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Recent trends in the management of dentoalveolar traumatic injuries to primary and young permanent teeth

REVIEW ARTICLE

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Abstract – One of the commonly encountered dental emergencies is dentoalveolar traumatic injuries (DTIs). Unfortunately, DTIs result in fractured, displaced, or lost anterior teeth and this could have significant negative functional, esthetic, speech, and psychological effects on children thus affecting their quality of life. Although it is impossible to guarantee permanent retention of a traumatized tooth, patient age, severity of injury, and timely treatment and follow up of the tooth using recommended procedures can maximize the chances for success. This review examines the recent trends in the management of DTI to primary and young permanent teeth. Electronic search of scientific papers written in English from 1990s to 2009 was accomplished using Pub Med search engine. Dental practitioners should follow current literature and consider carefully evidenced-based recommendations that may enhance periodontal healing and revascularization of avulsed permanent teeth.

Background

One of the commonly encountered dental emergencies is dentoalveolar traumatic injuries (DTIs). Unfortunately, DTIs result in fractured, displaced, or lost anterior teeth and this could have significant functional, esthetic, speech, and psychological effects on children thus affecting their quality of life (1). Although it is impossible to guarantee permanent retention of a traumatized tooth, patient age, severity of injury, and timely treatment and follow up of the tooth using recommended procedures can maximize the chances for success (2, 3). This review examines the recent trends in the management of DTI to primary and young permanent teeth. Electronic search of scientific papers from 1990s to 2009 was accomplished using Pub Med search engine. The inclusion criteria were English language, publication year, experimental studies and review articles, the age of the study group, and the management technique. The search terms used were the following: dental, trauma, injury, primary teeth, permanent teeth, enamel infraction, crown fracture, crown-root fracture, root fracture, luxation, avulsion, and replantation. In addition, some text books and guidelines were used in this review.

A proper definition of DTI is an injury that results from an external force, involving the teeth, the alveolar portion of the maxilla or mandible, and the adjacent soft tissues (4, 5). Different frequencies of DTI are reported in the literature, depending on the employed methodology, the type of dentition, and patients' age. The frequency of DTI is inversely proportional to age (6, 7). Several epidemiological studies investigated DTI in schoolchildren by means of clinical examinations and questionnaires, which might increase significantly the number of cases (8, 9). The number of DTI decreases significantly when epidemiologic studies are performed in a hospital environment (6, 10). This is attributed to two reasons: minor dental injuries such as concussion and subluxation are not usually reported in hospital settings, and school-based studies usually involved large slice of the community in contrast to the limited hospital reported cases.

The greatest occurrence of DTI to the primary dentition is when motor coordination is developing and children are more susceptible to falls (6, 11). Most injuries to permanent teeth occur secondary to falls, followed by traffic accidents, violence, and sports (6, 12–14). Boys are twice as likely as girls to report DTI and are much more likely to experience such trauma more than once (7). Children with special needs are in more danger of having trauma than others. This occurs more frequently in people who have intellectual disability, sensory impairment, attention-deficit/hypersensitivity disorder, seizures, abnormal protective reflexes, or muscle incoordination (15–20). Occlusal relationship is another risk factor because the frequency of DTI is significantly higher for children with increased overjet and inadequate lip coverage (21–23). Damage to teeth is the most common complaint against anesthetists in cases of difficult intubation or presence of pre-existing dental pathology or prostheses (24, 25).

There is some evidence that preventive measures may be effective in reducing the risk of DTI. Therefore, dentists and physicians should collaborate to educate the public about prevention and treatment of oral traumatic injuries (26, 27). The American Academy of Pediatric Dentistry encourages the use of mouthguards during sporting activities, which reduce the incidence and severity of dental injuries (27–29). The use of helmets and seat belt can reduce the incidence and severity of these injuries when motor vehicle crashes occur (30). Many preventive approaches are beyond the scope of medical and dental professionals, for example, safety considerations in automobile construction such as air-bags, seatbelts, and molded dashboards (7). Similarly, rubber floors could be installed in places where accidents in children most likely occur, such as school and park playgrounds. For the elderly, installation of helping bars and anti-skid floors would be of great help (6). Early orthodontic treatment in predisposed children may be an effective prevention strategy (23).

Management of DTIs

DTIs are usually a combination of trauma to the soft tissues, teeth, and their supporting tissues (dental polytrauma) (31). The management of these injuries is categorized individually for descriptive purpose only.

Management of injuries to the hard dental tissues and the pulp

Enamel infraction

As a rule, infractions do not require treatment. However, in case of multiple infraction lines, the enamel surface is sealed with an unfilled resin to avoid the uptake of stains from tobacco, food, drinks, or other liquids (26, 32, 33).

Uncomplicated crown fracture

For small fractures confined to enamel, rough margins and edges can be smoothed. For larger fractures exposing dentin, treatment strategy implies the application of glass-ionomer cement to the deepest dentin layer and permanent restoration using a dentin bonding agent and composite resin to complete the hermetic seal against bacterial irritant, which is more critical to pulpal healing (2, 11, 26, 32–39). The benefit of calcium hydroxide (CaOH) liner is questionable, because it has been indicated that CaOH disintegrates beneath dental restorations with time, consequently compromising the pulpal healing (32, 37). Reattachment of the crown fragment and laminate veneers are other alternatives that can be considered (32, 40). Whatever treatment is decided, it is essential that the crown's anatomy and occlusion be restored immediately to prevent labial protrusion of the fractured tooth, drifting or tilting of adjacent teeth into the fracture site or over eruption of opposing incisors (32).

Complicated crown fracture

Treatment decisions for primary teeth are based on life expectancy of the traumatized tooth and vitality of the pulpal tissue. Pulpal treatment alternatives are pulpotomy, pulpectomy, or extraction (11, 26, 35).

In young permanent teeth and immature developing teeth, it is advantageous to preserve pulp vitality by pulp capping or partial pulpotomy (Cvek pulpotomy) and bacteria-tight coronal seal. While in mature teeth, pulpal treatment alternatives are direct pulp capping, partial pulpotomy, and pulpectomy depending on the exposure size and the time elapsed between accident and treatment. In extensive crown fractures, a decision must be made whether treatment other than extraction is feasible (2, 33, 34, 36).

There is no doubt that CaOH has been widely used for vital pulp therapy. The strong alkalinity of CaOH contributes to its action. It provides a bactericidal environment in which subsequent repair and hard tissue bridge can occur (41, 42). Mineral trioxide aggregate (MTA) has lately been shown to be a pulp capping material, which produces a hard tissue barrier. It has a high sealing ability and can set in a moist environment. During the setting reaction, calcium hydroxide ions are released and high alkalinity is present in the exposed area. At present, MTA appears to be a promising candidate as an alternative to CaOH (42–45). Portland cement also has a potential to be used as a less-expensive pulp capping material in comparison with MTA (46). It has been claimed that bioactive molecules (i.e. biological modulators that have been identified during tooth and bone embryogenesis and cloned experimentally) may provide new therapeutic tools in vital pulp therapy (47). Direct capping or implantation of these molecules in the pulp may stimulate the differentiation of mesenchymal cells with varying degrees of dentine bridge formation and coronal or radicular pulp mineralization. Several animal studies have reported the use of bone sialoprotein, specific amelogenin gene splice products, emdogain, dentonin, collagen products, and bone morphogenic proteins with variable degrees of success (48–51). However, further human research is required to increase the knowledge about clinical and histological effects of these bioactive molecules by implementing long-term randomized controlled trials. So far, emdogain is the only material on the market (available in gel form, Emdogain; Biora, Malmö, Sweden) that is used for direct pulp capping in human teeth with successful clinical and histological results (52, 53).

Crown/root fracture

When the primary tooth cannot or should not be restored, the entire tooth should be removed unless retrieval of apical fragments may result in damage to the succedaneous tooth (11, 26, 35).

In general, vertical crown-root fractures in permanent teeth must be extracted. A definitive treatment alternative for diagonal fractures is removal of the coronal fragment followed by a supragingival restoration to allow gingival healing. This procedure should be limited to superficial fractures that do not involve the pulp (i.e. chisel fracture). If the fracture is subgingival, surgical exposure of fracture surface by gingivectomy or osteotomy can convert the subgingival fracture to a supragingival one. This procedure should be limited to the palatal aspect of the fracture in order not to compromise the esthetics. If the pulp is exposed and root formation is complete, root canal treatment is indicated. Otherwise, pulp capping or pulpotomy is advised for the completion of root formation. Orthodontic extrusion of apical fragment to expose subgingival fracture site is used for uncomplicated crown-root fractures if pulp vitality is to be preserved. Surgical extrusion of apical fragment to expose subgingival fracture site is used when there is completed root development, and the apical fragment is long enough to accommodate a postretained crown (2, 26, 33, 36, 54). Fiber-reinforced composite resin posts have been introduced lately as an alternative to cast or prefabricated metal posts for restoring endodontically treated teeth, because the elastic moduli of these fiber posts are closer to that of dentin than that of metal posts (40, 55, 56). Vital root submergence is indicated in young individuals as an alternative to extraction where the abovementioned treatment alternatives cannot be carried out to maintain the dimensions of the alveolar process for a future implant (54).

Root fracture

Treatment alternatives for primary teeth include extraction of coronal fragment without removing apical fragment or observation for spontaneous healing (11, 26, 35). A permanent tooth with root fracture and positive pulp sensitivity is repositioned and stabilized with a flexible splint for 4 weeks to permit pulpal healing and hard tissue repair of the fracture. If the root fracture is near the cervical area of the tooth, stabilization is beneficial for a longer period of time (up to 4 months) (26, 36, 57–59).

Pulp necrosis in root-fractured teeth is attributed to displacement of the coronal fragment and mature root development. If pulp necrosis develops, root canal treatment of the coronal tooth segment to the fracture line is indicated to preserve the tooth. The apical segment will usually contain vital pulp tissue, which need not be removed. The coronal segment should be treated with an interim dressing of CaOH to arrest inflammation and to stimulate apexification, which will permit adequate obturation with gutta-percha and sealer (34, 36, 60). However, CaOH dressing requires long treatment time and this application needs periodic changes of the material. Several authors have recently reported the use of MTA in root-fractured teeth as an apical plug, which has given excellent clinical results (61–63). In cases in which root fracture is close to the alveolar crest and the coronal segment is mobile, endodontic treatment can be performed on both segments if they are suitably aligned for instrumentation. An intraradicular splint such as stainless-steel endodontic file can then be placed and fixed with polycarboxylate cement, thus reducing the mobility of the coronal segment. This technique can be a quick remedy especially for patients who cannot make a second visit to the dental clinic (64, 65). If the coronal fragment of root fracture is dislodged, it should be discarded. Orthodontic extrusion of the root is carried out after root canal therapy. Alternatively, extraction and dental prosthesis could be considered if age and other factors are favorable (60). However, this can lead to labio-lingual collapse of the alveolar process later on. A preferred alternative treatment is submerged vital root fragment (54).

Management of injuries to the periodontal tissues

Concussion

No treatment is needed. Monitoring of pulpal condition is recommended, because there is a minimal risk for pulp necrosis. A flexible splint can be used for the comfort of the patient for 7–10 days, or according to trauma diagnoses of adjacent teeth (2, 11, 26, 34–36, 66).

Subluxation

No treatment is needed for primary teeth. However, a subluxated permanent tooth should be relieved from any occlusal interference, stabilized by using flexible splint for no more than 2 weeks, and followed up carefully (2, 26, 34, 36, 66).

Extrusive luxation

Treatment decisions for primary teeth are based on the degree of displacement, root formation, and the ability of the child to cope with the emergency situation. For minor extrusion (<3 mm) of an immature developing tooth, repositioning and stabilization for 1–2 weeks is indicated. Indications for extraction are severe injury or if the tooth is nearing exfoliation (11, 26, 35, 67).

Extruded permanent teeth should be repositioned and splinted for up to 3 weeks. Monitoring the pulpal condition is essential to diagnose root resorption. In immature developing teeth, revascularization can be confirmed radiographically by evidence of continued root formation and pulp canal obliteration; such teeth usually return to positive response to sensibility testing. In fully formed teeth, a continued lack of response to sensibility testing is an evidence of pulpal necrosis, together with periapical rarification and sometimes crown discoloration, which requires endodontic treatment. A 2-week course of treatment with CaOH before obturation with gutta-percha and sealer cement can help minimize the risk of inflammatory resorption (2, 26, 34, 36, 67–70).

Lateral luxation

Treatment modalities in primary teeth aim to allow passive repositioning or actively reposition and splint for 1–2 weeks to allow for healing, except when the injury is severe or the tooth is nearing exfoliation (26). Similarly, permanent teeth are repositioned and splinted for up to 3–4 weeks. In case of marginal bone breakdown, 3–4 weeks extra splinting time is added. Recommendations for monitoring the pulpal condition are the same as described for extrusive luxation (2, 26, 34, 36, 67, 71–73).

Intrusive luxation

For primary teeth, the treatment decision is to allow spontaneous reeruption except when displaced into the developing successor, then, extraction is indicated (11, 26, 35). Treatment alternatives for permanent teeth include: passive repositioning (allowing reeruption to its pre-injury position especially in teeth with immature root formation), active repositioning (with traction), or surgical repositioning and then stabilizing the tooth in its anatomically correct position. Prophylactic endodontic treatment is initiated using a temporary filling with CaOH within the first 3 weeks of the traumatic incident, because there is considerable risk for pulp necrosis, pulp canal obliteration, and progressive root resorption (2, 26, 34, 36, 73–75). Immature permanent teeth that are allowed to reposition spontaneously demonstrate the lowest risk for healing complications (76, 77).

Avulsion

To prevent further injury to the developing successor, avulsed primary teeth should not be replanted (11, 26, 35, 78, 79). In contrast, avulsed permanent teeth should be replanted as soon as possible and stabilized for 7–10 days, up to 2 weeks (73, 79–81). An evidence-based study found no evidence to contraindicate the current guidelines and suggests that the likelihood of successful periodontal healing after replantation is unaffected by splinting duration (82). If the tooth cannot be replanted within 5 min, it should be stored in a medium that will maintain vitality of the periodontal ligament fibers (81, 83). Transportation media for avulsed teeth include (in order of preference): Viaspan® (a specialized tissue storage medium used when transporting livers for transplantation, ViaSpan is a registered trademark of Barr Laboratories, Inc., Montvale, NJ, USA), Hank's balanced salt solution (HBSS) (tissue culture medium), cold milk (skim or low fat), saliva (buccal vestibule, under the tongue, or in a cup with patient's spit), physiological saline, or water (78, 84, 85). An *in vitro* study has compared the effect of storage in milk, HBSS, and Viaspan® on the vitality of human lip fibroblasts (86). It was found that the groups stored in milk maintained a high percentage of vital cells for 6 h (68.2%). At 12 h, milk's effectiveness had dropped to 43.4% vital cells and it was not effective at all at 48 h (0.024% vital cells). HBSS was extremely effective for 24 h with 71.3% vital cells remaining. At 48 h, the percentage of vital cells dropped to 38.0% and by 120 h, no cells survived. Viaspan® was the most effective storage medium at all observation periods and at 168 h still had 37.6% vital cells present.

Limited tooth storage in a cell-compatible medium prior to replantation has been studied, and healing results were compared with immediately replanted teeth (30, 78). Tetracycline is antibacterial and has proven anti-resorptive properties that would limit the area of root surface damaged by inhibiting collagenase activity and osteoclast function, thus promoting favorable healing. Tetracycline also promotes fibroblast and connective tissue attachment thereby enhancing regeneration of periodontal attachment, which could be beneficial to a replanted tooth (87). Corticosteroids have been widely used to reduce inflammatory responses and osteoclastic bone resorption (88). Alendronate is a third-generation bisphosphonate and is currently being used to inhibit pathologic osteoclast-mediated hard tissue resorption in disease states such as osteoporosis. Experimental studies showed that soaking avulsed teeth in alendronate resulted in significantly less loss in root mass because of resorption compared to those teeth soaked in HBSS or saline (89, 90). Emdogain (enamel matrix protein) has been shown to promote periodontal ligament proliferation. The periodontal ligament cells on the socket wall may be important progenitor cells for Emdogain (91). ViaSpan® has also showed an improvement in periodontal healing compared to other media (85).

The outcome of replantation depends on the stage of root development and the extra-oral time. If the avulsed tooth has a closed apex and extra-oral time is < 60 min (early replantation), the replanted tooth will have the best prognosis compared to delayed replantation (80). The ideal time to begin root canal treatment is within 10–14 days postreplantation and before splint removal. There is a statistically significant association between extirpation within 14 days and an increased likelihood of successful periodontal healing and prevention of external inflammatory root resorption (92). CaOH is recommended for intracanal medication for up to 1 month followed by root canal filling, or obturation can be carried out when an intact lamina dura can be visualized radiographically. It is generally agreed that CaOH has a beneficial effect on the outcome, because of its antibacterial properties, ability to dissolve necrotic tissue, and its ability to prevent or control inflammatory resorption (93, 94). The medicament Ledermix (corticosteroid-antibiotic intracanal paste) has been proposed following pulp extirpation as intracanal medicament (80). The anti-inflammatory and antibacterial actions may decrease root resorption by directly inhibiting resorptive cells (95, 96). Bryson et al. tested the effect of the immediate placement of Ledermix compared to CaOH in the pulp canal of dog teeth that had been dried for 60 min. The Ledermix-treated roots showed 59% favorable healing compared to 14% for the CaOH group, which did not differ from the control group (97). To date, no human clinical studies have compared the effectiveness of Ledermix and CaOH as intracanal medicaments. An animal study (98) evaluated the effectiveness of bisphosphonate as an intracanal medicament in the root canals of avulsed monkey teeth. Overall, bisphosphonate resulted in a worse outcome than CaOH concerning both root resorption and ankylosis.

Delayed replantation (more than 60 min) of avulsed tooth with closed apex has a poor long-term prognosis. The periodontal ligament will be necrotic and not expected to heal. The goal of delayed replantation is to promote alveolar bone growth to encapsulate the replanted tooth. The eventual outcome is ankylosis and resorption of the root. In children below the age of 15 years, if ankylosis occurs, and when the infraposition of the tooth crown is more than 1 mm, decoronation is recommended to preserve the contour of the alveolar ridge (36, 81, 99, 100). Root canal treatment can be carried out on the tooth prior to replantation, or it can be carried out within 14 days later as for other replantations. The tooth is immersed in 2% sodium fluoride solution for a minimum of 5 min up to 20 min. This will decrease the rate of osseous replacement resorption (31). Several animal studies have evaluated the effects of root surface treatment with effervescent vitamin C (Redoxon), propolis (natural resinous substance collected by Apis mellifera bees from various plants), emdogain, ethylenediamine tetraacetic acid (EDTA), and sodium fluoride in late replantation. No statistically significant differences between treatment modalities were seen for the prevention of replacement resorption and ankylosis (91, 101–104).

Avulsed teeth having open apices and an extra-oral time < 60 min are also replanted and stabilized 7–10 days, and up to 2 weeks (79, 81). The goal in replanting still-developing (immature) teeth in children is to allow for possible revascularization of the tooth pulp (2, 36). Cvek et al. (87) reported that the revascularization rate doubled after doxycycline soak. If there is evidence of pulpal infection or inflammatory resorption, the pulp should be removed and calcium hydroxide placed immediately, aiming to stimulate apexification and halt the inflammatory response (68). Similarly, MTA has been used to obturate immature avulsed incisors with open apices (105).

It was believed that delayed replantation (more than 60 min) of avulsed teeth with open apices had a poor long-term prognosis: the periodontal ligament will be necrotic and not expected to heal, and osseous replacement resorption or ankylosis will occur. Therefore, some authors have concluded that such teeth should not be replanted (2, 79). The recent guidelines recommend replantation to maintain alveolar ridge contour because the ankylosed roots will ultimately be transformed to bone during the remodeling process. Root canal treatment can be performed on the tooth prior to replantation through the open apex. Again the tooth is immersed in a 2% sodium fluoride solution for 20 min to enhance periodontal healing (36). If ankylosis occurs, it is recommended to perform decoronation where the tooth crown is removed and the ankylosed roots left in the alveolus to be substituted by bone (36, 81). Recently, there is a new emphasis on the regenerative potential of dental pulp (pulp revascularization) in managing avulsed immature teeth with pulp necrosis. This will be described in the following section.

Current research in pulp revascularization

Pulp revascularization can be achieved in immature traumatically avulsed teeth, with necrotic but uninfected pulps (106). This process can occur under certain biological conditions as follows. The immature avulsed tooth has an open apex, short root, and intact but necrotic pulp tissues that act as a scaffold into which the new tissues grow. Tissues from the apical portion of the pulp have ready access to the root canal and a relatively short distance for proliferation to reach the coronal pulp horns. These new tissues replace the necrotic coronal portion of the pulp. Pulp revascularization is more favorable in a bacteria-free environment which is attainable in case of avulsed tooth, because the crown is usually intact rather than being carious or with an access cavity. However, some reports have indicated that it might be possible to revascularize immature permanent teeth with apical periodontitis (107–109).

The procedure used for pulp revascularization in immature avulsed teeth with necrotic pulp has been described by several authors as follows (106, 108–110). The avulsed tooth is replanted, and the canal is disinfected coronally through access opening with copious irrigation with 5.25% sodium hypochlorite without mechanical instrumentation in the root canal. This is followed by the application of mixture of triantibiotic paste (ciprofloxacin, metronidazole, and minocycline) inside the canal space. A blood clot is induced mechanically in the canal space from the coronal side by using a root canal file to the level of the cementoenamel junction to provide a scaffold for the ingrowth of new tissue. The coronal access is sealed by applying MTA at the level of the cervical area of the canal and a bonded resin coronal restoration above it. This is followed with clinical and radiographic follow up, which showed evidence for healing. Several case reports (110–112) have shown continued root development similar to adjacent and contralateral teeth, and root wall thickening.

This treatment approach offers clinicians great potential to avoid traditional apexification with CaOH or the need to achieve an artificial apical barrier with MTA. Further, this approach can help rescue infected immature teeth by physiologically strengthening the root walls. There has been considerable discussion as to the correct terminology for pulp revascularization. This procedure could be an example of pulpal regeneration or the beginning of stem cell technology. It is clearly not apexification because the apex is closed and the canal walls thicker. Apexogenesis uses remaining vital root pulp to attain a closed apex and thicken the dentinal walls, which is not applicable here. Presently, we can only say that the pulp space has returned to a vital state (106). It has been suggested that topical application of an angiogenic factor (e.g. vascular endothelial growth factor and fibroblast growth factor (FGF-2)) prior to replantation might be beneficial for the treatment of avulsed teeth (113, 114).

Researchers are working toward regenerative approaches that offer high levels of success. Regenerative endodontic therapy is the creation and delivery of tissues to replace diseased, missing, and traumatized pulp. These potential approaches include root canal revascularization, postnatal (adult) stem cell therapy, pulp implant, scaffold implant, three-dimensional cell printing, injectable scaffolds, and gene therapy. Although the challenges of introducing endodontic tissue engineering therapies are substantial, the potential benefits to patients and the profession are equally remarkable, because tissue engineering therapy offers the possibility of restoring natural function instead of surgical placement of an artificial prosthesis (115).

Stem cells are pluripotential cells with the ability to proliferate and differentiate into many cell lines. The most familiar application of adult stem cell therapy is bone marrow transplantation to treat a variety of diseases. Suggested applications related to oral health care have included healing and regeneration of dental and periodontal tissues as well as craniofacial structures (e.g., repair of cleft lip/palate). Pulpal tissue of primary teeth and surgically removed third molars may serve as a source of adult mesenchymal stem cells. The American Academy of Pediatric Dentistry recognizes the emerging field of regenerative therapy and encourages dentists to follow future evidence-based literature to educate parents about the use of dental stem cells with respect to autologous regenerative therapies. This should be accomplished only with integrity and appropriate informed consent to assure the highest ethical standards and quality of outcomes (116).

Conclusion

Dental trauma occurs in isolation or in association with facial injuries or multi-system injuries without a predictable pattern of intensity and extent. Preventive approaches are the sole way to minimize these injuries. Successful management must include four major areas of consideration: dentoalveolar response to the forces of trauma, evaluation and management of changes in vitality of the dental pulp, control of infectious and inflammatory periodontal disease throughout the period of evaluation and management, and restoration of the dentition and supporting structures. Dental practitioners should follow current literature and consider carefully evidenced-based recommendations that may enhance periodontal healing and revascularization of avulsed permanent teeth.

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