Determining the Fracture Strength of the Reattached Fragment of Anterior Teeth: An In Vitro Study

Santosh Kumar, Rahul Maria

Abstract
The reattachment of dental fragments, as a conservative treatment, should be the first choice to restore fractured teeth. The aim of this study was to evaluate the effect of different reattachment techniques on impact strength of human incisors. Method material: Experimental specimens were sectioned at the mesial-incisal proximal edge 3 mm from the incisal edge in a labio-lingual direction at 25° inclination apically using a diamond disk. Then the teeth were restored with one-step adhesive and dual cure resin luting cement and restored with composite. The extracted central incisor teeth in the three groups were sectioned and re-attached using three different techniques. Sound teeth composed the control group. Simple re-attachment, Over contouring & Internal dentinal groove formation. The specimens were mounted on a custom made fixture for determination of shear bond strength using universal testing machine. The shearing force was noted and shear bond strength was calculated and recorded in kilogram force units KgF. Data was submitted to Kruskal Wallis ANOVA was used to test the difference in fracture strength between the four groups. Mann whitney u test was used to check for statistically significant differences between 2 groups. The results of our study showed that Group III (Overcontouring) had the highest strength recovery followed by group IV (Internal dentinal groove) and the least being Group II (Simple re-attachment). Conclusion Over-contouring technique had the highest strength recovery almost similar to the sound intact teeth. Simple re-attachment without additional preparation has least strength recovery.

Key words: Anterior teeth, Reattachment, Fracture strength.

Introduction
Fracture of anterior teeth is a relatively common event that affects children and adolescents due to fall and sports injuries. Coronal fracture by trauma is the most frequent type of dental injury in the permanent dentition (25%). The most affected teeth are upper incisors due to their anterior position and protrusion caused by the eruptive process.

In the pre-adhesive era fractured teeth were restored using acrylic resin or complex ceramic restorations associated with metals. These restorations did not promote adequate long-term aesthetics and also required a significant tooth reduction during preparation. Because of difficulty in obtaining good retention, there were few attempts to re-attach fragments.

Chosack and Eildeman published the first case report on reattachment of a fractured incisor fragment in 1964. In 1977, Spasser performed the endodontic treatment and the tooth fragment was retained with three dentin pins. In the late 1970s, Tenny (1978), Starkeg (1979) and Simonsen (1979) reported cases of fragment re-attachment using enamel etching and resin composite.

Re-attachment of tooth fragment is today the first choice for restoring fractured teeth, whether or not the technique is combined with resin composites. This offers several advantages over conventional acid-etch composite restorations. Improved esthetics is obtained since the original shape, color, brightness and surface texture of enamel are maintained. The incisal edge translucency is preserved. The original tooth contours and contacts are maintained. It acts as a short to medium term temporary restoration with the potential for indefinite service. It is more economical. Some of the disadvantages of reattachment include attempts to re-attach fragments.

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The less-than ideal esthetics if the tooth fragment is allowed to dehydrate, color changes of the bonded fragment, the necessity for the continuous monitoring, the discoloration of auto-curing resins, its unknown longevity, the predicted eventual separation of the repair because of progressive breakdown of the bonded junction (cyclic fatigue, hydrolytic degradation).

Many techniques have been proposed for re-attaching the fragment to the remaining tooth:
- Use of a circumferential bevel before re-attaching,
- Placement of a chamfer at the fracture line after bonding,
- Use of a ‘V’-shaped enamel notch,
- Placement of an internal groove or,
- Placement of a superficial over contour over the fracture line.
- Some authors also indicate bonding of the fragment without any additional preparation.

The aim of this in-vitro study was to evaluate and compare the shear strength of sound and restored maxillary central incisor teeth using different re-attachment techniques, namely: Simple re-attachment, Over contouring & Internal dentinal groove placement.
Materials & Methods

This in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics. The materials used were (Fig.1):

1. Dual cure resin luting cement: Duo-Link, BISCO.
2. "One-bottle” adhesive system: One step, BISCO.
3. Shade A2 dentin—Aelitefil, BISCO.
4. Pumice powder.
5. Saline (0.9%).
6. Chloramine (0.5%).

Methodology

A total of 70 extracted permanent human maxillary central incisors that were non-carious, devoid of attrition, abrasion and other structural defects were used for the present study. The teeth were thoroughly cleaned with slurry of pumice. The teeth were disinfected in 0.5% chloramine for 24 hours and stored for one month in 0.9% saline solution.

The steps involved in the study are as follows:

Sectioning of sound teeth: Experimental specimens were sectioned at the mesial-incisal proximal edge 3 mm from the incisal edge in a labio-lingual direction at 25° inclination apically using a diamond disk. Fragments were matched and stored at room temperatures in sterile water for no longer than 48 hours.

Restoration of fractured teeth:

The specimens were divided into four groups, with the control group having 10 samples and other 3 groups having 20 samples each. The groups formed were:

Group I: Control group -(n=10) consisted of intact sound teeth which were not subjected to sectioning.

Group II: Simple re-attachment -(n=20) no additional preparation was made. The sectioned fragments were re-attached using one-step adhesive and dual cure resin luting cement.(Fig.2)

Group III: Over contouring -(n=20) Following re-attachment the teeth were prepared on the buccal surface by means of cylindrical diamond finishing bur-extending 2.5mm coronally and apically from fracture line at a depth of 0.3mm. Then the areas were treated with one-step adhesive and dual cure resin luting cement and restored with composite.(Fig.3)

Group IV: Internal dentinal groove -(n=20) Internal groove of 1 mm deep and wide were placed within the fragment and remaining teeth by means of # 2 round carbide bur with a high-speed hand piece. Then the teeth were restored with one-step adhesive and dual cure resin luting cement and restored with composite.(Fig.4)

Fracture strength of restored teeth

The specimens were mounted on a custom made fixture for determination of shear bond strength using universal testing machine. A knife-edge chisel (0.5mm in cross section) was used to deliver the force so that contact was achieved 2 mm from the incisal edge. The shearing load was applied at a cross head speed of 1 mm per minute. The shearing force was noted and shear bond strength was calculated and recorded in kilogram force units Kgf.

Results

The extracted central incisor teeth in the three groups were sectioned and re-attached using three different techniques. For each group, the fracture strength was expressed as a percentage (%) of load required to fracture the sound tooth, in such a way that it established a relationship between the fracture strength of an intact tooth and fracture strength obtained from restored fractured tooth after it was manipulated by different techniques as described earlier, i.e. simple re-attachment, over contouring & internal dentinal groove formation. The original strength required to fracture an intact tooth was 26.7 Kgf (control group), and the study groups. i.e. Group II,III,IV, after the aforesaid techniques were evaluated in the same manner and then the Mean fracture strength (Kgf), standard deviation (SD) and strength recovery (%) of each restored group were noted and are presented here .The mean force and standard deviation required to fracture each study group are as follows : Group-I 26.71±1.83 Kgf; Group-II 09.78±0.58 Kgf; Group-III 24.41±0.82 Kgf; and Group-IV 23.84 ±0.43 Kgf, (Table 1).

According to the methodology used, within the parameters of this in vitro study the following conclusion can be drawn:
Fragment re-attachment with additional preparation is a realistic alternative for restoring esthetics and function to the traumatized teeth.

10 teeth in the Control group showed a mean fracture strength of 26.71 ± 1.83.
20 teeth in the Simple re-attachment group showed a mean fracture strength of 9.78 ± 0.58.
20 teeth in the Over contour group showed a mean fracture strength of 24.41 ± 0.82.
20 teeth in the Internal dentinal groove group showed a mean fracture strength of 23.84 ± 0.43.

Kruskal Wallis ANOVA was used to test the difference in fracture strength between the four groups. The test showed a p value of < 0.000 thus there is a statistically significant difference in the fracture strength between the four groups. Mann whitney u test was used to check for statistically significant differences between 2 groups.

Control group was statistically significantly different from simple re-attachment group (p<0.000), over contour group (p<0.000) and internal dentinal groove group (p<0.000).
Simple re-attachment group was statistically significantly different from control group (p<0.000), over contour group (p<0.000) and internal dentinal groove group (p<0.000).
Over contour group was statistically significantly different from control group (p<0.000), simple re-attachment group (p<0.000) and internal dentinal groove group (p=0.035).
Internal dentinal groove group was statistically significantly different from control group (p<0.000), simple re-attachment group (p<0.000) and over contour group (p=0.017).

20 teeth in the simple re-attachment group showed a mean Recovery percentage of 36.61 ± 2.16.
20 teeth in the over contour group showed a mean Recovery percentage of 91.37 ± 3.07.
20 teeth in the internal dentinal groove group showed a mean Recovery percentage of 89.24 ± 1.62.

Kruskal Wallis ANOVA was used to test the difference in Recovery percentage between the three groups. The test showed a p value of < 0.000 thus there is a statistically significant difference in the Recovery percentage between the three groups. Mann whitney u test was used to check for statistically significant differences between 2 groups.

Simple re-attachment group was statistically significantly different from over contour group (p<0.000) and internal dentinal groove group (p<0.000).
Over contour group was statistically significantly different from simple re-attachment group (p<0.000) and internal dentinal groove group (p=0.017).
Internal dentinal groove group was statistically significantly different from simple re-attachment group (p<0.000) and over contour group (p<0.017).

Table 1: Fracture Strength and Standard Deviation of Different Groups

<table>
<thead>
<tr>
<th>Group</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Median</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control Group</td>
<td>10</td>
<td>26.71</td>
<td>1.83</td>
<td>26.86</td>
<td>22.77</td>
<td>29.52</td>
</tr>
<tr>
<td>Simple Re-Attachment Group</td>
<td>20</td>
<td>9.78</td>
<td>0.58</td>
<td>9.65</td>
<td>8.89</td>
<td>10.74</td>
</tr>
<tr>
<td>Over-Contour Group</td>
<td>20</td>
<td>24.41</td>
<td>0.82</td>
<td>24.21</td>
<td>23.28</td>
<td>26.13</td>
</tr>
<tr>
<td>Internal Dentinal Groove Group</td>
<td>20</td>
<td>23.84</td>
<td>0.43</td>
<td>23.71</td>
<td>23.18</td>
<td>24.61</td>
</tr>
<tr>
<td>Total</td>
<td>70</td>
<td>20.40</td>
<td>6.88</td>
<td>23.66</td>
<td>8.89</td>
<td>29.52</td>
</tr>
</tbody>
</table>

Kruskal Wallis ANOVA : p value < 0.000 : Significant

Based on the statistical analysis, the study reveals that when all the study groups i.e. II, III, IV compared to the Group I, the best technique employed was the Group III: Over contour, followed by Group IV: Internal dentinal groove and the least was the Group II: Simple re-attachment.

Discussion
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 effects on the patient and their parents. A number of treatment options have been used in the past for restoration of fractured teeth depending on the site of fracture. Several alternatives were developed to restore the...
fractured crown, i.e. resin crowns, stainless steel crowns, orthodontic bands, pin-retained resin, porcelain jacket crowns, porcelain bonded crowns and resin composite restorations. All these alternatives are reliable, however, these techniques are not conservative, require wear of sound dental structure, and have some technical difficulties to obtain perfect tooth contour, color and translucence to match it to the remaining crown portion. Besides, they are time-consuming and high priced.\textsuperscript{12}

With the advent of composite resins in dentistry, the fractured incisors were more often restored with these tooth coloured resins. The composite resin has the disadvantage of poor abrasion resistance in comparison with enamel and sometimes problems with colour matching and sensitivity.\textsuperscript{11}

Considering the disadvantages presented by the conventional restorative techniques, Chosack & Eidelman, in 1964, had proposed the restoration of fractured crowns using the dental fragment. Adequate retention of the fragments could only be achieved with the advent of adhesive dentistry. At present, reattachment of fractured tooth fragments should be the first choice to restore fractured incisor teeth in children as it helps to preserve dental tissues during the growth phase.\textsuperscript{12,13}

This technique offers several advantages over other techniques. It is a conservative procedure. It provides total aesthetic recovery, because the tooth contour, color, translucence, and surface texture are the same as that of the natural tooth. It also provides color stability over time and wear at similar rate as the other teeth. The clinical procedure is safe and simple, therefore less time in chair is required, which might reduce the cost of the treatment.\textsuperscript{11}

80\% of traumatized incisors fracture in an oblique fashion from labial to lingual aspects with the fracture line proceeding in an apical direction. This is an unfavorable fracture pattern that exhibits low resistance to labially applied forces. This also occurs when fractures are approximately perpendicular to long axis of the tooth. In order to replicate nature, the experimental specimens in this study were sectioned at 3 mm from incisal edge at a 250 inclination apically in a facio-lingual direction using a diamond disc.\textsuperscript{13}

It is observed that the association of adhesive systems with high strength materials such as composites could lead to higher fracture strength recovery. Considering this fact, nano-hybrid resin composite( Aelitefil, BISCO), and a dual cure resin luting cement( Duo-Link, BISCO), in conjunction with a dentin bonding agent: One-bottle adhesive system,( One-step, BISCO) were used.

In the present study we have evaluated the shear bond strength of re-attached fragments using 5th generation resins by means of three different techniques:

a. Simple Re-attachment
b. Over-contouring
c. Internal dentinal groove.

The results of our study showed that Group III (Over-contouring) had the highest strength recovery followed by Group IV (Internal dentinal groove) and the least being Group II (Simple re-attachment).

In Over -contouring (Group III) good performance could be attributed to increase in adhesion area provided by tooth preparation around the fracture site. The greater the extension of material on the surface, the better the force distribution over a large enamel area, contrary to what occurred in simple re-attachment (Group II), where the stress concentration is limited to the fracture line.

The lower fracture strength found in Group II (bonded only) may be partly due to the smaller bonded area. This bonding technique may have a shorter longevity since only 36.6\% of the strength of sound teeth was achieved. This finding was in accordance to A Reis, et al. (2001).\textsuperscript{12,13}

However, the greater exposure of resin composite may diminish the long term esthetics due to process of abrasion and discoloration that occurs in composites with time. Polishing at recall appointments may solve this problem. This drawback does not occur when bonding is performed without additional preparation (Group I), however, this technique should be avoided because of its low fracture strength and consequently the highest vulnerability to future fractures.\textsuperscript{12,13}

Placement of internal dentinal groove (Group IV) may provide excellent fracture strength and higher esthetic durability almost similar to Group III. It is likely that the greater adhesion area and placement of an internal resin bar which acts as an opponent to the compression load applied on buccal surface could be responsible for the good results obtained in this group. Also, this technique did not alter the precise fit between the fragment and the remaining tooth. Esthetically, the most favorable situation exists when there is minimal disruption of enamel at the labial fracture site, and the segments fit together with no discernible defects.

This facilitates an accurate apposition of the fragment and minimizes an enamel/composite interface as placement of an internal dentinal groove can also provide good fracture strength to restored teeth, it should be preferable.\textsuperscript{12,13} Some authors claimed that this technique compromises esthetics, as the internal resin composite can modify the shade of the teeth. However, one may consider this as groove size and material dependent. The simple re-attachment (Group II) had an overall fracture strength recovery of 36.6\%, which indicated that re-attachment without preparation exhibited less than 50\% of fracture strength displayed by intact teeth.

According to Busato (1986), the re-attachment technique must be chosen based on the quality of fit between segments. When the segments fit together with no discernible
disruptions or defects, techniques that avoid resin composite exposition would be preferable. On the other hand, when enamel structure is lost in the trauma event, it may be more convenient to use an over contour technique so that the esthetics can be obtained simultaneously with increase in adhesion area.1,2,3 Another relevant variable concerning reattachment techniques is the material used. Badami & others (1995) showed that the strength of restored teeth was dependent on the adhesive system applied. However, these studies indicate that there are more factors involved in the retention of the fragment and reattachment longevity.1,2,3 Based on the results of this study, the null hypothesis tested was rejected since there were differences among the techniques used to restore fractured teeth.1,2,3

Summary and Conclusion
The present in vitro study was carried out in the Department of Conservative Dentistry and Endodontics, to determine fracture strength of reattached fractured anterior teeth using different techniques.

According to the methodology used, within the parameters of this in vitro study the following conclusion can be drawn:

1. Over-contouring technique had the highest strength recovery almost similar to the sound intact teeth. Simple reattachment without additional preparation has least strength recovery.
2. Fragment reattachment with additional preparation is a realistic alternative for restoring esthetics and function to traumatised teeth.

References