Dental Injuries and Management

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Abstract

Traumatic dental injuries affect 1 to 3% of the population, and disproportionately affect children and adolescents. The management of these injuries incorporates the age of patients, as children between 6 and 13 years of age have a mixed dentition. This helps to preserve the vitality of teeth that may be salvaged after a traumatic event. The clinical examination of these cases involves a thorough examination of the maxilla and mandible for associated fractures and any lodged debris and dislodged teeth or tooth fragments. The objective is to rule out any accidental aspiration or displacement into the nose, sinuses, or soft tissue. After ruling out any complications, the focus is on determining the type of injury to the tooth or teeth involved. These include clinical examination for any color change in the teeth, mobility testing, and testing for pulp vitality. Radiographic evaluation using periapical, occlusal, panoramic radiographs, and cone beam computed tomography is performed to view the effect of trauma on the tooth, root, periodontal ligament, and adjoining bone. The most commonly used classification system for dental trauma is Andreasen's classification and is applied to both deciduous and permanent teeth. Managing dental trauma is based on the type of injury, such as hard tissue and pulp injuries, injuries to periodontal tissue, injuries of the supporting bone, and injuries of the gingiva and oral mucosa. Hard-tissue injuries without the involvement of the pulp typically require restoration only. Any pulp involvement may require endodontic treatment. Fractures involving the alveolar bone or luxation of the tooth require stabilization which is typically achieved with flexible splints. The most common procedures employed in managing dental injuries include root canal/endodontics, surgical tooth repositioning, and flexible splinting. Recognition and treatment of these injuries are necessary to facilitate proper healing and salvage of a patient's natural dentition, reducing future complications to patients.

Keywords
- trauma
- tooth
- luxation
- fracture

The incidence rate of traumatic dental injuries (TDIs) is approximately 1 to 3%, with the highest incidence among 12-year-old children.[1] Children and adolescents report a disproportionally higher number of traumatic dental injuries, approximately 18 to 20%.[2] Boys tend to be at higher risk of injuries compared with girls, and children who are higher risk takers tend to have repeated dentoalveolar trauma. Evidence of incisal dentoalveolar trauma has been reported among one in four adults in the United States.[3]

Age is a large factor in determining an appropriate approach to treatment. Most of these children will have primary teeth or a mixed dentition of primary and permanent teeth.[4] It is important to consider the age and corresponding eruption status of affected teeth.

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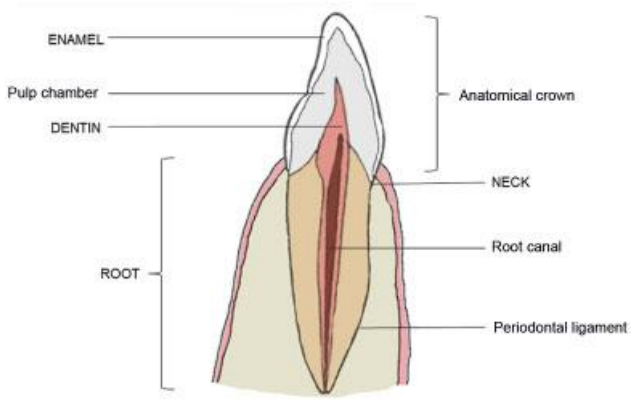

Fig. 1 General tooth anatomy (Dental Anatomy Section, p. 3[5]).

Fig. 2 Panoramic radiograph demonstrating mixed dentition in an adolescent patient (Mixed Dentition Section, p. 5[5]).

Dental Anatomy

Teeth are primarily composed of four dental tissues (►**Fig. 1**). Enamel, dentin, and cementum are hard or calcified tissues, the pulp or tooth core are composed of blood vessels, connective tissue, and nerve, that is, soft or uncalcified tissues.

Enamel: it is a calcified tissue covering crown of the tooth. It is not composed of any living cells and requires restoration for repair.

Anatomical crown: visible part of the tooth and is covered by enamel.

Pulp chamber: space occupied by blood vessels, connective tissue, and innervation at the center of teeth.

Neck: area where the crown connects to the root.

Dentin: calcified tissue which lies below enamel and cementum. Composed of microscopic tubules which are thought to conduct sensations of from the tooth surface to the pulp.

Cementum: connective tissue covering tooth and root and provides attachment to the periodontal ligament.

Periodontal ligament: connective tissue fibers connecting root surface to the tooth socket.

Mixed Dentition Stage

Mixed dentition or transitional dentition stage (►**Fig. 2**) is the time period in the dental development of children when deciduous and secondary teeth erupt into the oral cavity. This stage typically lasts between 6 and 13 years of age.[5] It can be difficult to evaluate malocclusion in mixed dentition as teeth are in various stages of eruption. Developing teeth may react unfavorably to a traumatic disturbance; premature loss of developing teeth may lead to subsequent misalignment of permanent teeth.

Clinical Examination

Any evaluation of a trauma patient should first involve assessing the ABCs (airway, breathing, and circulation) of trauma. If necessary, airway evaluation should involve a flexible laryngoscopy to evaluate the nasal airway, nasopharynx, oropharynx, piriform sinuses, supraglottis, glottis, and subglottis. Aspiration of teeth may require urgent rigid bronchoscopy with removal of the foreign body.

Once the ABCs have been stabilized, a thorough examination should be conducted to rule out the presence of associated fractures of the maxilla and mandible. An intraoral soft tissue examination should include assessment for the presence of mucosal laceration of the lips, tongue, palate, floor of mouth, and buccal mucosa and vestibule. Before any examination, it is advisable to thoroughly remove any debris and foreign substances. Active bleeding should also be controlled. Gingival lacerations are usually associated with displaced teeth. Bleeding along the gingival crevice and marginal gingiva are indicative of damage to the periodontium, periodontal ligament, or an underlying fracture of the mandible. All teeth should be accounted for and any missing tooth fragments which are not seen on clinical examination should be considered aspirated or displaced into the nasal cavity, maxillary sinus, or adjoining soft tissues. Radiographic evaluation of head, neck, chest, and abdomen are conducted to eliminate the suspicion of tooth fragments displaced to these areas.

Fractures involving the alveolar process which protrude through overlying mucosa are usually self-evident. Crepitation and mobility of alveolar fragments on palpation can indicate an underlying fracture. Fractures are also evident in the case of a previously unknown step deformity, gross malocclusion, or pain on palpation of alveolar segment.

After removing debris and blood from tooth surface, a thorough examination of tooth structure is conducted. All infarctions, fractures, or cracks on the tooth surface are noted. These infarction lines can be detected using a light beam shined parallel to the long axis of the tooth. Further investigation into the extent of the fracture should be undertaken, that is, whether fracture extends dentin, pulp, etc. A change in tooth color or translucency indicates pulp exposure. Indirect fractures of the crown root in one quadrant are usually accompanied by similar fractures in the ipsilateral jaw.

Displaced Teeth

While displaced teeth are usually self-evident, dental occlusion examination provides clues to minor degrees of tooth movement. The most common direction of dislocation is buccolingual.[6] Lateral luxation and intrusion have fewer clinical signs as the teeth get locked in position. Apical and lingual displacement of the apex of a primary tooth can interfere with a permanent successor.

Mobility Testing

Testing for mobility should be conducted horizontally and axially using manual palpation or a tongue blade. If a tooth appears very mobile but is not displaced, a root fracture is suspected. When multiple teeth on an alveolar segment appear mobile, a dentoalveolar fracture is suspected.

Pulp Testing

Vitality tests evaluate conduction of stimuli to sensory receptors in the dental pulp. These tests can be difficult to perform and, in many cases, are unreliable in an acute trauma setting. Especially in children, the lack of reliability and false-negative results make it an unreliable choice. The laser Doppler Flowmetry has recently been used to assess pulpal flow and vitality.[7] Pulp testing fares better when testing several weeks after the traumatic event [8]. Others tools such as heated gutta percha tips, ice, or cold air flow can also be used.[7,8]

Radiology

The objective of radiology is to evaluate the effect of injuries on the tooth, root, periodontal ligament, and status of adjacent bone. In children they provide a further perspective on underlying developing teeth. Viewing fractured teeth from multiple radiographic angles is recommended. Guidelines suggest the following radiographic views:

- Periapical radiograph with 90-degree angulation central beam for the tooth of interest.
- Periapical radiograph lateral angulations of the mesial and distal aspects of the tooth.
- Occlusal view.

Periapical radiographs provide the most detailed view on root fracture and teeth dislocation. Occlusal radiographs help to evaluate root fractures and lateral luxation with lingual displacement of the crown. They are also more comfortable for patients, as they apply less pressure on the traumatized area. Suspected jaw fractures or alveolar ridge fractures require the use of extraoral radiographs, such as panoramic radiograph. These radiographs are best suited to screen fractures of the condyle, subcondylar region, and mandibular angle or body fractures. Access to routine dental X-rays can be limited in a hospital setting and a computed tomography (CT) scan may be the only means of radiographic evaluation in an acute-trauma setting.

Radiographic findings: displaced teeth usually appear as a widening of the periodontal ligament or displaced lamina dura.[9] Extruded teeth show the appearance of a periapical radiolucency compatible with the shape of the apical portion of the root.[9]

Types of Traumatic Dental Injuries and Classification

The purpose of these classifications is to provide a universal and comprehensive overview of dentoalveolar fractures for communication and treatment planning. The various systems of classification take into consideration multiple factors, such as etiology, anatomy, pathology, and treatment. The three most common systems are Ellis and Davey classification (primarily developed to classify anterior teeth injuries), Sander and Andreasen's, or the World Health Organization (WHO). Andreasen's classification (►**Table 1**) was originally adopted by the WHO and is the most widely used in literature.[8,10,11] This classification can be applied to both the deciduous and permanent dentition.

Management of Traumatic Dental Injuries, Based on Injury Type and Location

Fractures involving the crown to the depth of dentin require mostly bonding. If the pulp is involved, root canal treatment is typically required. Fractures to the gingival margin are extracted. Injuries to the periodontium and the supporting alveolar structures require stabilization in younger patients. Avulsion of teeth occurs due to the soft and flexible nature of the bone; however, the loss of teeth/avulsion in adults may also be due to alveolar fracture or poor periodontal status. Patients with alveolar fracture are stabilized with splinting, arch bar placement or open reduction and, internal fixation. The challenge is inadequate space for the placement of arch bars without damaging the teeth. In patients with poor periodontal status, no attempt is made to salvage the tooth. Dental implants have higher predictability in these cases. The priority in stabilization of the tooth is primarily to salvage and maintain the bone that would help in the placement of dental implants at a later time (typically 6 months).

Guidelines for managing traumatic dental injuries are appended below:

- *Enamel infraction:* an incomplete crack or fracture of the tooth crown with no associated symptoms or tenderness (►**Fig. 3A**). Any associated symptoms or sensitivity would require further radiologic evaluation for luxation. The surface of the crack or fracture is bonded with resin to prevent stains or discoloration. No follow-up is required unless an infarction is associated with a luxation or other fracture. The tooth should continue to display root development if it is immature.
- *Enamel fracture*: it involves complete fracture of enamel without visible dentin exposure (►**Fig. 3B**). There are no signs of tenderness or sensitivity. If present, this may be associated with luxation injury. Radiographs of the teeth should also include lip and cheek to identify enamel fragments. If the tooth fragment is available, it can be bonded to the fracture surface. If unavailable, restoration and contouring with composite resin is recommended. Clinical and radiographic examination should occur at 6 to 8 weeks and 1 year after treatment. The fractured tooth should show continuous root development if it is immature.

Table 1 World Health Organization Andreasen's classification (1994): based on anatomic, therapeutic and prognostic considerations

Injuries to dental hard tissue and pulp	Enamel infraction	Enamel fracture	Enamel–dentin fracture	Complicated-crown fracture	Uncomplicated crown–root fracture	Complicated crown–root fracture	Root fracture	
Injuries to periodontal tissue	Concussion	Subluxation	Extrusive luxation	Lateral luxation	Intrusive luxation	Avulsion		
Injuries to supporting bone	Comminution of the maxillary alveolar socket	Comminution of the mandibular alveolar socket	Fracture of the maxillary alveolar socket	Fracture of the mandibular alveolar socket	Fracture of the maxillary alveolar process	Fracture of the mandibular alveolar process	Fracture of the maxillae	Fracture of the mandible
Injuries to gingiva or oral mucosa	Laceration of gingiva or oral mucosa	Contusion of gingiva or oral mucosa	Abrasion of gingiva or oral mucosa					

- *Enamel–dentin fracture*: the fracture is limited to dentine and enamel, with associated structural tooth loss; however, there is no pulp exposure (►**Fig. 3C**). On percussion, any sign of tenderness would require evaluation for possible luxation or root fracture injury. Pulp testing usually provides positive results. The loss of dentin and enamel is evident radiographically. Periapical, occlusal, eccentric, lip, and cheek radiographs should be taken to identify any root fractures, tooth displacement, or tooth fragments that are not evident on clinical examination. Any available tooth fragment may be bonded to the tooth. Lack of natural tooth fragments would require restoring exposed dentin with glass ionomer cement, composite resin, or any other dental restorative material. A fracture with proximity to pulp of 0.5 mm would require placing a calcium hydroxide base over the fractured area before restoring it with a dental material. Follow up at 6 to 8 weeks and 1 year is recommended to observe continued root development in children and positive response to pulp testing. No root development and growth in deciduous teeth may need endodontic treatment.
- *Enamel–dentin–pulp fracture*: this fracture results in enamel–dentin loss with exposure of pulp (►**Fig. 3D**). Percussion will yield tenderness, indicating underlying luxation or root fracture. Exposure of pulp causes sensitivity. Loss of dentin and enamel will be evident radiographically. Periapical, occlusal, eccentric, lip, and cheek radiographs should be taken to identify any root fractures, tooth displacements, or tooth fragments that are not evident on clinical examination. In young patients, it is important to preserve pulp vitality by pulp capping or partial pulpotomy. Mature teeth require endodontic intervention, that is, root canal treatment, pulpotomy, or pulp capping, depending on the extent of pulp exposure. Fractured crowns can be restored with dental restorations or available tooth fragments can be bonded to the fractured area. Six to 8 weeks and 1 year of follow-up is recommended for pulp-vitality testing and observance of continued development in deciduous teeth.
- *Crown-root fracture without pulp exposure*: this fracture of the tooth involves enamel, dentin, and cementum without pulp exposure (►**Fig. 3E**). The fracture can extend below to the gingival margin. The tooth is tender on percussion; coronal tooth fragments may be mobile. The extent of the fracture to root apex may not be visible. Periapical, occlusal, and eccentric radiographs are recommended to determine root fracture lines. Temporarily stabilizing loose segments to adjacent tooth or teeth is recommended until a treatment plan is confirmed.

In the long term, there are multiple ways to manage crown-root fractures. The fractured fragment can be removed and the apical segment can be restored until the gingival margin. Alternatively, an osteotomy, osteoplasty, or gingivectomy can be performed to remove the fractured fragment, followed by endodontic treatment and post and core restoration. The tooth can be repositioned to a coronal position and remove the fractured fragment or completely

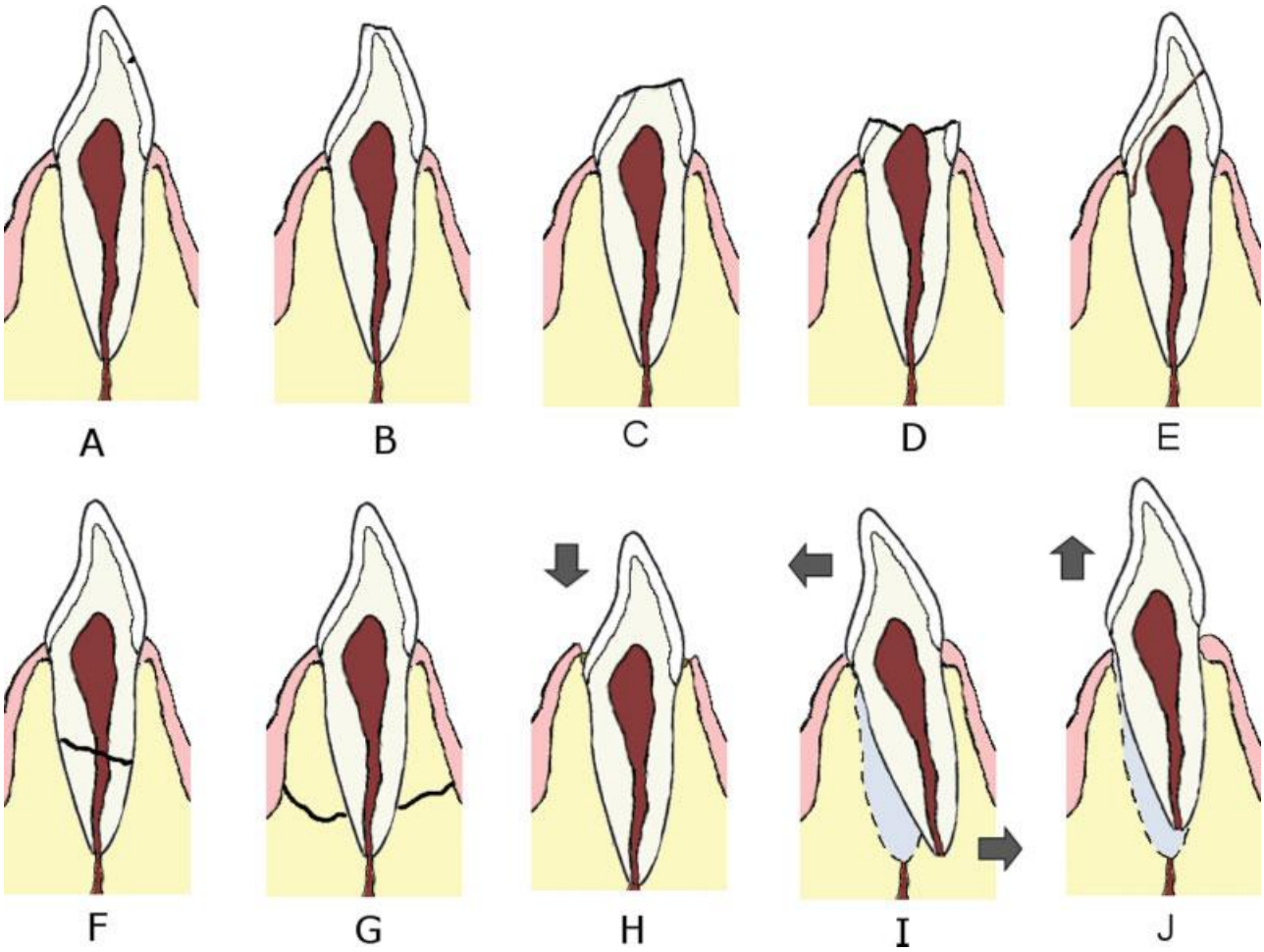

Fig. 3 Types of dental trauma. **A**: Enamel infarction; **B**: Enamel fracture; **C**: Enamel-dentin fracture; **D**: Enamel-dentin-pulp fracture; **E**: Crown-root fracture; **F**: Root fracture; **G**: Alveolar fracture; **H**: Intrusive luxation (arrow indicates direction of axial displacement); **I**: Lateral luxation (arrows indicate displacement in lingual/palatal or labial direction); **J**: Extrusive luxation (arrow indicates tooth mobility) (Management of Traumatic Dental Injuries based on injury type and location Section, p. 10[5]).

extract the tooth and fractured fragments and follow this with implant restoration. The implant should be monitored for stability and retention with favorable healing. If necessary, a complete extraction followed by a bridge restoration can also provide aesthetic and limited functional relief. Follow-up should be conducted in 6 to 8 weeks and up to 1 year. Ideally, the retained tooth should be asymptomatic. The deciduous teeth should show continued development. Complications following this fracture include sensitivity, nonvitality, apical periodontitis, lack of development in deciduous tooth, and implant failure.

- *Crown–root fracture with pulp exposure*: it is a fracture involving, enamel, dentin, cementum, and exposure of pulp chamber. The tooth is tender on percussion and coronal segment is mobile with the extent of tooth to apex not being visible. Periapical and occlusal radiographs are recommended. The loose segment should be temporarily stabilized to adjacent tooth or teeth, until a treatment plan is confirmed. In case of open apex, pulp preservation can be attempted with pulpotomy. This is especially indicated in young patients with newly erupted permanent teeth. Long-term treatment for this type of injury follows the same guidelines as crown-root fracture without pulp exposure.
- *Root fracture*: in root fractures, the coronal aspect of the tooth can be mobile or displaced. Tenderness on percussion may be present and the gingival sulcus will show bleeding. Tooth sensation may be lost due to nerve damage and the crown may show transient discoloration (red or gray). The fracture line will be either horizontal or oblique (►**Fig. 3F**). Fractures of the cervical third of tooth tend to be horizontal, while fractures of the apical third are usually oblique. The displaced tooth fragment should be repositioned as soon as possible, and the repositioning should be checked radiographically. The tooth should be stabilized to an adjacent tooth using a flexible splint for 4 weeks. If the fracture is more cervical, stabilization is recommended for longer (3–4 months). It is important to monitor healing and pulp vitality for 1 year. Any sign of necrosis requires endodontic treatment of the coronal aspect of the tooth to the fracture line. The tooth should show signs of repair between fractured segments. Follow-up should occur at 4 weeks for radiographs and splint removal, 6 to 8 weeks for clinical and radiographic evaluation, and 1 to 5 years for clinical and radiographic evaluation.

- *Alveolar fracture*: the fracture can extend to the alveolar bone and adjacent bone (►**Fig. 3G**). Several teeth, including the segment, will display mobility. Occlusion change may be noted due to misalignment of the fractured segment. The fracture lines can be located at any level compared with the marginal bone. Panoramic radiographs are recommended, in addition to occlusal views and periapical radiographs at three angles. Cone beam CT imaging is also indicated. One should reposition the displaced segment and check for proper occlusion before splinting. Any gingival lacerations should be splinted. The splinted segment should be kept stable for 4 weeks. After 4 weeks, splints can be removed and radiographs taken. Clinical and radiographic follow-up should continue for 4 months, 6 months, 1 year, and 5 years. Teeth should show response to sensory testing.
- *Concussion*: tapping or percussion of tooth results in tenderness; however, there are no signs of mobility or displacement. These injuries do not usually require treatment, though observing pulp condition requires follow-up for 1 year. Radiographic and clinical examination should occur at 4 weeks, 8 weeks, and 1 year.
- *Subluxation*: tenderness on tapping or percussion will be noted. There will be increased mobility but no displacement. This is typically accompanied with bleeding from gingival crevice. Transient pulpal damage can also be present. Usually, no radiographic findings are visible. The injury may not require treatment; however significant mobility requires splinting to an adjacent tooth for 1 to 2 weeks. If a splint is placed, it may be removed after 2 weeks. Clinical and radiographic examination should occur at 2, 4, 8 weeks, 6 months, and 1 year.
- *Intrusive luxation*: the tooth is displaced into the alveolar bone axially (►**Fig. 3H**). The tooth will be immobile and produces an ankylotic sound (high metallic) upon percussion. Bleeding may be present on the gingival crevice, and the tooth may appear more apically placed or sunken compared with adjacent teeth. The periodontal ligament space may be absent along all or part of the root. The cementoenamel junction is located more apically to adjacent teeth and at some angles to the marginal bone. In younger patients with deciduous teeth, a tooth with incomplete root formation should be allowed to erupt without intervention. If no natural movement is seen, orthodontic repositioning is indicated. In cases of intrusion greater than 7 mm, the tooth should be surgically repositioned. For permanent teeth, less than 3 mm of intrusion should be allowed to erupt naturally. If no movement is observed for 2 to 4 weeks, one should surgically or orthodontically reposition teeth before ankyloses develops. Intrusion at or beyond 7 mm should be surgically repositioned, followed by flexible splinting to an adjacent tooth for an additional 4 to 8 weeks. Most teeth will require endodontic therapy as pulpal necrosis is highly likely. Splint removal is indicated at 4, 6, or 8 weeks, accompanied by clinical and radiographic examination for up to 1 year. Yearly follow-up for 5 years are recommended, monitoring that a tooth retains its corrected position.
- *Lateral luxation:* this injury is categorized by displacement of tooth in the lingual/palatal or labial direction (►**Fig. 3H**). The tooth is immobile on percussion and is accompanied by an ankylotic (high metallic) sound. The alveolar process is fractured and bleeding in the gingival crevice may be present. A widened periodontal ligament space is present and best appreciated on an occlusal or eccentric radiograph. The tooth can be repositioned using forceps or digits. Radiographs should be used to confirm disengagement from bony lock. The tooth should be splinted to the adjacent tooth with a flexible splint for up to 4 weeks. The splint is removed at 4 weeks with clinical and radiographic examination recommended at 4 weeks, 8 weeks, 6 months, and 1 year, followed by yearly follow-up for 5 years. Any signs of pulp necrosis would indicate endodontic treatment.
- *Extrusive luxation:* here, the tooth is significantly mobile and appears elongated (►**Fig. 3J**). Bleeding in the gingival crevice may be present. An apical radiograph shows an increase in periodontal ligament space in the apex. The tooth should be gently repositioned in the tooth socket and radiographically confirm repositioning. A flexible splint should be attached to adjacent teeth for 2 weeks. Any pulpal necrosis in permanent teeth will require endodontic treatment. The splint should be removed at 2 weeks and clinical and radiographic examination should occur at 2 weeks, 4 weeks, 8 weeks, 6 months, and 1 year, followed by yearly follow-up for 5 years. Radiographs should show healed periodontium. The marginal bone height should correspond to height after repositioning.

Procedures in Traumatic Dental Injury Management

Endodontic treatment/root canal: endodontic treatment is necessary for inflamed or infected teeth to prevent future complications. Traumatic injuries to the tooth pulp may be unnoticed clinically, but are associated with acute pain, and can develop into an abscess. Root canals and associated pulp chambers are hollow structures within teeth and house dental innervation and blood supply. Endodontic treatment removes these structures to shape, clean, and decontaminate these hollow areas using files, irrigating solutions, and obturating fillings.

Surgical tooth repositioning: in surgical tooth repositioning, the following two basic techniques are employed: tipping and bodily movement relative to the alveolar process. The objectives are to move the tooth into a more desirable position and maintain pulp vitality. Movement of the tooth apex should be very limited. Newly erupted teeth with a wide apical foramen tolerate repositioning most favorably.[12] The application of the following criteria increase the likelihood of success with surgical repositioning:

- Root length: greater success has been achieved when a root length of half or more has grown before surgical repositioning. If an adequate root length is not present, the root grows in length only to a certain extent.
- Root parallelism: moving the apical portion of the tooth too distal increases the likelihood of pulpal death and

ankylosis. Panoramic radiographs provide the best guides to achieve parallelism.
- Occlusion: maintaining occlusal contact between repositioned tooth and opposing teeth provides better results and reduces the likelihood of ankylosis. Any delay in eruption of the repositioned tooth may cause the opposing tooth to supraerupt.

Periodontal health: recurrent periodontal inflammation lessens the chances of successful repositioning. Proper occlusion prevents trauma and inflammation in the periodontium.

Flexible splinting: splints are advocated to stabilize repositioned teeth to optimize healing for pulp and periodontal ligament. The objectives of splint stabilization can be enumerated as follows:

- Splinting materials should be readily available in an office armamentarium.
- Additional manipulation of the injured tooth should be minimal.
- Physiologic movement of the tooth should be allowed.
- Gingival tissue impingement and occlusal interference must be avoided.
- Easy access should be available for endodontic treatment.
- Oral hygiene should be maintained.
- Removal should be easy.

Rigid splints increase chances of external resorption and eventual early tooth loss. A wire of 4 mm is considered the clinical threshold for flexible and rigid splints, with 0.41 rectangular orthodontic wire or 0.45 multistranded flexible and titanium trauma splints considered flexible splints. Studies have found no benefit to extending splinting to more than one adjacent tooth.[13] The International Association of Dental Traumatology guidelines recommend flexible splints for all injury classifications except alveolar fracture.

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