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Survival analysis of fragment reattachments and direct composite restorations in permanent teeth after dental traumatic injuries

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Abstract

Background/Aim: In case of crown fractures after traumatic dental injuries, the affected teeth can be restored either with reattachment of the fractured fragment or with a direct composite restoration. So far, longevity data for reattachments and direct composite restorations with regard to different failure types (pulp necrosis and infection, restoration loss) are scarce. Therefore, the aim of this retrospective study was to evaluate the restorative and biological survival of reattached fragments and composite restorations after crown fractures in permanent teeth.

Material and Methods: Dental records of patients treated between 2000 and 2018 were retrospectively analysed regarding the restoration (reattachment or direct composite restorations) of teeth with crown fractures. Survival (no further intervention) and restorative and/or biological failure of all restored teeth were recorded. Statistical analysis was performed using Kaplan–Meier statistics, and the mean annual failure rates for two and 5 years were calculated. Furthermore, the effect of potential risk factors on survival was assessed. Log-rank tests and univariate Cox regression models (likelihood ratio tests) were used to assess the univariate effect of all variables of interest. Variables with a p-value ≤.10 were included in a multivariate Cox regression model with shared frailty ($p < .05$).

Results: Overall, 164 patients with 235 teeth (uncomplicated crown fracture: N = 201, complicated crown fracture: N = 34) were included (1.6 ± 2.5 years observation time). Of these, 59 teeth were restored with reattachment of the fragment and 176 with a composite restoration. Overall, composite restorations had a significantly higher survival rate than reattachments ($p = .002$). The cumulative survival after 2 years was 42.9% and 65.0% for teeth treated with a reattachment (mAFR = 34.5%) and a composite restoration (mAFR = 19.3%), respectively. When differentiating between failure types, restoration failure and pulp necrosis were significantly more frequently detected in reattached crown fractures compared to composite restorations (restorative failure: $p = .001$; biological failure: $p = .036$). In the multivariate Cox regression model, the variable jaw and luxation significantly influenced the survival when the

tooth was restored with a composite restoration. The survival was not influenced by the fracture type.

Conclusions: Restorative and biological failures were more frequently detected when the tooth was restored with a reattached fragment compared to a direct composite restoration. Both, restoration failure and pulp necrosis with infection should be considered as frequent complications after restoration of crown-fractured teeth which emphasizes the necessity of regular and short follow-up intervals throughout the first 2 years.

KEYWORDS
adhesive reattachment, composite restoration, crown fracture, dental traumatic injury, survival

1 | INTRODUCTION

Traumatic dental injuries (TDI) occur very frequently, especially in children and young adults. Twenty-five per cent of all school children and 33% of adults experience dental trauma to the permanent dentition, with the majority occurring before the age of 19.[1] Whereas luxation injuries are the most commonly reported TDIs for primary teeth, crown fractures are most prevalent in the permanent dentition.[1,2] As the maxillary incisors are the most commonly injured teeth due to their exposed position, a functional, aesthetic and time-efficient restoration is frequently demanded.[3] According to the current International Association of Dental Traumatology guidelines, crown fractures confined to enamel and dentine may be treated either with a direct composite restoration or with an adhesive reattachment of the fractured fragment.[4] As long as the fragment is intact, reattachment is often preferred in dental practice. This technique facilitates the restoration of the tooth with its original anatomy, colour and function in a minimum amount of time.[5,6] Unfortunately, clinical studies regarding the survival of reattached fragments are scarce, and results from laboratory investigations cannot be transferred to clinical settings without limitations.[7] Furthermore, longevity data of direct composite restorations in fractured anterior teeth are restricted to a few clinical studies.[8,9] Considering these limitations of data, the aim of this retrospective study was to provide longevity information about the survival of the pulp and the restoration with respect to the type of restorative treatment (reattachment or direct composite restoration) and to identify potential variables affecting the survival.

2 | MATERIALS AND METHODS

The study was approved by the local ethics committee of the University Medical Centre Göttingen (no.19/8/19) and conducted in accordance with the Declaration of Helsinki (Registration on www.drks.de; ID: DRKS00028519). The study included patients affected by dental trauma who were treated at the Department of Preventive Dentistry, Periodontology and Cariology at the University Medical Centre Göttingen between January 2000 and December 2018.

Before treatment, each patient was examined clinically and radiographically. When the coronal fragment had been saved, reattachment was considered, irrespective of pulp exposure and the defect size. In order to obtain all relevant information about the treatments, two investigators (C.M. and F.H) reviewed all digital and paper-based dental records of all patients having received direct composite restorations or reattachments of the coronal tooth fragment after a TDI. All permanent teeth that had sustained enamel-dentin-fractures were included. A fracture was considered complicated if it was associated with a pulp exposure and uncomplicated if there was no pulp exposure. Exclusion criteria were as follows: cases with inadequate documentation, teeth with pulp necrosis and infection or previously root-filled, fractures limited to enamel, crown-root-fractures, definitive treatment provided elsewhere, temporary restorations and severely damaged teeth without the possibility of preservation.

The data extraction included the following: first, individual-related variables (gender, age); second, details about the traumatized teeth [the date of the dental trauma, fracture type (with/without pulp exposure), tooth luxation (yes/no)]; and third, relevant information about the corresponding treatment [the date of the restoration, restoration type (reattachment or composite restoration), restorative materials (adhesive application mode and composite material) and the date of the last clinical or radiologic review]. Due to the low risk of complications after concussion and subluxation of permanent teeth, these injuries were defined as 'no luxation'.[10] In contrast, all severe injuries (extrusion, lateral luxation, intrusion and avulsion) were summarized as 'luxation'. In case of inadequate documentation or if the minimum required information could not be taken from the patient's records, the case was excluded.

All reattachments and direct composite restorations still in situ without further intervention until the date of censoring (last review) was considered as 'survived'. Two events were defined as failures: first, restorations were rated as failed if either the fragment detached or at least one of the involved surfaces of the composite restoration had been restored again. In case of restorative failure, restorations were regarded as failed at the date of intervention. Second, biological failure was recorded in case of negative pulp sensibility tests

followed by endodontic treatment or if the tooth was extracted. Equally, the date of intervention was regarded as the failure date.

Statistical analysis was carried out using the software R (version 4.1.2, www.r-project.org) and the packages 'survminer' (version 0.4.9), 'survival' (version 3–3.13) and 'dplyr' (version 1.0.8). The level of significance was set at $\alpha = .05$. The restorative and the biological survival were assessed up to 5 years by Kaplan–Meier statistics. Mean annual failure rates (mAFR) at 2 and 5 years were calculated by the following formula[11]

$$(1-y)^z = 1-x$$

$$y = 1-\sqrt[z]{1-x}$$

where y = mAFR, x = the failure rate and z = the number of observation years.Log-rank tests (categorical variables) and univariate Cox regression models (likelihood ratio tests, continuous variables) were used to assess the univariate effect of all variables of interest. Subsequently, variables with a p-value ≤ 10 were included in a multivariate Cox regression model with shared frailty of correlated observations (restorations within the same patient). Hazard ratios and the respective 95% confidence intervals were calculated for variables significantly associated with failure. For both univariate and multivariate analyses, all complications (restorative and biological) were regarded as failure.

Additionally, the survival of reattachments and composite restorations was separately assessed for restorative and biological complications. Univariate log-rank tests were performed to compare both treatment options.

3 | RESULTS

A total of 208 patients with 312 traumatized permanent teeth with crown fractures were eligible for inclusion. Of this population, 44 patients with 77 teeth were excluded due to inadequate documentation (N = 24), endodontic treatment prior to coronal restoration (N = 31), fractures limited to enamel (N = 10), crown-root-fractures (N = 2), definitive treatment elsewhere (N = 5) or temporary restorations (N = 5). Hence, 235 teeth (uncomplicated crown fracture: N = 201; complicated crown fractures: N = 34) from 164 patients (103 males/61 females; mean age 18.2 ± 10.3 years) were included. Of these, 59 teeth were restored with fragment reattachment and 176 teeth were treated with a direct composite restoration. The mean observation time was 1.6 ± 2.5 years. The maxillary central incisors were the most frequently affected teeth (N = 185, 78.7%), followed by the maxillary lateral incisors (N = 31, 13.2%). Mandibular incisors (N = 16, 6.8%), canines (N = 2, 0.85%) and premolars (N = 1, 0.43%) were less frequently affected.

Table 1 presents the potential risk factors subjected to the univariate analysis. For reattachments, the time between trauma and definitive treatment and the adhesive application mode were found to be significant with regard to failure. For direct composite restorations, significant factors were the jaw and tooth luxation. Results of the multivariate Cox regression analyses revealed the lower jaw to decrease and a luxation injury to increase the risk for failure when the tooth was restored with a composite restoration (Table 2).

The distribution of failed cases with regard to their diagnosis after TDI is shown in Table 3. There were 59.3% of the teeth treated with reattachment and 77.8% of the teeth restored with a direct composite restoration that had survived until censoring. Regarding the prevalence of complications, almost all teeth that had a luxation injury in addition to the crown fracture developed pulp necrosis and infection. Restorative failure occurred in both groups, irrespective of the diagnosis.

In the reattachment group, 50% of the biological and restorative failures occurred within the first year after treatment (Table 4). In contrast, for teeth restored with a composite restoration, 50% of all biological and restorative failures were observed within the first 1.5 and 2 years, respectively.

Survival probabilities regarding both events were assessed up to 5 years by Kaplan–Meier statistics for reattachments as well as composite restorations (Figure 1). The cumulative survival after 2 years, irrespective of the failure type, amounted to 42.9% and 65.0% for teeth treated with a reattachment (mAFR = 34.5%) and a composite restoration (mAFR = 19.3%), respectively.

4 | DISCUSSION

The current study presents data about the outcome and survival probability of reattached fragments and composite restorations of permanent teeth with coronal fractures after TDI. Consistent with the literature, the maxillary central incisors followed by the maxillary lateral incisors were the most commonly affected teeth with a total percentage of 91.9%.[3,9,12] Regarding the pulp, the majority of the included teeth (85.5%) had an uncomplicated fracture, which is consistent with previously published data.[13,14] Nevertheless, both clinical situations may be treated either with a reattachment of the fragment or with a direct composite restoration.[4,9,15,16] In case of pulp exposure, the pulp needs to be treated appropriately with a bioactive agent as a pulp capping material (e.g. MTA or calcium hydroxide suspension), irrespective of the following restoration type.[4] The key information from this study is that the survival of the treated tooth regarding both failures (restorative and biological) is significantly reduced when a fragment was reattached compared to having a direct composite restoration. This finding is partially confirmed by a previous study stating a significant higher rate of restoration losses in case of reattachments.[9] However, reattachment is often considered to be the method of choice as the fragment represents the ideal reconstruction of morphology and texture.[6,17] Another advantage aspect is that reattachment is a very time-effective procedure, which is especially important when treating very young patients.

An explanation for the higher cumulative survival rates for composite build-ups compared to reattachments is the probability of bevelling the restoration margins and enlarging the bonding surface area to the enamel. Several studies have been published in order

TABLE 1 Descriptive data (absolute numbers and percentages for categorical variables, means and standard deviations for continuous variables) and *p*-values from the univariate analysis if all complications are regarded as failure

	Reattachments (N = 59) patients (*n* = 49)		Composite restorations N = 176) patients (*n* = 119)	
	N (%)/mean ± SD	*p*-Value	N (%)/mean ± SD	*p*-Value
Gender		.340		.570
Male	37 (62.7)		116 (65.9)	
Female	22 (37.3)		60 (34.1)	
Age (years, mean ± SD)	16.5 ± 10.8	.420	18.7 ± 10.2	.297
Jaw		.880		**.045**
Maxilla	54 (91.5)		165 (93.8)	
Mandible	5 (8.5)		11 (6.2)	
Fracture type		.240		.730
With pulp exposure	19 (32.2)		15 (8.5)	
Without pulp exposure	40 (67.8)		161 (91.5)	
Pulp treatment		.310		.360
None/indirect pulp capping	41 (69.5)		160 (90.9)	
Direct pulp capping/ pulpotomy	18 (30.5)		16 (9.1)	
Material used for pulp treatment		.310		.450
None	38 (64.4)		152 (86.4)	
Calcium hydroxide	18 (30.5)		20 (11.4)	
Biodentine	3 (5.1)		1 (0.6)	
MTA	0 (0.0)		3 (1.7)	
Tooth luxation[a]		.180		**<.001**
No	55 (93.2)		163 (92.6)	
Yes	4 (6.8)		13 (7.4)	
Time between trauma and definitive restoration (days, mean ± SD)	0.9 ± 3.9	**.054**	38.7 ± 80.0	.660
Adhesive application mode (N = 205)[b]		**.013**		.79
Etch and rinse	50		150	
Self-etch	2		3	
Composite material		.400		-
Flowable only	43 (72.9)		0 (0.0)	
Sculptable	16 (27.1)		176 (100.0)	

Note: Due to the effect of rounding, some numbers do not add up to 100%. *p*-Values ≤ .10 are marked in bold.

[a]no: None, concussion, subluxation; yes: Extrusion, luxation, intrusion, avulsion.

[b]reduced number of teeth due to missing data.

to assess the ideal technique for adhesive reattachments of fractured crowns. Preparation techniques, different adhesive strategies and different materials have been examined extensively in ex vivo studies.[7,18–25] Possible techniques are the preparation of an external chamfer, an internal groove or the over-contour technique.[7,22] The internal groove and the over-contour techniques almost reached the fracture strength of an intact tooth, recovering 97.2% and 90.5%, respectively.[22] Nevertheless, the influence of these preparation techniques should be analysed carefully as the methods to obtain simulated fragments are different. Sectioning of the crowns with a diamond saw results in hard tissue loss and a lack of mechanical interlocking between the fragment and the remaining tooth, whereas a fracture produces two parts that fit together without a discernible gap.[7]

Regarding the adhesive application mode, the data of the present study show the most frequent use of an etch and rinse adhesive system. The use of phosphoric acid as a separate conditioner still represents the gold standard for reliable enamel bonding and may

TABLE 2 Parameters in the multivariate cox regression analysis (*p*-value, hazard ratio, 95% CI = 95% confidence)

Variable	Reattachments		Composite restorations	
	p-Value	Hazard ratio (95% CI)	*p*-Value	Hazard ratio (95% CI)
Jaw				
Mandible vs. maxilla (=1)	–	–	**<.001**	<0.001 (<0.001–<0.001)
Time between trauma and definitive treatment	.713	–	–	–
Luxation				
Yes vs. no (=1)	–	–	**<.001**	7.53 (3.10–18.34)
Adhesive application mode				
Self-etch vs. etch and rinse (=1)	.552	–	–	–

Note: p-Values ≤ .05 are marked in bold.

TABLE 3 Overview of survival and complication rates for reattachments and composite restorations with regard to their diagnosis after dental trauma

Restorative treatment	Type of injury	Survival		Complications					
				Restorative failure		Biological failure		Total	
		N	%	N	%	N	%	N[a]	%
Reattachment (N = 59)	Uncomplicated crown fracture without luxation (N = 37)	26	70.3	11	29.7	0	0.0	11	29.7
	Uncomplicated crown fracture with luxation (N = 3)	0	0.0	2	66.7	3	100	3	100
	Complicated crown fracture without luxation (N = 18)	9	50.0	8	44.4	5	27.8	9	50.0
	Complicated crown fracture with luxation (N = 1)	0	0.0	0	0.0	1	100	1	100
	Total:	35	59.3	21	35.6	9	15.3	24	40.7
Composite restorations (N = 176)	Uncomplicated crown fracture without luxation (N = 149)	125	83.9	24	16.1	0	0.0	24	16.1
	Uncomplicated crown fracture with luxation (N = 12)	1	8.3	3	25.0	11	91.7	11	91.7
	Complicated crown fracture without luxation (N = 14)	11	78.6	3	21.4	0	0.0	3	21.4
	Complicated crown fracture with luxation (N = 1)	0	0.0	0	0.0	1	100	1	100
	Total:	137	77.8	30	17.0	12	6.8	39	22.2

[a]one tooth may have multiple complications.

guarantee a bonding force stronger than self-etch adhesives.[26,27] However, not only the technique used to reattach a fragment but also the fracture pattern has an effect on the longevity of reattachments.[28] Fractures perpendicular to the long axis of the tooth and oblique fractures running from the labial to the palatal/lingual aspect with a fracture line proceeding in an apical direction have no palatal or lingual support, and, therefore, they are less resistant to labial forces.[29] Unfortunately, these unfavourable fracture patterns account for 80% of all crown fractures.[28,30]

In contrast to the present study, another study on the performance of reattached fragments reported a higher success rate of 73.3% over a similar mean observation time of 1.7 ±2.7 years and a second or even third reattachment after several detachments resulted in higher success rates of 82.9% and 84.4%, respectively.[12] Nevertheless, the marginally increased probability for detachment in teeth with complicated crown fractures was confirmed by that study.[12]

Another publication with a mean observation time of 1.4 ±2.5 years also reported slightly higher success rates of 72.6% and 80.7% for reattachments and composite restorations, respectively.[9] However, there was no significant difference between restoration types concerning the biological failure, while the present study reported significant differences for both restorative and biological failures. An explanation for the different success rates of

TABLE 4 Overview of the periods until restorative or biological failure occurred with regard to the restoration type

		Restorative failure			Biological failure		
Restorative treatment	Time (years)	N	%	Cum. %	N	%	Cum. %
Reattachment (N = 59)	<0.5	10	47.6	47.6	3	33.3	33.3
	0.5–1.0	4	19.0	66.6	2	22.2	55.5
	1.1–1.5	1	4.8	71.4	1	11.1	66.6
	1.6–2.0	–	–	–	0	–	–
	>2.0	6	28.6	100	3	33.3	100.0
	Total:	21	100	100	9	100	100
Composite restorations (N = 176)	<0.5	5	16.7	16.7	2	16.7	16.7
	0.5–1.0	7	23.3	40.0	3	25.0	41.7
	1.1–1.5	2	6.7	46.7	1	8.3	50.0
	1.6–2.0	5	16.7	63.4	2	16.7	66.7
	>2.0	11	36.6	100	4	33.3	100
	Total:	30	100	100	12	100	100

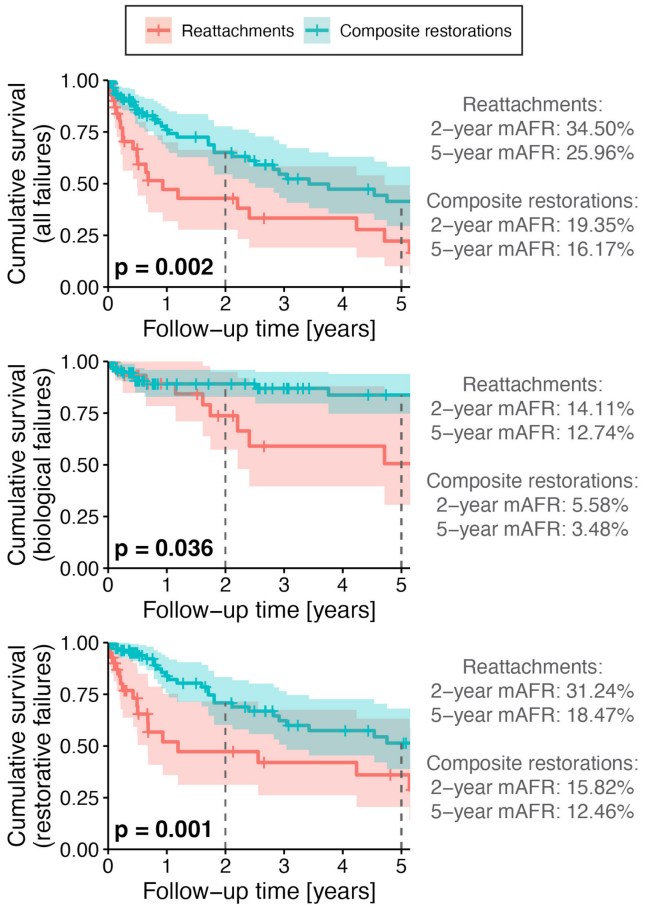

FIGURE 1 Kaplan–Meier survival plots over 5 years for different failure levels (all complications, biological failures only, restorative failures only). *p*-Values from log-rank tests. Both 2-year and 5-year mean annual failure rates (mAFR) are displayed for each failure level.

these studies compared to the present investigation might be the different inclusion criteria and an included patient population with ages ranging from 0–86 years.[9,12]

It can be speculated that the reason for the increased biological failure of teeth restored with a reattachment compared to composite restorations might be the higher prevalence of complicated crown fractures in the group of reattachments. Without any doubt, fragments require a certain size to be found by the patient subsequent to the TDI and to enable the reattachment procedure for the dentist, increasing the probability for pulp involvement. However, owing to the limited number of included cases with a complicated crown fracture, a significant influence of the fracture type on the development of pulp necrosis was not established by the present study. Nevertheless, when viewing the data in this context, notable trends for the association between pulp involvement and subsequent pulp necrosis can be observed (Table 3).

Despite the lower survival probability of reattachments observed in the present study, this finding should be carefully interpreted as many factors which could not be identified from the available data may influence the success of the reattachment procedure. Due to its minimal invasiveness and aesthetics, it should still be considered as a reliable short-term option.[6]

In the univariate analysis, the survival of both restoration types depended on several variables (Table 1). In the Cox regression model, only the lower jaw and an additional luxation injury remained significantly associated with the survival of composite restorations. Another traumatic injury was one of the main reasons for restoration loss.[15,31] As maxillary incisors are the most common teeth affected by TDI, these teeth are also exposed to a higher risk for a second injury than mandibular teeth.[9,12,13,32] Furthermore, maxillary incisors are subjected to off-axial loads which might result in a higher failure susceptibility. Consistent with the literature, the second significant variable associated with failure was a concomitant luxation injury.[9,15,32] These teeth are more prone to pulp necrosis because of the compromised blood supply to the pulp after luxation which results in a reduced capacity to prevent bacterial invasion.[33]

In general, the present study reported a reduced restorative survival rate for composite restorations compared to previous

published data.[34,35] The reason why teeth receive composite restorations seems to have an influence on the success of the restoration. Whereas one study on traumatized teeth stated a high rate of replacements (87%) within the first 5 years after restoration,[8] the survival of composite build-ups of healthy teeth (including situations with large surface areas: recontouring of teeth, closing of diastemas) exhibited a 5-year survival rate of 84.6%.[34]

Another relevant aspect regards the time point when endodontic or restorative failure may occur. Of all documented endodontic failures, 55.5% and 41.7% occurred within the first year for reattachments and composite restorations, respectively. A study that assessed the longevity of reattachments and composite restorations with regard to the type of fracture and a concomitant luxation injury reported percentages between 64.3% and 89.5% of all endodontically failed cases within the first year.[9] These values and the results from the present study emphasize the necessity of follow-ups at quarterly intervals for the first 2 years after traumatic crown fracture. Regarding the loss of the restoration, 66.6% and 40.0% of all reported restorative failures occurred within the first year for the reattachments and composite restorations, respectively. These percentages are even lower than reported by a similar study evaluating the longevity of reattachments with respect to the type of fracture.[12]

The strength of the present investigation is the detailed analysis of data including multiple variables observed from the dental records. Furthermore, all included patients were treated from the beginning of the year 2000, indicating that treatments were carried out based on the current clinical guidelines.[36–38] The results from the survival analyses provide valuable information about the prognosis of complicated and uncomplicated crown fractures with respect to the restoration type.

Some limitations of this retrospective study are related to the study design. First, the information was collected from digital and paper-based records, radiographs and trauma documentation sheets. Therefore, completeness of the documentation could not be assured and resulted in exclusion of certain cases. Furthermore, despite the published clinical guidelines, different diagnostic and treatment decisions might have been made due to different levels of experience and skills of dentists working in the Department of Preventive Dentistry, Periodontology and Cariology. Second, with a mean observation time of 1.6 years, this study provides mid-term clinical information compared to previously published studies.[8,39] Several patients might have asked other dentists in private practices to perform the monitoring after TDI without the authors' knowledge. Therefore, these cases were lost to follow-up, resulting in a decreased number of patients over an increasing observation time.

5 | CONCLUSION

Restorative and biological failures were more frequently detected in case of reattached fragments compared to direct composite restorations. Both failures should be considered as a frequent complication after restoration of crown-fractured teeth. Pulp necrosis with infection is more likely to occur in cases with a concomitant luxation injury. For both restoration types, most complications occurred within the first 24 months after the trauma, which highlights the necessity of regular and short follow-up intervals throughout the first 2 years.

AUTHOR CONTRIBUTIONS

All authors have made substantial contributions and approved the final version of the manuscript.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study protocol was approved by the local ethics committee (no.19/8/19).

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REFERENCES

1. Levin L, Day PF, Hicks L, O'Connell A, Fouad AF, Bourguignon C, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: general introduction. Dent Traumatol. 2020;36:309–13.
2. Atabek D, Alaçam A, Aydintuğ I, Konakoğlu G. A retrospective study of traumatic dental injuries. Dent Traumatol. 2014;30:154–61.
3. Andreasen JO. Etiology and pathogenesis of traumatic dental injuries. a clinical study of 1,298 cases. Scand J Dent Res. 1970;78:329–42.
4. Bourguignon C, Cohenca N, Lauridsen E, Flores MT, O'Connell AC, Day PF, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and luxations. Dent Traumatol. 2020;36:314–30.
5. Sarapultseva M, Sarapultsev A. Long-term results of crown fragment reattachment techniques for fractured anterior teeth: a retrospective case-control study. J Esthet Restor Dent. 2019;31(3):290–4.
6. Olsburgh S, Jacoby T, Krejci I. Crown fractures in the permanent dentition: pulpal and restorative considerations. Dent Traumatol. 2002;18:103–15.
7. Loguercio AD, Mengarda J, Amaral R, Kraul A, Reis A. Effect of fractured or sectioned fragments on the fracture strength of different reattachment techniques. Oper Dent. 2004;29:295–300.
8. Spinas E. Longevity of composite restorations of traumatically injured teeth. Am J Dent. 2004;17:407–11.
9. Bissinger R, Müller DD, Reymus M, Khazaei Y, Hickel R, Bücher K, et al. Treatment outcomes after uncomplicated and complicated crown fractures in permanent teeth. Clin Oral Investig. 2021;25:133–43.

10. Andreasen FM, Pedersen BV. Prognosis of luxated permanent teeth—the development of pulp necrosis. Endod Dent Traumatol. 1985;1:207–20.
11. Opdam NJM, Bronkhorst EM, Loomans BAC, Huysmans M. 12-year survival of composite vs. amalgam restorations. J Dent Res. 2010;89:1063–7.
12. Bissinger R, Müller DD, Hickel R, Kühnisch J. Survival analysis of adhesive reattachments in permanent teeth with crown fractures after dental trauma. Dent Traumatol. 2021;37:208–14.
13. Ramachandran A, Khan SIR, Al-maslamani M, Baskaradoss JK. Pattern of traumatic dental injuries among adults. Open Access Emerg Med. 2021;13:201–6.
14. Tapias MA, Jiménez-García R, Lamas F, Gil AA. Prevalence of traumatic crown fractures to permanent incisors in a childhood population: Móstoles, Spain. Dent Traumatol. 2003;19:119–22.
15. Andreasen FM, Norén JG, Andreasen JO, Engelhardtsen S, Lindh-Strömberg U. Long-term survival of fragment bonding in the treatment of fractured crowns: a multicenter clinical study. Quintessence Int. 1995;26:669–81.
16. Yilmaz Y, Zehir C, Eyuboglu O, Belduz N. Evaluation of success in the reattachment of coronal fractures. Dent Traumatol. 2008;24:151–8.
17. Yilmaz Y, Guler C, Sahin H, Eyuboglu O. Evaluation of tooth-fragment reattachment: a clinical and laboratory study. Dent Traumatol. 2010;26:308–14.
18. Bruschi-Alonso RC, Alonso RCB, Correr GM, Alves MC, Lewgoy HR, Sinhoreti MAC, et al. Reattachment of anterior fractured teeth: effect of materials and techniques on impact strength. Dent Traumatol. 2010;26:315–22.
19. Demarco FF, Fay R-M, Pinzon LM, Powers JM. Fracture resistance of re-attached coronal fragments—influence of different adhesive materials and bevel preparation. Dent Traumatol. 2004;20:157–63.
20. de Sousa APBR, França K, de Lucas Rezende LVM, do Nascimento Poubel DL, Almeida JCF, de Toledo IP, et al. In vitro tooth re-attachment techniques: a systematic review. Dent Traumatol. 2018;34:297–310.
21. Pusman E, Cehreli ZC, Altay N, Unver B, Saracbasi O, Ozgun G. Fracture resistance of tooth fragment reattachment: effects of different preparation techniques and adhesive materials. Dent Traumatol. 2010;26:9–15.
22. Reis A, Francci C, Loguercio AD, Carrilho MR, Rodriques Filho LE. Re-attachment of anterior fractured teeth: fracture strength using different techniques. Oper Dent. 2001;26:287–94.
23. Reis A, Kraul A, Francci C, de Assis TGR, Crivelli DD, Oda M, et al. Re-attachment of anterior fractured teeth: fracture strength using different materials. Oper Dent. 2002;27:621–7.
24. Pagliarini A, Rubini R, Rea M, Campese M. Crown fractures: effectiveness of current enamel-dentin adhesives in reattachment of fractured fragments. Quintessence Int. 2000;31:133–6.
25. Farik B, Munksgaard EC, Suh BI, Andreasen JO, Kreiborg S. Adhesive bonding of fractured anterior teeth: effect of wet technique and rewetting agent. Am J Dent. 1998;11:251–3.
26. Lührs A-K, Guhr S, Schilke R, Borchers L, Geurtsen W, Günay H. Shear bond strength of self-etch adhesives to enamel with additional phosphoric acid etching. Oper Dent. 2008;33:155–62.
27. Rosa WL, Piva E, Silva AF. Bond strength of universal adhesives: a systematic review and meta-analysis. J Dent. 2015;43:765–76.
28. Reis A, Loguercio AD, Kraul A, Matson E. Reattachment of fractured teeth: a review of literature regarding techniques and materials. Oper Dent. 2004;29:226–33.
29. Dean JA, Avery DR, Swartz ML. Attachment of anterior tooth fragments. Pediatr Dent. 1986;8:139–43.
30. Murchison DF, Worthington RB. Incisal edge reattachment: literature review and treatment perspectives. Compend Contin Educ Dent. 1998;19:731–4.
31. Pissiotis A, Vanderas AP, Papagiannoulis L. Longitudinal study on types of injury, complications and treatment in permanent traumatized teeth with single and multiple dental trauma episodes. Dent Traumatol. 2007;23:222–5.
32. Shahmohammadi R, Sheikhnezami M, Moradi S, Jafarzadeh H, Azarpazhooh A. Treatment outcomes of permanent immature teeth with crown fracture: a retrospective cohort study. J Endod. 2021;47:1715–23.
33. Robertson A, Andreasen FM, Andreasen JO, Norén JG. Long-term prognosis of crown-fractured permanent incisors. The effect of stage of root development and associated luxation injury. Int J Paediatr Dent. 2000;10:191–9.
34. Frese C, Schiller P, Staehle HJ, Wolff D. Recontouring teeth and closing diastemas with direct composite buildups: a 5-year follow-up. J Dent. 2013;41:979–85.
35. Oliveira GMS, Ritter AV. Composite resin restorations of permanent incisors with crown fractures. Pediatr Dent. 2009;31:102–9.
36. Flores MT, Andreasen JO, Bakland LK, Feiglin B, Gutmann JL, Oikarinen K, et al. Guidelines for the evaluation and management of traumatic dental injuries. Dent Traumatol. 2001;17:97–102.
37. Flores MT, Andersson L, Andreasen JO, Bakland LK, Malmgren B, Barnett F, et al. Guidelines for the management of traumatic dental injuries. I. Fractures and luxations of permanent teeth. Dent Traumatol. 2007;23:66–71.
38. Diangelis AJ, Andreasen JO, Ebeleseder KA, Kenny DJ, Trope M, Sigurdsson A, et al. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and luxations of permanent teeth. Dent Traumatol. 2012;28:2–12.
39. Robertson A, Robertson S, Norén JG. A retrospective evaluation of traumatized permanent teeth. Int J Paediatr Dent. 1997;7:217–26.

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