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PERSPECTIVE: RIFAT LATIFI: ATLS in Kosova and the "Ghost" Trauma Hospital Building: Is there a hope that trauma care will improve?

MENTOR AHMETI, BATON KELMENDI, MELISSA MISIALEK, DORUNTINA BUNJAKU, FATLUME ARIFAJ, LUAN JAHA, DRITON SADIKU, RIFAT LATIFI: Establishment of Advanced Trauma Life Support (ATLS®) In Kosova through Kosova College of Surgeons and Sanford Health/Sanford Health World Clinics Partnership: The Initial Report

ALAN BILOSLAVO, MANUELA MASTRONARDI, PAOLA GERMANI, NICOLO DE MANZINI: Cutting-Edge Insights: Advancing Laparoscopy in the Management of Diffuse Peritonitis

AJAI K MALHOTRA: Intra-abdominal vascular injuries in severe multiple injured patients: repair, shunt, ligate?

LUMNIJE KQIKU, KURT ALOIS EBELESEDER, RIFAT LATIFI: Treatment and Outcomes of Acute Traumatic Dental Injuries: A Narrative Review

ALBION TOTSI: Management of Esophagogastric Junction Cancer

YEKTA ALTEMUR KARAMUSTAFAOGLU: Innovation in Tracheal Tumors and Stenosis: Recanalization with Endobronchial Shaver

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Treatment and Outcomes of Acute Traumatic Dental Injuries: A Narrative Review

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Abstract

Background: Dental trauma in the primary and permanent dentition can result from a variety of facial or bodily injuries and often does not occur in isolation. The aim of this narrative review is to describe the current management of traumatic dental injuries after immediate treatment as well as the prognosis and complications after delayed treatment.

Method: A search of current literature was conducted using the PubMed, Web of Science, Scopus and Google Scholar databases up to 2024. Immediate or delayed treatment, outcomes of the dento-alveolar trauma, and post-treatment complications are analyzed.

Results: Of a total of 1,217 results were initially obtained, of which 28 papers were selected and results were independently analyzed. Eighteen (18) clinical and six (6) animal studies, as well as four reviews regarding crown fractures /crown root fractures, and all type of luxations were analyzed and included in this study.

Early intervention is essential for the natural biological processes involved, and thus crucial for favorable outcomes. Delays disrupt the delicate healing environment, leading to increased complications. Finally, the guide for injuries to permanent and primary dentition: https://dentaltraumaguide.org are recommended.

Conclusion: Early management of dento-alveolar trauma significantly improves functional and esthetic outcomes.

Keywords: acute dental trauma, luxation, avulsion, crown fractures, root fractures, early or delayed treatment

Introduction

Dental trauma in the primary and permanent dentition can result from a variety of facial or bodily injuries and often does not occur in isolation. It is usually sudden, accidental, unexpected, unintentional and frequent.

Twenty percent of all people suffer a dental injury during their lifetime with more than 50% of traumatic

dental injuries (TDIs) occurring in children and adolescents. Males tend to have higher rates of dental injury than females, which may be related to the type of sport and protective equipment[1,2,3]. TDIs require rapid and multidisciplinary involvement to achieve an optimal treatment outcome. Incorrect and untimely treatment, especially in children and adolescents, leads to deviant healing patterns that can be difficult to compensate for later.

This study reviews the literature on the healing of TDI after immediate treatment as well as the prognosis and complications after delayed treatment.

Before presenting the main text a concise survey on actual classification, treatment and outcomes of TDI is given.

Classification of TDI

The most widely used classification was developed by Andreasen in 1970 [4] and accepted by the World Health Organization (WHO) in 1992 [5].

The strength of the Andreasen system is that it is very closely related to the specific tissue injuries, treatment methods and subsequent complications of dental injuries. Over the years, it has become a worldwide standard for clinicians and researchers. Andreasen's TDI classification system distinguishes between *fractures* of the dental hard tissues and *luxation's* (injuries to the periodontal tissues). We will recap briefly the types of injuries bellow.

Injuries to the dental hard tissues (fractures)

Fracture injuries are the most common TDI in the permanent dentition. Fracture injuries of the dental hard tissues comprise: crown fracture, crown root fracture, root fracture and fracture of the alveolar process.

A *crown fracture* is confined to the tooth crown. An enamel fracture is confined to the enamel, a dentin fracture involves also the dentin. In dentin fractures, the pulp can be exposed (complicated crown fracture) or not exposed (uncomplicated crown fracture (Fig.1 and 2).

A *crown root fracture* involves both the crown and the root (s) of a tooth with or without pulp exposure. A *root fracture* is confined to the root of the tooth involving cementum, dentin and the pulp (Fig.3). The *fracture of the alveolar process* is a rare but complex dental injury [6]. Not only is the alveolar bone involved, but also the pulp and periodontal ligament of several teeth, concomitant injuries can be vertical lacerations of the gingiva, root fractures, crown fractures, extrusion, or avulsion



Figure 1. Uncomplicated crown fracture localized mesial of maxillary left central incisor tooth.

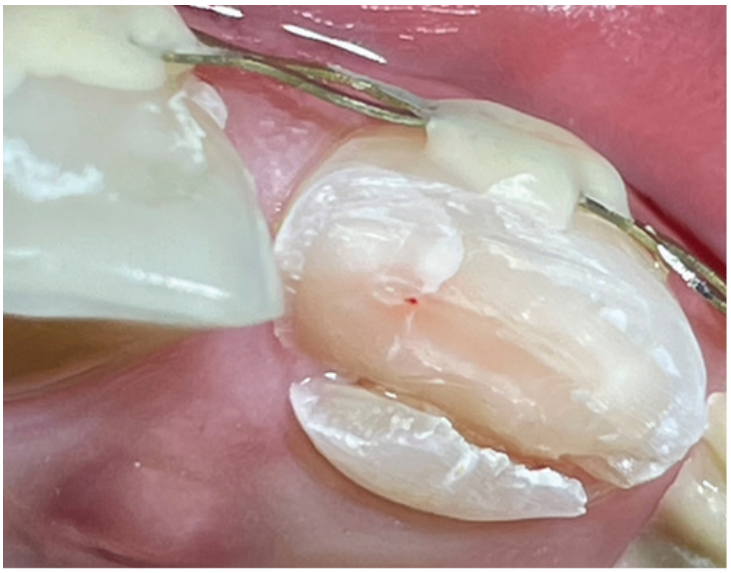


Figure 2. Complicated crown fracture teeth with exposed dental pulps of maxillary left central incisor tooth.

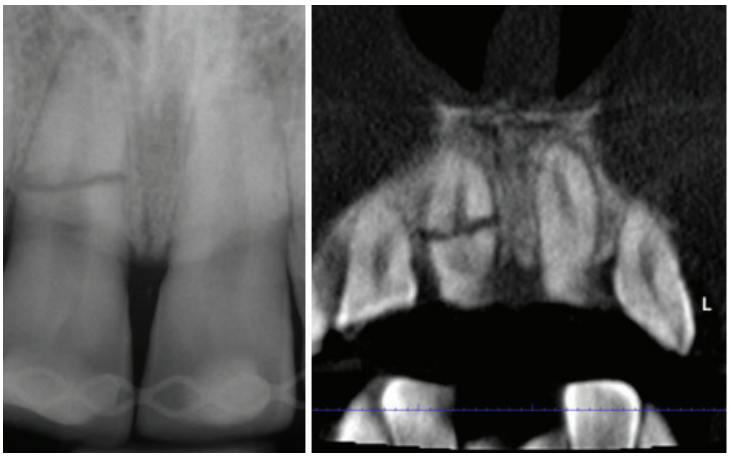


Figure 3. Root fracture. Radiographic examination: fracture line localized in the root of maxillary right central incisor tooth.

can also be found. Clinically, one or more teeth are displaced in the same direction and can be moved as a unit (Fig.4).

Injuries to the periodontal ligament (PDL) and alveolar bone (luxations)

Luxation injuries are the most common TDI in the primary dentition.

Several types of luxations can be distinguished:

Concussion and Subluxation are injuries to the PDL resulting in edema or partial rupture. The affected tooth is tender to percussion and shows an increased mobility but is not dislocated. Accompanying injuries may be by lip swelling and gingival sulcus bleeding (Fig.5).

Traumatic Extrusion is characterized by displacement of the tooth to the axial direction resulting from a subtotal rupture of the periodontal ligament and is accompanied by strong gingival sulcus bleeding and possible rupture of the papillae.

In a *Lateral luxation* the tooth is displaced in a labial or palatal direction with parts of the fractured labial bone plate remaining on the displaced root. The tooth can be immobile and thus inhibit occlusion. The papillae may be ruptured, and the palatal gingival margin may be compressed.

Traumatic *Intrusion* of a permanent tooth is a rare but serious injury [7,8,9,10].

The tooth is displaced axially into the alveolar bone and frequently penetrating the labial bone plate, may disappear completely in the tissues or is penetrating the nasal cavity.

Avulsion is the most serious form of dental trauma; the tooth is displaced out of its socket completely resulting in the disruption of the blood supply to the pulp and exposure of the cells of the periodontal ligament to the external environment [11,12] (Fig. 6).

Injuries to the dental pulp

Pulp exposure, tooth avulsion, tooth dislocation and loosening should be considered also pulpal emergencies. Regarding the type of luxation injury, a more correct pulp diagnosis (which is essential as the basis for the appropriate management strategy) can be given. The pulp plays a key role in the management of traumatic dental injury and is strongly associated with outcome.

Injuries to the soft tissues

Soft tissue injuries of the gingiva or the oral mucosa



Figure 4. Alveolar process fracture immediately after trauma



Figure 5. Luxation injuries / clinical examination after dental trauma



Figure 6. Avulsion, clinical situation after complete displacement of the tooth from its socket /maxillary right central incisor tooth.

can be found in the form of lacerations, bruises or abrasions (Fig.7).

Diagnosis of traumatic dental injuries

Correct diagnosis is possible by combining the patient's history, clinical examination, and further diagnostic and radiographic evaluation. Despite the limitations of conventional 2D radiography in visualizing three dimensional anatomical structures, this type of radiography combined with clinical examination remains the standard of care and should always be considered in the initial evaluation of the patient [13]. Cone beam computed tomography (CBCT) can provide valuable additional information, but its use should always be weighed against the potential risks particularly in children whose tissues are more sensitive to the effects of ionizing[14]. CBCT should be considered in situations where further imaging is required to obtain an accurate diagnosis and develop a correct treatment plan in cases of complex dentoalveolar trauma, such as root fractures where communication of the fracture lines with the oral cavity is likely, and complications such as root resorptions [14,15].

Timing of and Management Techniques of Dental Injuries

TDIs are considered emergencies and initially treated as such. Immediate management of dental trauma involves assessing the extent of injury, controlling bleeding, and minimizing pain and swelling. It is further essential to avoid additional damage to the injured tooth and to minimize the pathways of infection.

Repositioning / Replantation and Splinting

Depending on the type of luxation injuries, specific treatment approaches are recommended and all luxated teeth may require repositioning, splinting and antimicrobial therapy (Fig.8). The purpose of the splint is to fix the tooth in the repositioned position and thus to re-establish

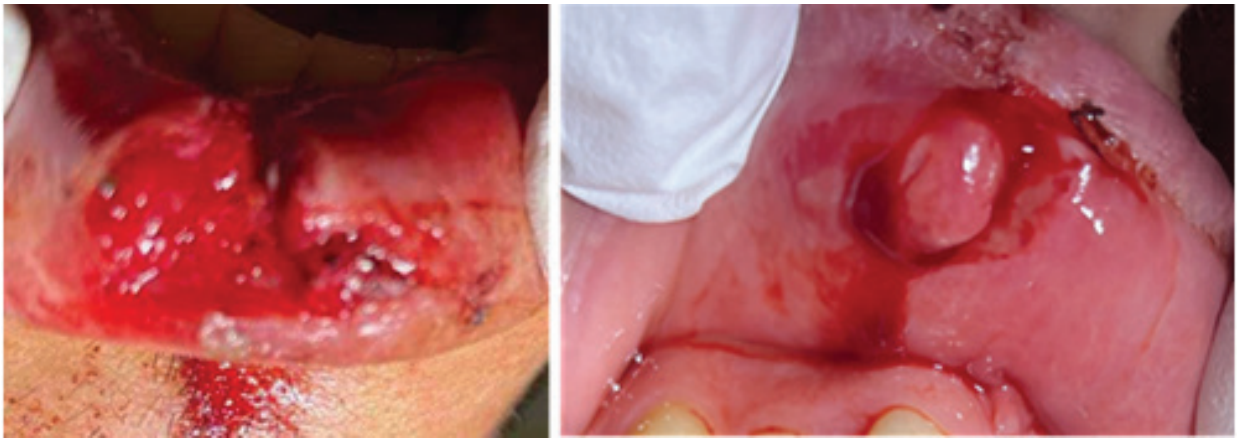


Figure 7. Soft tissue injuries clinical examination immediately after dental trauma



Figure 8. Avulsion of the maxillary right central incisor tooth. Replantation and Splinting immediately after dental injuries

oral hygiene and chewing function. It is probable that functional stimulation plays a role in repair [16,17,18]. Generally, a splinting duration of 3-4 weeks is recommended. In case of alveolar bone fracture or root fracture the splint can be left for up to 12 weeks.

Sutures Techniques

Soft tissue injuries and lacerations must be sutured promptly. The application of sutures with incisal tension results in the displacement of the cusps of burst papillae into the interdental space. This action ensures that the body can defend the interdental space from an early stage (rapid regeneration of the marginal epithelium) (Fig 9). When the suture is pulled towards the incisal, it also moves towards the incisal, becomes loose and can be easily removed. As the button of the suture only presses against the splint and not on the papilla, it is not forcibly deformed and heals virtually by itself within 2-3 days.

Dentine sealing

In the case of uncomplicated crown fracture emergency management is to cover the exposed dentin with a bacteria-tight seal (dentin bonding + flowable composite and employing acid etch technique (Fig.10).

Reattachment (crown fractures, crown-root fractures)

If a tooth fragment is available and intact, it can be reattached to the tooth (Fig.11). In a crown root fracture temporary stabilization of a loose segment to adjacent



Figure 9. Sutured of injured gingiva / papillae



Figure 11. Fragment reattachment of the maxillary right central incisor tooth immediately after crown fracture.

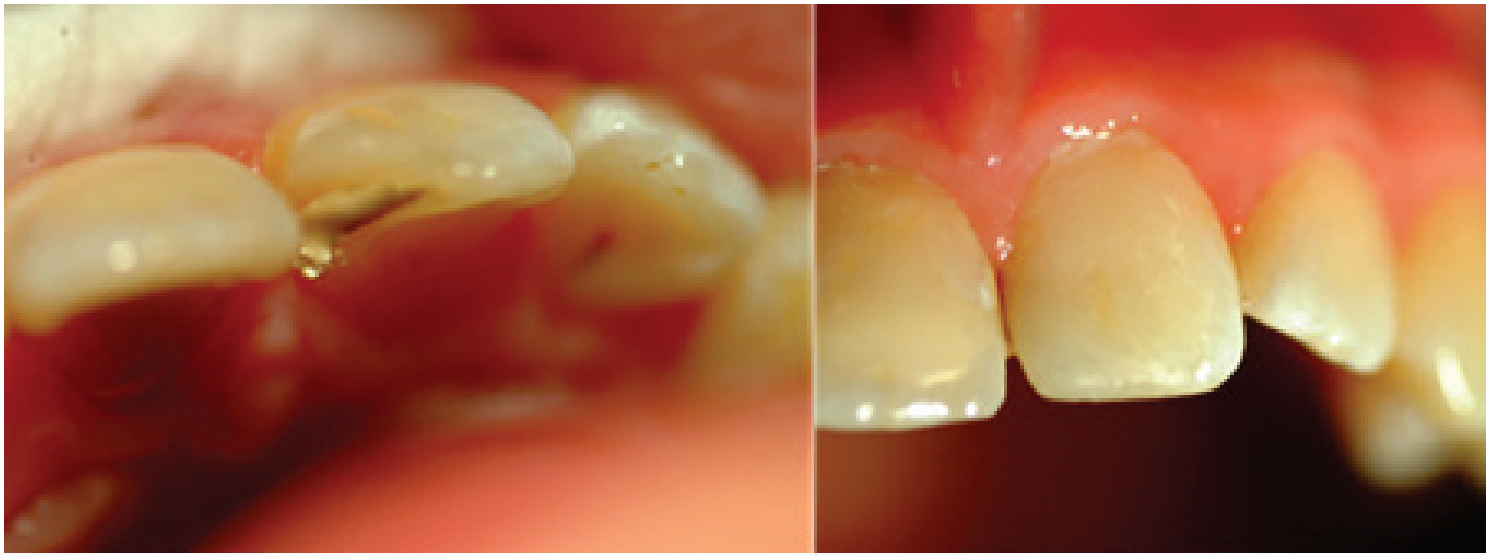


Figure 10. Exposed dentin sealing: dentin bonding + flowable composite and employing acid etch technique.

teeth can be performed until a definitive treatment plan is made.

Vital pulp treatment

In the case of exposed endodontic tissue, vitality-preserving measures are preferred (vital pulp treatment, VPT) *Direct pulp capping* aims to preserve the vital pulp by application of a biomaterial directly onto the exposed tissue.

Antimicrobial Therapy

Complications following dento-alveolar trauma are frequently induced microbially. The International Association of Dental Traumatology/IADT [19] guidelines recommend systemic use of antibiotics in specific situations, such as open wounds or fractures that extend into the oral cavity. The used of systemic antibiotics after avulsion and replantation has been advised as a means of preventing infection-related reactions and reducing the incidence of inflammatory root resorption [20].

Amoxicillin or penicillin for a period of one week remain the preferred initial options, given their efficacy in addressing oral flora and the relatively low prevalence of adverse effects.

Materials and Methods

A search of current literature was conducted using the PubMed, Web of Science, Scopus and Google Scholar databases for reviews up to June 2024. Scientific articles were searched using the following keywords such as "acute dental trauma" or "tooth avulsion", "root fractures", "alveolar process fracture", or "treatment of dental trauma" and "early or delayed treatment of dental trauma".

Of a total of 1,217 results were initially obtained, removing duplicates produced a set abstract of n=62. Finally, 28 papers were selected, and results were independently analyzed. Eighteen (18) clinical and six (6) animal studies, as well as four reviews regarding crown fractures /crown root fractures and all type of luxations were analyzed and included in this study.

The treatment time and subsequent complications of dental injuries were analyzed. The purpose of these review is to provide information for the immediately or delayed treatment, outcomes of the dentoalveolar trauma, and post-treatment complications. This review literature represents the best available evidence based on the available literature evidence on which a clinician can make decisions on the choice of the appropriate treatment approach for traumatized permanent teeth.

Results

The literature consistently supports the benefits of early treatment in dental

Trauma Immediate care minimizes complications and preserves the integrity of the tooth and surrounding structures. Delayed intervention is often associated with higher morbidity and more complex treatment requirements.

For the crown fractures and crown root fractures is usually recommended that to treated shortly after injury such as dentin wound sealing, reattachment of fractured fragment and capping of the pulp exposures (Table 1).

All types of displacement of teeth necessitate immediate intervention repositioned and immobilized to prevent later the complications (Table 2).

Several studies have shown that early replantation is crucial for the best chances of success and prognosis for avulsed permanent teeth primarily depends on the actions taken at the place of accident (Table 3).

Table 1. The main outcomes of the included studies regarding crown fractures and crown root fractures

Study	Findings
Rock et al 1974[25]	Found a significant increase in frequency of pulp necrosis for teeth with crown fracture treated later than 3 days after injury.
Ravn 1981[33]	In this study 3144 permanent incisors with crown enamel-dentin fracture as the only damage and in 923 incisors with enamel-dentin fracture combined with other symptoms on the damaged tooth were examined and observed for more than 2 years. With respect to cervical pulpotomy, significant relationship was found between pulp necrosis and a treatment delay of more than 24 h.
Cvek et al 1982a[26]	Authors concluded that the conditions for vital pulpotomy treatment are favorable, at least during the first few days after trauma, because after 7 days of exposure, the inflammatory response is more pronounced but does not extend more than 2 mm into the pulpal tissue
Cox et al 1985[27]	This animal study showed that exposed pulpa for 0 or 1 h showed damage due to mechanical exposure alone. Teeth left open for 24 hours and 7 days showed inflammatory infiltration, and several teeth exposed for exposed for 7 days showed partial or total necrosis.
Pitt Ford & Roberts 1991[28]	The authors suggest that direct pulp capping may be successful even if delayed for 24 h after injuries.
Al-Nazhan 1995[29]	Delayed treatment of traumatic dental injuries appears frequency of pulp necrosis as complication.

Study	Findings
Robertson et al 2000[30]	The authors investigated 455 permanent teeth with crown fractures, associated with luxation injury and without pulpal and with pulp exposures and concluded that: healing was related to the more clinical factors such as time interval from injury until initial treatment.
Andreasen 2002[23]	In this survey of Andreasen the delayed treatment complications were analyzed for the various dental trauma groups. The authors concluded that by crown root fracture for better healing outcome the treatment approach should be immediately /within a few hours or within the 24 hours after injury.
American Association of Endodontists 2007[31]	Pulp extirpation is generally recommended within 7 to 10 days post-replantation. AAE recommended than when the tooth is immature and has been replanted almost immediately, pulp extirpation is generally recommended within 7 to 10 days post-replantation.
Hinckfuss & Messer 2009[32]	This meta-analyses study found that pulp extirpation delayed beyond 14 days after tooth replantation is associated with an increased risk of developing inflammatory resorption. Therefore, the pulp should be removed from mature teeth within 14 days of replantation, and from immature teeth where maintenance of pulp vitality is unlikely, to prevent this outcome
Wang et al 2014[24]	Reported that injuries without dentin coverage had a nearly threefold increase in the likelihood of pulp necrosis compared with pulp necrosis compared to teeth with dentin coverage.
Krastl et al 2020[22]	To prevent pulp necrosis resulting from crown fractures, it is imperative that fragment reattachment or direct composite restoration be performed as soon as possible following the accident. If this is not possible during the initial emergency treatment, the placement of the restoration can be postponed if the dentinal wound is sealed properly to prevent pulp infection.

Table 2. The main outcomes of the included studies involving luxations injuries

Study	Findings
Andreasen 1970[34]	This study evaluated the clinical and radiographic follow-up of 108 patients with 189 dislocated permanent teeth for 1 to 12 years. Periodontal ligament healing was negatively influenced by delayed treatment: repositioning and splinting of 5 hours or more for all types of dislocations.
Andersson 2001[35]	Delayed treatment (>24 hours) in luxation injuries often results in necrosis and infection. Complicated healing processes are common.
Andreasen 2002[23]	In the survey of the Andreasen and al the consequences of treatment delay on periodontal healing have been analyzed for the various dental trauma groups. The authors concluded that dislocation with displacement shows a certain time relationship between treatment time and healing outcome and recommends immediate repositioning and mobilization within a few hours or within 24 hours of injury. Immediate splinting is indicated to avoid incidental dislocation of the replanted tooth.
Cunha et al 2002[40]	The authors concluded that surgical repositioning / immediate repositioning by the intrusions teeth did not impede the repair process or cause additional damage within the study period.
Humphrey et al 2003[39]	The authors investigated clinical outcomes for permanent tooth luxations/intrusions in a children and adolescents and concluded that failure was more common when active repositioning/immediate surgical repositioning was delayed beyond 2 weeks.
Levin 2004[36]	Prompt and appropriate management is necessary to significantly improve the prognosis for many dento alveolar injuries.
Rocha et al 2015[37]	The authors concluded that patients who sought treatment nine weeks after the trauma episode exhibited a 10-fold increased risk of developing inflammatory resorption when compared with patients who sought treatment promptly after dental trauma. Furthermore, they posited that delayed treatment may negatively impact the prognosis of severe luxation and replanted teeth. When traumatic injuries are diagnosed and treated early, post-traumatic complications may be controlled, allowing conservation of the tooth in oral cavity.
Antipovienė et al 2021[38]	In order to prevent complications following dental injuries, it is imperative that immediate treatment be administered. It is therefore recommended that educational programs related to TDIs be made available to patients, parents, and teachers.

Table 3. The main outcomes of the included studies regarding avulsion and replantation

Author	Findings
Andersson & Bodin 1989[45]	The authors included Twenty-one avulsed human permanent teeth in their study and followed them up for 5 years. According to radiographic evaluation of root resorption, they revealed that teeth replanted within 15 min after the avulsion have a favorable long-term prognosis with significantly increases the chances of periodontal ligament healing and reduces the risk of root resorption.
Andreasen et al 1995[21]	The authors replanted 400 avulsed permanent teeth and examined for periodontal ligament healing. The authors concluded that using standardized radiographic and clinical examination Immediate replantation is recommended and teeth with immediate reimplantation has the lowest risk of ankylosis.
Barret et al 1997[46]	A very important factor for a favorable prognosis after replantation is the speed with which the tooth is replanted to prevent desiccation and loss of normal physiological metabolism of the periodontal ligament cells.
Trope 2002[47]	In the treatment of injured teeth, time is the most important factor. The more time has passed before reimplantation, the greater the risk of inflammatory root resorption and replacement resorption. The chances of revascularization also decrease.

Author	Findings
Malsamani et al 2018[43]	In this study, the authors evaluated and investigated the delayed replantation in rabbits and found that delayed replantation > 60 minutes extraoral dry time results in ankylosis complication.
Wang et al 2019[42]	The objective of this study was to assess the impact of various factors on the survival of replanted teeth in pediatric patients. The findings indicated that non-physiological storage for a duration of less than 30 minutes was a crucial determinant of periodontal healing in replanted teeth. The extra-alveolar period was identified as a significant factor influencing the survival of replanted teeth.
Lauridsen et al 2020[48]	The objective of this study was to evaluate the risk of ankylosis in human teeth that had been replanted after a period of dry storage prior to replantation. The findings indicated that the risk of ankylosis increased with an increase in the length of dry time and immediate replantation should be considered for avulsed teeth.
Demir et al 2020[49]	The findings of this study indicate that delayed replantation of an avulsed tooth in a pediatric patient is a viable treatment option, even in cases with a poor prognosis where the tooth has undergone extended extra-alveolar dry storage. The rationale for this approach is based on the belief that delayed replantation plays a crucial role in the child‘s jaw and facial development.
Malmgren 2002[41]	Concluded that Delayed replantation has a poor long-term prognosis.
Gul et al. 2024[44]	A total of 116 patients with 145 replanted avulsed permanent teeth were selected from a comprehensive dental trauma database at Copenhagen University Hospital. The teeth were replanted at different times, ranging from less than six minutes to over 60 minutes. The results demonstrated that immediate replantation had the lowest risk of ankylosis.

Discussion

In this study we have shown that early treatment of dental fractures, dislocations, and dentoalveolar fractures, and crown improves the prognosis, while the delayed treatment has been proven to have negative impact [21].

If a tooth fragment is available and intact by crown fractures/crown-root fractures

it can be reattached to the tooth immediately after injuries. If this is not possible during the initial emergency treatment, the placement of the restoration can be postponed if the dentinal wound is sealed properly to prevent pulp infection [22,23].

The most common complications after a dental accident are pulp necrosis, infection of the root canal system with apical periodontitis, internal or external resorption (inflammation or replacement), root growth disorders, loss of the periodontal ligament (ankylosis), loss of tooth structure and tooth discoloration.

Pulp necrosis following uncomplicated crown fractures is rare. Nevertheless, Wang et al. reported that injuries without dentin coverage had a nearly threefold increase in the likelihood of pulp necrosis compared with pulp necrosis compared to teeth with dentin coverage [24]. Different studies found a significant increase in frequency of pulp necrosis for teeth with crown fracture treated later after injury [25,26,27,28,29,30]. Pulp extirpation is not recommended in the primary emergency treatment of dental trauma. American Association of Endodontists recommended pulp extirpation within 7 to 10 days post-replantation [31]. Hinckfuss & Messer concluded that pulp extirpation delayed beyond 14 days after tooth replantation is associated with an increased risk of developing inflammatory resorption [32].

The outcome depends on the condition of the pulp, the loss of tooth substance, and the presence of bacteria. Therefore, the aim of treating dental trauma is ultimately to protect and restore pulp function. Healthy pulpa has a better prognosis than pulpa without blood supply and is more resistant to bacterial invasion [33]. The presence of bacteria in the root canal system can cause internal inflammatory resorption and damage to the periodontal ligament.

Periodontal ligament healing was negatively influenced by delayed treatment: repositioning and splinting of 5 hours or more for all types of dislocations [33].

Many authors concluded that dislocation with displacement shows a certain time relationship between treatment time and healing outcome and recommends immediate repositioning and mobilization within a few hours or within 24 hours of injury. Immediate splinting is indicated to avoid incidental dislocation of the replanted tooth[23,36,37,38,37]. Displacement of teeth; subluxation; extrusion; lateral dislocation and intrusion can disrupt the neurovascular supply to the pulp, and the pulp causes ischemia that can lead to necrosis[39]. Cunha et al [40]conluded that surgical repositioning / immediate repositioning by intrusion’s teeth did not impede the repair process or cause additional damage within the study period.

Delayed replantation has a poor long-term prognosis [41]. Early treatment, preferably within 30 minutes of the injury, can significantly impact the prognosis [21,42]. Many authors agree that an extraoral drying time of 60 minutes leads to necrosis and resorption of the replacement [43,44]; therefore, an extraoral exposure time of the avulsed tooth of approximately 15 minutes would be ideal to avoid

replacement resorption [21, 45].A very important factor for a favorable prognosis after replantation is the speed with which the tooth is replanted to prevent desiccation and loss of normal physiological metabolism of the periodontal ligament cells and the risk of ankylosis increased with an increase in the length of dry time [46,47,48,49]. Tooth avulsion needs to be treated properly and immediately [50].

To improve prognosis and minimize complications, a prompt and correct emergency management is necessary as long as life threatening injuries are taken care of first. If traumatic dental injuries are not properly treated special dental luxations, the injury site becomes a portal of entry for bacteria and the patient may develop an infectious emergency. Therefore, it is especially important for children and adolescents to receive initial treatment at the right time to avoid complications. Immediate management of dental trauma involves assessing the extent of injury, controlling bleeding, and minimizing pain and swelling.

Conclusions

Outcomes and prognosis of dental trauma varies depending on the type and severity of the injury, but timely and proper treatment are most important one. Early intervention and appropriate management contribute significantly to favorable outcomes.

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