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Evaluation of tooth-fragment reattachment: a clinical and laboratory study

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Abstract – *Purpose*: To evaluate the restoration of fractured teeth by reattaching tooth fragment to its tooth remnant in a group of children and adolescents, and to compare the results with those of a laboratory study.
Materials and Methods: The clinical study was conducted on 43 fractured incisors: 22 uncomplicated crown fractures (Group A) and 21 complicated crown fractures (Group B). The 43 incisal fragments: 23 were kept dry for 47 h and 20 were kept wet for 24 h by the patients before they were reattached. The fragments were kept in 0.9% saline solution for 30 min before reattachment. The fragments in Group A were reattached using a dentin bonding agent, a flowable and a hybrid resin composite, whereas the fragments in Group B were reattached to the tooth remnant after a pulpotomy was performed. The laboratory study was conducted on 56 extracted incisors. Teeth were divided equally into four groups: Group I – Uncomplicated crown fracture + wet medium; Group II – Uncomplicated crown fracture + dry medium; Group III – Complicated crown fracture + wet medium, and Group IV – Complicated crown fracture + dry medium. The fragments were then reattached in a manner that was similar to that used in the clinical study. The restored teeth were then re-fractured. All data were analyzed statistically.
Results: In the clinical study, the restored teeth were followed up for 2 years. Neither the type of trauma nor the storage medium had any significant effect on the survival, color, and bond strength of the restored teeth when assessed in the clinical and laboratory study. The color disharmony that was encountered initially in restored teeth resolved significantly on its own accord within 12 months after reattachment of the fragment.
Conclusion: Fragment reattachment can be used to treat fractured teeth successfully in children and adolescents.

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One way to treat fractured tooth due to trauma is to reattach the tooth fragment to its remnant using a composite resin (1–4). The technique of reattaching a tooth fragment was first described by Chosack and Eidelman (5) in 1964, and this technique has numerous advantages over the other techniques: the shape and color of the restored tooth are maintained, the patient suffers no negative social and emotional effects after tooth restoration, and it is fast, reliable, and cost-effective (2, 3, 6–8).

The reattachment procedure usually involves storage and preparation of the fragment prior to its reattachment, and these procedures are important determinants of the overall clinical outcome. The results of several studies have shown that fragment discoloration is due to dehydration of dentin in the fragment and decreased bond strength between the tooth remnant and fragment (9, 10). Accordingly, it recommended that the fragment be kept moist in either tap water or physiologic saline until its reattachment to prevent the occurrence of these problems (9–11). Some investigators (12–14) claim that a good outcome can be achieved without additional preparation, such as making an internal enamel groove, an internal dentin groove, or a V-shaped groove in the external enamel of the tooth remnant and/or fragment prior to the reattachment procedure. Others (3, 7, 15–19) recommend that the tooth remnant or fragment should undergo additional preparation before reattaching the fragment. In fact, results from *in vitro* studies on fragment reattachment have shown that additional preparation to the tooth remnant and/or fragment improves the bonding between the tooth remnant and fragment (20–22).

In the dental literature, there are only a few studies on the survival of restored teeth after fragment reattachment. Cavalleri and Zerman (23) treated fractured crowns using either a composite resin when the fragment was not available, or fragment reattachment when the fragment was available. Five years after restoration, they found that 100% of the teeth that had been restored by fragment reattachment re-fractured, whereas 40% of the teeth that had been restored using a composite resin re-fractured (23). Andreasen et al. (24) reported their results on reattachment after acid etching alone and after acid etching together with a dentin bonding agent. The rate of survival of restored teeth that had been etched with acid only was 50% at 1 year, whereas that of teeth restored with acid etching and a dentin bonding agent was 50% at 3 years. Spinas (25) reported that all teeth that had been restored by fragment reattachment needed to be replaced completely 7 years after restoration. In view of the paucity of data on the overall clinical outcome of tooth restoration by fragment reattachment, we undertook a clinical and a laboratory study aimed at evaluating the effect of trauma type and the storage medium on the survival, color, and bond strength of restored teeth after fragment reattachment.

Materials and methods

Study design

The study consisted of two parts: a clinical and a laboratory study. The clinical study evaluated the effects of trauma type and the type of storage medium of the fragment on the survival of the restored tooth. To this end, we (i) compared the color harmony between tooth remnant and fragment, and (ii) determined the rate of pulpal survival in the restored tooth. The laboratory study compared the effects of trauma type and the type of storage medium on the bond strength between the tooth remnant and the reattached fragment.

Clinical study

A prospective clinical study was performed between 2003 and 2007 in the Pedodontics Department, School of Dentistry, Atatürk University, Erzurum, Turkey. The study involved children aged from 6 to 15 years (mean 10.4 ± 2.6) who presented at the Pedodontics Department with fragments of broken teeth following trauma.

The inclusion criteria for the study were that the patient (i) did not have an ongoing medical problem, periodontal disease, and caries of the tooth remnant; (ii) had no previous history of fractured teeth due to trauma and had not undergone a previous restoration to a fractured tooth by either fragment restoration or other methods; and (iii) was able to return for regular follow-up examinations.

Group A consisted of 22 incisors from patients who presented at our clinic 35 h (average) after trauma with an uncomplicated crown fracture that involved enamel and dentin. Group B consisted of 21 incisors from patients who presented at our clinic 38 h (average) after trauma with a complicated crown fracture that involved the enamel, dentin, and exposure of the pulp. Of the 43 incisal fragments, 23 were kept dry for 47 h and 20 fragments were kept in tap water for 24 h by the patient before reattachment. Thirteen of the 22 incisal fragments in Group A, and ten of the 21 incisal fragments in Group B were kept dry by the patient before reattachment. The remaining incisal fragments in the two groups were kept in tap water before they were reattached.

Treatment protocols

On arrival at the clinic, all the incisal fragments from Groups A and B were placed in 0.9% saline solution (İ.E. Ulagay, Istanbul, Turkey) for 30 min. Each patient was treated under local anesthesia (Ultracaine DS; Aventis, Istanbul, Turkey), and a rubber dam was placed to isolate the fractured tooth.

In Group A, the dentin was not covered with liner cement before the reattachment procedure. No pre-reattachment preparations were carried out on either the tooth remnant or the incisal fragment of the fractured tooth. Prior to reattachment, the incisal fragment was removed from the saline solution, dried gently with an air spray, and then was fastened to a piece of adhesive wax for ease of handling. The tooth remnant was separated from the mesial and distal teeth by a celluloid band during the reattachment procedure. The tooth remnant and incisal fragment were etched with 35% phosphoric acid using the total-etch technique. The acid was removed using a water spray. Then, the surfaces were dried using polyurethane pellets (Pele Tim; Voco, Cuxhaven, Germany). Dentin bonding agent (Prime & Bond NT™; Dentisplay, Konstanz, Germany) was then applied according to the manufacturer's instructions. After 20 s, the bonding agent was spread using an air spray for 3–5-s, and then cured under a visible light source for 10 s. In Group B, pulpotomy was performed on the tooth remnant by placing calcium hydroxide (Life Fast Set; Kerr, Salerno, Italy) directly onto the exposed pulpal tissue. The remnants of the pulpal tissue in the incisal fragments were removed using a slowly rotating round bur (S1-012-RA; NTI, Kahla, Germany). The cavities of the tooth remnant and the incisal fragment were filled with a flowable resin composite (Tetric Flow, Ivoclar Vivadent, Schaan, Liechtenstein). Care was taken to ensure that the cavities were not over-filled with the resin composite. The resin was then cured under a visible light source for 20 s. Before reattaching the fragment, flowable resin composite was applied to the broken tooth surfaces. When reattaching the fragment, the operator made every effort to ensure that the fit between the tooth remnant and the incisal fragment was as good as possible.

After the incisal fragment had been reattached in its original place, the excess resin composite was removed using a dental probe. The resin composite on each tooth surface (buccal and lingual) was light-cured for 20 s. To achieve optimal function and esthetics, the tooth was bandaged using a hybrid resin composite (Valux Plus, 3M ESPE, Seefeld, Germany) that was the same color as the resin composite. The fracture lines on the buccal and lingual surface were double-chamfered using a round diamond bur (FG010010; HRC101, Berlin, Germany). The double chamfer was etched with 35% phosphoric acid for 60 s after which the acid was removed using a water spray and the surface of the tooth was dried with polyurethane pellets. The dentin bonding agent was then applied as previously described. The selected hybrid composite resin was applied and cured under a visible light source for 40 s. The tooth was finished and polished using Sof-Lex™ polishing discs (3M ESPE). The rubber dental dam was removed and occlusion was checked. All the patients were given instructions on oral hygiene.

Follow-up examinations

The clinical follow ups were conducted at 3-month intervals during the first year, at 6-month intervals during the second year, and at 12-month intervals in subsequent years. At each clinical follow-up examination, the following were evaluated: fragment position, fragment stability, gingival swelling, and presence of abscess, sinus tract formation, sensitivity to percussion, and the response to the pulp test. Furthermore, the color harmony between the tooth remnant and incisal fragment, and between the adjacent healthy teeth and the restored tooth was evaluated using Cvar and Ryge's (26) modified rating system which has three scores: (i) Alpha: there is no mismatch in color, shade and/or translucency between the restoration and the adjacent tooth (ii) Bravo: there is a mismatch in color, shade and/or translucency between the restoration and the adjacent tooth, and (iii) Charlie: there is a mismatch between the restoration and the adjacent tooth outside the normal range of tooth color, shade and/or translucency. Color harmony was scored on images that were obtained using a 10.1 mega pixel digital camera (Panasonic Lumix DMC-FZ50; Matsushita Electric Industrial Co, Ltd, Kadoma Osaka, Japan) at illumination of 5000 K ± 10% (Fuji Film Macro Ring Light TT-MED; Fuji Photo Film Co., Ltd., Tokyo, Japan).

Radiological follow-up examinations were conducted at 6-month intervals during the first year and at 12-month intervals in subsequent years. In these examinations, the following were assessed: pulp canal obliteration, intactness of the lamina dura, extent of breakdown of marginal bone, external inflammatory resorption, replacement root resorption, apical radiolucency, and formation of a dentinal bridge in the teeth that had undergone pulpotomy. In addition, the restored teeth were scored according to the stage of root development using the method that was described initially by Moorrees et al. (27) and modified later by Andreasen et al. (28) using the following formula:

$R_{1/4-3/4}$: Root length 1/4–3/4,
R_c: Root length complete,
$A_{1/2}$: Apex half-closed, and
A_c: Apical closure complete.

Laboratory study

The laboratory study was performed on 56 permanent upper incisor teeth that had been extracted recently from patients because of periodontal problems and had no developmental defects of the crown, caries, and a restoration of any type. The tissue remnants on the root surfaces of the teeth were removed using a dental scaler. The mesiodistal and buccolingual widths of all the teeth were measured using calipers (Dentaurum, Inspringen, Germany). Using an independent two-sample *t*-test, we determined that the sizes of the teeth in the two groups were not significantly different from each other. The teeth were divided randomly into two groups of 28 teeth; a group in which an uncomplicated coronal fracture was created, and a second group in which a complicated coronal fracture was created. For these purposes, the pulp horn line of each tooth was identified radiographically and then marked on the vestibular enamel surface. All the teeth were then embedded in an acrylic resin block. For those teeth in the first group, the acrylic resin surface was 1 mm above the pulp horn line, and for those teeth in the second group, the acrylic resin surface was 2 mm below the pulp horn line. Each specimen was then placed in an Insitron testing device (Hounsfield, Roydan, UK) in such a manner that the angle between the vestibular surface of the tooth and horizontal plane was 180 degrees. A force was then applied to the vestibular enamel surface of the embedded tooth, 4 mm from its edge at a 90° angle using a 0.5 mm thick stainless steel rod. The crosshead speed of the testing device was 0.5 mm min^{-1} (Fig. 1). The force required to fracture each tooth was recorded in Newtons. Both the tooth remnant and incisal fragment of each tooth were then numbered to ensure that each remnant could be matched correctly to its fragment at the time of fragment reattachment. Each test group was then subdivided into two groups. In one group, the tooth remnant and its incisal fragment were kept at room temperature in tap water for 24 h prior to reattachment (wet medium). In the other group, the remnant and fragment were kept at room temperature for 47 h prior to reattachment (dry medium). The experimental groups were as follows:

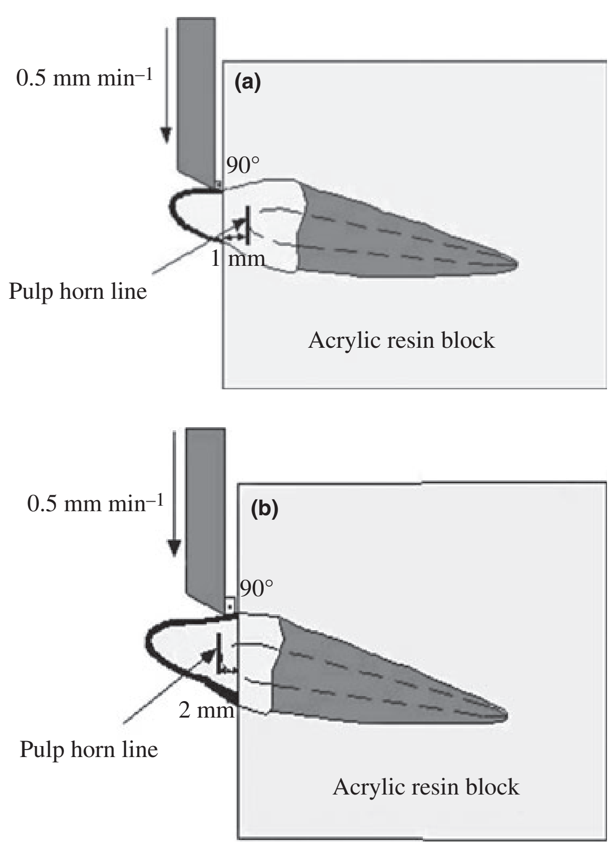

Fig. 1. Diagram explaining the creation of (a) an uncomplicated crown fracture and (b) a complicated crown fracture in the laboratory study.

Group I: Uncomplicated crown fracture + wet medium
Group II: Uncomplicated crown fracture + dry medium
Group III: Complicated crown fracture + wet medium
Group IV: Complicated crown fracture + dry medium

All incisal fragments were placed in 0.9% saline solution for 30 min before reattachment. The method of reattachment for all fragments was the same as that described for the clinical study. The restored teeth were then thermocycled for 250 cycles between 5 and 55°C and then stored in tap water for 24 h at 37°C prior to further testing. The restored teeth were then re-fractured by applying a force to the identical surface of the restored tooth using the Instron testing device at a crosshead speed of 0.5 mm min^{-1}. The force required to refracture each restored tooth was recorded in Newtons.

Statistical analysis of the data

Clinical study

The Wilcoxon signed rank sum test was used to analyze the results of the study parameters namely, the effects of trauma type, and the type of storage medium of the fragment on the rate of survival of the restored teeth.

Laboratory study

An independent two-sample *t*-test was used to compare the forces that were required to cause uncomplicated and complicated fractures (fracture resistance forces) before and after the fragments were reattached. The effects of the storage medium on the bond strengths of the restored teeth were compared by a univariate analysis of variance. The bond strengths and baseline fracture resistance forces of those teeth in which the tooth fragment had been kept in either the wet or dry storage medium were compared using a paired Student's *t*-test. All the statistical analyses were performed using a computerized statistical program (SPSS 15.0, SPSS Inc., Chicago, IL, USA). The level of significance was set at 5%.

Results

Clinical study

Table 1 presents the time points at which follow-up examinations were made on the restored teeth in the clinical study. All restored teeth were evaluated. The restored teeth were followed for 2 years (mean 24.6 ± 14.4 months). Three (7.0%) of the 43 restored teeth had re-fractured due to another traumatic injury. One of these teeth was from Group A (in the 24th month, wet medium) and the other two were from Group B (one in the 24th month, wet medium and the other in the 35th month, dry medium). The remaining 40 teeth (93.0%) were still intact and completely functional at the last follow-up examination. None of the patients was lost during the follow-up period.

The rates of survival of the restored teeth for uncomplicated and complicated fractures at the last follow-up examination were 95.7% and 90.0%, respectively. These rates were not significantly different from each other ($P > 0.05$).

When the effect of wet and dry storage medium was compared, the rates of survival of the restored teeth at the last follow-up examination were 90.0% and 95.7%, respectively. Again, these rates were not significantly different from each other ($P > 0.05$).

The rate of survival of the pulp in the tooth remnant at the last follow-up examination was 100% for uncomplicated tooth fractures and 95% for complicated tooth fractures, respectively. These rates were not significantly different from each other ($P > 0.05$).

At the clinical follow-up examinations, we did not find any problems in fragment position and stability. We found also no gingival swelling, abscess, or sinus tract formation and response to pulp testing in both groups. However, we did find that one tooth in Group B was sensitive to percussion.

Data on color harmony between the tooth remnant and its incisal fragment and between the restored tooth and the adjacent healthy teeth were as follows. At the time of reattachment, 19 (44%) of the 43 teeth had Alpha scores, 18/43 teeth (42%) had Bravo scores, and 6/43 teeth (14%) had Charlie scores. After 12 months, the number of teeth with Alpha scores increased, and there were no teeth with Charlie scores: 36/43 teeth (84%) had Alpha scores and the remaining seven teeth (16%) had Bravo scores. These seven teeth that had Bravo scores at 12 months had Bravo scores at the time of fragment reattachment.

There was no clinical and radiological evidence of (i) pulp canal obliteration, (ii) breakdown of marginal bone, (iii) external inflammatory resorption, and (iv) root resorption in the restored teeth irrespective of whether the type of tooth fracture was uncomplicated or complicated. However, in Group B, we found that one tooth had an intact lamina dura and apical radiolucency, and there was formation of a dentin bridge in 11 teeth. The scores for root formation and apical closure of the 43 restored teeth were $R_{1/4} = 1$, $R_{1/2} = 4$, $R_{3/4} = 3$, $R_c = 5$, $A_{1/2} = 1$, and $A_c = 29$. At the last follow-up

Table 1. Time points at which follow-up examinations were made on the restored teeth in the *clinical* study

	Follow up (months)							
Groups	6–8	9–11	12–17	18–23	24–35	36–47	48+	Mean duration ± SD
Group A	4	2	5	–	4	7	–	23.2 ± 14.1
Group B	4	1	2	1	7	4	2	26.1 ± 14.9
Mean duration	7.3	9.0	13.0	23.0	28.5	39.6	55.0	24.6 ± 14.4

examination (55 months), these scores were $R_{1/4} = 0$, $R_{1/2} = 0$, $R_{3/4} = 2$, $R_c = 1$, $A_{1/2} = 5$, and $A_c = 35$.

The mean kappa value for intra-examiner repeatability for clinical assessment, color harmony, and radiographic evaluation was 0.85.

Laboratory study

Table 2 summarizes the fracture resistance forces of the original and restored teeth. There were no statistically significant differences between the fracture resistance forces that were required to cause either an uncomplicated fracture or a complicated fracture. When the fracture resistance forces were compared with respect to either the fracture type (uncomplicated or complicated) or the environment in which the teeth were kept (wet or dry) prior to their reattachment, no statistically significant differences were found. However, statistically significant differences were found when the fracture resistance forces of the original teeth were compared with those of the restored teeth with respect to either fracture type or the pre-reattachment environment. The fracture resistance forces of the restored teeth ranged from 16.2% to 29.7% of those of the original teeth, and these values were statistically significantly different ($P < 0.05$; Power = 1).

Discussion

Although it has been argued that the results of *in vitro* studies cannot be extrapolated to the *in vivo* condition, it has been claimed that they may help to predict the outcome of clinical applications (29). Therefore, we felt that it was important that this study has both a clinical and a laboratory-based component to examine the overall clinical outcome after fragment reattachment, particularly with respect to the survival of the restored teeth.

We found that neither the type of trauma nor the storage medium had any effect on the survival of restored teeth after reattachment. Of the 43 restored teeth, three had re-fractured because of a second trauma. Some authors (3, 7, 15–19) have proposed that restored teeth with reattached fragments are less likely to refracture when the either the tooth remnant and/or incisal fragment is prepared prior to the reattachment procedure. Therefore, it could be argued that there would have been fewer re-fractures if the tooth remnant and/or fragment had been prepared prior to reattachment. However, we considered that additional preparation to either the tooth remnant and/or its fragment would be counterproductive to the protective nature of the reattachment procedure. The outcome of the remaining 40 restored teeth was clinical success. Contributory factors to this high success rate may be the bond strength of the bonding agent, and the type of flowable resin composite and hybrid resin composite that were used in the reattachment procedure. The dentin bonding agent that was used in this study, namely Prime Bond & NT™ is an acetone-based resin. Hence, we suggest that the water-chasing ability of acetone effectively displaced water from the dentin surface, resulting in optimal resin infiltration into the collagen network (30). In addition, the bonding agent contains nano-sized filler particles. Although controversial, it is claimed that these nano-sized particles increase the bond strength of the material due to their capacity to penetrate the spaces between the collagen microfibrils, thereby providing 'nano-retention' (31, 32). The strength of the resin bond after hardening is 193 N, which is considerably higher than the estimated bite strengths (155 N) (33) of children who participated in this study.

It has been reported that the strength of the bond between the tooth fragment and tooth remnant is reduced when the fragment is kept in a dry environment for more than 1 h prior to its reattachment (10). Farik et al. (10) recommended that fragments that were initially kept in a dry environment should be kept moist (in water) for at least 24 h prior to their reattachment. The results of our study are not in agreement with those of Farik et al. (10). In the laboratory study, we found that the fracture resistance forces of tooth fragments and remnants that were kept in a dry environment for 47 h followed by 30 min in 0.9% saline were not significantly different from those for teeth that had been kept in tap water for 24 h prior to their reattachment. These findings were the same as the results that were obtained from the clinical study. In our clinical study, we found no differences in the rates of survival of restored teeth, regardless of whether the fragments were kept either dry or moist prior to reattachment. Lee et al. (34) reported that the residual chlorine from saline solutions that are used to store tooth fragments can negatively influence bond strengths. They found that the bond strength of tooth fragments that were kept in 0.9% saline solution prior to reattachment was significantly lower than those that was in distilled water prior to reattachment. We did not keep the incisal fragments in distilled water prior to their reattachment. Therefore, it could be argued that if we had used distilled water to store the fragments prior

Table 2. Fracture resistance forces of the original and restored teeth that were measured in the laboratory study according to the type of trauma (uncomplicated or complicated) and the environment of the tooth fragment prior to reattachment (wet or dry)

Groups	*n*	The force required to fracture each tooth (±SD) (Newton)	The force required to fracture reattached teeth (±SD) (Newton)	% Change (decrease)
Group I (uncomplicated crown fracture + wet medium)	14	961 ± 308	194 ± 55	79.8
Group II (uncomplicated crown fracture + dry medium)	14	727 ± 272	191 ± 67	73.7
Group III (complicated crown fracture + wet medium)	14	768 ± 117	228 ± 116	83.8
Group IV (complicated crown fracture + dry medium)	14	1008 ± 281	163 ± 65	70.3

to their reattachment, we could expect higher bond strength and a more successful clinic outcome than that reported in the clinical study. Therefore, we suggest that there is a need for further studies to determine the ideal storage solution for tooth fragments before their reattachment.

It has also been reported that color disharmony can occur between the tooth fragment and tooth remnant when the fragment is kept in a dry environment prior to its reattachment (3). Furthermore, some investigators reported that the color disharmony may disappear within 12 months because of water absorption by the fragment after its reattachment (3, 11, 35). In addition, Capp et al. (36) reported that fracture strength of a tooth that had been kept in a dry environment for 48 h could be restored when restored after only 30 min rehydration, and this may be promising for conserving the original color of the tooth. At the time of reattachment in our clinical study, 19 of 43 teeth had Alpha scores and of the remaining 24 teeth, 17 had Alpha scores after 12 months. From these results, we believe that 12 months is not always long enough to achieve color harmony when fragment reattachment is used to restore fractured teeth. This finding is not in agreement with the results of a recently published study of Yilmaz et al. (11). One likely reason for this difference is the time between the tooth fracture and the reattachment of the tooth fragment. In this study, all teeth were reattached after approximately 36 h, whereas this time was 18 h in the previously published Yilmaz et al. (11) study.

Andreasen and Andreasen (9) proposed that discoloration of the fracture line may be due mainly to the use of chemically cured composite resins as the bonding agent. To overcome this problem, they recommended the combined use of light-cured composite resin and double chamfering of the fracture line. In our clinical study, no discoloration was noted on the reattachment line when we followed this recommendation.

Prior to the fragment reattachment procedure, 21 teeth had complicated crown fractures. These teeth were treated endodontically by a pulpotomy. Pulpotomy was the preferred treatment because of the increased potential for contamination due to the size of the pulp exposure (>2 mm) and the prolonged exposure time (average 38 h) (37).

Robertson et al. (38) proposed that postprocedural complications with pulp involvement in restored teeth after fragment reattachment are related to the injury itself rather than the treatment. Furthermore, they noted that obliteration of the pulp canal and pulpal necrosis occurs rarely in coronal fractures, even when the pulp is exposed (38). However, they did comment that luxation injuries that occurred concomitantly with crown fractures have a significant deleterious effect on pulpal prognosis with respect to pulpal necrosis and obliteration of the pulp canal (38). We noted that none of the 43 fractured teeth suffered from a luxation injury or obliterated pulp canal. Only one of the 43 teeth developed pulpal necrosis. The tooth in which this occurred had a complicated crown fracture initially and was treated endodontically by a pulpotomy. At the 24-month follow-up examination of this tooth, no pathologies were observed clinically or radiologically, and a dentin bridge had formed. At the 36-month follow-up examination, this tooth re-fractured in the 35th month due to a second trauma. Thus, pulpal necrosis may have developed due to loss of protective barrier function of the restoration and the late presentation of the patient after the second trauma. The dentinal bridge is not a good protective barrier, because it contains cellular elements and multiple wide-tunnel defects (39–43). Cox et al. (39) have reported an association between tunnel defects in the dentinal bridge and necrosis due to inflammation. Therefore, we are of the opinion that the pulpal necrosis which occurred in one tooth in our clinical study might be associated with tunnel defects in the dentin bridge.

In our clinical study, no delay was noted in the root development of the restored teeth with complicated or uncomplicated crown fractures and open apices. This is in agreement with the previous findings. Robertson et al. (38) found that root development continued in teeth with crown fractures and open apices when there was no concomitant luxation injury.

All three forms of pathologic root resorption (surface, inflammatory, and replacement) have been reported to occur after luxation injuries with displacement or root fractures (9). In our study, none of the fractured teeth had a concomitant luxation injury or root fracture, and it is probably for this reason that we did not find any pathological root resorption in the restored teeth after fragment reattachment.

Conclusions

1. The type of trauma that causes coronal fractures or storage medium in which the fragment is kept prior to its reattachment has no effect on the survival, color, and bond strength of restored teeth after fragment reattachment. In addition, fragments can be reattached to fractured tooth remnants successfully without additional preparation of the tooth remnant and/or fragment after coronal fractures.
2. Although the color disharmony that is encountered initially in restored teeth after fragment reattachment resolves significantly on its own accord within 12 months, this length of time may not always be long enough to achieve full color harmony in all cases of fragment reattachment.
3. Based on the results from our laboratory study, the fracture resistance force of restored teeth after fragment reattachment is significantly lower than that of un-restored natural teeth.

Clinical relevance

Fragment reattachment can be used to treat fractured teeth successfully following trauma in children and adolescents.

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