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Incidence and prognosis of crown discoloration in traumatized primary teeth: A retrospective cohort study

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Abstract

Background/Aim: Knowledge of factors influencing the occurrence of crown discoloration following traumatic dental injuries in primary teeth and understanding its possible consequences can help dentists to provide appropriate care. The aim of this retrospective cohort study was to investigate the incidence of crown discoloration following trauma in primary teeth. This study also estimated the risk of pulp necrosis with subsequent infection of the root canal system and pulp canal obliteration in discolored teeth.

Material and Methods: Records of children treated at the specialized trauma center of the Federal University of Pelotas during a period of 10 years were analyzed. Patient details including the type of injury, presence of crown discoloration, pulp necrosis, and pulp canal obliteration were collected. Photographs of teeth with crown discoloration were assessed to evaluate the color presented (yellow or dark). Chi-square tests and Poisson regression were used for data analyses ($P < .05$).

Results: A total of 355 children with 628 traumatized teeth were included in the study. The incidence of crown discoloration was 27.9%, and 20.5% of the teeth were affected. Discoloration was higher in children whose age at the time of trauma was 2-4 years ($P = .020$), and it was associated with the type of injury ($P = .019$). Discolored teeth had a twofold risk of pulp necrosis and subsequent infection of the root canal system (RR 1.98 95% CI 1.42-276; $P < .001$) and a higher risk of pulp canal obliteration (RR 8.47; 95% CI 4.95-14.51; $P < .001$) than did teeth without discoloration. Teeth with dark and yellow discoloration were significantly associated with pulp necrosis and pulp canal obliteration, respectively ($P < .001$).

Conclusions: This study demonstrates the importance of monitoring traumatized primary teeth with crown discoloration, particularly those appearing darker, owing to their higher risk of pulp necrosis and subsequent infection of the root canal system.

KEYWORDS

deciduous tooth, longitudinal studies, pediatric dentistry, tooth discoloration, tooth injuries

1 | INTRODUCTION

Crown discoloration has been considered by the International Association of Dental Traumatology as an important outcome of traumatic dental injuries (TDI) mandating investigation in patients.[1] Primary teeth present a bluish-white tonality. Following TDI, teeth may become yellow, gray, brown, black, or pink.[2,3] The alteration in color can be permanent or transient. There are only a few studies on the mechanism that cause discoloration. Among other causes, it occurs due to the pulp hemorrhaging as a result of the trauma, in which hemoglobin and erythrocytes are released. The penetration of hemosiderin (pigment originating from hemoglobin) into the dentine can lead to a change in crown color.[2,4] Discoloration of the crown is one of the most common sequelae of TDI to the primary dentition.[2,4–7] Frequently, crown discoloration may be the only indication of TDI to a tooth, necessitating the parents to seek dental treatment for their children.

Diagnosis and treatment of a discolored crown is directly related to the status of the dental pulp.[8] Discoloration may be present in a tooth with a normal pulp or it may be associated with histopathological reactions and conditions such as pulp canal obliteration, pulp necrosis, and pathological root resorption.[2,9] Thus, the prognosis of teeth with crown discoloration may represent a challenge to the dentist.[5] For instance, a case involving a young patient with an asymptomatic dark discolored primary incisor may be a clinical dilemma to a dentist regarding the decision to intervene or to monitor.[2]

Pulp diagnosis in traumatized teeth may be more complex as the immediate pulp responses after trauma indicate damage to the pulp, but not necessarily pulp necrosis.[8] Pulp necrosis may occur even in a tooth with pulp canal obliteration. Accurate diagnosis of an altered pulp in traumatized primary teeth is extremely challenging. According to Mocelini et al,[8] studies on dental trauma present different criteria for the diagnosis of pulp necrosis. Visual inspection of the pulp after access cavity preparation is considered the gold standard for determining the pulp condition. A study describing the condition of the pulp in traumatized asymptomatic primary incisors with dark coronal discoloration that were treated endodontically found 98% had a necrotic pulp.[10] However, others have shown that teeth with dark discoloration may remain asymptomatic until natural exfoliation and may never develop any pathologic sign or symptom to indicate the need for root canal treatment or extraction.[2] The final pulp diagnosis is rarely based on an isolated finding, but rather on a variety of observations made by the clinician.[3,8] Treatment is not required unless clear clinical evidence of infection of the pulp is present.[11]

The influence of factors related to trauma such as the type of trauma and number of teeth affected, and that of factors associated with the age of the patient, on the occurrence of crown discoloration is not clear. Few cohort studies have evaluated the prognosis of the pulp condition based on the presence of crown discoloration and the color.[2–4] Knowledge of the risk of pulp complications in teeth affected by discoloration, especially from longitudinal studies with large sample sizes, can aid in the establishment of an appropriate treatment plan and follow-up.

The aim of this retrospective cohort study was to investigate the incidence of crown discoloration following TDI in primary teeth. Further aims were to estimate the risk of pulp necrosis with subsequent infection of the root canal system and pulp canal obliteration in teeth presenting with dark and yellow discoloration. The hypothesis of the study was that pulp alterations are expected to be higher in children with tooth discoloration.

2 | MATERIALS AND METHODS

This retrospective cohort study was based on file records of children treated at the Center for the Study and Treatment of Dental Trauma in the Primary Dentition (NETRAD, the acronym in Portuguese) of the Federal University of Pelotas, Brazil, during a period of 10 years (from May 2002 to July 2012). The study was approved by the Human Research Ethics Committee of the School of Dentistry under protocol number 187/2011. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were used to report the findings in this study.[12]

The service offered in the study setting included access, treatment, and follow-up for TDIs affecting the primary dentition. All patients treated were routinely followed-up until complete root formation of their succeeding permanent teeth. Parents or legal guardians were initially interviewed regarding the child's medical history and history of dental trauma. Subsequently, clinical findings were documented, and radiographs and photographs were taken. Dental trauma diagnosis was based on clinical examination and radiographic findings, using the Andreasen and Andreasen criteria by a professional experienced in pediatric dentistry.[13] The protocol of care was based on recommendations of the International Association of Dental Traumatology Guidelines (IADT).[14]

All cases of injury affecting primary incisors, with complete TDI documentation (clinical photos, radiographs, and trauma data sheet), and a minimum follow-up of two dental appointments were included in the study. In addition, cases were included only when the patients' guardians consented to share information related to the patient's history, their dental injury, and their consequences. Teeth with caries or with alteration in color following endodontic treatment were excluded, as the discoloration in such cases could be attributed to causes other than trauma.

Data were collected from file records of patients, which included clinical information, radiographic examination findings and photographs routinely performed in patients. Clinical details such as gender, age at the time of TDI, number of traumatized teeth, the type of TDI, presence of crown discoloration, and the time elapsed between the dental injury and occurrence of discoloration were also recorded. Details of the type of dental trauma (support or hard tissue trauma) were collected from dental records and classified using the Andreasen criteria.[13]

In order to determine the clinical condition of the pulp and the radiographic condition of the pulp space and the periapical tissues, clinical records and radiographs were evaluated in all teeth irrespective of the presence or absence of discoloration. The pulp condition was classified as normal or with pulp canal obliteration when there was evidence of deposition of hard tissue along the walls of the root canal and in the coronal pulp chamber as compared with the non-injured contralateral tooth.[13,15,16] A pulp diagnosis of necrosis with subsequent infection of the root canal system was made when there were clinical symptoms of infection such as swelling, abscess, or sinus tract associated with the traumatized tooth or when there were radiographic signs such as periapical bone rarefaction, and/or inflammatory root resorption.[16–18]

Photographs of patients with tooth discoloration were assessed by two evaluators, who performed in duplicate the color classification of the discolored tooth/teeth. In case of disparity, a third researcher was consulted. Teeth with crown discoloration were classified as dark (including grey and brown teeth) or yellow.[2,3] When the patient had more than one tooth with alteration in color, all the affected teeth were included in the study. Photographs were taken by personnel trained in the use of photographic equipment. Each patient was positioned with the Frankfort horizontal plane parallel to the floor. A professional digital camera Nikon D40 (Nikon Co) was used for photography wherein the flash was used to standardize the illumination. No correction for color, brightness, or contrast was performed. The photographic assessment method for dental trauma has been considered valid and reliable as compared to oral clinical examinations.[19]

Calibration for the classification of the radiographic condition of the pulp space and the periapical tissues was tested based on the kappa coefficient, using 80 periapical radiographs depicting different conditions. Results of the examiner were compared with a gold standard, and the kappa value was calculated as 0.91, showing excellent agreement. The inter-examiner Kappa value for dental color classification, based on the evaluation of 20 photographs, was 0.8.

The data were entered in a Microsoft Excel 2010 spreadsheet and analyzed in Stata 14.0. (Stata Corp. LP). The association of the difference in frequency of crown discoloration with factors related to the patient and to the traumatized teeth, including pulp condition, was assessed by a chi-square test ($P < .05$). The relative risk (RR) and 95% confidence intervals (CI 95%) for the occurrence of pulp necrosis and pulp canal obliteration in the presence of crown discoloration were calculated using a crude estimate, and the results adjusted using Poisson regression with robust variance based on age and type of dental trauma. Further, the frequency of pulp necrosis and pulp canal obliteration with the time elapsed between the TDI and the diagnosis of crown discoloration was described, but no inferential analysis was performed owing to a small sample size.

3 | RESULTS

There were 898 teeth affected and treated for TDI. They were detected in 576 children who reported during the study period. Of these, 221 patients (270 teeth) were excluded from the study owing to technical errors in the radiographs or due to their failure to seek follow-up. Hence, a total of 628 teeth, in 355 patients, were included. Most of the teeth were maxillary central incisors (78.35%). The follow-up period of the study subjects ranged from 7 months to 6 years.

The incidence of crown discoloration was 27.9% in the patients. Table 1 depicts the study sample and the presence of crown discoloration according to demographic characteristics of the patients, and the number of teeth affected. Most of the patients were boys (60.3%) aged between 2 and 4 years (50.7%), with one or two teeth affected (44.2% and 43.7%, respectively). Maxillary central incisors were the most affected teeth (78.3%). The age at the time of TDI in children with the highest prevalence of crown discoloration was 2-4 years ($P = .020$). The gender and number of teeth injured were not associated with the presence of crown discoloration.

Considering all the teeth, the incidence of crown discoloration was 20.4%. Table 2 shows that the incidence of crown discoloration varied according to the type of traumatic dental injury ($P = .019$) and the age at the time of TDI ($P = .003$). Frequency of crown discoloration was higher in teeth that suffered subluxation (27.7%) followed by those with enamel–dentin fracture (25.0%). With reference to the color presented, 52.0% of the affected teeth were darkened and 48.0% had yellowish discoloration. Table 2 also describes the color presented according to the type of injury and the age at the time of TDI.

There were 53 teeth (8.44%) that developed pulp canal obliteration and 115 (18.31%) showed clinical and radiographic signs of pulp necrosis with subsequent infection of the root canal system. The latter included periapical bone rarefaction in 81.73% of the affected teeth (94/115), sinus tract associated with the traumatized tooth in 17.39% (20/115), and/or inflammatory root resorption in 9.57% (11/115). Table 3 depicts the clinical/radiographic conditions

TABLE 1 Presence of crown discoloration according to the child's gender, age at the time of traumatic dental injury (TDI), and number of teeth affected (n = 355 children)

Variables	Total N (%)	Discoloration n (%)	P[a]
Overall	355 (100.0)	99 (27.9)	
Gender			
Male	214 (60.3)	63 (29.4)	.422
Female	141 (39.7)	36 (25.5)	
Age-TDI			
<2 y	72 (20.3)	15 (20.8)	.020
2-4 y	180 (50.7)	62 (34.4)	
>4 y	103 (29.0)	22 (21.4)	
Number of teeth			
1	157 (44.2)	44 (28.0)	.526
2	155 (43.7)	46 (29.7)	
>2	43 (12.1)	9 (20.9)	

[a]chi-squared test.

TABLE 2 Distribution of crown discoloration according to type of traumatic dental injury (TDI) and age at the time of TDI (n = 628 teeth)

		Crown-discoloration present			Color			
					Yellow		Dark	
Variables	Total N	n	(%)	*P*[a]	N	(%)	n	(%)
Total	628	128	20.4		61	48.0	66	52.0
Type of TDI								
Enamel fracture	58	13	22.4	.019	6	46.2	7	53.8
Enamel-dentin fracture	44	11	25.0		2	18.2	9	81.8
Enamel-dentin-pulp fracture	23	5	21.7		0	-	5	100
Crown-root fracture	21	0	-		0	-	0	-
Concussion	60	8	13.3		3	37.5	5	62.5
Subluxation	173	48	27.7		27	56.2	21	43.8
Lateral luxation	97	20	20.6		10	50.0	10	50.0
Intrusive luxation	113	14	12.4		8	57.1	6	42.9
Extrusive luxation	39	8	20.5		5	62.5	3	37.5
Age-TDI								
<2 y	130	16	12.3	.003	9	56.2	7	43.8
2-4 y	319	81	25.4		39	48.1	42	51.9
>4 y	179	30	16.8		13	43.3	17	56.7

[a]chi-squared test.

TABLE 3 Pulp condition according to the presence of crown discoloration (n = 628 teeth)

		Pulp condition						
		Normal		Pulp canal obliteration		Necrosis with infection		
Variable	Total N	n	(%)	N	(%)	n	(%)	*P*[a]
Crown discoloration								
No	501	409	81.5	17	3.4	76	15.1	<.001
Yes	127	53	41.4	36	28.1	39	30.5	
Color								
Normal	501	409	81.5	17	3.4	76	15.1	<.001
Yellow	61	27	43.6	25	40.3	10	16.1	
Dark	66	26	39.4	11	16.7	29	43.9	

[a]chi-squared test.

of the pulps in the teeth included in the study. No clinical or radiographic alteration was detected in 81.5% of teeth with normal color and in 41.4% of the discolored teeth. The pulp condition was altered in 18.5% of teeth with no alteration in color and 58.6% of the discolored teeth. Of the yellow teeth, 40.3% had pulp canal obliteration and of the dark teeth 43.9% had clinical and radiographic signs of pulp necrosis and subsequent infection of the root canal system.

Discolored teeth had a twofold risk of necrosis (RR 1.98; 95% CI 1.42-2.76; $P < .001$) and an eight times higher risk of pulp canal obliteration (RR 8.47; 95% CI 4.95-14.51; $P < .001$). Considering the color, the risk of pulp necrosis was nearly three times higher in dark teeth (RR 2.69; 95% CI 1.92-3.78; $P < .001$) but was not different in the yellow teeth as compared to teeth without alteration in color ($P = .794$). However, the risk of pulp canal obliteration was eight times higher in the yellow teeth (RR 8.18; 95% CI 5.04-13.29; $P < .001$) and two times higher in the dark teeth (RR 2.35; 95% CI 1.26-4.36; $P = .007$), compared to teeth without alteration in color (Tables 4 and 5).

Of 61 teeth which were diagnosed with discoloration in the 3 months following injury, 47.5% did not show pulp changes during follow-up. However, 29.5% showed evidence of pulp canal obliteration and 22.9% had pulp necrosis with subsequent infection of the root canal system. Discoloration was diagnosed 4 months or longer after the TDI in 67 teeth. In these teeth, 37.3% had pulp necrosis, 35.8% had no alteration of the pulp, and 26.9% had pulp canal obliteration.

TABLE 4 Risk of pulp canal obliteration according to the presence of crown discoloration

	Risk of pulp canal obliteration					
	Crude			Adjusted[a]		
Variable	RR	95%CI	*P*	RR	95%CI	*P*
Crown discoloration						
No	1.00			1.00		
Yes	8.31	4.82-14.31	<.001	8.47	4.95-14.51	<.001
Color						
Normal	1.00			1.00		
Yellow	8.18	5.10-13.11	<.001	8.18	5.04-13.29	<.001
Dark	2.24	1.21-4.13	.010	2.35	1.26-4.36	.007

Note: Crude and adjusted analysis with relative risk (RR) and 95% confidence interval (CI) (n = 628 teeth).

[a]Adjusted for child age by the time of the injury and type of dental trauma.

TABLE 5 Risk of pulp necrosis and subsequent infection of the root canal system according to the presence of crown discoloration

	Risk of pulp necrosis and infection					
	Crude			Adjusted[a]		
Variable	RR	95% CI	*P*	RR	95% CI	*P*
Crown discoloration						
No	1.00			1.00		
Yes	2.01	1.44-2.81	<.001	1.98	1.42-2.76	<.001
Color						
Normal	1.00			1.00		
Yellow	1.07	0.58-1.95	.837	0.92	0.51-1.67	.794
Dark	2.90	2.06-4.09	<.001	2.69	1.92-3.78	<.001

Note: Crude and adjusted analysis with relative risk (RR) and 95% confidence interval (CI) (n = 628 teeth).

[a]Adjusted for child age by the time of the injury and type of dental trauma.

4 | DISCUSSION

The present study investigated the incidence of crown discoloration following TDI in primary teeth and their risk of pulp complications. The data showed that one-fifth of the traumatized primary teeth showed crown discoloration, with a high risk of pulp necrosis and infection of the root canal system, especially the darkened teeth. A few cohort studies have investigated the incidence of discoloration in primary dentition, and a high frequency of this finding has been reported.[2,4,6] The study size was determined by the number of patients who had complete records with documentation of all the findings throughout the study period. The final sample size (n = 355) was comparable to the desired sample size (n = 322) required to estimate the incidence of crown discoloration at a 95% confidence level with a margin of error of 3.5% and an incidence rate of 53% based on a previous study.[6]

The association of tooth discoloration with the type of tooth trauma was also investigated in this study. Although a higher risk of discoloration could be expected in more severe trauma,[20] the findings are in accordance with previous studies that failed to show an association between trauma severity and crown discoloration.[4,18,21] In the present study, even teeth with mild injuries were characterized by a high frequency of discoloration. Subluxation was the TDI that most frequently resulted in teeth discoloration, followed by enamel-dentin fracture. Also, the number of teeth injured in a patient was not related to the presence of crown discoloration. These findings indicate the importance of dentists warning the parents/guardians about the risk of discoloration in a traumatized tooth, regardless of the trauma type.

A higher prevalence of crown discoloration was detected among children whose age at the time of TDI was 2-4 years. Differences in blood supply and the stage of development of the tooth may be contributory to this finding. However, the results were not adjusted for other confounding variables that could influence this association.

A systematic review and meta-analysis has been conducted with an aim to verify the association between pulp necrosis and crown discoloration in traumatized primary teeth.[8] A positive association was reported between the two parameters when including studies that used clinical and radiographic examination for the diagnosis of pulp necrosis. However, when considering studies with visual inspection of the pulp alone via an endodontic access

cavity, which is considered the gold standard for determining the pulp status, there was no significant association between the studied variables. As a correct pulp diagnosis can only be obtained with histopathological analysis, the outcome measure based on clinical and radiographic evaluation should be analyzed with caution as it may be less accurate.

Results of the present study showed that yellowish teeth had a low risk of pulp necrosis and subsequent infection of the root canal system, compared to teeth with normal color. On the other hand, nearly half of the darkened teeth had pulp necrosis. These findings reinforce previous studies which showed that yellow discoloration is usually related to pulp canal obliteration, and the dark color is attributed to necrosis of the pulp.[6,10] These results underscore the importance of monitoring teeth with dark discoloration, in order to provide diagnosis and timely management of a necrosed pulp as soon as clinical signs and symptoms are evident. Consequently, the number of visits for discolored teeth should be higher than that for teeth without discoloration, as this is a relevant outcome of TDI according to the IADT.[1]

In the present study, most teeth with crown discoloration did not show signs of pulp necrosis and subsequent infection of the root canal system. Hence, the real incidence of pulp necrosis in those teeth remains unknown. The absence of signs of pulp necrosis show that such cases are not indicated for endodontic intervention. This is in agreement with the IADT guidelines,[14,22] which state that discolored teeth should be monitored, and an interventional procedure should be undertaken only when there is an additional clinical (abscess, excessive mobility, or fistula) or radiographic sign (periapical radiolucency or pathological root resorption).

While the risk of pulp necrosis and subsequent infection of the root canal system for the yellow teeth was same as that for teeth with normal color, an eight times higher risk of pulp canal obliteration was observed in the former. The impact of these findings for clinical practice is that yellow teeth have a high probability of maintaining a normal pulp and non-invasive procedures are indicated in such cases.[23] The pulp canal obliteration may be a result of damage to the neurovascular supply coupled with ischemia followed by necrosis or revascularization. However, when revascularization occurs, it can induce the formation of osteodentin, bone, or dentin tissue on the canal walls, subsequently leading to pulp canal obliteration.[24] The yellow color can reflect amorphous calcification following hemorrhage into the pulp, or the accelerated deposition of secondary dentin resulting from the stimulation of odontoblasts following the damage that occurs to the pulp tissue during the injury.[25]

Crown discoloration occurring more than 3 months following TDI had a higher incidence of pulp necrosis with subsequent infection of the root canal system. Previous studies have shown that discoloration may either occur shortly after trauma or delayed color change can be observed.[26] There is a risk of bias in determining the elapsed time between an injury and the discoloration. It is possible that the lack of precision in the assessment of the time elapsed after injury can contribute to a lack of association between the two parameters. There is no clinical evidence to date for determining the time up to which traumatized primary teeth should be followed up to ensure that pulp necrosis will not occur. Thus, dentists are advised to follow up patients for at least several months but preferably for up to several years after the TDI.

The strengths of the present study are its longitudinal design and its sample size whereby many traumatized primary teeth were evaluated until their exfoliation. This helped to provide a more precise estimate of the prognosis. The method used in this study to classify tooth discoloration was based on the photographs, in order to ensure a standardized evaluation. A previous study has shown that the photographic method can be used to detect TDI at a population level,[19] 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 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.

Knowledge about the risk of pulp necrosis and crown discoloration may help dentists to determine a tooth's prognosis following dental trauma and to provide an appropriate treatment plan. The findings in this study reinforce the need to monitor traumatized primary teeth with crown discoloration, especially darkened teeth,[11] due to the increased risk of pulp necrosis and subsequent infection of the root canal system. Noteworthy, a traumatized primary tooth with discoloration may remain asymptomatic until its exfoliation, without the need for any invasive treatment other than clinical and radiographic monitoring. Thus, an active surveillance approach must be emphasized in these cases.

The findings of this retrospective cohort study showed that the frequency of pulp necrosis and subsequent infection of the root canal system as well as the frequency of pulp canal obliteration were higher in discolored teeth compared to teeth with normal color. Considering the color, dark teeth were associated with an increased risk of necrosis, while the risk of pulp canal obliteration was higher in yellow teeth.

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CONFLICT OF INTEREST

The authors confirm that they have no conflict of interest.

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