Comparison of Fracture Strength of Three Different Restorative Protocols for the Management of Re-Fracture of Teeth with Uncomplicated Crown Root Fractures

Amolkumar LOKADE[1] https://orcid.org/0000-0002-5989-0832
Nitesh TEWARI[2] https://orcid.org/0000-0002-6747-5110
Morankar RAHUL[2] https://orcid.org/0000-0002-2924-8857
Vijay Prakash MATHUR[2] https://orcid.org/0000-0002-2710-1894
Arnab CHANDA[3] https://orcid.org/0000-0002-6266-078X

[1]Department of Pediatric Dentistry, ESIC Dental College and Hospital, Rohini, New Delhi, India
[2]Department of Pediatric Dentistry, Centre for Dental Education and Research, All India Institute of Medical Sciences, New Delhi, India
[3]Centre for Biomedical Engineering, Indian Institute of Technology, Delhi, India

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ABSTRACT

INTRODUCTION: Fragment reattachment has been suggested as an interim emergent treatment modality for crown root fractures of permanent incisors. However, they may re-fracture leading to fragment dislodgement, even with in the acute phase. Hence, this in vitro study aimed to compare the efficacy of three management protocols of re-fracture of teeth with uncomplicated crown root fractures.

MATERIAL and METHODS: Sixty mandibular bovine incisor teeth were selected and were fractured to simulate uncomplicated crown root fracture. Fragments were rehydrated and reattached as per the etching–bonding protocol and stored in artificial saliva. They were refractured and randomly allocated to three groups for rebonding: Group-I(reattachment without rehydration), Group-II-(rehydration and reattachment), and Group-III-(restoration using composite). Universal testing machine was used to evaluate the force required to fracture them.

RESULTS: Group III showed the highest mean force (338.95±81.94N, 95%CI- 300.60, 377.30), followed by Group II (255.56±58.19N, 95%CI-198.32, 252.79). The lowest value of force required to fracture was observed in Group I (141.76±60.16N, 95% CI-113.60, 169.92).

CONCLUSION: The force required for fracture was greater in the teeth where composite restoration was done instead of re-bonding of dislodged crown-root fragment. Among the reattachment groups, the force required to fracture was greater when rehydration was performed.

Keywords: *Crown root fractures, fracture resistance, fragment reattachment, rehydration, traumatic dental injuries*

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INTRODUCTION

Traumatic dental injuries (TDI) are common in children and adolescents and they result in a significant health challenge due to its social, economic, and functional impacts.[1] Crown-root fracture is one of the severe forms of TDI involving both crown and root of a tooth.[2,3] It occurs because of oblique or horizontal impacts on the labial surface of the crown. Biomechanically, such forces result in stresses between the point of labial impact and the lingual or palatal aspect of cervical portion of the root.[3,4] The fracture occurs due to the tensile strain developing between the line joining the two stress zones.[2]

The International Association of Dental Traumatology (IADT) guidelines recommend fragment reattachment for immediate management of uncomplicated crown–root fractures in permanent teeth. It has to be performed during the acute phase and later a definitive treatment plan can be finalized. This may include orthodontic or surgical extrusion, root submergence, intentional replantation with or without 180-degree rotation, extraction or auto-transplantation. These guidelines also advise rehydration of the fragment as an important step prior to reattachment.[3,5] Reattached fragments can provide good and long-lasting aesthetics due to preservation of the gross anatomic form, color and surface texture of the tooth. It is more conservative and comparatively simple to perform. It also helps in restoring function and eliciting positive emotional response from the patients.[5,6,7] This may especially be important in crown root fractures in mixed dentition (8–12 years). In these cases, clinicians may be inclined to maintain vitality to achieve root maturity, and fragment reattachment or bonded restorations are useful. Additionally, strategies for prosthodontic rehabilitation are limited in this age group.[8]

The dental trauma literature related to fragment reattachment in crown root fractures is limited. Lokade et al. compared two rehydration protocols prior to simple reattachment. They found that significantly greater forces were required in teeth rehydrated by humidification.[8] Reinjury of injured teeth is common and it can result in dislodgement of the reattached crown root fragment.[9,10] Failures may also occur due to abnormal occlusal forces, premature contacts, and parafunctional habits.[7] If a dislodgement occurs, preparation is required on the two interfaces (the tooth and the fragment) covered with a layer of composite resin. This is followed by either re-bonding of the dislodged fragment or a composite restoration. To the best of our knowledge, none of the studies have assessed protocols related to re-bonding in the failed cases of reattached fragments in teeth with uncomplicated crown–root fractures. Hence, this study aimed to evaluate and compare the force required to fracture for three management protocols in such scenarios.

MATERIALS and METHODS

The protocol was approved by the Institute's Ethical Committee (IEC-942/24-11-2022) before the start of the study. Mandibular bovine incisors with similar dimensions (length, 26±2 mm; width, 15±2 mm, measured by a digital Vernier caliper, Mitutoyo Corporation, Tokyo) were collected. They were cleaned from debris and calculus using ultrasonic scaler and evaluated under 2.5X magnification (Hovivo Dental World, Delhi, India). Those free from cracks, caries, or any other kind of structural abnormalities were selected. Teeth were stored in normal saline at room temperature (25-28 degrees centigrade) until the start of the experiment. Due to the lack of previous data, a sample size of 20 teeth per group was estimated for this preliminary study.

The simulation of traumatic fracture was carried out as per the protocol described by previous study.[8] Briefly, an indelible pencil was used to mark a line extending from mesial line angle of the labial surface at the contact area to the junction of the cervical and middle thirds of the distal line angle of the labial surface of the root. The line was mirrored to the lingual surface of the tooth. A diamond disc mounted on a slow speed hand piece was used along this line to create a groove of 1 mm depth (Figure 1A). Force was manually applied perpendicular to the fracture line, using a dental mallet. This could result in simulation of a crown root fracture (Figure 1B and 1C). All the steps were performed by one trained and calibrated operator with prior experience in this area. This was done to reduce inconsistencies in the amount and direction of force applied. Tooth stumps were stored in artificial saliva, while, the fragments were subjected to drying at room temperature (25-28 degrees centigrade) and pressure (1001–1004 hPa) for 24 hours.

The next step involved rehydrating the fragments for 15 minutes in a self-designed humidification chamber which had been developed in 2019 and used in previous studies. It comprises of two air tight boxes of plastic placed one over the other and interconnected by a hole of 2 cm diameter. A humidifier procured from market is placed in the lower compartment and the lid of the upper compartment is closed to obtain 82±2% humidity when operated for 10 minutes. The humidity measurements are done by an industrial grade hygrometer whose probe is housed in the upper box. The fragment samples that are to be humidified are kept in a perforated tray in the upper box so that rehydration by humidification can be achieved.[8,11,15] The fragments and tooth stumps were dried by using a cotton roll, and acid etching was performed for 30 seconds (Scotch Bond Multipurpose etchant, 32% phosphoric acid, 3 M/ESPE, São Paulo, Brazil). It was washed with distilled water for 10 seconds and a three-way syringe was used to dry the samples for 10 seconds. A bonding agent (Adper Single Bond 2, 3 M/ESPE, São Paulo, Brazil) was applied using a

microbrush and light-cured for 10 seconds (Elipar, 3 M ESPE, USA). A flowable nanocomposite (A2 shade, Filtek™ Z350XT, 3 M/ESPE, São Paulo, Brazil) was applied to the tooth stump and the fragment, and their positions were verified prior to curing. The excess composite was removed, and curing was performed for 10 seconds on each side (Figure 1D). All samples were again stored in artificial saliva and thermocycled by using two baths having a temperature differential of 6–60°C for 2000 cycles and a dwell time of 30 seconds in each bath. This was done to simulate the variations in the temperatures present in oral cavity to which restorative materials and reattached fragments are subjected to.[7,8,11]

In the subsequent part of the experiment, a computer-generated sequence was used to randomly allocate the samples to (n=20 each): Group I-reattachment without rehydration; Group II-rehydration with humidification and reattachment; and Group III-composite restoration. A mallet was used to apply force perpendicular to the labial surface at the visible fracture line for each sample (Figure 1E). This was also performed by the same operator as previously described. It resulted in refracture and dislodgement of the reattached fragments. The fragments and tooth stumps were coded by using Arabic numbers 1 to 60 so that they could be matched during other steps. They were stored in artificial saliva for 24-48 hours period, till the next stage of experimentation.

An ultrasonic scaler tip was used to mechanically abrade and remove the visible resin from all the fragments and tooth stumps. Simple reattachment was performed by using the etching and bonding protocol without rehydration in Group I, whereas the fragments were rehydrated by placing them in a humidification chamber for 15 minutes prior to reattachment in Group II. The fragments in Group III were discarded and nanohybrid composite (A2 shade, packable Filtek™ Z350XT, 3 M/ESPE, São Paulo, Brazil) was used in increments of two millimeters to restore the tooth to normal size, shape and contours as per the recommended protocol of etching and bonding. The composite was cured for 30 seconds for each increment.

Thermocycling was performed again using the protocol described above. The samples were embedded in an acrylic cylinder (21 mm in length) so that the fracture line remained exposed for testing the force required to fracture (Figure 1F). A tangential load of 500 kg at a speed of 1 mm/min in the incisal direction was applied via a universal testing machine (MTMS, India). It was applied on the labial surface of the samples at the junction of the incisal and middle thirds on the fracture line via a blunt needle force applicator. The force required to refracture was evaluated for each sample (Figure 1G). All the experiments were performed within four weeks of sample collection, and attempts were made to follow the best practices of storing the bovine teeth. The data were entered into a Microsoft Excel Sheet, and the statistician was blinded to the nature of the groups. Statistical analysis was performed with Stata-14 (USA) via ANOVA and Tukey's post hoc test.

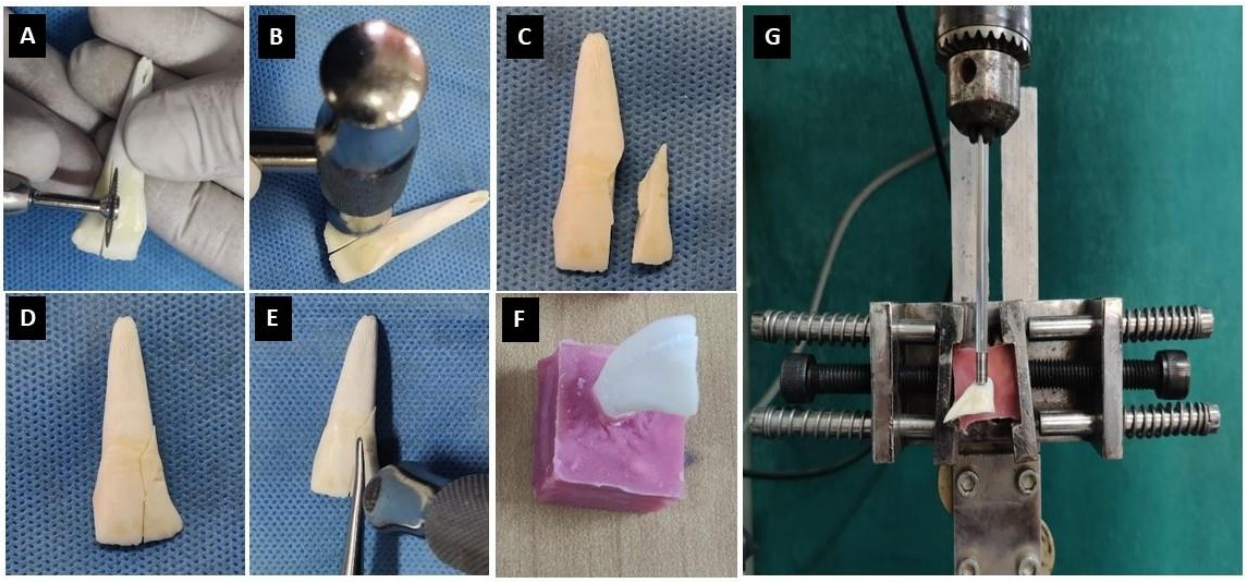

Figure 1: Showing the steps of preparation of the bovine tooth samples and their testing- A) Groove preparation B) and C) Fracture D) Re-approximation of the fragment and tooth E) Re-Fracture F) Reattached sample after thermocycling and being mount in the acrylic for final testing G) Testing of sample by a universal testing machine.

RESULTS

The highest mean force for refracture was seen in Group III (338.95 ± 81.94 N, 95% CI-300.60, 377.30), followed by Group II (255.56 ± 58.19 N, 95% CI-198.32, 252.79). The lowest amount of force required to refracture was recorded in Group I (141.76 ± 60.16 N) (95% CI-113.60, 169.92) (Table 1, Figure 2). The mean differences between all the groups were statistically significant (<0.001) (Table 2).

Table 1: Mean force required to fracture (Newton) and the results of statistical analysis via one-way ANOVA.

Groups	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval		ANOVA
					Lower Bound	Upper Bound	
Group I	20	141.7635	60.16937	13.45428	113.6034	169.9236	Between Groups -Sum of Squares 391760.184, DF−2 Mean Square 195880.092
Group II	20	225.5620	58.19187	13.01210	198.3274	252.7966	within Groups- Sum of Squares, 260725.076 DF−57 Mean Square 4574.124
Group III	20	338.9540	81.94953	18.32447	300.6004	377.3076	F Value- 42.824 p < .001

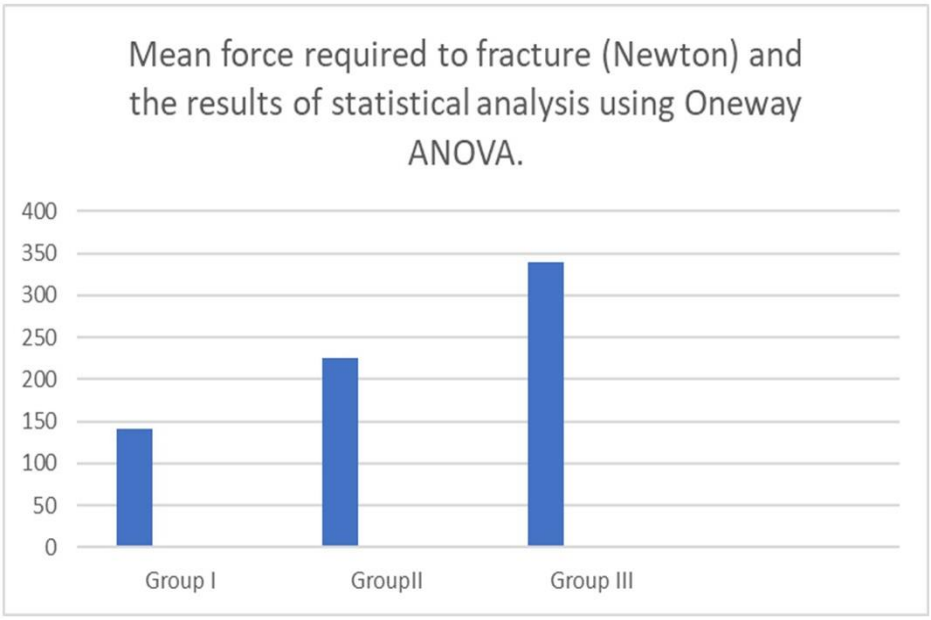

Figure 2: Mean force required to fracture the re-reattached fragments in the three groups- Group I- Reattachment without rehydration, Group II- Reattachment with rehydration, Group III- Composite restoration.

Table 2: Mean differences between the groups and their statistical significance (Tukey's post hoc tests)

Group Comparisons	Mean Difference	Standard Error	Significance	95% Confidence Interval	
				Lower Bound	Upper Bound
Group I vs Group II	-83.79850	21.38720	≤ 0.001	-135.2651	-32.3319
Group I vs Group III	-197.19050	21.38720	≤ 0.001	-248.6571	-145.7239
Group II vs Group III	-113.39200	21.38720	≤ 0.001	-164.8586	-61.9254

DISCUSSION

Reattachment of the fractured fragments and their stabilization are recommended as immediate management in uncomplicated crown–root fractures until definitive treatment can be performed. Although it is difficult to obtain adequate access and isolation when intra-alveolar fracture lines extend very deep, effective fragment reattachment protocol has been suggested.[3] This can save the patient from pain due to mobile fragments and the distress of undertaking extensive treatment procedures

during the acute phase of the injury. It also helps in providing psychological consolation. The greatest concern, however, is the predictability of treatment and sequelae of dislodgement of reattached fragments within few hours or days.[7,13]

Khandelwal et al evaluated the effectiveness of fragment reattachment in crown root fractures and reported reasonable short-term success, even in teeth with pulp exposures. However, it was based on a lower level of evidence from multiple case reports and case series.[4] The reasons for dislodgement may be procedural problems, repeat trauma episodes, or abnormal occlusal forces.[7,8] The dislodgement of such fragment can lead to further complications such as pulp exposure and necrosis and require the extensive treatment procedures that can be avoided in the acute phase of trauma.[8] Since the treatment options after dislodgement of reattached fragments in teeth with crown root fractures had never been explored, this in vitro experiment using bovine incisors was designed. It was envisaged that even though the results would not have a high level of evidence, they would discern a trend that may be reassessed in clinical trials in the future.

The best practices for in vitro experimentation were followed to reduce confounding factors and simulate oral conditions.[1,14,15] The choice of bovine teeth and their standardization were based on previous studies and similarity of bovine and human dentin.[5-7] The simulation of fracture lines and other steps of the experiment were also performed as per the established protocols.[7,8,11,15] The lowest force required to fracture the reattached fragments was observed in teeth where reattachment was performed without rehydration, whereas the highest force required was observed in the teeth that were restored using nanohybrid composite. The micromechanical bonding to the enamel, dentin, and cementum surfaces results in a layer of residual composite resin after the reattached fragments are dislodged. As a result, the dentinal tubules no longer remain conducive to the penetration of bonding agents and subsequent bonding with the composite.[15] Even with the greatest efforts to remove the visible layer of the resin, complete removal might not have been possible in the present experiment. Among the teeth managed by fragment reattachment, the greater force required for fracturing the fragments in Group II can be attributed to the humidification of the abraded dentin, which allows better penetration of bonding agents, even in these cases.[13] This finding was similar to the observations of previous studies.[8,11,14,15] The rehydration has been a known factor for improving the prognosis of the fractured teeth and the humidification chamber helps in making it more objective and scientific.[8,11,15] The incremental layering of the composites and curing of each layer might also have resulted in better polymerization and increased resistance to fracture. As a result, the more consistent treatment option in such cases seems to be a light-cured composite restoration after adequate removal of the resin tags from the broken tooth stumps, preferably under magnification. The superiority of this approach over re-bonding fragments was also observed in uncomplicated crown fractures.[15] Further, previous works have emphasized the role of shear bond strength when it comes to the fragment reattachment or composite resin-based restoration of fractured teeth. Though the differences between the conventional and fiber reinforced composites were not significant, they were much lower than the intact tooth. It is of great importance that most of the impacts leading to re-injury cause shearing stress and tangential loads that lead to re-fractures.[16] Although more complex in crown root fractures, it may be a viable solution when isolation can be established. This research has clinical application in immature permanent teeth or in age groups where options for prosthodontic rehabilitation are limited. Since, there are areas of concerns and weaknesses associated with composite resin restorations in crown-root fractures, the comprehensive rehabilitation by using full coverage crowns and post endodontic reinforcement must always be considered in intermediate and long term follow ups. This can be a potential area for future research with improvement in bonding materials. Further, the trends observed need clinical validation using *in vivo* study designs.[7]

Analysis of the tooth stump and fragment surfaces by using profilometry or scanning electron microscopy could have been important for characterizing the samples in greater detail. However, it was not performed because of the preliminary nature of the experiment and must be viewed as a limitation. Recently, the recommendation regarding simple reattachment as the best method for fragment reattachment has been challenged with emerging evidence in favor of different reinforcement protocols.[17] This was also not explored in the present study and can be an area of exploration for future researchers.

CONCLUSION

Within the limitations of the present study, it may be concluded that the force required to fracture was highest in the teeth where composite restoration was performed instead of re-bonding of dislodged crown-root fragment. Among the reattachment groups, the force required to fracture was higher when rehydration using humidification was performed.

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