A story of dental injury and orthodontics

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Abstract
Approximately ten percent of patients who seek orthodontic treatment have experienced a Traumatic Dental Injury (TDI). TDI occurs in different age groups ranging from preschool children to adults. Both primary and permanent teeth can be injured, and the sequelae of TDI complicate orthodontic treatment. This article gives a review on the epidemiology and etiology of TDI, and also the relation between TDI and orthodontics.

Introduction

Traumatic Dental Injuries (TDI) are a serious public dental health problem throughout the world [1-7]. About 10.3% of patients seeking orthodontic treatment have suffered from dental trauma. Maxillary incisors are the most vulnerable teeth to TDI, with increased overjet and incompetent lip coverage considered to be the most significant predisposing factors [2,3]. Indeed, traumatized incisors can impose challenges to orthodontists during orthodontic treatment. Early orthodontic intervention can however help prevent TDI of maxillary incisors [8].

This article will discuss the epidemiology and etiology of TDI, early stage orthodontic prevention of TDI, dental trauma problems present during orthodontic treatment and how to manage cases with traumatized teeth in orthodontics.

Epidemiology

TDI are commonly seen in 92% of patients presenting with oral injuries [1]. Epidemiological studies worldwide and in the past four decades have reported varying prevalences of TDI in children and adolescents (*Tables 1 and 2*). In the 0–18 years old group, these prevalences ranged from 8% to 76%. In most studies the 0 – 6 years old group varied from 9.4% to 40% [4].

In Sweden, the incidence of TDI in rural areas has been reported to be 11.7%. Urban areas and northern Sweden account for incidences of 30% and 35%, respectively. One Swedish study showed that 13 out of a 1000 individuals experienced dental injuries every year [5,6]. In the UK, about 4% of patients suffered from TDI in 15 months, while the prevalence in the population was about 34% [7]. The prevalence of TDI in Italy was about 20.26% [9]. In Romania, the recorded overall prevalence of TDI was 24.5% from 2003 to 2011. An Australian study reported the incidence of dental trauma in West Australia to be 11.7% [10].

In Taiwan, East Asia, research indicated 16.5% of children in the central region [11] and 19.9% of children in the southern region [12] had a positive history of dental trauma. In South Asia, one Indian study revealed a relatively high prevalence of TDI in children 4 – 6 years old. The incidence of dental injury was 76.13%, but the author did not explain the reason for recording such a high prevalence in the group. However, two other Indian studies revealed much lower rates of 8.17% and 14.4%, respectively [13-15]. The former study included children 8 – 13 years old, while the latter included those 12–15 years old. Jon et al. reported an incidence of 14.5% of dental injuries in an Arabian population in Kuwait [16].

Many epidemiological studies have been carried out in Brazil. School children aged 5–15 years old have been covered in these studies. Here, the prevalence rates included a range from 9% to 50%. The reported values vary among different age groups [4,17-21].

In terms of gender, most studies report that males have a significantly higher incidence of TDI than females. The ratio lies between 1.2:1 to 2:1. The highest frequency of TDI was recorded in children with mixed dentition, aged from 7–12 years old, with the maxilla more frequently involved than the mandible [22]. The most commonly affected teeth are the upper permanent central incisors (79.6%) followed by lateral incisors (16.4%) [2].

Predisposing Factors

TDI affects the maxillary permanent incisors most frequently according to previous literature. The cause of dental injury to upper anterior teeth is multifactorial [2,22-24]. It can be divided into two categories: dental and non-dental.

Dental factors

Most of the studies considered an increased anterior overjet (OJ) to be the most significant predisposing factor for dental injury on maxillary incisors. It has been reported that children with an increased anterior OJ of more than 3 mm are two times more at risk of TDI on upper incisors than those with an OJ less than 3 mm. The risk of dental injury increases with OJ size [22,24]. Various studies define the OJ value as 5 mm. Children with an OJ of more than 5 mm have a three-fold higher risk of suffering from dental injury on upper anterior teeth [17,18]. However authors Koroluk [25] and Stokes [26] have argued that an increased OJ might not be positively correlated with the risk of dental injury. In their studies they found no difference between mean OJ values of children with and without incisor injury. The controversy is most likely caused by different sample sizes, social behavioral differences and other confounding factors.

Lip coverage is also a significant factor associated with maxillary incisor trauma. Most studies concluded that children with incompetent upper lips were more likely to experience traumatic injury [2,18,23,27-31]. Mouth breathing was also suggested by numerous studies to be one of the contributing factors to dental injury.

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In summary, children aged 7 – 12 years old who have increased anterior OJ, protrusive upper incisors, incompetent upper lips, Class II malocclusion and a habit of mouth breathing are prone to maxillary incisor traumatic injury. Patients with dental features like those listed above have a high risk of experiencing TDI, and prevention should therefore be considered [23] (*Figures 1 and 2*).

Non-dental Factors

With the exception of malocclusion which is a dental factor leading to dental injury, there are several non-dental factors which may affect children's vulnerability to dental injury [32].

Age, gender and social activities are common predisposing factors of TDI. According to previous studies, children with mixed dentition were more prone to dental injury than adolescents and adults. Males were more susceptible to dental injuries and frequently experiencing them than females. In preschool children, falls were the main cause of dental injury, while in school children sports injuries (*Figure 3*) and school altercations were the major causes of TDI. In adolescents and adults the most common etiologic factors were assaults and traffic accidents, often related to consumption of alcohol or usage of illicit drugs [3,12,19].

Socioeconomic influences can also be significant predisposing factors [33]. Nicolau et al. discovered that children and adolescents who experienced unfavorable psychosocial environments had more traumatic dental injuries than those from more favorable environments [34]. Bendo et al. reported a higher incidence in dental injuries associated with a higher score on the Social Vulnerability Index (SVI). These represented a poorer socioeconomic condition including neighborhood infrastructure, access to work, income, sanitation services, healthcare services, education, legal assistance and public transportation [35]. Levy et al. also found lower injury rates among residents living in high socio-economic localities [36].

Figure 1. *An 8 year old with an increased anterior overjet (10 mm) and overbite, protrusive upper incisors and incompetent lips. This patient was of pre-pubertal age and at high risk of suffering from dental injury.*

Figure 2. *An upper removable plate with a labial bow and Adam's clasps was constructed in order to retract the upper incisors and reduce the overjet. TDI-related prevention advice was provided to the patient and parent with regard to the upper incisors.*

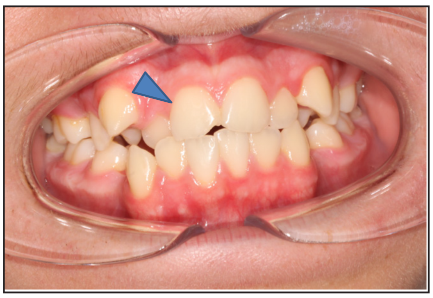

Figure 3. *#11 with an enamel fracture, due to a sports-related injury.*

Orthodontic Intervention

According to previous studies, patients with an increased anterior OJ and inadequate lip coverage were at increased risk of sustaining traumatic injuries to their upper incisors. Many authors suggested that orthodontic treatment could reduce the likelihood of upper incisor injuries in these patients [25,31,37,38].

Orthodontic intervention including the utilization of removable plates and 2 X 4 fixed appliances [39] can be used to retract upper anterior teeth and reduce anterior OJ at the early mixed dentition stage. A maxillary removable plate with a labial bow and two Adam's clasps is used to retract the upper anterior incisors by tipping the teeth distally (*Figures 1,2 and 4*). The fixed 2 X 4 appliance provides more control of the anterior teeth: it can retract and intrude the anterior teeth at the same time. Further, a controlled tipping movement can also be achieved using this appliance.

Orthopedic treatment in patients with a Class II, division 1 malocclusion with extra-oral traction or functional appliances has long been a popular topic in orthodontics. Numerous studies have been conducted to investigate the biological basis of orthopedic treatment, the treatment effects and the appropriate time to carry out the treatment.

The skeletal and dental features of a patient with a Class II, division 1 malocclusion and skeletal component

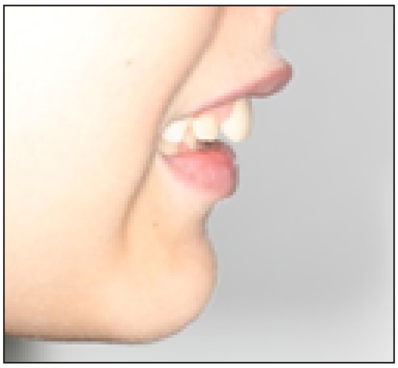

Figure 4. *Six months following the delivery of the plate, the patient's overjet was reduced as a result of the retraction of the upper incisors. The patient had also been vigilant in avoiding injury to her upper incisors. The anterior overbite was deepened after retraction and would be corrected by subsequent orthopedic or fixed orthodontic treatment.*

are: overgrowth of the maxilla and reduced growth of the mandible in the Anteroposterior (AP) direction, protrusive upper incisors, excessive anterior OJ and inadequate lip coverage. Extra-oral traction using headgear was reported to be able to restrain the growth of the maxilla and retract upper incisors, allowing the growth of the mandible to catch up with the growth of the maxilla. This led to the eventual reduction of excessive OJ and correction of the skeletal class II pattern [40]. Functional appliances such as a bionator [41], twin block [42] and Herbst [43] have been used to achieve a similar result as those reported in headgear-based studies. It is has also been reported that functional appliances can stimulate the growth of the mandible and guide the direction of mandibular growth [44]. However, the skeletal effects were not clinically significant in comparison to their dentoalveolar effects [45]. It is therefore not unreasonable to suggest the implementation of orthodontic treatment at an early stage when the permanent maxillary incisors erupt. And theretofore, the anterior OJ can be reduced in order to prevent high risk patients from suffering TDI [25,32].

The value of early treatment, or two-phase treatment, of Class II malocclusion is however a controversial issue, despite the publication of many randomized controlled trials in the USA and UK. Early treatment of Class II malocclusion comprises two stages: (i) the treatment of skeletal class II discrepancy at the early mixed dentition or pre-pubertal age, using functional appliances or headgear, and (ii) comprehensive orthodontic treatment at the early permanent dentition stage. Results from previous research show that early treatment can produce significant skeletal and dentoalveolar changes at stage one, but the benefits will later diminish by stage two. Two-stage treatment increases treatment time and cost, but produces little benefit. Hagg and Pancherz's study on mandibular growth observed that sagittal condylar growth in patients treated at the growth peak, around late mixed or early permanent dentition, was twice that of those treated three years before or after the peak [46]. Many authors have therefore suggested a later one-stage treatment at late mixed dentition with orthopedic appliances initially, followed by orthodontic fixed appliance treatment [45,47,48].

Overall, at pre-pubertal age, in order to prevent TDI in a patient who has an increased OJ with Class II skeletal discrepancy, a removable plate or 2 X 4 appliance can be utilized for a short period of time (3 to 6 months). Consideration of orthopedic treatment is recommended at a later stage when the patient reaches his or her growth peak. Subsequently, comprehensive orthodontic treatment with a fixed appliance can be undertaken. Based on previous literature, orthodontic intervention protocols for patients at increased risk of TDI are shown in *Figure 5*.

Traumatized teeth and orthodontic treatment

Traumatized permanent maxillary incisors often complicate orthodontic treatment. According to previous studies, TDI of permanent maxillary incisors can be divided into two categories based on the time of their injury: pre-eruption and post-eruption trauma.

Pre-eruption: Intrusive injury of primary maxillary incisors can induce developmental disturbances of their permanent successor germs or change their position due to the close anatomic relationship between the apices of the primary teeth to the germs [49]. The primary incisor is driven deeply into the alveolar bone either palatally or labially and invades the dental follicle of its permanent successor. The distance between the permanent teeth and the apex of the primary incisor is only about 3 mm, and may only consist of fibrous tissue [50]. Injury of permanent tooth germs by their primary predecessors can result in severe development anomalies. These may include enamel hypoplasia, crown and root dilacerations, and odontoma-like tooth formation. The prevalence of permanent teeth malformation following trauma to their predecessors ranges from 25% to 69% [51].

Enamel hypoplasia: According to the literature, intrusion of primary incisors is strongly associated with hypoplastic enamel in their permanent successors (*Figure 6*). Amelogenesis relies on the normal function of ameloblasts. Displacement in the normal alignment or synchronized activity of ameloblasts may result from the intrusion of a primary incisor. It may also cause irreversible destruction to the active enamel epithelium, leading to the arrest of matrix formation and eventual deformed pits and grooves [49,52,53]. The typical clinical appearance of enamel hypoplasia is the enamel defect associated with a white or brown discoloration.

Bonding to hypoplastic enamel surface has a high failure rate. The bonding strength between hypoplastic enamel and adhesive is lower than that with normal enamel [54]. The enamel surface available for bonding on hypoplastic enamel is reduced. Etching with 37% phosphoric acid has failed to produce satisfactory results despite that it is thought to be feasible in most cases [55]. The alteration of enamel mineral and protein content also affects the bonding performance when using the acid-etch technique [56].

Constant, multiple bonding failures during orthodontic treatment are often frustrating for both the orthodontist and patient. Efficient orthodontic treatment often cannot be delivered due to bonding failure with brackets, and this will increase the duration of treatment. Glass Ionomer Cement (GIC) based adhesives such as resin reinforced glass ionomer cement can be used to replace the conventional acid-etch adhesives. GIC forms a chemical bond to enamel and dentine via an ion exchange mechanism which relies less on microtag formation and mechanical bonding [54,57]. However, its shear bonding strength is significantly lower than that with composite within the initial 30 minutes after bonding, but increases markedly in 24 hours. Therefore, clinicians have suggested the application of a fairly light force to the brackets during ligation of the first wire [58]. Sodium hypochlorite (NaOCl) is an effective protein denaturant which does not affect the mineral content of the enamel. It has been proven to be capable of removing excessive amounts of protein in the enamel, thus making the enamel crystal more accessible to the acid-etching solution. Pretreating the enamel surface with 5% NaOCl before bonding has been reported to enhance bonding of orthodontic brackets to hypoplastic enamel. The application of NaOCl is however, restricted from treating enamel with low mineral content [59]. Traditional banded appliances have been suggested by some authors to overcome the bonding problems, but at the expense of compromising patient esthetics. Temporary restoration of defective teeth

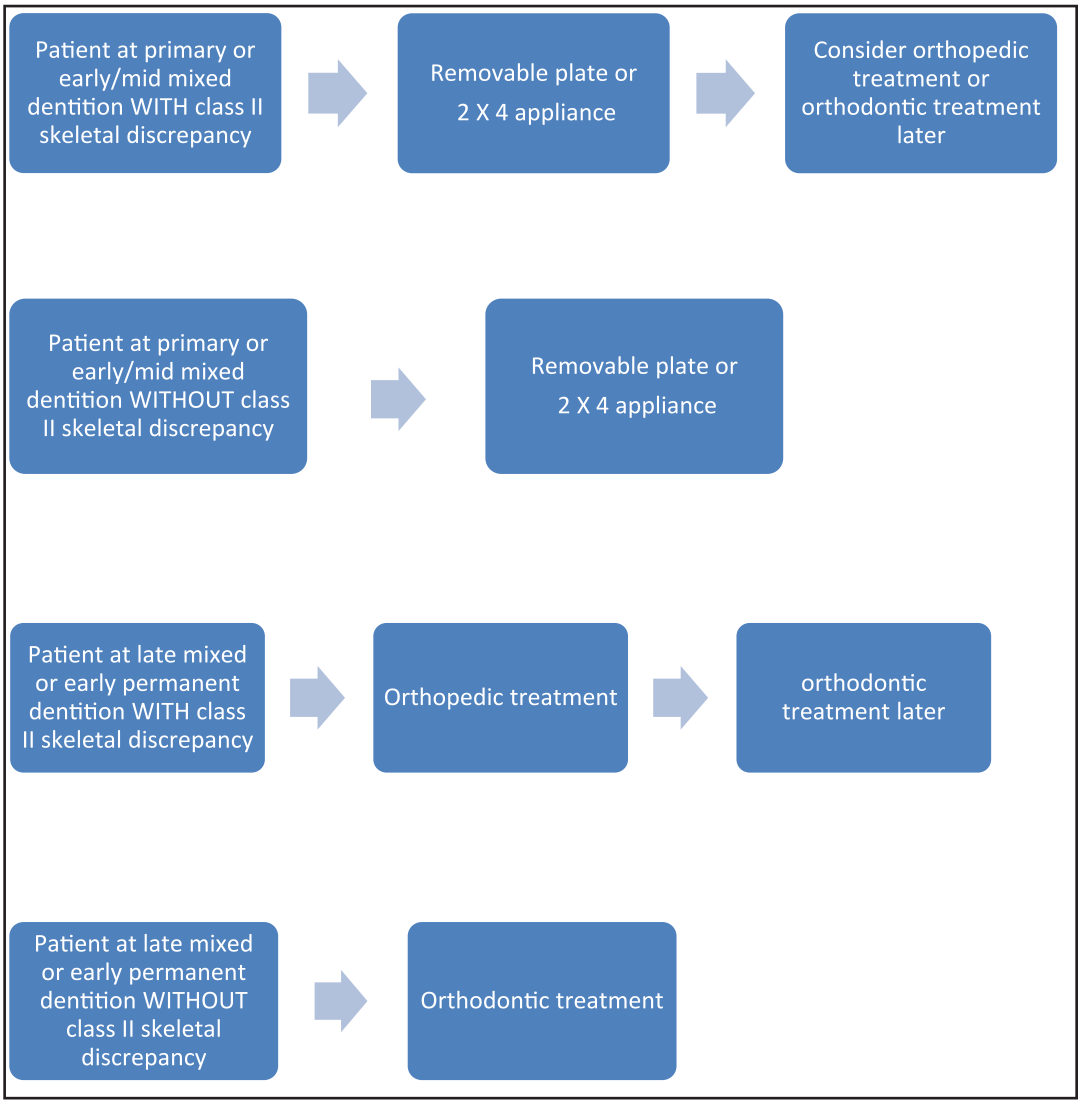

Figure 5. *Orthodontic intervention for patients with a high risk of TDI.*

Figure 6. *Enamel hypoplasia of the permanent teeth. (From Gomes AC, Messias LP, Delbem AC, Cunha RF. Developmental disturbance of an unerupted permanent incisor due to trauma to its predecessor. Journal of Canadian Dental Association. 2010; 76: a57.)[53].*

with either direct or indirect composite resin veneers to permit bonding of orthodontic brackets is another means of solving the problem [60]. Permanent restoration with porcelain veneers before bonding has also been suggested. If there is insufficient crown height, banding or veneers are not possible. Here, preformed stainless steel crowns with brackets or porcelain fused to metal crowns can help to cover the hypoplastic enamel [61,62]. Patients with mild crowding who only need minor adjustments can benefit from orthodontic removable appliances. These appliances include removable plates made of acrylic with stainless steel springs

Figure 7. *The patient had a diastema between #11 and #21. #12 crown was broken down due dental caries. And #22 was peg shape.*

and clear aligners. The vacuum-formed clear thermoplastic aligners made of plastic were introduced into orthodontics in the 1980's. These were initially retainers and later developed into a tooth-moving device. These are removable and do not need to be bonded, and are therefore an ideal tool to solve the orthodontic bonding problem. Nowadays, some clear aligner systems can correct mild to moderate malocclusion as effectively as conventional fixed appliances [54,62,63] (*Figures 7-10*).

Dilaceration and impaction: 'Dilaceration' was defined by Andreasen (1971) as, "… the abrupt deviation of the long axis of the crown or root portion of the tooth. This deviation originates from a traumatic non-axial displacement of already formed hard tissue in relation to the developing soft tissue".

Figure 8. *Clear aligners were used during the treatment.*

Figure 9. *Patient wearing the clear aligners. There were no brackets bonded.*

Figure 10. *The diastema was closed, #22 restored by composite resin, #12 ready for extraction and replacement by dental implant.*

It must differentiated from the term ‘angulation’, which is a curvature of the root due to the gradual change of position during development without abrupt deviation of the tooth germ during odontogenesis [1]. An acute mechanical injury to the permanent tooth germ is the most accepted main etiology of tooth dilacerations. However, there is a second hypothesis suggesting that the cause of dilaceration is not from direct injury, and that the disorder is due to ectopic development of the tooth germ [64].

The typical clinical features of a dilacerated tooth include non-eruption, delayed or ectopic eruption of the affected permanent tooth with or without a retained primary predecessor. Adjacent teeth tend to occupy the space of unerupted (*Figure 13*) or ectopic erupted teeth (*Figure 14*), resulting in crowding and a midline shift. Sometimes the height of the alveolar crest at the affected site is different. If there is impaction, the impacted tooth may be palpable or impalpable at the labial sulcus or palatal side depending on its position. The condition may be asymptomatic and unnoticeable to the patient. Unerupted dilacerated teeth are usually detected by panoramic radiograph screening during orthodontic examination. Conventional radiographs including periapical film, occlusal film and a lateral cephalogram are used to evaluate the morphology, position and associated pathology of the dilacerated tooth. Cone Beam Computed Tomography (CBCT) is considered the most powerful tool to investigate the impacted dilacerated tooth.

Orthodontic treatment is complicated by the side effects of impacted dilacerated teeth. Space loss results in a shortened dental arch, crowding and uncoordinated upper and lower arches. Pathoses such as a dentigerous cyst, ankylosis or root resorption may arise from an impacted tooth [65]. Therefore, intervention should start early to maintain the arch length, prevent adjacent teeth from occupying the space and also prevent any pathological changes. If space has already been lost, it must be regained in order facilitate the eruption of the affected tooth (*Figure 11*). Guided eruption must be carried out with surgical crown exposure and followed by orthodontic traction (*Figure 13*). Orthodontic attachments such a gold chain and lingual button can be combined with a power chain, thread or ligature wire for traction. In cases with severe crowding, extraction should be considered to alleviate the crowding and provide space for the impacted tooth (*Figure 12*). There are three techniques for exposing the impacted tooth: excisional uncovering, Apically Positioned Flap (APF) and the close flap technique [66-68]. The orthodontist should evaluate several criteria before determining the suitable method for exposition. These criteria include: (i) position of impaction (labial or palatal), (ii) height of impaction (above or below the mucogingival junction), (iii) the amount of attached gingiva and (iv) the relation to the adjacent teeth. The details of surgical exposure of impacted teeth in orthodontics are summarized in *Table 3*.

A prolonged duration of orthodontic treatment is expected with unerupted dilacerated teeth. Other complications associated with treatment include loss of tooth vitality, ankylosis and root resorption. These should also be considered and will be discussed in the next section.

Post-eruption

Crown fracture without pulpal involvement: Crown fracture injuries include enamel fractures and enamel dentine fractures. Crown fracture without pulpal exposure is the most frequent type of injury to permanent incisors of school children [18,69,70]. Most incisors with crown fractures occur in a combination injury. Here, concussion and sublaxation injuries are the most frequent types [18].

Patients with upper incisor crown fractures have compromised esthetics, phonetics and function. Bracket positioning is crucial for a pre-adjustment edgewise system. In order to ensure precise tooth movement, a bracket should be placed at the center of the clinical crown of an upper incisor. Indeed, the irregular shape of the crown can become a challenge for bracket positioning (*Figures 3 and 14*). Restoration of the broken crown with composite resin is preferred before the initial bonding of brackets. Pulp vitality should be tested before orthodontic treatment starts.

Root fracture

The incidence of root fracture in injured permanent teeth ranges from 0.5 to 7% [71]. Injury with root fracture generally affects the dentine, cementum, pulp and periodontal ligament. Horizontal root fractures predominate in maxillary central incisor injuries, and pulp necrosis takes place in 25% of the cases [72]. The sequelae of root fractures are categorized into four types, and include healing with (i) calcified tissue, (ii) connective tissue, (iii) bony tissue and (iv) granulation tissue. Treatment of root fractures often involve splinting the affected tooth and endodontic therapy of the coronal segment [73,74].

Figure 11. *A 10 year old patient with a history of TDI on the upper primary incisor. #21 was impacted. #11 and #22 moved mesially occupying the space. Periapical and occlusal fims have been taken in order to evaluate the dilacerated and impacted #21; A lateral cephalogram shows the dilacerated #21 and the OPG shows its impaction. A quadhelix has been used to create space for #21.*

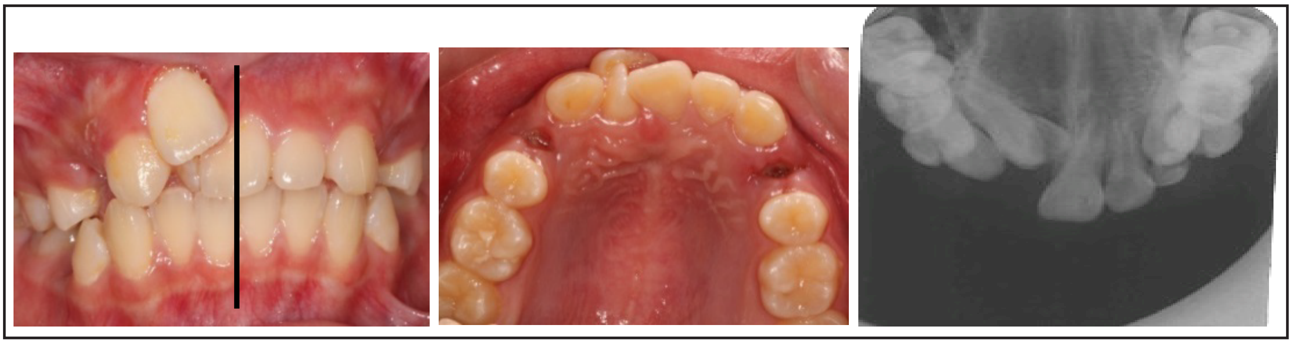

Figure 12. *A 14 year old patient with a history of TDI on the upper primary incisor, #11, with dilacerations and ectopic eruption. In a., an upper midline shift was caused by the mesial drift of #21 due to the ectopic eruption of #11. In b., severe crowding occurred due to space loss, and extraction of premolars was required to regain space. With c., occlusal film revealed the overlapped roots of #11 and #12.*

Figure 13. *Orthodontic traction following APF surgery (Courtesy: Dr Yousef Abdalla).*

The response of teeth with horizontal root fractures to orthodontic force has always been an enigma. Very few studies can be found in this area and are all case reports. According to some of these reports, it is possible for the movement of these teeth provided care is taken. Zacchrisson and Jacobsen suggested observation for at least two years before commencing orthodontic treatment [75]. Havland et al. reported a case of horizontal root fracture at the junction of the apical and middle third of the root of a maxillary central incisor. The incisor was moved palatally and intruded by one unit with orthodontic force two years after the trauma. The follow up test results were within normal limits following the treatment [76]. Two decades later, Duggan et al. reported two maxillary central incisors with horizontal root fractures were moved – with protrusion, intrusion and retroclination – by orthodontic fixed appliances. The periodontal ligaments of the two teeth were complete without any breakdown, even at the level of the fracture line before the treatment started.

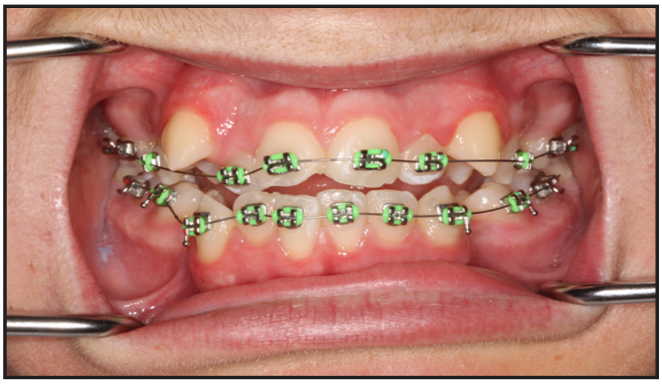

Figure 14. There was difficulty in determining the bracket position for #11. Restoration of the incisal edge was required following orthodontic treatment.

resorption and replacement root resorption (ankylosis) [1]. Significant inflammatory or replacement root resorption can result from traumatic dental injuries. According to previous studies, orthodontic tooth movement usually induces mild superficial root resorption at the apical area. However, it rarely results in significant morbidity and the process will cease after removing orthodontic force.

Severe root resorption can be induced by orthodontic treatment on previously traumatized incisors, possibly due to the existing damage of periodontal ligament and cementum, especially at the apex. Orthodontic movement of traumatized incisors generally results in an average root resorption of 1.07 ± 1.19 mm compared with a change of 0.64 ± 1.04 mm for trauma-free cases [80]. Traumatized teeth that have already undergone root resorption are more sensitive to orthodontic force [81]. Records of traumatized teeth before orthodontic treatment is therefore recommended [80].

Table 1. The prevalence of dental injuries in schoolchildren worldwide from 1988 to 2013.

Authors	Country	Year	Sample size	Age (year)	Prevalence (%)
Stockwell AJ [10]	Australia	1988	66500	6-12	11.7
Forsberg CM [23]	Sweden	1990	1635	7-15	18
Josefsson E [96]	Sweden	1994	752	7-17	11.7
Petti S [9]	Italy	1996	824	6-11	20.26
Borssén E [6]	Sweden	1997	3007	1-16	35
Hamilton FA [7]	UK	1997	2022	11-14	34
Chen YL [11]	Taiwan	1999	1200	7-8(second grade)	16.5
Huang B [12]	Taiwan	2009	6312	15-18	19.9
Cortes [17]	Brazil	2001	3702	9–14	13.6
Jon Årtun [16]	Kuwaiti	2005	1583	13-14	14.5
Soriano EP [18]	Brazil	2007	1046	12	10.5
Kumar A [15]	India	2011	963	12-15	14.4
Patel MC [14]	India	2012	3708	8-13	8.79
Francisco SS [19]	Brazil	2013	765	9-14	16.5

Table 2. The prevalence of dental injuries in preschool children worldwide from 1990 to 2013.

Authors	Country	Year	Sample size	Age (year)	Prevalence (%)
Forsberg CM [23]	Sweden	1990	1635	0-7	12
Jones [97]	USA	1993	493	3-4	23
Borssén E [6]	Sweden	1997	3007	1-6	20
Hargreaves JA [98]	South Africa	1999	1466	1-5	15%
Oliveira LB [4]	Brazil	2006	625	5(y)-59(m)	9.4
Granville-Garcia AF [20]	Brazil	2010	820	1-5	20.1
V. P. P. Costa [21]	Brazil	2013	576	8-89(m)	45.5
Bhayya DP [13]	India	2013	1500	4-6	76.13

Both teeth remained functional and asymptomatic after the treatment [77]. Healey et al. reported a case with similar results [78]. However, another case by Erdermir et al. showed that the distance between the two segments of a fractured root of an incisor increased after orthodontic treatment started one year following the trauma. The tooth remained functional and mobility was within normal range after 6 months [79].

Currently, there are no specific guidelines for moving root fractured teeth in orthodontics. Based on previous reports, a waiting period of a minimum of two years is required after the trauma and before initiating orthodontic treatment. The periodontal ligament of the affected tooth must be complete. The tooth must be asymptomatic and have no radiographic signs of pathology and the mobility of the tooth must be within normal limits.

External root resorption

Three types of external root resorption have been described. They are superficial root resorption, inflammatory root resorption and replacement root resorption (ankylosis) [1].

The etiology of orthodontic induced root resorption is multifactorial. Besides a history of previous trauma, other risk factors should also be taken into consideration. Abnormal root shape has been reported to be one of the most significant factors associated with root resorption. Dilacerated maxillary incisors and pointed teeth show greater root resorption in general than blunted teeth [82,83]. Previously traumatized teeth with mild apical damage and intact periodontal ligaments do not show any higher tendency towards root resorption during orthodontic treatment than non-traumatized teeth. Timing of treatment is crucial, and therefore it is recommended to wait for at least 4 to 5 months after an injury in order to permit healing of the periodontal tissue [84].

Treatment mechanics have been reported to have an impact on root resorption. "Jiggling force", which is produced

***Table 3.** Surgical techniques for uncovering impacted teeth under different situations.*

	Excisional uncovering		**Apically positioned flap**		**Closed flap technique**	
Advantages (adv) and disadvantages (disadv)	adv	disadv	adv	disadv	adv	disadv
	Simple, less traumatic	Lose gingival attachment after eruption	Preserve keratinized gingiva	Higher gingival level, gingival recession, intrusive relapse	More esthetic	Patient discomfort, secondary surgery, less keratinized gingiva
Position	Labial, not covered by bone		Labial and palatal		Labial or palatal or center of alveolus	
Height	Occlusal to mucogingival junction		Occlusal or not significantly apical to mucogingival junction		Significantly apical to mucogingival junction	
Gingiva	Keratinized gingiva present, 2-3 mm wide		Can be used when not enough keratinized gingiva present		Keratinized gingiva present	
Adjacent teeth	Do not position over the root of adjacent teeth		Can be used when positioned over the root of adjacent teeth		Do not position over the root of adjacent teeth	

Source: Kokich [68,99], Bishara [66], Bedoya [100], Crescini [101], Ngan [65]

by intermaxillary elastics or removable appliances, has been suggested by many studies to be the cause of root resorption [80]. Some authors believe that uncontrollable tipping and intrusion were more likely to produce root resorption than bodily movement due to the high stress level in the periodontal ligament [85]. Heavy forces and prolonged treatment time are also believed to cause resorption. Many authors have suggested that root resorption is directly related to the distance moved by the roots [80]. Cases with premolar extractions have greater resorption (1.43 mm) than non-extraction cases (1.09 mm). Displacement of the root by more than 1.5 mm in the anteroposterior dimension has a greater resorption by more than 0.5 mm [83]. However, some authors have explained that the proximity of roots to the lingual or palatal cortical plate has a more significant relation to resorption than the extent of root displacement [86]. In upper premolar extraction cases, maxillary incisors are retracted closer to the palatal cortical plate. Nevertheless, despite the numerous studies, none of them have been able to provide convincing evidence to support their hypothesis. Further investigations are required to shed light on this myth.

The recommendations for managing teeth with TDI to avoid severe root resorption are made based on previous literature. They are as follows:

1. Keep a comprehensive record of the traumatized teeth including the history, examination results and radiographs.
2. Allow for a minimum of 5 months before commencing orthodontic treatment.
3. Try to avoid displacing the root for more than 3 mm. Choose non-extraction plans if possible.
4. Maintain light force during the treatment, using controlled tipping movement and avoiding intrusion.
5. Avoid the contact of roots with the lingual and palatal cortical plate.
6. Keep the treatment duration as short as possible.

Replacement resorption followed by tooth ankylosis always takes place after replantation of avulsed tooth due to TDI. The cementum of the root fuses together with the alveolar bone, making the tooth irresponsive to orthodontic force. Furthermore, if ankylosis occurs in the maxillary incisors of the growing child, the ankylosed tooth will not move together with the alveolar bone growth. This will result in infraposition of the affected incisor with a poor esthetic appearance [87,88].

There has been several treatment protocols performed for ankylosed incisors. Surgical luxation followed by orthodontic traction has been used by some authors to successfully move ankylosed teeth [89,90]. However, there are risks involved with this method. Reankylosis and intrusion of adjacent teeth during orthodontic traction may occur. Another alternative is to extract the ankylosed tooth and close the space, or replace it with a dental implant. But such traumatic extractions of ankylosed teeth may lead to esthetic bone deficiency at the extraction site, particularly at the anterior incisal area where the buccal plate is thin. Therefore the final restoration may not be esthetically acceptable [91]. A more conservative alternative treatment to the extraction of ankylosed teeth was suggested by Malmgren in order to preserve the alveolar ridge. This method is defined as decoronation which involves raising a mucogingival flap, subcrestal removal of the crown, leaving the root in the alveolus which will be replaced by bone. It can help to reduce the risk of developing severe infra-position of the ankylosed teeth in children under 10 years old before their growth spurt [92].

Distraction osteogenesis using an internal device has been used for edentulous alveolar process augmentation in the vertical dimension since the 1990's. A segmental osteotomy is usually performed to create a block of alveolus, and an internal device used to transport the block vertically into the deficient area [93,94]. This technique has gained popularity in treating ankylosed teeth in orthodontics. The ankylosed tooth can be moved along with a block of alveolus after a segmental osteotomy has been performed around the tooth. The transportation can be done either by a distraction device fixed internally [88] or by using a fixed orthodontic appliance [91]. Although distraction osteogenesis is a very useful tool in treating ankylosis, there are several drawbacks. The distraction device is too bulky, uncomfortable and can only produce lengthening in a linear direction [95]. Using orthodontic force to move the alveolus is restricted to a relatively short distance from the occlusal plane. Therefore further investigations are needed to evaluate the value of this treatment modality.

Conclusion

Traumatic dental injury is common among people of all ages, especially in children from 7 to 12 years old. Maxillary incisors are affected most frequently in the general population. Prevention of traumatic injury of maxillary incisors should be carried out at an early stage. TDI often complicates orthodontic treatment. It is recommended that a detailed history be taken regarding the injury, as TDI in orthodontic cases must be evaluated with care. Orthodontic treatment planning varies depending on the type of problem and severity relating to the TDI. There is no clear guideline available in terms of treating teeth with TDI in orthodontics. Therefore, orthodontists are advised to obtain sufficient knowledge on dental trauma, assess the situation on an individual basis and refer to previous literature for guidance. The author of this review has provided some treatment protocols for certain scenarios that are commonly seen, based on the information gathered from previous studies and reports. However, each case should still be considered individually before the orthodontic treatment plan is made.

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