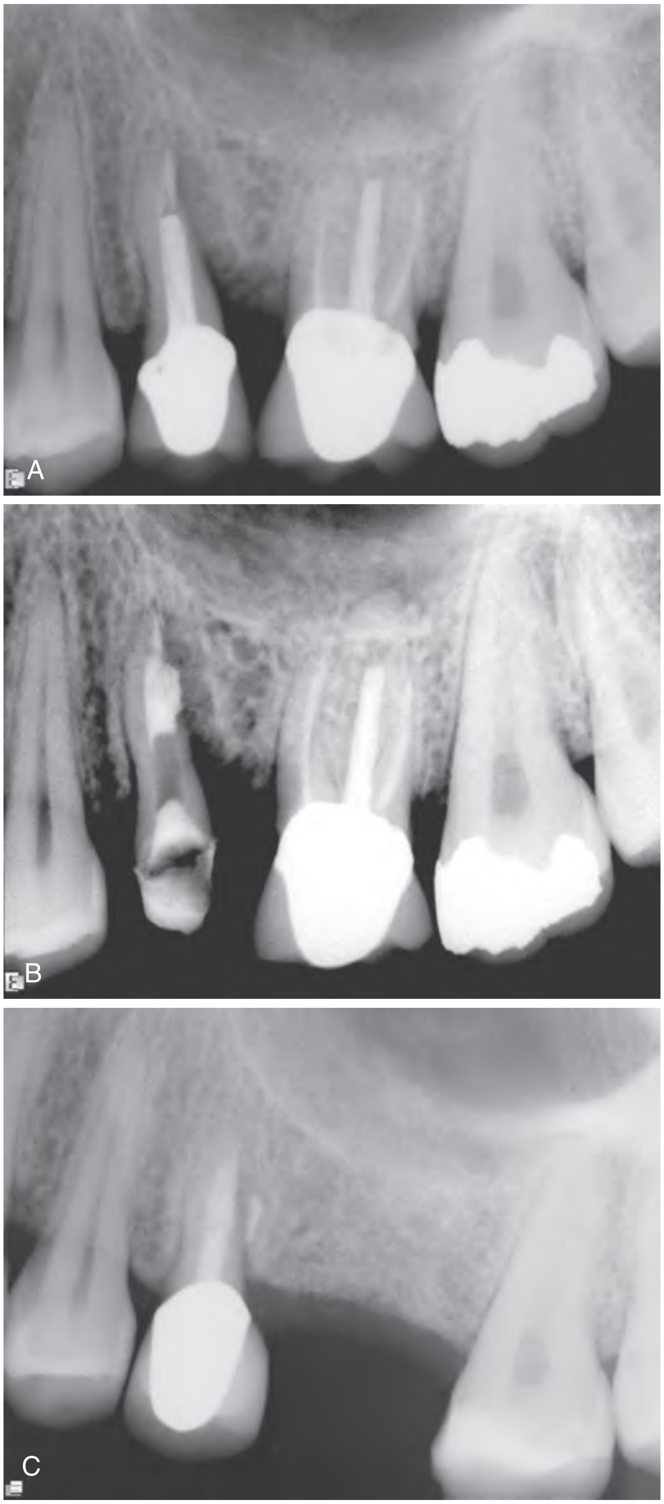
To prevent root perforation, gutta-percha may be removed to the desired level with heated pluggers or electronic heating devices, such as the "Touch N Heat" or System B (SybronEndo, Orange, CA). This "pilot" post space provides a path of least resistance for the post drills. Attempting to remove gutta-percha with a drill can only result in perforation. When a canal is prepared to receive a post, drills should be used sequentially, starting with a size that fits passively to the desired level. Miscalculation and incorrect preparation may result in perforation at any level. Knowledge of root anatomy is necessary for determining the size and depth of posts.

Indicators

Appearance of fresh blood during post space preparation is an indication for the presence of a root perforation. The presence of a sinus tract stoma or probing defects extending to the base of a post is often a sign of root fracture or perforation. Radiographs often show a lateral radiolucency along the root or perforation site.

Treatment and Prognosis

As outlined earlier, the prognosis of teeth with root perforation during post space preparation depends on the root size, location relative to epithelial attachment, and accessibility for repair. Management of the post perforation generally is surgical if the post cannot be removed. If the post can be removed, nonsurgical repair is preferred (Fig. 18.17). Ideally, repair of the perforation should be done immediately after the perforation is diagnosed (Fig. 18.18). Teeth with small root perforations that are in the apical region and are accessible for surgical repair have a better prognosis



• **Fig. 18.17** **(A)** Lateral root perforation is evident in a patient who has had a previous root canal therapy. **(B)** After removal of the post and cleaning the root canal, the apical portion of the root was filled with mineral trioxide aggregate (MTA). **(C)** Postoperative radiograph taken 9 years later shows absence of any periradicular pathosis.

than those that have large perforations, are close to the gingival sulcus, or are inaccessible. Because of the complexity of diagnosis, surgical techniques, and follow-up evaluation, patients with post perforations should be referred to an endodontist for evaluation and treatment.

Other Accidents

Aspiration or Ingestion

Aspiration or ingestion of instruments is a serious event but is easily avoided with proper precautions. Use of the rubber dam is the standard of care to prevent such ingestion or aspiration and subsequent lawsuits.

The disappearance of an instrument that has slipped from the dentist's fingers followed by violent coughing or gagging by the patient and radiographic confirmation of a file in the alimentary tract or airway are the chief signs. These patients require immediate referral to a medical service for appropriate diagnosis and treatment. According to a survey by Grossman, 87% of these instruments are swallowed and the rest are aspirated.[69] Surgical removal is required for some swallowed (Fig. 18.19) and nearly all aspirated instruments.

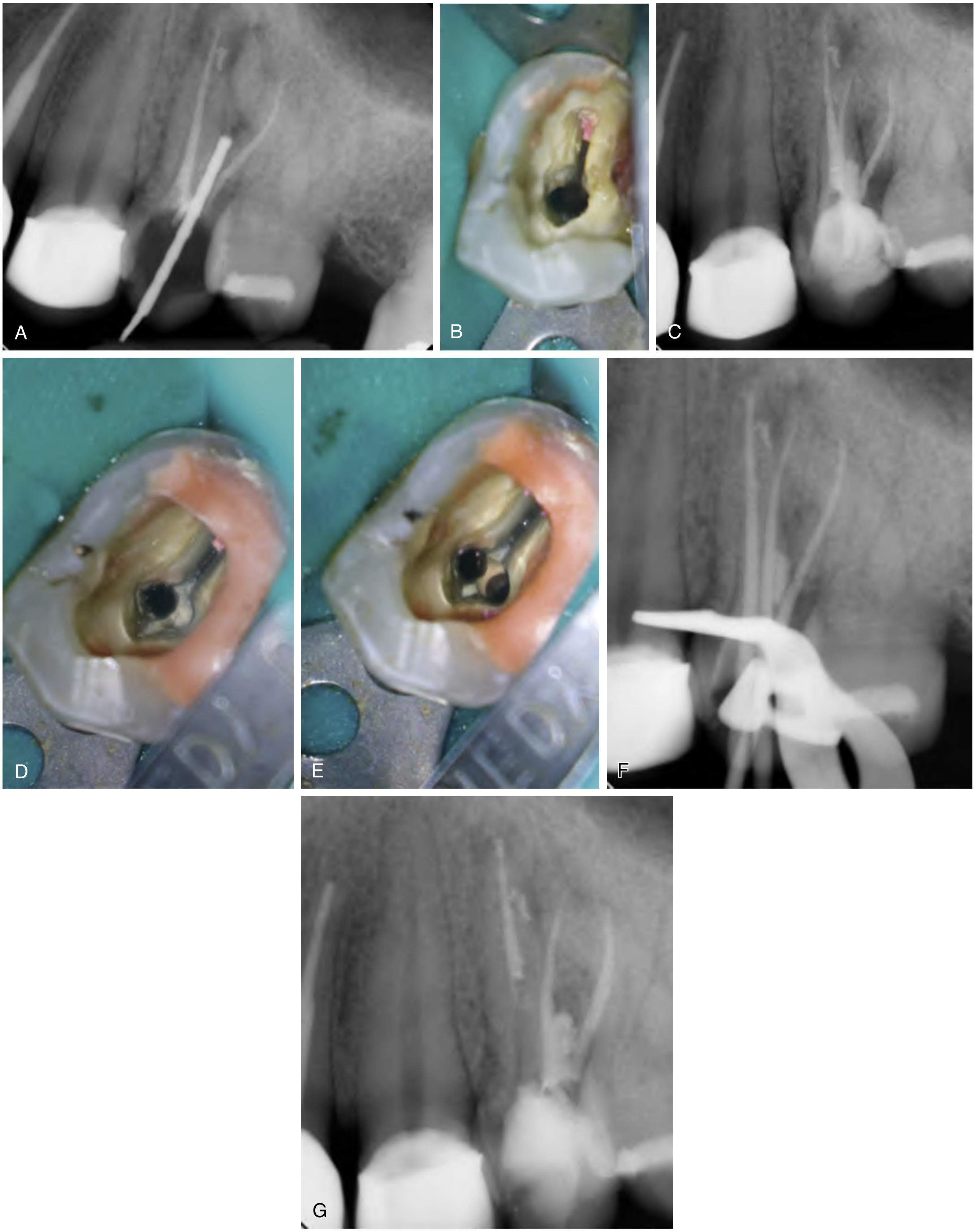
Extrusion of Irrigant

Wedging of a needle in the canal (or particularly out of a perforation) with forceful expression of irrigant (usually sodium hypochlorite) causes penetration of irrigants into the periradicular tissues and inflammation and discomfort for patients.[70] Extrusion of NaOCl into the periapical tissues can cause a life-threatening emergency.[71] This situation is called *sodium hypochlorite accident*. A survey of the Board-Certified Endodontists in the United States showed that about one third of the endodontists have experienced an NaOCl accident.[72] NaOCl accidents happened more commonly in maxillary posterior teeth diagnosed with pulp necrosis and periapical lesion.[72] Loose placement of irrigation needles and careful irrigation with light pressure and use of a side-perforated needle precludes forcing the irrigating solution into the periradicular tissues. In addition, it is recommended to place a rubber stop on the irrigation needle, shorter than working length, to stay away from apical foramen during irrigation. Up-down movement of the needle during irrigation also helps to prevent locking needle inside the canal. Sudden prolonged and sharp pain during irrigation followed by rapid diffuse swelling (the "sodium hypochlorite accident") usually indicates penetration of solution into the periradicular tissues. The acute episode will subside spontaneously with time (Fig. 18.20). In teeth with open apices, the use of less concentrated irrigants, or saline, will prevent the possibility of irrigation accidents.

Initially, there is no reason to prescribe antibiotics. If there is a visible swelling an incision and drainage is recommended to reduce the pressure.[70] Treatment is palliative. Analgesics and steroids are prescribed, and the patient is reassured. Because the outcome is so dramatic, evaluation is performed frequently to follow progress.

Accidental Injections

In dentistry, local anesthesia, saline, sodium hypochlorite, chloroform, hydrogen peroxide, formalin, and alcohol are frequently used. They are all clear, transparent solutions and each has specific indications for use. Accidental injection occurs when a clear solution like sodium hypochlorite, chloroform, or formalin is loaded into an empty local anesthetic cartridge. A recent review study showed that the following solutions were injected inadvertently: sodium hypochlorite, formalin, formocresol, chlorhexidine, benzalkonium chloride (zephiran), 1:1000 adrenaline, and lighter fuel.[73] In all incidents, the patients felt immediate severe pain in the area of injection. Overall, long-term consequences were more devastating when the accidental injection was an inferior alveolar nerve block compared with local infiltrations.[73]



• **Fig. 18.18** **(A)** Perforation during post space preparation in tooth #12. The periapical radiograph shows a missed MB canal. **(B)** After locating and preparing the MB canal. The image shows the orifice of MB below the level of furcation perforation. **(C)** Perforation repaired with mineral trioxide aggregate (MTA) and the pathway of MB was kept patent using a single cone of gutta-percha. **(D)** After MTA setting, the cone in MB was removed. **(E)** The retreatment continued in DB and P canals. The image shows pulp chamber floor built up with MTA. **(F)** Radiograph with master cones in all three canals. **(G)** Final radiograph showing adequate root canal treatment in all three canals, perforation in the pulp chamber floor repaired, and a post space prepared in the P canal.

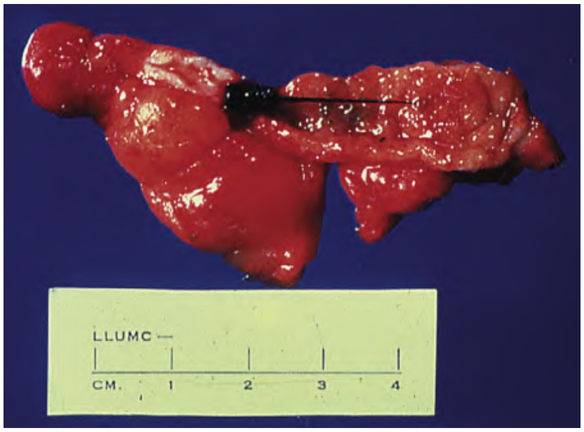
Study Questions

6. Which perforation has the worst prognosis?
   a. Perforation at the apical third
   b. Perforation at the middle third
   c. Perforation at the crestal bone level without pocket formation
   d. Perforation at the crestal bone level with pocket formation
7. Which one is the main reason for overfilling?
   a. Lack of apical stop caused by overinstrumentation
   b. Apical resorption
   c. Inadequate taper
   d. All of the above
8. Which accidental injection can have the most devastating effects?
   a. NaOCl injected as inferior alveolar block
   b. NaOCl injected as infiltration in anterior maxilla
   c. Normal saline injected as inferior alveolar block
   d. Normal saline injected as buccal infiltration
9. In which of the following is the risk of NaOCl accident higher?
   a. Maxillary posterior teeth
   b. Maxillary anterior teeth
   c. Mandibular posterior teeth
   d. Mandibular anterior teeth
10. In what pulpal/periapical condition is the risk of NaOCl accident the highest?
   a. Irreversible pulpitis with symptomatic apical periodontitis
   b. Pulp necrosis with periapical lesion
   c. Pulp necrosis with normal periapex
   d. Irreversible pulpitis with normal periapex

ANSWERS

Answers Box 18

1 c. Long canal with small diameter and curvature
2 b. Small diameter instrument with minimal taper
3 b. Inner wall
4 b. To loosen the fractured instrument
5 a. The number of canals and the thickness of the canal wall
6 d. Perforation at the crestal bone level with pocket formation
7 d. All of the above
8 a. NaOCl injected as inferior alveolar block
9 a. Maxillary posterior teeth
10 b. Pulp necrosis with periapical lesion



• **Fig. 18.19** A swallowed broach resulted in removal of a patient's appendix and a subsequent lawsuit against a dentist who did not use a rubber dam during root canal therapy. (Courtesy Dr. L. Thompsen.)

• **Fig. 18.20** **(A)** NaOCl was inadvertently expressed through an apical perforation in a maxillary cuspid during irrigation. Hemorrhagic reaction was rapid and diffuse. **(B)** No treatment was necessary; the swelling and hematoma disappeared within a few weeks. (Courtesy Dr. James Stick.)

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Video 18.0: Procedural Accidents Introduction
Video 18.1: Repair of Furcation Perforation
Video 18.2: Repair of Lateral Perforation
Video 18.3: Removal of Separated Instrument