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Fracture strength of tooth fragment reattachments with postpone bevel and overcontour reconstruction

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Abstract – The purpose of this study was to test the actual resistance against fracture of a crown fragment fractured and reattached using three different techniques of preparation. Forty bovine incisors were randomly assigned into four groups of which the first was the control group. The elements of the three experimental groups were all cut at a fixed distance of 3 mm for the incisal margin on the buccal surface of the crown in a plane normal to the buccal surface itself, and subsequently re-bonded using an adhesive system. After the reattachment, on the teeth of group 2, a circumferential chamfer was performed along the fracture line; on the teeth of group 3 a groove called 'overcontour' was made also along the fracture line; the teeth in group 4 received a chamfer on the buccal surface and an overcontour on the lingual surface. Finally, all the elements were encompassed in chalk blocks and the models were mounted on the 858 Mini Bionix to perform a fatigue load test. A force was applied on the buccal surface of each tooth at 1.5 mm from the incisor margin, with a velocity of 1 mm min^{-1}, through the use of a steel prick. All the elements of groups 2, 3 and 4 demonstrated a lower resistance to fracture in comparison with the elements of the control group. The teeth of group 2 showed a resistance to fracture equal to 36.1% of the resistance of the elements in the control group; in group 3 the resistance was equal to 50.2%, while in group 4 the resistance reached 55.9%. The difference in resistance between group 3 and group 4 did not result statistically significant ($P = 0.82$). Reattachment of coronal fragments does not restore the resistance to fracture to an equal level of the intact teeth, in a static test. The different techniques of preparation significantly modify the resistance to the fracture of a re-bonded fragment. The technique of the circumferential chamfer produced results that were less favourable in terms of resistance against fracture.

The uncomplicated fracture of a crown is absolutely the most common form of traumatic lesion, affecting around 25% of the population under the age of 18 (1). In most cases, the group of upper incisors is affected because of the position and protrusion taken during the eruptive process (2).

The treatment of an uncomplicated coronal fracture is a considerable challenge for the dentist because many parameters are implicated in the successful outcome of the restoration: the necessity to obtain an aesthetic result that nears itself to the natural form and dimension, the opacity and translucency, the fluorescence and opalescence of the original tooth.

Over the years, a large number of techniques have been employed to coronal fractures. The first methods included crowns of pure steel, orthodontic bands, resin held by pins (3) and porcelain crowns (4, 5). However, these types of treatment did not always guarantee an adequate long-lasting aesthetic result and required substantial sacrifice of the dental structure during the preparation (6).

With the advent of new systems of dentinal bonding and the technique for acid-etching the enamel, a restoration with filled resins is, without a doubt, the treatment of choice whenever the fractured fragment is no longer available. In fact, the incremental technique, through the application of successive layers of resin, yields a restoration more opaque in the dentinal region and more translucent in the region of the incisor's margin. It is capable of restoring a natural translucence, shape and texture to the traumatized tooth.

Nevertheless, the long-term seal of fourth class restorations remains modest in terms of duration and aesthetics (7). Browning and Dennison (8) tried to clarify the causes of failure in these restorations: they came to the conclusion that the principal reasons are related to the adhesive system used (failure of the bonding accompanied by the fracture of the filled resin) or dependent on the material used (cohesive fracture of the filled resin).

In the last three decades, many authors have proposed a valid alternative to conservative treatment of these fractures represented by the re-bonding of the fractured fragment. The first to present the re-bonding technique were Chosack and Eildeman (9).

The treatment proposed included the endodontic removal of the pulp and the filling of the root canal with a pin on which the coronal fragment was then bonded with an unspecified glue. However, before the era of acid-etching and the advent of new bonding methods, this type of treatment was only considered a temporary restoration.

The first to describe in detail the clinical procedure of the restoration of complicated and uncomplicated coronal fractures, through the use of the fractured incisor fragment, was Andreasen et al. (10). This technique was baptized as the 'GLUMA technique' and was applied to the restoration of 76 permanent incisors.

Although they are not supported by laboratory studies or clinical experimentations, many other studies on re-bonding of the incisor margins were published at the end of the 1980s by numerous authors (11–19). Many techniques and just as many new materials were utilized.

Today, the re-bonding of the incisor fragment is one of the more attractive methods for the restoration of crowns with composites to restore anterior fractured teeth, and offers a lot of advantages compared with the conventional restoration with filled resins (Table 1).

Despite the fact that the re-bonding of dental fragments is commonly suggested in literature as the therapeutic approach to the coronal fracture, there is still no agreement on which technique provides superior mechanical resistance and longevity for the restoration.

In the case of reattachment, many authors sustain the necessity of the use of additional preparations to augment the retention of the re-bonded fragment, while others confide in the improvement of consolidated techniques of dentinal bonding that offer a resistance equal to that which is offered by the enamel (14, 18, 20–22).

It is possible to bevel at the circumference the enamel margins of the tooth and of the fragment before the bonding to obtain a better retention and to make the fracture line less visible, because it is later covered with filled resin (16, 23–26). However, by means of this method the precise adaptation between the tooth and the fragment is lost, so it makes difficult its correct positioning. For this reason some have preferred making the chamfer after the re-bonding procedure (27, 28).

Table 1. Advantages of the re-bonded fractured fragment

Advantages
Excellent aesthetics
Natural brightness and texture
Colour match to remaining crown portion
Maintenance of original tooth contours
Preservation of identical occlusal contacts
Incisal margin wear match to that adjacent tooth
Conservative and cheap technique
Less time consuming

Silva Filho and Esberard (29) proposed to put the chamfer only on the lingual surface as the use of filled resins on the buccal surface interferes with the long-term aesthetic result of the restoration because of the fading process and the abrasion of the material.

New techniques have also been introduced in an attempt to improve the aesthetics, some of which are very difficult to carry out, such as the one that includes the preparation with a V-shaped notch within the depth of the enamel (11, 30).

Other authors have proposed a technique in which a groove is cut into the depth of the dentin of the fractured fragment and then filled with a filled resin to increase the force of the bonding (11, 26, 30).

In spite of the unanimous struggles and improvements of the dentinal bonding techniques, the majority of these bonding methods are completely empiric. Until now the effective resistance of re-bonding against forces that imitate a second trauma or the forces of physiologic tear and incision has been verified only in few studies (31).

The purpose of this study was to test the actual resistance against fracture of a crown fragment fractured and reattached using three different techniques of preparation: circumferential bevel, circumferential overcontour, buccal bevel + lingual overcontour. The null hypothesis to be tested was that there was no difference in fracture resistance of the different techniques used to re-attach tooth fragments.

Material and methods

Forty bovine lower incisors were used, extracted with non-traumatic methods from the mandibles of animals aged from 8 to 10 months. Once they were extracted, the incisors were submerged for 24 h in a 4% Clorexide S® (Nuova Farmec SRL, Settimo di Pescantina, Verona, Italy) solution and subsequently conserved for 1 month in a physiological solution (NaCl 0.9%) at room temperature.

The dental elements were randomly divided into four groups, each of which was composed of 10 teeth, one control group and three experimental groups (Fig. 1):

- group 1_IT: intact tooth (control group);
- group 2_CB: circumferential bevel;
- group 3_CO: circumferential overcontour;
- group 4_BBLO: buccal bevel + lingual overcontour.

The teeth in groups 2, 3 and 4 were cut at a fixed distance of 3 mm from the incisal margin on the buccal surface of the crown in a plane normal to the buccal surface itself. The incision was carried out under a continuous jet of water using separating discs for ceramic 0.2 mm thick.

Each element was prepared immediately before the bonding procedure. Each fragment was then re-bonded by means of the adhesive system Scotchbond 1 (3M ESPE, St Paul, MN, USA) and a filled resin Filtek P60 (3M ESPE).

For the polymerization, the Curing Light 2500 (3M ESPE) lamp was utilized. In groups 2, 3 and 4, the fractured enamel surface from the incisor fragment and

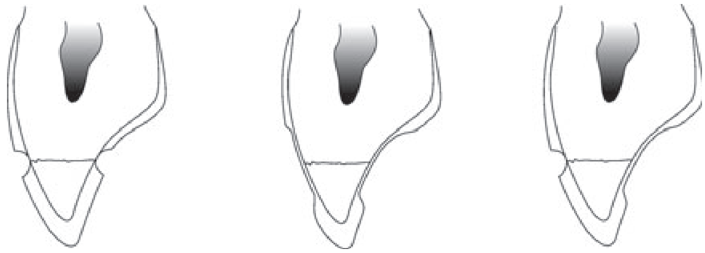

Fig. 1. The three different preparation designs used in the experimental groups.

from the remaining portion of the tooth was etched using orthophosphoric acid at 35% (3M ESPE Scotchbond) for 30 s; on the dentinal surface it was applied for 15 s.

The fracture surfaces, once they were abundantly rinsed, were dried avoiding the dehydration of the dentinal portions through the 'wet bonding' technique, and on each a layer of Scotchbond 1 (3M ESPE) was applied.

After having spread and dried the layer of adhesive with a jet of air, the adhesive was polymerized for 40 s. The two surfaces were subsequently bonded together through the application of a thin layer of filled resin Filtek P60 (3M ESPE) which was polymerized for 40 s first on the buccal surface and then on the lingual surface of the dental element.

After the re-bonding, a circumferential chamfer, 0.5 mm deep was practiced along the fracture line of the teeth in group 2, utilizing a fine grain diamond bur, with a ball shape (rif. 801, 314,016; Komet Italia srl, Milan, Italy), mounted on a turbine.

In group 3, instead, a groove 0.3 mm deep was prepared on all elements, on both the buccal and lingual surfaces, which was extended for 2.5 mm coronally and apically from the line of fracture, through the use of a fine grain cylindrical diamond bur (rif. 836KR, 314,016; Komet Italia srl), mounted on a turbine (32).

The teeth in group 4 were prepared with a chamfer 0.5 mm deep on the buccal surface using a diamond ball-shaped bur (rif. 801, 314,016; Komet Italia srl), and a groove about 0.3 mm deep on the lingual surface which is extended for 2.5 mm coronally and apically from the line of fracture, utilizing a cylindrical diamond bur (rif. 836KR, 314,016; Komet Italia srl), both mounted on a turbine.

The preparation of the bonding surfaces in groups 2, 3, and 4 was executed with the same methods:

- application of the acid etching for 30 s;
- rinsing and drying;
- application of one layer of adhesive;
- polymerization of the adhesive for 40 s;
- application of a filled resin;
- polymerization for 40 s.

Finally, all of the elements were finished using flexible 'pop on' discs (Sof-Lex Pop On polishing disks; 3M ESPE).

One week after the re-bonding procedure, to perform the subsequent fracture tests, each single dental element was englobed in an aluminium tube filled with plaster. The aluminium had a thickness of 1.5 mm; the square cross-section of the tube was 15 mm and the length was 30 mm. The teeth were incorporated in such a way so that the cut surface was normal to the major axis of the parallelepipedon. Furthermore, the amelo-cemental junction was consistently placed 2 mm inside the plaster.

The specimens were mounted on a MTS 858 Mini Bionix II axial machine, controlled by a MTS Testar IIm (MTS System Corporation, Eden Prairie, MN, USA), to perform the fracture load tests. The tube axis of each specimen was consistently placed normal to the actuator axis, with the buccal surface of the crown placed upwards. The samples were clamped on a stiff plate with a groove for correct placement and with the possibility of adjustment for the different tooth shapes (Fig. 2).

The test force was applied to the buccal surface of each tooth consistently at 1.5 mm from the incisal margin by means of a sharp-edged steel scalpel with a 45° chamfer. Tests were performed in displacement control at a load rate of 1 mm min^{-1}: force and displacement were recorded respectively by the load cell and the linear variable differential transformer (LVDT) of the axial machine.

The force necessary to ultimately fracture the bonded fragments, named F_u, was measured in Newtons and recorded for all samples of the four groups. The incisors of the control group were fractured after being englobed in the block of plaster in the same manner as the experimental groups. F_u values of groups 2, 3 and 4 were also expressed as a percentage of the force necessary for provoking a fracture in intact teeth.

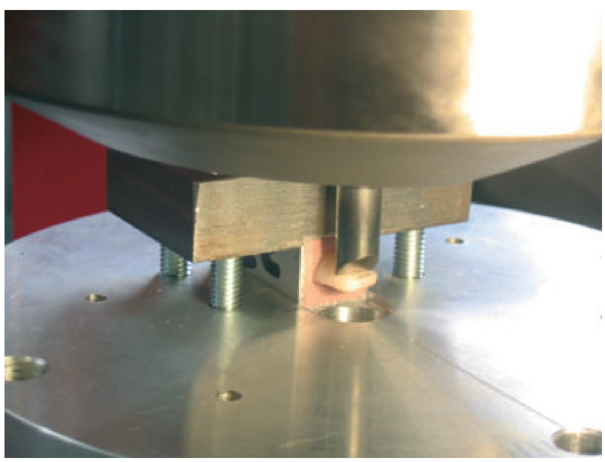

Fig. 2. Specimen mounted on a MTS 858 Mini Bionix II axial machine, controlled by a MTS Testar IIm, to perform the fracture load tests.

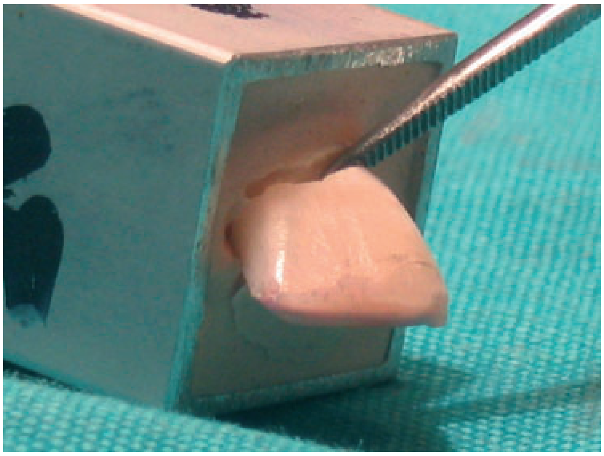

Fig. 3. In the control group only one tooth presented an oblique coronal-radicular fracture in a vestibular-lingual direction.

Results

In the control group, nine of 10 elements presented an uncomplicated fracture of the crown which affected either the mesial or distal corner. Only one tooth presented an oblique coronal-radicular fracture in a buccal-lingual direction (Fig. 3). All other teeth showed fractures in correspondence of the load application line.

The fracture surface of all re-bonded teeth was coincident with the adhesive restored interface (Fig. 4). Table 2 shows the mean values of the fracture forces F_u measured to fracture the elements in all four groups.

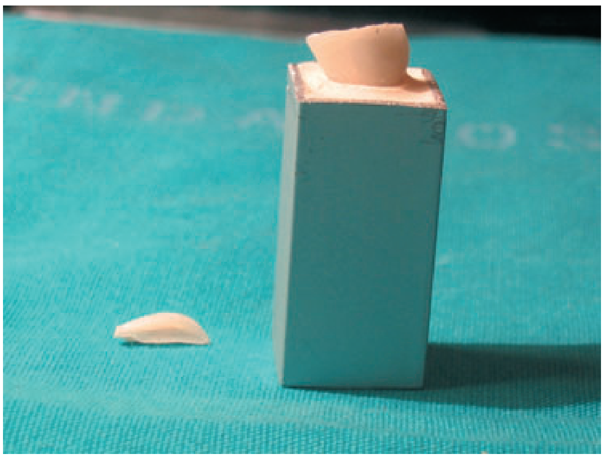

Fig. 4. The fracture surface of all re-bonded teeth was coincident with the adhesive restored interface.

Table 2. Mean values of the forces used and resistance

	Mean force (Newtons)	Medium resistance (%)	SD medium resistance (%)
a	2 957 652	100%	100%
b	1 069 753	36.10%	34.40%
bc	1 486 208	50.24%	43.80%
c	1 653 966	55.90%	43.30%

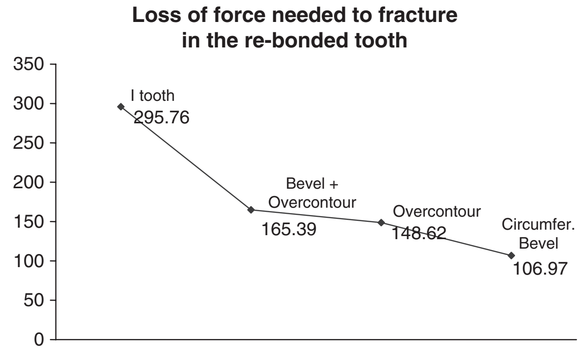

Fig. 5. Loss of force needed to fracture in the group 2, 3 and 4 compared with the element of control group ($P < 0.0001$).

In terms of mean values of the four groups, the fracture strength of teeth in group 2_CB resulted to be 36.1% of the strength of control group 1_IT. In group 3_CO, the mean strength resulted equal to 50.2% of strength of intact teeth, while in group 4_BBLO a strength value of 55.9% of intact teeth strength was reached.

For the statistical analysis of the data ANOVA followed by Tukey's test was used. The resistance against fracture of the re-bonded elements was calculated in proportion to the force necessary in provoking the fracture of whole teeth.

All of the elements of groups 2, 3 and 4 demonstrated a significant reduction of force needed to fracture when compared with the elements of the control group ($P < 0.0001$) as has been highlighted in Fig. 5.

The force necessary to fracture the teeth in group 2 resulted significantly inferior to the force necessary to fracture the teeth in group 4 ($P = 0.0024$), but not when compared with group 3 ($P = 0.159$). The force needed to fracture the teeth in group 3 was not statistically different from that of the teeth in group 4 ($P > 0.1$).

Discussion

The lowest force necessary to cause the detachment of the incisor bonded fragment was recorded in the teeth of group 2_CB. The bonding technique with the circumferential chamfer guaranteed just 36.2% resistance against fracture of a whole tooth and would therefore have guaranteed a rather poor long-term seal.

The teeth in group 3 (overcontour technique) and in group 4 (combined chamfer + overcontour technique) present a resistance against fracture almost equal to 50% that of the whole tooth. This could be attributed to the increase of the surface area of adhesion after the preparation of the tooth in the region of the fracture line.

The teeth in group 4 obtained results of resistance against fracture tendentially but not significantly superior compared with group 3, possibly because of the lower amount of dental structure removed during the preparation of the buccal surface. This could be important from a clinical point of view since, at an equal value of resistance against fracture, a more conservative preparation of the coronal buccal surface is able to enhance the aesthetic outcome of the whole restoration. In fact, the removal of a great quantity of enamel and its subsequent covering with a filled resin exposes the restoration to chromatic alterations which are typical when these materials are exposed to the oral cavity. The solution combining chamfer + overcontour could possibly remedy the aesthetic gaps.

In 2001, Reis et al. (32) highlighted that the resistance of the restored dental elements with the chamfer technique was equal to 60.6% of that of the whole tooth, while the resistance of teeth restored by the use of overcontour was equal to 97.2%.

Such a difference compared with the results that have surfaced from our study could be explained by the fact that Reis et al. (32) tested the resistance of dental restorations on human teeth and not bovine. Worthington et al. (33) employed bovine teeth, and the resistance value of the teeth re-bonded through the use of the chamfer technique was about 50% of that of the whole teeth. Munksgaard et al. (34) also found that the value of resistance against fracture in re-bonded teeth was half of that of whole elements, utilizing sheep elements, in this case.

Bovine incisors represent a valid alternative to human incisors, in adhesion tests, in that they are more easily available and can be selected so that they can be of the same size and all of the same age (35, 36). Furthermore, no significant difference was noticed in the mechanisms and in the force of adhesion of human and bovine dentin, even though results that indicate how the bonding force in bovine teeth is inferior to that of human teeth, have been published (32, 37, 38).

Also, the method employed to obtain the fragment of the incisor margin was to provoke its fracture and not to cut the crown of the teeth (39). Loguercio et al. (40) confronted the cutting procedure and the fracturing procedure of the coronal fragment in association to different bonding techniques. Their results showed how the force necessary to cause the detachment of the fragment cut and re-bonded was clearly inferior to the force recorded in fractured teeth. Furthermore, in the group with the cut teeth, the percentage of resistance of the various re-bonding techniques did not demonstrate any significant differences, on the contrary to what happened in the group with fractured teeth.

The dentinal bonding systems show different characteristics of adhesion to the enamel and to the dentin for which it is necessary to be very careful when preparing equivalent bonding surfaces (39).

In the attempt to obtain an equal amount of area exposed, all of the teeth were cut at the same distance from the incisor margin (3 mm). By the method used for this set, we tried to reduce to a minimum the variation in resistance to fracture resulting from the thickness of the layers of enamel and dentin present. However, the anatomy of the surface produced by the cut is certainly different from the surface resulting from the fracture. With the cut, a smear layer is produced that is otherwise not found on a fractured surface. A fractured surface tends to be parallel to the direction of the enamel prisms, while the orientation of the surface exposed by cutting is dictated by the direction of the cut. In the end, our choice was dictated by the fact that the cut establishes a repeatable condition absolutely necessary for an *in vitro* study, although it does not exactly simulate an accidental fracture.

Another variable to consider, when evaluating the results of the resistance tests, is the material used for the re-bonding. The development of adhesive systems that are always becoming more efficient has encouraged many authors to employ only these systems for re-bonding fractured fragments (20, 22, 41, 42). Other authors, instead, have preferred adding to the adhesive systems materials such as flowable resins (22, 31, 43–45), filled resins both auto-polymerizable and auto/photo-polymerizable (21, 32), and photo-polymerizable filled resins as well (46).

In our study, as an added bonding material, a photo-polymerized filled resin was used with the purpose of replacing the loss of dental structure because of the cutting procedure. It is not clear from the works present in the literature if the lower resistance to fracture of the restoration can be correlated to the fragility of the methacrylate base. Recently, Reis et al. (47) published a new *in vitro* study from which it results that the use of only the adhesive system, or of this in combination with other materials such as flowable resins and filled resins, gives similar results when the fragment is re-bonded without additional preparations. Moreover, these authors tested the adhesive system associated with the interposition of a filled resin and with the chamfer technique, executed on the buccal surface of the tooth, noticing values of resistance against fracture higher than those obtained without the employment of additional preparations. This data suggests that the technique used for the re-bonding is much more important than the association of different supporting materials. Other authors also reached the same conclusions (46).

Conclusions

The overcontour technique and the combined buccal chamfer-lingual overcontour technique are able to guarantee a resistance of the restoration equal to at least 50% of that of a whole tooth in an experimental model of bovine elements cut *ad hoc*. The technique of the circumferential chamfer produced results that were less favourable in terms of resistance against fracture.

The combined chamfer + overcontour technique could be able to remedy the buccal chromatic alteration that derives from the abundant application of filled resin material in the overcontour technique guaranteeing a better aesthetic outcome of the restoration.

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