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Management Of Crown-Related Fractures in Children: An Update Review

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Abstract

Traumatic dental injuries (TDIs) are a serious public health problem. Epidemiology of dental trauma indicates that these injuries are more prevalent in child population of the world. Children are the sufferers in two-thirds of all TDIs observed. Although being a major fraction, crown-related fractures are a less severe form of TDIs with respect to their complications and sequelae. However, as with other types of traumatic injuries, the delay in seeking for immediate care following a traumatic injury and the lack of appropriate treatment may compromise long-term outcomes. This article reviews the occurrence, management, and prognosis of crown-related fractures in primary and permanent teeth in light of the recent literature.

An overview of traumatic dental injuries

The oral region comprises a very small area (1%) of the total body ¹. However, traumatic injuries affecting this part of the body are one of the most common dental health problems in the general population ². In various epidemiologic studies, the prevalence of these injuries has been reported to range between 6% and 37% ³⁻⁷. This considerable variation is due to a number of different factors such

as the trauma classification used, the dentition and the population (e.g. race, age group, ethnicity, socioeconomic status) studied, together with the geographic and behavioral aspects of the study locations and countries⁸. As stated by Glendor⁹, the significance of traumatic dental injuries (TDIs) arises from the conditions and consequences associated with them:

1. Their occurrence is frequent¹⁰.
2. They generally tend to occur at young ages when growth and development take place¹¹.
3. Their treatment is often complicated, time-consuming, and expensive, requiring multidisciplinary approach¹².
4. Due to their irreversible characteristics, they have a long-lasting impact on quality of life of the affected individual¹³.

Recent epidemiologic studies in preschool children showed that TDI prevalence varies from 6.1% to 62.1%¹⁴⁻¹⁹, with the most affected age group being the 1- to 3-year-olds^{16, 20-23}. However, in school children, the prevalence ranged between 5.3% and 21%²⁴⁻²⁹, and 7–12 years age group had the highest frequency for TDIs^{27, 30, 31}.

Age is a well-known risk factor for TDIs⁹. In many Western countries, more than half of all children experience a traumatic dental injury before adulthood^{11, 32, 33}. However, a study by Thomson et al.³⁴ has shown that the rate and absolute number of injuries among older people have increased during the 1990s. They also found a general increase in the contribution of falls to the occurrence of trauma. These findings lead to the expectation of an increase in the number of dental and maxillofacial traumas due to accidental falls among this population^{9, 35}. Nevertheless, most of the older individuals in the developed countries are likely to retain their teeth for longer³⁴.

Maxillary central incisors are the most frequently affected teeth in both primary and permanent dentitions^{30, 36, 37}. TDIs usually affect a single tooth, but certain trauma events such as sports, violence, and traffic accidents result in multiple tooth injuries^{5, 9, 38}. In most epidemiologic studies, boys were found to experience more TDIs than girls for both dentitions^{20, 28-30, 39-41}. However, in Western societies, there is an increasing interest among girls to participate in traditionally 'male-dominated' sports, which is also expected to include other areas of life^{9, 42}. Hence, a decrease in boy/girl ratio is likely to occur in the years ahead.

Despite the confounding factors such as gender and age⁴³, increased overjet with protrusion, a short upper lip, incompetent lips, and mouth breathing have been cited as major oral predisposing factors for TDIs^{24, 42, 44-46}. Major causes of TDIs include falls, collisions, and being struck by a hard object. All sport activities involve a certain risk with regard to orofacial injuries, and in individuals dealing with high-risk (e.g. American football, hockey, ice hockey, mountain biking)⁴⁷⁻⁵⁰ or medium-risk (e.g. basketball, soccer, team handball, tae kwon do, boxing)⁵¹⁻⁵⁵ sports, the risk of injury increases⁵⁶. Traffic accidents²⁵ are another major group of cause, followed by violence (assaults)⁵⁷, child maltreatment including physical/sexual abuse and neglect⁵⁸, and torture⁷. Risk factors also include medical conditions such as attention-deficit hyperactivity disorder⁵⁹, and obesity⁶⁰. TDIs have also been reported to have a higher frequency among children with cerebral palsy, epilepsy, learning difficulties, and visual and/or hearing impairment⁶¹⁻⁶⁵.

Epidemiologic investigations report a high incidence of dental injuries related to accidents within and around the home for the primary dentition and to accidents at home and school for the permanent dentition^{3, 36, 45, 66}. Crown fractures are the most commonly observed injuries in permanent dentition, whereas luxation injuries are more prevalent in the primary dentition^{7, 67}.

When looked from the 'age perspective', it would be truthful to state that TDIs mostly affect children and adolescents^{68, 69}. They are the victims of two-thirds of all dental injuries⁶⁸. Another observation is that 33% of adults experience trauma to the permanent dentition; however, the majority of these injuries occur before age nineteen⁹. As declared by The United Nations Convention on the Rights of the Child⁷⁰, every human being below the age of 18 years is a child. With these, bearing in mind, the present literature review aims to focus on crown-related TDIs in children. In both primary and permanent dentitions, their management and prognosis will be reviewed.

Infraction

An incomplete fracture (crack) of the enamel without loss of tooth structure is defined as infraction⁷¹. Unlike the spontaneous infractions observed in posterior permanent teeth, trauma-related infractions of anterior teeth do not cause pain⁷². The cracks in enamel are commonly arrested when reaching the dentino-enamel junction (DEJ)⁷³. The 'crack arrest' phenomenon that could be explained by the elastic modulus mismatch of enamel and dentin prevents these cracks from reaching into the underlying dentin⁷³.

The literature has no data with regard to the occurrence of infractions in the primary dentition. In traumatized permanent incisors, the occurrence has been reported to range between 10.5% and 12.5%⁷⁴. Infractions can create pathways for invasion of the root canal system by bacteria⁷⁵. Pulp necrosis was observed in 3.5% of teeth when infraction was the sole injury⁷⁴. However, this figure rose to 34.5% with associated supportive tissue damage such as subluxation.

Whenever detected, the management of this type of injury is rather easy with currently available adhesive systems. Sealing off the enamel with an unfilled resin with prior use of an etch-and-rinse adhesive seems to be highly beneficial in preventing further infection that could arise from these sites⁷⁵.

Crown fractures

Crown fracture is a type of traumatic injury in which a portion of tooth enamel is lost following a perpendicular or obliquely directed impact force to the incisal edge of the tooth. The clinical presentation, possible complications, and sequelae of crown fractures are less severe than those of luxation injuries.

In literature, the term 'uncomplicated' is generally used to refer to enamel and enamel-dentin fractures of teeth, while 'complicated' is reserved for enamel-dentin-pulp fractures. Whether it is an enamel-dentin or enamel-dentin-pulp fracture, a crown-fractured tooth should be treated immediately⁷⁶. The exposed dentin in an uncomplicated fracture or the pulp in a complicated fracture must be protected from the oral environment with appropriate dressing as an emergency treatment⁷⁷. Provided the dentin/pulp wound has been sealed, restorative treatment can also be carried out at a later stage⁷⁸.

Enamel fracture

A complete fracture of enamel without visible sign of exposed dentin is referred to as enamel-only crown fracture⁷¹. These fractures comprise a major proportion (up to 82%) of all crown fractures observed in the primary dentition^{14, 18, 79-82}. Of crown fractures, enamel fractures are the second most common type of fracture, after enamel–dentin fractures^{27, 30}. In both dentitions, the prognosis of this type of injury is very favorable, unless the condition is associated with a luxation injury^{41, 83, 84}. In enamel-only fractures of the permanent dentition, pulp necrosis develops in approximately 1.7% of affected teeth⁸³. In permanent teeth, the risk of pulp canal obliteration and root resorption in permanent teeth has also been reported to be 0.5% and 0.2%, respectively. However, there are no existing conclusive data with regard to prognosis of enamel fracture in the primary dentition.

Recontouring or smoothing of the sharp edges in minor fractures (<2 mm), using polishing disks (on slow-speed handpiece) or fine diamond burs (on high-speed air turbine handpiece), is recommended for the management of this type of injury^{85, 86}. This is particularly important in small children to avoid further injury to soft tissues and nutrition-related problems. Bonded resin composite is required to restore the missing tooth structure and to fulfill the esthetic demand of the patient with more extensive injuries.

Enamel–dentin fracture

Enamel–dentin fractures result in the loss of enamel and dentin without exposing the pulp⁷¹. They are the most common type of TDIs in the permanent dentition⁸. Among all crown fractures, the prevalence of enamel–dentin fractures ranges from 2.5% to 32.6%^{14, 18, 41, 79-81, 87} in the primary dentition and from 2.4% to 33% in the permanent dentition^{5, 87-90}.

An enamel–dentin fracture involves dentin. This injury exposes a considerable amount of dentinal tubules, whose numbers vary from 15 000 (at the DEJ) to 45 000 (pulp) per mm²⁹¹, depending on the location of the fracture line. Together with their proximity to the pulp and the size of the tubules due to the lack of peritubular dentin⁹², the number of exposed dentinal tubules is a major point of concern, as they constitute a potential pathway of invasion for bacteria and subsequent pulpal disease⁹³.

Due to its tubular structure, dentin is a very porous barrier that could readily be penetrated when open to the oral environment, leading to bacterial invasion of the pulpo-dentin complex and may act as a cause of pulpal disease⁷⁵. *In vivo* studies have demonstrated the invasion of tubules by bacteria within 1 week of exposure⁹⁴. In the course of time, an increase in the number of infected tubules along with the depth of infection is observed⁹⁵. As an initial response to reduce the diffusion of noxious stimuli through the dentinal tubules, the pulp increases the outward flow of the dentinal fluid by inflammatory process⁹⁶. Dentinal fluid components involved in host defense (e.g. albumin, fibrinogen, and IgG) interact directly with bacteria and products and reduces the permeability of dentin⁹⁷ by production of sclerotic or reparative dentin⁹⁸. A critical factor in this process is the continuation of an intact pulpal vascular supply⁹⁹. Another contributory factor is the proper sealing of exposed dentin as, when left untreated, bacterial invasion of dentinal tubules overcomes the pulpo-dentinal defense mechanisms, resulting in infection of the pulp and the root canal system⁹³. In such clinical situations, the extent of the fracture is a good determinant in assessing pulpal prognosis¹⁰⁰. Deeply extended

fractures confined to the mesial or distal corners lead to a higher frequency of pulp necrosis than superficial corner or horizontal fractures ¹⁰¹.

Treatment of enamel and enamel–dentin fractures is quite successfully accomplished with the use of dentin adhesives and resin-based composites. Reattachment of the crown fragment, if available, is the choice of treatment ⁷¹.

In cases where reattachment is not possible, an interim or a definitive treatment could be performed. In late referral cases, with suspected possible luxation injury, it is advisable to provide an interim seal of the exposed dentin with glass ionomer cement and to monitor the pulpal status ⁷¹. Here it is important to note that, except for the conditions involving a thin layer of exposed dentin (i.e. 0.5 mm or less) with the absence of bleeding, the use of a calcium hydroxide base is not necessarily required ⁷¹. Once the pulpal condition is suitable, the tooth can be restored with the use of total etch technique and resin-based composites ¹⁰². With contemporary composite resin restorations, the need to use a calcium hydroxide liner has been disputed, primarily because of its poor capacity to adhere to dentin ¹⁰². Pulling away of the material from dentin by the contraction forces inherent in the setting reaction of composite resins is another concern ¹⁰³. Over time, hard-setting calcium hydroxide undergoes physical as well as chemical degradation as indicated by the observation that bacteria can penetrate the material ¹⁰⁴. Therefore, pulp protection is not necessary, except for critical regions. It would prevent formation of a good hybrid layer with resin tag penetration into the tubules that compromises bond strength and sealing efficacy of the future restoration ¹⁰⁵.

Complications following crown fractures are uncommon, with pulp necrosis being the most frequent one ¹⁰⁶. Concomitant luxation injury has been reported to increase the likelihood of pulp necrosis ⁸⁴. Borsen and Holm ¹⁰⁷ and Robertson ¹⁰¹ have noted that pulp necrosis develops in approximately 2% of teeth with uncomplicated crown fractures. Cavalleri and Zerman ¹⁰⁸ reported 6% pulp necrosis in crown-fractured immature teeth. In Ravn's study ¹⁰⁰, pulp necrosis was observed in 3.2% of teeth in which enamel–dentin fracture was the only damage.

Enamel–dentin–pulp fracture

In this type of injury, the fracture involves both enamel and dentin, and the pulp is exposed ⁷¹. Among all crown fractures, enamel–dentin–pulp fractures have a prevalence of 2.7–14.7% in the primary dentition ^{18, 30, 79} and 5–8% in the permanent dentition ¹⁰⁹.

Teeth with enamel–dentin–pulp fractures need to be treated as emergencies with the utmost care given to the preservation of pulp vitality, especially in young patients with underdeveloped teeth. Therapeutic approaches for the treatment of traumatically exposed pulps include the following:

1. Direct pulp capping
2. Pulpotomy
 - i. Partial pulpotomy (Cvek's pulpotomy)
 - ii. Coronal pulpotomy
3. Pulpectomy

Procedural steps of direct pulp capping and pulpotomy, both of which aim to preserve pulp vitality in young permanent teeth, have been extensively reviewed in the literature ^{86, 110-114}. For primary teeth, the American Academy of Pediatric Dentistry ¹¹⁵ recommends direct pulp capping with mineral trioxide aggregate (MTA) or calcium hydroxide, only in traumatic pinpoint exposures of the pulp. Other suggested treatment alternatives include pulpotomy with MTA ¹¹⁶ or calcium hydroxide paste ¹¹⁷ utilizing solutions of Buckley's formocresol, ferric sulfate ¹¹⁵, and sodium hypochlorite ^{118, 119}; pulpectomy ¹²⁰; and extraction ^{117, 120}.

In permanent teeth, success rates of vital pulp therapies are 81–88% for direct pulp capping ^{121, 122}; 94–96% for partial pulpotomy ¹²³⁻¹²⁵; and 72–79% for cervical pulpotomy ^{126, 127}. While the reported success rates of both cervical pulpotomy and partial pulpotomy are satisfactory, the following advantages of by partial pulpotomy favor its use in traumatic pulp exposures ^{114, 128}:

1. The cell-rich coronal pulp tissue is preserved, providing a better healing potential.
2. Physiologic apposition of dentin is maintained in the cervical region (which is lost and dentinal walls are weakened by cervical pulpotomy).
3. There is no need for subsequent endodontic treatment, as it is frequently recommended after cervical pulpotomy.
4. The natural color and translucency of the tooth are preserved.
5. It is possible to perform sensitivity testing.

The technique employed during pulpotomy is another contributory factor to successful healing. Clinicians should refrain from using slow-speed burs or hand instruments (e.g. excavators), as the injury caused by them is greater than that of the exposure itself. It has been shown that injury to the underlying tissue is minimal when a gentle surgical technique utilizing high-speed diamond or tungsten burs is employed for cutting ¹²⁹.

The IADT guidelines for permanent teeth ⁷¹ recommend direct pulp capping and partial pulpotomy without any mention on the size of pulp exposure, the elapsed time, and maturity level. This is interesting in that, until recently, the choice of treatment has been fundamentally determined by the size of pulp exposure, the maturity of the injured tooth, the time elapsed, the degree of contamination, and the size of the remaining tooth structure ^{110, 130, 131}.

As stated by Bakland and Andreasen ¹³², the size of traumatic pulp exposure has relatively less importance on the prognosis. A healthy pulp, regardless of how much tissue is exposed, has a great ability to survive as long as it can be protected from bacteria ^{111, 133}. However, when the retention of the dressing material is questionable, partial or coronal pulpotomy should be considered to safeguard the surgical wound ^{128, 130}. The rationale behind this consideration is that such procedures allow for maximal thickness of the sealing restoration as well as removal of the inflamed and possibly compromised tissue ¹³⁴.

When a tooth becomes a candidate for vital pulp therapy, the level of root development is a major point of concern. The use of vital pulp therapy is not necessarily confined to developing teeth. Any tooth, regardless of the stage of development and maturity, can be preserved after traumatic or accidental exposure if the pulp is healthy ¹¹¹. Clinicians, when treating a crown fracture with pulp

exposure, should bear in mind that continuing pulp vitality facilitates continuing root development ¹²⁴. Radiographic examination must look not only at the apical part of the root but also at the cervical region and the dentinal walls as a misleading diagnosis could result about the maturity level of the tooth. A young and still developing tooth often lacks root thickness, which needs to develop even if its apical opening appears closed ¹¹¹. This is the reason for the replacement of the term 'apexogenesis' by 'maturogenesis', as the latter 'fully' describes the concept and rationale of vital pulp therapy ^{135, 136}.

The amount of time that has elapsed since the accident is an important factor to consider before deciding on the treatment approach for the traumatically exposed pulp. It is suspected that the risk of contamination and the depth of infection through the exposed area increase by the elapsed time ¹¹⁰, and root canal therapy or coronal pulpotomy is performed ¹¹¹. Both these procedures lead to unnecessary removal of vital and productive tissue that could have been preserved ¹¹¹. At this point, a dilemma arises on how much and/or at what depth the pulp tissue should be removed. This is judged by the clinical assessment of bleeding from the pulp chamber, which should be controlled within 3–5 min under the slight pressure of a cotton pellet soaked in physiologic saline or other solutions such as sodium hypochlorite ^{111, 114, 137, 138}. If no bleeding occurs or it is excessive (uncontrollable) and dark in color, then the pulpal status should be regarded as unhealthy. The condition may then necessitate a more invasive procedure (e.g. coronal pulpotomy or pulpectomy) ¹¹⁴. In a pulpotomy procedure, the ability to establish proper hemostasis appears to be more important than the size of pulpal exposure ¹³⁹.

In vital pulp therapy, tissue removal should be confined to the inflamed pulp. However, the difficulty in assessing the exact level of inflammation is also widely acknowledged. Cvek et al. ¹⁴⁰ have clearly demonstrated that, in mechanical exposures of monkey pulp that were left untreated for up to 168 h (=7 days), inflammation was limited to the coronal 2–3 mm of the pulp. Together with this finding and his strong belief in preserving the pulp tissue as much as possible, Dr. Miomir Cvek developed the 'partial pulpotomy' technique. This technique became very popular especially among pediatric dentists and subsequently called with his name as the 'Cvek pulpotomy'. With the use of this technique, many teeth have the chance to survive despite the challenging conditions created by trauma.

In light of the above-mentioned considerations, it is possibly safe to say that the remaining tooth structure and prevention of infection are the major concerns when performing vital pulp therapy ^{111, 133, 134, 141}. Both of these concerns have a common basis, microleakage. Both the capping/pulpotomy materials and the restoration should resist and prevent microleakage on the fractured tooth.

To heal, a wound should be protected from infection. Pulp exposures are especially vulnerable to infection, as there is no self-healing capacity unless the wound is properly protected ¹⁴². Hence, material selection is the first and critical step toward this goal. For vital pulp therapies in permanent teeth, the use of zinc oxide eugenol, corticosteroids, antibiotics, calcium hydroxide, hydrophilic resins (dentin adhesives), resin-modified glass ionomer, tricalcium phosphate cement, and MTA have been proposed ¹⁴³. Calcium hydroxide, with its high reputation resulting from numerous clinical and laboratory studies, is a cornerstone in dentistry. In the last two decades, however, MTA has emerged as an useful material in the repair of accidental ¹⁴⁴ or inflammatory root perforations ¹⁴⁵ and inflammatory root resorptions ¹⁴⁶, as a root end filling material ¹⁴⁷, and as an apical plug for open

apexes¹⁴⁸. Its possible use in pulp capping and pulpotomy procedures has also been investigated^{138, 149-154}.

Both materials have certain similarities: Due to their high alkalinity (pH = 12.5), they have an excellent antibacterial property^{151, 155}. This helps to maintain a bacteria-free environment at the amputation site during the critical time when the hard-tissue bridge is formed. With the use of MTA, this period has been shown to last for at least 8 weeks¹⁵⁶. Secondly, they have the capacity to induce hard-tissue formation. Their high pH helps them to solubilize growth factors sequestered in dentin during tooth development^{157, 158}. The release of these factors and other bioactive cell signaling molecules may cause the recruitment of undifferentiated pulpal cells to the wound site, leading to the production of a hard-tissue bridge¹⁵⁹. When a non-setting calcium hydroxide is used, a zone of liquefaction necrosis beneath the calcium hydroxide and a deeper zone of coagulation necrosis next to the vital pulp tissue are generated¹⁵⁹. This latter zone plays a stimulating role to form a bone-like hard-tissue bridge between calcium hydroxide and the vital pulpal tissue¹⁶⁰. Blood vessels may become included in the bridge formation during this process^{150, 160, 161}. By the time, through unavoidable dissolution, calcium hydroxide loses its antibacterial effect and the condition allows bacteria to use these vascular inclusions to enter the pulp, which may result in pulpitis^{162, 163}. In contrast, MTA stimulates hard-tissue formation with a very narrow zone of coagulation necrosis¹⁶⁴⁻¹⁶⁶. Next to that zone, a reparative dentinogenesis zone is found. Subsequently, a dentinal bridge is formed faster than that with calcium hydroxide and with fewer vascular inclusions^{150, 167}.

Another prominent characteristic of MTA is its high resistance to bacterial penetration/leakage. MTA closely adapts to adjacent dentin¹⁶⁸⁻¹⁷⁰. This is most likely due to a physical bond between MTA and dentin (a layer of hydroxyapatite is created as a link)¹⁶⁸. The created seal prevents and reduces bacterial penetration to the pulp amputation site^{171, 172}. Murray et al.¹⁷³ demonstrated that the reparative activity of the pulp occurs more readily beneath capping materials that prevent bacterial microleakage, a feature favoring the use of MTA.

There is also a procedural difference between two materials when performing vital pulp therapy. If a paste form is not being used, pulpal bleeding must be stopped before calcium hydroxide can be placed on the wound¹¹¹. However, because of its hydrophilic character, MTA requires moisture to complete its setting reaction. It can be placed in the presence of blood¹¹¹, which is advantageous in some clinical situations.

Dark staining created, when gray MTA is used in capping or pulpotomy of anterior teeth, is a matter of concern. By the introduction of its white formula, this undesired effect has been minimized to an extent; however, the observed instances of slight discoloration continue to be a problem to be resolved¹¹¹.

Based on accumulating evidence, MTA may be regarded as a suitable successor to calcium hydroxide in a variety of clinical situations. However, more long-term research is necessary to entirely replace calcium hydroxide with MTA.

Crown–root fractures

A fracture comprising enamel, dentin, and cementum is defined as crown–root fracture. Depending on the pulp involvement, this injury is classified into two categories, that is, uncomplicated and complicated. Crown–root fractures are the least observed crown-related injury with a prevalence ranging from 2% to 2.5%^{87, 174} in primary teeth and 0.5% to 5% in permanent teeth^{174, 175} among all TDIs. Little information is available with regard to pulp prognosis in crown–root fractures. Existing data are mostly related to the survival of the affected teeth following different treatment procedures.

Direct trauma is usually the main cause of crown–root fractures in the anterior region, while indirect trauma generally results in fractures extending below the gingival crevice without pulp exposure¹⁷⁴. The level and position of the fracture line and the amount of remaining root determine the type of treatment. Crown–root fractures require multidisciplinary approach, which involves contributions from oral surgeons, endodontists, orthodontists, pediatric dentists, periodontologists, and prosthodontists. As an emergency procedure to alleviate pain from mastication, fragments in crown-fractured teeth can be splinted until a definitive treatment plan could be realized. The recommended treatment options in permanent dentition are as follows¹⁷⁴:

1. Removal of coronal fragment and supragingival restoration
2. Surgical exposure of fracture surface (gingivectomy + osteotomy if needed)
3. Orthodontic extrusion of apical fragment
4. Surgical extrusion of apical fragment
5. Vital root submergence
6. Extraction of the tooth

Removal of coronal fragment and supragingival restoration are indicated for superficial fractures without pulp exposure. In this approach, gingival healing is facilitated presumably through formation of a long junctional epithelium, which is followed by restoration of the coronal part¹⁷⁴. The restoration could be performed by reattachment of original fragment (especially in young patients with still developing teeth), resin composite restoration with adhesives, and full crown coverage^{105, 176, 177}.

Surgical exposure of the fracture surface aims to carry the apical fragment from a subgingival to a supragingival position. To this end, gingivectomy and/or osteotomy can be used if the esthetics would not be compromised (i.e. only on the palatal aspect of the fracture)¹⁷⁴. In this approach, the coronal fragment should comprise one-third or less of the clinical root¹⁷⁸.

In orthodontic extrusion of apical fragment, the fracture line is moved to a supragingival position¹⁷⁴. It is the only preferable approach in uncomplicated crown–root fractures, as it is desired to keep the pulp vital. In complicated crown–root fractures, it is an alternative treatment in which downgrowth of osseous and/or gingival tissues is guided to reconstruct the defects by slow orthodontic extrusion. However, the technique requires patient compliance and is more time-consuming than surgical extrusion. Heithersay¹⁷⁹ has introduced a rapid extrusion technique for the management of these cases, which was further developed by Ingber¹⁸⁰. In complicated crown–root fractures, endodontic treatment of the root is usually completed prior to the use of this technique. The extrusion of a non-vital tooth can be accomplished within 3–4 weeks. It should be kept in mind that relatively small

diameter of the extruded apical fragment could be problematic during restoration and should be assessed beforehand¹⁸¹. As the stretched marginal periodontal fibers may cause relapse following orthodontic extrusion, fibrotomy should be performed. It is performed before initiation of the retention period, which should last at least 3–4 weeks^{182, 183}. A new method of orthodontic extrusion utilizing neodymium–iron–boron magnets has been described by Bondemark¹⁸⁴. The magnets are attached to the remaining root and incorporated in a removal appliance. The treatment results in extrusion of the root over a period of 9–11 weeks.

Crown–root-fractured tooth where coronal fragment comprises less than half of the root length is a candidate for surgical extrusion of apical fragment^{185, 186}. In dental trauma literature, a modified form of this approach exists as ‘intentional replantation’¹⁸⁷⁻¹⁸⁹. Surgical extrusion can be chosen if the root formation is complete and the root length following surgical procedure would be enough to support a postretained crown^{187, 190}.

When the restoration of a crown–root-fractured tooth is not possible and it is desired to keep the apical fragment in place to maintain the alveolar width and height in a young individual, vital or non-vital root submergence is the choice of treatment^{191, 192}.

Extraction of the tooth is indicated when the coronal fragment comprises more than one-third of the clinical root and the fracture line follows the long axis of the tooth¹⁷⁴. However, as the supporting bone rapidly resorbs following extraction¹⁹³, every effort should be exerted to preserve the volume of the alveolar process (e.g. root submergence). If unavoidable, implant treatment (in patients with completed growth), orthodontic space closure (in still growing patients), and autotransplantation can be considered in conjunction with extraction¹⁹⁴.

All of the above-mentioned treatment approaches have their own advantages and disadvantages^{105, 190}. Depending on the treatment employed, the advantages include easiness to perform (coronal fragment removal, gingivectomy), being conservative (fragment removal, vital root submergence), and possibility of a rapid final restoration (fragment removal, gingivectomy, surgical extrusion). Likewise, the disadvantages include requirement of root canal therapy (orthodontic and surgical extrusion), treatment procedure in an esthetic sensitive region (forced orthodontic and surgical extrusion), risk of external root resorption (surgical extrusion), and the magnitude of total/future costs (orthodontic extrusion, extraction).

For primary teeth, the IADT guidelines¹¹⁷ recommend two treatment approaches based on the clinical findings: (i) fragment removal only if the fracture involves only a small part of the root and the remaining tooth part is large enough to allow a coronal restoration, and (ii) for all other instances, extraction should be performed. McTigue⁸⁶ suggests extraction when the fracture in a primary tooth extends through the crown to the root. If extraction cannot be performed easily, root fragments should be left to resorb spontaneously to avoid injury to the developing tooth bud¹⁹⁵.

Summary

As with other dental trauma cases, crown-related fractures need timely referral to the dentist for the treatment of injury as delays can affect the long-term outcomes¹⁹⁶. Yet, the literature shows considerable delays in seeking for immediate care of the injured teeth¹⁹⁶⁻²⁰⁰. The reported delays have

exceeded 1 month and even 1 year following a traumatic injury^{197, 199, 201}. A contributing factor may be the type of traumatic injury, which was reported by Pugliesi et al.¹⁹⁸. They have found that 51.1% of the patients sought care within 1–15 days following a luxation injury, while this figure was 52.7% for hard-tissue injuries and only after 16 days. In addition, the transit time either to a dentist or from referring practitioner(s) to hospital (e.g. in rural areas) and waiting times in the hospital may be the cause of delays¹⁹⁶. However, its significant part may be linked to negligence and/or low level of knowledge of the importance of immediate management of dental trauma^{2, 202, 203}. The consequence of all these factors is the unmet treatment need of an injured person. Epidemiologic studies have drawn attention to injured and untreated teeth of both dentitions in children from different populations of the world^{15, 42, 45, 204, 205}. In several studies, the percentage of children with untreated damage was well over 90% with major proportion belonging to the crown-related fractures^{45, 205, 206}.

These observations underline not only the great treatment need, but also the neglected treatment for TDIs^{42, 205-207} both by the patient/parent and, to some extent, by the dentist. In a recent study, Zaitoun et al.²⁰⁸ have reported that 39% of patients were deemed to have received inappropriate treatment according to the criteria drawn up by the study group. Moreover, inappropriate management (incorrect pulp management and/or inadequate protection of exposed dentine) in complicated and uncomplicated crown fractures was 70.6% and 40%, respectively²⁰⁸. Hence, appropriateness of the initial (emergency) treatment is another important aspect that should be reviewed from the dental profession's side.

An efficient dentinal seal is essential in crown-related fractures. This will prevent further bacterial invasion and let the pulp to cope with the trauma by eliciting its inherent physiologic defense mechanisms. Studies have shown that the failure to protect exposed dentin is the most common example of inadequate management²⁰⁸. It is a fact that treatment significantly decreases the likelihood of pulp necrosis¹⁰⁰, which emphasizes the importance of performing immediate restoration of crown-fractured teeth and the need to treat these traumatized teeth as emergencies⁸⁵.

The prognosis of crown fractures is quite favorable in both dentitions with proper treatment. However, their management in a preschool child may sometimes be quite challenging and stressful depending on the patient's anxiety and cooperation level. Such a situation may involve a risk of potential damage to the developing permanent tooth buds (e.g. in a crown–root fracture). Hence, immediate referral to a pediatric dentist is advisable to minimize the potential emotional trauma to the child and prioritize the healthy development of the permanent incisors⁸⁶.

On the other hand, any blow that causes a tooth to fracture is likely to also cause a luxation injury²⁰⁹. This is especially important in late referral cases as the elapsed time between injury and treatment could mask the underlying luxation injury (e.g. subluxation). Therefore, the clinician should be alert and look for an associated luxation injury in all crown-fractured teeth.

This review considered the occurrence, management, and prognosis of crown-related fractures in primary and permanent teeth in light of the recent literature. It was concluded that, with timely referral and appropriate management, the prognosis and long-term outcome of such cases could be optimized. To this end, the dentist should also make every effort to preserve vitality of teeth in especially younger children with immature primary and permanent teeth.

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