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A Retrospective Evaluation of Crown-fractured Permanent Teeth Treated in a Pediatric Dentistry Clinic

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Abstract

A retrospective study was carried out on the dental trauma records of 93 patients (55 boys, 38 girls) with 129 crown-fractured teeth. The patients' average age was 9.57 years (SD 1.57), ranging between 7 and 15 years. Uncomplicated crown facture (comprising enamel–dentin) was the most observed type of injury (n=107, 83%). Only 15 patients (16.13%) sought treatment in less than 24 h following the injury. Of 41 injured teeth (31.79%) the apices were open at the time of presentation at the clinic. The initial treatment of these injured teeth were interim restoration with acid-etch and composite (69%), Cvek amputation (2.33%), fragment reattachment (1.55%), apexification (APX, 10.07%), and root-canal

treatment (RCT, 17.05%). Out of 94 teeth, which were diagnosed as vital on admittance, 23 (24.46%) later developed pulp necrosis and required APX or RCT depending on their apical status. In 66 teeth (51.16%) definitive treatment was provided with only esthetic restoration (ER), while in 15.50% and 26.68% of injured teeth ER was carried out following APX and RCT, and RCT, respectively. Definitive treatment was provided in 3–6 months for 29.45% of the injured teeth, while 27.13% and 20.16% of teeth received definitive treatment within 1–3 months and 6 months to 1 year, respectively. Type of crown-fracture, elapsed time following injury, and vitality of the tooth on admittance and pulp necrosis observed were significantly related to the total time spent for definitive treatment ($P < 0.05$).

Dental traumatic injuries are common health problems in child and adolescent populations. Approximately 50% of children are exposed to dental trauma before the age of 15 ([1]). Besides representing a considerable proportion of dental emergencies, traumatic injuries are frequently the cause of esthetic and psychologic problems in children adolescents ([2-4]). The reported prevalence of these injuries has ranged from 6% to 37% for different countries ([5-10]). The common etiological factors have been reported as falls, collisions, sports accidents, violence, and traffic accidents ([5]).

Among other types of traumatic injuries in permanent dentition, crown fracture is the most common with a reported prevalence ranging from 26% to 76% ([11-13]). Crown fracture is a type of traumatic injury in which a portion of tooth enamel is lost following a perpendicular or obliquely directed impact force to the incisal edge of the tooth. Fractures of enamel and enamel dentin (without pulpal involvement) are defined as 'uncomplicated.' However, the term changes into 'complicated,' when the fracture involves enamel and dentin, and exposes the pulp ([5]). In most studies, uncomplicated crown fractures have been reported to be the most common injury to the permanent teeth ([12], [14-16]). A frequent observation is that maxillary central incisors tend to be the most affected teeth ([11-13], [17]).

Traumatic injuries to the teeth require immediate attention. However, depending on the type of trauma and its impact on the pulp, complications may arise; affecting the overall treatment times and costs. The purpose of the study was to retrospectively evaluate pulpal prognosis of crown-fractured permanent teeth and the outcome of treatment provided in a pediatric dentistry clinic.

Patients and methods

The study was carried out on the dental trauma records of patients presented for treatment at the Department of Pediatric Dentistry, Faculty of Dentistry, Hacettepe University, in Ankara, Turkey, between December 1999 and April 2004. The study sample consisted of patients with crown fractures. Only uncomplicated (enamel–dentin) and complicated crown-fractured teeth were included in the study. Initial examinations following injury, follow up, and definitive treatment of these patients were all carried out by the pedodontists at the department. Two clinicians examined each patient's record, radiographs of teeth, and data related to the following fields were recorded:

- *Information related to the patient:* Patients' age and gender.

- *Information related to the injury:* Type of crown fracture, number of injured teeth, and time elapsed following injury.

- *Information related to the injured tooth:* Type of tooth, vitality of the tooth on admittance and at the end of the treatment, apical status (open or closed apex).

- *Information related to the treatment provided:* Type of initial treatment provided, pulp necrosis observed during the course of treatment, type of definitive treatment provided and the total time spent for the definitive treatment.

Statistical analysis was carried out by chi-squared test using spss for Windows v 10. The significance level was set as *P* < 0.05.

Results

Dental trauma records of 93 patients, 38 girls (40.9%) and 55 boys (59.1%), were evaluated. The average age of the patients was 9.59 years (range 7–15, SD 1.57 years). **Figure 1** shows the distribution of patients' ages by gender. Fifty-eight patients (62.4%) had only one injured tooth, while 34 (36.5%) had two and one (1.1%) patient had three affected teeth.
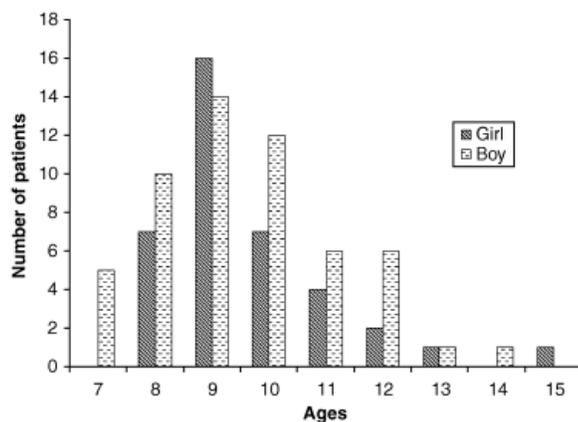

Figure 1 Distribution of age groups by gender.

There was a tendency for delay in immediate presentation for dental treatment among the study population. Only 15 patients (16.13%) were referred to the clinic in less than 24 h following the injury. Thirty-nine patients (41.94%) were seen in 1–7 days after the injury. The number of patients seen 1–4 weeks after the injury was 24 (25.81%). While eight patients (8.60%) sought treatment 1–6 months after the injury, seven (7.52%) patients were referred to the clinic after more than 6 months. The relation between elapsed time following injury and type of crown fracture is presented in **Fig. 2**. Type of crown fracture and apical status of injured teeth are shown in **Fig. 3**. **Table 1** shows the distribution of teeth by vitality on admittance and apical status.
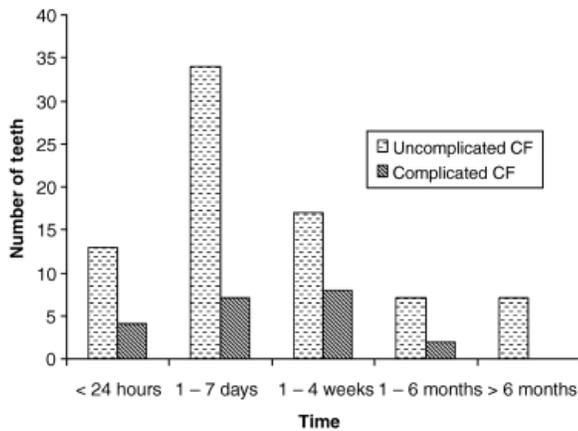
Figure 2 Elapsed time following injury by type of crown fracture.
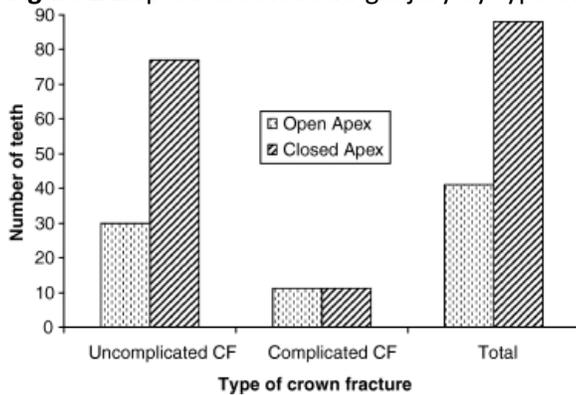
Figure 3 Type of crown fracture by tooth maturity.

Table 1. Distribution of teeth by vitality on admittance and apical status

	Teeth, *n* (%)					
	11	12	21	31	41	Total
Vital/open apex	14 (51.85)	2 (7.41)	10 (37.04)	1 (3.70)	1 (3.70)	28 (21.71)
Vital/closed apex	31 (48.43)	1 (1.56)	29 (45.31)	3 (4.68)	2 (3.12)	66 (51.16)
Non-vital/open apex	7 (53.85)	0 (0.00)	6 (46.15)	0 (0.00)	0 (0.00)	13 (10.08)
Non-vital/closed apex	13 (59.09)	0 (0.00)	9 (40.91)	0 (0.00)	0 (0.00)	22 (17.05)
Total	65 (50.38)	3 (2.33)	54 (41.86)	4 (3.10)	3 (2.33)	129 (100)

CF, Crown fracture; APX, Apexification treatment; RCT, Root-canal treatment; PN, Pulp necrosis; ER, Esthetic restoration.

Distribution of teeth by the studied parameters is presented in **Table 2**. The total number of crown-fractured teeth was 129. Of these, 22 teeth (17%) presented complicated crown fractures, while 107 (83%) had uncomplicated crown fractures. The most affected teeth were the maxillary central incisors (*n* = 119, 92.24%). In nearly one-third of injured teeth (*n* = 41, 31.79%) the apices were open at the time of presentation at the clinic. Only 94 teeth (72.87%) were diagnosed as vital on admittance.

Table 2. Distribution of teeth by the studied parameters

	Teeth					
	11, *n* (%)	12, *n* (%)	21, *n* (%)	31, *n* (%)	41, *n* (%)	Total *n(n*/129)
Type of injury						
Uncomplicated CF	51 (47.70)	3 (2.80)	46 (43.00)	4 (3.74)	3 (2.80)	107 (82.95)

Complicated CF	14 (63.63)	0 (0.00)	8 (36.37)	0 (0.00)	0 (0.00)	22 (17.05)
Apical status						
Open apex	21 (51.22)	2 (4.87)	16 (39.02)	1 (2.44)	1 (2.44)	41 (31.79)
Closed apex	44 (50.00)	1 (1.13)	38 (43.18)	3 (3.41)	2 (2.27)	88 (68.21)
Vitality on admittance						
Vital	45 (47.87)	3 (3.19)	39 (41.49)	4 (4.25)	3 (3.19)	94 (72.87)
Non-vital	20 (57.14)	0 (0.00)	15 (42.85)	0 (0.00)	0 (0.00)	35 (27.13)
Initial treatment						
Interim restoration	42 (47.19)	3 (3.37)	37 (41.58)	4 (4.49)	3 (3.37)	89 (69.00)
Cvek amputation	2 (66.67)	0 (0.00)	1 (33.33)	0 (0.00)	0 (0.00)	3 (2.33)
Fragment reattachment	1 (50.00)	0 (0.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (1.55)
APX	7 (53.84)	0 (0.00)	6 (46.16)	0 (0.00)	0 (0.00)	13 (10.07)
RCT	13 (59.09)	0 (0.00)	9 (40.91)	0 (0.00)	0 (0.00)	22 (17.05)
Complication observed						
PN (requiring APX)	6 (75.00)	1 (12.50)	1 (12.50)	0 (0.00)	0 (0.00)	8 (6.20)
PN (requiring RCT)	7 (46.68)	0 (0.00)	6 (40.00)	1 (6.66)	1 (6.66)	15 (11.63)
No complication	52 (49.05)	2 (1.89)	47 (44.34)	3 (2.83)	2 (1.89)	106 (82.17)
Vitality at the end						
Vital	32 (45.07)	2 (2.82)	32 (45.07)	3 (4.22)	2 (2.82)	71 (55.04)
Non-vital	33 (56.90)	1 (1.72)	22 (37.94)	1 (1.72)	1 (1.72)	58 (44.96)
Definitive treatment						
ER	29 (43.94)	2 (3.03)	30 (45.45)	3 (4.55)	2 (3.03)	66 (51.16)
Cvek Amp. + ER	2 (66.67)	0 (0.00)	1 (33.33)	0 (0.00)	0 (0.00)	3 (2.32)
Fragment reattachment	1 (50.00)	0 (0.00)	1 (50.00)	0 (0.00)	0 (0.00)	2 (1.56)
APX + RCT + ER	12 (60.00)	1 (5.00)	7 (35.00)	0 (0.00)	0 (0.00)	20 (15.50)
RCT + ER	20 (54.05)	0 (0.00)	15 (40.55)	1 (2.70)	1 (2.70)	37 (28.68)
Extraction	1 (100.00)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	1 (0.78)

CF, Crown fracture; APX, Apexification treatment; RCT, Root-canal treatment; PN, Pulp necrosis; ER, Esthetic restoration.

As regards the initial treatment of these injured 129 teeth, 89 (69%) received interim restoration with acid-etch and composite resin, 22 (17.05%) were extirpated and root-canal therapy (RCT) was initiated. In 13 teeth (10.07%) apexification (APX) was required, while in three teeth (2.33%) Cvek amputation was performed. Fragment reattachment was carried out on two teeth (1.55%).

During the course of the treatment pulp necrosis was observed in 23 teeth (17.83%). Accordingly, APX and RCT were initiated in 8 and 15 teeth, respectively.

In 66 teeth (51.16%) esthetic restoration was the definitive treatment. However, 60 teeth (46.5%) were estethically restored following any one type of endodontic treatment, either APX or RCT. Performed fragment reattachment procedure was successful and remained as the definitive treatment of two teeth (1.56%). One tooth was extracted due to failure of APX and root resorption.

The distribution of vital and non-vital teeth before the initial treatment and at the end of treatment related to the type of injury, and apical status is presented in **Table 3**.

Table 3. Distribution of vital and non-vital teeth before the initial treatment and at the end of treatment related to the type of injury and apical status

	At the initial treatment, n (%)			At the definitive treatment, n (%)		
	Vital	Non-vital	Total	Vital	Non-vital	Total
UCF open apex	25 (83.3)	5 (16.7)	30 (23.3)	18 (60.0)	12 (40.0)	30 (23.3)
UCF closed apex	65 (84.4)	12 (15.6)	77 (59.7)	51 (66.2)	26 (33.8)	77 (59.7)
CCF open apex	3 (27.3)	8 (72.7)	11 (8.5)	2 (18.1)	9 (81.9)	11 (8.5)
CCF closed apex	1 (9.1)	10 (90.9)	11 (8.5)	0 (0.0)	11 (100.0)	11 (8.5)
Total	94 (72.9)	35 (27.1)	129 (100.0)	71 (55.1)	58 (44.9)	129 (100.0)

UCF, Uncomplicated crown fracture; CCF, Complicated crown fracture.

Twelve teeth (9.30%) could be definitively treated in less than a month. In 38 teeth (29.45%) definitive treatment took 3–6 months to complete, while in 35 (27.13%) and 26 (20.16%) teeth definitive treatment was accomplished within 1–3 months and 6 months to 1 year, respectively. The number of teeth whose definitive treatment took more than 1 year was 18 (13.96%).

The percentage of teeth with uncomplicated and complicated crown fractures of patients admitted to the clinic in 0–24 h after injury were 16.8% and 18.2%, respectively ($P > 0.05$). With regard to elapsed time following injury and pulp necrosis observed, the relationship was statistically insignificant. However, when elapsed time following injury and total time spent for definitive treatment are concerned, percentage of teeth seen at the clinic within 24 h to 7 days after injury and with total time spent less than 6 months was 47.7%. The corresponding figure was 25.6% for teeth whose definitive treatment took more than 6 months (χ^2=11.591, $P < 0.05$).

Of the teeth whose definitive treatment were accomplished within 3–6 months, 74.4% had uncomplicated and 25.6% had complicated crown fractures ($\chi^2 = 13.072$, $P < 0.05$). Vitality on admittance had a significant effect on the total time spent for definitive treatment. While percentage of vital teeth that were definitively treated in less than 6 months was 52.7%, the corresponding figure for non-vital teeth was 14.0% ($\chi^2 = 4.864$, $P < 0.05$). There was also a significant relationship between pulp necrosis observed and the total time spent for definitive treatment. Of the teeth without pulp necrosis, 77.4% were definitively treated in less than 6 months, however, 17.4% of teeth with pulp necrosis could be treated in the same period ($\chi^2 = 29.566$, $P < 0.05$).

Discussion

In treatment timing guidelines reviewed by Andreasen et al. (18) crown fractures were placed into the last category in which delayed treatment (after 24 h) has been recommended for this type of injury. Crown fractures are a less severe form of traumatic injury when their clinical presentations, possible complications, and sequelae are compared to those of luxation injuries. However, timely referral to the dentist after any traumatic injury and seeking immediate care for the injured tooth is of great importance. Delays in treatment can have adverse effects on long-term outcomes (19-21).

The results of a prevalence study by Tovo et al. (**17**) relating to crown fractures among schoolchildren indicated that only 20% of children sought treatment after dental injury. In their study Marcenes et al. (**22**) also reported that the treatment of traumatic lesions was highly neglected (96.7%). In the present study, only 16.13% of patients were referred to the clinic within 1 day following a crown fracture injury. Lack of information about dental trauma and its consequences might be responsible for delays in seeking dental care after a traumatic injury.

Access to dental care is another point that contributes to this problem. The institution where the data of the present study were obtained does not offer after office hours dental service. This point may be an explanation for trauma cases with late presentation times observed. Trauma cases occurring in the evening and night times were likely to be referred in the following day(s). Providing after office hours or dental emergency service is important and the ways for improvement of such service should be explored.

Following an enamel–dentin fracture, potential invasion of sectioned tubules by bacteria via exposed dentin is a point of concern. Bacteria and their products have been suggested as one of the most important etiological factors in inflammatory reactions of the human dental pulp. Existing passive and active defense mechanisms of pulp limits bacterial invasion (**23**). The outward flow of dentinal fluid within the tubules puts up a 'passive' resistance to bacterial invasion through a gradient of hydrostatic pressure (**24**). The 'active' mechanism consists of an immediate inflammatory response to outside stimuli, bacterial toxins or bacteria. Invasion of the dentinal tubules by polymorphonuclear leukocytes and formation of plasma protein clotting in the extravascular space next to the affected dentin take place (**25**). A critical factor in this process is the intact pulpal vascular supply (**26**). Efficient and proper sealing of dentin also contributes to the healing in crown fracture injuries. It has been stated that only in the case of improper sealing will further irreversible pulpal lesions occur (**27**).

In the present study, initial treatment of the fractured teeth was mostly carried out by an interim restoration with composite resin. During these procedures total etching technique in combination with acetone-based adhesive system was utilized. The use of total etching technique has been favored as it would provide more durable restorations of crown-fractured teeth (**28**). Calcium hydroxide liner was not used during interim restoration beneath the composite covering. Its use in contemporary restorative procedures with composite resin has been disputed, primarily because of its poor capacity to bond with dentin (**28**). Pulling away of material from dentin by the contraction forces inherent in the setting reaction of composite resins have been reported (**29**). Olsburgh & Krejci (**27**) did not find indirect pulp capping necessary to protect the pulp as it would prevent resin tag penetration into the tubules, and hence reduce sealing efficacy and bond strength of the future restoration. In addition, in clinical service the properties of hard-setting calcium hydroxide seem to undergo physical as well as chemical changes as indicated by the observation that bacteria can penetrate the material (**30, 31**).

Complications following crown fractures are uncommon and the most observed is pulp necrosis (**11, 27**). Concomitant luxation injury has been reported to increase the likelihood of pulp necrosis (**32**). Borssen et al. (**7**) reported that pulp necrosis developed in 2% of the teeth with uncomplicated crown fractures. A similar finding has been reported by Robertson (**33**). Cavalleri & Zerman (**34**) reported that pulp necrosis occurred in 6% of incisors with crown fractures in immature teeth. In a study by Ravn (**35**), pulp necrosis was observed in 3.2% of teeth with enamel–dentin fracture as the only damage. In

the present study, pulp necrosis was observed in 23 teeth with uncomplicated crown fractures (8 with open apices, 15 with closed apices), making 21.5% of 107 teeth. The relatively high number of pulp necrosis observed in this study might be explained by the following factors.

The first one is related to initial diagnosis and vitality testing of the teeth on admittance. Despite the efforts to make an accurate diagnosis of crown-fractured teeth, the possibility of undetected or undiagnosed existing concomitant luxation injury, i.e., subluxation, cannot be ruled out. This is particularly true for patients with late presentation times, which might have masked the underlying luxation injury. Further, the trauma causing the loss of tooth structure may have affected the circulatory system of the pulp to the extent that the repair potential of the tissue is compromised (**28**).

The assessment of pulp vitality is a crucial diagnostic step in the practice of dentistry, especially in decision-making after traumatic injuries. The present methods of assessing pulp vitality (electric and thermal testing) are of limited use with children, often resulting in false-positive or false-negative results (**36**). Each test depends on the patient's perceived response to a stimulus as well as the dentist's interpretation of that response (**37**).

Recent studies have shown that blood circulation and not innervation is the most accurate determinant in assessing pulp vitality as it provides an objective differentiation between necrotic and vital pulp tissue (**38**). The newer pulp testing devices, some of which are still under development stage, detect the blood supply of the pulp through light absorption and reflection and are considered to be more accurate and non-invasive. They rely either on the detection of changes in the light absorption as it passed through the tooth, as in pulse oximetry (**36**, **39**) and dual wavelength spectrophotometry (**40**) or the shift in light frequency as it is reflected back from a tooth, as in laser Doppler flowmetry (**41**, **42**). In the present study, diagnosis of pulp vitality of teeth has been mostly carried out by electric pulp testers. With the availability of these devices, objective and accurate readings of pulp vitality of injured teeth could have been obtained on admission. However, this issue needs further exploration.

Direct and indirect biological risks of resin-based materials to the dentin–pulp complex have been reported in a critical review by Bouillaguet (**43**). He has classified these risks broadly into two categories: direct risks stemming from the toxicological properties of the materials themselves and indirect risks stemming from microbiological leakage. From a toxicological point of view, biocompatibility of dentin-bonding agents is imperative when they are placed on etched dentin near the pulp where tubular density and diameter are greatest (**43**). Bonding agents are also at greater risk for incomplete cure as they are thin, and oxygen inhibition of polymerization is a significant factor (**44**). On the other hand, any unpolymerized monomer in the composite is a potential biological liability if it leaches from the composite toward the pulp of the tooth (**45**). The results of cytotoxicity studies have confirmed that risk assessment of dentin adhesives must also be considered with a long-term view (**43**).

The selection of restorative materials has an important influence on bacterial leakage (**46**). The placement of enamel-bonded resin composite and adhesive-bonded resin composite does not seem to result in a perfect seal with cavity walls, because bacteria were detected in these restorations (**47**). The detection of bacteria beneath composite resin restorations demonstrates the continued need for improvement in the adherence and marginal sealing ability of these materials (**18**, **46**). It would seem

that restorative materials that form the most perfect sealing with tooth structure are able to prevent the bacterial microleakage most. The prevention of bacterial microleakage will limit the severity of pulp inflammation and help maintain pulp tissue vitality (**46**).

Following a crown fracture, the amount of exposed dentin should also be taken into consideration as it could influence the number of dentinal tubules exposed and their proximity to the pulp in a young permanent tooth. Ravn (**35**) has emphasized the relationship between extent of dentin exposure and pulpal necrosis as well as influence of treatment on pulpal necrosis. However, no classification regarding this matter has been carried out during registration of trauma cases of the present study.

There is increasing evidence that the influence of the operator is of paramount importance in the performance of dentin-bonding agents (**43**). Different operators are involved in the treatment and follow up of the trauma cases of the present study. Although, for each case, the procedures have been performed under supervision of the authors of the study (HCG and NA), operator-related differences and their contribution to the presented results cannot be ruled out.

Conclusions

Quick, timely and appropriate management of dental traumatic injuries would contribute to better prognosis of injured teeth. In this context, providing after office hours or dental emergency service is of great importance. There is also a great need for raising public awareness regarding the traumatic injuries of dental origin and their consequences. Operator-related factors (diagnosis, selection of adhesive system, and restorative material as well as their application, either interim or definitive) should be the subject of future improvement.

Acknowledgments

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