











A 14-Year Follow-Up Study of Sequelae in Primary Teeth and Permanent Successors After Dental Trauma

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ABSTRACT

Objective: To evaluate the presence of sequelae in primary teeth and their permanent successors, as well as associations between TDI and the presence of sequelae in both teeth. **Material and Methods:** In this 14-year retrospective study, 2,290 records were reviewed, 192 patients who suffered dental trauma in primary teeth were followed until the eruption of successor teeth were included. Descriptive, chi-square, and regression logistic with generalized estimating equations tests were performed ($p < 0.05$). **Results:** 362 primary and successor teeth were followed. Sequelae were present in 71.8% of primary teeth and 25.7% of their successors. Teeth with complicated fracture (100%), extrusion (100%) and avulsion (100%) resulted in the largest amounts of sequelae in primary teeth and intrusion (61%) on their successors. Age was associated with sequelae in permanent teeth ($p < 0.01$). Extrusion (OR 10.06; CI 2.12-47.63) and intrusion (OR 7.51; CI 2.73-20.70) had a higher risk to cause sequelae in primary and permanent teeth, respectively. **Conclusion:** The type of injury involved influenced the sequelae in traumatized teeth and their successors, and the age of the child influenced the presence of sequelae in permanent teeth.

Keywords: Tooth Injuries; Child; Tooth, Deciduous; Dentition, Permanent.

Introduction

Traumatic dental injuries (TDI) are a significant problem worldwide, frequently occurring in childhood. The world prevalence of TDI in primary teeth (PT) is 22.7% and varies considerably among the continents, ranging from 14.2% in Europe to 26.5% in America and 27% in South-East Asia [1]. Approximately one-third of preschool children suffer TDI while are learning to walk, and psychomotor development promotes imprecise movements [2]. The etiology of dental trauma includes falls, collisions, traffic accidents, child abuse, and sports accidents [3]. TDI affects negatively the quality of life of preschool children independently of the severity [4].

The strength and the axis of impact will determine the type of injury. In PT, hard tissue fractures happen, but luxation injuries are more prevalent [3]. The various types of TDI include fracture of dental hard tissues with or without pulp involvement and support tissue lesions. The prognosis of traumatized teeth depends on the severity of the injury; knowing them becomes necessary to predict the possible consequences that are often neglected. Few studies follow the affected PT until exfoliation, highlighting the lack in the importance of monitoring these teeth after trauma, and beyond that, the number of publications that assess the sequelae in PT is disproportionate in relation to its significance [5-7]. The effects in PT vary largely and include pathologic changes such as pulp necrosis, internal and/or external root resorption, ankylosis, obliteration of the pulp canal, and loss of supporting tissue, among others [8].

The traumatized tooth may not be the only one affected; the malformation of the developing tooth germs may also be caused by a trauma to a PT. The possible risks of sequelae in a permanent successor (PS) should be considered due to the close anatomical relationship between the apices of the PT and their developing PS [9]. The age of the child at the moment of injury, the level of root resorption of the traumatized tooth, the type and severity of the injury, and the developmental stage of the PS are important to predict the degree of possible damage of sequelae in permanent teeth [10]. The consequences may affect only the coronal or root region, or the whole of the permanent tooth germ [11]. Sequelae in the permanent tooth include enamel hypoplasia, crown dilaceration, root dilaceration, partial or complete arrest of root formation, sequestration of the permanent tooth germ, and disturbances in eruption [8].

After TDI, follow-up is essential to early detection of sequelae and to minimize their consequences since some PT sequelae do not appear immediately [12]. A recent systematic review reinforces the need for further analytical observational studies that standardize diagnostic methods, the evaluation of sequelae, the sampling process, and with considerable sample [13]. Careful clinical and radiographic examinations at regular intervals are important to follow PT and PS. The consequences on the successor tooth may not be easy to predict or may not be evident until the tooth erupts [14]. In this context, the present study was conducted to evaluate the presence of sequelae in primary teeth and their permanent successors, as well as the associations between TDI and the presence of sequelae through a 14-years follow-up study.

Material and Methods

Study Design and Ethical Clearance

This retrospective observational study evaluated records of 2.290 patients who attended, from 2005 to 2019, the *Centro de Vigilância e Monitoramento de Traumatismos Dentoalveolares* (CVMT®) of the *Universidade Federal do Rio de Janeiro*, Brazil. This study was approved by the Ethics Committee of the *Clementino Fraga Filho Hospital* under the number 3776447/2019.

Data Collection

The CVMT® is a reference dental trauma center in the city of Rio de Janeiro and offers free patients access, treatment, and monitoring of TDI that affected primary and permanent dentition. The service follows the World Health Organization classification of injury types modified by Andreasen and Andreasen [8] for routine diagnostics, and the protocol of care was based on recommendations of the International Association of Dental Traumatology Guidelines [15] and its update over time.

During dental consultations, initially, parents or legal guardians were interviewed regarding the child's medical history and history of dental trauma. Subsequently, clinical findings were documented, the necessary treatments were done and radiographs and photographs were taken before and after the procedure. The patients were always instructed to return for a review. Clinical (intra and extraoral techniques) and radiographic follow-ups of the patients were carried out periodically (weekly, monthly) according to the type and severity of the injury. Dentists who performed the initial interviews, examinations, emergency treatments, and follow-up procedures were MSc students who had received prior training and were supervised by a senior professor with experience in dental trauma.

The sample included records of patients from 0 to 12 years who had one or more TDI on PT that have been attended, diagnosed, treated, and followed with follow-up visits until complete root formation of their PS. At the last review visit, the fully erupted PS was evaluated, and an assessment of developmental disturbances was made. It is important to point out that a child could present more than one tooth with a traumatic injury. Records with incomplete documentation (clinical photos, radiographs and trauma data sheet) and patients who did not attend follow-up visits were excluded from the study. The authors sought to minimize the risk of bias by using a standardized dental record from the reference centre for dental trauma, in which the following data were collected:

- Sociodemographic characteristics: gender (male/female); age at the moment of trauma (≤ 3 years old or > 3 years old);
- History of trauma: etiology (fall from own height, fall from a high surface, collisions, sports accident, other falls, automobilistic accident, others); local of trauma (home, street, school, others); type of injury (enamel fracture, enamel-dentin fracture, complicated fracture, root fracture, subluxation, concussion, intrusion, avulsion, lateral luxation, extrusion); affected tooth/teeth (upper central incisors, upper lateral incisors, upper canine, lower central incisors, lower lateral incisors, lower canine); recurrence of trauma (yes/no);
- Attendance after trauma: primary clinical and radiographic sequelae (premature loss, crown discoloration, fistula, abscess, infra occlusion, pathological resorption, periapical lesion, pulp calcification, ankylosis); permanent clinical and radiographic sequelae (enamel discoloration, enamel hypoplasia, eruption delay, early eruption, ectopic eruption, crown dilaceration, root dilaceration, partial arrest of root formation, impaction) and management (follow-up, extraction, restoration, pulpectomy, prescription).

Data Analysis

The data were tabulated in a spreadsheet created in Statistical Package for Social Sciences (version 21.0; SPSS Inc., Chicago, IL, USA) and analyzed descriptively in terms of frequencies and statistically by non-parametric Chi-square test with a significance level of 5% ($p \leq 0.05$). To include more than one tooth per patient in the analysis, a multilevel analysis was applied, in which each patient represented an individual cluster. Furthermore, the regression logistic with the generalized estimating equations (GEE) test was applied in the statistical analyses. The odds ratio was used to assess the chance of sequelae in PT and PS following dental

trauma in PT. The statistical analyses were performed by a statistical expert. The confidence interval was set at 95%.

Results

A total of 192 patients, with 362 traumatized PT and their PS, were included in the study. The prevalence of TDI was slightly higher in 107/192 (55.7%) males than in females with 85/192 (44.3%). The mean age of patients was 3.55 (± 1.58), and the higher prevalence of children's trauma was at two (n=44; 22.9%), three (n=41; 21.4%), four (n=37; 19.3%) and five (n=32; 16.7%) years old. The most common causes of trauma were falls (n=144; 75%), followed by collisions (n=10; 5.2%) and sports accidents (n=9; 4.7%). The most common place was at home (n=123; 64.1%), followed by the street (n=39; 20.3%) and the school (n=21; 10.9%) and the most affected PT were the upper central incisors a total of 287 teeth (79.3%), followed by 43 (11.9%) upper lateral incisors.

About types of TDI, the tooth may suffer more than one injury. Subluxation was the most prevalent support tissue (22.7%), and enamel fracture (9.4%) was the most prevalent hard tissue. Table 1 illustrates the frequency of each TDI and clinical and radiographic sequelae in traumatized PT and PS. PT with complicated fracture (100%), extrusion (100%), and avulsion (100%) had more sequelae than the other teeth without these conditions. PT with intrusion (61%) had more sequelae in PS than the other teeth.

Table 1. Frequency of types of traumatic injuries in primary teeth, clinical and radiographic sequelae in traumatized primary teeth, and permanent successor according to each type of injury (n=362).

Injuries*	Presence of Sequelae		
	N (%)	Primary Teeth** N (%)	Permanent Teeth** N (%)
Support Tissues			
Concussion	67 (18.5)	39 (58.2)	11 (16.4)
Subluxation	82 (22.7)	56 (68.3)	13 (15.9)
Lateral luxation	41 (11.3)	25 (61.0)	09 (22.0)
Extrusion	13 (3.6)	13 (100.0)	02 (15.4)
Intrusion	59 (16.3)	43 (72.9)	36 (61.0)
Avulsion	46 (12.7)	46 (100.0)	12 (26.1)
Hard Tissues			
Enamel fracture	34 (9.4)	18 (52.9)	02 (5.9)
Enamel-dentin fracture	18 (5.0)	10 (55.6)	01 (5.6)
Complicated fracture	16 (4.4)	16 (100.0)	07 (43.8)
Root fracture	10 (2.8)	09 (90.0)	04 (40.0)

*The tooth may have more than one type of injury; **The tooth may have more than one sequelae.

The main management in PT was follow-up; 224 teeth (61.9%) did not need any intervention, while 94 teeth (26.0%) were extracted. Other management was done, 39 (10.8%) teeth were restored and 30 (8.3%) were endodontically treated. Furthermore, 6 (1.7%) children received medication.

Of these 362 PT, 260 (71.8%) presented sequelae, while 93 PS (25.7%) showed some developmental disturbance. The tooth may have more than one sequel and they were divided into clinical and radiographic for PT and PS (Table 2). All sequelae were counted regardless of the severity. In PT, 439 (279 clinical and 160 radiographic) sequelae were computed, while 98 (90 clinical and 8 radiographic) were computed in PS. In PT, the most prevalent clinical sequelae were premature loss (39.8%), while in radiographic sequelae, the most prevalent were pathological resorption (20.7%). In PS, the most prevalent clinical sequelae were enamel discoloration (9.4%), while in radiographic sequelae, the most prevalent was root dilaceration (1.1%).

Table 2. Clinical and radiographic sequelae presented for primary teeth and their permanent successors.

Variables	N (%)
Clinical Sequelae in Traumatized Primary Teeth	
Premature loss	144 (39.8)
Crown discoloration	95 (26.2)
Fistula	24 (6.6)
Abscess	10 (2.8)
Infraocclusion	06 (1.7)
No Sequelae	83 (22.9)
Radiographic Sequelae in Traumatized Primary Teeth	
Pathological resorption	75 (20.7)
Periapical lesion	44 (12.2)
Pulp calcification	37 (10.2)
Ankylosis	04 (1.1)
No Sequelae	202 (55.8)
Clinical Sequelae in Permanent Successor	
Enamel discoloration	34 (9.4)
Enamel hypoplasia	32 (8.8)
Eruption delay	10 (2.8)
Early eruption	08 (2.2)
Ectopic eruption	04 (1.1)
Crown dilaceration	02 (0.6)
No Sequelae	272 (75.1)
Radiographic Sequelae in Permanent Successor	
Root dilaceration	04 (1.1)
Partial arrest of root formation	03 (0.8)
Impaction	01 (0.3)
No Sequelae	354 (97.8)

In a sample of 192 patients, 47 (24.5%) patients had one or more new cases of trauma. Of these 24/107 boys (12.5%) and 23/85 girls (12%) had a recurrence of the dental trauma since the first episode. Thus, of the 47 patients, 35 (18.2%) had just one new episode. At the moment of the trauma recurrence, 23/47 had between 0-3 years (23.2%) and 24/47 had more than 3 years (25.8%). No association between trauma recurrence and individual characteristics such as gender ($p=0.45$) and age ($p=0.67$) was observed in the present study.

Table 3 shows the association between the age and the presence of clinical and radiographic sequelae in PS was confirmed. Children younger than 3 years old at the moment of trauma presented more sequelae ($p<0.01$) than the other patients older than 3 years at the time of injury. The reference variable was age higher than 3 years old at the moment of trauma. In relation to the type of injury and the presence of sequelae, PT with extrusion had more chance to have sequelae when compared with other types of injuries in support tissues (OR 10.06; CI 2.12-47.63; $p<0.01$). Avulsion was not considered because it always causes premature loss of PT. PT with intrusion had a significantly higher risk to cause sequelae in PS (OR 7.51; CI 2.73-20.70; $p<0.001$). The reference variable used to compare the injuries with the sequelae in PT and PS were the crown fractures.

Table 3. Association between the presence of sequelae and type of injury in primary and permanent teeth and age of children.

Dependent Variable	Independent Variables	p-value	OR	CI (95%)	
Sequelae in primary teeth	Age***	0-3 years	0.99	0.99	0.49-2.00
	Support Tissues**	Concussion	0.15	0.50	0.19-1.28
		Subluxation	0.83	0.90	0.35-2.32
		Lateral luxation	0.82	0.88	0.31-2.48
		Extrusion	<0.01*	10.06	2.12-47.63
Sequelae in permanent teeth	Age***	Intrusion	0.40	1.56	0.54-4.49
		0-3 years	0.05*	1.88	0.98-3.61

Support Tissues**	Concussion	0.91	1.07	0.32-3.55
	Subluxation	0.80	0.87	0.29-2.58
	Lateral luxation	0.47	1.54	0.47-5.01
	Extrusion	0.84	0.82	0.12-5.38
	Intrusion	<0.001*	7.51	2.73-20.70
	Avulsion	0.23	1.99	0.63-6.27

OR: Odds Ratio; IC: Interval Confidence (95%); *Statistical significance ($p \leq 0.05$); **Reference variable – fractures; ***Reference variable – >3 years.

Discussion

The present study followed up 362 traumatized PT until the complete root formation of their PS, allowing the evaluation of sequelae in both dentitions in a longitudinal point of view.

Bibliometric analysis done by Feldens et al. [5], Kramer et al. [6] and Liu et al. [7] showed that despite the importance of TDI in PT, there are not many longitudinal studies. In dental journals, the researches mainly concerned permanent dentition and most are case reports and cross-sectional studies. There are different reasons to explain this common profile of articles, as the fact that PT are temporary and the necessity of long-term follow-up decreases parental acceptance of treatment [16]. Other reasons are the difficulty of treating children and the fact that the majority of professionals are not prepared to face children's behavior and fears.

Males were more predisposed to suffer trauma events, corroborated with a meta-analysis by Corrêa-Faria et al. [17]. Children between 2 and 5 years presented the highest number of TDI; this result agrees with some epidemiological studies in population samples developed in Brazil [18,19]. As far as etiology is concerned, in agreement with the finding of other authors, falls were the most frequent etiologic factor for dental trauma [18,20], and those accidents happened mostly at home [20]. According to Carvalho et al. [20], this can be explained due to the fact that children around the age of one to four years old spend most of their time at home, learning how to stand, walk and due to their curiosity, trying to explore their environment. The most affected teeth were the upper central incisors, which is a consensus in the literature because of their anterior location [16,18-20].

The prevalence of trauma in PT associated with supporting tissues was higher than in hard tissues, in agreement with the findings in the literature [16,18,21]. The higher prevalence of luxation can be explained due to the larger spinal spaces that make the bone more porous, resulting in some flexibility to the shorter roots of the PT compared to the PS, in addition to the large volume of teeth in relation to the bone [11,20]. The most common type of supporting tissue injury was subluxation, in agreement with Assunção et al. [18] and Mendoza-Mendoza et al. [22], but different from other authors [16]. This result may be a consequence of CVMT® being a reference center at Rio de Janeiro, Brazil, and daily a lot of preschool aged children are referred to university, independently of the severity of trauma. The municipal public health system usually has not dentists that serve this age group because of their behavioral complexity. Despite of this, enamel fractures were the most common type of fracture, in line with another study [21].

Worldwide, emergencies are a challenge and dentists should be prepared to attend them and should advise parents about the importance of treatment and long-term clinical and radiographic follow-up of TDI in PT [21]. According to Qassem et al. [12], even 3-4 years after trauma, sequelae in traumatized teeth were still diagnosed. Among PT of this study, the majority did not need any intervention and as well as Amorim et al. [21], the follow-up was considered like a management. CVMT® follows the concept of minimal intervention and receives several new emergency cases every day of different severities. The treatment is not charged, which makes parents have higher adherence to these follow-up visits. The second most prevalent management was the

extraction; Rasmusson and Koch [23] reported in a study that during the follow-up period, many extractions were done after the development of late complications in a variety of types of luxation injuries, mainly subluxation and concussion. Furthermore, the poor prognosis and the inability of the child to accept complex dental treatment contributed to the high number of extractions. Despite not being evaluated in the present study, other study showed that treatment after trauma has no influence in the presence of sequelae in the successor teeth [24].

The prevalence of sequelae in PT in the present study was high. Although the lowest number of consequences involved teeth with enamel fracture, enamel-dentin fracture and concussion, the rates of them reached more than 50%. Sequelae in PS range from 5.6% to 61%. This prevalence reinforces the importance of not neglecting the clinical and radiographic follow-up of traumatized PT by professionals and also reinforces the need to inform parents and caregivers about the possible consequences both in the PT and in the PS, even in cases of less severe TDI. Follow-up is essential for the early diagnosis of sequelae, as well as to propose interventions when necessary, minimizing their negative influence on children's social aspects.

This study divided the sequelae into clinical and radiographic to emphasize the importance of a long-term follow-up, mainly due to radiographic changes in which the parents do not realize that are occurring. Premature loss was the most frequent clinical sequel in PT and this finding may be a consequence of the high number of extraction and avulsion cases, that results in immediate loss of traumatized tooth. The crown discoloration was also a frequent clinical sequel. According to Qassem et al. [12] and Goettems et al. [20], a high frequency of crown discoloration was observed in teeth that suffered subluxation. Pathological resorption was the most common radiographic sequel in PT and Qassem et al. [12] and Mendoza-Mendoza et al. [22] reported a high frequency of this sequelae in teeth that suffered intrusion. The high number of these injuries in this study may explain the high number of these sequelae types. In addition, Cardoso and Rocha [25] showed that trauma recurrence is a risk factor for the development of pathological resorption. The sample of this study had some patients with one or more new episodes of trauma in the same tooth. A meta-analysis done by Magno et al. [26] found a positive association between individuals that have suffered previous dental trauma and new episodes of TDI. According to the results of this study, gender and age were not influencing factors for trauma recurrence and there are few studies [17,21,25-27] in the literature. New researches are necessary to evaluate the factor related to trauma recurrence.

In PS, the most frequent clinical sequelae were enamel discoloration and enamel hypoplasia, in agreement with other studies [10,21]. These coronary alterations can be explained by the age of the children since the majority were younger or had 3 years in the moment of trauma and normally, the development and mineralization of the permanent tooth crown usually ends around this age. Root dilaceration was the prevalent radiographic sequelae in PS. De Amorim et al. [28] showed that root dilacerations were mostly caused by intrusion and avulsion in PT and children older than 3 years were statistically more susceptible to have this sequelae than younger ones, for being necessary that successor teeth be at the stage of root development. The sample of the study was composed of children up 7 years at the moment of trauma and the follow-up visits allowed the observation of this sequel. The large number of luxation, mainly composed for severe injuries such as intrusion and avulsion, and the root curvature of PT provokes a slight rotary movement during the TDI and may hurt the germ of PS [9].

The frequency of sequelae in PT compared with another longitudinal study [22] was higher, and the fact that CVMT® is a reference center and many children arrive there looking for treatment after the appearance of the sequel, can explain this high frequency. It should also be noted that some teeth suffered more than one

injury and the number of severe traumas was also high. All traumatized teeth that suffered complicated fractures, extrusion and intrusion developed at least one type of sequel. In PS, in agreement with the literature [21,22], this study has shown that more than half of teeth that suffered intrusion had some sequel. Some injuries by the large displacement inside the alveolus for the strength and axis of trauma [25] have more chances to reach the developing permanent germ. The high prevalence of dental trauma in children at early ages may result in serious damage to the permanent dentition. Statistically, was observed an association between sequelae in PS and age of the patient at the moment of trauma. Children 3 years old or younger had statistically more sequelae than the others in PS, in agreement with the literature [21]. At these ages, the permanent tooth is in the initial stage of odontogenesis and the root of PT is still large, the physiological resorption has not started and this characteristic can contribute to the severity of the alteration. A statistical association was also observed between the presence of sequelae in PT and PS and type of injury. Extrusion showed more chance to cause some sequel in PT and as expected, intrusion was the injury that will probably cause more sequelae in PS. Both types of trauma result in tooth displacement and severe damage to the periodontal ligament related to compression or rupture of neurovascular bundle [8].


Some limitations of the study can be considered. The sample is a possible limitation, it is necessary that patient comes to the reference center to the follow-up during years, even if he/she has not a complaint, like pain, for example. Another limitation is the retrospective character of the study, that enable time bias due to the loss of contact with the patient and the evaluation of records contributes to the loss of data. Moreover, despite the examiners being calibrated in each survey, some small differences in diagnostic decisions may occur. The occurrence of TDI and the infrequent perceptions of the event and the non-reporting of information, due to parental forgetfulness, during the anamnesis may be related to memory bias, since the attendance of many injuries was not immediate.










There is a lack of importance and knowledge placed on TDI in primary dentition, meanly by parents and teachers [29,30], who are often poorly informed about risks and consequences of dental trauma and what can be done to prevent them [25]. At the moment of injury, emergency management should be initiated immediately, this affects completely the prognosis of trauma. According to Goettems et al. [27], patients with history of dental trauma in PT are more susceptible to suffer TDI in permanent dentition. There is insufficient scientific evidence from longitudinal studies in preschool children on which to base public health interventions on primary dentition and due to biological factors results from studies of permanent dentition cannot be used [31]. It is important that teachers, parents and children are included in health education programs aimed on how to proceed, about the importance of treatment, follow-up visits and preventive measures. Further long-term control studies with preschoolers should be conducted to confirm the results of treatment observed in practice.

Conclusion

The most common sequelae were premature loss and enamel discoloration, in PT and PS respectively. Teeth with complicated fracture, extrusion and avulsion had more sequelae in PT and traumatized teeth with intrusion caused more sequelae in PS. Statistically, extrusion has more chance to cause some sequelae in PT, while intrusion may cause more sequelae in PS. Children >3 years old can have less sequelae in PS than children ≤ 3 years at the moment of trauma.

Authors' Contributions

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All authors declare that they contributed to critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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