# 11

# Management of Traumatic Dental Injuries

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## CHAPTER OUTLINE



## LEARNING OBJECTIVES

*After reading this chapter, the student should be able to:*

1. Describe the clinical and radiographic features of enamel fractures, uncomplicated crown fractures, complicated crown fractures, crown-root fractures, root fractures, concussion, subluxation, luxations (lateral, extrusive, and intrusive), avulsions, and alveolar fractures.
2. Describe possible short- and long-term responses of pulp, periradicular tissues, and hard tissues to the injuries listed previously.
3. List pertinent information needed when examining patients with dental injuries (health history, nature of injury, and symptoms).
4. Describe the diagnostic tests, radiographic imaging, and procedures needed in examining patients with dental injuries and interpret the findings.
5. Describe the importance of cone beam computed tomography (CBCT) imaging in patients with dental trauma.
6. Describe appropriate treatment strategies (immediate and long-term) for various types of traumatic injuries.
7. Recognize outcomes of traumatic dental injuries.
8. Recognize pulp space obliteration and describe management considerations.
9. Recognize surface resorption, inflammatory (infection-related) resorption, replacement (ankylosis-related) resorption, and cervical resorption and describe their respective prevention/treatment strategies.
10. Describe the preventive measures and treatment strategies for traumatic dental injuries in primary and permanent dentition.

## Examination and Diagnosis

Patients who have suffered impact trauma to the head often present with dental injuries that may be their chief concern. These types of incidents often result in injuries to other tissues ranging from soft tissue lacerations to bone fractures and even brain injury. For this reason, a complete history and examination are always indicated, even though the dentist may not be the first provider encounter for the patient. The urgency often associated with an accident or injury can easily result in important signs or symptoms being overlooked, so repetitive examinations can help ensure that all injuries are identified and addressed. For dentists, it is easy to focus solely on injuries to the teeth and the oral cavity, but a basic knowledge of extraoral examination procedures in these scenarios is critical to the overall care of the patient.[1]

### Mental Status

The first step in examining a patient who has suffered a head injury is to assess his or her mental status. A reliable and true history can only come from someone whose mental status is unimpaired. This step can be accomplished with just a few basic questions about the patient's name, age, the current date, and

current general location.[2] If the patient can answer these questions without hesitation or confusion, the assumption that his or her mental state is unaffected can be made, and the practitioner can proceed with taking a history and performing the necessary examinations.

## History

The patient history typically starts with the chief complaint, which normally involves a statement in the patient's own words regarding the current problem that has caused him or her to seek care. In the case of trauma, for example, that might be: "I fell and broke my tooth," or "I got an elbow to the mouth playing basketball, and now my teeth feel loose."

Next, the history of the present illness should be explored. The details regarding how the injury occurred can help direct the subsequent physical examination. Important questions to ask include:

*When and how did the injury occur?* Date and time should be recorded as well as the nature of the injury, such as a fall, a fight, a sports injury, or an auto or bicycle accident. It is also critical to ask the patient if he or she lost consciousness. This information can alert the practitioner to the possibility of a concussion or possible brain injury and might indicate that a neurologist referral is appropriate. Reports of headache, dizziness, and blurred or double vision would also indicate the need for a referral and should be the topic of inquiries as well.

*Have you experienced other injuries to your mouth or teeth in the past?* Repeated injuries, particularly of similar patterns, might indicate physical abuse, particularly in children. They can also result from sports injuries or other high-risk behaviors or occupations.[1] Previous injuries may have resulted in previously undetected crown or root fractures, or even osseous fractures. Repeated injuries in the same anatomic region may affect the healing capacity of the tissues due to scarring and changes in the vascular anatomy.

*What problems are you currently having with your mouth?* Pain, mobility, bleeding, and occlusal interferences are common symptoms. The patient's description of symptoms can aid in diagnosis.

## Medical History

The patient's medical history must also be obtained because there may be significant findings that could affect treatment decisions. Medications taken and medication allergies should be recorded. A review of systems should also be completed to determine whether any systemic conditions are present. The patient's tetanus immunization status should also be determined because a booster might be necessary in the presence of injuries that carry the potential for contamination, such as an avulsion or penetrating lip and soft tissue injuries.[3]

## Clinical Examination

Examination of the patient should begin with extraoral structures to determine the extent of any injuries. A cranial nerve examination is appropriate and should be completed. Sense of smell, visual acuity, and perception of sound are subjective and will depend on patient response, but movement of facial muscles, eyes, tongue, and the ability to "tense" the neck are clinically observable and will provide an objective assessment of cranial nerve function.[2]

**• BOX 11.1 Selected Symptoms of Concussion**

**Affective/Emotional Symptoms**
- Anxiety/nervousness
- Clinginess
- Depression
- Emotional distress
- Irritability*
- Personality changes
- Sadness

**Cognitive Symptoms**
- Amnesia
- Confusion
- Delayed verbal and other responses
- Difficulty concentrating*
- Difficulty remembering*
- Disorientation*
- Feeling "foggy"*
- Feeling "slowed down"*
- Feeling stunned
- Inability to focus
- Loss of consciousness
- Slurred speech
- Vacant stare

**Sleep**
- Decreased sleep
- Difficulty falling asleep
- Drowsiness*
- Increased sleep*

**Somatic/Physical symptoms**
- Blurred vision
- Convulsions
- Dizziness/poor balance
- Fatigue
- Headache
- Lightheadedness
- Light sensitivity
- Nausea
- Noise sensitivity
- Numbness/tingling
- Tinnitus
- Vomiting

*Common in self-report symptoms checklists.
From Scorza, KA, Raleigh, MF, O'Connor, FG. Current concepts in concussion: evaluation and management, *Am Fam Physician*, 85: 123–132, 2012.

Cognitive function is also important. As previously mentioned, loss of consciousness, headache, dizziness, and visual disturbances can indicate a brain injury.[4] Clinically, speech difficulties, inability to focus, or displaying a "vacant stare" may also alert the practitioner to the possibility of a concussion or other brain injury (Box 11.1).

## Soft Tissue Examination

The extraoral soft tissues should be examined to determine the extent of any lacerations or soft tissue injuries. The presence of ecchymosis should also be noted. Postauricular ecchymosis is a cardinal sign of a LeFort III fracture, which is often otherwise asymptomatic. Any foreign bodies or material should also be identified and removed from injured soft tissues. This requirement is particularly true in the instance of crown fractures paired with

• **Fig. 11.1** Laceration of soft tissues requiring sutures.

lip lacerations. Radiographic confirmation as to the presence or absence of tooth fragments in the lip or perioral tissues is important. Severe lacerations could require suturing for adequate healing (Fig. 11.1).

### Facial Skeleton

The facial skeleton should be examined for potential fractures. Extraorally, this is accomplished largely through palpation, but the presence of ecchymosis can provide a clue as to a possible fracture. A "step" in the borders of the orbit, abnormal mobility of the nose, or depression and mobility of the zygomatic arch are all indications of fractures. Intraorally, abnormal mobility of segments of the dentition can indicate a cortical plate fracture or, more extensively, an alveolar fracture. A marked change in alignment or displacement of the teeth as a block may indicate a fracture of the maxilla or mandible. The posttreatment significance of these fractures is that teeth involved in the plane of fracture are at risk of developing pulp necrosis.[5,6]

## Teeth and Supporting Structures

Examination of the teeth and supporting structures will provide the information necessary to assess the extent of damage to the hard tissues, potential pulpal injury, and periodontal damage. A methodical approach to this examination will ensure a thorough evaluation of all injuries.

### Mobility

Teeth should be examined gently for mobility, noting whether adjacent teeth move with the same degree of mobility. In the presence of an alveolar fracture, when one tooth is tested for mobility, the adjacent teeth involved in the fracture will move in unison. The degree of horizontal mobility should be recorded: 0 for physiologic mobility, 1 for slight mobility (up to 1 mm), 2 for significant mobility (1 to 2 mm), and 3 for severe mobility (greater than 2 mm), both horizontally and vertically. If no mobility is detected, the teeth should be percussed to detect any sign of intrusion or ankylosis, which would present as a "metallic" sound relative to other teeth.

### Displacement

Displacement of teeth from their normal position should be noted. This type of injury is referred to as a *luxation* (discussed later in this chapter).

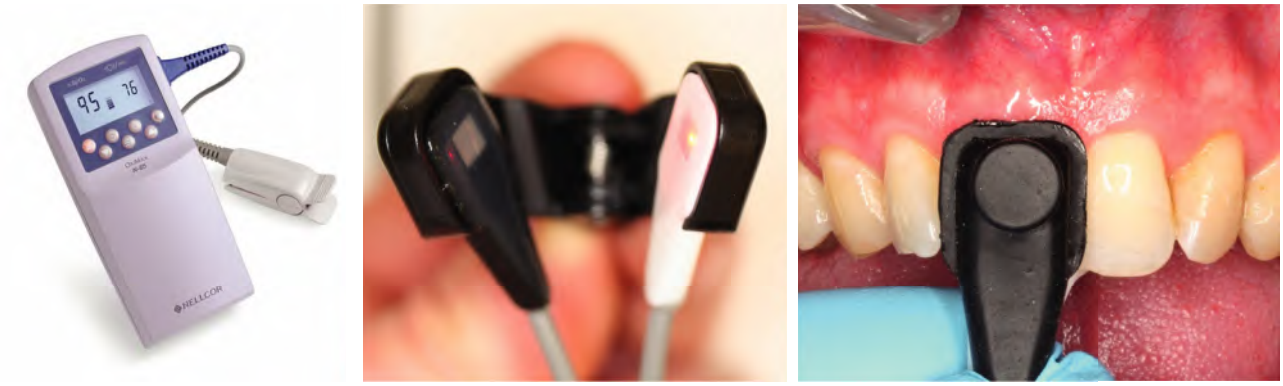
### Periodontal Damage

Injury to the supporting structures of the teeth can result in a spectrum of clinical signs, including swelling, bleeding, ecchymosis, and lacerations. Visual inspection of the soft tissues for signs of injury should be the first step, followed by gentle palpation of the periodontium and alveolar processes. Palpation can reveal signs of cortical plate or alveolar fractures that may not have been noted during mobility testing. Injury to the periodontal ligament (PDL) can often result in edema and bleeding in the ligament, which may not be visible to the clinician. In this instance the teeth will likely be sensitive to percussion, which is a useful test for the identification of periodontal injury. This testing method should be performed as gently as possible, because injured teeth/periodontium are likely to exhibit a much lower threshold for pain. It is preferable to test unaffected teeth first to establish a baseline response and to gain the patient's confidence and understanding of the procedure. It is always important to test several adjacent teeth away from the site of injury, as well as opposing teeth. This additional test permits recognition of other dental injuries of which the patient may not have been aware and which might not have been obvious on visual examination. This test also provides baseline information in the event that future complications arise.

### Pulpal Injury

The ideal pulpal response to an impact injury would be complete recovery after a traumatic incident. Two other potential outcomes may occur, however. One outcome would be calcific metamorphosis in which the pulp is gradually replaced by calcified tissue. This result can be recognized clinically by a yellow discoloration of the crown and radiographically by a narrowing or even disappearance of the pulp space. The other potential outcome is pulp necrosis, which can be caused by apical displacement that disrupts the pulpal blood supply.[7] Pulp necrosis can lead to external inflammatory root resorption if not treated in a timely manner. Typically, resorption occurs without clinical symptoms, so continued follow-up is vitally important in ensuring optimal treatment.

The status of the pulp tissue may be determined by symptoms, history, and clinical testing. The most commonly employed and reliable tests are electrical pulp testing (EPT) and the cold test. These modalities test the neural response of the pulp tissue and depend on the patient's subjective response. Fulling and Andreasen demonstrated that the late differentiation of the Aδ nerve fibers in the dental pulp explain the lack of reliable and predictable responses to pulp testing in erupting, developing teeth.[8] In young patients, cold testing is the most reliable subjective test to assess pulp status. Ideally, an objective assessment of the pulpal blood supply would provide a better diagnostic test in determining pulp vitality. Current evidence demonstrates that pulpal blood circulation can be accurately assessed with laser Doppler flowmetry and with pulse oximetry (Fig. 11.2).[9-15] In a study by Gopikrishna and colleagues, pulse oximetry was shown to provide a more constant indication of pulp vitality compared with EPT or cold testing after an impact injury, although with time, the EPT and cold tests would often return to normal responses.[16] The overriding principle regarding the necessity of endodontic treatment in the case of impact injury is the development of pulp necrosis; accurate assessment of the pulp status is critical, so the ability to detect pulpal blood circulation would represent the definitive test in making this determination.



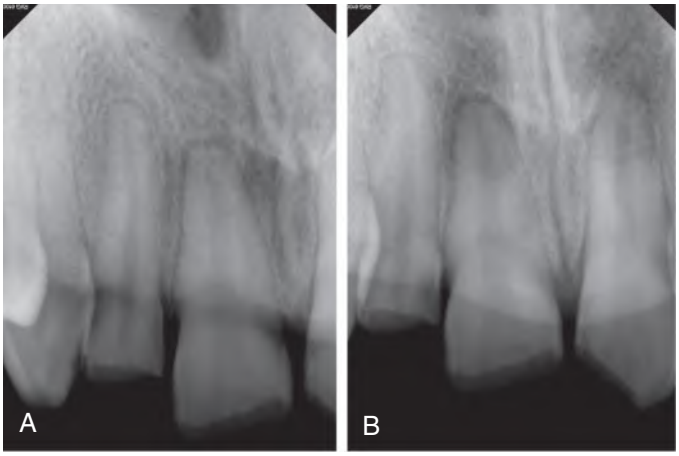
• **Fig. 11.2** Pulse oximetry unit with a commercially available sensor that fits dental tissues. (Courtesy Covidien.)

**TABLE 11.1 Radiographic Classification of Odontogenic Development**

| Classification | Description |
|---|---|
| 0 | No crypt |
| 1 | Presence of a crypt |
| 2 | Initial calcification |
| 3 | One-third crown completed |
| 4 | Two-thirds crown completed |
| 5 | Crown almost completed |
| 6 | Crown completed |
| 7 | One-third root completed |
| 8 | Two-thirds root competed |
| 9 | Root almost open (open apex) |
| 10 | Root apex completed |

## Radiographic Examination

Radiographs can assist in revealing fractures of the bone and teeth as well as the stage of root development in children. Knowledge of the developmental stages of permanent teeth is essential for clinical practice in several dental specialties, because it may influence diagnosis, treatment planning, and outcomes. In 1960 Nolla published a classification system for odontogenic development based on radiographic interpretation (Table 11.1). This system has been widely used,[17] and it is particularly important for appropriate diagnosis and treatment of traumatized teeth. Luxation injuries and horizontal root fractures are often overlooked on routine radiographic examination, so multiple angles of exposure are indicated to increase the predictability of identifying these entities, making assessment and diagnosis as complete as possible (Fig. 11.3).[18,19] Crown fractures are more likely to be detected by conventional radiographs and clinical examination, but root fractures depend on the angulation of two-dimensional (2D) radiographs for detection and diagnosis. Recent advances in three-dimensional (3D) imaging (cone beam computed tomography [CBCT]) allow evaluation in three dimensions to detect fractures of the roots and alveolar bone (Fig. 11.4).[20]



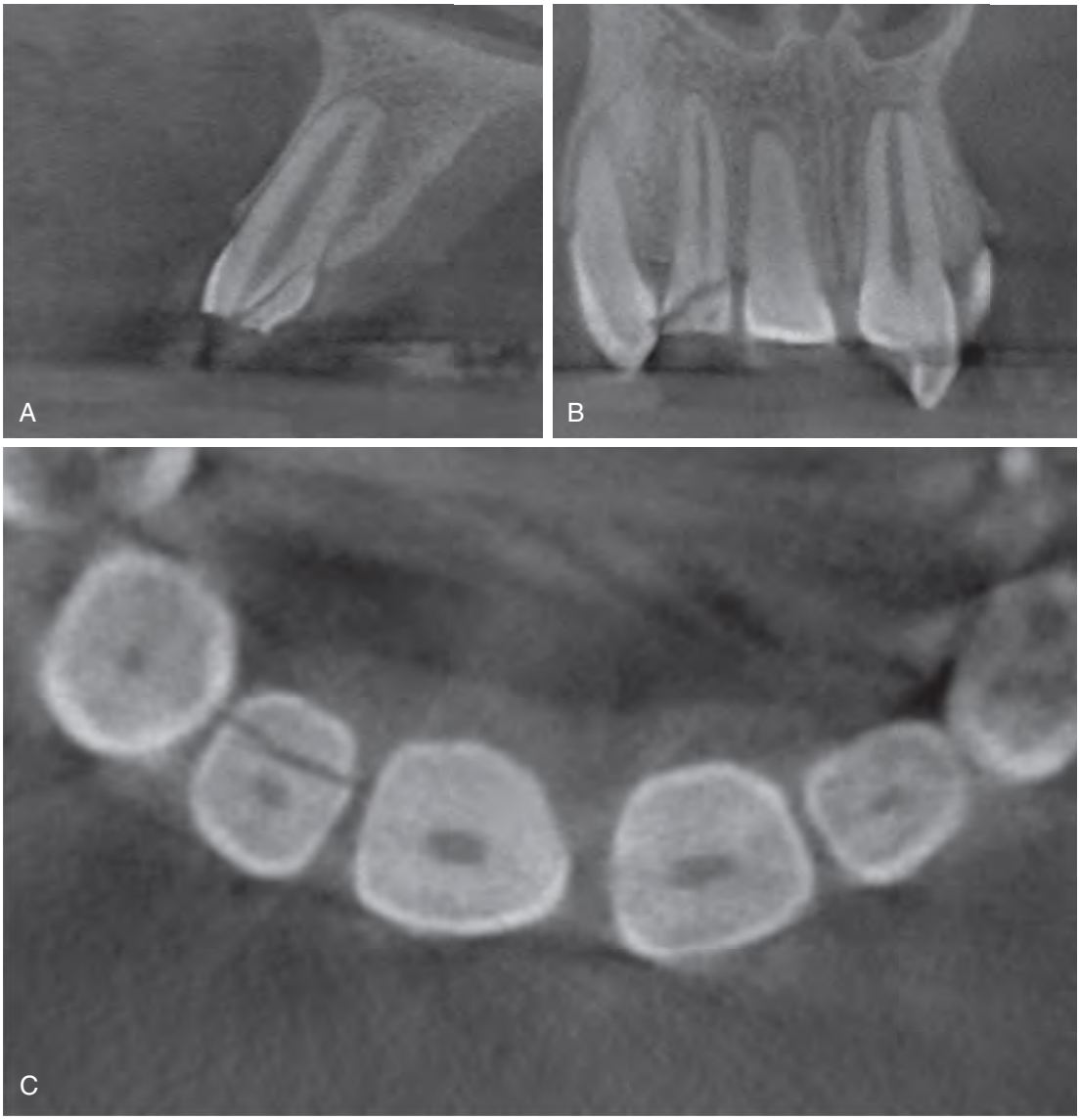

• **Fig. 11.3** Complicated crown fracture of the maxillary right central and lateral incisors and maxillary left central incisor. **A** and **B,** Periapical radiographs at different horizontal angles.

## Importance of Cone Beam Computed Tomographic Analysis in Trauma

Traumatic dental injuries are complex and could involve several tissues. Furthermore, they can be challenging when discussing diagnosis and treatment planning. As stated in the previous section, radiographic examination is important in identifying the type and the extent of traumatic injuries to the dental tissues and the periodontium. The guidelines provided by the International Association of Dental Traumatology (IADT) outline the number and types of 2D radiographs that would be helpful in diagnosis of dental traumatic injuries.[21] However, 2D imaging has its limitations in serving as a diagnostic tool in trauma due to its limitation to two dimensions, superimposition of other structures, projection geometry, and so on.[22] Hence, there may be incidences where some types of trauma may go undiagnosed and therefore untreated.

3D imaging includes various imaging modalities that include computed tomography (CT), magnetic resonance imaging (MRI), and CBCT.[23] CBCT produces images in three dimensions with less radiation exposure than a traditional CT.[24,25] CBCT units can be classified according to the imaged volume or field of view (FOV) as large FOV (6- to 12-inch or 15- to 30.5-cm) or limited FOV systems (1.6- to 3.1-inch or 4- to 8-cm).[26]

The use of CBCT in dental trauma was first described in 2007. Several studies have reported the use of CBCT and digital




• **Fig. 11.4** Complicated crown fracture of the maxillary right central and lateral incisors and maxillary left central incisor – as seen in the saggital **(A),** coronal **(B)** and axial **(C)** sections of this CBCT image. (same case as in Fig. 11.7).

radiography for differential diagnosis,[27-29] assessment of treatment outcomes[30,31] endodontics,[32] oral and maxillofacial surgery,[26] implantology,[33] and orthodontics, with reliable measurements for reconstruction and imaging of dental and maxillofacial structures.[34,35] CBCTs provide a 3D image of a 3D structure in three orthogonal planes (axial, sagittal, and coronal).[36,37]

In 2016 the American Academy of Oral and Maxillofacial Radiology/American Association of Endodontists (AAOMR/AAE) joint position statement gave multiple recommendations for the use of limited FOV CBCT. Recommendation #11 states, "Limited FOV CBCT should be considered the imaging modality of choice for diagnosis and management of limited dento-alveolar trauma, root fractures, luxation, and/or displacement of teeth and localized alveolar fractures, in the absence of other maxillofacial or soft tissue injury that may require other advanced imaging modalities."

CBCT overcomes several limitations of 2D radiographs. CBCT provides a considerable amount of information and can differentiate between many types of airspaces and structures such as bones, airways, sinuses, and so on.[22] CBCT imaging also enables the clinician to view teeth in three dimensions, and often cases that appear to be straightforward on a periapical radiograph may have a completely different presentation when viewed in three dimensions (Figs. 11.5 and 11.6).

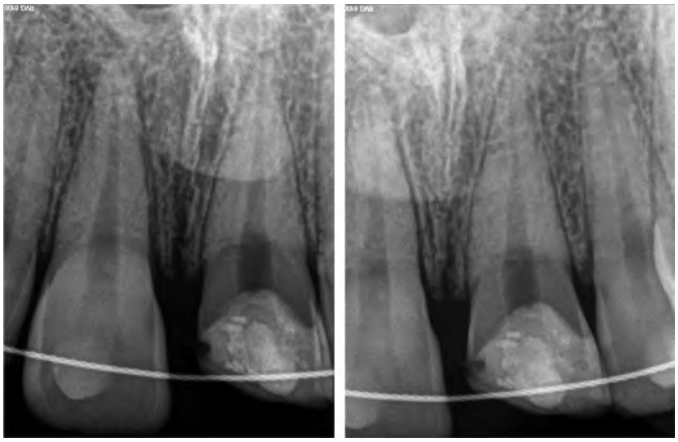
## Injuries to the Hard Dental Tissues and the Pulp

### Enamel Fractures

Chips or cracks that are confined to the enamel do not directly constitute a threat to the pulp tissue. However, when those cracks or chips are the result of an impact injury, they may also cause a slight luxation injury that can damage blood vessels that supply the pulp. A clinical sign that this injury may have occurred is tenderness to percussion of the affected tooth. If this injury is indeed a finding on examination, the practitioner should follow the recommended guidelines according to the type of trauma (discussed later in the chapter). Simply smoothing any rough edges or restoring missing structure may be all that is necessary to address the chips or cracks noted.

## Uncomplicated Crown Fractures

Uncomplicated crown fractures involve the dentin as well as the enamel but do not result in a pulp exposure. This type of injury is not often severely painful but may present more of a cosmetic concern to the patient. This situation does not require urgent care in most instances, and generally prognosis for pulp survival is favorable unless there is a concurrent luxation injury.[18] If there is no observable displacement, a luxation injury might be suspected in cases where tenderness to percussion or bleeding from the sulcus is present.



• **Fig. 11.5** Preoperative radiograph of the maxillary left central incisor that was diagnosed with a complicated crown fracture. The fractured segment was removed, a partial pulpotomy was completed and the tooth was restored with a composite restoration.

Treatment of uncomplicated crown fractures normally involves the restoration of the missing tooth structure, typically by employing an acid etch composite resin technique (Fig. 11.7). This conservative approach generally will not present a significant risk of pulp pathosis. An even more conservative approach would be to bond the tooth fragment back into place if it was salvaged. Both clinical studies and in vitro bonding experiments have demonstrated that reattachment of dentin-enamel crown fragments is an acceptable restorative procedure.[38] Employing this technique restores the dental anatomy with normal tooth structure, so esthetics and wear will match the adjacent teeth, and the status of the pulp can be reliably monitored.

## Complicated Crown Fractures

Complicated crown fractures involve the enamel and dentin in a location that results in an exposure of the pulp tissue. The extent of the fracture, stage of root development, and time since the injury occurred should be recorded because these parameters will influence treatment decisions.

Considering the extent of the fracture will help determine the treatment of the pulp and what restorative needs exist. A smaller fracture that appears amenable to an acid-etch restoration may be a good candidate for vital pulp therapy, whereas an extensive fracture that will require a foundation and crown to restore would be a candidate for conventional endodontic treatment (Fig. 11.8). The final treatment plan will of course depend on the age of the patient.

The stage of root development is an important factor to consider when choosing between vital pulp therapy and conventional endodontic treatment. Teeth with incomplete root formation often have thin dentin walls, so every effort should be made to preserve the pulp so that continued dentin deposition can proceed, and root


• **Fig. 11.6** Cone beam computed tomography (CBCT) (same case as Fig. 11.5). Sagittal section demonstrates the palatal aspect of the maxillary left central incisor, which was not restored adequately. This problem could not be visualized clinically or with the PA radiograph (Fig. 11.5) taken before the CBCT. The PA (Fig. 11.5) showed an intact restoration on tooth #9 and the palatal aspect could not be visualized on the PA.

development can continue to completion. The most accepted technique to accomplish this goal is a shallow pulpotomy followed by an acid-etch composite restoration or reattachment of the enamel-dentin fragment. Depending on the amount of tooth loss and restorative needs, this treatment plan can also be appropriate for fully formed teeth in adults. However, if there is structure loss that requires a crown to restore the tooth, endodontic treatment is recommended.[39]

## Treatment of Crown Fractures

Teeth with crown fractures that expose the pulp tissue can be treated by pulp capping or a shallow pulpotomy, both of which constitute vital pulp therapy, or by conventional endodontic treatment. If vital pulp therapy is planned, the prognosis will be maximized if the time between the injury and treatment is minimal, although successful pulpotomy procedures after several weeks of exposure have been reported.[40-42]


• **Fig. 11.7** Uncomplicated crown fracture of the maxillary right central incisor. Preoperative **(A)** and postoperative **(B)** views of restoration with composite resins. (Courtesy Dr. Gabriela Ibarra.)

## Vital Pulp Therapy

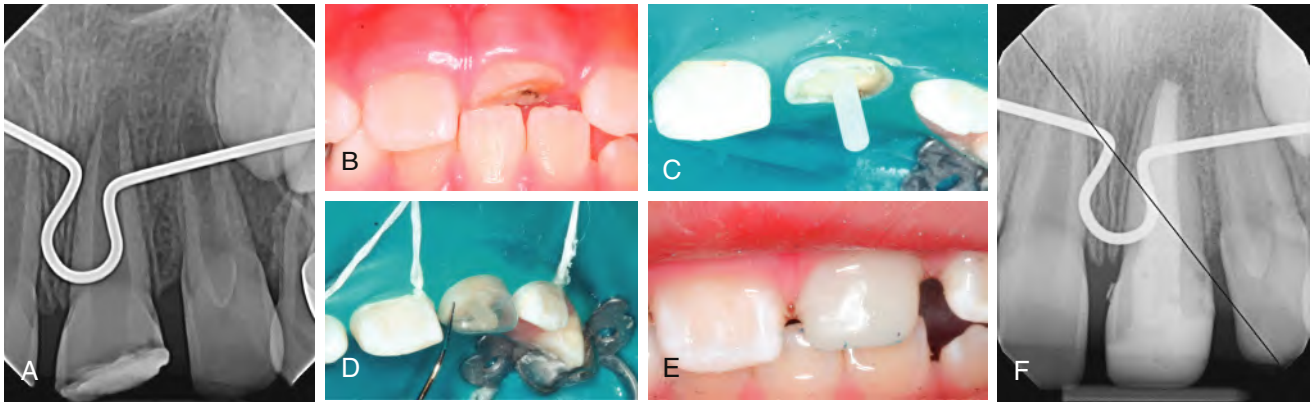
The primary reason for considering vital pulp therapy is to preserve the pulp tissue. As previously mentioned, this therapy is of paramount importance in teeth with incomplete root formation. Continued root development will result in increased dentin thickness, which will translate to increased strength and fracture resistance. In the classic literature, pulpotomy is described as removal of the pulp tissue to a point just apical to the cementoenamel junction (CEJ). If the cervical dentin has not reached optimum thickness, performing a pulpotomy in this fashion will prevent any further dentin formation in this critical area of the tooth. Subsequently, a more conservative approach to pulp removal has been popularized by Cvek, which involves removing a minimal amount of tissue to a point where hemostasis can be obtained.[40] This technique will not only preserve the radicular pulp but will also likely preserve the majority of the coronal pulp, allowing the opportunity for greater hard tissue formation.

## Case Selection for Vital Pulp Therapy

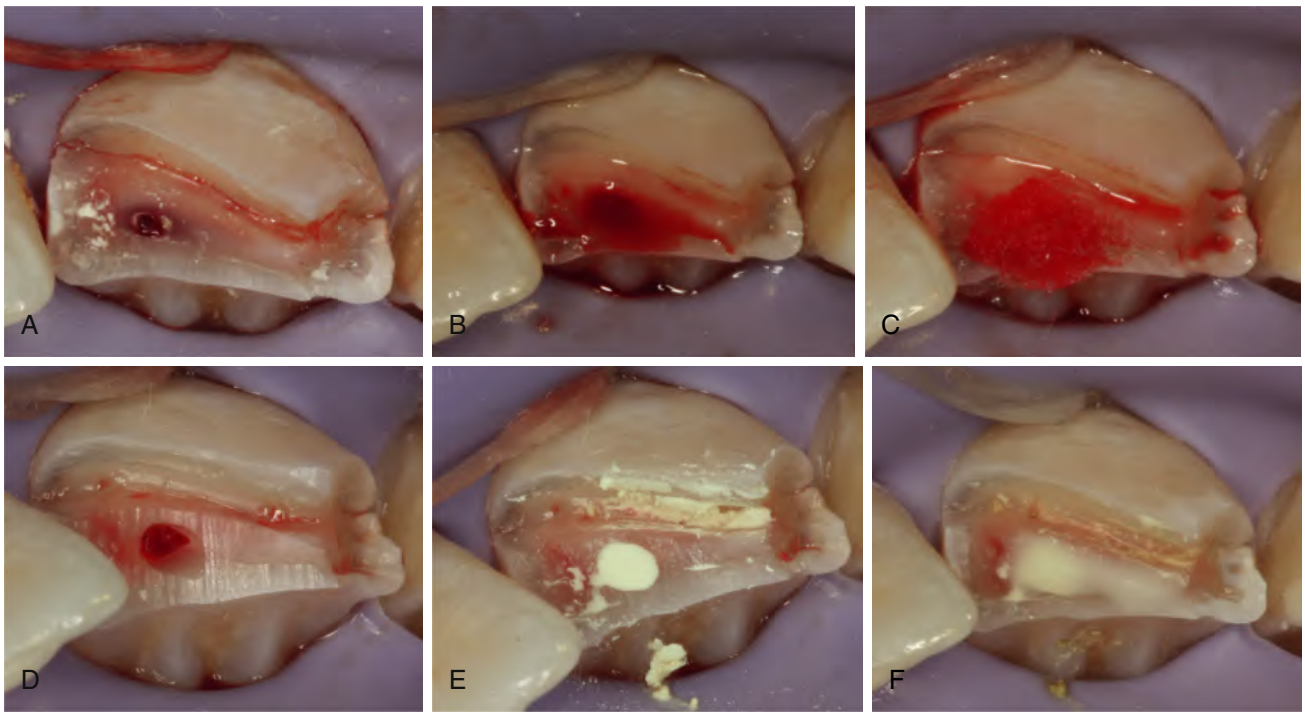
Both immature and mature teeth that can subsequently be restored with an acid-etch composite are candidates for the shallow pulpotomy technique. In general, this procedure is more important in those immature teeth in which root formation is not yet completed.

## Technique

The shallow pulpotomy procedure (Fig. 11.9) requires anesthesia and rubber dam isolation. Once isolated, the dentin surface should be cleaned to remove any foreign matter and any loose fragments that might remain. Extruding granulation tissue at the pulp exposure site can be removed by a spoon excavator so that the actual size of the exposure can be observed. Next, the pulp tissue is removed to a depth of approximately 2 mm below the exposure. This is a relatively small volume of tissue but helps ensure removal of contaminated pulp. This stage of pulp removal is accomplished using a water-cooled, round diamond bur in a high-speed handpiece. After removing the pulp




• **Fig. 11.8** Preoperative periapical radiograph **(A)** and clinical photograph **(B)** of a complicated crown fracture of the maxillary left central incisor. **C** and **D,** Upon completion of the endodontic therapy, a fiber post was placed, followed by the coronal restoration. The results are shown in a postoperative clinical photograph **(E)** and a final periapical radiograph **(F)**.




• **Fig. 11.9** Complicated crown fracture of the maxillary right central incisor. The partial pulpotomy procedure is clinically illustrated in the following steps: **A,** Pulp is exposed; **B,** pulpal tissue is excised 2 mm below the exposure; **C,** bleeding is controlled by pressure only (cotton pellet moistened with saline); **D,** hemostasis is obtained; **E,** white mineral trioxide aggregate (MTA) seal is applied; **F,** protection of the MTA is achieved using a layer of glass ionomer lining.

to the desired depth, the area can be irrigated with saline and hemostasis obtained, which may occasionally require some gentle compression. Typically, hemostasis will be obtained within 5 minutes, at which time the exposure site should be sealed with either a bioceramic putty or mineral trioxide aggregate (MTA). Care should be taken to avoid forcing the material into the pulp space. If MTA is used, it is preferable to confirm that it has set completely, which would necessitate that the patient return the next day. With a high viscosity bioceramic putty, the tooth can be restored immediately. Once the exposure site is sealed, the tooth is then restored with an acid-etch composite to replicate the contour, or the enamel-dentin fragment is bonded back into place.[43] This step completes the treatment, but follow-up to monitor pulp status is indicated.

## Treatment Evaluation

Treatment outcome should be assessed after 6 months and then annually. This examination should include evaluation of pulp responsiveness to either cold or EPT, or both. Radiographic evidence of continued root formation is a strong indication of treatment success. If the pulp remains responsive and if continued root formation is observed, the vital pulp therapy procedure would be considered definitive treatment, which should have a favorable long-term prognosis (Fig. 11.10).[42,44]

## Endodontic Treatment

Teeth with complete root formation can be treated either by vital pulp therapy or by conventional endodontic treatment. In cases where restorative needs dictate that a crown, or particularly a post and crown, are necessary, conventional root canal treatment is necessary.

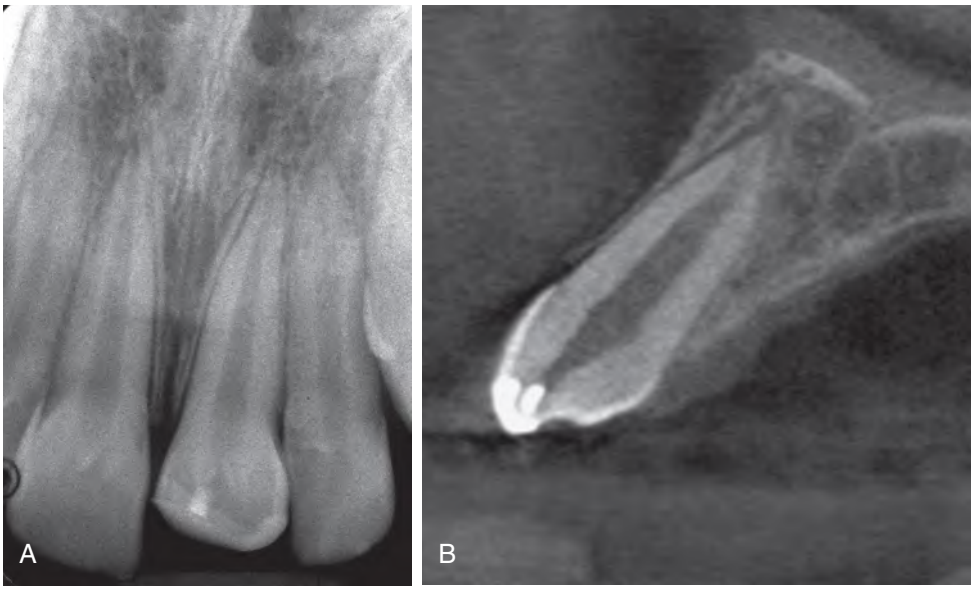
## Crown-Root Fractures

These fractures typically present in an oblique orientation, often splitting the crown in a diagonal direction and extending onto the root surface, which makes it a more serious injury. A less common variation of this type of fracture is one in which the crown appears to have shattered (Fig. 11.11). The pieces are held in place only by the part of a fractured segment that remains attached to the PDL. In these fractures, the pulp is usually exposed.

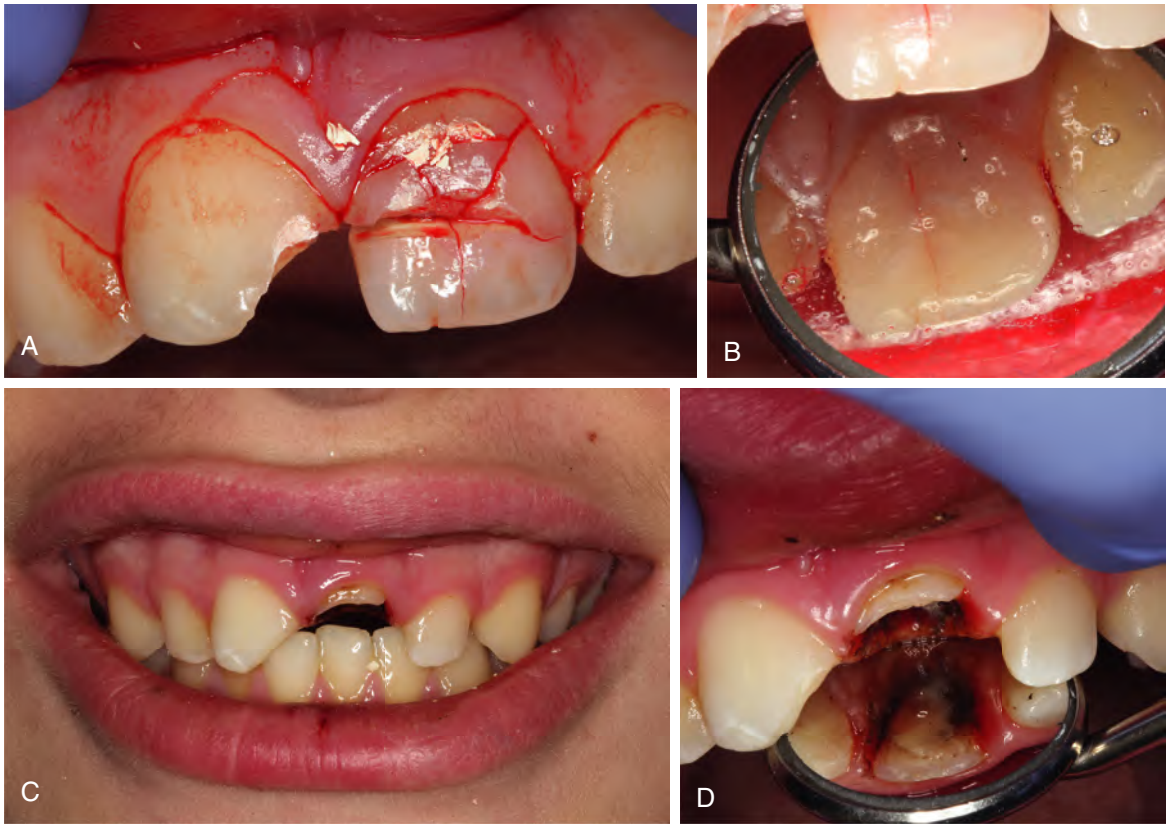
In contrast to the previously described impact injuries in which posterior teeth are rarely involved, crown-root fractures are often seen in premolars and molars as well. Cusp fractures that extend subgingivally are common. Diagnostically, however, they may be difficult to identify in the earlier stages of development and might require transillumination or a dye technique to detect at this point. Similar difficulties are encountered in detecting vertical fractures along the long axis of the root.

Crown-root fractures of the posterior teeth are not always associated with a single impact of a traumatic event. If that is the case, however, bicycle or motor vehicle accidents are often the culprits. The risk of this type of fracture is also increased with a sharp blow to the chin, which can cause the teeth to slam together. Skin abrasions under the chin may be an extraoral sign of such an injury.

Until recently, removal of all loose fragments was recommended as part of the examination to determine the extent of the injury and determine restorability of the tooth or teeth. This practice may still be necessary in some instances, but with the current




• **Fig. 11.10** Six-month follow-up after partial pulpotomy. Periapical radiograph **(A)** and sagittal view **(B)** obtained with cone beam computed tomography (CBCT).



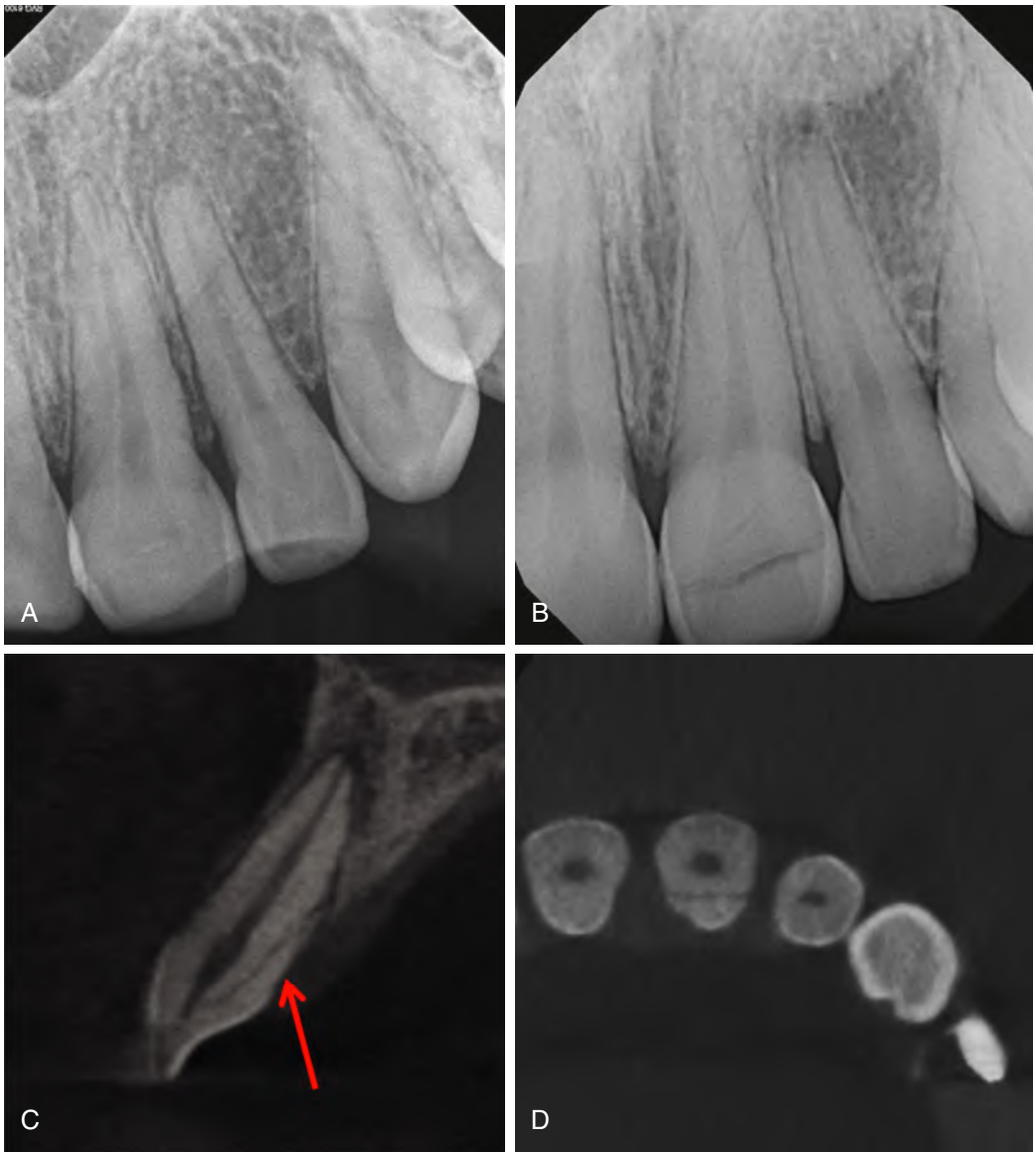

• **Fig. 11.11** **A** and **B,** Buccal and lingual photographs of a crown and root fracture immediately upon presentation. **C** and **D,** Images after removal of the fractured segments.

restorative options in adhesive dentistry, repair of these injuries can be more predictable than in the past. Current recommendations are to attempt bonding loose fragments together, particularly if root development is not yet complete.[39]

Teeth that present with a "shattered" appearance often have extension of the cracks onto the root surface. Additional imaging studies such as angled radiographs and CBCT may assist in identifying radicular as well as osseous fracture lines (Fig. 11.12).[19,45]

## Emergency Care and Treatment Planning

Teeth exhibiting crown-root fractures often present with significant symptoms of pain and discomfort, particularly if there is a




• **Fig. 11.12** **A** and **B,** Periapical radiographs demonstrating a crown fracture line. **C** and **D,** Sagittal and axial slides confirming the presence and extension of the fractures lines *(arrow).*

mobile fragment that moves easily with speaking or other functional movements. Injuries such as these require urgent care to alleviate the patient's symptoms and stabilize the teeth. This care may consist of simply bonding loose tooth fragments but often includes the initiation of pulpal treatment as well (Fig. 11.13). In teeth with incomplete root formation, a shallow pulpotomy would be preferable to a pulpectomy so that root formation might continue. Pulpectomy is the treatment of choice if the root formation is complete and fully developed (Fig. 11.14). Definitive treatment is best postponed until the overall endodontic/restorative treatment plan has been finalized.[39]

Crown-root fractures are often complicated by pulp exposures and extensive loss of tooth structure. In developing a definitive treatment plan, several aspects must be considered:

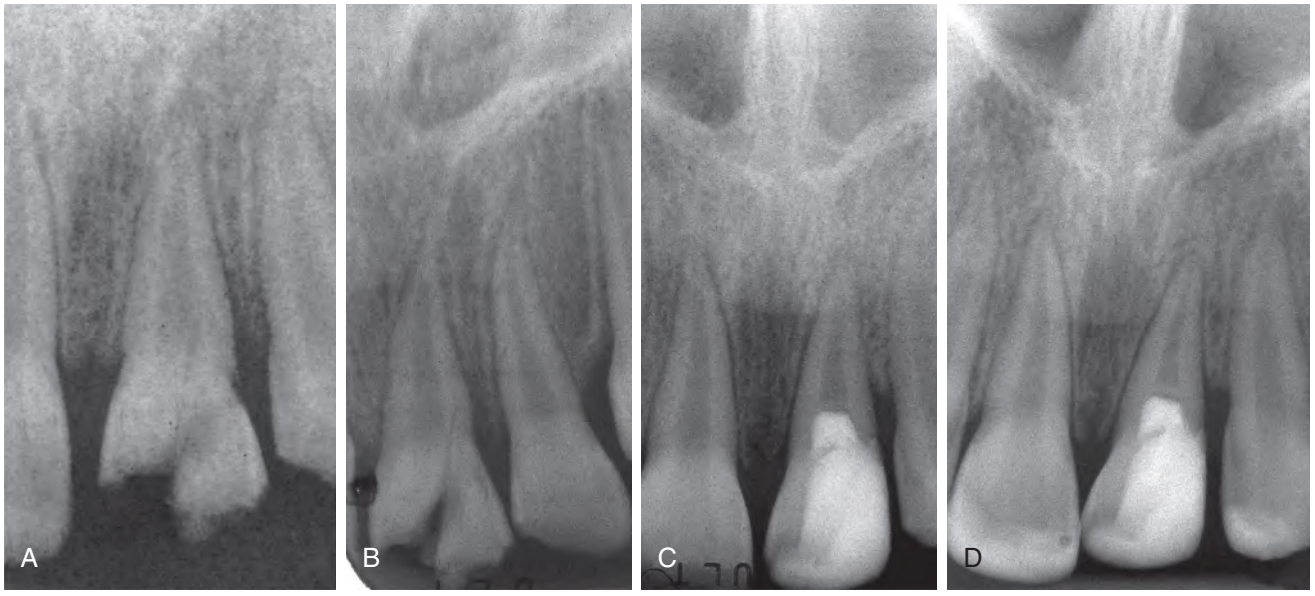
- Will pulpotomy or pulpectomy be the better choice for treating a particular tooth?
- After removal of all loose fragments, will the tooth still be restorable? In the event that fragments are bonded together to allow root formation to continue, will this last long enough for root formation to be complete or to allow the alveolus to develop adequately for the placement of an implant?
- Is the subgingival fracture margin at a level that would allow placement of a restoration margin, or will extrusion or periodontal surgery be necessary?
- Should the tooth be extracted and replaced with a bridge or implant? Alternately, if the tooth is extracted, could the space be closed with orthodontic treatment?

These are a few critical considerations that must be included in making treatment decisions. Because of the complexity involved in these cases, a team approach involving specialists in pediatric dentistry, endodontics, periodontics, orthodontics, oral and maxillofacial surgery, and prosthodontics is beneficial in developing a treatment plan to optimize the outcome for the patient.

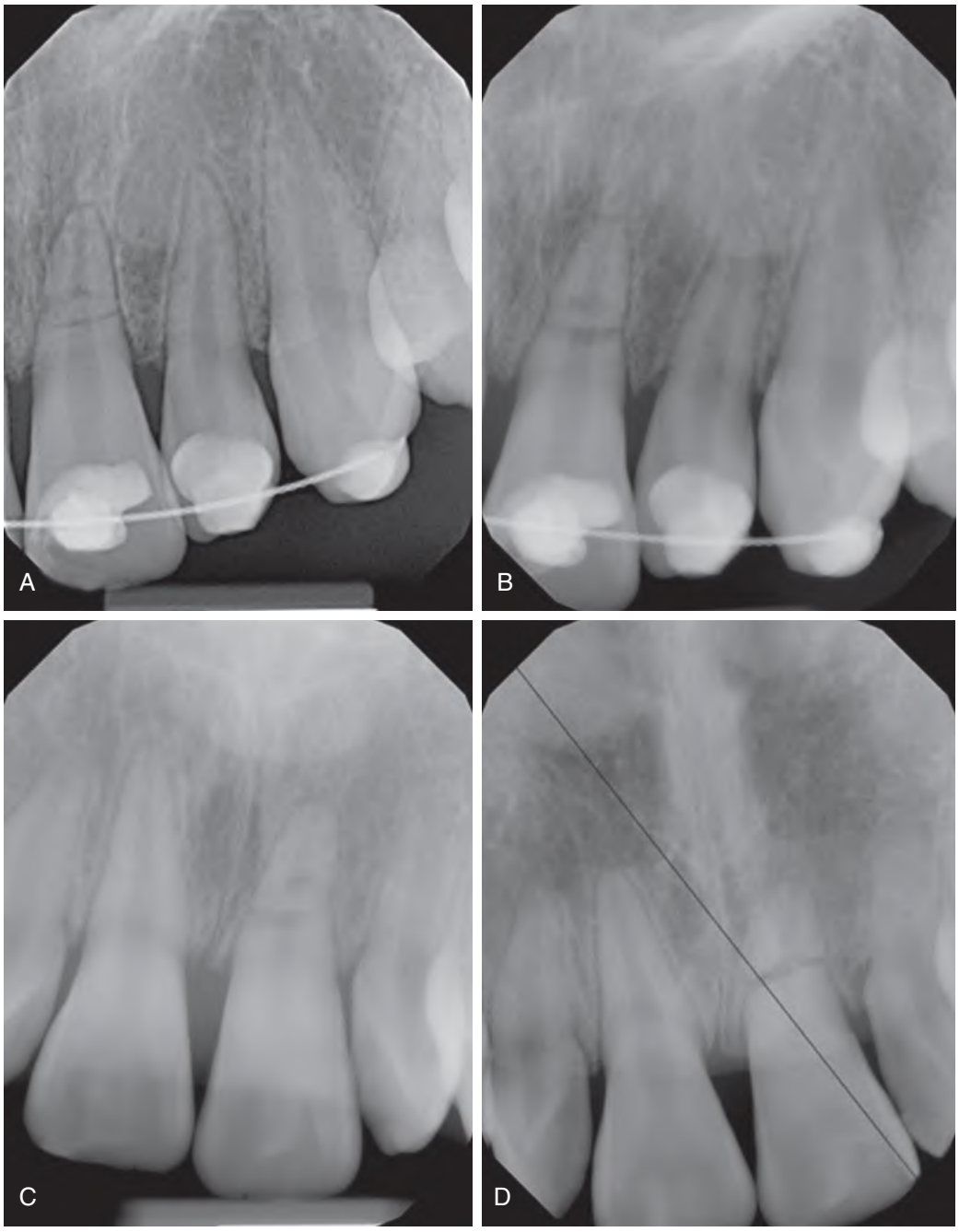
## Root Fractures

Root fractures that do not involve the crown of the tooth have also been termed *intra-alvelor root fractures*, *horizontal root fractures*,


• **Fig. 11.13** **A–D,** Crown-root fracture of the maxillary left central incisor. Emergency procedure for stabilization of the coronal fragment using acid etch/resin applied to the remaining tooth structure.




• **Fig. 11.14** Crown-root fracture of the maxillary left central incisor treated with cervical pulpotomy. **A** and **B,** Periapical radiographs at different horizontal angles. **C,** Two-month follow-up. **D,** Six-month follow-up.

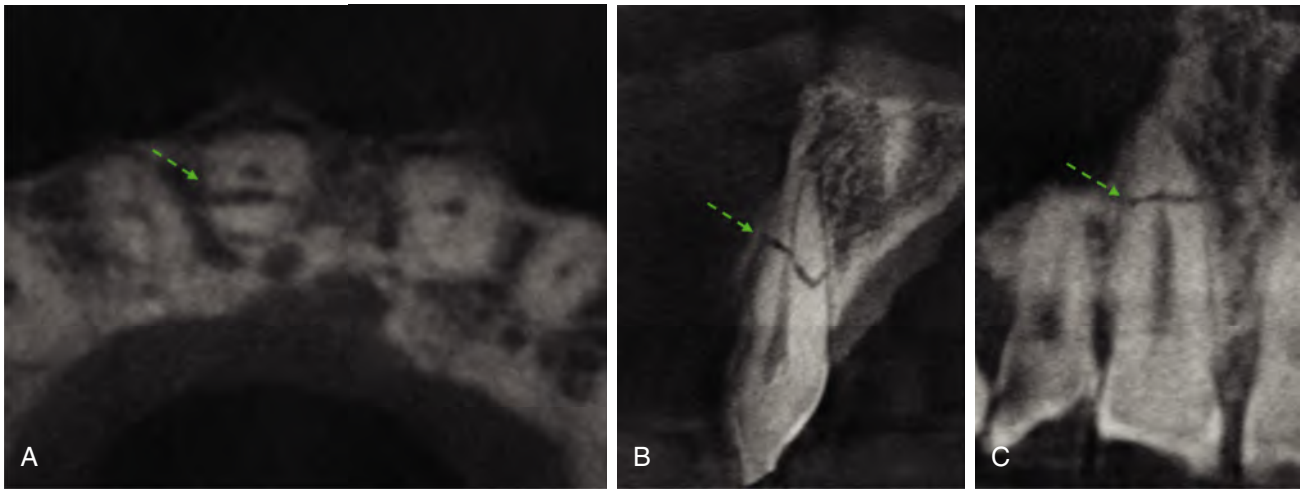



• **Fig. 11.15** Root fracture of the maxillary left central incisor. **A** and **B,** Immediate postoperative radiographs after reduction and splinting. **C,** Six-month follow-up. **D,** Follow-up at 18 months.

and *transverse root fractures*, depending on location and orientation relative to the long axis of the tooth. These types of fractures do not occur often and may be difficult to detect and diagnose.[1,19,46,47]

Radiographically, a root fracture is visualized only if the beam passes through the fracture line. Because these fractures are often oblique in orientation, they may be missed by a radiograph exposed by conventional paralleling technique. For this reason, it is recommended to obtain an additional exposure at a steep vertical angle whenever a root fracture is suspected. This additional angle (approximately 45 degrees) allows detection of many fractures, particularly in the apical area (Fig. 11.15).[46,48] Recently May and colleagues demonstrated that CBCT is most useful in cases in which conventional radiography yields inconclusive results or shows a fracture in the middle third of the root.[49] In such cases, CBCT may rule out or confirm the presence and allow evaluation of the course of the fracture through the root structure in a labiolingual direction (Fig. 11.16).

Clinically, root fractures may present as mobile or displaced teeth with pain upon biting and possible occlusal interference. Symptoms are typically mild, and if there is no mobility or displacement of the coronal segment, the patient may not be aware of any problem and may not seek treatment.[50] In general terms, the more cervical (or coronal) the location of the fracture, the greater the chance and degree of mobility and displacement of the coronal segment and the greater the likelihood of pulp necrosis of this segment if it is not promptly repositioned. Splinting is indicated for fractures occurring in the cervical or middle thirds of the root.[39,51,52] Root fractures

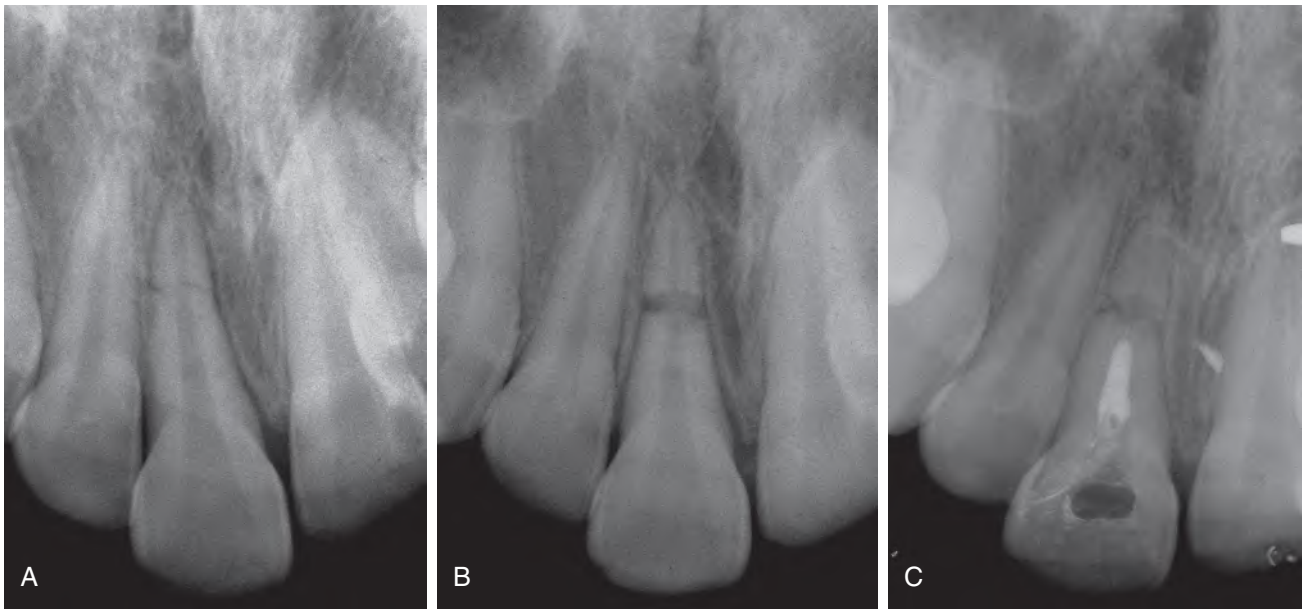



• **Fig. 11.16** Root fracture of the maxillary left central incisor. Cone beam computed tomography demonstrates the fracture in all three planes: axial **(A)**, sagittal **(B)**, and coronal **(C)**.


• **Fig. 11.17** Root fracture of the maxillary right central incisor. **A** and **B,** Periapical radiograph and clinical photograph of the tooth when the patient arrived at the emergency department. **C** and **D,** Reduction, repositioning, and splinting.

that occur in the apical third typically do not require any immediate treatment, but long-term observation is indicated (Video 11.1).[51]

Emergency care for root fractures: specifically repositioning and stabilization should be completed without delay for the most favorable outcome (Fig. 11.17). Repositioning of the displaced coronal tooth segments is easier if completed soon after the injury because healing will not have started. Delayed repositioning may require orthodontic intervention to allow movement of the coronal segment into optimal position. After the repositioning, the coronal segment must be splinted to stabilize its position and




• **Fig. 11.18** Root fracture of the maxillary right central incisor. **A,** Preoperative periapical radiograph. **B,** One month later after removal of the splint. Note the separation of the coronal and apical fragments. Endodontic therapy of the coronal fragment was initiated. **C,** Two-year follow-up.

allow repair of the periodontal tissues and alveolar bone (see Fig. 11.17). Four to 6 weeks of stabilization is normally sufficient, although fractures located close to the crest of the alveolar bone may require longer periods of stabilization.[51] The outcome of this treatment should be evaluated periodically.

## Sequelae of Root Fractures

Calcific metamorphosis is a common occurrence after a root fracture, usually in the coronal segment, but occasionally both coronal and apical segments can be affected. In this event, EPT may be of limited value in evaluating pulp status. In the absence of other signs of pulp necrosis, such as a radiolucency, either apical or adjacent to the fracture, lack of response to EPT alone does not necessarily indicate the necessity for root canal treatment. Frequently, the apical pulp will remain vital, even if pulp necrosis develops in the coronal segment (see Fig. 11.15).[53-56]

The healing of root fractures will occur either through hard tissue healing or connective tissue healing, or there can be a lack of healing. Hard tissue healing occurs with the deposition of calcified tissue originating from the apical pulp and PDL and is most likely to occur when little or no displacement of the coronal segment occurred during the injury. Connective tissue healing is more likely to occur with a greater degree of displacement and would be characterized by a fracture line that remains visible radiographically, but the lamina dura of the socket wall appears to be intact. Lack of healing after a root fracture typically occurs in the presence of bacterial contamination and pulp necrosis. This circumstance may present with apical symptoms such as tenderness to percussion, and the lamina dura of the socket may be disrupted on radiographic examination[46,54,57,58]

## Root Canal Treatment

Root canal treatment is indicated when pulp pathosis develops subsequent to a root fracture. Normally this pathosis will be due to pulp necrosis in the coronal segment that will subsequently lead to inflammatory changes in the adjacent supporting tissues, resulting in radiolucencies adjacent to the fracture (Fig. 11.18).[54] When necessary, endodontic treatment in these cases can be complex, and referral to a specialist should be strongly considered. When treatment is indicated for teeth with horizontal root fractures, it is normally limited to the coronal segment as the pulp in the apical segment usually remains vital.[53-56]

## Study Questions

1. Which of the following is a pulpal response after a traumatic incident?
   A. Calcific metamorphosis
   B. Discoloration of the crown
   C. Pulpal necrosis
   D. All of the above.
2. The unreliable responses to pulp testing in erupting, developing teeth has been attributed to the
   A. Lack of nerve fibers.
   B. Late differentiation of the Ad fibers.
   C. Late differentiation of the C fibers.
   D. Late differentiation of the Ab fibers.
3. Treatment of uncomplicated crown fractures involves
   A. Restoration of the missing tooth Structure.
   B. Pulpotomy.
   C. Root canal therapy.
   D. Extraction of the tooth.
4. Which of the following statements best describes a Cvek pulpotomy?
   A. Removal of minimal amount of the coronal pulp.
   B. Removal of the entire coronal pulp.
   C. Removal of the entire coronal pulp and part of the radicular pulp.
   D. No removal of any pulp tissue.
5. Which of the following is a sequelae of root fractures?
   A. Calcific metamorphosis.
   B. Healing of the root fracture with hard tissue.
   C. Healing of the root fracture with connective tissue.
   D. All of the above.

## Injuries to the Periodontium

Injuries to the periodontium involve trauma to the supporting structures of teeth and often affect the neurovascular supply to the pulp. These injuries include:

- Concussion
- Subluxations
- Luxations (extrusive, lateral, intrusive)
- Avulsions

In general, the more severe the degree of displacement of the tooth from the socket, the greater the damage to the periodontium and to the dental pulp. Injuries to the periodontium could range from mild to severe and treatments for each of them may differ, depending on the type of injury.

The clinical descriptions of these injuries should be sufficient to make the initial diagnosis However, the pulpal status must be continually monitored until a definitive diagnosis can be made, which in some cases may require several months or years. Dichlorodifluoromethane (DDM) and EPT are used in monitoring pulpal status.[59] Table 11.2 provides a summary of the typical clinical findings associated with different types of injuries to the periodontium.

### Examination, Diagnosis, and Pulp Testing

A good clinical examination followed by sensitivity tests, which include cold (DDM) and EPT, should be used to evaluate the sensory response of teeth that have been injured. Several adjacent and opposing teeth should be included in the test. An initial lack of response is not unusual, nor is a high reading on the pulp tester.[60] In these cases, the sensibility tests are repeated in 4 to 6 weeks, and the results are recorded and compared with the initial responses. If the pulp responds in both instances, the prognosis for pulp survival is good. A pulp response that is absent initially and present at the second visit indicates a probable recovery of vitality, although cases of subsequent reversals have been noted.[61] If the pulp fails to respond both times, the prognosis is questionable, and the pulp status uncertain. In the absence of other findings indicating pulp necrosis, the tooth is retested in 3 to 4 months. Continued lack of response may indicate pulp necrosis, but lack of response may not be enough evidence to make a diagnosis of pulp necrosis; that is, the pulp may permanently lose sensory nerve supply but retain its blood supply. After some time, the pulp often responds to testing if it recovers.[62]

*Concussion* injuries generally respond to pulp testing. Because the injury is less severe, the pulpal blood supply is more likely to return to normal.

Teeth in the *subluxation* injury group also tend to retain or recover pulpal responsiveness but less predictably than teeth with concussion injuries.

*Extrusive*, *lateral*, and *intrusive luxation* injuries involve displacement of the teeth and therefore more damage to apical vessels and nerves. Pulp responses in teeth with extrusive, lateral, or intrusive luxations are often absent. These pulps often do not recover even if the pulp is vital (has blood supply) because sensory nerves may be permanently damaged. Exceptions are immature teeth with wide-open apices; these teeth often regain or retain pulp vitality (responsiveness to sensitivity tests) even after severe injuries.[62]

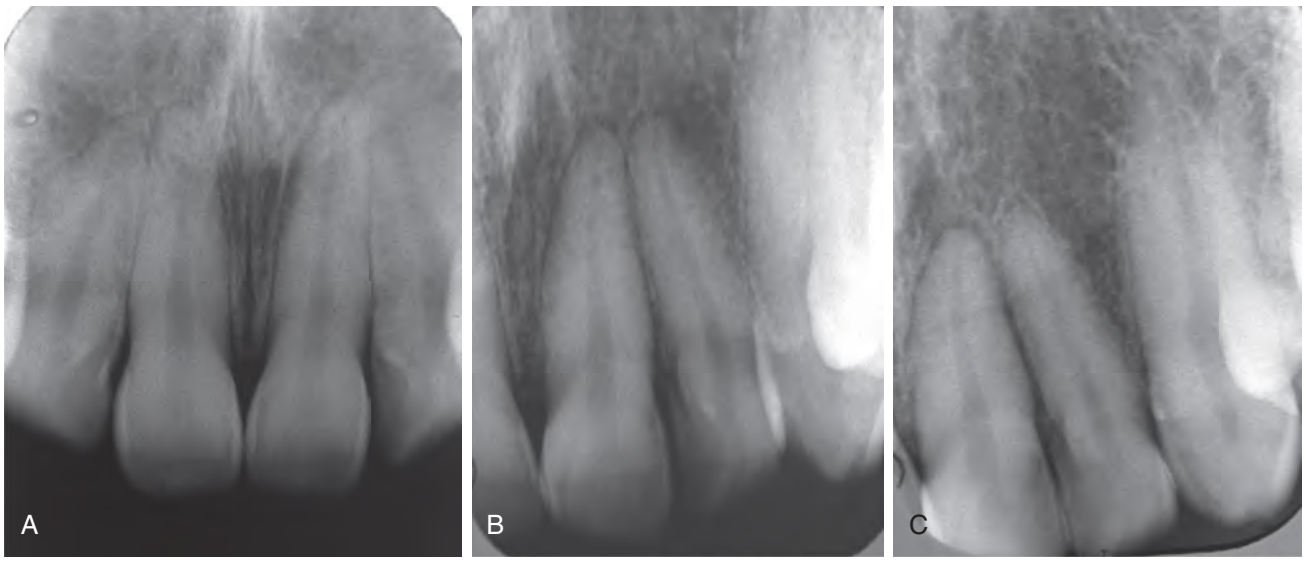
Monitoring of pulpal status with pulp testing and radiographic evaluations is essential for a long enough period to permit determination of the outcome with a degree of certainty (this process may take 2 years or longer). Pulpal status is best monitored with pulp testing, radiographic findings, and observation for developing symptoms and for crown color changes.[62,63]

**TABLE 11.2 Differential Diagnosis for the Most Common Injuries to the Periodontium**

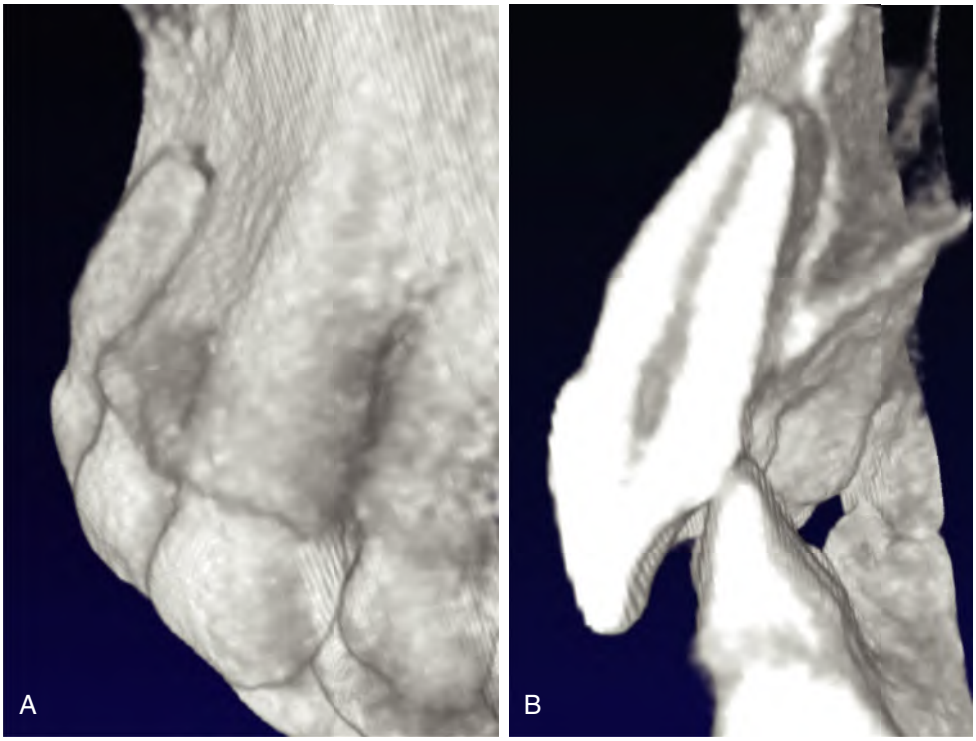
| | Sensitivity Percussion | Mobility | Displacement |
|---|---|---|---|
| Concussion | Yes | No | No |
| Subluxation | Yes | Yes | No |
| Luxation | Yes | Yes | Yes |

### Radiographic Evaluation

The initial radiograph taken after the injury will not disclose the pulpal condition. However, it is important for evaluation of the general injury to the tooth and alveolus and serves as a basis for comparison for subsequent radiographs. Additionally, as stated in the earlier section, CBCT is important in trauma cases, especially in luxation and avulsion injuries, when a concomitant alveolar fracture is suspected (Figs. 11.19 and 11.20). 3D imaging allows for better




• **Fig. 11.19 A–C,** Periapical radiographs failed to reveal the position of the tooth in relation to its alveolus.




• **Fig. 11.20** Cone beam computed tomography. Transaxial volumetric reconstruction **(A)** and sagittal plane view **(B)** demonstrating lateral luxation of the maxillary left central incisor with a concomitant alveolar fracture.

diagnosis of alveolar fractures and confirms the correct position of the tooth in the socket, as stated previously in this chapter.

Radiographs are also indicated for early diagnosis and treatment of external resorptions and periradicular bony changes. Resorptive changes, particularly external changes, may occur soon after injury; if no attempt is made to arrest the destructive process, much of the root may be rapidly lost. Inflammatory (infection-related) resorption can be intercepted by timely endodontic intervention.[64]

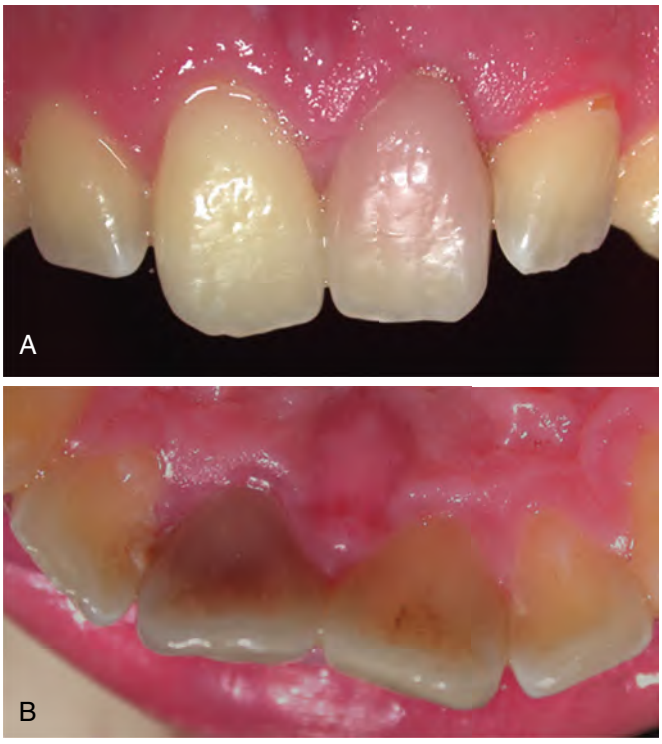
Periodic radiographs show whether the root of a developing tooth is continuing to grow (a positive sign indicating recovery of the pulp). Another finding may be pulp space calcification or obliteration, a common finding after luxation injuries in immature teeth.[65] Also called *calcific metamorphosis*, this canal obliteration may be partial or nearly complete (after several years) and does not indicate a need for root canal treatment, except when other signs and symptoms suggest pulp necrosis.[65]

### Crown Color Changes

Pulpal injury may cause discoloration, even after only a few days. Initial changes tend to be pink. Subsequently, if the pulp does not recover and becomes necrotic, there may be a grayish darkening of the crown, often accompanied by a loss in translucency (Fig. 11.21). In addition, color changes may take place as a result of calcific metamorphosis of the pulp. Such color changes are likely to be yellow to brown and do not indicate pulp pathosis. Other signs, findings, or symptoms are necessary to diagnose pulp necrosis.[62,65]

Discoloration could be reversed. This reversal usually happens relatively soon after the injury and indicates that the pulp is vital. Because of unpredictable changes associated with traumatized teeth, long-term evaluation is recommended.[62]

The next part of this chapter describes the injuries and the recommended treatment for each type.




• **Fig. 11.21** Crown color changes as a result of pulpal injury after a luxation injury: buccal view **(A)** and lingual view **(B)**.

## Concussion

This is an injury to the tooth-supporting structures *without increased mobility or displacement* of the tooth *but with pain on percussion.* Concussion injuries generally respond to pulp testing because the injury is less severe; the pulpal blood supply is

more likely to return to normal. No radiographic changes are found.[66]

Treatment:

1. Note that no treatment is usually necessary.
2. Prescribe a soft diet for 14 days.
3. Prescribe chlorhexidine rinses.
4. Follow up.

## Subluxation

Subluxation is an injury to the tooth-supporting structures resulting *in increased mobility* but *without displacement of the tooth.* Although sulcular bleeding might be present, this clinical finding does not provide a diagnosis.

Teeth with subluxation injuries are sensitive to percussion. The teeth are not displaced, and the pulp may respond normally to testing, sometimes after initially failing to respond. No radiographic changes are noted.[66]

Treatment:

1. Note that no treatment is usually necessary.
2. Relieve the occlusion.
3. Prescribe a soft diet.
4. Apply a splint only in case of marked loosening for up to 2 weeks.[67]
5. Prescribe chlorhexidine rinses.
6. Follow up and monitor pulpal status.

## Luxation

Luxation is an injury to the tooth-supporting structures resulting *in increased mobility*, *with displacement of the tooth.*[66] The injury may displace the tooth in three possible directions: extrusive, lateral, or intrusive.

### *Extrusive Luxation*

With extrusive luxation, teeth are partially displaced from the socket along the long axis. Extruded teeth have greatly increased mobility, and radiographs show displacement. The pulp usually does not respond to testing.[59,66]

### *Lateral Luxation*

Teeth may be displaced in any direction besides axially. These teeth could be displaced lingually, buccally, mesially, or distally (i.e., away from their normal position in a horizontal direction).[66] However, this type of luxation injury is usually accompanied by comminution or fracture of either the labial or the palatal/lingual alveolar bone. This consequence is because of the impact, which usually comes from the facial aspect that causes the crown to be displaced lingually and the apex buccally, creating a subsequent alveolar fracture. If the apex has been severely displaced, the pulp may permanently lose sensory nerve supply but retain its blood supply. A metallic sound on percussion might indicate that the root tip has been forced into the alveolar bone.

Treatment for extrusive and lateral luxations:

1. Reposition and splint. Extrusive and lateral luxation injuries require repositioning and splinting. The duration of splinting varies with the severity of injury. Extrusions may need only 2 weeks, whereas lateral luxations that involve bony fractures need 4 weeks.[66]
2. Prescribe a soft diet.
3. Prescribe chlorhexidine rinses.
4. Treat with root canal therapy. Root canal treatment is indicated for teeth with a diagnosis of irreversible pulpitis or pulp necrosis. Such a diagnosis often requires a combination of signs and symptoms, such as discoloration of the crown, lack of pulp response to pulp testing, and a periradicular lesion seen radiographically.[66]
5. Monitor for possible endodontic treatment. Severe cases of either extrusive or lateral luxation of mature teeth may require endodontic therapy within the first 2 weeks to prevent the onset of resorption (Fig. 11.22).

• **Fig. 11.22** Severe extrusive luxation. The tooth was retained only by soft tissue.

### *Intrusive Luxation*

In this type of injury, the teeth are forced into the sockets in an axial (apical) direction, at times to the point of not being clinically visible. They have no mobility, resembling ankyloses (Fig. 11.23).[68,69]

### *Treatment for Intrusive Luxation*

This treatment differs slightly from the extrusive and lateral luxation cases and depends on stage of root maturity.[68-70]

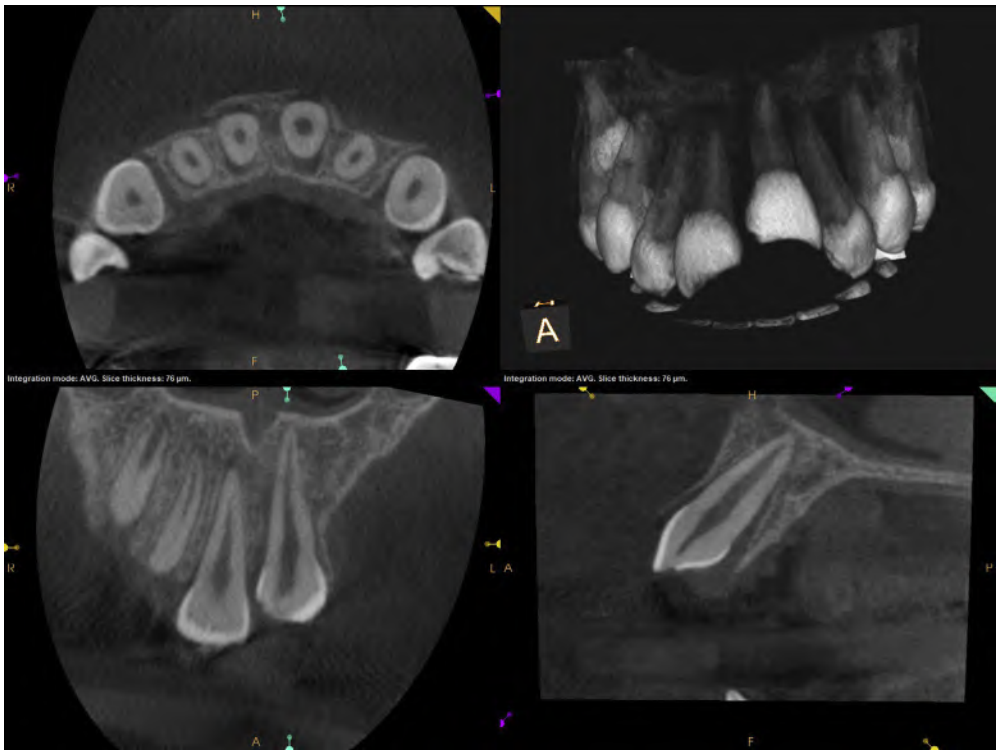
### *Open Apex*

If the root is incompletely formed with an open apex, it may reposition spontaneously. A clinical study revealed that in young patients 12 to 17 years of age who have complete root formation, spontaneous reeruption is possible and was found to be the best treatment with regard to marginal periodontal healing.[68]

In teeth with immature roots, the pulp may revascularize.[68,71] However, the patient must be monitored carefully, because complications that include pulp necrosis along with lack of continued root development could arise. Root canal treatment should be performed in these cases.

### *Closed Apex*

In older patients (i.e., older than 17 years of age) with complete root formation, either surgical or orthodontic extrusion should be attempted. Intrusively luxated teeth undergo pulp necrosis approximately 85% to 100% of the time.[68,69,71,72] Hence, root




• **Fig. 11.23** Severe intrusive luxation: Cone beam computed tomographic imaging shows the extent of intrusion of the maxillary left central incisor.

canal therapy is indicated for these teeth within the first 2 weeks to prevent the onset of resorption.

## Avulsion

This circumstance could be described as the complete separation of a tooth from its alveolus by traumatic injury. This separation can lead to extensive damage to the pulp and the periodontal tissues. The prognosis of the teeth depends entirely on the *extraoral dry time/period* and the *storage media*. The storage media is important to preserve the PDL cells and the fibers attached to the root surface.[73]

## Treatment

Three situations involving avulsions may arise: (1) the tooth has already been replanted; (2) the extraoral dry time has been less than 60 minutes; or (3) the tooth has been out for *longer* than 60 minutes and has not been kept in a storage medium.

### *Immediate Replantation*

The prognosis is improved by replantation immediately after avulsion and should always be encouraged.[74-76]

- Leave the tooth in place.
- Clean the area with water spray, saline, or chlorhexidine.
- Verify normal position of the replanted tooth both clinically and radiographically.
- Apply a flexible splint for up to 2 weeks.
- Administer systemic antibiotics.
- If the avulsed tooth has been in contact with soil, and if tetanus coverage is uncertain, refer to a physician for a tetanus booster.
- Initiate root canal treatment within 7 to 10 days after replantation and before splint removal.

### *Replantation Within 60 Minutes of Avulsion—Tooth with a Closed Apex*

If replantation is not feasible at the place of injury, the tooth should be brought to the dental office in media to keep it moist and prolong the vitality of the PDL cells.[77,78] The most common storage medium is Hanks Balanced Salt Solution (HBSS), which is commercially available as a kit (Save-A-Tooth; Phoenix-Lazerus, Pottstown, Pennsylvania, USA). However, if not available, milk is an excellent alternative.[79-84]

When the patient arrives, the following steps are recommended:

1. Place the tooth in a cup of physiologic saline while preparing for replantation.
2. Take radiographs of the area of injury to look for evidence of alveolar fracture. Consider the use of CBCT, if indicated.
3. Administer local anesthetic.
4. Examine the avulsion site carefully for any loose bone fragments that may be removed. If the alveolus is collapsed, spread it open gently with an instrument.
5. Clean the root surface and apical foramen with a stream of saline and soak the tooth in saline, thereby removing contamination and dead cells from the root surface.
6. Irrigate the socket gently with saline to remove contaminated coagulum.
7. Grasp the crown of the tooth and avoid handling the root and replant the tooth with slight digital pressure to accomplish complete seating.
8. Check for proper alignment and correct any hyperocclusion. Soft tissue lacerations should be tightly sutured, particularly cervically.
9. Stabilize the tooth for 2 weeks with a flexible splint; nylon, stainless steel, or nickel-titanium wires up to 0.016 inch (0.4 mm) in diameter are significantly more flexible.[85]

### Replantation Within 60 Minutes of Avulsion—Tooth with an Open Apex

When the patient arrives, the following steps are recommended:

1. Place the tooth in a cup of physiologic saline while preparing for replantation.
2. Administer a local anesthetic.
3. Examine the alveolar socket, looking for fracture of the socket wall.
4. If available, cover the root surface topically with a tetracycline-based antibiotic before replanting the tooth.[86-88]
5. Replant the tooth with slight digital pressure.
6. Suture gingival lacerations, especially in the cervical area.
7. Verify normal position of the replanted tooth.
8. Apply a flexible splint for 2 weeks.
9. If the avulsed tooth has been in contact with soil and if tetanus coverage is uncertain or if the previous one was administered more than 10 years earlier, refer to a physician for a tetanus booster.
10. Administer systemic antibiotics. Unlike mature teeth for which endodontic therapy should be initiated within a week, immature teeth with open apices may revascularize, but they must be evaluated at regular intervals of 2, 6, and 12 months after replantation. If subsequent evaluations indicate pulp necrosis, lack of root development, and apical closure, root canal treatment, probably including apexification, is indicated.[89]

### Replantation with Dry Time Longer Than 60 Minutes—Tooth with a Closed Apex

If a tooth has been out of the alveolar socket for longer than 60 minutes (and has not been kept moist in a suitable medium), PDL cells and fibers will not survive, regardless of the stage of root development.[73,79] Replacement root resorption (characterized by ankylosis) is likely to be the eventual sequela of replantation. Therefore treatment efforts before replantation include treating the root surface with fluoride to slow the resorptive process.[73]

When the patient arrives, the following steps are recommended:

1. Examine the area of tooth avulsion and examine the radiographs for evidence of alveolar fractures.
2. Remove attached nonviable soft tissue/PDL carefully with gauze.
3. Root canal treatment can be performed before replantation, or it can be done within 2 weeks.
4. Administer local anesthesia.
5. Irrigate the socket with saline.
6. Replant the tooth slowly with slight digital pressure.
7. Verify normal position of the replanted tooth clinically and radiographically.
8. Stabilize the tooth for 4 weeks using a flexible splint.
9. Administer systemic antibiotics.
10. If the avulsed tooth has been in contact with soil, and if tetanus coverage is uncertain, refer to a physician for a tetanus booster.

Soaking the tooth in a 2.4% solution of sodium fluoride (acidulated to a pH of 5.5) for 20 minutes has been suggested to slow down osseous replacement, but this approach is not an absolute recommendation.[90]

### Replantation with Dry Time Longer Than 60 Minutes—Tooth with an Open Apex

The management of these teeth is similar to those with a closed apex.

1. Remove attached nonviable soft tissue carefully with gauze.
2. Root canal treatment can be performed before replantation, or it can be done 7 to 10 days later.
3. Administer local anesthesia
4. Irrigate the socket with saline.
5. Examine the alveolar socket.
6. Replant the tooth slowly with slight digital pressure.
7. Verify normal position of the replanted tooth clinically and radiographically.
8. Stabilize the tooth for 4 weeks using a flexible splint.
9. Administer systemic antibiotics.
10. If the avulsed tooth has been in contact with soil, and if tetanus coverage is uncertain, refer to a physician for a tetanus booster.

## Patient Instructions

Antibiotics are recommended for patients with replanted avulsed teeth.[91,92]

- For children under the age of 12 years, penicillin V 25-50 mg/kg of body weight in divided doses every 6 hours for 7 days can be prescribed.
- In patients 12 years of age or older, doxycycline 100 mg two times per day for 7 days is the current recommendation. Amoxicillin in an appropriate dose for age and weight, can also be given as alternative to tetracycline.

A tetanus booster injection is recommended if the previous one had been administered more than 10 years earlier.[93] Supportive care is important. Instruct the patient (and parents) to maintain a soft diet for up to 2 weeks, to brush with a soft toothbrush after every meal, and to use a chlorhexidine mouth rinse (0.12%) twice a day for a week.

## Sequelae of Dental Trauma

### Pulp Necrosis

When the pulp is diagnosed as necrotic, the main factor to be considered is the stage of root development. If the root is fully matured, root canal therapy is the treatment of choice as stated in the next section. In immature teeth with open apices, treatment options include apexification or, more recently, regenerative endodontic treatment.

### Teeth with Open Apices

1. *Calcium hydroxide apexification:* Apexification could be done in the traditional manner, which incorporates long-term use of calcium hydroxide for up to 18 months. This method was first introduced by Kaiser in 1964 and made popular by Frank in 1966.[94,95] Many studies have described the successful formation of an apical barrier with the long-term use of calcium hydroxide.[96,97] However, such long-term treatment processes may result in decreased fracture resistance of these teeth.[98-100]
2. *MTA apexification:* In 2001 Witherspoon and Ham reported using MTA for single-visit apexification treatment of immature teeth with necrotic pulps.[101] This study demonstrated that the use of an MTA apical plug provided a scaffolding for the formation of a hard tissue barrier and subsequently a better apical seal. Furthermore, MTA apical plug has shown to increase the fracture resistance of immature teeth.[102,103]
3. *Regenerative endodontics:* Regenerative endodontic procedures (REPs) for the treatment of immature teeth with necrotic pulps and apical periodontitis have gained much attention in recent years.[104,105] Studies have shown that although the outcomes of these procedures are somewhat unpredictable, in successful cases there is increased thickness of the canal wall and length of the root, which makes these teeth less prone to fractures.[104-107]

### *Teeth with Closed Apices*

#### Root Canal Treatment

An avulsion injury causes the neurovascular supply to be severely compromised along with loss of vascularization to the pulp, thereby causing necrosis.[75,108] In the mature replanted tooth, root canal treatment is indicated and should be started 7 to 10 days after replantation.[21] The use of calcium hydroxide as an antimicrobial intracanal interappointment medicament may be helpful.[92,109] It is particularly beneficial if the root canal is infected, a condition that would be likely to occur when root canal treatment is delayed more than a few weeks after replantation. However, as discussed in the previous section, long-term calcium hydroxide therapy could significantly decrease fracture strength.[98-100]

The procedure consists of cleaning and shaping, followed by calcium hydroxide placement for a minimum of 1 to 2 weeks.[109] The root canal is then obturated with gutta-percha and sealer. Long-term evaluation is necessary to monitor for possible resorption.

Restoration of the coronal access opening is necessary once the root canal treatment is completed. This step is important to prevent bacterial leakage into the root canal system.[110,111]

## Pulp Canal Obliteration (Calcific Metamorphosis)

The complete or partial calcification of the root canal space is a common finding after luxation injuries in immature teeth with a well-vascularized pulp.[65,112] Canal obliteration may be partial or nearly complete (after several years) and does not indicate a need for root canal treatment except when other signs and symptoms suggest pulp necrosis.[65]

## Root Resorption

External root resorption is a frequent occurrence in replanted avulsed teeth.[113] Three types have been identified and studied extensively: surface, inflammatory, and replacement.[114,115]

### *Surface Resorption*

Also called "repair-related resorption," surface resorption is transient and shows as lacunae of resorption in the cementum of replanted teeth. They are not usually visible on radiographs. If resorption does not continue, the lacunae are repaired by deposition of new cementum.

### *Inflammatory Resorption*

Inflammatory resorption occurs as a response to the presence of infected necrotic pulp tissue in conjunction with injury to the PDL (Fig. 11.24). It occurs with replanted teeth in addition to other types of luxation injuries. Inflammatory resorption is characterized by loss of tooth structure and adjacent alveolar bone. Resorption usually subsides after removal of the necrotic, infected pulp, so the prognosis is good. Hence, root canal treatment is recommended routinely for replanted teeth with closed apices to prevent the occurrence of inflammatory resorption.

### *External Replacement (PDL-Related) Resorption*

In replacement resorption, the tooth structure is resorbed and replaced by bone, resulting in ankylosis in which bone fuses directly to the root surface (Fig. 11.25). The characteristics of ankylosis are lack of physiologic mobility, failure of the tooth to erupt along with adjacent teeth (leading to infraocclusion in young individuals), and a "solid" metallic sound on percussion. Currently no treatment is available for replacement resorption, which tends to be progressive until the root is completely replaced by bone.[114-116] In teeth that have had long extraoral dry periods, the resorptive process may be slowed (but not halted) by immersing the tooth in fluoride before replantation.[117-119] Research is ongoing to delineate the mechanism of replacement resorption and find various methods to slow or halt the process.[117]

## Alveolar Fractures

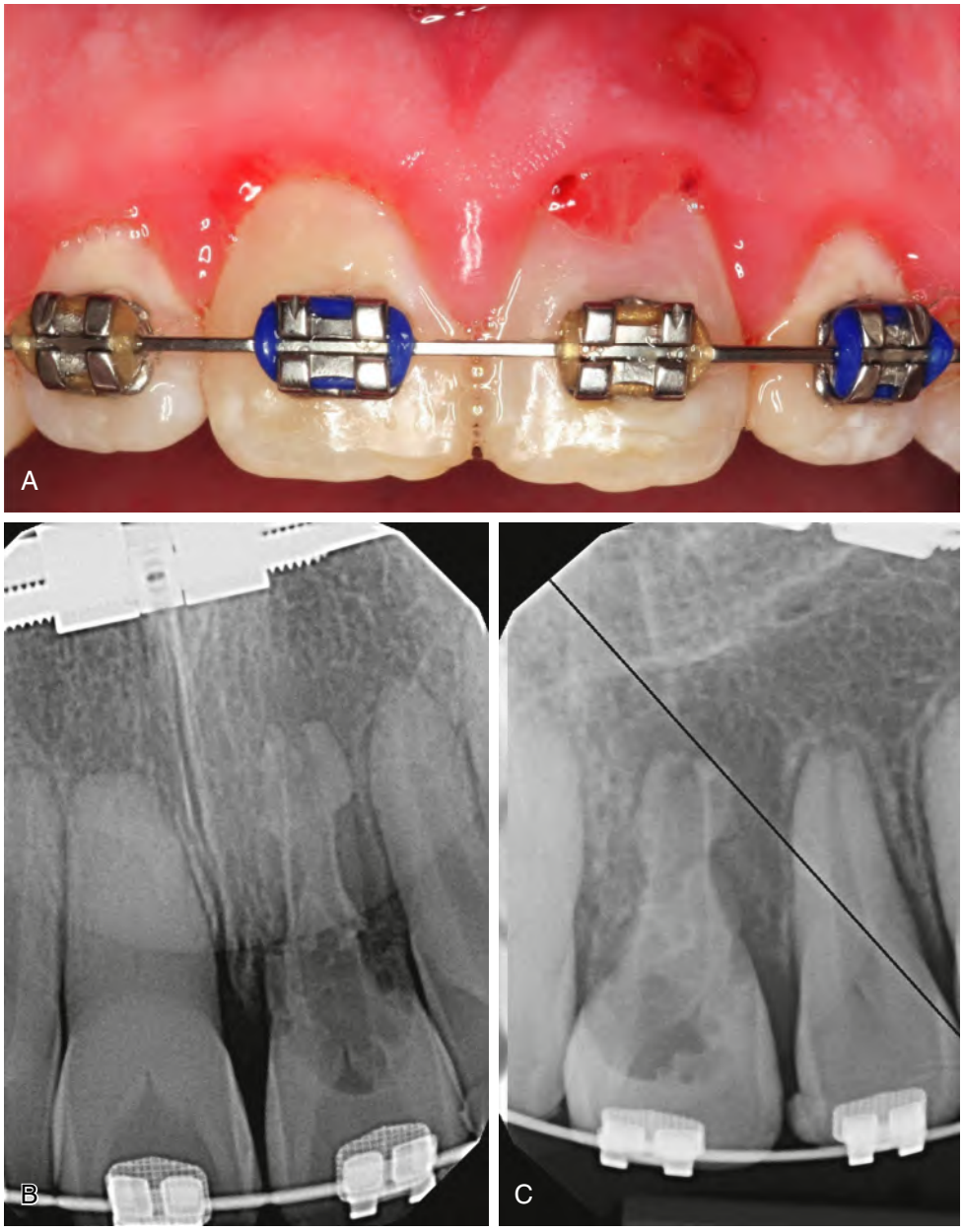
Pulp necrosis and luxation injuries are often associated with alveolar fractures, which may in turn be associated with other major facial injuries (Fig. 11.26).[120] It is important to diagnose the presence of the fracture, which would dictate the treatment options and management, consisting of reduction and splinting of the segment to the adjacent teeth. The use of CBCT is highly recommended (as mentioned earlier in the chapter). When the patient is able to have the teeth examined, those in the line of fracture and adjacent teeth are evaluated. Lack of response to pulp testing, if not reversed within 3 to 6 months, may indicate pulp necrosis, but the presence of other indicators (apical radiolucency or symptoms) is necessary before root canal treatment is recommended.[121] Major facial injuries are usually managed by oral and maxillofacial surgeons who would also manage the related dental trauma.

# Management of Traumatic Injuries in the Primary Dentition

Young children are often difficult to examine and treat primarily due to the sustained traumatic experience and fear. In some instances, the treatment of traumatic injuries to the primary dentition may mirror those of the permanent dentition; however, the clinician should be aware that the root of the injured primary tooth may be in close proximity to the permanent successor (Fig. 11.27). Treatment involves a thorough clinical and radiographic examination, followed by a diagnosis and necessary treatment, keeping in mind that these injuries may or may not have significant effects on the permanent successors.[122-124] Multiple studies have reported the possible sequelae to the permanent teeth after trauma to the primary teeth. These mainly included discoloration, tooth malformation, and enamel hypoplasia.[122,125] After diagnosis and an explanation of the treatment options to the parents or guardians, the clinician along with the parent or guardian should decide the treatment option that would benefit the patient.

Primary teeth could sustain various types of trauma; however, luxation injuries are the most common and most of these injuries will heal spontaneously.[126-129] Some other injuries, like complicated crown fractures (with pulp exposure), root fractures, alveolar fractures, extrusive and lateral luxations, require urgent treatment (Fig. 11.28). Treatment options depend on the proximity of the apex of the primary tooth and its developing permanent successor and on the degree of root resorption of the primary tooth. Hence, treatment should be aimed at minimizing additional trauma or damage to the permanent successors.

The following are some of the guidelines for treating traumatized primary teeth.[127,128]




• **Fig. 11.24** A 14-year-old patient presented for consultation 5 years after avulsion of the maxillary left central incisor. A clinical photograph **(A)** and radiographic examination (**B** and **C**) revealed the presence of external inflammatory root resorption.

## Enamel fracture

Smoothen sharp edges. No additional treatment is necessary.

## Crown Fractures Without Pulp Exposure

If the fracture site is small, smooth the sharp edges or seal the exposed dentin with glass ionomer. If the fractured segment is larger, the tooth can be restored with a composite restoration.

## Crown Fractures with Pulp Exposure

The treatment should be aimed at preserving pulp vitality. Partial pulpotomy with calcium hydroxide followed by a glass ionomer lining and a composite restoration should be the treatment of choice if possible. However, extraction may be indicated, depending on the patient's age, cooperation, and ability to cope.

## Crown-Root Fractures

If the fracture involves only a small part of the root and the rest of the tooth is stable and allows for a coronal restoration, only the fractured fragment should be removed. If the crown-root fracture is large and/or exposes the pulp, extraction is indicated.

## Root Fractures

If the coronal fragment is not displaced, no treatment is required unless problems develop subsequently.

If the coronal fragment is displaced, repositioning and splinting may be considered. If repositioning is not an option, then removing the coronal segment and leaving the root apex in situ is the treatment of choice. Any attempt to remove the root apex may damage the permanent tooth bud.

## Alveolar Fractures

Alveolar fractures are severe injuries that may dictate treatment while the patient is under general anesthesia. The displaced segment should be repositioned and splinted for up to 4 weeks. Teeth in the fracture line should be monitored.

• **Fig. 11.25** Periapical radiograph of a 12-year-old patient 2 years after replantation of the maxillary right central incisor. Note the presence of replacement root resorption (dentin replaced by bone) in the absence of radiolucencies.

## Luxation Injuries

### *Concussion and Subluxation*

These injuries require no treatment other than promoting good oral hygiene to prevent healing complications. Brushing with a soft toothbrush and the use of alcohol-free 0.12% chlorhexidine topically on the affected area with a cotton swab for a week should be encouraged.

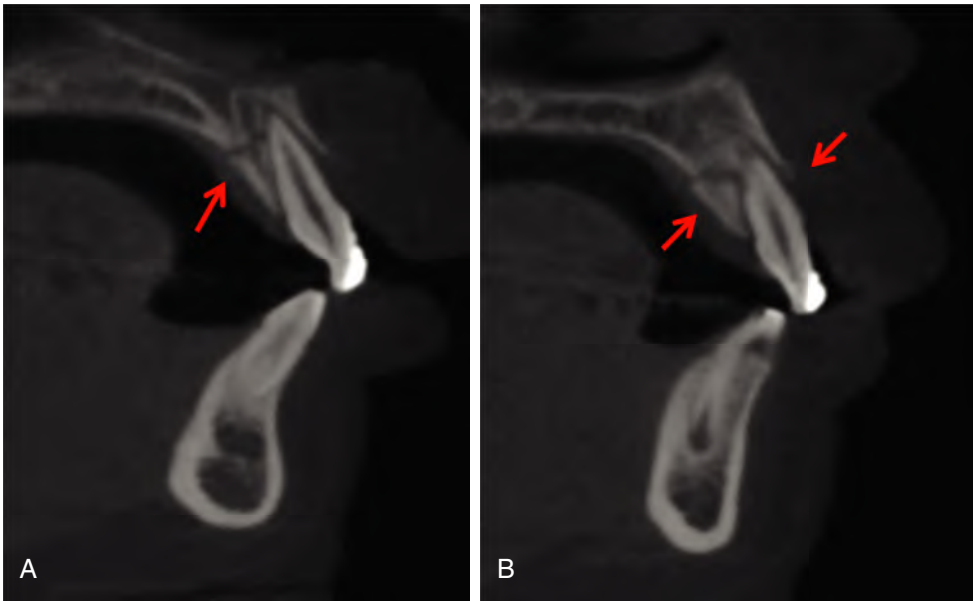
Crown discoloration could occur after some luxation injuries. This discoloration is usually the main complaint for seeking treatment. However, studies have demonstrated that the positive association between the pulp status and crown discoloration should be considered with caution and that discoloration is not considered an indication for treatment.[130-133] Discolored teeth should be followed and should be treated when signs of infection develop (e.g., sinus tract, abscess etc.). Pulp canal obliteration is the other common sequela after luxation injuries. This obliteration changes the primary crown to a darker yellow color, which is not pathologic and requires no treatment (Fig. 11.29).[127,128,134]

### *Extrusive Luxations*

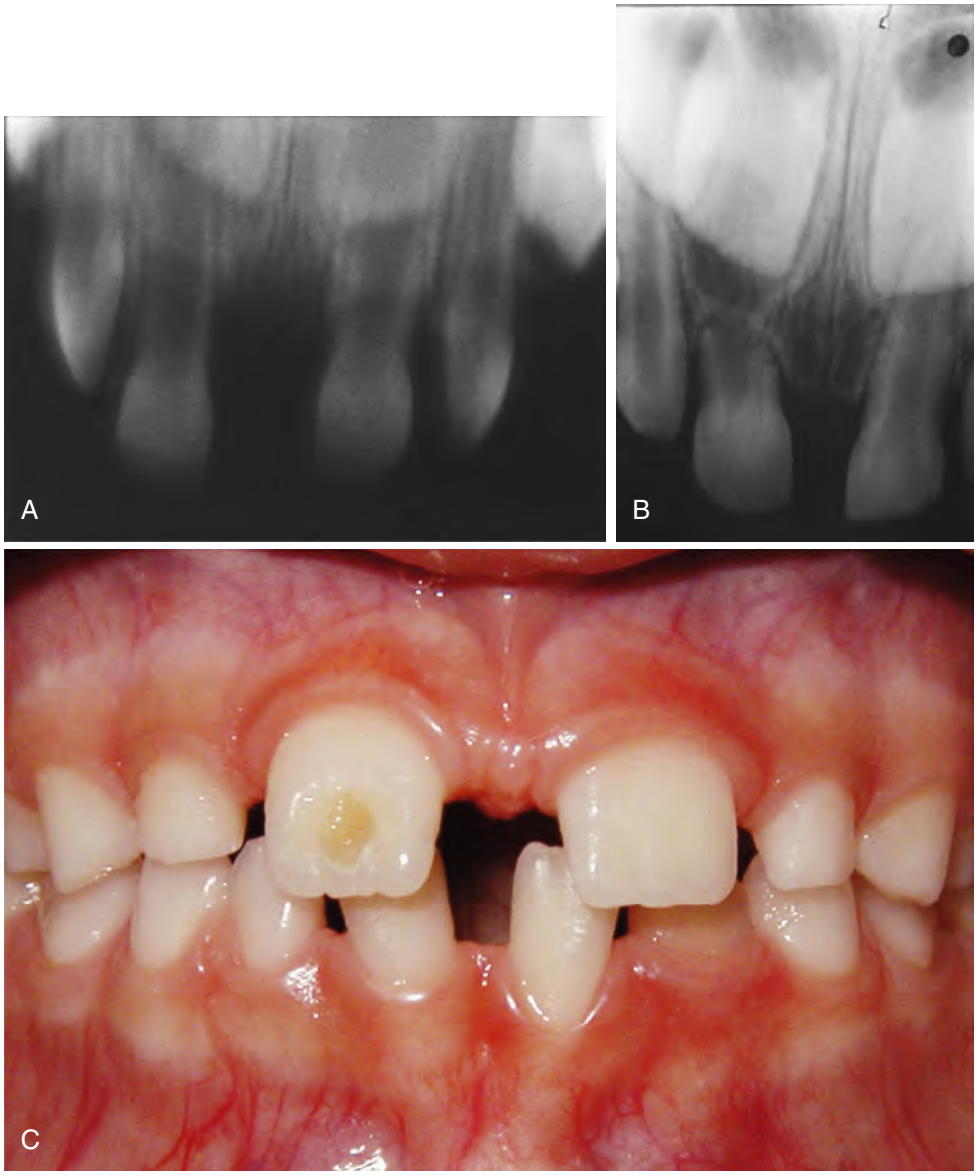
The treatment would depend on the degree of extrusion, root formation, mobility, and the ability of the child to manage the treatment procedure. For minor extrusions the tooth may be left untreated for spontaneous realignment or repositioned if there is occlusal interference. Extraction may be the treatment of choice for severely extruded teeth.

### *Lateral Luxations*

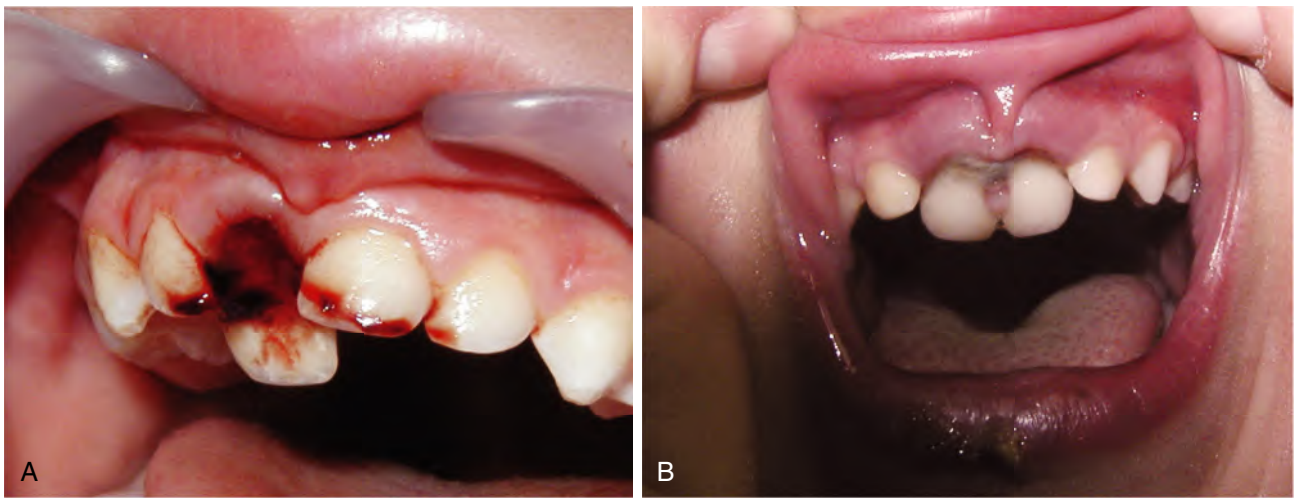
For minor lateral luxations, the tooth may be left untreated for spontaneous realignment or repositioned if there is occlusal interference. In case of minor occlusal interferences, minor occlusal adjustment may be indicated. In cases of more severe occlusal interferences, the tooth may be repositioned after the use of local anesthesia. In cases of severe displacement (crown is displaced labially), extraction is the treatment of choice.



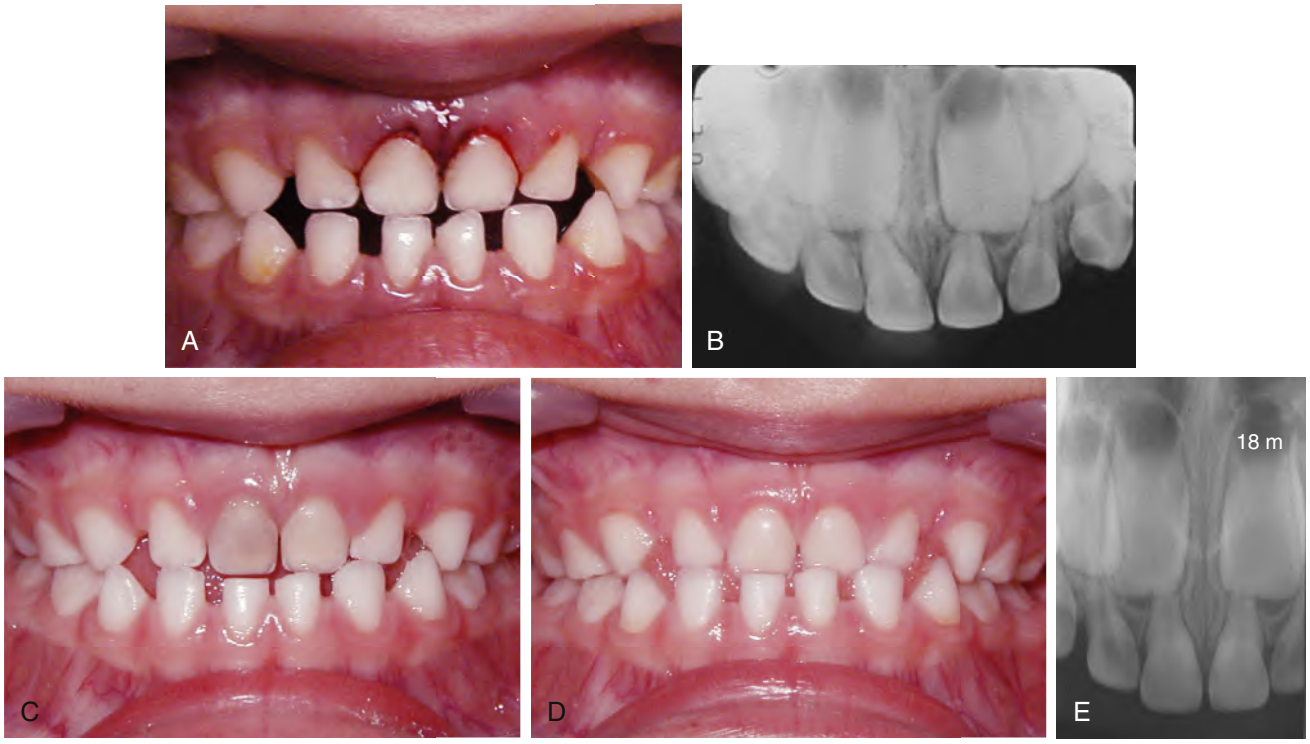

• **Fig. 11.26** Alveolar fractures of the lingual (**A** and **B**) and buccal **(B)** cortical plates.




• **Fig. 11.27** Hypoplasia in a permanent incisor after avulsion and subsequent replantation of a primary central incisor. A 1-year-old boy fell and struck the central incisors against a table. The primary right central incisor was avulsed and replanted. The patient followed a 7-day course of amoxicillin. **A,** Radiograph at the time of injury shows the replanted immature central incisor. **B,** At the 3-year, 5-month follow-up control, the root has been almost completely resorbed. The contralateral tooth shows complete root formation. **C,** Crown hypoplasia of the right permanent successor at 7-year follow-up control.




• **Fig. 11.28** Treatment priorities after traumatic injuries in the primary dentition include urgent care to alleviate pain and enable recovery of masticatory function. **A,** Severe tooth displacement. **B,** Extrusive luxation of both primary central incisors.




• **Fig. 11.29** Color changes in primary teeth after a subluxation injury. A 5-year-old girl fell while playing and struck her front teeth against the floor. **A,** The girl arrived in the clinic within 1 hour for clinical examination. Both central incisors were mobile but not displaced. Bleeding from the gingival crevice was observed. Because of minor occlusal interference, slight grinding of the opposite teeth was performed. Oral hygiene instructions given to the mother included topical use of chlorhexidine. **B,** Radiograph at the time of injury shows no radiographic changes. **C,** After 1 month, there was no occlusal interference, but gray discoloration is seen in both central incisors. **D,** At 18-month follow-up control, the color of the crowns had returned to normal. **E,** Periapical radiograph shows pulp canal obliteration in both traumatized teeth.


• **Fig. 11.30** Importance of accurate diagnosis after intrusions and avulsions in the primary dentition. **A,** Intrusive luxation. A maxillary right central incisor has been deeply intruded in the alveolar socket, giving the appearance of having been avulsed. **B,** Avulsion. The avulsed tooth was brought into the clinic, confirming that it was not intruded.

### *Intrusive Luxations*

If the apex of the primary tooth is displaced toward or through the buccal bone, the tooth can be left in place for spontaneous repositioning.[126,129] The intruded tooth should be carefully extracted if it impinges on the permanent successor.

## Avulsions

Replantation of avulsed primary teeth is not recommended because of the risk of damage to the permanent successor (Fig. 11.30). A radiographic examination helps with confirmation of the avulsed tooth and with the stage of development of the permanent tooth bud.

## Patient Instructions

Parents should receive information about how to brush their children's teeth after an injury. Careful oral hygiene after each meal, in addition to topical use of 0.12% chlorhexidine twice per day for 1 week should be recommended. A soft diet for 10 days and restriction of the use of an intraoral pacifier are also recommended. There is no evidence to support the use of systemic antibiotics in the management of luxation injuries of the primary dentition.[127] If the child's medical status warrants antibiotic coverage, the clinician should contact the pediatrician whenever possible because pediatricians may give recommendations for a specific medical condition.

# Prevention

Dental and maxillofacial trauma is common and seen in high-risk populations, which include children, athletes, individuals with disabilities, the geriatric population, and military personnel.[135-140] However, most dental traumatic injuries are preventable, and proper management can prevent adverse complications. Management involves primary management, which would involve (1) education, (2) early orthodontic treatment in predisposed children, and (3) protective devices for contact sports. Secondary prevention would entail early diagnosis and treatment of trauma before complications develop.[141]

## Primary Management

Education should focus on the prevention of dental trauma, which includes addressing the known risk factors early on. Educating people regarding the implementation of therapeutic guidelines at the site of injury is also necessary. Several studies have reported the need for such an education campaign among school staff, parents, nurses, coaches, physicians, paramedics, and even dentists.[142-148] Early orthodontic treatment is necessary because dental trauma has been found to be more prevalent among children with an incisal overjet of more than 7 mm and/or with incompetent lips.[149,150] In these patients, the maxillary anterior teeth are directly exposed to any impact without interposition of soft tissues. Hence, early orthodontic treatment is also highly recommended to prevent dental trauma.

Contact sports can result in a higher likelihood of traumatic injuries to the teeth.[138,151] Dental professionals should educate patients and the public about mouthguard protection for contact sports. Studies have demonstrated that mouthguards contribute to a lower prevalence of dentoalveolar trauma among athletes who play contact sports.[152-154] Mouthguards usually fall in to one of the three categories: stock mouthguards, mouth-formed mouthguards, or custom-made mouthguards. Comfort, the ability to speak and breathe easily, esthetics, and the athlete's perception of how the mouthguard affects their image all influence which mouthguard will be selected and whether the mouthguard will actually be used.[141] Current research supports the fact that neither the mouth-formed and nor the custom-made mouthguards pose any negative effects on athletic performance and strength; however, the custom-made mouthguards were found to be more comfortable and did not cause any breathing difficulty.[155-157] Other studies have reported that the custom-made mouthguards are superior in their protective function.[141]

## Secondary Management

Diagnosis and prompt treatment of trauma are necessary to avoid future complications. This chapter focused on the secondary management of trauma and discussed the diagnosis and treatment of various traumatic injuries.

### Study Questions

6. What percentage of intrusive luxated teeth with closed apices undergo pulp necrosis?
   A. 5-20%
   B. 25-40%
   C. 55-70%
   D. 85-100%
7. Which of the following factors can affect the prognosis of avulsed teeth?
   A. The tooth type
   B. Time of injury
   C. Extraoral dry time
   D. Patient's lip closure
8. Which of the following statement does not describe Inflammatory Resorption?
   A. It occurs in response to the presence of infected necrotic pulp tissue.
   B. It is characterized by the loss of tooth structure.
   C. Tooth structure is resorbed and replaced by bone.
   D. It subsides after the removal of the necrotic pulp.
9. Avulsed primary teeth should always be replanted.
   A. True
   B. False
10. Which of the following factors is involved in the primary prevention of trauma?
    A. Education
    B. Early orthodontic treatment in predisposed children
    C. Protective devices for contact sports
    D. All of the above.

### ANSWERS

#### Answer Box 11

1. Correct answer: D. All of the above.
2. Correct answer: B. Late differentiation of the Ad fibers.
3. Correct answer: A. Restoration of the missing tooth structure.
4. Correct answer: A. Removal of minimal amount of the coronal pulp.
5. Correct answer: D. All of the above.
6. Correct answer: D. 85–100%
7. Correct answer: C. Extraoral dry time
8. Correct answer: C. Tooth structure is resorbed and replaced by bone.
9. Correct answer: B. False.
10. Correct answer: D. All of the above.

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