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Analysis of pulp prognosis in 603 permanent teeth with uncomplicated crown fracture with or without luxation

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Abstract – *Aim*: To analyze the pulp prognosis of uncomplicated crown-fractured teeth with or without concurrent luxation injury in adolescent. *Material and methods*: Complete dental records of traumatized permanent teeth were obtained, including the patient's name, gender and age, position of the traumatized tooth, its stage of root development, time elapsed between dental injury and treatment, diagnosis, clinical procedures, and follow-up period. Pulp prognosis was evaluated over a period of at least 6 months using Andreasen's classification. Kaplan-Meier method and Cox regression were used to examine the risk factors inherent to the prognosis of pulp healing, with $P < 0.05$ accepted as statistically significant. *Results*: The study involved 603 teeth with uncomplicated crown fractures followed up for 6 months or longer, of which 104 suffered luxation at the same time. The frequency of pulp necrosis in teeth with complete root development was higher than those with incomplete root development. For uncomplicated crown fracture with luxation, crown-fractured teeth with intrusion had a higher incidence of pulp necrosis than other types of concurrent luxation (OR: 33.613). The incidence of pulp necrosis within 3 months was significantly higher than in other time periods ($P = 0.021$), and the median survival time was 53 days (95% confidence interval: 34–67 days). *Conclusions*: Existence of concurrent luxation injury and complete root development are important risk factors of pulp necrosis in teeth with uncomplicated crown fractures in adolescent.

Dental trauma is the second most common cause of tooth loss in children and adolescents. Nearly 50% of children under 15 years of age have suffered dental traumatic injuries (1). It has been estimated that 26–76% of injuries involve the loss of dental hard tissue in various categories of trauma (2, 3). Crown fractures of permanent teeth are the most common type of traumatic dental injury, and Ravn (4) reported that pulp necrosis was rarely appeared in this type of trauma, while Robertson et al. (5) reported a significant risk of associated pulp necrosis. Because fracture of the crown exposes the dentinal tubules, pathways to the pulp are available for a variety of noxious agents in the oral environment including bacteria and toxins; pulp necrosis is thus observed in 5–15% of enamel-dentin crown-fractured teeth (6, 7).

Several retrospective studies have described the assessment of pulp prognosis following tooth luxation, but crown fracture was an exclusion criterion in these studies (4, 6, 7). Thus, only few researches are about pulp healing and the timespan of development of pulpal necrosis when crown fracture injuries are accompanied by luxation (5, 8, 9).

Standard protocols for the treatment of dental traumatic injuries are often absent, although the International Association of Dental Traumatology suggests a Dental Trauma Guide to outline the treatment of certain cases (10). This lack of standardization of treatment is largely due to the uncertain prognosis of many types of traumatic dental injuries and the paucity of studies with a sufficiently large sample size to provide accurate data with regard to long-term prognosis. There has been limited epidemiological research into traumatic dental injuries in children and adolescents, and there is insufficient information available with regard to prognosis of certain dental traumatic injuries.

The aim of the present study was to analyze the pulp prognosis of uncomplicated crown-fractured teeth with or without concurrent luxation injury in adolescent. Teeth were followed up for 6 months or longer in the Department of Pediatric Dentistry, Peking University School and Hospital of Stomatology.

Materials and methods

This study recruited the dental records of child patients with traumatized permanent teeth treated in the Department of Pediatric Dentistry, Peking University School and Hospital of Stomatology from 2000 to 2009. The dental records from 2000–2006 were

reviewed and converted into Microsoft Excel format by one researcher, while those from 2007 to 2009 were processed by a second researcher. To ensure the consistency of recording between these researchers, 600 records from 2000 to 2006 were re-checked by the second researcher before statistical analysis. The case inclusion criteria were as follows: (i) the first treatment for the dental injury was performed in the Department of Pediatric Dentistry or Dental Emergency Department, Peking University School and Hospital of Stomatology; (ii) the traumatized teeth had not previously experienced dental trauma; (iii) the dental records were complete, including the patient name, gender and age, the position of the traumatized tooth, the stage of root development, the time elapsed between dental injury and treatment (<2 h, 2–24 h, >24 h), diagnosis, clinical examination and tests, clinical procedures, and follow-up period. Clinical tests included electric pulp test (EPT) examination, sensitivity to percussion, mobility, and radiographic analysis. Calcimol LC® calcium hydroxide material (VOCO, Cuxhaven, Germany) was applied as a dentin protector in dentin-fractured teeth.

The pulp prognosis was evaluated in crown-fractured teeth without pulp exposure more than a period of 6 months or longer. These teeth were divided into two groups. Group A included teeth suffered uncomplicated crown fracture injury without luxation and Group B included teeth suffered uncomplicated crown fracture with concurrent luxation injury. The pulp prognosis was categorized [as in previous studies (5)] as pulp survival, pulp necrosis or pulp obliteration (Table 1). If two of three clinical symptoms (crown discoloration, negative EPT, tenderness to percussion) were observed together with radiographic apical radiolucency or/and inflammatory resorption, the tooth was diagnosed as undergoing pulp necrosis. If spontaneous pain or swelling occurred, the tooth was diagnosed as having undergone pulp necrosis. The stage of root development was subclassified as 'complete' or 'incomplete'. On periapical radiographs, roots with apical foramen less than 1 mm diameter were designated as 'complete', while with apical foramen, more than 1 mm diameter was designated as 'incomplete'. Andreasen's classification (1) was applied in this study. All traumatized teeth included in the statistical analysis have been reviewed on a standardized schedule at 2 weeks, 1, 3, 6, 12, 18, and 28 months. Patients were advised to seek help at their own dentist if they experienced any toothache or swelling.

Table 1. Classification of final pulp prognosis (5)

Diagnosis	Clinical criteria	Radiographic criteria
Pulp survival	Normal crown color Normal electrometric pulp testing (EPT)	No pathologic changes
Pulp necrosis	Crown discoloration Negative EPT Percussion tenderness	Apical radiolucency Inflammatory resorption
Pulp obliteration	Yellow crown discoloration	Constriction of pulp canal

EPT, electric pulp test.

Data were processed and analyzed using Statistical Package for the Social Sciences (SPSS), version 13.0 (SPSS Inc., Chicago, IL, USA). Survival analysis was used to analyze data. Kaplan-Meier method and Cox regression were used to examine the risk factors inherent to the prognosis of pulp healing, with $P < 0.05$ accepted as demonstrating statistical significance. We investigated the patient's age, the position of the injured tooth, the time elapsed between dental trauma and treatment, the administration of emergency treatment (or not), sensitivity to percussion (or not) at first visit, the stage of root development, trauma type, and the clinical procedure (dentine protector applied or not) as potential risk factors.

Results

A total of 2069 patient records describing 3703 traumatized permanent teeth dating from January 1, 2000 to December 31, 2009 were identified in the archives of the Department of Pediatric Dentistry, Peking University School and Hospital of Stomatology in a search conducted by 16 dentists and 10 students. Of these records, 603 teeth with uncomplicated crown fractures were followed up for 6 months or longer. These 603 teeth were further subdivided into those that had no concurrent luxation injury (499) and those had (104). The follow-up period was specified as 6–12, 12–24, 24–36, or >36 months (Table 2).

Pulp prognosis of uncomplicated crown fracture with or without luxation

Of the 499 teeth with simple crown fracture and no luxation, 72 (14.4%) had only enamel fractures, whereas 427 (85.6%) had dentin fracture. Three of the 72 enamel-fractured teeth were diagnosed as having pulp necrosis due to toothache at 175, 135, and 698 days after injury and were found to have time delays from trauma to dental clinic of 24 h, 2, and 3.5 days, respectively. Sixty-seven (64.2%) of those teeth were restored with composite resin or glass ionomer cement without any dentin protection, and 53 (55.8%) were sensitive to percussion. Treatment details, time elapsed between trauma and treatment, and root development have been included in the analysis (Table 3). The frequency of pulp necrosis was higher in teeth with complete root development compared with those with incomplete root development ($P < 0.05$), and the risk of pulp necrosis was higher in teeth with dentin fracture (OR: 3.556) compared with those with enamel fracture (Table 4).

Of 104 teeth with uncomplicated crown fracture and concomitant luxation, the median survival time was 53 days (95% confidence interval: 34–67 days; Fig. 1). Pulp necrosis was significantly more likely to occur within 3 months (44%) than in other time periods ($P = 0.021$). Furthermore, the cumulative proportion rate of pulp necrosis was 72.2% within 12 months (Table 5). The stage of root development and type of injury (i.e., with or without luxation) were found to be risk factors in pulp necrosis. The frequency of pulp

Table 2. Distribution of followed up time in 603 uncomplicated crown-fractured teeth

	6–12 months	12–24 months	24–36 months	>36 months	Total
	N (%)				
UCF	49 (9.8)	202 (40.5)	185 (37.1)	63 (12.6)	499
+ Luxation	45 (43.3)	9 (8.7)	23 (22.1)	27 (26.0)	104
+ Concussion	9 (30.0)	3 (10.0)	11 (36.7)	7 (23.3)	30
+ Subluxation	27 (50.0)	2 (3.7)	10 (18.5)	15 (27.8)	54
+ Extrusion	6 (50.0)	2 (16.7)	-	4 (33.3)	12
+ Lateral luxation	1 (33.3)	1 (33.3)	1 (33.3)	-	3
+ Intrusion	2 (40.0)	1 (20.0)	1 (20.0)	1 (20.0)	5

UCF, uncomplicated crown fracture.

Table 3. Clinical details of crown-fractured teeth

	Clinical details		Root development	PN (%)[1]
Uncomplicated crown fracture	Treatment	+ dentin protector	Incomplete	11.3
			Complete	13.7
		− dentin protector	Incomplete	31.2
			Complete	39.0
	Time elapsed between dental trauma and treatment	<2 h	Incomplete	3.5
			Complete	11.9
		2–24 h	Incomplete	17.3
			Complete	20.1
		>24 h	Incomplete	35.5
			Complete	36.0
Uncomplicated crown fracture with luxation	Treatment	+ dentin protector	Incomplete	64.9
			Complete	69.7
		− dentin protector	Incomplete	73.6
			Complete	77.9
	Time elapsed between dental trauma and treatment	<2 h	Incomplete	67.0
			Complete	73.1
		2–24 h	Incomplete	77.8
			Complete	70.1
		>24 h	Incomplete	73.4
			Complete	72.5

PN, pulp necrosis.
[1]Cumulative PN rate at 36 months.

Table 4. Risk factors for pulp prognosis in uncomplicated crown-fractured teeth

Influence factor	B	SE	Wald	df	Sig.	OR
Root development stage[1]	0.230	0.098	10.589	1	0.002	1.577
Type of injury[2]	1.388	1.513	6.291	1	0.024	3.556

B, regression coefficient; SE, standard error; df, degrees of freedom; Sig, significance value; OR, odds ratio.
[1]0: in development; 1: fully developed.
[2]0: enamel fracture; 1: dentin fracture.

necrosis was higher in teeth with complete roots than in those with incomplete root development ($P < 0.05$), and the risk of pulp necrosis was higher in teeth with uncomplicated crown fracture and intrusion (OR: 33.613) than in those with other types of concurrent luxation (Table 6).

Discussion

Previous studies have shown that 0–3.5% of enamel-fractured teeth and 0.5–6% of dentin-fractured teeth develop pulp necrosis (4, 7, 11, 12). In this study, the incidence of pulp necrosis in enamel- and dentin-fractured teeth was 4% and 22%, respectively, notably higher than those previous estimates. The low 'follow-up rate' might bias the assessment of pulp necrosis in dentin-fractured teeth because only 499 of 1131 teeth with uncomplicated crown fractures (32.2%) were followed up longer than 6 months in the study. As many patients whose teeth were repaired esthetically and without any lasting pain or discomfort would not return to the hospital for follow up, which might result in an over-estimation of pulp necrosis rate in dentin-fractured teeth in the study.

For dentin fracture teeth protected using a dentin protector before definitive light-cured composite resin restoration, the cumulative proportion rate of pulp

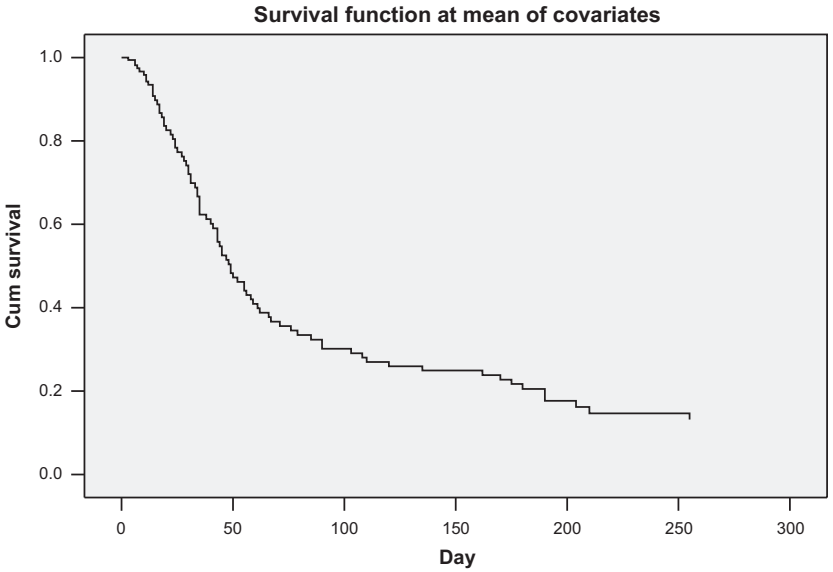

Fig. 1. Survival of crown-fractured teeth with luxation.

Table 5. Cumulative proportion rate of pulp necrosis in uncomplicated crown-fractured teeth with different types of luxation

	Root development	3 months (%)	6 months (%)	12 months (%)	36 months (%)
UCF	Incomplete	0.0	1.2	2.0	2.5
	Complete	1.5	3.7	6.1	7.2
+ Concussion	Incomplete	14.8	25.7	35.1	71.5
	Complete	39.5	46.8	78.6	79.0
+ Subluxation	Incomplete	23.1	31.6	54.5	87.5
	Complete	57.9	60.5	79.7	82.1
+ Extrusion	Incomplete	23.8	23.8	45.5	78.5
	Complete	59.6	63.8	71.3	77.9
+ Lateral luxation	Incomplete	53.5	52.5	75.0	81.0
	Complete	51.2	57.0	78.1	90.0
+ Intrusion	Incomplete	66.7	70.3	87.5	90.0
	Complete	75.0	83.3	87.5	91.3

UCF, uncomplicated crown fracture.

Table 6. Risk factors for pulp necrosis in uncomplicated crown-fractured teeth with concomitant luxation

Influence factor	B	SE	Wald	df	Sig.	OR
Root development[1]	0.759	0.278	7.459	1	0.006	2.136
Luxation type[2]			28.826	4	0.000	
Subluxation	0.759	0.278	7.459	1	0.006	2.136
Extrusion	0.832	0.551	2.276	1	0.131	2.297
Lateral luxation	1.206	0.394	9.345	1	0.002	3.339
Intrusion	3.515	0.715	24.191	1	0.000	33.613

B, regression coefficient; SE, standard error; df, degrees of freedom; Sig, significance value; OR, odds ratio.
[1]0: in development; 1: fully developed.
[2]Luxation type: 0, concussion; 1, subluxation; 2, extrusion; 3, lateral luxation; 4, intrusion.

survived was 72.0% at the point of 36 months. It seemed that dentin protection aided pulp healing process by repelling the exogenous chemo-physical factors that may otherwise induce pulp necrosis. However, dentin protection and treatment delay (varied widely from 30 min to 10 days) were not factors significantly related to pulp necrosis in multivariate analysis.

In the present study, pulp necrosis was more likely to occur in luxated teeth than in non-luxated teeth, with the relative risk in crown-fractured teeth increased when it was concurrent with concussion (OR: 1.206), subluxation (OR: 2.136), extrusion (OR: 2.297), lateral luxation (OR: 3.339), or intrusion (OR:33.613). Luxation implies more serious injury, which may have consequences not only in the hard tissue but also in the periodontal tissue (e.g., periodontal concussion and injury), both of which would threaten the health of the pulp, especially in teeth with intrusion. Similar results were reported in Andreasen's study (1). Besides luxation, our results indicated that root development may be a significant risk factor in pulp necrosis, suggesting that the root development status have an important influence on the prognosis of the pulp following dental trauma in adolescents (8, 9, 13). The risk of pulp necrosis in teeth with complete roots was more than double that

in teeth with incomplete root development. It is likely that the wide apical foramen of incompletely developed roots facilitates pulp revascularization, thus preventing the spread of inflammation (1, 13, 14). Recent literature has raised the prospect of revascularization of the root canal system and pulp space in immature teeth (15, 16). After luxation trauma, some teeth with incomplete root development may undergo sterile necrosis and be amenable to revascularization. However, Kling et al. (15) found that only 18% of 154 immature human avulsed teeth were revascularized when they were replanted into their sockets. As at 12-months pulp necrosis, cumulative proportion rate was 72.2%, the timescale of the necrosis is often incompatible with revascularization, we have not focused on pulp revascularization in the present study.

As pulp necrosis is a common complication with traumatized teeth, it is critical that dentists are aware of the timescale in which necrosis generally occurs. In the present study, the incidence of pulp necrosis occurring within 3 months was significantly higher than in other time periods, while the median survival time was 53 days. Thus, the first 3 months after injury could be considered to be the key window during which dentists should be most vigilant for signs of worsening pulp health. We also found that at 12-months pulp necrosis, cumulative proportion rate was 72.2%. It's recommended that a follow-up period of more than 1 year is necessary for evaluation of pulp healing.

We have shown here that the degree of trauma (luxation vs no luxation and luxation type) and the stage of root development are key risk factors in the development of pulp necrosis in teeth with uncomplicated crown fractures. For crown-fractured teeth with luxation, most pulp necrosis occurred within 12 months of initial trauma. These findings should help dentists to formulate their strategy for treating and monitoring pulp health after dental trauma.

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