Effects of traumatic dental injuries of the primary dentition to the developing permanent teeth: a retrospective cohort study of 14 years

Vanessa Polina Pereira da Costa  
Universidade Federal de Pelotas

Fernanda Vieira Almeida  
Universidade Federal de Pelotas

Giulia Tarquinio Demarco  
Universidade Federal de Pelotas

Maria Giulia Larroque Silva da Motta  
Universidade Federal de Pelotas

Elaine de Fátima Zanchin Baldissera  
Universidade Federal de Pelotas

Alexandre Emídio Ribeiro Silva  
Universidade Federal de Pelotas

Caroline de Oliveira Langlois  
Universidade Federal de Pelotas

Marília Leão Goettems (marilia.goettems@gmail.com)  
Universidade Federal de Pelotas

Research Article

Keywords: tooth injuries, primary dentition, pediatric dentistry, cohort study

Posted Date: June 12th, 2023

DOI: https://doi.org/10.21203/rs.3.rs-3011139/v1

License: © This work is licensed under a Creative Commons Attribution 4.0 International License.  Read Full License
Abstract

Objectives

This retrospective cohort study aimed to determine the occurrence of sequelae in permanent teeth following trauma in primary dentition in children treated at a Dental Trauma Center in Brazil for 14 years.

Material and Methods

Records of 140 children, with complete information about trauma and presence of sequelae, were included. Photographs and radiographs of permanent successors were evaluated to determine presence of long-term complications. Chi-square tests and Poisson regression were used for data analyses (p ≤ 0.05).

Results

A total of 244 traumatized primary teeth were evaluated in 140 children, and 81 (33.2%) of the permanent successors presented sequelae, affecting 40% of the children. Enamel discoloration (53.1%) and enamel hypoplasia (28.4%) were the most prevalent sequelae presented and the occurrence of sequelae was higher following intrusive luxation (53.3%) and avulsion (39.4%). Risk of sequelae was higher for teeth with supporting tissue trauma (RR 2.68; 95% CI 1.32–5.42; P < 0.001) than for teeth with hard tissue trauma. Risk was lower when children had more than 4 years at the time of TDI (RR 0.41; 95%CI 0.25–0.66; P < 0.001).

Conclusions

Prevalence of sequelae in permanent teeth following trauma in primary dentition was high, especially in children with up to 2 years of age at the time of TDI and who suffered supporting tissue trauma.

Clinical relevance: Findings reinforce the importance of long-term follow-up of dental trauma in primary dentition. Close monitoring and knowledge about the risk of sequelae to permanent teeth can help dentists determine prognosis after dental trauma and provide an appropriate treatment plan.

Introduction

Traumatic dental injuries (TDI) to the primary dentition are one of the most common public oral health problems affecting children. The prevalence of TDI in children is considerably high, reaching up to 41.6% [1]. Injuries can cause sequelae not only to the affected teeth but also to the developing permanent teeth [2]. The close relationship between the apices of the primary predecessors and the germs of the permanent successors is a relevant factor that can lead to developmental disturbances in the permanent dentition [3].

The developmental disturbances prevalence has been reported in the literature ranging from 12–74% [2]. This condition can vary from enamel hypo calcifications to an arrest of the permanent bud development [4]. The developing permanent teeth may be directly involved after trauma, causing mild to severe hypoplasia, displacement, damage to the tooth germ or an extended range of morphological and functional disturbances. In some cases, the effects of oral and dental injuries caused by trauma appear later, with the eruption of the permanent incisors, when ectopic eruption, malalignments, and other developmental disturbances become visible [5–8].
The damage secondary to trauma appears to be considerably greater when it occurs at a younger age [6, 9, 10], but some studies failed to find a correlation between the age of trauma and frequency of subsequent developmental disturbances [11]. Factors such as the degree of root resorption of the traumatized deciduous tooth and the stage of development of the successor may influence development of sequelae [2, 5, 11]. The type and severity of the injury are also critical determinants for the presence of this condition [2].

Results of a systematic review [12] indicate the need for further quality studies on the involvement of the permanent successor tooth following trauma in the primary dentition. Since it is not possible to carry out randomized controlled clinical trials, perhaps cohort studies with large sample sizes would be the most appropriate to learn more about the consequences of trauma in the primary dentition on the permanent teeth. Few cohort studies [10, 13] have evaluated the occurrence of sequelae in permanent teeth accompanied from the moment that trauma occurred in the primary dentition.

Thus, the aim of this study was to determine the occurrence of sequelae in anterior permanent teeth of children who suffered TDI in the primary dentition, treated at a specialized dental trauma center, adopting a conservative long-term follow-up. Also, the association of children's age, type of trauma and presence of sequelae in primary teeth with the occurrence of developmental disturbance was evaluated.

**Material and Methods**

**Study settings and design**

This retrospective cohort study collected data from the clinical records and radiographs of children treated by the Center for the Study and Treatment of Dental Trauma in the Primary Dentition (hereafter, NETRAD, the acronym in Portuguese), between May 2002 and June 2016. This service is connected to the Pediatric Dentistry Clinic at the School of Dentistry of the Federal University of Pelotas, southern Brazil. The study was approved by the local Human Research Ethics (Protocol 187/2011). The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines was used for the report of the findings of the present study.

The NETRAD service provides access, treatment, and follow-up assistance for TDI's in the primary dentition, until complete root formation of the permanent successor. The diagnosis of the TDI was based on both clinical and radiographic findings, using the Andreasen and Andreasen, 2001 [14] criteria by a professional with experience in pediatric dentistry. Protocol of treatment is based on the International Association of Dental Traumatology (IADT) Guidelines [15]. The parents or legal guardians signed an informed consent agreement form.

**Data collection**

Data was collected by a previously trained researcher. Information from the patients’ clinical records included age (at the time of the TDI), sex (boy/girl), type of TDI, presence of sequelae in primary dentition, teeth involved in the TDI and the presence of sequelae in permanent teeth. The researcher was also trained and calibrated to conduct radiographic analyses to determine the presence of sequelae in primary and permanent teeth. Radiographic evaluations were performed using an X-ray viewing box and a magnifying glass. The
radiographs of all the appointments of the patients were assessed. Photographs routinely performed in the patients were also evaluated.

The inclusion criteria were: records with complete documentation about the TDI and a minimum follow-up of two dental appointments. The children should have the permanent teeth successor totally erupted and with complete root formation by the time of data collection. Any incorrectly filled out dental records, poor-quality radiographic records, and children with caries in traumatized primary teeth were excluded.

The clinic and radiographic sequelae in permanent teeth were classified according to the criteria of Andreasen and Andreasen, 2001 [14] and the division of clinic and radiographic sequelae followed the criteria of Assunção et al., 2009 [3]. The clinic sequelae were: 1 = white or yellow-brown discoloration of enamel; 2 = enamel hypoplasia; 3 = crown dilaceration; 4 = eruption disturbances. The radiographic sequelae were: 1 = root dilaceration or angulation; 2 = root duplication; 3 = odontoma like malformation; 4 = partial or complete arrest of root formation; 5 = sequestration of permanent tooth-germ.

The type of TDI was classified according to Andreasen and Andreasen, 2001 [14] criteria. They were also classified as hard tissue trauma such as enamel fracture; enamel and dentin fracture; enamel, dentin and pulp fracture; crown-root fracture; radicular fracture; alveolar fracture and supporting tissue trauma such as concussion; subluxation; lateral luxation; extrusive luxation; intrusive luxation and avulsion.

Clinical and radiographic sequelae present in primary teeth were classified according to the following criteria[16–18]. The clinical sequelae were: 1 = color change (including yellow and grey discoloration); 2 = presence of fistula and/or swelling; 3 = abnormal position; 4 = premature loss of the tooth. The radiographic sequelae were: 1 = pathological root resorption; 2 = accelerated root resorption (as compared with the homologous non-injured teeth); 3 = pulp obliteration; 4 = periapical radiolucency, considering that no alterations were observed in the first examination. When more than one possible sequel was present in one tooth, all the sequelae detected were recorded.

**Calibration procedure**

Intra-examiner variability was tested based on the kappa coefficient, using 70 periapical radiographs presenting different conditions. The results of the examiner were compared with a gold standard, in this case, a PhD in Radiology. The value of the Inter-examiner weighted kappa was = 0.80 and intra-examiner weighted kappa was = 0.97.

**Data analysis**

Data was entered in duplicate in an Excel spreadsheet and statistical analysis was performed using Stata 14.0 (Stata Corp. LP, College Station, TX, USA). Data analysis included descriptive statistics and associations were determined using the chi-squared test. Poisson regression with robust variance was used to estimate the relative risk (RR) and 95% confidence intervals (CI 95%) for the occurrence of sequelae, according to type of TDI, age and sex. The level of significance was set at 5% (p ≤ 0.05).

**Results**
Of the total of 931 available dental records of children, 459 were excluded because they did not have permanent teeth completely erupted and with a fully formed root at the time of evaluation, remaining 472 records. Of these, 331 were not included due to other exclusion criteria (less than 2 follow-up, presence of dental caries or missing information). Thus, 140 eligible clinical records of children with 244 traumatized primary teeth were evaluated. Of the total of 244 traumatized primary teeth, 81 (33.2%) of the permanent successors presented sequelae.

The characteristics of the children in relation to sex, age (at time of TDI) and number of affected teeth are shown in Table 1. The boys suffered more TDI's than girls (54.3%) but presented similar frequency of sequelae in permanent teeth (p = 0.63). Younger children (aged with 2–4 years) presented more occurrence of TDI, and frequency of sequelae was higher when children had < 2 years at the time of TDI (p = 0.07). Number of affected teeth was associated with the presence of sequelae in permanent teeth: children that had 2 or more teeth involved in TDI in the primary dentition presented more sequelae in the permanent teeth (p = 0.05).

The association between type of TDI and the occurrence of sequelae to permanent teeth showed that intrusive luxation (53.3%), followed by avulsion (39.4%) and subluxation (37.1%) were the types of TDI that presented higher frequency of sequelae in the permanent dentition (p = 0.026). There was no association of post-
traumatic sequelae in the primary dentition with the occurrence of sequelae in the permanent dentition (Table 2).
Table 2
Presence of sequelae in permanent teeth in relation to type of TDI and presence of sequelae in the primary teeth (n = 244 teeth).

<table>
<thead>
<tr>
<th>Variables</th>
<th>Total</th>
<th>Presence of sequelae</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n (%)</td>
<td>n (%)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>244 (100)</td>
<td>81 (33.2)</td>
<td></td>
</tr>
<tr>
<td><strong>Type of TDI</strong></td>
<td></td>
<td></td>
<td>0.026**</td>
</tr>
<tr>
<td>Enamel fracture</td>
<td>17 (7.0)</td>
<td>3 (17.6)</td>
<td></td>
</tr>
<tr>
<td>Enamel and dentin fracture</td>
<td>09 (3.7)</td>
<td>2 (22.2)</td>
<td></td>
</tr>
<tr>
<td>Enamel, dentin and pulp fracture</td>
<td>06 (2.4)</td>
<td>1 (16.7)</td>
<td></td>
</tr>
<tr>
<td>Crown-root fracture</td>
<td>15 (6.2)</td>
<td>3 (20.0)</td>
<td></td>
</tr>
<tr>
<td>Concussion</td>
<td>14 (5.7)</td>
<td>3 (21.4)</td>
<td></td>
</tr>
<tr>
<td>Subluxation</td>
<td>62 (25.4)</td>
<td>23 (37.1)</td>
<td></td>
</tr>
<tr>
<td>Lateral luxation</td>
<td>28 (11.5)</td>
<td>4 (14.3)</td>
<td></td>
</tr>
<tr>
<td>Intrusive luxation</td>
<td>45 (18.4)</td>
<td>24 (53.3)</td>
<td></td>
</tr>
<tr>
<td>Extrusive luxation</td>
<td>15 (6.2)</td>
<td>5 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Avulsion</td>
<td>33 (13.5)</td>
<td>13 (39.4)</td>
<td></td>
</tr>
<tr>
<td><strong>Type of TDI</strong></td>
<td></td>
<td></td>
<td>0.02*</td>
</tr>
<tr>
<td>Hard tissue</td>
<td>47 (19.3)</td>
<td>9 (19.2)</td>
<td></td>
</tr>
<tr>
<td>Supporting tissue</td>
<td>197 (80.7)</td>
<td>72 (36.6)</td>
<td></td>
</tr>
<tr>
<td><strong>Sequelae in primary teeth</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fistula/swelling</td>
<td></td>
<td></td>
<td>0.436**</td>
</tr>
<tr>
<td>No</td>
<td>200 (95.7)</td>
<td>64 (32.0)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>9 (4.3)</td>
<td>4 (44.4)</td>
<td></td>
</tr>
<tr>
<td>Crown discoloration</td>
<td></td>
<td></td>
<td>0.984*</td>
</tr>
<tr>
<td>No</td>
<td>160 (76.6)</td>
<td>52 (32.5)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>49 (23.4)</td>
<td>16 (32.6)</td>
<td></td>
</tr>
<tr>
<td>Ectopic position</td>
<td></td>
<td></td>
<td>0.454*</td>
</tr>
<tr>
<td>No</td>
<td>189 (90.4)</td>
<td>60 (31.7)</td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>20 (9.6)</td>
<td>8 (40.0)</td>
<td></td>
</tr>
<tr>
<td>Premature loss</td>
<td></td>
<td></td>
<td>0.802*</td>
</tr>
<tr>
<td>No</td>
<td>162 (77.5)</td>
<td>52 (32.1)</td>
<td></td>
</tr>
<tr>
<td>Variables</td>
<td>Total n (%)</td>
<td>Presence of sequelae n (%)</td>
<td>p</td>
</tr>
<tr>
<td>-------------------------------</td>
<td>-------------</td>
<td>----------------------------</td>
<td>-------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>47 (22.5)</td>
<td>16 (34.0)</td>
</tr>
<tr>
<td>Pathological resorption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>152 (98.1)</td>
<td>47 (30.9)</td>
<td>0.929**</td>
</tr>
<tr>
<td>Yes</td>
<td>3 (1.9)</td>
<td>1 (33.3)</td>
<td></td>
</tr>
<tr>
<td>Accelerated resorption</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>147 (94.8)</td>
<td>46 (31.3)</td>
<td>0.708**</td>
</tr>
<tr>
<td>Yes</td>
<td>8 (5.2)</td>
<td>2 (25.0)</td>
<td></td>
</tr>
<tr>
<td>Periapical radiolucency</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>134 (86.4)</td>
<td>42 (31.3)</td>
<td>0.798*</td>
</tr>
<tr>
<td>Yes</td>
<td>21 (13.6)</td>
<td>6 (28.6)</td>
<td></td>
</tr>
</tbody>
</table>

*Chi-squared test; **Fisher's exact test

Relative to the types of sequelae present in the permanent teeth, the discoloration of enamel (53.1%) and hypoplasia (28.4%) were the most prevalent. Of the TDI in the primary teeth, the subluxation and intrusive luxation were the types that were most associated with discoloration of enamel and enamel hypoplasia, respectively. The intrusive luxation was also responsible for the occurrence of crown dilaceration and odontoma-like malformation in the permanent teeth (Table 3).

**Table 3.** Distribution of type of sequelae in permanent teeth according to TDI suffered in primary teeth (n=81).

Table 4 shows results of Poisson regression analysis. Risk of sequelae was higher for teeth with supporting tissue trauma (RR 2.68; 95% CI 1.32–5.42; P < 0.001) than for teeth with hard tissue trauma. Risk was lower when children had more than 4 years in the moment of trauma (RR 0.41; 95% CI 0.25–0.66; P < 0.001).
<table>
<thead>
<tr>
<th></th>
<th>Discoloration of enamel n (%)</th>
<th>Enamel hypoplasia n (%)</th>
<th>Crown Dilaceration n (%)</th>
<th>Eruption disturbance n (%)</th>
<th>Root angulation or dilaceration n (%)</th>
<th>Odontoma-like malformation n (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total</strong></td>
<td>43 (53.1)</td>
<td>23 (28.4)</td>
<td>6 (7.4)</td>
<td>1 (1.2)</td>
<td>6 (7.4)</td>
<td>2 (2.5)</td>
</tr>
<tr>
<td><strong>TDI</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enamel fracture</td>
<td>3 (7.0)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Enamel and dentin fracture</td>
<td>-</td>
<td>1 (4.4)</td>
<td>-</td>
<td>-</td>
<td>1 (16.7)</td>
<td>-</td>
</tr>
<tr>
<td>Enamel, dentin and pulp fracture</td>
<td>1(2.3)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1 (16.7)</td>
<td>1 (50.0)</td>
</tr>
<tr>
<td>Crown-root fracture</td>
<td>-</td>
<td>3 (13.0)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Concussion</td>
<td>14(32.6)</td>
<td>6 (26.1)</td>
<td>1 (16.7)</td>
<td>1 (100.0)</td>
<td>1 (16.7)</td>
<td>-</td>
</tr>
<tr>
<td>Subluxation</td>
<td>2 (4.7)</td>
<td>1 (4.4)</td>
<td>1 (16.7)</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lateral luxation</td>
<td>13(30.2)</td>
<td>6 (26.1)</td>
<td>3 (50.0)</td>
<td>-</td>
<td>1 (16.7)</td>
<td>1 (50.0)</td>
</tr>
<tr>
<td>Intrusive luxation</td>
<td>3 (7.0)</td>
<td>2 (8.7)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Extrusive luxation</td>
<td>6 (14.0)</td>
<td>4 (17.4)</td>
<td>1 (16.7)</td>
<td>-</td>
<td>2 (33.3)</td>
<td>-</td>
</tr>
<tr>
<td>Avulsion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **Age (TDI)**            |                               |                         |                          |                            |                                       |                                  |
| < 2 years                | 25 (58.1)                    | 15 (65.2)               | 3 (50.0)                 | -                          | 2 (33.3)                              | 1 (50.0)                         |
| 2-4 years                | 14 (32.6)                    | 5 (21.8)                | 2 (33.3)                 | -                          | -                                     | 1 (50.0)                         |
| > 4 years                | 4 (9.3)                      | 3 (13.0)                | 1 (16.7)                 | 1(100.0)                   | 4 (66.7)                              | -                                |
Table 4
Risk of sequelae in permanent teeth according to independent variables. Crude and adjusted Poisson regression analysis (n = 244 teeth).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Risk of sequelae</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Crude RR</td>
<td>95% CI</td>
<td>P</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>1.00</td>
<td>1.00</td>
<td>0.987</td>
</tr>
<tr>
<td>Female</td>
<td>1.01</td>
<td>0.70–1.44</td>
<td>0.001</td>
</tr>
<tr>
<td>Age</td>
<td></td>
<td>0.001</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>&lt;2 years</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>2–4 years</td>
<td>0.67</td>
<td>0.44–1.00</td>
<td>0.67</td>
</tr>
<tr>
<td>&gt;4 years</td>
<td>0.45</td>
<td>0.28–0.72</td>
<td>0.45</td>
</tr>
<tr>
<td>Type of TDI</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard tissue</td>
<td>1.00</td>
<td></td>
<td>1.00</td>
</tr>
<tr>
<td>Supporting tissue</td>
<td>2.47</td>
<td>1.22–5.02</td>
<td>0.012</td>
</tr>
</tbody>
</table>

Discussion

The present study investigated the effects of traumatic dental injuries in the primary dentition to the developing permanent teeth. A high prevalence of sequelae in permanent teeth was detected; especially enamel discoloration and hypoplasia, following intrusive luxation, avulsion, and subluxation in primary teeth. Trauma in younger children was associated with development disturbances, reinforcing the importance of early diagnosis and close monitoring after traumatic dental injuries.

These results confirm previous studies that showed a relationship between age at the moment of trauma and the presence of sequelae in the permanent dentition [5, 19–22]. The child’s age at the time of trauma is one of the most critical factors to determine the presence of developmental disturbances. Children who suffered trauma at younger age, when teeth are at stages 1–3 of Nolla, may have long term effects on the crown of the developing permanent tooth [2]. However, crown sequelae may be present at any age of trauma, since enamel maturation and mineralization occur even after initial root formation [6, 20]. On the other hand, the most severe damage to the root portion occurs when the child is between 4–7 years old and the permanent tooth is in root formation, at stages 4–6 of Nolla [2].

The type of trauma in the primary dentition can influence the occurrence of sequelae in the permanent dentition [2, 3, 23]. Intrusion and avulsion are associated with adverse consequences to the developing permanent teeth [3, 6]. This can be explained by the fact that these types of TDI's cause tooth dislocation, due
to the high resilience of the alveolar bone and the larger trabecular spaces in the first years of the child's life [24, 25]. The damage to the permanent tooth germ may be by direct contact, by displacement of the follicle, by lesioning the epithelium of the enamel of the germ or by infection from the trauma, which causes a greater number of neutrophils in the surrounding bone, also causing injury to the epithelium of the enamel [4, 6]. In the present study, trauma involving the supporting tissues (intrusive luxation, followed by avulsion and subluxation) in the deciduous teeth generated the most sequelae in the permanent dentition. So, showing, as previously in the literature [26], that this type of trauma had the most chance to result in these sequelae. Previous studies have also shown an association between subluxation and occurrence of defects to permanent successors [5, 27].

Authors also correlate the severity of TDI with the occurrence of sequelae in permanent teeth. Therefore, the greater the severity of trauma (i.e., tooth dislocations), the greater the occurrence and severity of sequelae in permanent teeth [28], as per example, intrusion, responsible for the occurrence of coronary laceration and malformation of the odontoma type. In a study, with finite element analysis, the authors found that during the impact of TDI on primary teeth, the stress, caused by traumatic forces, that had the greatest potential to damage the formation of the permanent successor, was in the dental follicle and the surrounding bone tissues [29].

The most prevalent clinical sequel was white or yellow-brown discoloration of enamel (Fig. 1), corroborating with a previous finding of the literature [2]. Previous studies [5, 30] also found similar results to the present study. In other studies, enamel hypoplasia was found to be the most prevalent clinical sequel, whereas in the present study this sequel was the second most prevalent type [10, 11, 31, 32]. The predominance of enamel alterations in detriment of other sequelae can be explained by the fact that enamel discoloration or hypoplasia can be caused by less severe trauma in the deciduous dentition [33].

The association between post-traumatic sequelae in the primary dentition and sequelae in the permanent successor was also investigated. Similarly, to the study of De Amorim, Estrela and da Costa [5], the present study did not show an association between the occurrence of sequelae in the deciduous dentition and in the permanent dentition. According to the authors, the recommendations to extract injured primary teeth to avoid the appearance of primary teeth complications, that might increase the chances of sequelae to permanent teeth, should be reviewed [5]. Also, it should be noted that in a dental trauma service, the follow-up is done carefully, following a protocol, which allows early diagnosis and intervention in the sequelae of the primary dentition, to minimize the effects on the permanent tooth germ. Also, regarding these effects, the history of TDI to the primary teeth has been shown to predict the occurrence of it in the permanent successors, showing the relevance of this long-term follow-up, in order to establish preventive measures [34].

Therefore, the long-term clinical and radiographic monitoring should be encouraged to minimize the risk of sequelae with the establishment of an early diagnosis and appropriate treatment plan. The results of the present study emphasize the importance of this monitoring, until the permanent successor's irruption. Special attention should be given to trauma to the deciduous dentition involving young children with the diagnosis of trauma to the supporting tissues.

Amongst the strengths of the present study, are its longitudinal design and its large sample size. This helps to provide a more precise estimate of the prognosis. The method used in this study to classify tooth discoloration
was based on the photographs, to ensure a standardized evaluation. A previous study has shown that the photographic method can be used to detect TDI at a population level [35], as it demonstrated an adequate level of agreement between the photographic method and clinical examination for anterior dental trauma.

However, the present study is not free of limitations. Retrospective cohort studies rely on information collected from clinical records. A certain level of information bias may be expected, as some patients had to be excluded due to missing information or owing to technical errors in radiographs, low-quality photographs or even due to failure to seek follow-up. Additionally, a convenience sampling method was adopted and, therefore, the results cannot be generalized at a population level. More high-quality, prospective, controlled studies would be needed to reach a higher level of scientific evidence about the effects on permanent teeth of trauma in primary dentition [12]. Close monitoring and knowledge about the risk of sequelae to permanent teeth can help dentists determine prognosis after dental trauma and provide an appropriate treatment plan.

Conclusions

The findings of this retrospective cohort study showed that the prevalence of sequelae in the permanent dentition is a relevant problem. Younger children presented high occurrence of TDI and increased risk of developing sequelae in the permanent teeth, especially after sustaining trauma to the supporting tissues. Enamel discoloration and hypoplasia were the most prevalent sequelae in permanent dentition.

 Declarations

Compliance with ethical standards

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethical approval: All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the local Human Research Ethics Committee of the Federal University of Pelotas (Protocol 187/2011).

Funding: This study was financed in part by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil (CAPES) – Finance Code 001.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Author Contributions: Vanessa Polina Pereira da Costa, Maria Giulia Larroque Silva da Motta and Marilia Leão Goettems contributed to the study conception and design. Material preparation, data collection and analysis were performed by Vanessa Polina Pereira da Costa, Maria Giulia Larroque Silva da Motta, Marilia Leão Goettems, Elaine de Fátima Zanchin Baldisseira, Alexandre Emídio Ribeiro Silva and Caroline de Oliveira Langlois. The first draft of the manuscript was written by Fernanda Vieira Almeida and Giulia Tarquinio Demarco and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.
References


Figures

Figure 1

Example of white or yellow-brown discoloration of enamel a) mesial and incisal surface right central incisor (11) and incisal of left central incisor (21); b) buccal surface of left central incisor