

Concise Review

Implications of Post-Traumatic Treatment of Immature Maxillary Incisors

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ABSTRACT

The aim of this review was to discuss traumatic dental injuries in view of their treatment implications to provide an evidence-based resource for clinicians when planning treatment for traumatised immature maxillary incisors. Dental trauma to immature maxillary incisors can result in various complications, such as critical fractures, resorptions, or ankylosis, and might lead to tooth loss. Traumatized teeth may exhibit various unaesthetic discolourations as a result of different dental trauma sequelae or materials used for treatment. All of the above can influence patients' social experience, including self-esteem, confidence, eating and speaking abilities, as well as proper development and growth of the jaw bones. Treatment of traumatised immature incisors should focus not only on the acute phase but on the long-term consequences. Any time gained with the tooth in the jaw bone, free of infection, is an achievement, as it allows normal growth and development. All these aspects are discussed in this narrative review, and an evidence-based summary resource is suggested for clinicians to use when planning treatment for traumatised immature maxillary incisors.

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Background

Trauma to the maxillofacial region accounted for 9% to 33% of all trauma reported from hospital emergency departments.^{1,2} Dental trauma occurs in 5% of all injuries in children and adults.³ According to the International Association of Dental Traumatology (IADT), 25% of all schoolchildren experience trauma to their dentition.⁴ Importantly, the evident decrease in the prevalence and severity of dental caries in children has made traumatic dental injuries (TDIs) the most severe public health challenge amongst youth.⁵ The most common TDIs occur in boys (twice as many as girls)⁶ between the ages of 7 and 12, and they mainly involve the anterior maxillary teeth.⁷ The highest risk for TDI is related to falls during sports activity,⁷ and this happens mostly in children with class 2, division 1 malocclusions.⁸ The IADT guidelines recommend making

every effort to save immature permanent teeth.⁴ Saving immature teeth, in which the pulps can heal, will allow continued root development and prevent long-term negative consequences.⁴ Therefore, this paper aims to discuss TDIs, given their implications, and provide an evidence-based resource for clinicians when planning treatment for traumatised immature maxillary incisors.

Methods

A nonsystematic, narrative review of the literature was conducted to synthesise the published literature on the topic and describe its current state of the art.⁹

Review

The consequence of dental trauma to the immature maxillary incisors can influence various aspects related to the patient (Figure 1). It can influence patients' self-esteem, confidence, eating and speaking abilities, and proper development and growth of the jaw bones. Complications related to dental trauma may include fractures, infection, and root resorption, which may lead to a loss of the traumatised teeth if not addressed timely and correctly.^{10,11}

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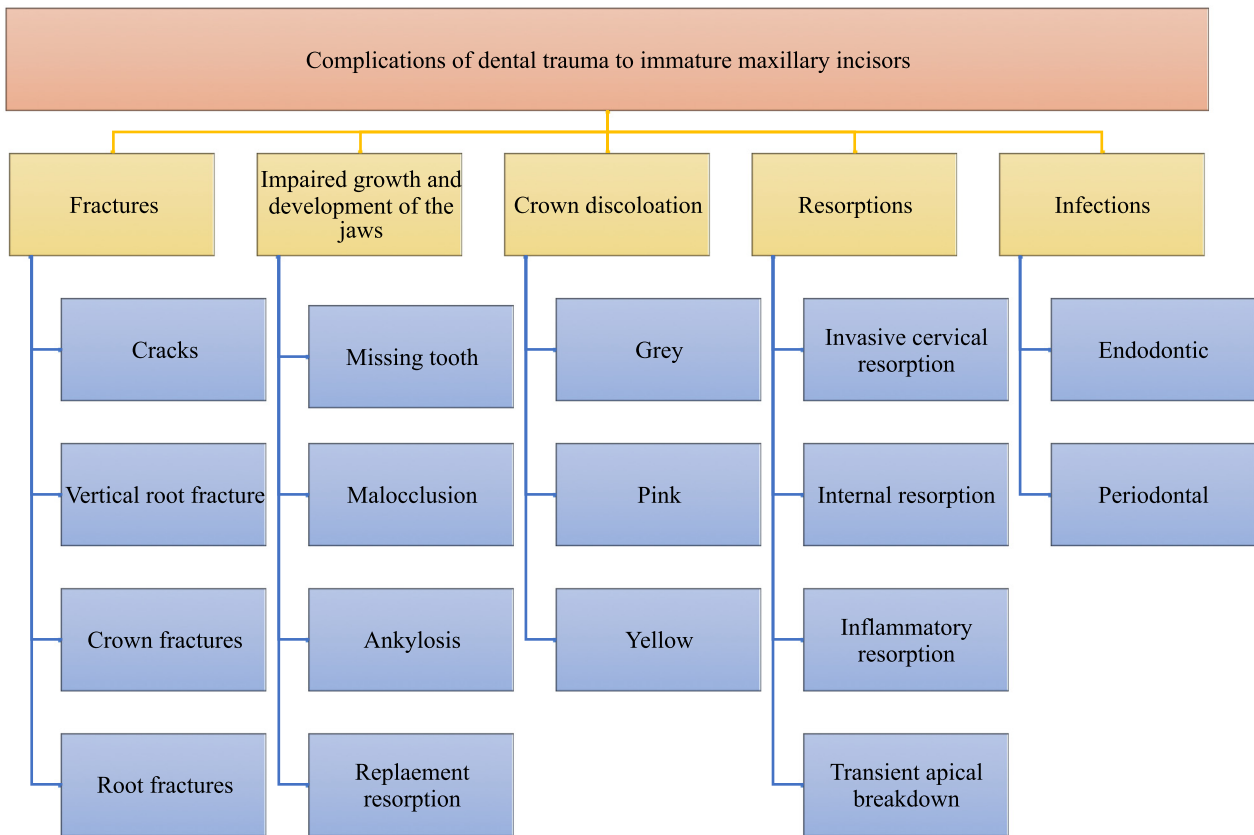


Fig. 1 – Possible complications of dental trauma of maxillary incisors in children.

Fractures

Fractures following dental trauma may appear in the crown and involve the root (Figure 2). If catastrophic, they may result in an extraction and a missing tooth at a young age. Because traumatised immature teeth have thin dentinal walls and an unfavourable crown-to-root ratio (Figure 2), their long-term prognosis is compromised. For types of fractures and treatment recommendations, the readers are referred for further reading.¹²

Vertical root fractures (VRFs) may occur as a consequence of endodontic treatment and post preparation, leading to an extraction of the tooth.¹³ Although the relationship between the age of the patient and VRFs is still not entirely understood, the changes in the micromechanical properties of dentin with age could mean decreased resistance to VRFs in root canal-treated teeth with post preparations.¹³

Traumatised teeth with external inflammatory root resorption, a severe posttraumatic complication, benefit significantly from long-term calcium hydroxide treatment.^{8,14} However, placing a calcium hydroxide dressing for an extended period in traumatised nonvital immature teeth during apexification increases the risk of cervical root fracture.^{15,16} Therefore, immediate apexification with mineral trioxide aggregate (MTA) would be preferable over a long-term calcium hydroxide barrier induction in terms of preservation of tooth strength. Limited evidence has shown that teeth treated with MTA demonstrated an initial decrease in fracture strength and increased strength after 1 year.¹⁷

Interestingly, it was reported that fiber posts helped propagate forces evenly along the axis of the root of the tooth.¹⁸ The evidence to support the use of fiber posts to reduce the fracture risk of immature teeth is contradictory.^{18,19} Some studies showed no significant influence on fracture resistance with the placement of a fiber post in endodontically treated immature teeth.¹⁹ Others found that fiber post, or composite resin, increased the fracture resistance of simulated immature teeth compared to gutta-percha.^{18,20} Also, the remaining bone level directly influences the fracture resistance of endodontically treated teeth restored with fiber posts, a composite core, and an all-ceramic crown.²¹

Impaired growth and development of the jaw bones

A recent systematic review found that children with anterior missing teeth are more likely to be bullied than children with normal occlusion.²² Furthermore, self-esteem was found to be affected negatively by a malocclusion.^{23,24} Additionally, maxillary incisors play a phonetic role, as with the letter “F,”²⁵ and have a role in incising food and in anterior guidance. Thus, clinicians should keep these teeth in place for as long as possible, for example, by replantation of an avulsed tooth⁶ or autotransplantation to a site of a lost tooth.²⁶

Although several treatment options exist to manage a missing tooth, most of the alternatives (such as orthodontic treatment, removable and fixed partial dentures, and implants) impose a challenge in children due to the nature of the developing jaw bones. Tooth autotransplantation is the

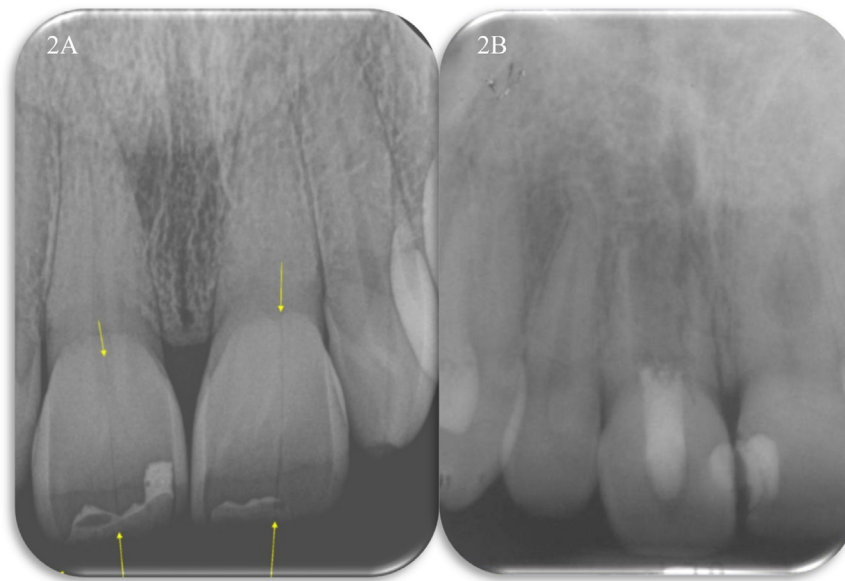


Fig. 2 – A, A periapical radiograph showing pulp canal obliteration in the right and left central maxillary incisors with a history of trauma. Fracture lines are seen in the crowns (yellow arrows). A periapical radiolucent lesion associated with the left maxillary incisor is evident, and the complete pulp obliteration imposes challenges on an orthograde endodontic treatment. B, Traumatized immature teeth are characterised by thin dentinal walls and an unfavourable crown to root ratio; thus, their long-term prognosis is compromised with a higher risk for a fracture or more severe implications in case of a periodontal disease in the future because the root is shorter.

replacement of a tooth with another functional tooth within the patient's dentition,²⁶ and it can serve as a promising treatment alternative in a case of a loss of a maxillary incisor in children and adolescents. High success rates of 95% were reported with autotransplantations done on immature teeth.²⁶ The ability of transplanted teeth to erupt and remain harmonious with adjacent teeth allows natural space closure, greater aesthetics, reduced cost, and reduced treatment time compared with implants²⁶ and enables soft and hard tissue preservation and further development. Even if the tooth has been missing for a long time and bone loss has occurred, bone regeneration in the recipient socket and the presence of lamina dura in the transplant site were observed.²⁶ Failures of autotransplantation of teeth were mainly seen due to replacement resorption and ankylosis.^{26,27} In cases where replantation of an avulsed tooth resulted in replacement resorption, the patient can continue with orthodontic treatment that aims to achieve a more favourable tooth position for future alternative treatment plans, such as an implant, autotransplantation, or bridge placement.²⁸ Moreover, the autotransplanted tooth will allow preservation of the alveolar bone in the area of the missing tooth (compared to an extraction site), which can be used for a future implant in case of a failure. Although no specific success criteria were established for transplanted teeth,²⁷ it can be considered a valid procedure to replace lost teeth in the maxilla, presenting high survival and success rates and overall satisfactory aesthetics.^{28,29}

Another treatment alternative in case of a missing incisor can be an orthodontic treatment to close the space. If a maxillary incisor is lost, the decision to close the space completely or partially should be made during the mixed dentition stage

to avoid mesial tipping of the incisor and a rapid midline shift.^{6,30} Hence, space maintenance is essential to prevent asymmetry and space loss.⁶ When an immature tooth undergoes orthodontic treatment, it is advised to observe the tooth for continued root development through clinical and radiographic assessments.⁸ When previously traumatized teeth undergo orthodontic treatment, special attention should be given to avoid excessive pressure to decrease the root surface resorption risk.⁶ It is advised to complete the obturation of nonvital traumatized teeth prior to orthodontic movement.⁸ Mouth guards are available for contact sports for children with proclined incisors prior to initiating and during treatment with orthodontic appliances.⁸ Overall, because the central maxillary incisors are the teeth most frequently affected by avulsion,³¹ an orthodontic treatment to compensate for the large gap created by the missing tooth might not be a feasible option, as it will result in an asymmetry of the midline or will significantly influence the interjaw relations.

Regardless of age, a removable partial denture (RPD) is a viable treatment option to replace missing teeth in children.³² In very young children, an RPD is commonly used to replace multiple teeth in patients with syndromes involving anodontia or oligodontia, such as hypohidrotic ectodermal dysplasia.³³ However, in dental trauma, only a single central incisor is often missing. Although the RPD can be a simple and fast aesthetic solution that maintains the space for a future fixed prosthesis in adulthood, bone loss in the area of the missing tooth will still occur, and less bone will be available for a future implant resulting in an aesthetic bony defect in the ridge shape. Also, RPDs can be inconvenient to use and require patient's compliance. The use of an RPD to replace a



Fig. 3 – Dental trauma to the maxillary incisors can influence patients’ self-esteem and confidence, their eating and speaking abilities, and proper development and growth of the jaw bones. A, A 14-year-old girl has a history of dental trauma, resulting in a severe infra-occlusion of the right maxillary lateral incisor, crown fractures of both maxillary central incisors, a sinus tract in the area of the left maxillary lateral incisor, and an abnormal bite. B, A periapical radiograph shows the infra-occluded maxillary right lateral incisor with resorption in the crown. C, Clinical photo taken at 1-year follow-up after decoronation of an infra-occluded ankylosed right maxillary lateral incisor. The occlusal view shows preservation of the alveolar ridge. D, A periapical radiograph taken at the 1-year follow-up. The decoronation allowed preservation of the alveolar ridge area. The remaining root of the decoronated tooth can be noted and gradually replaced with bone (replacement resorption). E, A removable partial denture replacing a single decoronated right maxillary lateral incisor is shown.

single missing tooth should be discussed with the patient’s guardians, including the long-term treatment and possible future permanent treatment modalities with their respective risks and benefits. Figure 3 shows an RPD replacing a single decoronated right maxillary lateral incisor in a 14-year-old patient.

Preparing a traumatised tooth for a fixed partial denture presents an ethical and practical dilemma because more tooth structure would have to be removed whilst trying to achieve a design in favour of the strength of the restoration.⁶ Immature teeth usually present with a large pulp chamber, a clinically short crown, and an unfavourable crown-to-root ratio. Hence, the trauma from tooth preparation could surpass the trauma from injury, and preparation should not be into dentin.⁶ Additionally, due to the expected changes in the growing period of the children, including teeth eruption, permanent porcelain crowns should be avoided, and modifiable

materials, such as composite, should be used instead. Conventional bridges are not desirable management in traumatised immature teeth.⁶ Most importantly, a bridge can prevent normal eruption, development, and teeth movement during growth. Additionally, trauma cases are followed by a healing period, during which affected structures may change. Furthermore, their longevity is estimated to be between 8.3 and 10.3 years.^{33,34} Hence, replacing an unrescuable central maxillary incisor in a young patient with a fixed partial denture would mean multiple long-term restoration replacements,³⁵ which comes with additional costs and many visits to the dentist. Overall, the adverse biologic effects and risks might be greater than the benefits; therefore, avoiding bridges in the treatment planning of traumatised immature teeth is recommended.⁶

Although fixed restorative solutions, such as implants to replace a missing tooth, can be used in adults, they impose a challenge in young patients before or during growth spurts and are contraindicated before the completion of development.³⁶ Placement of implants in growing patients was previously reported in ectodermal dysplasia and dental trauma cases; however, infra-occlusion appears in growing patients because the implants do not erupt with adjacent dentition.³⁷ In addition, dental implants in children and young patients have a lower survival rate than those reported in adults and elderly patients.³⁸ The high rate of complications related to implant placement in TDI cases reveals the need for a thorough diagnosis of the teeth and surrounding tissues after injury.³⁹ It is advised to confirm completed skeletal maturation before implant placement,⁴⁰ and treatment planning at the time of injury is essential to aim to maintain the patient as a candidate for future implant placement.³⁷ An alternative, utilising mini-implants is a potential solution, which offer a decreased cost, decreased diameter, immediate prosthetic restoration, and simple surgical insertion.^{41–43} However, the evidence is limited and the follow-up ranged from short term to 4 years, with limited data presented.^{41–43} Hence, the evidence on mini-implants’ long-term outcomes is insufficient and these should not be considered as a primary option in treatment planning.

Bone growth and development are directly related to the eruption of a tooth.⁴⁴ It is known that TDIs, especially severe ones such as intrusion⁴⁵ and idiopathic causes, are the primary aetiology for ankylosis.⁴⁶ The risk of ankylosis of avulsed and replanted teeth increases with the increasing dry time, with the lowest risk for dry time <20 minutes (33.9%) and the highest for dry time >60 minutes (86.4%).⁴⁵ The absence of periodontal ligament and loss of normal mobility of the ankylosed tooth, when occurring during the eruption stages, can interfere with the normal eruption of a tooth. Because the rate of replacement resorption (a sequela as well as a cause of ankylosis) is more rapid in children than adults, infraposition of the ankylosed immature tooth and deformity of the alveolar ridge are possible ranges of sequelae in children.⁴⁷ Therefore, it is essential to diagnose ankylosis of the immature maxillary incisors as early as possible to prevent jaw bone deformation. The primary diagnostic measure for ankylosis is a metallic and dull sound on percussion test,⁴ a radiographic appearance of replacement resorption, and infra-occlusion (Figure 3). Unfortunately, the dentist could

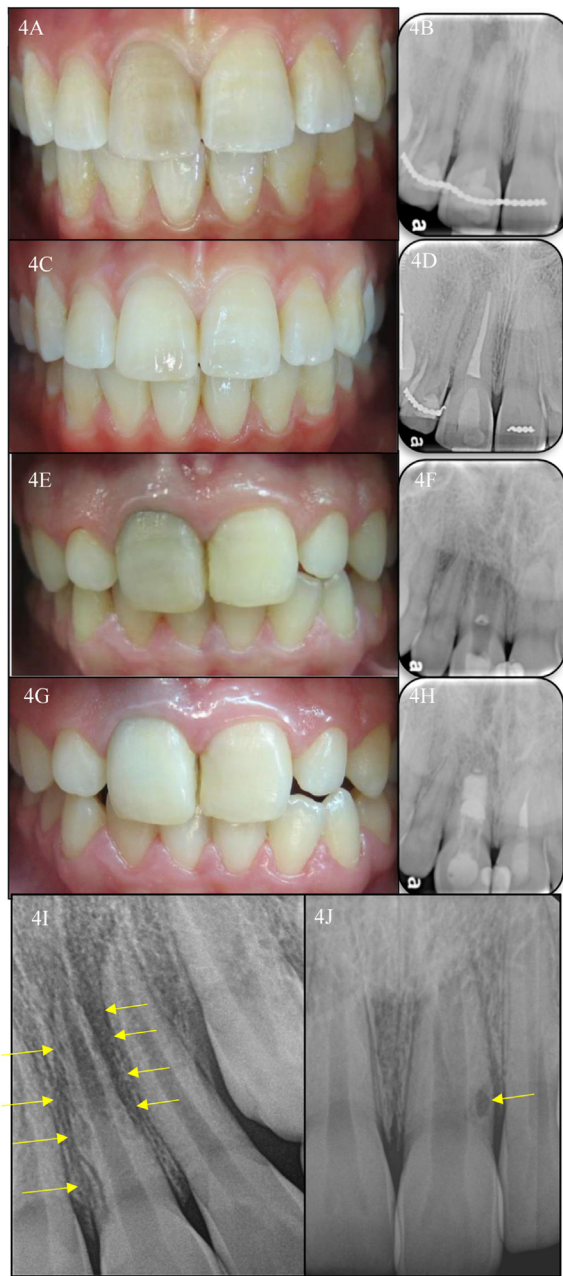


Fig. 4 – Complications after dental trauma.

Case 1: Crown discolouration from pulp necrosis. A, Grey-brown discolouration of a right maxillary central incisor diagnosed with pulp necrosis and history of an old trauma. B, The periapical radiograph shows a deep coronal restoration, a periapical radiolucent lesion, and an orthodontic wire following completion of an orthodontic treatment. C, An orthograde endodontic treatment was performed, followed by internal bleaching and a composite restoration in the access cavity. D, One-year follow-up periapical radiograph shows complete healing.

Case 2: Crown discolouration from regenerative bioceramic material. Grey discolouration of a right maxillary central incisor (E) with coronal staining as a result of mineral trioxide aggregate (MTA) placed in the cervical area of the tooth during regenerative treatment in the past, as shown on the periapical radiograph (F). G and H, The failing old MTA

easily miss early diagnosis of ankylosis,⁴⁷ and often it will be diagnosed only when a significant infra-occlusion of the ankylosed tooth has already occurred. Although extraction of the ankylosed tooth will reduce the deformity of the jaw in the area of the adjacent teeth, it will result in significant bone loss at the extraction site, causing aesthetic problems and challenges for a future implant.

Early diagnosis of ankylosis and intervention with decoronation prior to a significant infra-occlusion will allow ridge preservation for a future implant and less deformity of the jaw bone. Treatment modalities for ankylosed young teeth proved to have an unpredictable prognosis, except for decoronation, introduced as a more conservative treatment by Malmgren in 1984.⁴⁸ Decoronation, as an alternative to an extraction, allows preservation of alveolar bone around the retained root in addition to improved conditions for future treatment modalities.⁴⁸ After decoronation, replacement resorption of the retained root fragment will proceed until, gradually, the root might be entirely replaced by bone.⁴⁹ Surgical luxation, orthodontic movement, autotransplantation, composite build-ups, or extraction followed by implant placement are all suggested management options for ankylosed young teeth.^{50,51} Overall, decoronation should be considered when a significant infra-occlusion is evident in children prior to or during their growth spurt. Decoronation is a good treatment alternative to extraction, allowing partial preservation of the height and width of the alveolar ridge for a future implant site (Figure 3).

Crown discolouration

Traumatized immature teeth may exhibit various discolourations associated with the various dental trauma sequelae, including pulp necrosis, pulp canal obliteration (PCO), resorption, or staining caused by materials used for treatment. Greyish crown discolouration from pulp necrosis can be successfully prevented or treated by completely removing the necrotic tissue from the pulp space, often combined with internal bleaching if needed (Figure 4A–4D). It is important to note that no tissue should be left, and special attention

was removed, the tooth was endodontically re-treated by an orthograde approach, with apexification with MTA, followed by internal bleaching and fiber post with a composite restoration in the access cavity.

Case 3: Root resorption after dental trauma. I, A periapical radiograph shows radiolucent periradicular lesion and inflammatory root resorption on the distal aspect and replacement resorption on the mesial aspect of the root of the left maxillary central incisor, following an avulsion, reimplantation a year ago. Late diagnosis of the resorption resulted in thin root walls of the immature incisor.

Case 4: Root Resorption after Dental Trauma. J, A periapical radiograph showing invasive cervical resorption on the distal aspect of the root on a left maxillary central incisor with a history of an old dental trauma. In this case, the canal is also wide, compared to the homologous tooth on the right, due to loss of vitality and stopped development.

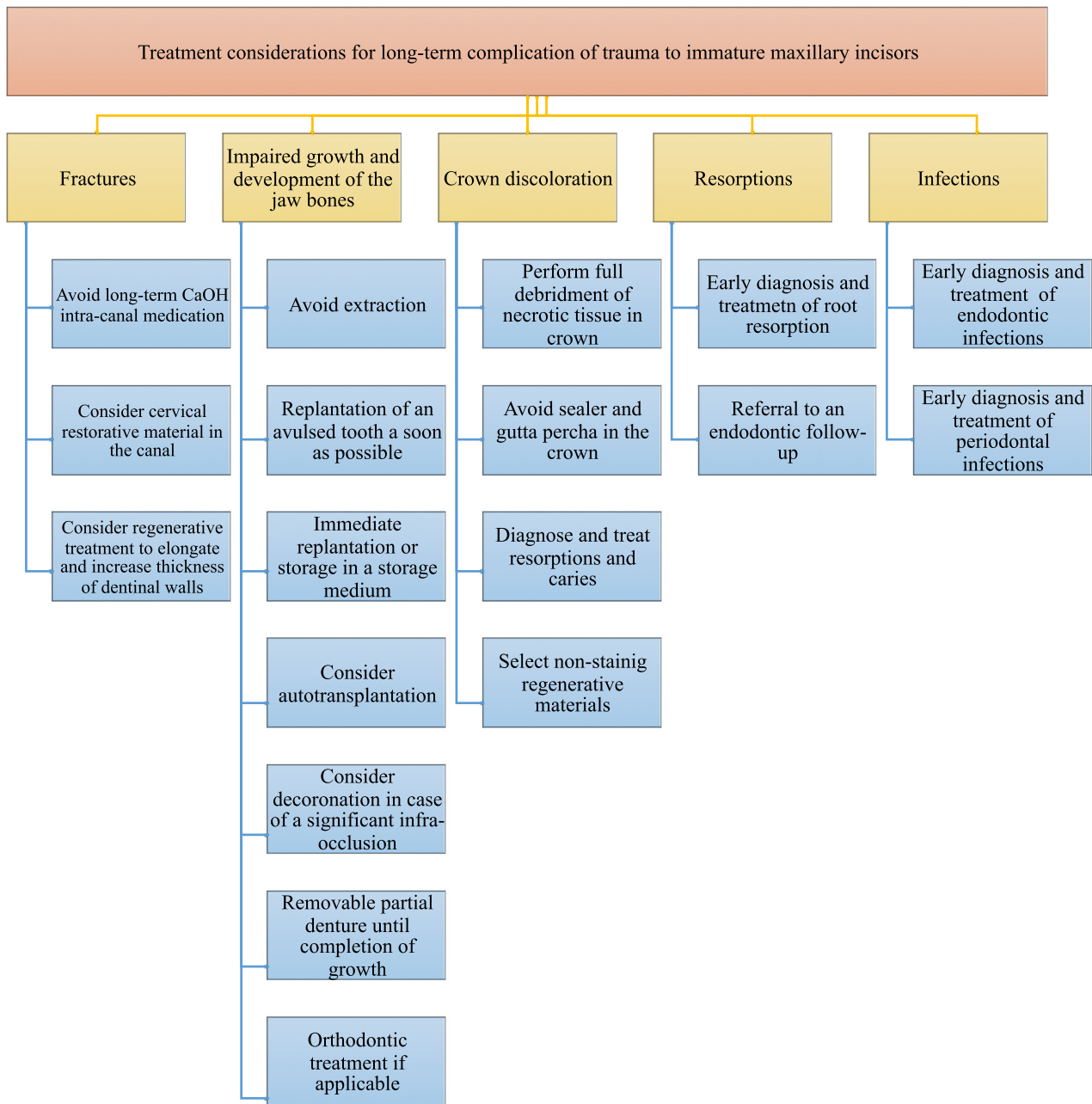


Fig. 5 – Treatment considerations for long-term possible complication of trauma to immature maxillary incisors.

should be given to the pulpal horns of the anterior incisors, as they may cause long-term staining of the crown.

Pink discoloration of the crown, as a result of resorption, can be successfully treated by removal of the resorbing tissue, internal bleaching if needed, and final tooth restoration (when indicated).

Yellowish crown discoloration as a result of PCO occurs due to excessive dentin deposition, which results in an opaque crown.⁵² There are few options to manage aesthetics in trauma cases with tooth discoloration. For the management of PCO, external bleaching should be attempted initially and should be followed with extracoronary restoration if tooth discoloration

shows no response.^{53,54} Internal bleaching should not be performed in a non-endodontically treated tooth,⁵⁵ and prophylactic root canal treatment (RCT) for internal bleaching is not indicated.⁵⁶ Internal bleaching with PCO is only indicated in cases with an RCT or after completion of an RCT due to endodontic reasons.⁵⁶

Discoloration of the traumatised tooth crown can also be caused by some reparative materials, which are often used for vital pulp therapy due to their regenerative properties when in contact with dental pulp tissue.^{57,58} Thus, to preserve the aesthetics in the anterior region when treating a traumatised immature maxillary incisor, it is essential to know

which regenerative materials will cause staining. As for MTA discoloured teeth, internal bleaching requires the removal of the discoloured MTA material at the material–dentin junction using an ultrasonic tip or high-speed burr prior to internal bleaching⁵⁹ (Figure 4E–H).

When using carbamide peroxide or hydrogen peroxide solutions for external bleaching in young patients, it is recommended to keep the concentration of the bleaching agent less than 10% and use it for 30 to 45 minutes.⁶⁰ Internal bleaching can be carried out in the same manner as in adults, using sodium perborate.⁶⁰

Infection and root resorption

The risk for pulp necrosis and infection varies amongst different trauma types.^{12,61–64} Infection can severely decrease the prognosis of the posttraumatic tooth; thus, it should be prevented. Although immature incisors have a good pulpal prognosis due to the wide open apical foramina and rich vascularisation,^{12,64} follow-up is important to identify early signs of infection. Delayed diagnosis of posttraumatic necrotic pulp in immature maxillary incisors, which have thinner dentinal walls and short roots, can result a rapid loss of the tooth due to inflammatory root resorption.^{11,64,65} (Figure 4I). The management of inflammatory root resorption can be complex and is beyond the scope of this review. An early as possible referral to an endodontist it recommended and readers are referred for further reading.^{11,64,65}

Invasive cervical resorption was also associated with dental trauma. Diagnosis can be challenging, as the teeth are mostly asymptomatic and early radiographic changes are hard to detect.^{65,66} Clinicians should look for pink colour changes in the crown as well as unusual radiolucent areas in the cervical area of the tooth (Figure 4J). Management is recommended by an endodontist and oftentimes will require a surgical approach and mechanical and chemical removal of the resorptive lesion under microscopic magnification, with or without an endodontic treatment.⁶⁶ Once invasive cervical resorption is detected in one tooth, other teeth should be checked carefully as well due to an increased risk.⁶⁶

Internal root resorption (IRR) was also associated with a history of trauma. Therefore, the traumatised tooth should be monitored clinically for pink colour changes of the crown as well as radiographic irregularities in the root canal shape.⁶⁵ Once IRR is suspected or diagnosed, then a referral to an endodontist is recommended, and the tooth will require endodontic treatment if it is restorable.

Replacement resorption, which is associated with ankylosed teeth, was discussed in detail the section on growth and development earlier.^{4,46,47}

Conclusions

Treatment of traumatised immature incisors should focus not only on the acute phase but also on the long-term consequences. A timely referral to an endodontist should be a priority in preventing and managing posttraumatic complications.

Any time gained with the tooth in the jaw bone that is free of infection is an achievement, as it allows normal growth and development. However, immature incisors sometimes cannot be saved, and alternative treatment options such as autotransplantation should be considered.

Further research should focus on ways to improve early diagnosis and management of posttraumatic complications, such as root resorption, and on long-term prevention of fractures of the immature maxillary incisors.

A summary of the long-term possible complications and treatment considerations can be found in Figure 5.

Author contributions

All authors have made substantial contributions to all of the following: (1) the conception and design of the review, (2) drafting the article or revising it critically for important intellectual content, and (3) final approval of the version to be submitted.

Conflict of interest

None disclosed.

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