Oral and Maxillofacial Trauma

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Faculty Disclosure

Contributing faculty, Mark J. Szarejko, DDS, FAGD, has disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

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The division planner and director have disclosed no relevant financial relationship with any product manufacturer or service provider mentioned.

Audience

This course is designed for all dental professionals, especially those who work in emergency and trauma care.

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Course Objective

The purpose of this course is to provide dental professionals with a deeper understanding of and appreciation for oral and maxillofacial trauma.

Learning Objectives

Upon completion of this course, you should be able to:

1. Outline the diagnosis and treatment of traumatic injuries to permanent teeth with completely formed (mature) roots.
2. Discuss the unique issues associated with assessing and treating traumatic injuries to permanent teeth with open apices.
3. Describe the assessment and treatment of traumatic injuries to deciduous teeth.
4. Effectively evaluate and treat root fractures in deciduous and permanent teeth.
5. Review the appropriate assessment and management of luxation injuries to permanent and deciduous teeth.
6. Describe the oral implications of traumatic injuries to other structures within the oral and maxillofacial complex, particularly fractures of the mandible.
7. Outline the most common traumatic injuries that occur to the structures of the oral and maxillofacial complex due to child abuse or domestic violence.

EVIDENCE-BASED PRACTICE RECOMMENDATION

Sections marked with this symbol include evidence-based practice recommendations. The level of evidence and/or strength of recommendation, as provided by the evidence-based source, are also included so you may determine the validity or relevance of the information. These sections may be used in conjunction with the course material for better application to your daily practice.

INTRODUCTION

Dentistry is usually equated with restorative treatments for carious lesions, nonsurgical and surgical treatment of periodontal disease, the prosthetic replacement of missing teeth, oral surgery, and endodontic treatment of teeth with pulpal inflammation or infection. The treatment of teeth that have undergone varying degrees of fracture from a traumatic incident, the reduction of fractured bones in the oral and facial regions, and the treatment of lacerated tissues within the oral and maxillofacial complex are not often encountered in the daily practice of dentistry. However, traumatic injuries to the teeth, the soft tissues within the oral cavity and perioral structures, and the underlying bone require dental intervention to preserve the teeth involved and to repair osseous and soft tissue defects. Prompt treatment allows form, function, and cosmetics to be restored and an optimal quality of life maintained for the patient.

The restoration of fractured teeth and roots can involve general dentists, endodontists, pedodontists, and periodontists, while fractures of the mandibular or maxillary arches are treated by oral surgeons in a hospital setting. Cases of complex trauma to the oral and facial region may also require the involvement of general surgeons, plastic surgeons, oral surgeons, and oral and maxillofacial prosthodontists, depending on the severity of the injury and the structures and tissues involved.

This course will highlight some of the most common traumatic injuries involving the teeth, facial bones, oral mucosa and perioral tissues, and the contiguous structures that comprise the oral and maxillofacial complex. Treatment guidelines for these cases will be discussed, but they are not a substitute for the clinician's independent diagnostic skills and clinical ability to assess and treat patients. Referrals to specialists may be necessary.

TRAUMATIC INJURIES TO TEETH: GENERAL CONSIDERATIONS

Teeth may sustain damage of various degrees from traumatic injuries. The magnitude, direction, and duration of force applied to the teeth, the pre-existing condition of the teeth involved, the amount of alveolar bone supporting the teeth, the age of the patient, and incidents of prior trauma to the affected teeth are among the factors that may influence the extent to which the teeth are damaged. Unfortunately, the impact absorbed by the teeth and the supporting alveolar bone may be severe enough to render them nonrestorable, with extraction(s) of the involved teeth the only option. In these cases, replacement of the affected teeth via fixed or removable prosthetics will comprise the treatment plan.

The treatment of traumatized teeth that are restorable will depend on the degree to which the crown, root, and supporting alveolar bone are damaged. The selection of restorative procedures will also reflect the stage of tooth development, as the treatment for deciduous (primary) teeth will differ from the approach for permanent teeth. For permanent teeth, the stage of root development will dictate the initial and long-term restorative treatment. This course will review the different treatment options available for the restoration of teeth with varying degrees of trauma at different stages of development.

The treatment of traumatized teeth requires prompt corrective action. It may consist of a procedure as conservative as a composite restoration to repair a small fractured portion of enamel of a single mature permanent tooth. However, complex cases can involve multiple traumatized teeth with or without pulpal involvement, fracture of alveolar bone, and/or damage to the oral mucosal tissues. Because the initial treatment provided for traumatized teeth is

a major factor for the short- and long-term prognosis, it is imperative that the practitioner has the clinical ability to provide the appropriate level of treatment for the involved teeth and adjacent oral and maxillofacial structures.

Children and adolescents with traumatized teeth can pose unique challenges. Patients in this age group may be in the "mixed dentition" stage, in which there is coexistence between newly erupted permanent teeth with incompletely developed roots and deciduous teeth. Inappropriate treatment of traumatized deciduous teeth with root anatomy that has not undergone the characteristic resorption that prepares them for their exfoliation and replacement by a permanent successor can lead to their premature loss and to damage of the crown of the underlying permanent tooth. Given this range of complexities, it is essential that each clinician performs an honest self-appraisal of his or her ability to successfully treat such trauma. Those who lack the necessary expertise should consider referral to another practitioner with demonstrated success in the treatment of traumatized teeth. Specialists such as pedodontists may provide the restorative and pulpal therapy for children and adolescents, especially those in the mixed dentition stage. These clinicians also have the expertise to provide sedation for pediatric patients who present with pain and a high level of anxiety subsequent to the traumatic injury of their teeth. Involvement of an endodontist may also be considered if the injuries to the pulp of teeth in any stage of development are beyond the abilities of the general dentist. Oral surgeons should be consulted when the fracture of the tooth or root is below the osseous crest, rendering it nonrestorable and complicated to extract.

Patients who have experienced trauma to the oral and maxillofacial complex may present to the office in a highly emotional state and with a great deal of pain. Even in emergency circumstances, initial protocols used before the initiation of dental treatment for any patient should not be abandoned. An initial medical history should be obtained for new patients and updated for existing patients. Patients who are minors by law require the consent of a parent or legal guardian before any treatment for the traumatized teeth begins. Clinicians should also be observant of injuries to other areas of the body that would require the immediate referral of the patient to the hospital emergency department. This is especially true if there are signs such as slurred speech, dizziness, difficulty maintaining consciousness, and nausea and vomiting, which could be symptoms of a traumatic brain injury. If the patient is medically stable, the next step is to determine whether treatment of the traumatized teeth is within one's clinical capabilities or if referral of the patient to another practitioner or specialist is warranted.

TRAUMATIZED PERMANENT TEETH WITH COMPLETELY FORMED (MATURE) ROOTS

Injuries to the oral and maxillofacial complex constitute 5% of the injuries for which patients seek emergency dental treatment, with this figure approaching 20% for children [1]. The most common cause of injuries to permanent teeth is accidental falls, followed by motor vehicle accidents, violent encounters, and sports injuries [2]. This section will discuss the structural damage of the teeth resulting from trauma, from least to most extensive. While the ideal outcome is to retain and restore traumatized teeth, those with extensive damage requiring endodontic treatment, periodontal (crown-lengthening) surgery, and build-ups with or without posts prior to the fabrication of a crown involve a substantial monetary investment, which may be beyond the financial means of some patients. In such cases, extraction of these potentially restorable teeth and the placement of a removable prosthesis provide a means to eliminate pain and restore function and cosmetics.

Any tooth may be injured during a traumatic incident; however, the position of the maxillary anterior teeth—the central and lateral incisors and the canines—make them most vulnerable to damage. Regardless of the teeth involved, the following discussion of the level of damage sustained and the corresponding treatment protocols apply.

INFRACTIONS

An infraction is the least severe damage evident on a traumatized tooth, featuring small cracks or craze lines with minimal depth and no lost enamel. Radiographs of the tooth appear normal, and the tooth is generally asymptomatic. Repeated traumatic incidents to the same tooth may result in a coalescence of these small cracks, which may then unite to form larger cracks and fracture of the enamel. Because no tooth structure is lost, restorative treatment is not needed, but areas with larger cracks may be etched and sealed with resin to prevent the development of stains and discoloration [3]. The prognosis for the retention of teeth with infractions is usually favorable, as is the pulpal response to the trauma. As the force that causes infractions is usually not of a magnitude that would compromise or sever the neurovascular supply of the tooth, pulpal complications are rare.

UNCOMPLICATED FRACTURES

Uncomplicated crown fractures may involve the enamel or both the enamel and the dentin, but do not involve the pulp. On the other hand, complicated crown fractures affect the enamel and dentin and result in exposure of the pulp. Classification systems to describe the degree to which the clinical crown of a tooth has been fractured as a result of trauma have been developed by Ellis and Davey and Andreasen [4; 5]. The Ellis and Davey system only describes permanent teeth, while the Andreasen classification is applicable to both deciduous teeth and permanent teeth [4; 5].

A simpler system, adapted from Ellis and Davey's original system, was created in the 1980s [6]. This system involves just four main categories: uncomplicated fractures that involve only the enamel; uncomplicated fractures that involve the dentin and enamel; complicated fractures that involve the dentin, enamel, and pulp; and loss of the entire crown.

Fractures of the Enamel

Uncomplicated enamel fractures involve portions of the enamel only, without the involvement of the underlying supporting dentin. In these cases, the loss of enamel is evident clinically and radiographically. The extent of tooth structure loss can vary from small portions to the entire incisal edge of anterior teeth or major portions of the enamel of the cusps of posterior teeth. If the fractured segment of the tooth cannot be located and the adjacent labial or buccal mucosa has sustained an injury, a radiograph of the contiguous soft tissues should be taken to determine if the tooth fragment has become embedded within the tissue. Tooth fragments found within the adjacent soft tissue should be removed to prevent the development of a foreign body reaction or infection.

Treatment for fractured areas of enamel is commensurate with the extent of tooth loss. An intact segment of fractured enamel can be bonded directly back to the area of the tooth from which it was lost, or composite restorations may replace fractured areas that lack an intact enamel segment for bonding. Restoring enamel fractures that involve the entire incisal edge of the anterior teeth can present a cosmetic and restorative challenge. An edge-to-edge anterior occlusion, whereby the incisal edges of the maxillary and mandibular teeth lack the appropriate overlap and occlude directly against each other, can generate considerable force during functional excursions, making these restorations susceptible to fractures. Parafunctional habits such as bruxing (grinding) can also increase the risk of damage to restorations of the incisal edges of anterior teeth. Complicating circumstances such

as these may require the use of less conservative restorations, such as porcelain veneers or crowns. These teeth are usually asymptomatic, but pulpal complications can occur if the traumatic force was enough to compromise the neurovascular supply to the tooth.

Fractures of the Enamel and Dentin

Uncomplicated crown fractures involving both the enamel and the dentin but not the pulp represent a progressive loss of tooth structure. The involvement of the dentin increases symptomology, complicates the ability to restore the tooth, and increases the chance of pulpal inflammation and degradation, for which endodontic therapy may be required.

When the crown of a tooth is traumatized such that the fracture exposes the dentin, fluid movement within the dentinal tubules stimulates a sensory response from the intradental A-type nerve fibers (A beta and A delta), the endings of which lie near the junction of the dentin and the pulp [7]. This stimulatory effect causes pain proportionate to the amount of dentin exposed and the proximity to the pulp. If dentin is only minimally exposed, there will be fewer and less severe symptoms than a fracture that exposes a large surface area of dentin or the deepest layer of dentin near the pulp. Bacterial infiltration into the newly exposed dentinal tubules can also stimulate an inflammatory response; therefore, it is imperative that fractures that extend into the dentin are restored promptly.

Composite restorative materials used today bond more strongly to enamel than to dentin. Fractures that involve the extensive loss of enamel and the subsequent reliance on bonding to dentin can result in an inadequate bond strength, a lack of retention, and ultimate failure of the restoration. The placement of a base such as calcium hydroxide should be considered prior to the restoration of teeth when an uncomplicated enamel-dentin fracture terminates within 1 mm of the pulp. Calcium hydroxide should be placed with a thickness of 0.5 mm, and because water solubility is a potential weakness of this material, it should be covered with another material.

A fluoride-containing material, such as glass ionomer, may be used as a liner and placed over the calcium hydroxide base, with the release of fluoride utilized as a mechanism for desensitization. Glass ionomers used for this purpose can also be etched with phosphoric acid prior to the placement of the composite resin restoration as a means of increasing the bond strength of the restoration to the tooth. It is critical that the glass ionomer liner is rinsed thoroughly after it is etched with phosphoric acid, as an acidic residue absorbed into the liner may cause post-procedural sensitivity [8].

Crowns should be considered when the fractured tooth has sustained extensive coronal damage and there is insufficient tooth structure to retain a composite restoration. Because the extent of pulpal involvement may be unclear in teeth that have sustained uncomplicated enamel-dentin fractures, temporary crowns may be used to protect the remaining tooth structure. If endodontic therapy is needed, the temporary crown can easily be removed and re-cemented to accommodate the needs of root canal therapy. If a permanent crown is cemented upon a traumatized tooth that subsequently requires endodontic therapy, accessing the tooth through the crown can lead to problems such as fracture of the porcelain component, requiring the fabrication of a new crown.

COMPLICATED FRACTURES

Complicated fractures involve the enamel and dentin with a direct exposure to the pulp. The treatment options for these teeth are dependent upon a few critical factors. The greater the amount of time that has elapsed between the traumatic exposure of the pulp and the initiation of treatment, the greater the risk and extent of bacterial contamination of the pulp by the resident oral bacteria. The inflammatory response of the pulp after a prolonged bacterial infiltration may not be remediable and may lead to irreversibly inflamed pulp or necrosis that requires endodontic therapy to alleviate the symptoms. The size of the pulpal exposure will also be consequential in teeth with complicated fractures. Smaller exposures cause less direct trauma to the pulp and provide a smaller portal of entry for bacterial contamination as compared with larger pulpal exposures. The pre-existing condition of the traumatized tooth is another consideration. Teeth with unrestored carious lesions or deep carious lesions restored in close proximity to the pulp may result in an exacerbation of symptoms as a result of traumatic injury to the pulp that can only be rectified by endodontic therapy.

Complicated fractures in teeth without pre-existing conditions may be restored with more conservative approaches than root canal therapy; direct pulp capping is one possible modality of treatment. This procedure involves placing a dressing in order to preserve the health of the pulp. This should only be attempted if there are no signs or symptoms of severe pulpal disease [9]. The gold standard material for pulp capping is calcium hydroxide [10]. With its high pH and strongly alkaline chemical designation, calcium hydroxide exerts a bactericidal effect upon microbial contaminants in the dentin and the pulp through the release of hydroxide ions [11]. Although beneficial, this property alone is not enough to heal and preserve the vital pulp. The initial response of the pulp to the alkalinity of calcium hydroxide is inflammatory, after which reparative cells emerge. These cells undergo a differentiation process and are considered odontoblast-like cells. They ultimately form a reparative dentin bridge at the site of the pulp exposure [12]. The ability of calcium hydroxide to extract growth factors from the dentin matrix is another feature that supports the production of a physical barrier at the site of the traumatic pulpal exposure [13].

The long-term success of the direct pulp capping technique depends upon several factors. The most important of these are the size of the initial exposure, the time elapsed before the pulp cap is applied, the pre-existing condition of the tooth, and the occlusal forces that are applied to the tooth. The variability and interplay among these factors impact the long-term success rates for this technique, which range considerably.

Although calcium hydroxide remains the most popular and widely known of the direct pulp capping agents, mineral trioxide aggregate (MTA) is another agent that has become popular since its approval for use by the U.S. Food and Drug Administration in 1998 [14]. Some studies have suggested that MTA is a better pulp capping agent than calcium hydroxide as it is associated with a lesser inflammatory response upon its placement and it forms a stronger dentin bridge in a shorter time than calcium hydroxide [15]. While additional comparative studies are needed to further evaluate these direct pulp capping materials, one meta-analysis found that MTA has a higher success rate and results in less pulpal inflammatory response than calcium hydroxide [16].

In addition to MTA, calcium silicate-based materials have gained in popularity due to their resemblance to MTA and their applicability in instances where MTA is indicated. One calcium silicate-based product (Biodentine) became commercially available in 2009. Biodentine has a wide range of applications including pulp capping. Studies of the product are generally favorable, although accumulation of long-term clinical trial data is needed [17].

The most frequent criteria by which long-term success is evaluated for a direct pulp cap intervention are lack of patient-reported symptoms, positive tests for pulp vitality, and the lack of the development of an apical lesion secondary to necrotic pulp (evident on x-ray). Patients should be advised that root canal treatment is always a possibility for teeth that require direct pulp caps after traumatic injury, even if there is a protracted lack of symptoms. Before endodontic therapy is begun, the teeth should be examined carefully for cracks or fractures that could preclude the ability to obtain a successful result.

TRAUMATIZED PERMANENT TEETH WITH OPEN APICES

When the permanent teeth of children and adolescents are injured, the approach to treatment is different than the approach for permanent teeth with complete root development. The Andreasen classification of crown fractures still applies to these teeth. However, the pulp chamber of immature permanent teeth occupies a larger volume of the clinical crown and is closer to the exterior surface of the tooth compared with the same tooth of an adult. Thus, what would be an uncomplicated fracture in an adult could be a complicated fracture with pulpal involvement in a child or adolescent.

Uncomplicated fractures of permanent teeth with open apices are generally amenable to treatment by the placement of composite restorations. Complicated fractures involving the pulp in teeth in which the root apex is still open present unique challenges. The initial concern is the alleviation of the pain that accompanies the traumatic injury and restoration of the function and cosmetics of the tooth. The ultimate challenge is to maintain the vitality of the pulp, which is essential in the completion of the development of the root, the closure of its apex, and the developing and thickening of the walls of the root canal. If the pulp becomes necrotic, the tooth will not complete the maturation process and will be more vulnerable to fracture compared with teeth with fully developed roots.

Treatment options for complicated fractures of incompletely developed permanent teeth with vital pulps and open apices depend on the extent to which the pulp has been exposed. Apexogenesis may be used to maintain the vitality of an exposed pulp of an immature permanent tooth as it promotes physiologic development and the closure of its apex [18]. Direct pulp capping with either calcium hydroxide or MTA followed by the placement of a definitive restoration is the most conservative approach [19]. The pulp may heal and allow root development to complete with no further endodontic treatment required. Patients with complicated fractures in immature permanent teeth who are treated with direct pulp capping should be monitored for signs of pain, swelling, or sensitivity to percussion. Radiographs should be taken on a periodic basis to determine if the root development and apical closure are commencing as expected. Even if root formation and apical closure progress, there is a possibility that endodontic treatment will be necessary in the future.

Complicated fractures that result in large areas of exposed pulp will not be amenable to the direct pulp capping technique. In these cases, a partial pulpotomy is more appropriate. This technique features the removal of 2–3 mm of the exposed pulpal tissue from the coronal aspect of the tooth, with a biologically compatible dressing placed over the remaining pulp tissue [20]. The objective of this technique is to preserve the vitality of the remaining pulpal tissue to allow for root development and apical closure, after which conventional endodontic therapy may be completed. The biocompatible material most frequently used to cover the coronal aspect of the pulpal tissue after a partial pulpotomy is calcium hydroxide. This material has some disadvantages, including a high solubility in oral fluids, inability to adhere to dentin, and the possibility of tunnel defects in the reparative dentin bridge allowing bacterial infiltration into the pulp [21]. MTA has seen increasing use for partial pulpotomy procedures, as it is biocompatible, provides a good seal, and maintains an extended high pH with associated bactericidal effects [22; 23]. Each material has its merits, and practitioners should determine which is most appropriate for the given clinical situation based on the success of their own experience coupled with clinical trials and updated research.

Direct pulp capping or partial pulpotomy techniques are not always successful in maintaining the vitality of the pulp. Large pulpal exposures and/or an extended length of time between the traumatic incident and the initiation of therapy may result in extensive bacterial contamination of the pulp chamber and ultimately necrosis of the pulp. If the immature permanent tooth has an open apex and is nonvital, apexification is indicated. This procedure is designed to induce the formation of a calcified apical barrier, which provides a definitive apical stop for a conventional root canal filling material, such as gutta-percha. Apexification involves removal of the coronal and non-vital tissue within the root and placement of an intra-canal medication (e.g., calcium hydroxide or MTA) to disinfect the canal space [24]. It is imperative that the temporary restoration that covers the access to the coronal pulp and canal has an adequate seal to prevent bacterial infiltration and reinfection. A definitive restoration such as a composite resin is then used to seal the access. The time to achieve apexification can range from 6 to 18 months, during which three-month recall appointments are necessary to monitor progress [25]. The development of a calcified barrier can be confirmed by radiographs or by the tactile sensation of a definitive apical stop as perceived by an endodontic instrument (e.g., a size 35 endodontic file). Conventional endodontic treatment may be completed after the apical barrier has been established. Patients should be advised that this procedure will not allow the root canal walls to develop and thicken, so the tooth and the root will remain more susceptible to fracture. Patients who engage in sports or any athletic activity should wear a protective mouth guard to decrease the potential for injury.

TRAUMATIZED DECIDUOUS TEETH

Among the deciduous teeth, the anterior teeth are most commonly damaged during oral and maxillofacial trauma. The restoration of traumatized deciduous teeth reflects their unique anatomy. Compared with permanent teeth, deciduous teeth have thinner enamel and dentin and larger pulp chambers, with pulp horns that can extend further toward the external surface of the tooth. The roots of deciduous teeth are narrower in a mesial-to-distal direction, and those of the deciduous molars have slender curvatures over the permanent bicuspids. The decision to restore a traumatized

deciduous tooth should take into consideration its life expectancy, especially when a complicated fracture involves the pulp. Teeth that are traumatized and painful and expected to be exfoliated soon should be extracted; those with an extended life expectancy should be restored.

Composite restorations may be used to restore deciduous teeth with uncomplicated fractures of the enamel with or without damage to the dentin. Larger uncomplicated fractures of anterior teeth may be restored with composite resin strip crowns, while stainless steel crowns are an option for posterior teeth.

Complicated fractures of deciduous teeth with small pulpal exposures may be treated with direct pulp capping with either calcium hydroxide or MTA applied directly to the exposure. Complicated fractures that involve large segments of the coronal pulp are beyond the therapeutic limits of the direct pulp capping technique; pulpotomy with placement of a long-term restoration is recommended in these situations [26]. If treatment is delayed or inadequate, traumatized deciduous teeth with pulpal involvement may become necrotic and develop an abscess or cellulitis, which is painful for the patient and may damage the underlying permanent tooth.

Methods such as apexification, apexogenesis, pulp capping, and pulpotomy are exacting procedures, and their success or lack thereof will influence the development of permanent teeth and the ability to retain deciduous teeth until they are ready to exfoliate. Clinicians who do not have the appropriate experience in this area should refer patients to a pedodontist or an endodontist.

According to the American Academy of Pediatric Dentistry, the presence of a root tip should not be regarded as a positive indication for its removal. The dilemma to consider when managing a retained primary tooth root is that removing the root tip may cause damage to the succedaneous tooth, while leaving the root tip may increase the chance for postoperative infection and delay eruption of the permanent successor. Radiographs can assist in the decision process. Expert opinion suggests that if the fractured root tip can be removed easily, it should be removed.

(https://www.aapd.org/media/Policies_Guidelines/BP_OralSurgery.pdf. Last accessed June 14, 2021.)

Level of Evidence: Expert Opinion/Consensus Statement

ROOT FRACTURES OF DECIDUOUS AND PERMANENT TEETH

Trauma to the teeth may cause fractures of the root in addition to complicated and uncomplicated fractures of the crown. As noted, anterior teeth are most frequently involved in oral and maxillofacial trauma, and when root fractures occur in deciduous anterior teeth, the prognosis is generally poor.

Deciduous incisors have roots that are narrower and smaller than their permanent successors, and fractures that extend onto the root surface will leave minimal residual root structure with which predictable pulpal and restorative therapy may be completed. In most cases, deciduous teeth with root fractures are best treated by extraction. The ability to obtain an adequate surgical purchase of the remaining segment of the deciduous tooth can be a challenge, especially if the fracture extends below the gingival margin at an oblique angle.

The extraction of any deciduous tooth entails a meticulous approach to ensure that its permanent successor it is not damaged. The ability of the pediatric patient to withstand a surgical procedure is another consideration. If any of these factors present a problem for the practitioner, referral to a pedodontist or an oral surgeon is appropriate, especially if the patient requires sedation.

The roots of permanent teeth are larger and more able to withstand traumatic forces compared with those of deciduous teeth. However, the roots of permanent teeth may still be fractured, and the amenability of these teeth to restoration depends upon the extent and location of the fracture, the pre-existing condition of the tooth, and the current periodontal condition for the tooth.

Root fractures in permanent teeth are usually an extension of a fracture through the enamel and dentin; the pulp may or may not be involved. Root fractures are uncommon, but when they do occur, 68% involve the maxillary central incisors and 27% involve the maxillary lateral incisors [27].

Vertical fractures are less common and have the worst prognosis, as they divide the tooth into mesial and distal or buccal and lingual halves. Tooth structure separated in this fashion is not amenable to endodontic treatment; the vertical fracture will not permit a hermetic seal or placement of a crown. Permanent teeth with vertical fractures are usually extracted, because the structural integrity of the tooth is irreversibly compromised. These extractions can be difficult, as the fractured segments offer an inadequate purchase for instrumentation and the remaining root fragment may be several millimeters below the osseous crest. Preservation of the alveolar ridge is essential if implants or removable prosthetics will be used to replace the extracted tooth or teeth, and clinicians should use a surgical technique to retrieve the fractured segments that minimizes the resection of bone but allows for adequate access and removal of the fractured roots.

Horizontal root fractures are the most common type and commonly occur in the maxillary anterior region, usually in the central incisors [28]. Horizontal root fractures are classified according to several features, including the extent of the damage and the location of the fracture. The extent of the fracture(s) is categorized as either single, multiple, or comminuted (pulverized), the last of which is associated with a poor prognosis for retention of the tooth. Partial or total fractures refer to the extent that the coronal fragment is dislocated. If the fractured coronal segment is in alignment with the rest of the root, the fracture is not displaced; those that lack alignment are considered displaced fractures. The location of the fracture is also subject to classification. Those that occur from the occlusal/incisal edge to the alveolar crest are zone 1 fractures, (analogous to a crown fracture) while zone 2 fractures are located between the alveolar crest of bone and 5 mm below this level (i.e., a cervical-root fracture). Zone 3 fractures, also referred to as middle/apical root fractures, occur anywhere from the root apex to 5 mm below the alveolar crest [29]. Most horizontal root fractures possess a combination of these features, with the prognosis for the retention of the tooth reduced as the number and complexity of these factors increase. Fractures of the root may be accompanied by fractures in the clinical crown of the tooth, which adds to the complexity of restoring the tooth.

Treatment of horizontal root fractures varies according to the complexity of the fracture, the degree of co-existing damage to the clinical crown, and the patient's preferences and ability to undergo and finance treatment, which may include endodontic therapy, periodontal (crown-lengthening) surgery, crown build-ups, and crowns. Most fractures heal, and not all require endodontic therapy [30].

Healing of the root fracture occurs by one of four different histologic types. Type I healing features calcified tissue (callus formation) developing and forming a union between the fractured segments. Type II healing is characterized by connective tissue uniting the fractured segments and the development of peripheral rounding at the fracture's ends. The combination of bone and connective tissue maturation and a separation of the coronal and apical fractured segments (as seen on x-ray) is indicative of type III healing. Type IV is the least favorable mode of healing and features the formation of granulation tissue between the fractured coronal and apical segments; this is indicative of pulpal necrosis [1].

Type I healing usually occurs when there is no or minimal dislocation of the fractured coronal segment, while type II healing is more likely when fractured coronal segments are laterally dislocated or extruded. If the tooth is traumatized before maturation of the alveolar process is complete, healing is typically type III. In this situation, the fractured coronal segment continues to erupt but the apical segment will remain in its pre-trauma position, with subsequent growth of both bone and connective tissue between the fractured segments. Type IV healing is an inflammatory reaction originating from a necrotic pulp [1].

Immediate endodontic treatment is not recommended for teeth with horizontal root fractures as only about 20% of teeth with this injury will ultimately develop pulpal necrosis [31]. The initial treatment of horizontal root fractures should reposition the fractured coronal segment if it has become displaced, with radiographic verification of proper alignment. A splint of composite resin can provide the initial fixation and stabilization and should remain in place for four weeks. Teeth with horizontal root fractures near the cervical area of the tooth may require splint stabilization for up to four months [3]. The occlusion of the affected tooth may be adjusted to minimize the forces applied against it after the application of the splint.

Approximately 70% to 80% of all horizontal root fractures will fully heal [32]. Despite this excellent prognosis, problems requiring endodontic therapy may occur in the initial stages of healing. Symptoms such as pain, sensitivity to apical palpation and percussion, and discoloration of the tooth often indicate a need for endodontic intervention. When these symptoms are absent, the healing status of the pulp should be monitored for at least one year before definitive endodontic treatment is initiated [33]. When teeth with horizontal root fractures develop pulpal necrosis, endodontic therapy is usually performed on the coronal segment only [27]. In these cases, extirpation of the necrotic tissue within the fractured coronal segment of the tooth is followed by the placement of calcium hydroxide or MTA in the root canal. If the tooth is asymptomatic, gutta-percha may be used for obturation of the canal; however, teeth with horizontal root fractures lack the definitive apical stop that provides a boundary for the gutta-percha. Clinicians who have not performed endodontic therapy on teeth with horizontal root fractures should consider the referral of the patient to a specialist for this procedure. These teeth may develop long-term problems, such as internal or external root resorption, despite an initial lack of symptoms or the completion of high-quality endodontic therapy. While some will need to be extracted, most teeth can be retained.

LUXATION INJURIES TO PERMANENT AND DECIDUOUS TEETH

The previous sections have discussed traumatic injuries to the clinical crown and the roots of both deciduous and permanent teeth. Another potential of traumatic injury to the teeth is luxation, the partial or complete displacement of a tooth from its secured position within the alveolar bone. Luxation injuries may occur in deciduous and/or permanent teeth, with varying treatment options and prognoses.

A traumatic injury to a primary or deciduous tooth in which there is no loosening or displacement from the alveolar socket is referred to as concussion. In these cases, the periodontal ligament absorbs the force of the injury, and its inflammatory response manifests as sensitivity to pressure on and percussion of the tooth [34]. The clinical position of the tooth remains unchanged, and there are no radiographic abnormalities. Usually, no treatment is needed, but occasional complications (e.g., lack of continuing root development) may occur in permanent teeth with incompletely formed roots. The pulpal status of these teeth should be monitored for one year, as injuries to the blood vessels can lead to an inflammatory response in the pulp and even pulpal necrosis [35].

Subluxation refers to a traumatic injury that causes increased mobility of the tooth without displacement. Sensitivity to percussion or palpation and gingival bleeding can occur. While mobility patterns exist, subluxated teeth are not associated with abnormal radiographic findings. In some cases, blood vessels may be injured, leading to pulpal necrosis. This type of injury necessitates endodontic therapy appropriate for the type of tooth (i.e., deciduous or permanent) and the stage of tooth development. A flexible splint may be used for up to two weeks for subluxated permanent teeth that demonstrate moderate mobility [33].

Extrusive luxation is defined as the partial displacement of a tooth from its socket in an axial direction coronally. These teeth have an elongated appearance compared to the adjacent teeth and have mobility of varying degrees. Radiographs will demonstrate an increased dimension of the periodontal ligament space in the apical region.

When deciduous teeth are affected, spontaneous repositioning within the socket is possible. If manual repositioning of an extruded deciduous tooth is attempted, it should be done with care and consideration for the permanent tooth bud developing beneath it. Extruded deciduous teeth with excessive mobility or those that are nearing exfoliation should be extracted [36].

Extruded permanent teeth should be repositioned as soon as possible after the injury to give the periodontal ligament and neurovascular supply a chance to heal. A flexible splint may be applied to promote stabilization within two weeks of the incident. Permanent teeth with incompletely formed roots should be monitored carefully to determine if revascularization has occurred, as evidenced by the continued development of the root. Permanent teeth with completely formed roots should be monitored for signs or symptoms of pulpal necrosis, for which endodontic therapy would be required.

Intrusive luxation involves displacement of the tooth axially into the alveolar bone, usually accompanied by a severing of the blood supply to the pulp and damage to the periodontal ligament [37]. The degree of intrusion is graded according to the amount of tooth visible after the injury. When more than 50% of the crown is visible, this is considered mild partial intrusion or grade I. Grade II injuries feature moderate partial intrusion in which less than 50% of the clinical crown is visible. Severe or complete intrusion of the crown is assigned grade III [38]. Approximately 90% of intruded deciduous teeth will reposition spontaneously within two to six months of the traumatic incident [39]. If the apex of the root of a deciduous tooth has been displaced toward the developing permanent tooth germ, the deciduous tooth should be extracted [40].

Some deciduous teeth that are retained after an intrusive injury will develop ankylosis, a condition in which the root of the tooth is fused directly to the bone. This can prevent the normal sequence of exfoliation of the deciduous tooth. If ankylosis is present, extraction of the deciduous tooth will be required to allow for the eruption of the permanent tooth. Ankylosed teeth can be difficult to remove, especially if the affected root is in close proximity to the developing permanent tooth. Referral to an oral surgeon or a pedodontist should be considered.

There is a significant risk that intrusive luxation of permanent teeth with completely formed roots will develop pulpal necrosis requiring conventional endodontic therapy. Permanent teeth with incompletely formed roots may reposition spontaneously and the vasculature necessary to complete the development of the root may be re-established. If this does not occur, orthodontic or surgical repositioning of the intruded tooth will be necessary. After an intruded tooth has been repositioned, a flexible splint should be applied for one to two months in order to provide stabilization [3]. The pulpal status of the repositioned tooth should be monitored for signs and symptoms of inflammatory change or necrosis. This is a special concern for necrotic permanent teeth with incompletely developed roots for which apexification procedure is necessary.

AVULSION

Avulsion is the complete displacement of the tooth from the alveolar socket—the most extreme of the traumatic displacement injuries of teeth. When this occurs to a deciduous tooth, it is not replanted due to the high potential for inflammation and necrosis, which can damage its permanent successor. The socket of the deciduous tooth should be inspected for retained root fragments and to rule out an accompanying fracture of the alveolar bone.

Avulsed permanent teeth are most commonly the result of sports injuries, accidental falls, motor vehicle accidents, and altercations. Locating the tooth may be difficult when avulsion is the result of an automobile accident or other serious trauma for which the treatment of more serious injuries takes precedence. If possible, time should be taken to attempt to find the tooth for replantation.

The amount of time that elapses between the actual avulsion of the tooth and its replantation into the socket remains the most important factor in ensuring the long-term retention of the tooth [41]. It is also critical that any portion of the periodontal ligament still attached to the avulsed tooth remains hydrated during transit to the dental office. Avulsed teeth that have been kept dry for 60 minutes will experience death of the cells of the periodontal ligament and a subsequent poor prognosis for replantation and retention [42]. Desiccation of the periodontal ligament will result in severe inflammation over much of the root surface upon replantation and decreases the likelihood of a successful replantation [43]. Commercially available transportation media solutions provide the best means of hydration for the periodontal ligament of an avulsed tooth, but because these accidents often occur without warning, alternative transport techniques may be employed. The avulsed tooth may be placed in the patient's buccal vestibule and immersed in the patient's saliva, with caution taken to avoid swallowing or aspirating the tooth. Patients may also expectorate into a clean container containing the avulsed tooth for transport. Cold milk or physiologic saline (0.9%) solutions are other options for transport media but are less beneficial than the commercial products or saliva [44]. Transport in water should only be considered if no other means of hydration is available, as its low osmolality can cause damage to the periodontal ligament if the tooth is immersed for more than 20 minutes [1].

Office treatment protocols will vary for avulsed permanent teeth with mature or immature roots. Before replantation, the surface of the root of an avulsed tooth should be inspected for visible debris and rinsed with sterile saline solution or water to prevent contaminants from being introduced into the alveolar socket. After the administration of a local anesthetic, the socket should be lightly aspirated to remove the blood clot and any debris that has accumulated. If the alveolar bone has fractured and collapsed into the socket, it will be an obstacle and should be repositioned prior to replantation of the root. Permanent teeth with closed apices should be replanted into the alveolar socket, with radiographic confirmation that the appropriate position has been re-established. A semi-rigid (physiologic) splint should be applied for seven to 10 days, unless there is an accompanying fracture of the alveolar bone, in which case the splint should remain affixed for four to eight weeks [1]. The occlusion of the avulsed tooth should be adjusted to minimize any additional force during functional excursions. There is no chance of revascularization of an avulsed permanent tooth with a closed apex, so endodontic therapy should commence within seven to 10 days of the placement of the splint. After debridement of the canal, calcium hydroxide may be used as a temporary obturating material. The calcium hydroxide should be changed every three months for six to 24 months, until there is radiographic evidence of the development of the periodontal membrane around the root, at which point conventional endodontic therapy may be completed [41].

Avulsed permanent teeth with open apices have the potential for revascularization and continued root development after replantation [43]. Soaking the avulsed tooth in a doxycycline solution for five minutes prior to replantation increases the chance of revascularization [45]. After the tooth has been replanted, a flexible splint should remain attached for two weeks, with the duration extended to four weeks if the tooth has been transported in dry storage for more than 60 minutes [44; 46]. The patient should be monitored every four weeks with pulp tests and radiographs to determine if necrosis is developing or if revascularization has been successful and the formation of the root is continuing. If necrosis develops, apexification with either calcium hydroxide or MTA should be conducted, with definitive endodontic therapy completed after a calcified apical stop has developed.

The teeth of patients with any type of luxation injury should be monitored carefully [44]. Even when prompt and appropriate treatment is provided, problems such as external root resorption and ankylosis can develop and challenge the ability to retain these teeth months or years after the traumatic incident. General practitioners with minimal experience in the treatment of luxation injuries should consider referral to practitioners with more expertise or specialists such as pedodontists or endodontists.

TRAUMATIC INJURIES OF OTHER STRUCTURES WITHIN THE ORAL AND MAXILLOFACIAL COMPLEX

To this point, this course has focused on traumatic injuries of the deciduous and permanent teeth and the various options that exist for their restoration and retention. This section will provide an overview of injuries that can occur to the supporting structures of the oral and maxillofacial complex in addition to or apart from the traumatic injuries sustained by the teeth.

FRACTURES OF THE MANDIBLE: ORAL COMPLICATIONS

The mandible is the only movable bone of the face and is the osseous structure most vulnerable to maxillofacial trauma [47]. The mechanism of injury of mandibular fractures differs by gender, with men most often sustaining fractures from assault (49.1%) and motor vehicle accidents (25.4%), and women most often sustaining them from motor vehicle accidents (53.7%), falls (23.7%), and physical assault (14.5%) [48]. Treatment of mandible fracture is completed in a hospital setting by an oral and maxillofacial surgeon or a general surgeon and is beyond the scope of this course.

Instead, this section will focus on some of the most common oral complications secondary to trauma sustained by this structure.

After surgical reduction of the fractured mandible, the most common complications are infection and nonunion of the separated segments [49]. When the integrity of the mucosa is compromised, the fractured segments of the mandible are exposed to bacterial and fungal species from the oral microflora. These micro-organisms may become pathogenic when they are introduced deep within the muscle and bone. Teeth with necrotic pulps and apical lesions are another possible source of bacterial contamination if the roots of the affected teeth approximate the fracture lines. Treatment consists of incision and drainage of the area, systemic antibiotics, and/or the removal of necrotic teeth or necrotic pieces of bone. Internal fixation devices should be removed and replaced if they become loose.

Infections are a particular concern with mandibular fractures, as they are one of the causes of nonunion of the fractured segments; inaccurate surgical reduction is another common cause. Treatment of nonunion of the fractured segments requires identification and resolution of the underlying cause. If an infection is present, it should be resolved before surgical reconstruction is attempted. Surgical reconstruction may consist of removal of any existing hardware at the fracture site, the removal of necrotic bone and granulomatous tissue, the use of autogenous bone grafts to replace osseous deficits, and/or the application of new hardware to unite the fractured segments [50].

Another complication that may occur during mandibular fracture is damage to the inferior alveolar nerve (IAN), which is a branch of the mandibular division (V3) of cranial nerve V (the trigeminal nerve). The IAN enters the mandible at the inner aspect of the ramus and proceeds anteriorly within the mandibular canal. The IAN provides motor innervation to some of the muscles of mastication and provides sensory innervation to the lower teeth and contiguous gingival tissues. The mental nerve branches from the IAN near the bicuspid area via the mental foramen and provides sensory innervation to surfaces of the lower lip. Fractured segments of the mandible can cause direct injury to the IAN via compression and result in paresthesia, which is described as a tingling ("pins and needles") feeling, within the affected area. The worst outcome occurs when force of the traumatic impact causes the nerve to be severed, which results in anesthesia, or a complete lack of sensation in the area. This type of injury to the IAN may also occur during surgical procedures, especially those that involve impacted mandibular wisdom teeth.

Another branch of the trigeminal nerve V3, the lingual nerve, provides sensory innervation to the anterior two-thirds of the tongue, the floor of the mouth, and the lingual gingival tissues. This nerve emerges between the medial pterygoid muscle and the ramus of the mandible before it courses anteriorly on the inner aspect of the mandible. The lingual nerve may sustain injuries when a mandibular fracture is complex and displaced or may be bruised or severed during oral surgery procedures (particularly extractions of impacted wisdom teeth). Bruising of the lingual nerve can lead to a paresthesia, while severing of the nerve leads to anesthesia of the affected areas.

Most nerves that have developed paresthesia secondary to trauma or iatrogenic incidents will resolve over time, but some can be permanent. Microsurgery techniques used to repair nerve damage, such as direct nerve repairs or autogenous nerve grafts, have variable rates and degrees of success [51]. Anesthesia, whether caused by trauma or by iatrogenic means, will remain a permanent condition for some patients. Home care instructions for patients who develop either condition should include instructions to avoid traumatizing tissue during eating or brushing. The maintenance of good oral hygiene at home can become a challenge for patients if the anesthesia is permanent, so frequent recall appointments may be necessary.

OTHER FACIAL FRACTURES

Although less common, fractures of the maxilla and the bony orbit (i.e., eye socket) may have complications that affect the oral cavity or structures. These types of fractures are generally the result of blunt force trauma to the face, usually as the result of a motor vehicle accident, violence, or fall [52]. The type and extent of maxillary fractures have historically been characterized using the Le Fort system as horizontal, pyramidal, transverse, or a combination of these types; however, there are some relatively common maxillary fractures that defy this system, including small areas of fracture. CT scans are the modality of choice for the diagnosis of maxillary fractures [53].

Of note for dental professionals is the risk of maxillary tuberosity fractures during molar teeth extraction [54]. The maxillary tuberosity provides important support to maxillary teeth, and large fractures of this structure can have serious long-term complications for patients. If this complication arises, it is vital that it is treated immediately by an oral surgeon.

INJURIES ASSOCIATED WITH CHILD ABUSE

There are no traumatic injuries to the facial structures or teeth that can provide indisputable evidence that a child has been abused or that an adult has been the victim of domestic violence. However, certain patterns of injuries and patient behaviors should begin to raise suspicion of abuse. Every state requires dentists to report suspected cases of child abuse and neglect to the appropriate authorities. In some cases, the failure to do so is a punishable offense [55].

The dental team is in an excellent position to evaluate potential cases of child abuse and neglect, as injuries to the head, neck, face, and intraoral regions are common among abused children. In one study, orofacial trauma was concurrent with 16% of proven cases of pediatric abusive head trauma ("shaken baby syndrome") [56]. As children mature, most will sustain bruises on their foreheads, knees, elbows, and other areas of bony prominences as a result of accidental injuries during athletic events or recreational activities. Injuries to soft tissues not supported by bone, such as the lips, the cheeks below the zygomatic arch, and the neck in various stages of healing, should be viewed with suspicion, especially if they are bilateral and/or inappropriate for the child's developmental age. A meticulous examination of the teeth, soft tissues, and perioral structures may reveal signs and symptoms that are suggestive, though not conclusive, of a pattern of abuse. The presence of bruise marks or petechiae on the soft palate may be a sign of forced oral sex. Bilateral bruising on the corners of the mouth may reflect the use of ropes or a gag placed in an effort to control or discipline the child. Similarly, bilateral bruising of the neck may be the result of an attempt to choke or shake a child. Torn frenal attachments or lacerations of the tongue, gingiva, or oral mucosa are also signs that bear further inquiry. Extensive traumatic damage to deciduous or permanent teeth, such as fractures, avulsions, or luxation, without a viable explanation is also suggestive of child abuse. When a parent or caregiver is reluctant to discuss the nature of the injuries or makes statements that are contradictory or inconsistent with the injuries, further investigation into their origin is warranted.

INJURIES ASSOCIATED WITH DOMESTIC VIOLENCE

The injury patterns indicative of physical abuse and domestic violence in adults may be severe. Domestic violence involves people of all ages, races, socioeconomic classes, religious affiliation, or gender identity. However, domestic violence is predominantly perpetrated by men against women [57]. Beyond physical abuse, domestic violence can include psychologic abuse, sexual assault/rape, coercive behavior, threatening words or gestures, stalking, and attempts to isolate the victim from

family and friends. In the absence of an admission or a plea for help from the victim, there are clinical signs that are strongly suggestive (though not definitive) of domestic violence. The oral mucosa may be bruised when slaps or hits push the intraoral tissues against teeth or bony prominences; the skin over the affected area may also exhibit bruises. Bilateral bruises on the neck and petechiae or bruising patterns on the face or neck may reflect attempts to strangle or shake the victim. Current or previous fractures of the nose, maxilla, or mandible (as evidenced by radiographic findings) alone or in conjunction with soft tissue injuries in various stages of healing should result in nonjudgmental and sensitive questioning regarding possible abuse.

These are never easy conversations to initiate, but for the safety of the victim it is essential that they are performed. Other clinical signs that may indicate potential domestic abuse include hair loss in asymmetrical patches, torn frenal attachments, fractures of anterior teeth that lack caries, bite marks, and injuries to the arms, legs, or hands. Each clinician has a moral and ethical obligation to discuss these clinical signs with the patient to determine their origin and to assist the patient to obtain the necessary help and resources to leave the abusive environment safely.

CONCLUSION

The treatment of oral and maxillofacial trauma can range from a simple composite restoration to the surgical reduction of complex mandibular fractures. This course has discussed some of the most common traumatic injuries affecting the teeth and structures in the oral and maxillofacial complex as well as appropriate treatment methods. However, it is by no means an exhaustive list of traumatic oral or dental injuries or the clinical methods by which they can be treated.

Trauma cases occur without warning and require prompt treatment for their successful remediation. Practitioners should conduct an honest self-appraisal of the clinical and patient management skills necessary for a successful clinical outcome. Participation in post-graduate continuing education courses and training provides a means to reinforce basic techniques or obtain updated information about the management of these traumatic injuries. Whether a fractured tooth is being restored in a private dental office or a fractured jaw is being treated in a hospital setting, expertise is required to provide for the needs of the patient.

Works Cited

1. Andreasen JO, Andreasen FM, Anderson L (eds). *Textbook and Color Atlas of Traumatic Injuries to the Teeth*. 5th ed. Oxford: Wiley Blackwell; 2018.
2. Flores MT. Traumatic injuries in the primary dentition. *Dent Traumatol*. 2002;18(6):287-298.
3. The International Association of Dental Traumatology. Dental Trauma Guidelines. Available at https://www.iadt-dentaltrauma.org/GUIDELINES_Book.pdf. Last accessed May 25 2021.
4. Bakland LK, Andreasen JO. Dental traumatology: essential diagnosis and treatment planning. *Endodontic Topics*. 2004;7:14-34.
5. Dental Trauma Guide. Permanent Teeth. Available at https://dentaltraumaguide.org/free-dental-guides/permanent-teeth. Last accessed May 25, 2021.
6. Dean JA. *Dentistry for the Child and Adolescent*. 11th ed. Maryland Heights, MO: Mosby; 2021.
7. Bui DX. Dentinal Hypersensitivity. Available at https://drbui.com/artdentinhypersensitivity.html. Last accessed May 25, 2021.
8. Lawson NC, Cakir D, Beck P, Ramp L, Burgess JO. Effect of light activation on resin-modified glass ionomer shear bond strength. *Oper Dent*. 2012;37(4):380-385.
9. Willerhausen B, Willerhausen I, Ross A, Kasaj A, Biettner M. Retrospective study on direct pulp capping with calcium hydroxide. *Quintessence Int*. 2011;42(2):165-171.
10. Dominguez MS, Witherspoon DE, Gutman JL, Opperman LA. Histological and scanning electron microscopy assessment of various pulp-therapy materials. *J Endodontic*. 2003;29(5):324-333.
11. Bindslev-Hosted P, Lovschall H. Treatment outcome of vital pulp treatment. *Endodontic Top*. 2002;2:24-34.
12. Goldberg M, Lacerda-Pinheiro S, Jegat N, et al. Bioactive molecules stimulate tooth repair and regeneration. *J Hard Tissue Biol*. 2006;15(2):36-45.
13. Weiner R. Liners, Bases, and Cements in Clinical Dentistry: A Review and Update. Available at https://www.dentistrytoday.com/materials/1482. Last accessed May 25, 2021.
14. Rao A, Rao A, Shenoy R. Mineral trioxide aggregate: a review. *J Clin Pediatr Dent*. 2009;34(1):1-7.
15. Aeinehchi M, Eslami B, Ghanbariha M, Saffar AS. Mineral trioxide aggregate (MTA) as pulp-capping agents in human teeth: a preliminary report. *Int Endodontic J*. 2003;36(3):225-231.
16. Li Z, Cao L, Fan M, Xu Q. Direct pulp capping with calcium hydroxide or mineral trioxide aggregate: a meta-analysis. *J Endod*. 2015;41(9):1412-1417.
17. Malkondu O, Kazandag MK, Kazazoglu E. A review on Biodentine, a contemporary dentine replacement and repair material. *Biomed Res Int*. 2014;10:160951.
18. Goldstein S, Sedaghat-Zandi A, Greenberg M, Friedman S. Apexification and apexogenesis. *N Y State Dent J*. 1999;65(5):23-25.
19. Jackson N, Waterhouse P, Maguire A. Factors affecting treatment outcomes following complicated crown fractures managed in primary and secondary care. *Dent Traumatol*. 2006;22(4):179-185.
20. Abarajithan M, Velmurugan N, Kandaswamy D. Management of recently traumatized maxillary central Incisors by partial pulpotomy using MTA: case reports with two-year follow-up. *J Conserv Dent*. 2010;13(2):110-113.
21. Cox CF, Subay RK, Ostro E, Suzuki SH. Tunnel defects in dentin bridges: their formation following direct pulp capping. *Oper Dent*. 1996;21(1):4-11.
22. Moghaddame-Jafari S, Mantellini MG, Botero TM, McDonald NJ, Nor JE. In vitro effect of ProRoot MTA on pulp cell apoptosis and proliferation. *J Endodontic*. 2005;31(5):387-391.
23. Caprioglio A, Conti V, Caprioglio C, Caprioglio D. A long-term retrospective clinical study on MTA pulpotomies in immature permanent incisors with complicated crown fractures. *Eur J Paediatr Dent*. 2014;15(1):29-34.
24. The American Academy of Pediatric Dentistry. Guideline on Pulp Therapy for Primary and Immature Permanent Teeth. Available at https://www.aapd.org/globalassets/media/policies_guidelines/bp_pulptherapy.pdf. Last accessed May 25, 2021.
25. Beslot-Neveu A, Bonte E, Baune B, et al. Mineral trioxide aggregate versus calcium hydroxide in apexification of non-vital immature teeth: study protocol for a randomized controlled trial. *Trials*. 2011;12:174.
26. Waterhouse PJ, Whitworth JM. Pediatric endodontics: endodontic treatment for the primary and young permanent dentition. In: Hargreaves KM, Berman LH (eds). *Pathways of the Pulp*. 11th ed. St. Louis, MO: Mosby Elsevier; 2016: e1-e19.
27. Wolner-Hanssen AB, von Arx T. Permanent teeth with horizontal root fractures after dental trauma: a retrospective study. *Schweiz Monatsschr Zahnmed*. 2010;120(3):200-206.
28. Majorana A, Pasini S, Bardellini E, Keller E. Clinical and epidemiological study of traumatic root fractures. *Dent Traumatol*. 2002;18(2):77-80.
29. Malhotra N, Kundabala M, Acharaya S. A review of root fractures: diagnosis, treatment and prognosis. *Dent Update*. 2011;38(9):615-616, 619-620, 623-624.
30. Aras MH, Ozcran E, Zorba YO, Aslan M. Treatment of traumatized maxillary permanent lateral and central incisors horizontal root fractures. *Indian J Dent Res*. 2008;19(4):354-356.

31. Cvek M , Tslinggardis G, Andreasen JO. Survival of 534 incisors after intra-alveolar root fractures in patients aged 7-17 years. *Dent Traumatol*. 2008;24(4):379-387.
32. Poi WR, Manfrin TM, Holland R, Sonoda CK. Repair characteristics of horizontal root fracture: a case report. *Dent Traumatol*. 2002;18(2):98-102.
33. Flores MT, Andersson L, Andreasen JO, et al. Guidelines for the management of traumatic dental injuries. I. Fractures and luxations of permanent teeth. *Dent Traumatol*. 2007;23(4):66-71.
34. The American Academy of Pediatric Dentistry. Guideline on Management of Acute Dental Trauma. Available at http://www.aapd.org/assets/1/7/G_Trauma.pdf. Last accessed May 25, 2021.
35. Andreasen JO, Andreasen FM. *Essentials of Traumatic Injuries to the Teeth*. 2nd ed. Copenhagen: Munksgaard and Mosby; 2009.
36. Holan G, McTigue D. Introduction to dental trauma: managing traumatic injuries to the primary dentition. In: Casamassimo PS, Fields HW Jr, McTigue DJ, Nowak A (eds). *Pediatric Dentistry: Infancy through Adolescence*. 6th ed. St. Louis, MO: Elsevier Saunders; 2018: 227-243.
37. Andreasen J, Cornelius CP, Gellrich N, Hillerup S, Kusumoto K, Schubert W. Dentoalveolar Trauma: Diagnosis. Available at https://surgeryreference.aofoundation.org/cmf/trauma/dentoalveolar-trauma. Last accessed May 25, 2021.
38. Gupta M. Intrusive luxation in primary teeth: review of the literature and report of a case. *Saudi Dent J*. 2011;23(4):167-176.
39. Godim JO, Moreira Neto JJ. Evaluation of intruded primary incisors. *Dent Traumatol*. 2005;21(3):131-133.
40. Day PF, Flores MT, O'Connell AC, et al. Guidelines for the management of traumatic dental injuries. 3. Primary teeth. *Dent Traumatol*. 2020;36:343-359.
41. Trope M. Clinical management of the avulsed tooth: present strategies and future directions. *Dent Traumatol*. 2002;18(1):1-11.
42. Kinirons M, Boyd D, Gregg T. Inflammatory and replacement resorption in reimplanted permanent incisor teeth: a study of the characteristics of 84 teeth. *Endodontic Dent Traumatol*. 2000;15(6):269-272.
43. Sigalas E, Regan J, Kramer P, Witherspoon D, Opperman L. Survival of human periodontal ligament cells in media proposed for transport of avulsed teeth. *Dent Traumatol*. 2004;20(1):21-28.
44. International Association of Dental Traumatology Guidelines for the Management of Traumatic Dental Injuries: 2. Avulsion of Permanent Teeth. Available at https://www.aapd.org/media/policies_guidelines/e_avulsion.pdf. Last accessed May 25, 2021.
45. Cvek M, Cleaton-Jones P, Austin J, Lownie J, Kling M, Fatti P. Effect of topical application of doxycycline on pulp revascularization and periodontal healing in reimplanted monkey incisors. *Endodontic Dent Traumatol*. 1990;6(4):170-177.
46. McIntyre J, Lee J, Trope M, Vann WJ. Permanent tooth replantation following avulsion: using a decision tree to achieve best outcome. *Pediatr Dent*. 2009;31(2):137-144.
47. Shah A, Qureshi Z. Post management complications of fracture mandible at the angle: an analysis. *Pakistan Oral Dent J*. 2011;31(2):260-262.
48. Afrooz PN, Bykowski MR, James IB, Daniali LN, Clavijo-Alvarez JA. The epidemiology of mandibular fractures in the United States, part 1: a review of 13,142 cases from the US National Trauma Data Bank. *J Oral Maxillofac Surg*. 2015;73(12):2361-2366.
49. Furr AM, Schweinfurth JM, May WL. Factors associated with long-term complications after repair of mandibular fractures. *Laryngoscope*. 2006;116(3):427-430.
50. Cienfuegos R, Cornelius CP, Ellis E III, Kushner G. Mandible: Special Considerations. Available at https://surgeryreference.aofoundation.org/cmf/trauma/mandible. Last accessed May 25, 2021.
51. Wolford LM, Eber Stevao LL. Considerations in nerve repair. *Baylor University Medical Center Proceedings*. 2003;16(2):152-156.
52. Aksoy E, Unlu E, Sensoz O. A retrospective study on epidemiology and treatment of maxillofacial fractures. *J Craniofac Surg*. 2002;13(6):772-775.
53. Moe KS, Byrne P, Kim DW. Maxillary and Le Fort Fractures. Available at https://emedicine.medscape.com/article/1283568-overview. Last accessed May 25, 2021.
54. Polat HB, Ay S, Kara MI. Maxillary tuberosity fracture associated with first molar extraction: a case report. *Eur J Dent*. 2007;1(4):256-259.
55. Kurtz-Weidinger D. Infant and Youth Health: Dental Team's Responsibility in Reporting Child Abuse and Neglect. Available at https://www.azdhs.gov/prevention/womens-childrens-health/oral-health/#maternal-child-oral-health-reporting-abuse. Last accessed May 25, 2021.
56. Becker DB, Needleman HL, Kotelchuck M. Child abuse and dentistry: orofacial trauma and its recognition by dentists. *J Am Dent Assoc*. 1978;97(1):24-28.
57. Centers for Disease Control and Prevention. National Intimate Partner and Sexual Violence Survey: 2015 Data Brief: Updated Release. Available at https://www.cdc.gov/violenceprevention/pdf/2015data-brief508.pdf. Last accessed May 25, 2021.

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