An In Vitro Comparison and Analysis of Different Restorative Materials and Techniques Used for Fragment Reattachment of Fractured Anterior Teeth

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Abstract

Anterior crown fractures are common dental injuries among children. Reattachment of fractured crown fragments has become popular as it is conservative and cost effective. The fracture resistance determines the bonding ability of the materials to resist re-fracture following fragment reattachment.

To evaluate the fracture resistance of reattached teeth using newer adhesive restorative materials (Composite Resin, Resin Modified Glass Ionomer cement, Compomer and Giomer) with techniques (simple reattachment and internal dentinal groove) used to reattach fractured tooth fragment.

90 extracted human permanent incisors were selected. 10 teeth were kept as control and 80 teeth were divided randomly into two groups (n=40) based upon the techniques. Further each group were divided into four sub-groups (n=10) based on material used for reattachment.

The specimens were fractured and reattached using different adhesives materials after different preparations techniques. All specimens were subjected for test in Universal Testing Machine at cross-head speed of 1mm/min. The load at which the reattached fragment debonded was recorded. This load represented the fracture resistance.

Analysis of Variance followed by Tukey HSD test.

When different reattachment technique were compared, the highest fracture resistance shown by Internal Dentinal Groove group followed by Simple Reattachment group. Whereas, when different materials were compared, the highest strength was shown by Compomer followed in descending order by Composite, Resin Modified Glass Ionomer cement and Giomer. Reattachment of fractured crown fragments using newer materials and technique aids in better results.

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Introduction

Traumatic dental injuries are the most disruptive and distressing emergencies which are presented in the dental practice.[1] Most dental injuries occur during the first two decades of life.[2] Anterior crown fractures are a common form of dental injury that mainly affects children and adolescents[3].

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The prevalence of these injuries has increased in the last 10-20 years.[4] The frequency of dental trauma is on the rise due to participation of children and teenagers in contact sports, automobile accidents, outdoors activities and falls.[3] Coronal fractures of permanent incisors represent 18-22% of all traumas to dental hard tissues. Out of these, 96% involve maxillary incisors (80% central incisor and 16 % lateral incisor).[4] The most affected teeth are the upper incisors due to their anterior protrusion and position caused by the eruptive process.[5]

Restoration of a fractured crown is important both aesthetically and functionally.[3] Earlier, methods like resin crowns, stainless steel crowns and pin-retained inlays have been used

with varying degrees of success. More recent esthetic techniques such as porcelain laminate veneers, porcelain fused to metal crowns and all ceramic crowns have largely replaced the older techniques. Although these more recent techniques gives a very esthetic result, they suffer from the drawback of jeopardizing the tooth structure and in cases of esthetic emergency, their application is not possible. Use of composite materials for restoration in such cases has been reported.[6] nonetheless, composite resins have the disadvantage of poor abrasion resistance, marginal staining, discoloration and lack of marginal integrity.[3] Considering this, the reattachment of fractured tooth fragments is one valid alternative for conservative treatment in such demanding situation where anterior teeth are involved.[4]

Reattachment of coronal fragments has been performed using different bonding agents as well as different adhesive materials. Apart from the different materials used for re-attachment, the preparation of tooth plus the fractured fragment before reattachment also matters. The preparation enhances retention and exposes more reactive enamel and also gives superior degree of aesthetics.[4]

The fracture resistance determines the bonding ability of the materials to resist re-fracture following fragment reattachment.[3] Usually, the resistance to fracture of the reattached tooth will not be the same as the intact tooth.[4] The reattached fragments are prone to re-fracture if one more traumatic episode occurs or under non-physiological use of the restored teeth. Hence, most concerns have been directed towards the fracture strength of reattached teeth.[3] Thus, this study was planned to estimate the fracture resistance of newer adhesive restorative materials (Composite Resin, Resin Modified Glass Ionomer cement, Compomer and Giomer) and techniques (Simple Reattachment and Internal Dentinal Groove) used to reattach fractured tooth fragment using universal testing machine (Instron).

Materials and methods

For present study ninety permanent anterior teeth extracted for periodontal reasons were collected **(Figure 1)**.

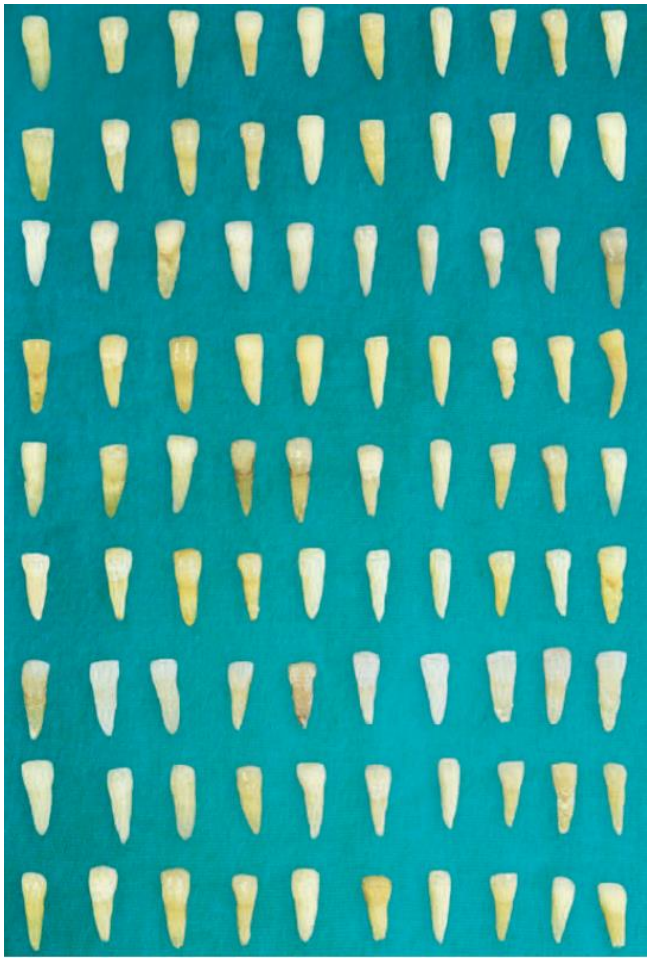

Figure 1. 90 Permanent Anterior Teeth.

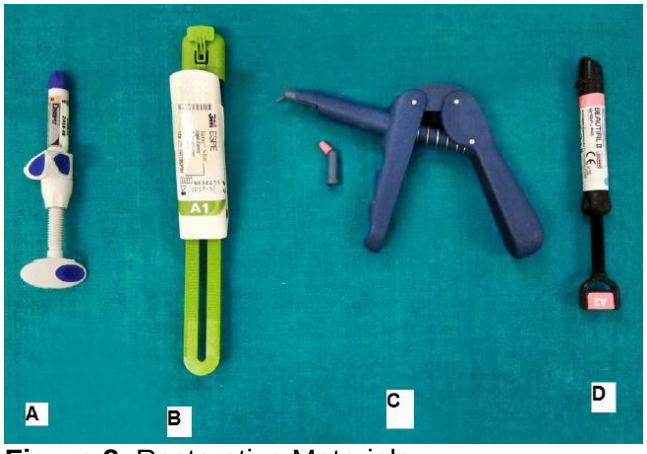

Figure 2. Restorative Materials

The restorative materials used were **(Figure 2)**:

- Composite Resin **(Esthet X HD)**
- Resin Modified Glass Ionomer Cement, RMGIC **(Ketac N 100)**
- Compomer **(Dyract XP)**
- Giomer **(Beautifill II)**

Preparation of Samples

Ninety extracted permanent single rooted teeth were selected. The extracted teeth were kept in 5% sodium hypochlorite solution for 1 hour and the soft tissue remnants and calculus on the tooth surface were removed mechanically. Then the teeth were stored in normal saline for further study. Initially one columnar acrylic block was prepared of height 3 cm and 1.5 cm width so that it could be easily held over the Instron while testing at later stage. Then a rubber base impression mould of the prepared acrylic block was made using a rubber base impression material and positive replicas were obtained by pouring the self-cure acrylic resin into the rubber base impression mould and simultaneously embedding the roots of the teeth into it to form the test samples which could be easily mounted over the Instron. This process was repeated till all 90 test samples were obtained **(Figure 3)**.

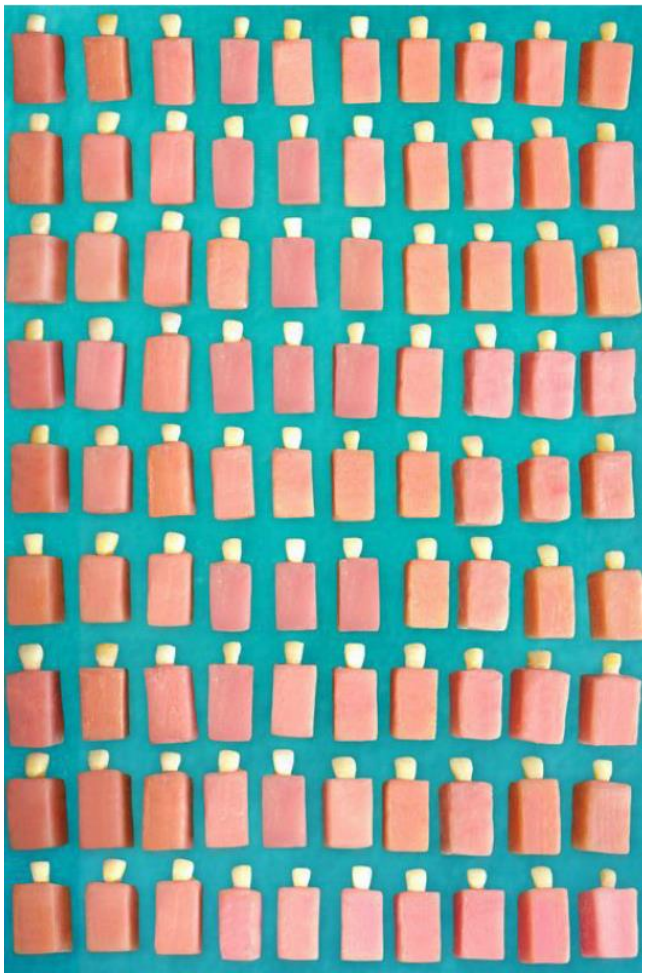

Figure 3. 90 Prepared Samples.

Design of Study Group

Ninety teeth were randomly divided into three study groups (Group A, B, C) as follows **(Table 1).**

Group A:	**Simple Reattachment Technique(n= 40)**
Group AI:-	Composite Resin (n=10)
Group AII:-	Resin Modified Glass Ionomer Cement, (n=10)
Group AIII:-	Compomer (n=10)
Group AIV:-	Giomer (n=10)
Group B:	**Internal Dentinal Groove Technique (n= 40)**
Subgroup BI:-	Composite Resin (n=10)
Subgroup BII:-	Resin Modified Glass Ionomer Cement, (n=10)
Subgroup BIII:-	Compomer (n=10)
Subgroup BIV:-	Giomer (n=10)
Group C:	**Control Group (n=10)**

Table 1. Design of Study Group.

Tooth in experimental group A and B were marked, 2.5 mm away from the incisal edge and then sectioned transversely along the long axis of the tooth using a double sided diamond disk (Figure 4, 5, 6). Remnants and fragments were matched and stored at room temperatures until further study.

Figure 4. Sectioning of the Sample.

The preparation of tooth and its fragment were as follows (Table 2).

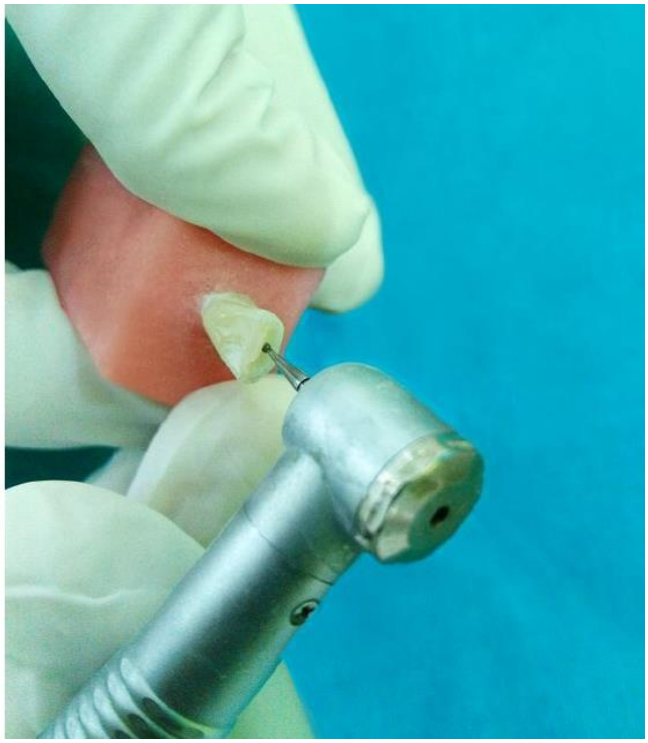

Figure 5. Preparation of Internal Dentinal Groove on the Tooth.

Figure 6: Preparation of Internal Dentinal Groove on the Fragment.

Group A:	**Simple Reattachment Technique**	No additional preparation was made.
Group B:	**Internal Dentinal Groove Technique**	Groove of 1 mm deep and wide was placed within the fragment and remaining teeth by means of a round carbide bur with a high-speed hand piece **(Figure 5 & 6).**
Group C:	**Control group**	Intact sound teeth which were not subjected to sectioning.

Table 2. Preparation of tooth and its fragment.

Re-Attachment Procedure

Reattachment of fragments in experimental group A and group B was done by using their respective adhesive materials as per manufacturer's instructions. Both tooth and fragment were etched with 37% phosphoric acid (Scotchbond Multipurpose, 3M ESPE) for 15 seconds. Then they were rinsed with water for 10 seconds and dried. A one-bottle dental adhesive (Single Bond 2, 3M ESPE) was applied with the help of an applicator tip to the conditioned surfaces in accordance with the manufacturer's instructions and light cured for 10 seconds. Afterward, a small increment of cement (adhesive materials) was applied to the tooth and the fragment, which was then reattached to its proper position using hand pressure. The resin cement was polymerized for 40 seconds on each surface, with a light curing unit. After polymerization, excess material was removed and finishing was done.

Evaluation

Samples were mounted on Instron. The rod of Instron was held perpendicular to the long axis of the tooth at the incisal third of the crown, parallel and adjacent to the bonding line. Thereafter, the load was applied at cross-head speed of 1 mm/min which was increased progressively until the reattached tooth fragment separated (Figure 7 & 8).

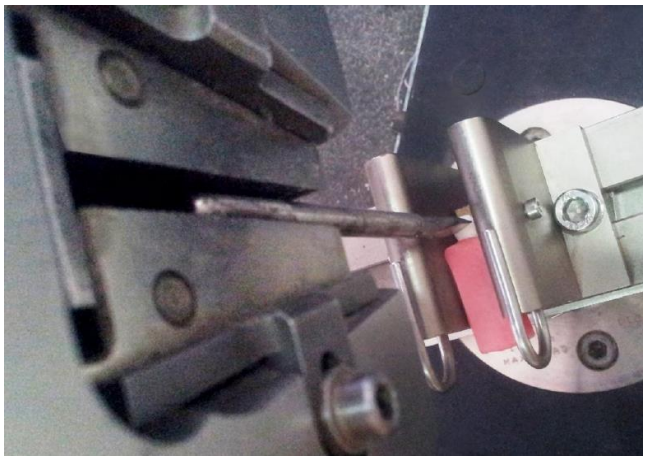

Figure 7. Load applied on sample mounted on Instron.

The load at which the reattached fragment debonded from the remaining tooth structure was recorded. This load represents the fracture resistance of the reattached tooth. The fracture resistance of all the specimens was recorded in the same manner. The data obtained was tabulated and subjected to statistical analysis.

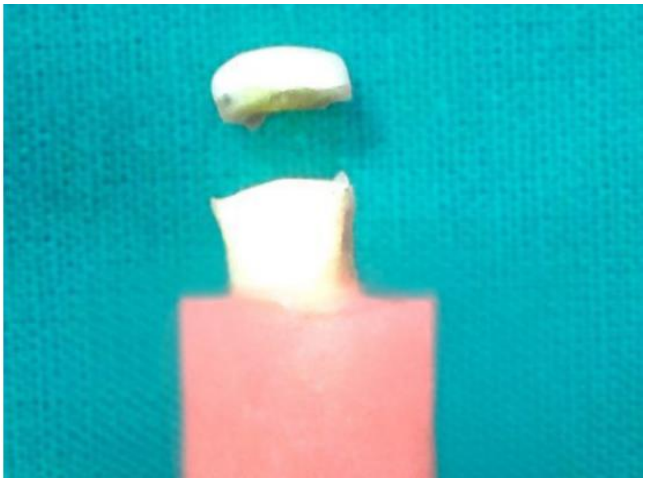

Figure 8. Detached tooth and fragment.

Results

For each subgroup independently as well as on overall assessment, mean fracture strength was found to be higher for internal dentinal groove technique (overall mean value 62.89) as compared to simple reattachment technique (overall mean value 50.12). However, the difference was not found to be significant statistically for subgroup II (Reattached using Resin Modified Glass Ionomer Cement). For other subgroups and on overall assessment, the difference was found to be statistically significant. On the basis of above evaluation, the following order of fracture resistance was observed in different groups.

Internal Dentinal Grove Technique > Simple Reattachment Technique

On between subgroup comparison of fracture resistance irrespective of technique using Tukey`s HSD test which revealed that all the between subgroup differences except for that between subgroups II (Resin Modified Glass Ionomer Cement) and subgroup IV (Giomer) were statistically significant. On the basis of above evaluation, the following order of fracture resistance was observed in different groups.

Control Group > Subgroup III (Compomer) > Subgroup I (Composite Resin) > Subgroup II (RMGIC) ~ Subgroup IV (Giomer)

Discussion

In-vitro tests play a very important role in providing the necessary information regarding the efficacy of new products in a short period of time and lesser cost.

In this present study the extracted teeth were kept in 5% sodium hypochlorite solution for 1 hour and the soft tissue remnants and calculus on the tooth surface were removed mechanically. Then the teeth were stored in normal saline. Munksgaard (1991), Farik (1998), Loguercio(2004), Shirani (2012) believes that reattachment with the hydration restores approximately 50% of the fracture strength of the original tooth.[7,8,9,10] In addition, according to Toshihiro (2005) appropriate hydration re-establishes esthetics and natural color. Therefore, hydration of the fragment should be considered a fundamental step in treatment of fractured teeth.[11]

Similar methodology was followed in this present study as elaborated by Singhal (2012) wherein each specimen was embedded in an acrylic resin block such that the long axis of tooth was parallel to the central axis of the block so that the specimens could be mounted over the Universal Testing Machine to evaluate the fracture resistance of reattached teeth.[3]

Regarding the therapy of dental injuries, over the years several methods were attended with varying rate of success and different degree of complexity.[12] To overcome the disadvantages presented by the conventional restorative techniques, Chosack & Eidelman (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.[13,14]

Reattachment of tooth fragment is possible only when the tooth fragment is present after the trauma and the fragment is intact with good adaptation to the remaining tooth. As stated by Bhargava *et al.* (2015) this method has a number of advantages shown in clinical and experimental studies. Reattached fragment to a great extent restores esthetics, as it uses the original tooth's shape, color, translucence and surface structure. Reattachment of tooth fragment of anterior teeth is simple to practice and economic method that has the potential to assume the incisal strength during tooth functioning. The method ensures increased wearing steadiness and thus creates better function. Other advantages of this method are

the psychological comfort of patient, less time spent in dental chair, precise reconstruction of tooth's morphology and usage of structure that wears out as the antagonists.[15,16] Attila *et al.*(2006), Singhal (2012) and Assila *et al*. (2016) described re-attachment procedure as an excellent short to medium term temporary restoration with potential for indefinite service.[3,17,18]

With the advent in hydrophilic adhesives that offer high bond strength values, some investigators Andreasen *et al*. (1993), Badami (1995), have attempted to reattach fragments using only these materials without an additional retentive preparation or simple reattachment as stated by Pusman *et al*. (2010).[19,20,21] In this present study, Composite Resin was one of the material used to evaluate the fracture resistance of reattached tooth fragment. Development of contemporary composite materials and the possibilities of contemporary adhesive dentistry are reason for new investigations connected with reattachment technique. Materials used for reattachment of fractured teeth are investigated by many clinicians as they also influence strength of the connection tooth structure – fragment as stated by Belcheva (2008).[15]

Farik *et al.* (2002) it is confirmed that most bonding systems fifth generation increase fracture resistance of reattached crown fragments when used in combination with resin.[15,22]

The next restorative material in consideration to evaluate was Polyacid-Modified Composite Resins, known trivially as Compomer. They were introduced to the dental profession in the early 1990s and were presented as a new class of dental material designed to coalesce the aesthetics of traditional composite resins with the fluoride release and adhesion of glass-ionomer cements as described by Nicholson (2006).[23]

Furthermore, Resin Modified Glass Ionomer Cement and Giomer were the last two restorative materials used in this present study to evaluate the fracture resistance of reattached tooth fragment. Resin modified GIC is mainly a glass ionomer with addition of small quantity of resin component such as hydroxyl-ethyl-methacrylate or Bisphenol-Aglycidyldimethacrylate. It primarily relies on chemical bond through ion-exchange between the material and the tooth substrate rather than mechanical bond. It may be the rationale for least fracture resistance of teeth reattached with resin modified GIC.[3]

Apart from the different materials used for re-attachment, the preparation of tooth as well as the fractured fragment before reattachment also matters. The preparation enhances retention and exposes further reactive enamel and also gives high degree of aesthetics.[4]

Reis *et al.* (2001) have reported that a simple reattachment with no auxiliary preparation of the fragment or tooth may not be able to restore even half of the fracture strength of intact teeth.[5] Rajput *et al*. (2010), Abdulkhayum *et al*. (2014) have advocated the necessity of using additional preparations to augment the retention of the reattached fragment. Such preparation methods include enamel beveling of the fragment and remaining crown, internal dentin groove, external chamfer, and the overcontour technique; all of which have their own advantages and disadvantages.[1,6,19,]

Megha *et al.* (2010) stated that mechanical properties in terms of increased fracture toughness; wear resistance, decreased polymerisation shrinkage as compared with conventional composites and chamfer preparation increases the surface area for application of the material.[24]

Michelle *et al.* (2011) mentioned that the preparation technique used, in particular the labial and lingual bevel, may have a positive effect on the Shear bond Strength of the reattached fragment.[25] Also Sushma *et al*. (2016) concluded that circumferential chamfer bonding with total etch bonding system could approximate the impact strength of the restored teeth to that observed in the sound teeth.[26]

Technique described by Reis *et al*. (2004) is placing an internal groove in dentin fragment and the remaining tooth.[5,18] Pushman *et al.* (2010) showed highest fracture strength recovery was achieved by internal dentinal groove as compared to overcontour and simple reattachment techniques.[19,27]

In light of many published studies that verified the efficacy of the fragment reattachment techniques, it has become apparent that both the preparation technique and the kind of material used to bond fractured fragments may have considerable effects on the fracture strength of such restored teeth.[19]

Fracture patterns obtained in laboratory do not essentially simulate clinical occurrences

as stated by Capp *et al*. (2009).[28] Also, Loguercio (2004) stated that the anatomy of the surface produced by the sectioning is undoubtedly different from the surface resulting from the fracture.[7] Badami *et al*. (1995) and Sengun *et al*. (2003) used sectioning to study fragment bonding dictated by the fact that the sectioning establishes a repeatable condition absolutely compulsory for an *in vitro* study, although it does not exactly simulate an accidental fracture.[3,21,29]

On overall comparison of mean fracture strength among different study groups, irrespective of material used for reattachment, result of the present study revealed that Internal Dentinal Groove technique had maximum fracture resistance as compared to Simple Reattachment technique. This may be accredited to the fact that placement of internal dentinal groove may provide excellent fracture strength and higher esthetic durability. It is probable that the greater adhesion area and permeability of an internal resin bar acts as an opponent to the compression load applied on buccal surface could be responsible for the good results obtained in this group as stated by Srilatha *et al*. (2012).[12] Also, this technique does not alter the precise fit between the fragment and the remaining tooth.[5]

The result of the present study were in accordance with the study conducted by Reis *et al.* (2002), Loguercio *et al*. (2004), Pushman (2009) who obtained highest fracture strength recovery using Internal Dentinal Groove technique. Authors found out that the placement of an Internal Dentinal Groove nearly restored the intact tooth fracture strength with recovering values of 90.5%. They advocated the necessity of using additional preparations to enhance the retention of reattached fragments.[7,19,30]

On the contrary, the study conducted by Worthington *et al.* (1999) showed that placement of any kind of preparation does not improve the fracture strength of fragment-bonded teeth compared to preparation less reattachment.[30,31]

Result of the study also revealed that Control group (Intact teeth) had maximum fracture resistance. This finding was in agreement with Badami *et al*. (1995), Demarco *et al*. (2004), Bruschi-Alonso *et al*. (2010) who concluded that no technique or material, when it was used individually, was capable of achieving the mechanical strength of sound teeth.[4,21,32,33] Conversely, another statement by Reis *et al.* (2001) says that fracture strength of reattached fragment may approximate that of sound teeth according to the materials used and techniques performed.[5,15]

The result depicted that Compomer had maximum fracture resistance, irrespective of technique used. This result may be attributed to the fact that Compomer has higher resin content, which is about 70% as compared to 30% in Resin Modified Glass Ionomer Cement. Higher the resin content better would be the mechanical properties of the material. In addition, an adhesive was applied over the etched surfaces in teeth reattached with Compomer. This adhesive layer favors good adherence to the substrate as they penetrate the micro-porosities created by etching. It creates a hybrid layer that provide good adherence to substrate by micromechanical interlocking and achieve a high degree of cross-linking.[3,34]

The result of the present study was in accordance with Brar *et al*. (2011) who concluded that Compomer showed maximum resistance to fracture when compared to Composite resin, Dual-cure resin cement and Resin-modified Glass Ionomer Cement.[4] Almaummar *et al.* (2001), Khinda (2016) in their study observed that Compomer showed higher bond strength than resin modified Glass Ionomer Cement, but less than composite resin.[3,35,36]

On the contrary, in a study conducted by Prabhakar (2007) there was no statistically significant difference in the impact strength values of fragment bonded teeth between Compomer and Composite. The reason for obtaining no statistically significant difference between Compomer and Composite could be due to physical properties such as compressive, biaxial flexure and diametral tensile strengths, fracture toughness and surface hardness of Compomer approaching to those of Composite.[23,34]

Conclusions

From the present study it was concluded that Internal Dentinal Groove technique had maximum fracture resistance when compared to Simple Reattachment technique. Among the materials tested, Compomer showed maximum fracture resistance followed in descending order by Composite Resin, Resin Modified Glass Ionomer Cement and Giomer respectively.

Declaration of Interest

The authors report no conflict of interest.

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