

# Direct Composite Resin Restoration of an Anterior Tooth: Effect of Fiber-Reinforced Composite Substructure

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**Abstract** - The aim of the study was to determine the static load-bearing capacity of fractured incisal teeth restored with the conventional adhesive-composite technique or by using fiber reinforced composites (FRC). Upper incisal teeth were prepared by cutting the incisal part of the crown horizontally. Restorations were made by three techniques. Group A (control group) was restored by reattaching the original incisal edge to the tooth. Group B was restored using composite resin. Group C was restored with composite and FRC. Restored teeth were statically loaded until fracture. Results suggest that an incisally fractured tooth restored with a combination of composite resin and FRC-structure provide the highest load bearing capacity.

KEYWORDS: Fiber-reinforced composite, Incisal edge fracture.

## INTRODUCTION

Recent investigations into the incidence of dental trauma, especially in the pediatric and adolescent populations, have suggested that a fracture of the crown of an anterior tooth is common and affects up to one-third of the patients in this age group<sup>1,2</sup>. In addition, some studies have reported estimates of about one out of every four persons under the age of 18 will sustain a traumatic dental injury in the form of an anterior incisal fracture<sup>3,4</sup>. Previous studies have described techniques to restore a fractured incisal edge to the original shape and color. One of these techniques is reattachment of enamel-dentin fragment with a dentine-bonding agent<sup>5-7</sup>. While the aesthetic outcome can be favorable, they tend to re-fracture or debond most often as a result of new trauma<sup>8,9</sup>. The improvement in the esthetic and physical properties of particulate filler composite resins (PFC) have established them as the material of choice for restoration of fracture incisal edges when used in conjunction with the acid-etch technique and dental bonding systems<sup>10,11</sup>. However, controversial results have been reported between studies, when PFC was used for restoring anterior teeth fractures. Some studies have shown a low long-term survival rate of PFC restored incisal fragments especially in high load-bearing areas<sup>12,13</sup>. Some other studies have reported acceptable results after long-term clinical use<sup>14,15</sup>. Attempts have been made to improve the load-bearing capacity of restoration by using different dentin bonding agents and adhesive resins<sup>9,16</sup>. However, these techniques resulted in fracture resistance in only 50-60% of the cases when compared to intact incisors<sup>16</sup>.

Fiber-reinforced composites (FRC) have been tested as dental materials and their use is growing for many dental

applications including complete dentures, removable partial dentures and fixed partial dentures<sup>17-19</sup>. Studies have shown FRCs to have superior physical properties over PFCs<sup>20,21</sup>. Many parameters are known to influence the properties of FRC<sup>20,22-25</sup>. These include fiber volume fraction, fiber adhesion to the resin matrix and fiber orientation. Although a lot is known about the properties of FRC itself, less information is available on the properties of a combination of FRC and PFC materials.

It has been hypothesized that PFC reinforced with FRC-structure could improve the static load-bearing capacity of composite restoration for fractured anterior teeth. Thus, the aim of this study was to determine the static load-bearing capacity of fragmented incisal edges restored with PFC reinforced with FRC-structure and to compare this method with other more conventional techniques.

## MATERIALS AND METHODS

Fifteen sound and caries-free extracted human upper central incisors per group were obtained and stored in 1% chlorine-amine. The teeth were mounted into acrylic block (diameter 2.5 cm) at the cemento-enamel junction using auto-polymerized acrylic resin. The crown length for each tooth was measured with digital calipers. One-third of the incisal portion of each tooth was removed from coronal edge of each tooth. By cutting the teeth horizontally using a thin stainless steel bur in a laboratory hand piece micromotor under a water coolant. (Figure.1 A, D). Teeth that showed any visible pulp exposures or cracks were excluded from the study. Each tooth was restored in order according to the groups to which they were assigned.

*Group A.* This group of teeth had the incisal edge reattached. The contact surfaces of both the incisal segment and the remaining tooth structure were etched for 20 s using a 37% phosphoric acid etch-gel. Subsequently, the gel was rinsed thoroughly and the tooth structure gently

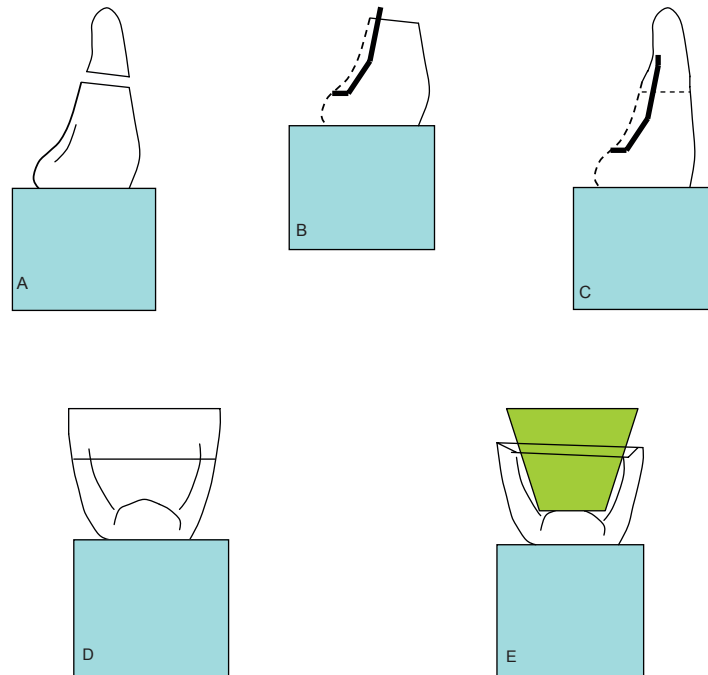
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**Table 1.** *Materials used in the study*

Brand	Manufacture	Lot no.	Composition
Z250	3M ESPE,St Paul, MN, USA	20040420	Bis-GMA, UDMA, Bis-EMA
Scotchbond (multi-purpose)	3M ESPE,St Paul, MN, USA		
1.Primer		1.4AN	1. HEMA, Bis-GMA, water
2.Adhesive.		2.4NU	2. HEMA, BisGMA
everStick net	StickTeck Ltd, Turku, Finland	2050426-ES-125	PMMA, Bis-GMA
Stick Resin	StickTeck Ltd, Turku, Finland	540 1042	BisGMA-TEGDMA



**Figure 1.** *Schematic drawing of repair procedures. A and D: cutting the incisal part of tooth. B and E: palatal Preparation and FRC application. C: PFC added to build up the incisal part.*

air-dried. Dentin primer and adhesive were applied according to the manufacturer's instructions. Polymerization was accomplished using a light-curing unit 30 s from both the labial and lingual aspects of the teeth. The wavelength of the light was between 380 and 520 nm with maximal intensity at 470 nm and light intensity was 800 mW/cm<sup>2</sup>. The teeth were stored in distilled water at room temperature after the procedure for 24 h before testing.

*Group B.* This group had the incisal portion of the teeth reconstructed with PFC. The simulated fracture lines of teeth were finished using a fine diamond bur. identical etching and adhesive bonding systems and technique were used as in Group A. PFC was applied and polymerized incrementally to recreate the missing incisal portion of the teeth using a hand light-curing unit 30 s from both the labial and lingual aspects of the teeth. Crown length was adjusted to the original length of the tooth. After finishing the procedure the teeth were stored in distilled water at room temperature for 24 h before testing.

*Group C.* This group had the incisal portion of the teeth reconstructed with PFC and FRC. A cavity preparation of 0.5 mm depth was prepared on the palatal surface of each tooth with a diamond bur using a water coolant (Figure 1 B, E).

Etching and bonding were carried out as described previously. Light-curing everStick Net (woven) fibers of E-glass (silanated) and dimethacrylate polymethyl methacrylate resin matrix were placed into the palatal cavity and extended above the simulated fracture margin. After polymerization of the FRC, the PFC was applied to build up the coronal part of the tooth structure (Figure 1 C). A thin layer of PFC was used to cover the FRC on the tooth. The restored teeth were stored in distilled water 24 h before testing.

### The loading test

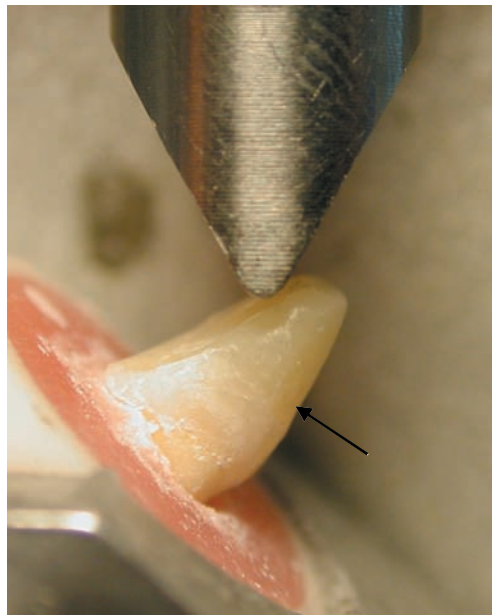
Static load was applied to the restored teeth with a material testing machine at a speed of 1 mm/min. The acrylic block containing the restored tooth was tightly fixed to the inclined metal base to provide a 45° angle between the palatal surface of the tooth and the loading tip (spherical Ø 2 mm) (Figure 2a). The loading event was registered until fracture for each tooth and the failure mode for each specimen was visually analyzed.

### Statistical analysis

Data of the fracture load values were recorded using PC software (Nexygen Lloyd Instruments Ltd) and statistically analyzed with analysis of variance (ANOVA) followed with Tukey's post hoc analysis at the  $P < 0.05$  significance level with SPSS version 10 to determine the differences among the groups.

### RESULTS

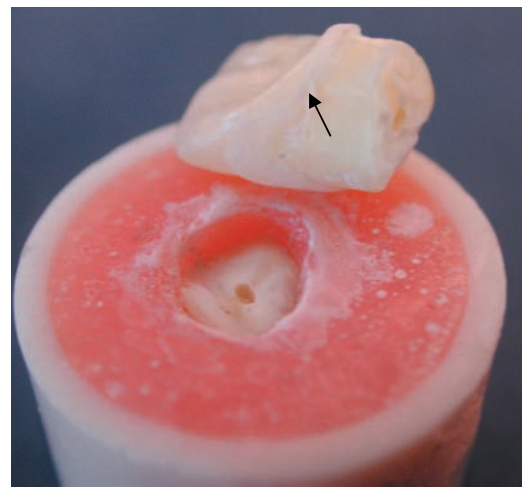
The load-bearing capacity of the restored teeth with different techniques is shown in Figures 3. The data showed that restored teeth with reattached pieces of tooth (Group A) revealed the lowest load-bearing values, whereas rebuilding the incisal edge using PFC (Group B) revealed 171% higher load-bearing values compared to Group A. Teeth restored with PFC and FRC (Group C) revealed a 331% higher load-bearing capacity than obtained with Group A (control group) (Figure 4). ANOVA revealed, that restoration technique significantly affected the load-bearing capacity ( $p < 0.001$ ). No statistical difference was found between Groups A and B ( $p > 0.05$ ), whereas Group C revealed statistical significant higher load-bearing capacity ( $p < 0.001$ ) compared to group A&B. Failure modes in Group A and B were debonding (adhesional failure) in all teeth (Figure 2b). In Group C, 70% of the teeth were fractured below cemento-enamel junctions (Figure 2c) and 30% revealed debonding of bonded pieces of restoration.



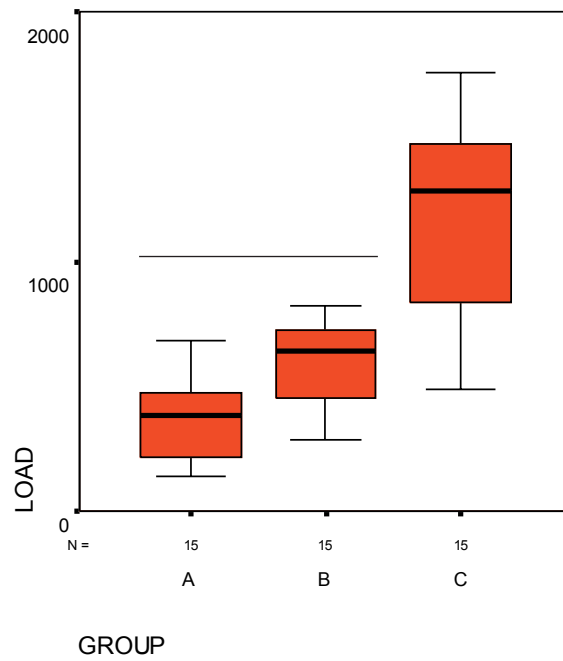
**Figure 2a.** Position of loading tip on the restored tooth. Arrow shows line between tooth and restored fragment.



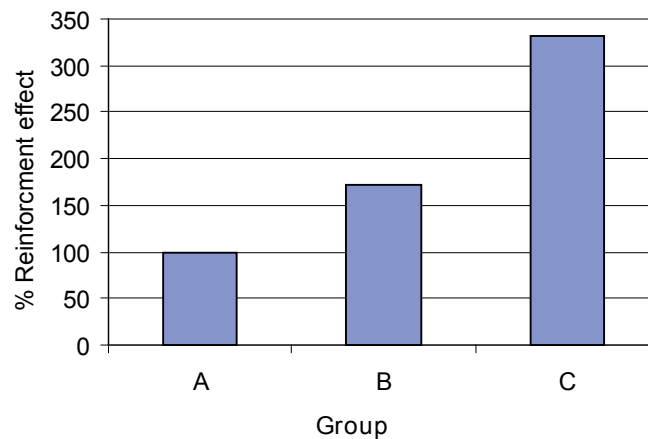
**Figure 2b.** Adhesional failure between the restoration and tooth.



**Figure 2c.** Cohesional failure below the cemento-enamel junction (CEJ). Arrow shows line of (CEJ).



**Figure 3.** Mean values of load-bearing capacity (Newton) of teeth restored by: A (Incisal edge reattachment), B (Incisal part made of PFC) and C (Incisal part made of PFC and FRC). Horizontal line above the boxes indicate groups that do not differ statistically from each other.



**Figure 4.** Reinforcing effect of restoring techniques compared to group A.  
 A (Incisal edge reattachment)  
 B (Incisal part made of PFC)  
 C (Incisal part made of PFC and FRC)

## DISCUSSION

This in vitro study was designed and conducted to restore fractured incisors using different techniques with the same bonding agent and PFC. Reattachment of a fractured piece may offer a conservative, cost-effective, and aesthetic option, if the tooth fragment is available after trauma. However, the load-bearing capacity of the reattached tooth fragment was lower compared to teeth restored using a conventional technique using PFC. A review of case reports in which the fracture pattern was determinable by photograph or description showed that 80% of traumatized incisors fractured due to debonding of the reattached incisal edge<sup>26,27</sup>. Direct composite restorations are commonly used as small anterior restorations and are not recommended for large restorations in regions

with high masticatory forces<sup>12,13</sup>. On the other hand, FRC is group of materials having high toughness and strength that has been used in many applications in dentistry. In addition the bond strength of chairside-fabricated FRC to tooth substructure is equally as good as that of PFC<sup>28</sup>. The data showed substantial improvement in the load-bearing capacity of restoration when FRC was used. A two to three times higher load-bearing capacity was obtained compared to conventional restorations when a fiber reinforced composite restoration was used. The function of the FRC was based on the theory that FRC in combination with PFC provides better mechanical properties of the restored incisal portion of the tooth by distributing the forces over a wider surface area. This diminished stress at the interface and it gave also larger bonding area, which have been beneficial under repeated loading condition.

Stress applied to the teeth and dental restorations is generally low and repetitive rather than being isolated and impact in type. However, because of a linear relationship between fatigue and static loading, the compressive static test gives also valuable information of load bearing capacity<sup>29,30</sup>. Another aspect that may lead to different fracture resistance values is the type of bonding technique and material used. However, for this study the bonding was standardized for all specimens.

The results of this study are in agreement with previous laboratory studies<sup>31</sup>. Which concluded that by using of FRC substructure under the particulate filler composite resin, the static load-bearing capacity of material combination was increased<sup>29,32</sup>. However, aging processes, such as alternate thermal stress, mechanical stress, and wear should also be taken into consideration.

The failure mode in conventional techniques was debonding (adhesional failure) of all restorations at the bonding line. In restorations reinforced with FRC, 70% of failure was due to fracture of the teeth below cemento-enamel junction (cohesional failure). This could be explained by the high strength of FRC, which exceeds the load-bearing capacity of the tooth, especially in teeth with thin roots. In addition, the mounting procedure of the teeth into acrylic block in this *in vitro* study was at cemento-enamel junction, without having 1 or 2 mm free below cemento-enamel junction to simulate periodontal ligament. Somewhat different failure modes of repairs with conventional techniques were reported by other researchers<sup>26,33</sup>. These differences could partly be explained by differences in the loading technique: In some studies, teeth were loaded at a 90-degree angle, whereas in this study the teeth were loaded in more clinically simulated conditions, i.e., using load angle of 45°.

## CONCLUSION

It was concluded that by using of FRC in repairs of fractured teeth, the load-bearing capacity of the restored incisal edge was substantially increased. However, it should be emphasized that the use of FRC substructure with composite surface is not a substitute for restorations made of conventional techniques. The results of this study suggest that the use of FRC substructure may offer one alternative to overcome some potential problems of composite restoration in high load-bearing areas.

## MANUFACTURER'S DETAILS

Self cure acrylic resin (Palapress, Heraeus Kulzer, Wehrheim, Germany).

Laboratory hand piece micromotor (Ultimate 500K, NSK, JAPAN).

Phosphoric acid etch-gel (3M Scotchbond, USA).

Light-curing unit (Optilux-501, Kerr, CT, USA).

Material testing machine (model LRX, Lloyd Instruments Ltd, Fareham, UK).

SPSS (Statistical Package for Social Science, SPSS Inc, Chicago, IL, USA).

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