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Trauma to Sequelae: A Review of Primary Teeth Trauma Induced Developmental Defects in Permanent Teeth

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Abstract
Trauma to primary teeth holds substantial clinical relevance, not only due to its direct impact on the affected deciduous dentition but also because of its potential to disrupt the development of closely associated succedaneous permanent teeth. Trauma involving supporting tissues, incidents occurring before the age of two, and injuries sustained outside the home environment were significantly associated with the emergence of developmental disturbances in permanent successors. The type and severity of sequelae in the permanent tooth are closely associated with the development phase of the tooth bud and nature of primary tooth trauma. Children with trauma of their primary teeth require regular monitoring until the eruption of the permanent teeth for the early diagnosis and treatment of possible sequelae. This review article comprehensively synthesizes formation, clinical implications, possible preventive and management strategies of ill effects pertaining to trauma-induced sequelae in the developing dentition.

Keywords: Primary tooth trauma, Developmental defects, Trauma sequelae, Intrusion, Avulsion.

Introduction

Traumatic dental injuries (TDIs) represent a significant public health issue due to their high prevalence among children. It affects from 8% to 62.1% of children between 2 and 5 years old, which is a critical time for the development of motor coordination and body balance. Moreover, their occurrences are unexpected causing negative esthetic, physical, and psychological repercussions impacting on patient's quality of life.[1]

Children are particularly susceptible to dental trauma during early childhood, especially in the first two years of life, as they begin to walk and engage in social interactions. Epidemiological data show that

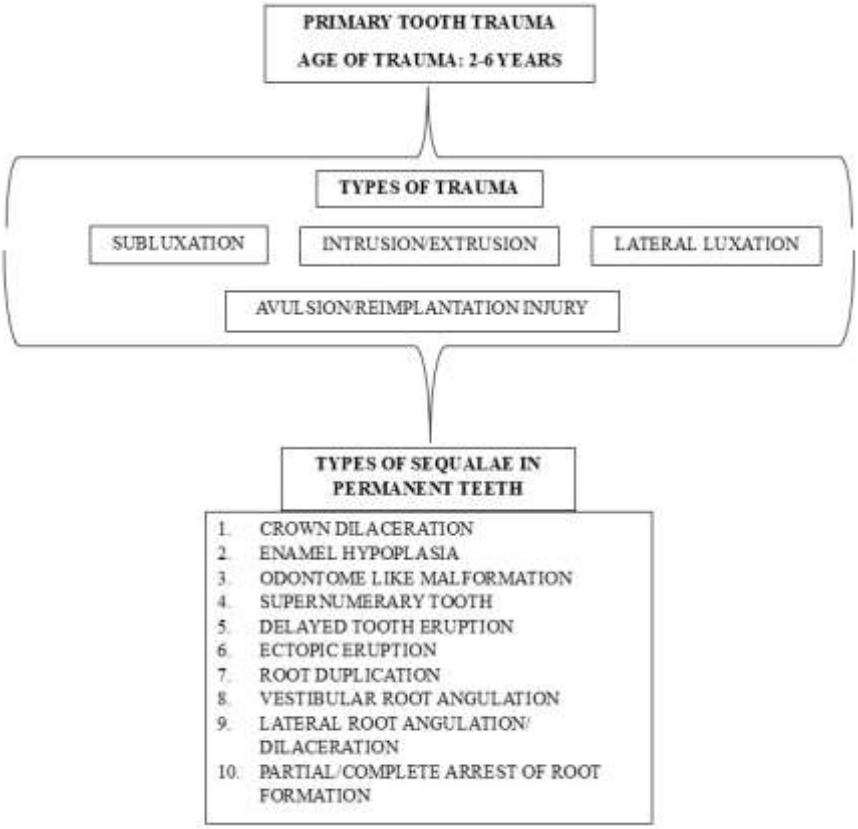
approximately 30% of children aged <7 years have trauma in ≥1 primary incisor, and about 40% of children go to the dentist for the first</mark> time due to dental trauma.[2]

Andreasen reported that trauma to primary teeth causes developmental defects in the succeeding permanent teeth at a frequency ranging from 12% to 69%.[3]

Because of the intimate anatomical proximity between the apex of primary teeth and the developing buds of permanent teeth, trauma to the primary dentition can potentially disrupt the eruption pattern of the permanent successors. The distance between the apex of the primary central incisor and the incisal edge of the permanent central incisor ranges from 2.97 mm at the age of 3 years to 1.97 mm at the age of 6 years.

The severity of sequelae is influenced by multiple factors, including the patient's age, extent of root resorption, type and magnitude of trauma, developmental stage of the permanent successor at the time of injury, and both the direction and intensity of the applied force.[2]

Figure 1: Trauma to Sequelae – A Cascade



Unfortunately, traumatic dental injuries are often underestimated by both parents and patients, leading to delayed visits to healthcare providers—typically only when acute symptoms such as inflammation or aesthetic concerns arise. The interval between trauma and professional intervention is critically important.[1]

Injuries to primary teeth are frequently overlooked due to their limited lifespan; however, they gain clinical relevance when sequelae manifest in the permanent dentition, making them a vital component of the patient's dental history.

This review article gives a detailed overview of the possible sequalae of developmental defects in permanent teeth due to primary teeth trauma.

Crown Dilaceration

The term 'dilaceration' was first introduced by Tomes in 1848 and refers to an abnormal bend or deviation in the alignment between a tooth's crown and its root (Latin: dilacero=tear up). This is a rare condition, representing only 3% of the total of injuries to developing teeth and usually occurs in permanent maxillary incisors because of the proximity of their tooth germs of the primary incisors are particularly vulnerable to trauma due to their anatomical position and developmental stage.[4]

This defect is usually associated with intrusion and avulsion of the deciduous tooth. The crown is most often displaced in a palatal direction for maxillary teeth and for the mandibular teeth in the opposite direction.

This injury is dependent on the age of the child, degree of displacement of the primary root apex; the degree of alveolar damage; and the stage of formation of the permanent tooth.[5]

Table 1: Relation between permanent crown involvement in dilaceration and timing of primary tooth trauma[6,7]

AGE AT THE TIME OF INJURY TO PRIMARY TOOTH	PERMANENT CROWN INVOLVEMENT IN DILACERATION
2-3 years of age	Half of crown
4-5 years of age	Entire crown

The pathology of crown dilaceration is explained by the theory involving displacement of the enamel epithelium and the mineralized portion of the tooth relative to the dental papilla and cervical loop. When trauma occurs, the already calcified coronal segment is physically displaced within the bone, while the apically located soft tissue structures—still undergoing calcification—remain in their original position. If these formative tissues survive the injury, they continue to develop along their initial trajectory, resulting in a misalignment between the newly formed and previously calcified portions of the tooth, thereby producing a dilaceration.[7]

During the trauma, the partially formed follicle of the permanent tooth is invaded by the apex of the primary tooth, causing the crown of the permanent tooth to twist lingually over the papilla. In this altered position, the displaced enamel epithelium may become active, forming a distinctive projection of deformed enamel into the pulp canal or externally at the crown-root junction.[6]

Crown dilacerations histological features often include a cone of hard tissue, with a central lumen, projecting into the root canal. This might act as a pathway for bacteria to enter the pulp, leading to pulp necrosis and abscess formation.[8]

Radiographic evaluation allows for early diagnosis of sequelae affecting the permanent dentition, even before tooth eruption. A dilacerated crown typically appears foreshortened compared to adjacent teeth on occlusal radiographs. Lateral projections further aid in confirming the diagnosis and assessing the direction of the dilaceration. Radiographic imaging is essential for detecting pulpal involvement, carious lesions, and evaluating the extent of crown deformity, all of which influence the treatment strategy and prognosis.[9]

Teeth with crown dilaceration sometimes erupt in normal alignment or exhibit facial or lingual displacement. Effective management of such teeth upon eruption is crucial for ensuring long-term function and minimizing treatment costs. Therefore, treatment planning should prioritize non-invasive and preventive approaches. Prompt sealing of the developmental defect is recommended, considering the complex endodontic anatomy often associated with these teeth. Further, cosmetic repair of unaesthetic newly erupted permanent teeth is critical for child's psychological wellbeing.[10]

Timely diagnosis and preventive management play crucial role in saving the tooth, as pulpal necrosis and periapical inflammation in these teeth without any decay may be a common feature after they erupt in the oral cavity. So, the restoration therapy should be instituted as soon as dilacerated area erupts to a level free of gingiva.[6]

Treatment options for crown dilacerations include:

a. Surgical exposure with or without orthodontic realignment
b. Removal of dilacerated part of crown
c. Temporary crown until root formation is complete
d. Semi or permanent restoration
e. Prosthesis or orthodontic space closure following extraction.[11]

Enamel Hypoplasia

Enamel hypoplasia is a surface defect of the tooth crown that is caused by a disturbance of enamel matrix secretion, defective calcification or defective maturation possibly due to a stress episode or any other associated factors.[12]

Frequency of enamel hypoplasia in the permanent successors following trauma is 12% . This sequela is usually found after intrusive luxation, extrusive luxation or avulsion when the permanent tooth germ is in a Nolla's stage between 1 and 5. During this period, the crown buds of the permanent successors are beginning their calcification, rendering them more susceptible to developmental disturbances. The impact from the fall, the type of trauma, and the successor's developmental stage (1/3 of crown completed) contributed to the severity of the enamel sequelae reported.[13]

Enamel hypoplasia due to trauma presents a white discoloration in clinical examination. However, products of blood degradation sometimes infiltrate the area affected during the enamel matrix development, resulting in yellow-brown discolorations. After eruption, the successor teeth may show a horizontal line surrounding the teeth's crown on the cervix area, known as circular enamel hypoplasia. This development disturbance can be detected by radiographic image, unlike the enamel opacities, which can only be diagnosed following crown eruption.[13]

The diagnosis of enamel hypoplasia typically involves a comprehensive dental assessment -detailed review of the patient's medical history and clinical examination of the dentition. Radiographic imaging may be employed to evaluate the extent of enamel deficiency and detect any associated structural anomalies. In select cases, histological analysis through enamel biopsy may be warranted to confirm the diagnosis.[14]

Clinical enamel hypoplasia characteristics include unfavourable aesthetics, higher dentin sensitivity, malocclusion, and dental caries susceptibility . The treatment challenge in this type of injury is to promote a complete oral rehabilitation in both aesthetics and in the patient's masticatory function .[13]

Various treatment protocols may be considered depending on the level of involvement, and the severity of the lesions. Usually, these approaches include enamel microabrasion, esthetic conservative restorations and dental whitening. [15]

Topical fluoride application is effective in reducing dentin sensitivity to thermal variations and to acid foods, which are frequently observed in permanent, recently erupted hypoplastic teeth. In most of cases, temporary glass ionomer restorations are necessary until definitive rehabilitation is possible.[13]

Composite resin restorations can effectively replicate the natural appearance of teeth, offering highly esthetic results. In most cases, enamel defects are primarily cosmetic rather than functional in nature.[15]

The early radiographic diagnosis is important in this kind of sequelae management, because it determines the appropriate clinical intervention, minimizing damages to the dentin and pulp.[13]

Odontome-Like Malformation

Odontomas are considered pseudo-tumoral lesions comprising both epithelial and mesenchymal components that, while histologically normal, exhibit disorganized structural architecture. They are classified into two types:

- Complex odontoma, characterized by the presence of all dental tissues arranged in a disordered configuration.
- Compound odontoma, where the dental tissues are organized in a more structured and recognizable pattern compared to the complex variant.[16]

A rare odontoma-like malformation may develop as a sequela to severe trauma involving a primary tooth, affecting the developing permanent successor during its early mineralization phase. This lesion presents as a mass of mineralized tissue resembling the dental germ and may feature a rudimentary or relatively normal root, typically arising during the initial stages of odontogenesis. The period between 0 and 3 years of age corresponds to the development and mineralization of the crown (Nolla's stage 4, 2/3 of the formed crown).[14]

The cleavage of the dental germ results in the development of separate elements of the tooth, featuring a structure similar to odontoma. This lesion is a conglomerate hard tissue having the morphology of a complex odontome.[17]

This condition typically arises following an intrusive or avulsive injury and is most likely to occur when less than one-fourth of the crown has completed formation.

Routine radiographs reveal the presence of these lesions and can block the pathway of tooth eruption and medialize or distalize teeth. Surgical removal is indicated. The need for surgical removal of these lesions may depend on its location. Orthodontic treatment post-surgery can achieve good functional and aesthetic outcomes.[18]

Supernumerary Tooth

A supernumerary tooth is any tooth or odontogenic structure that is formed from a tooth germ in excess of the usual number for any given region of the dental arch. Despite the proposal of several theories such as atavism, dichotomy, hyperactivity of the dental lamina, and progress zone concepts, the precise aetiology remains unclear.[19]

A recent study proposed traumatic injuries to primary incisors may play a contributory role in the etiology of supernumerary tooth development.[20]

Given the close proximity of the primary root apices to the developing permanent tooth crowns, it is highly likely that TDIs to the primary teeth can induce disturbances in the formation and maturation of the developing permanent successors. Despite the range of potential consequences following subluxation injuries to the primary teeth, to date, there have been documented reports of consequent supernumerary tooth formation following subluxation injuries to the maxillary primary incisors.[19]

The standard approach involves extraction of the supernumerary tooth; however, repositioning within the dental arch may be considered as an alternative in certain cases. When the supernumerary tooth is situated in the maxillary anterior region, surgical intervention is typically advised between eight and ten years of age, once the incisor roots have fully developed.[21]

Delayed Tooth Eruption

At 2-3 years of age, motor coordination is in the process of formation and children of both sexes begin to walk. Incisors are more susceptible to fracture in TDI. However, it should grab the parents' attention, as the absence or improper development of maxillary incisors in the form of unerupted teeth negatively affects facial aesthetics, which can lead to self-consciousness and difficulties in socializing in children.

The developing follicles of permanent successors usually lie in close proximity to the apices of primary tooth roots. In some cases, pulpal necrosis can interfere with the eruption pathway of the permanent tooth, either displacing it or impeding its emergence. Eruption may be delayed if the permanent bud has shifted position or if the overlying tissues are abnormally fibrous or thick—particularly following trauma, where connective tissue overgrowth during gingival healing can obstruct eruption. To assess the morphology of the affected tooth and the condition of surrounding bone, intraoral periapical radiography is strongly recommended. While surgical intervention may be required in certain cases, teeth with incompletely formed roots often retain the potential to realign and erupt spontaneously.[22]

In some cases, surgical exposure may be needed. The timing of intervention is critical to avoid the need for orthodontic forces to extrude the immature impacted incisors, and also to avoid any further orthodontic complications.[23]

Ectopic Eruption

A significant intrusion injury to the predecessor primary tooth may result in the permanent incisor's ectopic eruption. The permanent germ may have been physically displaced, the premature loss of the primary incisor may not have offered eruption guidance, or both may be to blame for the problem.

To manage ectopic eruption of incisors caused by trauma or aberrant eruption paths, fixed orthodontic appliances—such as those incorporating elastics, open coil springs, and modified fan-shaped designs—have been utilized effectively.[24]

Fixed orthodontic treatment can be continued to achieve proper alignment of the tooth resulting in good esthetic and functional rehabilitation.[25]

In cases of unconventional ectopic eruption (such as in nasal floor), surgical extraction can become the choice of treatment.

Root Duplication

This rare defect normally occurs as a division of the root into a mesial and distal portion. Root duplication in a permanent tooth is an uncommon developmental anomaly, often associated with severe intrusive luxation of the primary predecessor, typically occurring around the age of two.[26]

This condition tends to arise when the crown is only partially formed—specifically, when less than half of its structure is complete at the time of injury. A traumatic division of the cervical loop occurs, resulting in the formation of 2 separate roots. One author speculated that the intrusion of the deciduous tooth into the follicle of the developing tooth germ caused an acute tilting of the permanent tooth germ and the formation of second root. The avulsion and replantation of a primary tooth has been mentioned in some clinical reports as a cause of damage to permanent teeth.[27]

Histological findings reveal a calcium-traumatic line separating the hard tissue formed before from that which is formed after the injury. The pathogenesis of root duplication suggests that trauma-induced division of the cervical loop leads to the development of two distinct roots.[26]

Radiographic imaging serves as the primary diagnostic tool, while patient history and crown morphology provide supplementary information.[26]

On radiographs, the anomaly typically presents as mesial and distal roots emerging from a partially developed crown.[28]

Management strategies may be either conservative or surgical, depending on the extent and clinical implications of the lesion. In most cases, the crown is almost always aesthetically compromised. Conventional endodontic treatment followed by esthetic restoration can be performed on the pulpally involved tooth.[26]

Vestibular Root Angulation

Vestibular root angulation, often referred to as a 'sickle' incisor, is characterized by a pronounced curvature localized to the root, resulting from trauma. Unlike dilaceration, this condition reflects a gradual deviation in root development rather than an abrupt displacement of the tooth germ during odontogenesis, typically occurring between the ages of 2 and 5 years. The affected tooth is usually impacted, with the crown often palpable within the labial sulcus. This anomaly is exclusive to maxillary central incisors. The injuries to the primary dentition consist of intrusive luxation and avulsion.

The calcified segment of the permanent tooth germ becomes displaced, resulting in the non-calcified portion aligning at an angle relative to it.[28]

The treatment approach is determined based on the nature and extent of the malformation, as well as the precise position and anatomical characteristics of the affected teeth. Two different treatments approaches to manage the tooth need to be considered: surgical exposure with orthodontic traction vs extraction and prosthetic replacement with fixed bridge or implant placement later. [29]

Lateral Root Angulations or Dilacerations

This unusual defect appears as a mesial or distal bending confined to the root portion of the affected tooth. This type of lesion typically arises as a consequence of tooth avulsion.

Injuries to the primary tooth between the ages of 2-3 years can affect the buccal surface of the permanent maxillary incisor. This happens because the tooth germ of the permanent incisor is located palatal to the apex of the primary incisor. By the age of 4-5 years, the germ shifts labially coming closer to the resorbing root of the primary tooth. During this vulnerable developmental phase, trauma can transmit force along an oblique trajectory extending from the incisal edge of the permanent incisor to a point on the labial surface of its forming root.[28]

Even minimal impact may cause substantial disruption, as the force is concentrated at the sharp apex of the immature permanent root, directly affecting Hertwig's epithelial root sheath. The resorbing apex of

the primary tooth engages with the incisal edge of the permanent crown, displacing it upward into the follicle. Because the root is still in formation, the developed segment rotates in conjunction with the crown. Root development then typically resumes along its original trajectory, resulting in a distinct angular deviation between the pre- and post-traumatic portions. This produces a curvature along the longitudinal axis of the permanent incisor, clinically recognized as dilaceration.[28]

Identifying and diagnosing dilacerations is crucial prior to undertaking orthodontic therapy, endodontic procedures, or tooth extraction. Dilaceration of a crown can be visually observed if tooth is not impacted; however, radiographic examination is required to diagnose dilaceration in the root.

Root dilaceration must be assessed in both horizontal and vertical planes, typically classified as mesial, distal, labial/buccal, or palatal/lingual. Mesial or distal bends are readily visible on periapical radiographs. In contrast, when the curvature is directed labially/buccally or palatally/lingually, the central X-ray beam aligns nearly parallel to the deviated root segment. This results in a distinctive radiographic appearance: a circular radiopaque area with a central radiolucent spot, representing the apical foramen and part of the root canal—commonly referred to as the 'Bull's Eye' or 'target' sign. Surrounding this region, the periodontal ligament space appears as a radiolucent halo. The curved portion of the root shows increased radiopacity compared to the rest of the root due to the beam traversing a denser osseous structure.[28]

The difficulties in endodontic treatment of dilacerated tooth are noticed since the early diagnosis and coronal access stages until the obturation stage.

The prognosis for dilacerated teeth requiring endodontic treatment depends on both the extent of the deformity and the clinician's expertise. Complex root anatomy resulting from trauma can increase the risk of procedural complications, including root perforation and gutta-percha extrusion. [30]

Management of an impacted dilacerated permanent teeth can have two different treatment approaches:

1. surgical exposure with orthodontic traction or
2. extraction which may be followed by

- space closure by mesializing the lateral incisor in place of the central incisor with subsequent prosthetic restoration,
- surgical repositioning of the impacted central incisor,
- autotransplantation of a premolar to the region,
- restoration with an implant or a bridge after cessation of growth.[31]

Partial Or Complete Arrest of Root Formation

" Trauma to the primary dentition may infrequently result in partial or complete arrest of root development in the permanent successor, with an estimated incidence of approximately 2%.The injury to the primary dentition usually occurs between 5 and 7 years of age and normally affects maxillary incisors. The injury sustained is usually avulsion of the primary incisors.

Trauma during odontogenesis can significantly disrupt the morphogenetic processes of dental development, leading to structural anomalies in permanent teeth. The nature and severity of these malformations are influenced by both the stage of tooth development and the intensity of the trauma. Normally, root formation begins after crown development is complete—corresponding to Stage VI in Nolla's classification. At this point, enamel and dentin formation have reached the future cementoenamel junction, initiating root development under the guidance of the enamel organ. This organ gives rise to Hertwig's epithelial root sheath (HERS), a critical structure that determines root morphology. Any injury to HERS during this phase can impair its function, resulting in arrested or abnormal root formation.[7]

Some of these teeth remain embedded, while some other teeth erupt which are then lost due to inadequate periodontal support. Embedded ones should be surgically removed. Orthodontic treatment can be used to create space which was lost due to failure of eruption or retention of the rootless tooth followed by prosthodontic rehabilitation.[32]

Fixed orthodontic treatment can be continued to achieve proper alignment of the tooth resulting in good esthetic and functional rehabilitation.[25]

In cases of unconventional ectopic eruption (such as in nasal floor), surgical extraction can become the choice of treatment.

Table 2: Other Rare Sequelae Reported

Rare Sequelae	Possible Theory of Formation
Sequestration of the entire tooth germ	Infection due to trauma can complicate healing of jaw fractures. In these instances, swelling, suppuration and fistula formation are typical clinical features, sometimes leading to spontaneous sequestration of involved tooth germs. Radiographic examination discloses osteolytic changes around the tooth germ, including disappearance of the outline of the dental crypt.[31]
Dentigerous cyst	Theories regarding its formation suggest that the immature permanent tooth encounters a radicular cyst originating from its primary predecessor.[31] A possible origin is related to an inflammatory process (such as due to predecessor tooth trauma) that may affect a developing tooth resulting in proliferation of the reduced enamel epithelium [5,6,7,18,30]

Conclusion

Following any traumatic injury to primary teeth—particularly intrusive luxation—caregivers must be thoroughly informed about the potential impact on the developing permanent dentition. For all pediatric patients with a documented history of trauma to primary teeth, pre-eruptive radiographic evaluation is strongly advised to facilitate early identification and intervention for severe developmental anomalies.[23]

The risk of sequelae increases with both the severity of the trauma and the younger age at which it occurs. Prompt diagnosis and appropriate management of primary tooth injuries are essential not only to relieve the child's pain and discomfort but also to minimize the likelihood of damage to the permanent successor. Moreover, clinicians must be mindful to avoid instilling fear or dental anxiety during treatment.[33]

When managing sequelae affecting permanent teeth, comprehensive treatment planning and clinical expertise are paramount to selecting the most appropriate therapeutic approach and achieving optimal aesthetic outcomes. Long-term follow-up is indispensable to monitor treatment success; neglect by either the clinician or the patient may result in treatment failure and eventual loss of the affected tooth.[34]

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