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Evaluation of the fracture resistance of reattached incisal fragments using different materials and techniques

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Abstract – *Objectives*: When coronal fracture occurs in anterior teeth, fragment reattachment can be a valid alternative to a direct restoration. The aim of this study was to evaluate the influence of the material and the technique used to reattach the fragment. *Materials and methods*: Eighty sound maxillary and mandibular incisors were selected and randomly divided into eight groups ($n = 10$). The incisal third of each tooth was removed using a saw machine. The fragments in groups 1–4 were reattached using resin-based materials: group 1 adhesive, group 2 flow, group 3 composite, group 4 cement; in groups 5–8, the same materials mentioned before were used but a bevel was also performed on both labial and lingual surfaces. Shear bond strength (SBS) was calculated by applying a load incisal to the reattachment line. A two-way Anova was used to evaluate the influence of materials and techniques on the SBS. *Results*: The technique used was statistically significant ($P < 0.001$), while the material was not ($P = 0.793$). *Conclusions*: The choice of material seems to have no influence on the SBS, whereas a bevel performed on the labial and lingual surfaces can significantly improve the SBS of the reattached fragment.

Research has shown that fractures of anterior teeth are common among children, particularly those aged between 8 and 11 (1). Many techniques have been developed to restore uncomplicated fractured crowns, such as porcelain veneers (2) or jacket crowns; however, such treatments require substantial sacrifice of dental structure and sometimes even endodontic treatment (3). The development of resin composite materials has made it possible to have a more conservative approach toward the treatments of these injuries in as much as if the fragment of the fractured tooth is available, the reattachment of this fragment is possible (4–11). This approach offers several advantages, such as a better and longer lasting esthetic results (4–11), incisal margin wear that matches that of adjacent teeth and a faster procedure.

Reattachment of fragments has been performed with some kind of composite bonding or flow material. The methods have included bonding without preparation of the tooth or fragment (12–14). Various preparation techniques have also been attempted, prior to or after bonding. Regarding the former, these preparation techniques have included a v-shaped enamel notch (15, 16) both on the fragment and on the tooth; internal groove (9, 17) within the fragment and the remaining tooth; labial and circumferential bevel (18). These preparation techniques have sometimes been combined with a superficial overcontouring with composite over the fracture line, which may be circumferential or lingual (18). The reported results vary considerably, from fracture strength as high as that of sound teeth (including internal grooves on both tooth and fragment) (19, 20), to only approximately 50% (including labial chamfer and lingual overcontour) (18). Other studies have failed to demonstrate statistical differences in fracture strength between two and more techniques (21, 22).

The method of obtaining the fragment in the different studies also seems to be relevant. Four studies have reported controversial results regarding the performance of techniques used for reattachment (19–22) where distinct methodologies were employed to obtain the fragments. Worthington et al. (22) sectioned the incisal edge of the tooth, whereas Reis et al. (19, 23) fractured the teeth using a universal machine. Both of these methods were used in other experimental setups (24–28). In particular, Loguercio et al. (29) evaluated the effect of fractured or sectioned fragments on the fracture strength recovery of four techniques used for reattachment and resin composite buildups. They concluded that the way fragments are obtained in laboratory tests plays an important role.

Moreover, the speed applied to cause the trauma interferes with the results obtained (3, 30), as well as the load application distance to the fracture plane (28). Another variation found among published articles treating this approach was the use of different materials to reattach the fragment. These included using bonding agents only (3, 20, 21, 24, 31, 32), associating bonding agents with flowable resins (30, 33, 34), dual or self-cured luting cements (14, 19), or light-cured luting cements

(25). This illustrates how numerous factors play an important role in the fracture strength and longevity of the reattachment procedure. Only one study has been carried out which compares the combination of different materials and different application techniques (23). This study used mandibular molars and concluded that the choice of materials had less importance than the technique used. However, the effects of such combinations have never been investigated on the anatomically more slender incisor teeth, which are probably less fracture resistant than the stouter posterior teeth, and where most fractures actually occur.

Therefore, the purpose of this study was to evaluate the behavior of different materials when used in different application techniques to reattach a broken incisor fragment by studying the shear bond strength (SBS) at the fragment–tooth junction. The null hypotheses tested in this study were that the SBS is not influenced (i) by the material nor (ii) by the technique used to reattach the fragment.

Materials and methods

Eighty sound human maxillary and mandibular incisors, extracted for periodontal reasons, were inspected under optical magnification (2×). The teeth were cleaned from debris and calculus with curettes and ultrasonic tips; only teeth free from cracks, caries or any other kind of structural defects were selected and stored in a 0.01% thymol solution until prepared. The teeth were randomly divided into eight groups, each consisting of 10 teeth (five maxillary and five mandibular incisors). The teeth were measured on the labial side, from the cervical to the incisal edge, with a digital caliper. This measurement was then divided by three after which the tooth was marked at one-third from the incisal edge. Each tooth was embedded in acrylic resin up to two millimeters from the marker. Specimens were fixed and cut on the mark line, perpendicularly to the long axis of the tooth, with a water-cooled low-speed diamond saw (IsoMet; Buehler Ltd, Lake Bluff, IL, USA). For each tooth, one fragment was obtained, and specimens were then treated as follows:

Group 1

Both the fragment and the tooth were etched using 37% orthophosphoric acid (Scotchbond etchant; 3M-ESPE, St Paul, MN, USA) selectively for 30 s on the enamel and then 15 s on the dentin. The surfaces of the fragment and of the remaining tooth were rinsed with water for 30 s, then excess water was gently removed using air flow. The primer solution (Adper Scotchbond Multi-purpose primer; 3M-ESPE) was applied to the fragment and tooth. The solvent was made to evaporate using a gentle air flow for 5 s. The bonding solution (Adper Scotchbond Multi-purpose bonding; 3M-ESPE) was applied to both surfaces. The fragment was then reattached to the remaining tooth and light-cured (400 mW cm^{-2}, FreeLight 2; 3M-ESPE) for 20 s on both labial and lingual surfaces applying hand pressure.

Group 2

After applying the adhesive system (Adper Scotchbond 1XT; 3M-ESPE) and light-curing for 20 s both surfaces, the tooth and the fragment as in group 1, a coat of flowable resin (Filtek Supreme Flowable; 3M-ESPE) was applied. The fragment was reattached to the remaining tooth using hand pressure and the excess material on both labial and lingual surfaces was removed using a microbrush. The specimen was then light-cured as in group 1 while continuing to apply hand pressure.

Group 3

The treatment was the same as for group 2 but using a hybrid composite (Filtek Supreme Resin Composite; 3M-ESPE) instead of flowable resin.

Group 4

The treatment was the same of group 2 but using a dual-curing cement (RelyX ARC; 3M ESPE) instead of flowable.

Group 5, 6, 7, and 8

The fragment was reattached as in group 1, 2, 3, and 4, respectively, and then a labial and lingual bevel were performed on the reattachment line with a 2-mm round diamond bur (FG200; Intensiv SA, Grancia, Switzerland) mounted on a hand-piece at 34938 ***g***. The 1-mm-deep bevel was made applying the bur on the fracture line equally involving both sides of the fracture line. The bevel on the labial and lingual side was then etched using 37% orthophosphoric acid (Scotchbond etchant; 3M-ESPE) for 30 s. The surfaces were rinsed under running water for 30 s, and excess water was gently removed using air flow. The adhesive system was applied to the tooth according to the manufacturer's instructions. First, the primer was applied to the fragment and tooth with a rubbing action (Adper Scotchbond Multi-purpose primer; 3M-ESPE), and the solvent was allowed to evaporate using a gentle air flow. Then, the bonding was applied to both surfaces (Adper Scotchbond Multi-purpose bonding; 3M-ESPE). The bevel was light-cured on the labial surface for 20 s and on the lingual surface for another 20 s. Flowable composite resin (Filtek Supreme Flowable; 3M-ESPE) was applied at the junction of the two fragments and then light-cured for 30 s on the lingual surface and on the labial surface. A coat of resin composite (Filtek Supreme Resin Composite; 3M-ESPE) was then applied at the same location and light-cured for 30 s on the lingual and on the labial surface.

After bonding procedures, the specimens were placed in a Universal Testing Machine (Triax 50 Digital; Controls, Milan, Italy). The load was applied on the labial surface, perpendicularly to the long axis of the tooth, incisal to the reattachment line. A stainless steel tip was used at a cross-head speed of 0.75 mm min^{-1} as recommended by ISO Standard (ISO/TS 11405:2003 –

Dental Materials-Testing of adhesion to tooth structure). The fracture load was recorded in *N*.

The fracture surfaces of the teeth were photographed with a digital reflex camera (Nikon D70s; Nikon Corp., Tokyo, Japan) at a magnification of 1:1 (Micro-Nikkor 105 mm f/2.8 AF-D; Nikon Corp.). The surface area was measured with a dedicated software (ImageJ 1.39u; National Institutes of Health, Bethesda, MD, USA) and used to allow expressing SBS values in MPa.

The statistical analysis was performed with SPSS 12 (SPSS Inc., Chicago, IL, USA). The Kolmogorov–Smirnov test was applied to verify the normal distribution of data. A two-way ANOVA was used to establish the influence of the material (adhesive, flowable, composite, cement) and the technique used (standard, bevel) in fragment reattachment on the SBS. The significance level was set at $P < 0.05$.

Results

The obtained results are shown in Table 1. The two-way ANOVA showed that the variable 'technique' was statistically significant ($P < 0.001$), while the variable 'material' was not ($P = 0.793$). The interaction between 'material' and 'technique' was also statistically significant ($P = 0.018$).

Discussion

In the present study, the specimens were sectioned with a saw rather than fractured. Badami and Reis (29, 31) have shown that the surface of a sectioned tooth is different from a naturally occurring fractured one, as the fracture produces fragments with a good fitting. A fractured surface also tends to run parallel to the main direction of the enamel prisms, whereas the orientation of the sectioned surface is dictated by the alignment of the diamond saw used to section the incisal edge. Therefore, the fitting in this study, between the tooth and the fragment, was not perfect and sometimes even presented a gap. Hence, the results obtained in this study should be an underestimation of what could be achieved clinically using these techniques. However, using a saw resulted in smooth surfaces, which is an advantage as the number of defects in the adhesive interface is lower (35) and it allowed to standardize the mode of 'fracture' that would have been otherwise random. Furthermore, the teeth used for the experiment were teeth extracted for periodontal reasons, which are usually teeth of older people, whereas trauma happens usually in younger patients.

Table 1. Means and standard deviation for the different groups

Group	Technique	Material	Mean (MPa)	SD (MPa)
1	Standard	Adhesive	9.78	2.11
2	Standard	Flowable	8.89	3.18
3	Standard	Composite	7.55	2.50
4	Standard	Cement	7.86	1.12
5	Bevel	Adhesive + Bevel	12.04	3.27
6	Bevel	Flow + Bevel	12.55	3.13
7	Bevel	Composite + Bevel	13.85	3.36
8	Bevel	Cement + Bevel	12.05	3.76

Including maxillary and mandibular teeth in the groups was carried out for practical reasons as collecting 80 intact central incisors of each kind is difficult. Nevertheless, this could represent a source for bias, and care was taken to include the same number of maxillary and mandibular teeth in each group. The results obtained in this study showed no statistically significant difference in the SBS for the first 4 groups thus leading to the acceptance of the first null hypothesis. This is also confirming the results obtained by Loguercio et al. (29); in contrast, Farik et al. (36) have reported differences in SBS between filled and unfilled resins, stating that all the adhesives used for their test, except the adhesive Excite (Ivoclar Vivadent, Schaan, Liechtenstein) should be used with an unfilled resin when restoring fractured teeth by reattachment.

Observing the fracture surfaces, it was noted that in groups 1 to 4, all of the specimens failed at their weakest point, which in this case proved to be the reattachment line, more precisely the interface between the tooth and the repairing material. Considering the fact that the samples could be thought of as a three-layer system, the fact that the repair failed at the tooth material interface could be explained by the fact that one layer (the tooth) was immobilized in the holders of the testing machine and that the two other layers (repair material/fragment) were free. Another possible explanation for this type of failure is not having a perfect fitting: a discrepancy between the fragment and the tooth will act as a stress raiser (35). A third possibility would be that, having the force applied incisal to the reattachment line, the weakest point would be the interface.

On the other hand, statistically significant higher SBS was found when a postreattachment bevel was performed forcing us to reject the second null hypothesis.

Reis et al. (19) and Stellini et al. (18) had already highlighted that the resistance of reattached fragments with an additional preparation, such as the chamfer technique or bevel combined with an overcontouring have given values as high as 60% of the intact tooth. Other studies (20, 23) had also shown that a preparation postreattachment, such as a bevel or a chamfer, has a positive effect on fracture resistance. In a recent study, Stellini et al. (18) fractured cattle incisors and repaired them with different preparations postreattachment. He concluded that the overcontouring or the combination of a vestibular and lingual chamfer gave the tooth a fracture resistance 50% superior to that of an intact tooth.

In the groups where the bevel was performed on the labial and lingual side, the mode of failure changed. In many cases, the fracture propagated as far as the root and caused the whole crown to fracture. A possible explanation for this type of failure could be that the interface created allowed stress transfer further down the restored structure sometimes even to the enamel–cement junction.

From a clinical standpoint, the use of this fragment reattachment technique is in accordance with the minimal intervention concept (37). It reduces to the minimum the quantity of enamel and dentin lost and guarantees a complete *restitutio ad integrum* of the tooth.

Conclusions

Within the limitation of the present study, we can conclude that the type of material used does not have any influence on the SBS of the reattached fragment, whereas the preparation technique used, in particular the labial and lingual bevel, may have a positive effect on the SBS of the reattached fragment.

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