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An evaluation of various materials and tooth preparation designs used for reattachment of fractured incisors

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Abstract – *Background/Aim*: The present study was undertaken to evaluate and compare the fracture strength of various restorative materials and designs used in the reattachment of anterior fractured teeth. *Materials and method*: Sound human maxillary central incisors were selected for the study. These teeth were fractured using universal testing machine so as to obtain Ellis class II fracture with intact fragment. The fractured fragment was reattached to the tooth using three restorative materials namely, bonding agent, resin luting cement and nano-composite, and designs incorporated were simply bonding the fragment to the tooth and other one included a chamfer along the fractured line. The reattached teeth were again fractured and the mean fracture strength values recorded. *Results and Conclusion*: A combination of nano-composite (best material) and chamfer preparation (best design) gave the highest mean fracture strength values.

Trauma involving fracture of anterior teeth is a tragic experience for children and teenagers who require immediate attention not only because of damage to dentition but also because of the psychological effect of trauma to patient and their parents (1). Dental traumas are on a rise in children and teenagers due to involvement in contact sports, increased accidents, domestic fights and fall (2). Most Common type of fracture includes enamel and dentin without pulp exposure (42.7%) as compared with fracture of enamel only (31.2%) and enamel and dentin involving pulp (4.6%) (3).

A number of treatment options have been used in the past for restorations of fractured tooth depending on the site of fracture. However, with the advent of composite resins in dentistry, the aesthetic restoration most commonly practised in case of fracture involving enamel and dentin was to build up the tooth using composite resin. But composite resin has the disadvantage of poor abrasion resistance in comparison with enamel, sometimes problems with colour matching and sensitivity (4).

With the development of adhesive dentistry came the concept of "tooth fragment reattachment" making it possible for the dentist to use patient's own intact tooth fragment to restore the fractured tooth by reattaching the fragment back to the tooth (5).

However, the prognosis of the treatment depends on firm attachment of the fragment to the tooth, with impervious margins, strong bonding between the two segments and the tooth preparation.

An ideal dental material used for reattachment procedure must possess good fracture resistance to overcome the catastrophic propagation of flaws under an applied stress along with good biocompatibility, minimal gingival irritation and good bond strength. Apart from the material used, design of tooth preparation employed for the union of fractured fragment to the tooth also governs the fracture strength of the reattached tooth.

The present study aims to evaluate and compare the fracture strength of the reattached fractured tooth using various restorative materials and designs of tooth preparation in process of reattachment.

Materials and method

A total number of 104 permanent human maxillary central incisors were selected for the study. The intact teeth were obtained from the Department of Oral Surgery, D A V Dental College, Yamunanagar, Haryana. Each tooth was freshly extracted and kept in distilled water till the time of experimentation. The study involved ethical clearance which was duly obtained before the commencement of the study from the Kurukshetra University, Kurukshetra.

Teeth selected were non-carious, free from cracks, devoid of developmental defects and having intact incisal edges.

The study consisted of three steps:

1. Intentional fracture of sound teeth.
2. Reattachment of fractured teeth using three different materials and two different designs of tooth preparation.
3. Fracture of the restored teeth so as to evaluate and compare the fracture strength of different materials and designs of tooth preparation.

Step 1: intentional fracture of sound teeth

The buccal surface of each tooth was divided into transverse and longitudinal thirds. A point was marked near the mesio-incisal angle as shown in the (Fig. 1) for application of perpendicular loading. The load was applied to each tooth in a bucco-lingual direction by means of the stainless steel ball (2 mm^2) held at the head of the cylinder with the help of the Universal testing machine (INSTRON, LIOYD, LR100, UK) at a speed of 0.6 mm min^{-1} (6). The force needed to fracture the teeth was recorded. The fractured segment of each tooth was kept along with the respective tooth in saline.

Step 2: restoration of fractured teeth

The teeth were restored using three different materials namely, the bonding agent, luting resin cement and nano-composite. The various designs of tooth preparation used in the reattachment procedure included either simply bonding the tooth fragment to the fractured tooth or an external chamfer preparation along the fractured line. The samples were randomly divided into four main groups depending on the choice of the material used. The following materials were used; The trade names of the materials used in the study were bonding agent ADPER SINGLE BOND 2 (3M-ESPE); luting resin cement RELY-X ARC (3M-ESPE); nano-composite FILTEK Z350 (3M-ESPE). These groups were further divided into subgroups based on the design used, with thirteen teeth in each group as shown below:
Group 1A: bonding agent and simply bonding.
Group 1B: bonding agent and chamfer preparation.
Group 2A: luting cement and simply bonding.
Group 2B: luting cements and chamfer preparation.
Group 3A: nano-composite and simply bonding.
Group 3B: nano-composite and chamfer preparation.
Group 4: sound teeth

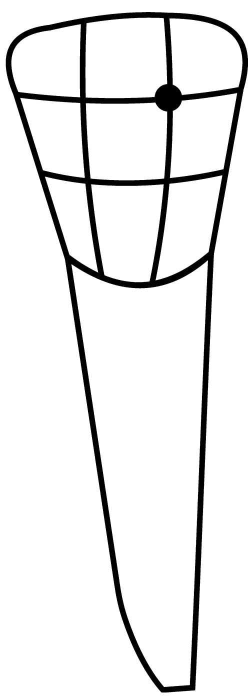

Fig. 1. Markings to show the site of fracture.

Step 3: fracture of restored teeth

All the samples were then subjected to fracture strength test using universal testing machine similarly as in Step 1 and breaking load was measured by recording the reading on the display panel of the machine. The data collected were tabulated accordingly and was subjected to statistical analysis.

Results

The mean fracture strength of all the groups were evaluated, compared and analysed using one way ANOVA and *Post-Hoc* Tukey's test.

Inter group comparisons obviously showed sound teeth to have maximum mean fracture strength (32.86 kgf). The mean fracture strength values of sound teeth were highly significant as compared with other tested materials (as shown in Table 1).

Amongst the tested materials, nano-composites gave the highest mean fracture strength values when the fragment was reattached using simply bonding (nano-composite = 17.08 kgf > luting cement = 12.19 kgf > bonding agent = 8.48 kgf). Similar results showing high mean fracture strength of nano-composites were found when we had used chamfer preparation (nano-composite = 26.47 kgf > luting cement = 17.11 kgf > bonding agent = 15.14 kgf).

The next material to give high mean fracture strength values was resin based luting cement when reattachment was performed using simply bonding (nano-composite = 17.08 kgf > luting cement = 12.19 kgf > bonding agent = 8.48 kgf). Also, when we used chamfer preparation, luting cement proved to be the second best material (nano-composite = 26.47 kgf > luting cement = 17.11 kgf > bonding agent = 15.14 kgf). The least mean fracture strength values amongst the tested material was found amongst the sample teeth reattached using bonding agent only when we employed simply bonding design (nano-composite = 17.08 kgf > luting cement = 12.19 kgf > bonding agent = 8.48 kgf). Bonding agent also showed the least mean fracture strength values when it was used along with chamfer preparation (nano-composite = 26.47 kgf > luting cement = 17.11 kgf > bonding agent = 15.14 kgf). Amongst the designs incorporated for reattachment of fractured incisors chamfer preparation along the fractured line after bonding the fragment to the tooth was found to give high mean fracture strength values compared with simply bonding the fragment. (Chamfer preparation + nano-composite = 26.27 kgf > simply bonding + nano-composite = 17.08 kgf; chamfer preparation + luting cement = 17.11 kgf > simply bonding + luting cement = 2.19 kgf; chamfer preparation + bonding agent = 15.14 kgf > simply bonding + bonding agent = 8.48 kgf).

Table 1. Mean fracture strength values and standard deviation of various study groups

Group	Sample number (n)	Mean fracture strength (kgf)	Standard deviation
1A = bonding agent and simply bonding	13	8.48	2.24
1B = bonding agent and chamfer	13	15.14	1.48
2A = luting cement and simply bonding	13	12.19	2.15
2B = luting cement and chamfer	13	17.11	2.44
3A = Nano-composite and simply bonding	13	17.08	2.50
3B = nano- composite and chamfer	13	26.47	3.07
4 = Sound teeth	26	32.86	4.06

Discussion

In the present study, only maxillary central incisors were included in the study because in natural conditions also, these teeth are most prone to trauma. Their proneness to fracture can be attributed to their anterior position and proclination.

The experimental design used in our study simulated a real trauma by fracturing the teeth to obtain natural Ellis Class II (7) with complete fragment available, using universal testing machine (INSTRON, LIOYD, LR100, UK). The force was applied by a small stainless steel ball (2 mm^2) at speed of 0.6 mm min^{-1}. It has been demonstrated in the previous studies that fracture strength of intact teeth and fragment bonded teeth tend to decrease when high crosshead speeds are employed (8).

Although earlier studies used various methods of obtaining tooth fragment like sectioning the incisal edge or placing small notches on two proximal surfaces and fracturing the teeth by using narrow forceps or by using a blunt instrument without making notches (9), but our study preferred intentional fracturing of teeth using universal testing machine to all other methods because intentional fracturing simulates trauma exactly, so fragments will fit to the remaining tooth as in case of natural trauma; the surface anatomy produced by fracturing is likely to be similar to that produced as a result of trauma and also no smear layer is produced on fractured surface (10).

Prior to fracture, the labial surface of each tooth was divided into transverse and longitudinal thirds. A point was marked near the mesio-incisal angle to create a specific site for application of perpendicular loading. Ellis Class II (7) fracture pattern was selected for our study as this fracture provides an ideal indication for reattachment procedure. In case of just enamel fracture, the fractured surface is so small that either rounding off of the margins is done or else the fragment obtained is not intact to allow reattachment due to brittle nature of enamel. However, in case of enamel and dentin fracture, as the fracture is quite massive, there are greater chances of availability of intact fragment, which can be bonded to the tooth with the help of reattachment procedure.

For the reattachment procedure, an adhesive agent is required that keeps the union of tooth and the fragment intact and also has enough fracture toughness to bear the masticatory load.

Inter-group comparisons had shown sound teeth to have maximum mean fracture strength. The high mean fracture strength of natural teeth is a proven fact in a large number of studies conducted. Our results also matched the findings of study by Demarco et al. (11), who confirmed that no material and technique studied was able to attain the fracture resistance of the sound teeth natural teeth.

Amongst the tested materials, nano-composites gave the highest mean fracture strength values with both the designs used. The higher mean fracture strength of nano-composite could be attributed to their superior mechanical properties on account of the nano-fillers present in them.

The next material to give high mean fracture strength values was resin-based luting cement when reattachment was performed using simply bonding. Also, when we used chamfer preparation, luting cement proved to be the second best material. The filler content in this luting cement was 67.5%, which could be accounted for its high mechanical properties i.e. high physical strength, high wear resistance, high adhesive strengths to a variety of materials.

Amongst the tested material, the least mean fracture strength values were found amongst the sample teeth reattached using only bonding agent.

Amongst the designs incorporated for reattachment of fractured incisors, chamfer preparation along the fractured line after bonding the fragment to the tooth was found to give significantly higher mean fracture strength values compared with simply bonding the fragment. The higher mean fracture strength of this design could be due to increased surface area for application of the material to join the two parts.

In our study, bonding agent and chamfer preparation group gave better mean fracture strength values (15.14 kgf > 12.19 kgf) as compared with luting cement and simply bonding; also, luting cement and chamfer preparation gave higher mean fracture strength values (17.11 kgf > 17.0 kgf) compared with nano-composite and simply bonding group.

The important inference that could be derived from this observation is that design of tooth preparation incorporated in reattaching the fractured fragment is more influential on the fracture strength values as compared with the material.

Conclusion

Based on the observations of our study, it is concluded that nano-composite and chamfer preparation along the fracture line can be used for the reattachment of the fractured anterior teeth as nano-composite offers high mechanical properties in terms of increased fracture toughness; wear resistance, decreased polymerisation shrinkage as compared with conventional composites (12) and chamfer preparation increases the surface area for application of the material. These two when used together can thus be said to be a useful combination in the reattachment procedure.

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