FRACTURE RESISTANCE OF TOOTH FRAGMENTS REATTACHED WITH DIFFERENT TECHNIQUES. AN IN VITRO STUDY

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ABSTRACT
Aim of the study to determine whether and to what extent the reattachment of fractured incisor tooth fragments is weakening the teeth and which adhesive material and technique offers the strongest bond to the tooth structure.

Materials and methods 48 extracted mandibular incisors divided into 4 groups were used. After fracturing the incisal third of each tooth, the fragments were reattached with different materials and techniques and the force necessary to fracture the teeth was measured.

Results Statistically significant differences were found between the group of teeth restored with composite resin in association with a prepared bevel and the other three groups. The first one showed significantly higher fracture strength.

Conclusion The materials and techniques used in this study affected the bond strength of the reattached teeth.

Keywords: crown fractures, reattachment

INTRODUCTION
Among dento-facial trauma, simple coronal fracture is the most common dental injury. It has been suggested that in the near future the incidence of dental trauma would exceed the incidence of caries and periodontal disease, due to the effective caries preventive programs among children and adolescents [1]. Regarding the therapy of dental injuries, over the years several methods were attended with varying rates of success and different degrees of complexity. Thus, veneers and ceramic crowns tend to sacrifice too much healthy dental hard tissue and raise quite serious problems regarding aesthetic matching of the adjacent and non-restored teeth. However, there are two simple methods that have become possible due to the development of adhesive techniques [2, 3]. The first one consist of restoring the coronal part of the tooth with composite resin and the second involves reattachment of the fractured tooth fragment [4, 5] with adhesives or with adhesives and composites.

The study was aimed to determine whether the repositioning and bonding of the fractured fragment makes the tooth more vulnerable to further injuries, and also to investigate the bond strength of different materials and techniques used in reattaching tooth fragments.

MATERIALS AND METHODS
In this study we used 48 mandibular incisors extracted due to periodontal disease. Teeth were debrided of dental calculus using an ultrasonic device and also the soft tissue remnants were removed with a No. 15 scalpel blade. Teeth were examined with a 3x magnifier loupe to eliminate those with structural defects, cracks or incipient carious lesions. During the period between extraction
and the onset of the experiment, the teeth were kept in a saline solution.

On the lingual surface of each tooth, at the approximate half of the crown a groove was cut parallel to the incisal edge using a diamond fissure bur of 0.5 mm diameter. The groove was intended to guide the future fracture line, as in previous tests we found that without it, the tooth fractured chaotically, in a non-reproducible manner.

Each tooth was embedded in a mass of acrylic resin (Duracryl, Spofa Dental) so as to leave only the crown of the tooth exposed. This was done in cylindrical fragments of a PVC pipe, 1.5 cm high and 16 mm in diameter.

To fracture the teeth, a 10 kg Charpy pendulum hammer was used (VEB Werkstoff Prüfmaschinen, Leipzig).

The teeth were set upright in the device and the incisal third of their buccal aspect was hit by the pendulum hammer. The amount of mechanical work necessary to fracture the coronal part of the teeth was noted, expressed in kgm or in Joules.

After intentional fracturing of the teeth the incisal dental fragments were repositioned and bonded with different restorative materials and finally they were fractured again under the same conditions.

In the first group, fractured tooth fragments were reattached by the simplest technique possible. Both parts of the tooth were etched for 15 seconds on the dentine and 40 seconds on the enamel with 37% orthophosphoric acid, after which they were washed thoroughly for 30-40 seconds and dried gently with a dry cotton pellet. On both dental fragments an abundant amount of adhesive was applied (Optibond SoloPlus, Kerr) which was distempered for 10-15 seconds. Next the dental fragments were repositioned and the excessive bonding agent was removed with a short blast of compressed air. Specimens were light cured for 20 seconds both from palatal and buccal surface. To achieve the perfect repositioning of the dental fragments a 3x magnifier loupe was used. During light curing some finger pressure was exerted on the incisal dental fragment.

In the second group demineralization and adhesive application was made in the same manner, but the bonding agent was blown to form a thin layer and light curing was done without the fragments being in contact. Afterwards a thin layer of flow composite (Revolution, Kerr) was applied on both dental fragments and finally they were repositioned, with a light digital pressure. Excess material was removed from the buccal and lingual aspect with an applicator. Maintaining the same pressure, each tooth was light cured on both sides for 20-30 seconds.

In the third group the tooth preparation technique was modified by preparing a 1.5 mm bevel buccally, at the fracture line, on both dental fragments. For this purpose a 1 mm diameter medium coarse cylindrical diamond bur was used (with red ring). This bevel of the two surfaces was etched with 37% orthophosphoric acid for 30-40 seconds, then washed thoroughly with water and dried with a dry cotton pellet. Afterwards the adhesive and the flow composite were applied in the same way as in the second group. The groove between the two bevelled surfaces was filled with flow composite.

In the fourth group a similar bevel of 1.5 mm was prepared and the usual acid etching was performed. Bonding application on the fractured fragments was performed as in the first group, where the fragments were immobilized in the correct position using and adhesive agent. The groove formed by the two bevelled surfaces was filled with a lower consistency nanohybrid composite (Grandio, VOCO). Light curing was done first from palatal and then from buccal, for 20 seconds each surface. Next, teeth were repositioned and the impact with the Charpy pendulum was performed for the second time. The
results were recorded again to be compared with the initial values.

RESULTS

The work needed to initially fracture the teeth was similar throughout the four groups. This was confirmed with the Kruskal-Wallis test, which showed that there were no statistically significant differences between the four original groups (p > 0.05).

After reattachment of the dental fragments the second fracture with the Charpy pendulum occurred more easily, thus less mechanical work was necessary to fracture the teeth (Fig. 1).

To more explicitly illustrate the difference between the resistances to fracture in intact versus bonded teeth we used the ratio of these two values. For instance a ratio of 0.5 would mean that the work needed to fracture the bonded tooth is 0.5 or 50% of the work needed to fracture the intact tooth (Fig. 2).

The highest value of ratio was found in the fourth group (0.83) and the lowest in the second group (0.68).

The Mann-Whitney statistical test was used to compare the strength of reattachment within pairs of experimental groups.

Comparing the values of ratio in the first two groups (adhesive and adhesive + flow composite), we found a statistically significant difference (p < 0.01).

Between groups 1 and 3 (adhesive and adhesive + flow composite + bevel) no statistically significant differences were found (p > 0.05).

Between group 1 and 4 (adhesive and adhesive + composite + bevel), statistically significant differences were noted (p < 0.01).

Also there was a statistically significant difference (p < 0.01) between the second and third group (adhesive + flow composite and adhesive + flow + bevel).

Between the second and fourth group (adhesive + flow composite and adhesive + composite + bevel) the differences were statistically significant (p < 0.01).

Among the preparing techniques associated with bevel, fracture strength was significantly higher in the fourth group (p < 0.05) than that of teeth reattached with adhesive + flow composite + bevel (groups 3 and 4).

DISCUSSION

The simple non-penetrating tooth fracture, a common result of sports injuries or accidental trauma, is treated with a restoration
of composite material, or if the fractured fragment is kept and not too small, the tooth is recovered by simply repositioning and bonding of the fragment. This second method is very simple and convenient, but it requires high quality adhesive systems and the selection of proper techniques for the respective clinical situation [6]. Regarding the technique, the easier technique can be selected which implies the reattachment of the fragment exactly in its original position, without being subjected to prior treatments, or the more complex option can be chosen in which to improve adhesion, the two surfaces to come in contact are previously machined. This process consists of preparing a bevel at the edges of the fragments. The bevel can be straight or concave and it may be associated or not with the removing of a thin dentine layer from the free dental fragment (or both fragments).

Since it is assumed that a fractured tooth that is restored by reattachment will become more vulnerable to trauma, the present study aimed to determine how significant the loss of fracture strength was. For this type of study there is an already established experimental model, which consists of fracturing intact teeth and determining the necessary breaking force, followed by reattachment of the fragments and a new determination of the force necessary to refracture the restored teeth. The major advantage of this type of experiment is that each tooth serves as its own control and thus a specific value can be achieved for each tooth individually regarding the strength weakening. In such experiments, tooth fracture and the simulation of the traumatic impact can be performed with two types of devices. The first one is the Instron universal testing machine [7], and the second is the Charpy pendulum hammer. The difference between the two is that the first device strikes the tooth by linear motion and the latter one performs a rotary motion. Both systems are able to measure the impact force. In the present study the Charpy instrument was used.

To simulate fracture, some authors preferred to section the teeth with a bur [8], to reattach the fragments with composite and only then to hit the fragment with the pendular hammer or with the Instron instrument [7, 9]. However sectioning implies some disadvantages. First, the necessary force to detach the dental fragment cemented with composite can’t be compared to the force required to fracture the intact tooth. Second, the surface of the two sectioned dental halves are radically different from the surfaces that result from fracturing, because in the first case the two artificially prepared surfaces are covered by a thick smear layer while on the fracture surfaces there is no debris [4, 10]. This aspect dictates the choice of the bonding material and technique, and also the longevity of the adhesion [11]. Third, the lack of substance arising from the tooth sectioning makes it impossible to perfectly reassemble the two dental fragments.

Dental injuries generally occur at very young ages, but as tooth extractions is relatively rare in young children, especially on intact anterior teeth, in the present study adult mandibular incisors were used, which were extracted due to advanced periodontitis. In similar studies other authors used either lower or upper human incisors or animal incisors (usually from sheep) [7, 12, 13].

Because the dehydrated dental surfaces (especially in dentin) may adversely affect the adhesion of the reattached fragments [14, 15, 16], the teeth and dental fragments were kept in a saline solution. Fracture strength of the intact teeth showed no variations and the differences between the four groups were not statistically significant.

According to our expectations in all four groups the fracture strength was lower after reattachment of the fractured fragment. The
literature confirms this finding regardless of the material and technique used [7], but there is one study that demonstrated a very high adhesion, so that the fracture strength remained almost unchanged after the reattachment of the dental fragments [17].

In the first two experimental groups the repositioning relied on the perfect matching of the two dental fragments, a situation in which it is desirable that the material interposed between the fragments to be as thin as possible. This condition was achieved only in the first group, where the adhesion was obtained with a bonding agent. In the second group, the adhesive was used in combination with a thin layer of flow composite. Although at the reattachment of the fragments pressure was exerted, flow composites still have some thickness [18], rendering the intermediate layer somewhat thicker. Perhaps this is why the difference between the two groups was statistically significant.

Comparing the teeth restored only with adhesive with the bevelled teeth bonded with flow composite, in the latter group a better consolidation was noted. This is not surprising because it is well known that increasing the acid etched enamel surface by adding a bevel can lead to a better adhesion [17, 19, 20]. However, the difference obtained in the present study was not statistically significant. This was probably due to the fact that as the contact surface increases the mechanical strength and/or the elasticity of the flow composite decreases.

The bevel preparation enhanced the fracture strength in several other studies [21] but adding further preparations and retention fissures and grooves did not improve adhesion [22].

Teeth that were reattached with composite (the 4th group) showed the highest adhesion and the differences compared to all other groups were statistically significant. This can be explained with the presence of the bevel on one hand and by the mechanical strength of the composite material that fills the bevel on the other hand. Using composite for reattachment of the fractured dental fragments improved fracture resistance in other studies, too [23].

Since the specimens can be considered as consisting of three components (layers), the restoration cracked at the tooth-material interface could be explained by the fact that the first layer (tooth) was immobilized in the holder of the testing instrument and the other two layers (the restorative material and the fragment) were free. Another possible explanation for this failure is the lack of a perfect match: a discrepancy between the dental fragments may represent an area of increased stress. A third possibility would be that applying a force incisal from the reattachment, the low resistance area would be at the interface of the reattachment.

**CONCLUSIONS**

1. Reattaching a fractured incisal dental fragment is a quick and easy method of treatment but the tooth would fracture more easily in case of a future trauma.
2. In our study, bevelling the margins of the bonded surfaces enhanced the adhesion.
3. The highest fracture strength was achieved using both bonding and composite, compared to only bonding or bonding and flow composite.

**REFERENCES**