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Hydration and Dehydration Periods of Crown Fragments Prior to Reattachment

F Shirani • MR Malekipour • V Sakhaei Manesh
F Aghaei

Clinical Relevance

In the case of bonding the fragment of a fractured tooth, giving the fragment time to become rehydrated and considering treatment during a second appointment (scheduled 24 hours or more after the first visit) can lead to better bonding.

SUMMARY

Introduction: Tooth fragment bonding is an excellent treatment option in dealing with traumatic injuries of the anterior teeth. Rewetting the tooth fragment has been shown to increase restoration durability. The present study examined the effect various dry and wet storage periods had on the reattached fragment's bond to the tooth.

Materials and Methods: One hundred and eight human mandibular incisors were fractured and assigned to undergo a dehydration period of 30 minutes, six hours, 24 hours, or three days before the rewetting procedure. After fracturing the teeth and drying the fragments, each of the specimens was assigned to one of the three main groups (A, B, or C) intended to evaluate the effect of different rehydration periods. Groups A and B underwent a 30-minute and a 24-hour rewetting period, respectively. Group C served as a control (without a rewetting stage). Tooth fragments were then reattached and prepared for the strength test. Force was applied on the lingual side of the tooth at a 1 mm/min rate until failure.

Results: The mean loads (N) required to fracture the restored teeth were as follows: 204.43 ± 33.48 N, 322.59 ± 34.62 N, and 253.25 ± 29.05 N for groups A, B, and C, respectively. Two-way analysis of variance ($p<0.05$) showed that

Farzaneh Shirani, DDS, MSc, associate professor, Department of Operative Dentistry; and Torabi Nejad Dental Research Center, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

Mohammad Reza Malekipour, DDS, MSc, assistant professor, Department of Operative Dentistry, Faculty of Dentistry, Islamic Azad University (Khorasgan Branch), Khorasgan, Isfahan, Iran

*Vahid Sakhaei Manesh, DDS, School of Dentistry, Isfahan University of Medical Sciences, Isfahan, Iran

Faegheh Aghaei, DDS, private practice, Tehran, Iran

*Corresponding author: Vahid Sakhaei Manesh, School of Dentistry, Isfahan University of Medical Sciences, Hezar Jarib St., Isfahan 8174673461, Iran; e-mail: sakhaei@dnt.mui.ac.ir

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rehydration and dehydration periods as well as their interaction caused significant differences in the strength of the final restoration. Multiple comparison tests showed that, in general, significant differences were not seen among different dehydration times prior to the rewetting stage ($p>0.05$), except in the case of the 30-minute dehydrated specimens ($p<0.05$).

Conclusion: **Compared to a 30-minute period, a 24-hour rehydration of the tooth fragment before treatment seems to salvage enough moisture to result in an increase in reattachment strength.**

INTRODUCTION

The fragment bonding technique was first reported as a temporary treatment for crown fractures.[1] Since then, tremendous development has occurred in terms of both the materials used and in the treatment procedure itself. Crown fractures are very common among traumatic dental injuries, particularly in the permanent dentition. Among these injuries, uncomplicated crown fractures (crown fractures without pulp involvement) stand out as the most frequent type of fracture[2–5] and also represent the condition for which this technique (fragment bonding) is most frequently used. The numerous benefits of this technique with regard to both the patient and the dentist have made it a treatment of choice, especially in children.[6–10] The fragment bonding technique has been included in the recent guidelines for trauma management[11] and is considered a realistic, conservative, and cost-effective approach that provides long-lasting esthetics and restores function.[12,13]

Some laboratory studies[8,12] of this technique have shown results similar to those associated with intact teeth. In addition, the major shortcomings of composite restorations, the high failure rates in Class IV restorations, and their questionable long-term prognosis[4,7,14] have made the fragment bonding technique a more favorable approach. Preparation of a full crown or laminate veneer sacrifices tooth structure and may also be contradicted in younger patients.[7] Nevertheless, planning the final treatment with regard to the availability, adaptation, size, and number of fragments is of utmost importance.[7]

Contributions from several investigations have focused on the factors having an effect on the longevity of the restoration and the potential of this technique to yield better strength. Supplementary preparation of the bonding surfaces, which include tooth substance removal, has been shown to increase fracture strength.[6,15] Even though these additional preparations increase fracture strength, they prevent a precise fit between the two parts and are also in conflict with the conservative nature of this method. However, regardless of the bonding material and the technique used to reattach the tooth fragment, wetting and drying of the fragment appears to have a considerable effect on the fracture strength and appearance of the restoration.[15]

Various hydration and dehydration periods have been investigated.[15,16] Previous investigations show a downward trend in fracture strength as the dehydration time increases from five seconds to 24 hours. Rewetting the fragment for at least 24 hours after a 24-hour dehydration period had been suggested.[16] Others[15] demonstrated a 30-minute rehydration of the fragment to be sufficient after 48 hours of drying.

However, an optimum time that is both practical and beneficial in clinical conditions has yet to be determined. More research has to be done to determine whether the treatment should be carried out immediately or during a second appointment. Furthermore, the effect that different periods of dry storage may have on the fragment is also a matter of uncertainty.

The purpose of this study was to determine the effects of various drying and wetting storage periods on the fractured fragment and to reach a final conclusion as to which rehydration period is both better and more practical under clinical conditions. It was hypothesized that rehydration of dehydrated tooth fragments and the duration of this procedure affect the bond of the reattached fragment to the tooth.

MATERIALS AND METHODS

One hundred and eight intact human mandibular incisors (free of any cracks, caries, or structural defects and extracted because of periodontal problems) were selected. The dental plaque on the teeth was removed using an ultrasonic scaling device. Teeth were stored for less than four weeks in a physiological saline solution in 5°C refrigeration until the experiment was carried out.

The teeth were divided into a total of nine groups (A1-A4, B1-B4, and C1) on a simple random selection basis. Every subgroup contained 12 incisors. The numbers in each group name indicated the drying period of the specimens, and the letters (A, B, and C) on each label specify the rehydration period considered for the group. The specimens were studied in three main experimental groups: group A, group B, and group C. Group C, with only one subgroup (C1) of 12 incisors, served as the control group (Figure 1).

The tooth crowns were prepared for fracturing. A line was traced on each tooth 3 mm from the incisal edge and parallel to it. Then, using a diamond disc (reference no. 918F, D+Z, Diamant, Lemgo, Germany), an enamel-deep fracture line was made on the lingual side of each tooth along the traced line. On the labial side of the line, a small notch was made in the middle of the surface to prevent the blade to be used later from slipping (Figure 2). The crowns were then fractured by a perpendicular force applied labio-lingually. Force was applied on the enamel cut by a blade on the lingual surface of the tooth and by another blade positioned in the opposite direction on the labial surface (Figure 3). The surgical blades (No. 21, Aesculap AG, Tuttlingen, Germany) were replaced after every third sample. Any teeth displaying a fracture pattern different from the premeditated line or an unclear fracture line were discarded at this stage. The apical parts were kept in distilled water and at an ambient temperature afterward.

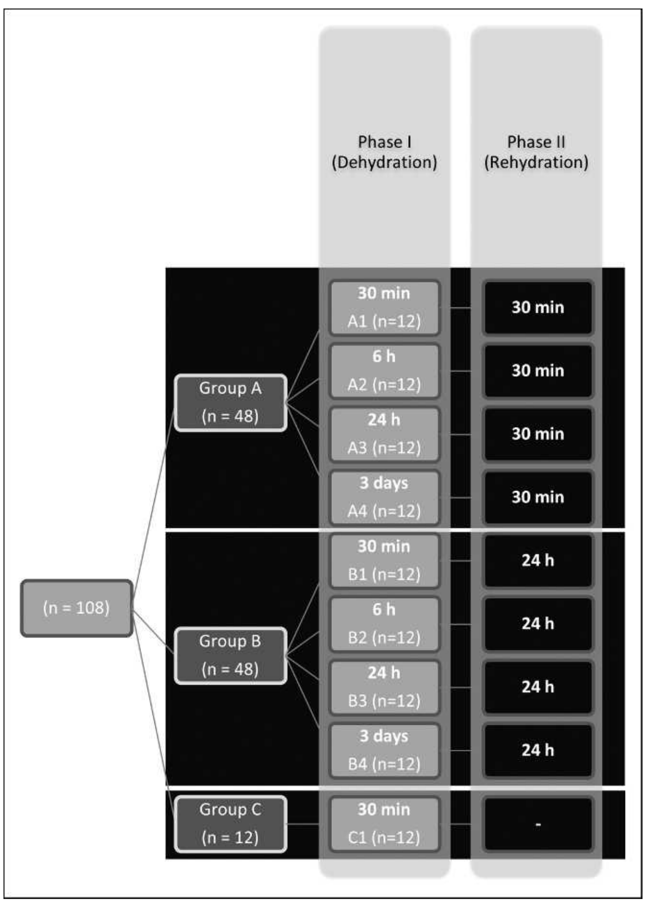

Figure 1. *Diagram illustrating the grouping of the teeth based on the dehydration and rehydration periods applied.*

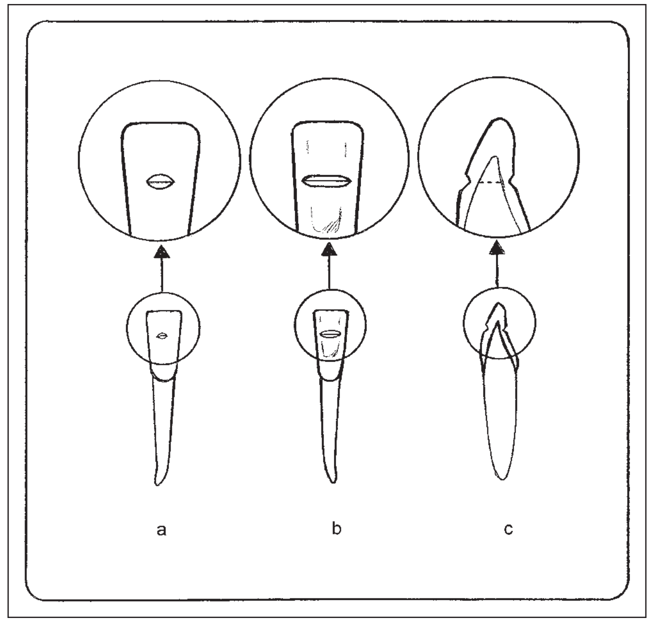

Figure 2. *Preparations on the tooth surface prior to fracturing from a labial (a), lingual (b), and proximal (c) view.*

Four dehydration periods in an ambient temperature (22°C, relative humidity of approximately 10%) were tested: group 1 (A1, B1, and C1) fragments were kept dry for 30 minutes; group 2 (A2 and B2) fragments for six hours; group 3 (A3 and B3) fragments for 24 hours; and group 4 (A4 and B4) fragments for three days.

Two wetting periods were administered after drying and before reattachment of the fragments. Group A (A1-A4) fragments were all immersed in distilled water for 30 minutes, while the group B (B1-B4) fragments followed this procedure for 24 hours. Group C (C1) fragments were reattached after the 30-minute drying time without a rewetting period.

The crown fragments were all reattached using the same technique. The fracture surfaces were etched using a 35% phosphoric acid gel (Ultra-Etch, Ultradent Products Inc, South Jordan, UT, USA) for 15 seconds and were then rinsed and gently air-dried to keep the surface moist. The bonding agent (Single Bond [batch no. 6KR], 3M ESPE, St Paul, MN, USA) was then used according to the manufacturer's instructions. Two coats of Single Bond were applied on the surfaces: the first layer, intended for priming, was applied for 10 seconds, and then the second

Figure 3. *Fracturing device used to fracture the teeth with two surgical blades mounted in a vise, 3 mm from the incisal edge of the incisor.*

layer was applied until a glossy look appeared on the surface. At each stage the bonding agent was air-thinned to remove any excess. Light curing was preformed for 20 seconds on each surface following the manufacturer's instructions using a light curing unit (Coltolux 75, Coltene/Whaledent Inc, Mahwah, NJ, USA) with a wavelength of 480 nm. A layer of low-viscous composite resin (Filtek Flow [batch no. 5GP], 3M ESPE) was placed on both bonding surfaces, and then the remnant and the fragment were pressed together into the proper position. After checking the exact realignment of the two reattached pieces, light curing was performed on the labial and lingual surfaces for 40 seconds. Excess composite resin was removed from all sides using a scalpel. The teeth were embedded by hand in an acrylic block, situated such that the long axis of the tooth would be parallel to the central axis of the block and at the same time the enamel cut would be parallel to the block surface. The crowns were exposed from above the tooth cingulum. Samples were put away in 37°C water in an incubator for 24 hours before the debonding test took place.

The specimens were mounted in a universal testing machine (Zwick Roell, ZO 20, Ulm, Germany). Stress was applied to specimens at a 1 mm/min rate until failure, using a 1-mm–wide chisel-shaped device. The attached device was placed perpendicular to the palatal surface of the tooth, 3 mm away from the incisal edge and adjacent to the reattachment line. The forces required to fracture specimens were calculated in Newtons (N). Recorded data were entered into a database, and statistical analysis was performed using SPSS version 11.5 (SPSS Inc, Chicago, IL, USA). Differences between all experimental groups were compared using two-way analysis of variance (ANOVA) followed by multiple comparison tests (Tukey *post hoc* tests). The significance level for all tests was set at 0.05. The remaining tooth particles were kept for further investigation concerning the fracture and detachment pattern.

RESULTS

Table 1 presents the mean forces required to fracture teeth in every group and subgroup separately. The two-way ANOVA revealed that the fracture load means were affected by both main factors (dehydration and rehydration periods) ($p<0.001$) and their interaction ($p<0.001$). The 30-minute dehydrated subgroups (A1, B1, and C1) had higher fracture load means ($p<0.001$). Fracture loads were also significantly lower in group A (with 30-minute rehydration) and higher in group B (with 24-hour

Table 1: *Ultimate Fracture Load Means (N) and Standard Deviations (SDs) of Various Dehydration (According to Their Subgroup Number [1–4]) and Rehydration (According to Their Group [A, B, and C]) Periods*[a]

Group	Subgroup	No. of Specimens	Dehydration Period	Rehydration Period	Mean, N	SD, N	Significance[b] ($p<0.05$)
A	A1	12	30 min	30 min	295.58	25.02	A
	A2	12	6 h	30 min	173.33	32.98	B
	A3	12	24 h	30 min	179.17	38.53	B
	A4	12	3 d	30 min	169.67	35.19	B
	Total (A)	48		30 min	204.43	33.48	
B	B1	12	30 min	24 h	331.00	29.87	C
	B2	12	6 h	24 h	324.75	31.87	C
	B3	12	24 h	24 h	313.38	37.62	AC
	B4	12	3 d	24 h	321.25	38.65	AC
	Total (B)	48		24 h	322.59	34.62	
C	C1	12	30 min	—	253.25	29.05	D
Total		108			262.43	73.83	

[a] *Subgroups with the same online capital letter did not differ significantly.*
[b] *Two-way analysis of variance (ANOVA) followed by Tukey tests.*

rehydration) ($p<0.001$). Multiple comparison tests showed statistically significant differences between the control group (30-minute dehydrated without rehydration) and each of the other groups and subgroups ($p<0.02$). The control group showed a lower mean compared to group B ($p<0.001$) and its subgroups and a higher mean compared to group A ($p<0.001$) and its subgroups. The mean fracture forces in group B (24-hour rehydrated) were the highest among all, whereas no significant differences were seen among the B1-B4 subgroups ($p>0.05$). The lowest means of fracture forces were indicated in the A2, A3, and A4 subgroups (with no significant difference among these subgroups [$p>0.05$]). Subgroup A1 (30 minute dehydration, 30 minute rehydration) means showed significant differences with most other subgroups, higher than those of subgroups A2, A3, A4, and C1 ($p<0.001$), but lower compared to subgroups B1 and B2 ($p<0.05$). The outcomes for the three-day dehydrated (A4 and B4) subgroups did not differ significantly from subgroups that were dehydrated for 24 hours (A3 and B3) and six hours (A2 and B2).

All specimens fractured and detached at the fragment-tooth interface, showing a similar pattern under 4× magnification.

DISCUSSION

The amount of strength recovery by fragment bonding still remains a controversial issue.[17] Some[6,13–15,17,18] believe reattachment with the hydration (or without dehydrating) of the surfaces and without any additional preparation restores approximately 50% of the fracture strength of the original tooth. Other studies[8,17,19,20] have reported this restoration to exhibit strength close to that associated with intact teeth. Although the improvements in dental materials can favor the use of this technique, it still may not be considered a standalone and definite treatment by some. However, the impact of hydration exists in spite of additional preparations on the surface,[15] usually intended to increase the restoration durability. In addition, the greater part of the dentin surface stays unchanged in some of the preferred preparations (eg, the "overcontour technique" which requires a superficial 0.3-mm–deep preparation into the buccal surface and on the fracture line).[17] In addition, appropriate hydration reestablishes esthetics and natural color.[2,9] Hence, hydration of the fragment should be considered a fundamental step in treatment of fractured teeth.

The method used to fracture teeth in this study was intended to simulate the fracture pattern and surface anatomy in traumatic situations and the micromechanical adaptation of the surfaces under clinical conditions. To obtain standardized fragments and dictate a similar fracture pattern in all specimens, the initial enamel cut line was made. Although the cross-head speed used in the debonding test does not simulate clinical conditions, and although the results may differ in higher velocities (relatively lower strengths), this technique has been accepted in similar investigations.[21–23] Similar to previous studies,[24,25] the combination of an adhesive and a low-viscous resin was intended to improve the mechanical properties of the treatment.[13,21,26,27] The etch-and-rinse technique employed has proven to result in restorations with greater longevity compared to enamel etching alone.[28]

The drying and wetting durations of the fragments were intended to resemble different possibilities in actual practice. The 30-minute rehydration period is similar to the time that treatment is carried out at the same appointment (with a 30-minute rehydration carried out by the dentist before treatment). The 24-hour rehydration is similar to the time between an initial visit and a second appointment the dental practitioner schedules for treatment. On the other hand, various drying periods were considered to simulate various times from the incident until the patient may consult a dentist.

The mean loads that caused fracture in each group represent a pattern of dehydration that begins at a very high rate, from the moment of fracture. The dehydration process does not reach its final state in 30 minutes, but it appears to have approached a plateau-like trend within six hours. Any further drying (up to three days) seems to be almost ineffective in the final strength of the tooth since no significant difference or decreasing trend is seen. These results correspond with those of Farik and others,[16] who also showed that the manner in which fracture strengths weakened with time was steeper at the beginning and became less noticeable later on. Even so, there is a point of difference: in this study drying the fragments for as few as 30 minutes diminished fracture strengths, compared to the over one-hour limit in the previous study.

In contrast to a recent study by Capp and others[15] that considered 30 minutes of rehydration sufficient, this research found that the results for 30-minute rehydration were unsatisfactory compared to those associated with a 24-hour period. There was one exception to this: when the fragment was dried for only 30 minutes and rehydrated for 30 minutes afterward (subgroup A1). This subgroup was the main reason the effect of dehydration periods as a factor and the interaction between the two experimental factors were statistically significant (since both became statistically insignificant with the exclusion of this dehydration period). Although the results for the A1 subgroup were significantly lower than those for the 24-hour rehydrated group, they were remarkably improved compared to those of the other subgroups that were rehydrated for 30 minutes (A2-A4). Therefore, it seems reasonable that if the patient is treated immediately after the accident (not far off the 30-minute limit), an acceptable treatment could be achieved with a 30-minute rehydration of the fragment (especially when it is not seen as a long-term treatment). However, regardless of the drying time, it appears to be advantageous to proceed with a 24-hour rehydration of the fragment. On the other hand, dental injuries should be classified as emergencies at all times, and as a result, it is believed that patients should be treated as soon as possible to improve the overall prognosis of both the pulp and the restoration.[4] Therefore, if the treatment is to be postponed to a second appointment, proper protection of the pulp and the remaining tooth structure should be taken into consideration, particularly to avoid any adverse biological or physical side effects. For example, the use of a hydrophilic restorative material to seal the exposed dentinal tubules would be appropriate.[5] The dentist may also prefer temporary restoratives to be able to regain the fit between the fragment and the remaining tooth structure.

There are some times during which the rehydration of the fragment may seem unnecessary: for example, when complete removal of the fragment's dentin is scheduled to take place during the treatment. This is because the dehydration process mainly affects dentin.[15] Another matter to take into account is that based on the bonding system used and its characteristics, the impact of dentin dehydration on bonding may differ.[29,30] For this reason, dehydration may have a different influence on bonding strengths when bonding agents other than Single Bond are utilized.

In the present study, it was impractical to calculate the bonded surface area in each specimen. Thus, to reduce any side effects related to this issue, and so the outcome would be able to represent fracture strengths, the number of specimens considered for this experiment was increased to 12 for each group. The teeth with differing crown widths, lengths, and thicknesses were excluded in the initial selection, and the teeth showing dissimilar fracture patterns were excluded after the fracture test.

An interesting observation that was not part of the research was that the specimens dried for a longer period appeared to lose their adaptability with the apical part more than the specimens with a shorter drying period. This may partially be because of an irreversible contraction in the dentin structure during dehydration. Undoubtedly, further research has to be done to prove such a point.

CONCLUSIONS

In this in vitro study,

- Twenty-four hour rehydrated specimens of dehydrated tooth fragments exhibited stronger bonds in comparison with the 30-minute rehydrated specimens.
- When the fragment had been dried for 30 minutes or less, rehydration for 30 minutes afterwards seemed to significantly improve the bonding strength of the reattachment.

Conflict of Interest Declaration

The author of this manuscript certifies that there is no proprietary, financial or other personal interest of any nature or kind in any product, service and/or company that is presented in this article.

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