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ORIGINAL ARTICLE

Complications and survival rates of teeth after dental trauma over a 5-year period

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Abstract
Objectives The purpose of this study was to evaluate whether the current guidelines of the International Association of Dental Traumatology (IADT) for emergency care of traumatised teeth result in lower complication rates.
Materials and methods Therapeutic strategies of 361 dental injuries in 291 patients treated at a university dental hospital over a 5-year period were investigated by evaluating the patients' records. Adherence to the guidelines of the IADT (Flores et al. Dent Traumatol 17:1–4, 2001; 49–52, 2001; 97–102, 2001; 145–148, 2001; and 193–196, 2001; Flores et al. Dent Traumatol 23:66–71, 2007; 130–136, 2007; and 196–202, 2007) was evaluated. Complications were also recorded according to the patients' records and analysed relative to the treatment and injury pattern. During follow-up visits, the teeth were inspected regarding pulp vitality and overall function of the injured tooth. The Kaplan–Meier survival analysis of pulps and teeth was performed for different injury categories.
Results The majority of injuries (322/361; 89.2 %) were treated according to the guidelines. When IADT guidelines were followed, complication rates were significantly lower than for cases treated without adherence to the guidelines. The most frequent complication was the loss of restoration, followed by pulp necrosis, abnormal mobility, and tooth loss. The overall survival analysis showed that in the permanent dentition, the loss of pulp vitality and tooth occurs within the first 6 months but may also occur later.
Conclusions The results of this study indicate that traumatised teeth that were treated according to the recommendations had a lower complication rate. In addition, the majority of pulp necrosis and tooth losses in the permanent dentition occurred within the first 6 months after trauma. These results indicate that early follow-up visits are essential to promptly treat complications.
Clinical relevance Adherence to the IADT guidelines for treatment of dental trauma may lead to more favourable outcomes when compared to cases treated without compliance to the guidelines.

Keywords Dental trauma · Complications · Survival analysis · Guidelines

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Introduction

Dental intervention after traumatic dental injuries can be considered either for acute or sub-acute treatment priority. Although certain traumatic patterns have acute treatment requirements, others can be treated sub-acutely within the following days. The International Association of Dental Traumatology (IADT) has established scientifically based, best practice guidelines for the treatment of traumatically injured teeth. These guidelines are regularly updated [1–9]. Over the last decade, these guidelines have become increasingly important and are widely accepted as the standard of care. Injuries of biological structures that require acute treatment include (1) the exposure of the pulp tissue secondary to complicated fractures or (2) extensive rupture of the periodontal ligament with displacement of the tooth due to lateral or extrusive dislocations or avulsions. To minimise interference with the healing process, repositioning of fractured bone or extrusion of severely intruded teeth should be

performed in a timely manner [10]. Although treatment guidelines have been based on the best and most recently available data, little is known regarding treatment outcomes after these treatment recommendations were implemented. To date, two studies have reported therapy outcomes for avulsions that were treated based on IADT recommendations. Stewart et al. showed that following the endodontic treatment recommendations of the IADT guidelines for avulsed teeth may lead to a more favourable outcome, whereas Roskamp et al. reported that immunological factors may play a larger role in treatment outcome than adherence to the guidelines [11,12]. However, there is no information about survival rates for other types of injuries in relation to IADT treatment recommendations. The objectives of this retrospective case–control study were to describe the general complication rates for all treatment groups relative to the use of IADT guidelines and to analyse the survival rates of pulp tissue and teeth after dental trauma.

Materials and methods

In adherence with the Declaration of Helsinki, ethical approval was obtained from the Human Ethics Committee of the Ludwig–Maximilians University, Munich (project no. 390-09). A retrospective design was used to address the objectives of this large case–control study.

Patients

Medical records of all patients (n=216) that were treated for dental trauma in the emergency department of the Department of Conservative Dentistry at the Ludwig–Maximilians University, Munich, Germany, over a period of 54 months (January 2004–July 2008) were retrieved from the patients' registry. A total of 361 traumatic dental injuries were recorded. The corresponding patients' records were analysed. The patient population consisted of patients that consulted the dental clinic for immediate care (142/216; 65 %) as well as referrals from private practitioners or other medical clinics (70/216; 32 %) and patients that came on their own accord for a second opinion or further treatment (4/216; 2 %). Less than one-fourth of the patients (23.8 %) presented with injuries of a deciduous tooth (86/361), and 76.2 % of all injured teeth were permanent (275/361). No patients were excluded from the study.

Treatment principles

For the primary dentition, the two main treatment goals were to provide atraumatic treatment to the young child and prevent harm to permanent teeth. For permanent dentition, the preservation of the biological structures to avoid inflammation and resorption was the main treatment goal, especially in growing patients. New internal treatment guidelines for dental trauma patients were established prior to 2004. These include accurate documentation of diagnostic findings on a standardised trauma form in combination with the adherence to the updated principles of the IADT guidelines [1–8] for treatment and follow-up. For referred trauma patients, clinicians are obliged to retrieve information regarding diagnostic and treatment protocols from their external care provider whenever possible.

Adherence to IADT guidelines

After retrieval of detailed information regarding the diagnosis and treatment procedures from the patients' records, injury patterns were categorised, and treatment protocols were evaluated and classified as either conforming or non-conforming to the current IADT guidelines [1–8]. In patients who had at least one additional visit, complications were also recorded. Data were rated as not available for cases with incomplete documentation or a lack of information. Complications were compared to the type of injury and treatment conformity. Cases that could not be unambiguously assigned were grouped separately.

Follow-up

All patients were informed to present for a follow-up exam. One independent investigator examined the corresponding teeth following a standardised investigation protocol. The clinical exam included a visual inspection and digital examination of the traumatised tooth and surrounding structures. Pulp necrosis was excluded by testing the sensitivity response of the pulp using a refrigerant spray (Orbis, Münster, Germany) and electric pulp testing (EPT, Parkell Inc., Farmingdale, NY, USA). Radiographs were only obtained when indicated by the actual guideline recommendations or whenever clinical symptoms were present. Data on the status of the pulp vitality, tooth loss, and presence of radiologically identifiable root resorption were recorded on a standardised form.

Statistics

The data were processed using Microsoft Excel® 2008 (V 12.8.3 Mac). The significance of the correlation between complications and treatment conformity was tested using Fisher's exact test (p<0.001). Survival rates of pulps and teeth were expressed as survival curves using the Kaplan–Meier estimator. For the survival analysis of the pulp and the tooth, injuries were grouped into three different categories for the primary and permanent dentition. The first group comprised of all types of crown fractures without pulp involvement, such

Table 1 Complications are significantly more common when the IADT guidelines are not followed

	Number of complications (%)			Σ
	Yes	No	No recall	
IADT conforming	40 (12.4)	107 (33.2)	175 (54.3)	322 (100)
IADT non-conforming	8 (47)*	–	9 (53)	17 (100)
Unknown	7 (31.8)	5 (13.6)	12 (54.5)	24 (100)

*$p<0.001$ (Fisher's exact test)

as enamel cracks, uncomplicated crown fractures, and crown–root fractures. Fractures with pulp involvement, such as complicated crown fractures, crown–root fractures, and root fractures, were combined in a second category. The third category consisted of luxation injuries and included all types of periodontal injuries.

Results

The treatment recommendations of the IADT were followed in 89.1 % of all cases (322/361), whereas 4.7 % (17/361) and 6.2 % (22/361) of the cases were non-conforming or used an undetermined treatment, respectively. A total of 84 complications in 55 teeth were recorded. Although 50 permanent teeth showed 94 % of the complications (79/84), only five primary teeth showed single complications. Overall, complication rates were significantly lower when the guidelines were followed (Table 1). The follow-up rate for the study was 59.5 % (122/216), and these visits corresponded to 49 primary and 166 permanent teeth.

Primary dentition

The following main strategies for emergency treatment were used: monitoring for isolated concussed and subluxated teeth (16/18; 88.9 %), extractions in root fractures (5/6; 83.3 %) and luxation injuries (2/71; 2.8 %), restoration of crown fractures (9/12; 75 %), and endodontic treatment in pulp-exposed coronal fractures (1/2; 50 %). None of the avulsed primary teeth were replanted. All intrusions were monitored for spontaneous re-eruption, and extractions were performed in unsuccessful cases. Only 6 % of all recorded sequelae affected primary teeth (5/84): two teeth of these had suffered from combined injuries, two were luxated, and one was fractured. Due to the small number of fractures during follow-up visits ($n=18$), a fracture survival analysis was omitted. A survival analysis for luxation injuries was performed for a 36-month period. This analysis revealed that pulp necrosis occurred mostly within the first 24 months after trauma and resulted in a survival probability of 64.1 %. Tooth loss was most frequent within the first 18 months with a predominance of extrusions and intrusions. The survival probability for teeth after 36 months was 68.4 % (Fig. 1).

Permanent dentition

The differentiated treatment strategies for the permanent dentition are summarised in Table 2. The analysis of complications showed that a loss of restoration was the most frequent incidence, followed by pulp necrosis, abnormal mobility, and tooth loss (Fig. 2). Among the luxation injuries, 50 % of all avulsions (6/12) showed complications, whereas 35.3 % of lateral luxations (6/17), 13.8 % of all subluxations and concussions (9/65), and 7.1 % of extrusions (1/14) showed unfavourable events. Among the fractures, 40 % of complicated crown–root fractures (2/5) had complications, followed by enamel–dentin fractures and crown–root fractures without pulp involvement (16/145; 11 %), and enamel–dentin fractures with pulp involvement (2/38; 5.3 %).

The follow-up period ranged from 1 to 67 months with an average of 23.2 months. The recall rate for permanent teeth

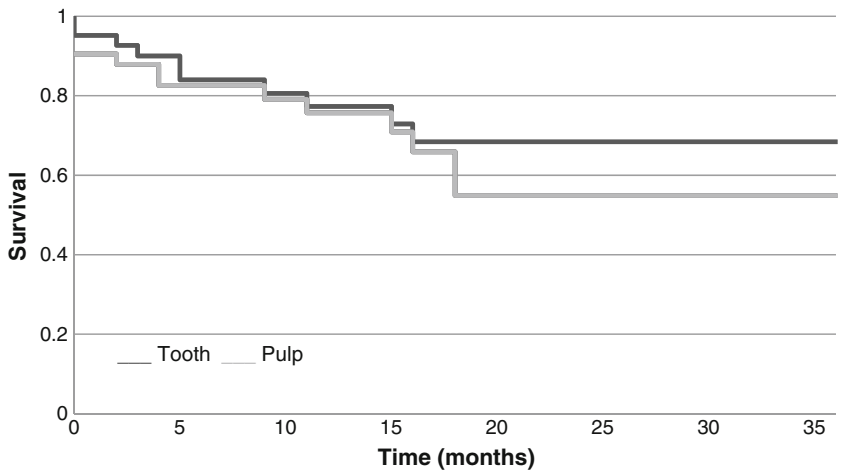

Fig. 1 The Kaplan–Meier curves express the survival rates of the pulp and tooth in luxation injuries in the primary dentition

Table 2 Distribution of treatment modalities for the permanent dentition including combined injuries (n=40)

Treatment		Diagnosis								
		Fractures				Luxations				
		Enamel–dentin fracture (n (%))	Enamel–dentin fracture and pulp exposure (n (%))	Crown–root fracture (n (%))	Root fracture (n (%))	Concussion (n (%))	Subluxation (n (%))	Dislocation (n (%))	Intrusion (n (%))	Avulsion (n (%))
Endodontic	Capping	15 (10.6)	17 (44.7)	3 (37.5)	1 (7.7)	–	–	–	–	–
	Pulpotomy	–	10 (26.4)	2 (25.0)	1 (7.7)	–	–	–	–	–
	RCT (<4 weeks)	1 (0.7)	7 (18.4)	2 (25.0)	3 (23.1)	–	2 (4.4)	10 (32.3)	–	4 (33.3)
	Non-RCT	126 (88.7)	4 (10.5)	1 (12.5)	8 (61.5)	20 (100)	43 (95.6)	21 (67.7)	4 (100)	8 (66.7)
Restorative	Intermediate	51 (36.0)	15 (39.5)	3 (37.5)	5 (38.5)	–	–	–	–	–
	Definitive[a]	86 (60.5)	22 (57.9)	4 (50.0)	–	–	–	–	–	–
	Unrestored	5 (3.5)	1 (2.6)	1 (12.5)	8 (61.5)	20 (100)	45 (100)	31 (100)	4 (100)	12 (100)
Repositioning splinting	R and S	–	–	1 (12.5)	9 (69.2)	–	22 (48.9)	31 (100)	–	11 (91.7)
	Orthodontic	–	–	–	–	–	–	–	3 (75.0)	–
	Non-orthodontic	142 (100)	38 (100)	7 (87.5)	4 (30.8)	20 (100)	23 (51.1)	–	1 (25.0)	1 (8.3)
Extraction	Extraction	–	1 (2.6)	–	1 (7.7)	–	–	–	1 (25.0)	1
	Fragment	–	–	4 (50.0)	3 (23.1)	–	–	–	–	–
	Non-fragment	142 (100)	37 (97.4)	4 (50.0)	9 (69.2)	20 (100)	45 (100)	31 (100)	3 (75.0)	11 (91.7)
∑		142 (100)	38 (100)	8 (100)	13 (100)	20 (100)	45 (100)	31 (100)	4 (100)	12 (100)

RCT root canal treatment

[a] Definitive restorations consist of 67 direct restorations and 47 fragment attachments

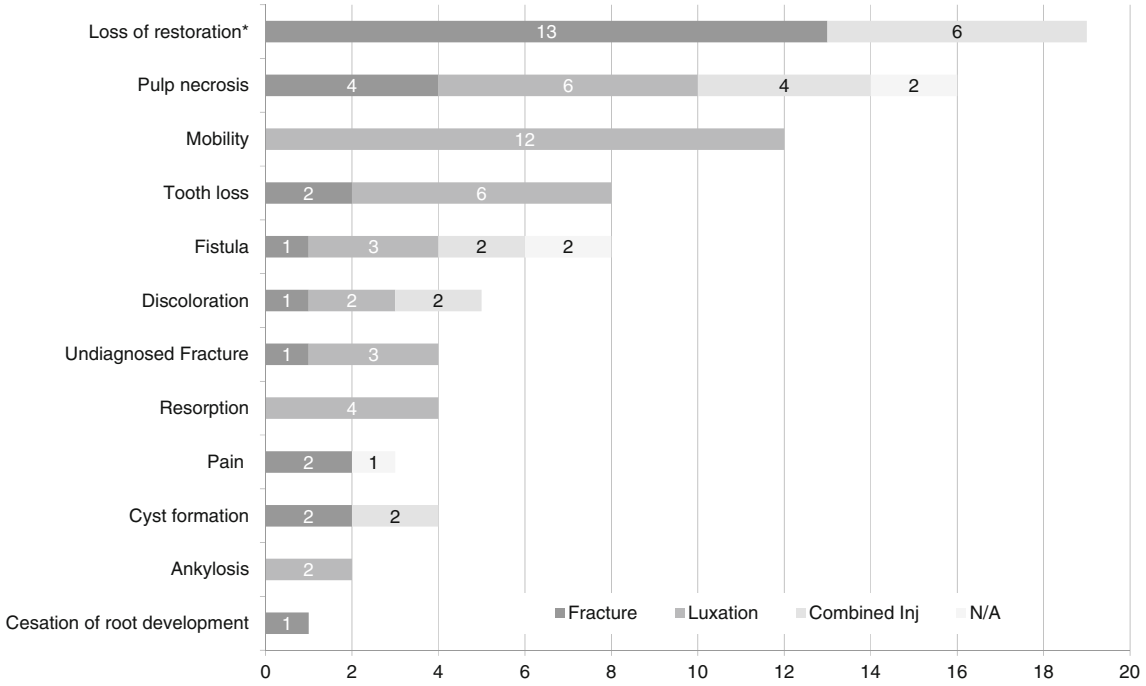

Fig. 2 Complications in the permanent dentition listed based on the type of injury. *Asterisk* denotes that the failed restorations comprised eight direct restorations and nine reattached tooth fragments

was 60.4 % (166/275) at the time of follow-up. No tooth loss after uncomplicated crown fractures was registered within the observation period, resulting in a survival rate of 100 %. Complicated crown fractures led to the loss of only one tooth during the observation period, corresponding to a survival rate of 95.7 % after 67 months. The survival rate for luxation injuries was approximately 86.8 % (Fig. 3). Pulp necrosis after uncomplicated crown fractures occurred most commonly within the first 6–12 months after trauma but was also diagnosed after a longer time period of up to 51 months. The survival probability after 67 months was 66.8 %. A loss of pulp vitality in complicated crown fractures was mainly observed on the day of trauma and within the first 6 months. The survival probability after 67 months was 52.9 %. Late loss of pulp vitality was also reported. Following luxation injuries, pulp necrosis was observed up to 24 months after trauma with an overall survival of 62.6 % (Fig. 4).

Discussion

One of the major findings of this study was that the complication rate (13.8 %) was lower than in other populations with previously reported rates of 23.0–84.4 % [13,14]. A large percentage of our patient population was treated based on IADT guidelines (89.1 %). Complication rates were significantly lower when the specific IADT guidelines that were current at the time of treatment were followed.

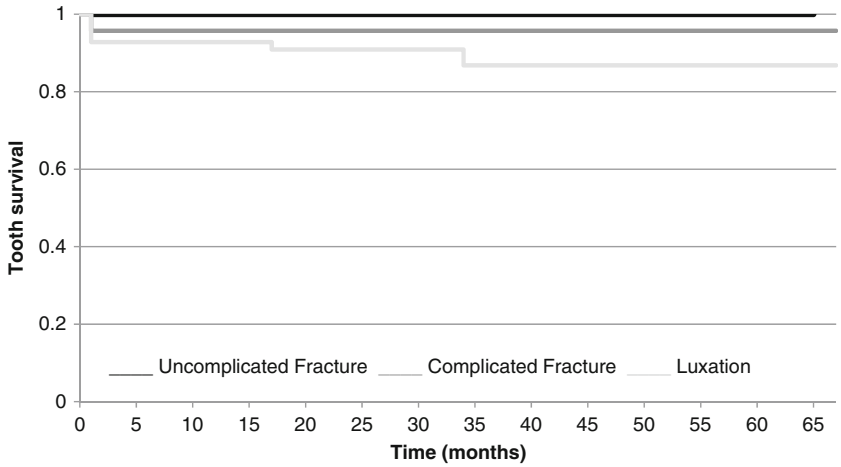

Fig. 3 Tooth survival rates of three groups of traumatic injuries are displayed as Kaplan–Meier curves.

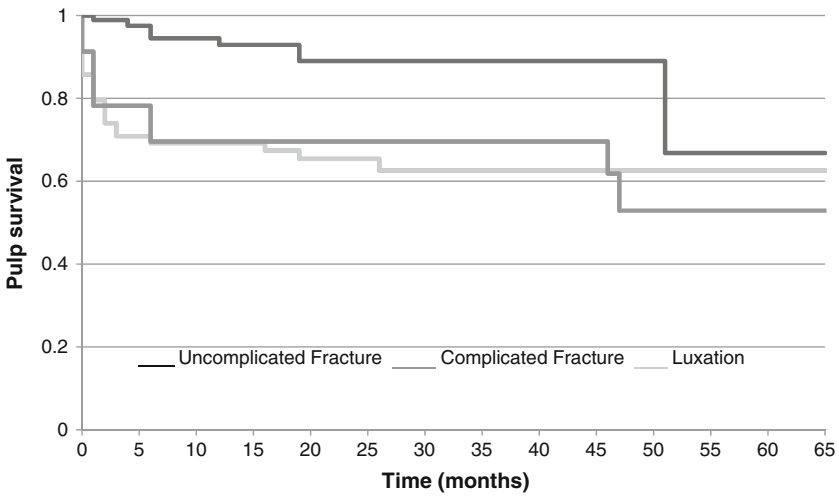

Fig. 4 The Kaplan–Meier estimator shows the pulp survival for luxations as well as complicated and uncomplicated fractures in the permanent dentition

The reported complications consisted of minor and major sequelae. Minor problems after trauma, such as the loss of restorations, have only little or no negative consequences for the biological structures when treated in a timely fashion. Major consequences, such as pulp necrosis, result in more complex and time-consuming treatment needs or even tooth loss [15,16]. In addition, the failure to address the loss of pulp vitality may lead to more serious complications, including apical periodontitis, fistula, or abscess [17,18]. Resorption and ankylosis are also major complications and may lead to tooth loss [14,19,20].

Combined injuries to the primary dentition have been shown to increase the risk of complications, which is in accordance with our findings that two out of three combined injuries resulted in complications [21]. The reduced recall rate at the time of follow-up (49/86; 56.9 %) can be explained by the fact that a considerable number of teeth will have undergone physiological exfoliation at the time of recall, and parents may not feel the need for further follow-up. No survival data were found in the literature for luxations of primary teeth. Pulp necrosis and tooth loss in luxation injuries are found within the first 24 months after trauma. After 36 months, the probability of pulp survival (64.1 %) and tooth survival (68.4 %) were almost equal. The survival of the primary teeth was lower relative to the permanent dentition. This observation illustrates one of the main treatment principles for the primary dentition, i.e., either tooth observation or extraction, rather than endodontic preservation, is employed whenever it is necessary to avoid or minimise damage to the permanent teeth. Considering that the overall life span of primary teeth is approximately 5–6 years, 24 months of pulp necrosis or tooth loss is a relatively long time. This indicates that regular recall is necessary until the occurrence of physiological exfoliation.

In permanent dentition, luxation injuries were twice as often associated with complications (22/108; 20.4 %) than fractures (20/188; 10.6 %). Teeth with combined injuries had a complication rate that was 1.5 times higher than that for fractures (6/40; 15 %). Other authors have described similar findings [15,16,22,23]. Complications were associated with specific trauma patterns. For fractures, including combined injuries, a loss of restoration was the most common complication (19/112; 16.9 %). In all cases, adhesive techniques were used for composite restorations or the reattachment of fragments if available. To enhance the fracture resistance, an additional preparation in combination with reattachment techniques has been suggested by several authors; in contrast, other authors did not observe a significant advantage with additional preparations [24–26]. In addition, the use of an unfilled bonding resin was found to improve restoration survival [27]. The effect of storage of fragments in moist conditions on the bond strength has also been discussed. Although Farik et al. suggested storing the fragment under moist conditions for 24 h before reattaching it, Yilmaz et al. did not find any significant effect on the longevity of adhesion of moist fragments [28,29]. The type of injury had no significant effect on the longevity of the attachments [29]. Our results show that fragments (9/47; 19.1 %) are lost almost three times more often than direct restorations (10/67; 6.7 %). None of the aforementioned factors could be linked to the higher rate of loss of reattached fragments. In conclusion, within the limitations of this study, the loss of restorations indicates that direct restorations are more reliable than fragment reattachments. Nevertheless, the reattachment of tooth fragments is an easy method to quickly achieve good aesthetical results and should not be disregarded in the setting of acute trauma.

In this study population, resorption was linked to luxation injuries, and the occurrence was found to be relatively low. Resorption accounts for only up to 5 % of all complications in permanent dentition (4/79). Hecova et al. reported a resorption rate of 5.6 % for extrusions [15]. Other luxation injuries have a higher prevalence of resorption and ankylosis, which range from 38 to 66 % for intrusions and from

57.7 to 80 % for avulsions [19,30–36]. The percentage of resorption in permanent dentition after severe luxation injuries, such as avulsions and intrusion, in this study is low (2/16; 12.5 %).

The occurrence of pulp necrosis depends on the effect of trauma on the endodontic tissue [16]. In crown fractures, the prevalence is reported to be up to 6 % [15,16,22,23,37,38]. In this study, only 3.8 % of fractures showed pulp necrosis (3/79). Depending on the trauma pattern, complicated fractures tend to have higher necrosis rates. The location and complexity of the fracture, unsealed wounded dentinal tubules with treatment delay, as well as concomitant luxation injuries increase the incidence of pulp necrosis [15,22,23]. A concomitant subluxation is reported to be eight times more likely to result in necrosis of the pulp than uncomplicated fractures alone [16]. For combined injuries, we found a complication rate of 7.5 % (3/40), which is twice as high as for fractures alone. The reported prevalence of pulp necrosis in luxated teeth varies and has been reported to be as high as 100 %. The prevalence depends on the extent of dislocation, maturity of the root concomitant crown fractures with dentin exposure, as well as gingival lacerations [19,31,39,40]. Our population included a relatively large number of cases with uncomplicated non-displaced luxations, which resulted in a low resorption rate.

Multiple retrospective case control studies have reported survival data for different types of luxation injuries focusing on various potential contributing factors. To our knowledge, survival data on crown fractures have not been reported to date; only one recent study on the survival of root fractures exists [40]. The survival of the tooth after root fracture depends on the depth of the fracture site and ranges from 33 % for cervical fractures up to 89 % for apical fractures for a 10-year period. The overall survival rates of fractures in our study were within this range. The majority of survival data focus on intrusions [19,20,41–43]. Therefore, the comparability of the present data is limited. Three studies addressed avulsions, where Lee et al. and Nikoui et al. reported on extrusions and lateral luxations, respectively [14,33,39,44,45]. Due to the high percentage of concussions and subluxations in the study population, the survival was relatively high in this sample. Following luxation injuries, we found pulp necrosis to occur within the first 6–12 months, which is in agreement with other studies. Following intrusions, pulp necrosis is reported to occur within the first months after trauma [19,20,41,42]. Lee et al. reported that pulp necrosis in the setting of mild to severe extrusion occurs within the first year after trauma [45]. Lateral luxations are also most likely to result in pulp necrosis within the first months after the insult [39]. Tooth loss in the study population was observed within the first 2 years after the pulp insult. These results are confirmed by previously reported data. After intrusion, a loss of teeth will occur within the first months after trauma [41]. After avulsions are replanted, tooth loss will commonly occur within the first 2–3 years [14,44]. Complications of fractures alone are rarely investigated. Dental fractures without luxations can lead to pulp necrosis within the first year, and the incidence of tooth loss is a very rare, especially in uncomplicated cases where emergency treatment is simple and prevents pulp infection by sealing the potential infection pathways to the pulp.

Conclusions

Within the limitations of this study, our results indicate that the adherence to treatment strategies recommended by the IADT will enhance treatment outcomes and lead to lower complication rates. A regular follow-up is necessary in the primary and permanent dentitions to treat complications as early as possible.

Conflict of interest This research work was funded by the institutional source with no conflict of interest.

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