Load Bearing Capacity of Fragmented Incisal Edges Restored with two Different Positions of Fiber Reinforced Composite Restoration

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KEY WORDS

Load bearing capacity;
Anterior tooth;
Fiber reinforced composite

ABSTRACT

Statement of Problem: About one out of every four individuals under the age of 18 will sustain a traumatic dental injury in the form of anterior incisal fracture. Development of fiber reinforced composite has provided new perspectives in the treatment of anterior fractured teeth.

Purpose: The aim of this in vitro study was to investigate the effect and position of the fiber on the load bearing capacity of composite restorations on fragmented incisal edge of the upper central incisors.

Materials and Methods: Eleven extracted maxillary incisors per group were prepared by cutting 3mm of the incisal edges horizontally. Group 1 was restored with particulate filler composite (PFC), group 2 with PFC and fiber in the mid-palatal surface, and group 3 was restored with PFC and fibers in the two sides of the palatal surface with the distance of 0.5-1mm. All the restored teeth were stored in distilled water for 7 days before they were statically loaded until they fractured in a universal testing machine. The data were analyzed using one way ANOVA and Tukey statistics. $p \leq 0.05$ was considered as significant. Failure mode was visually examined.

Results: The statistical analysis showed a significant decrease of fracture load from group 2 to the other two groups (p =0.05). There was statistically significant differences between groups 1 and 2 (p =0.019) and 2 and 3 (p =0.036). No significant differences were founded between groups 1 and 3. The failure mode in group 1 was debonding of the restoration from the adhesive interface, while in group 2, more than 75% of the teeth fractured below the cementoenamel junction (CEJ) or other parts of teeth. In group 3, the fractures occurred in restoration.

Conclusion: These results suggest that the incisally fractured tooth restored with fiber in the mid-palatal surface provide the highest load bearing capacity.

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Introduction

Injury to the anterior teeth is a relatively common event. Coronal fracture is the most frequent form of acute dental injury. Twenty-five percent of the American population between 6 and 50 years of age suffer from some injury in the upper and lower incisors [1]. It has been suggested that the incidence of dental trauma in the near future will overcome the incidence of caries and periodontal disease among children and teenagers [2]. Common restorative treatments such as laminated veneers or full-coverage restoration tend to sacrifice the healthy tooth structure and challenge clinicians to match the adjacent un-restored teeth. While the esthetics of this method can be desirable, the problem of such restoration is their tendency to re-fracture or debond, most often due to a new trauma [3-4].

Owing to the improvement in the esthetic and physical properties of particulate filler composite resins (PFC), they have become the material of choice for restoration of the fractured incisal edges in conjunction with the acid-etch technique and the dental bonding system. However, contradictory results have been reported when PFC has been used to restore the anterior tooth fractures. Some studies have shown a low long-term survival rate where PFC was used to restore the incisal fragment, especially in high stress bearing areas [5-6]. Some other studies have reported the acceptable result after long-term clinical use [7-8]. Attempts have been made to improve the load-bearing capacity of restoration by using different dentin bonding agents and adhesive resins [4-9]. However, by using these techniques, a fracture resistance of 50% to 60% was obtained when compared to intact incisors [9].

Restorative filling materials should have appropriate physical and mechanical properties as well as adequate esthetics. Attempts have been made to improve the properties of PFC by adding reinforcing fibers [10-11]. Formed fiber-reinforced composite (FRC) has superior physical properties over PFC, and many parameters influencing the properties of FRC have been reported [12-17]. These include fiber volume fraction, fiber adhesion to the resin matrix, and fiber orientation. Although much is known about the properties of FRC itself, less information is available on the properties of the material combination of FRC and PFC. It has been hypothesized that PFC reinforced with FRC could improve the static load-bearing capacity of composite restorations of the fractured anterior teeth. Thus, the aim of this study was to determine the static load-bearing capacity of the fragmented incisal edges restored with PFC reinforced with FRC in different positions of the fiber and to compare this method with the conventional restoration technique.

Materials and Methods

Thirty three sound, caries free human maxillary incisors were cleaned with hand instrument and restored in 1% chloramines (Scharlus, Spain). The crown length and width of each tooth were measured with periodontal prob and the silicon impression was taken from the coronal part as template in order to similarize the specimens after restoration. The teeth were mounted with 45˚ inclination into an acrylic block (diameter 2.5cm) at the cementoenamel junction using auto-polymerized acrylic resin (palapress, Heraus kulzer wehrheim, Germany). Three mm of the incisal part was cut from the coronal edge of each teeth. In order to achieve similar restorations in the specimens, these cuts were put horizontally, using a thin diamond cutting wheel (D&Z, Germany) under air and water cooling. The teeth that showed any visible pulp exposures or cracks were excluded from the study. The teeth were divided into 3 groups (n=11) and restored as follows. The materials used in the study are shown in table 1.

Group 1

The incisal margin was beveled using a coars flame bur. The bevel length was 0.5mm. The bevel region was etched for 30s for the enamel and 15 seconds for the dentin (extension of the etching region was 1mm more than the bevel region), using a 37% phosphoric acid gel (vivadent ivoclar, Germany). Subsequently, the gel was rinsed thoroughly and gently air dried. Dentin bonding was applied

Table 1 Materials used in this study

Products	Type	Compositions	Country	Manufacturer
Single bond	Total etch Bonding System	Bis-GMA,HEMA, Dimethacrylate, Polyakenoic acid, Copolymer, Initiator, 38% unter,ethanol	USA	3M-ESPE
Z250	Particulate filler composite	Bis-GMA, UDMA, Bis-EMA	USA	3M-ESPE
Scothbond a etchantGel	Etching Gel	Phosphoric acid 37%	Germany	Ivoclar vivadent
Ribbind- THM	Polyethylene fiber	Plasma treated [a] Polyethylene fibers %100	USA	Ribbond
Chloramine	Disinfectant	Chloramine T trihydrate	Spain	Scharlau
Putty	Impression material (Condensation_type) high consistency	Polysiloxane	Swiss	Coltene

according to the manufacturer's instruction (single bond-3M-ESPE, St Paul, MN, USA). Polymerization was carried out using a hand held light-curing unit (coltene, Whaledent, USA) for 20 seconds. The light intensity was 510±4 mW/cm^2. The incisal part was restored with particulate filled composite (PFC) (Z250, 3M, St Paul, MN, USA) and polymerized incrementally in two layer, using a hand held light-curing unit for 40s from both sides. The crown lengths were adjusted to be the same as the original length of the tooth.

Group 2
Small box (1 mm depth and height, 2 mm length) was prepared adjacent to the incisal margin on the mid-palatal surface of each tooth, using an inverted bur under water and air cooling. The margin was beveled and the etching and bonding agents were used as described previously. 2mm of the fiber (Ribond, USA) was cut and stored in bonding agent for 5 minutes on a dark place; then, the fiber was gently inserted in the palatal box and extended 1mm above the fracture edge (Fig 1-a). Polymerization was carried out using a hand held light-curing unit for 20 seconds. Then, the PFC was applied in two layers to restore the incisal part of the tooth structure. Curing was done as described previously.

Group 3
Two small boxes were prepared in two sides of the palatal surface with 0.5-1mm distance and margins were beveled. The etching and bonding agent were applied and two fibers were inserted and polymerized in the palatal boxes (Fig 1-b). Then the PFC was applied in two layers to restore the incisal part of the tooth structure and cured. All the restored teeth were stored in distilled water for 7 days before testing.

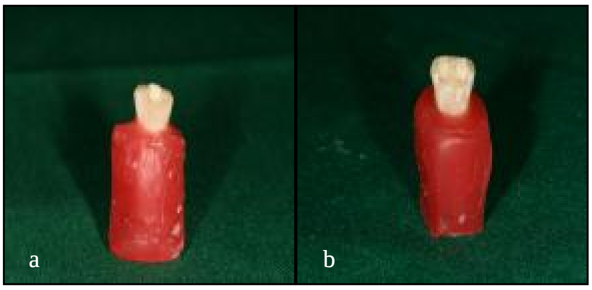

Figure 1 a Fiber in the central position (Group 2) **b** Fiber in two positions (Group 3)

Fracture load test to measure load bearing capacity
Static load was applied to the restored teeth with a material testing machine (Instron corp, Germany) at a speed of 1mm/min. The acrylic block containing the restored tooth was tightly fixed upright to the metal base to provide 45 degrees angle between the palatal surface of the tooth and the loading tip (spherical 2mm). Load was applied at the mid-palatal surface adjacent to the incisal edge. The load event was registered until fracture for each tooth and the failure mode of each specimen was visually analyzed.

Table 2 Load (N) bearing capacity (N) of the three groups

Group \ No	1	2	3	4	5	6	7	8	9	10	11
Group 1	858.0	618.5	522.5	401.6	441.6	402.8	735.8	404.0	406.5	412.8	410.2
Group 2	730.5	720.0	738.3	862.6	546.1	826.6	439.5	856.5	792.6	598.6	818.20
Group 3	446.2	372.4	327.5	658.0	349.3	764.6	452.1	421.5	840.0	347.9	860.0

Group 1: PFC Group 2: PFC+ one position of fiber Group 3: PFC+2 positions of fiber

Statistical Analysis

The data of the fracture load values were recorded and statistically analyzed with analysis of variance (ANOVA) followed by Tukeys posthoc analysis. The significant level was set at $p \leq 0.05$ in SPSS version 16 (SPSS, Chicago, IL, USA) to determine the difference between the groups.

Results

The load bearing capacity of the restored teeth is shown in table 2. The data showed that the restored teeth with PFC and fiber in the central palatal surface (Group 2) had the most load bearing values (Figure 2).

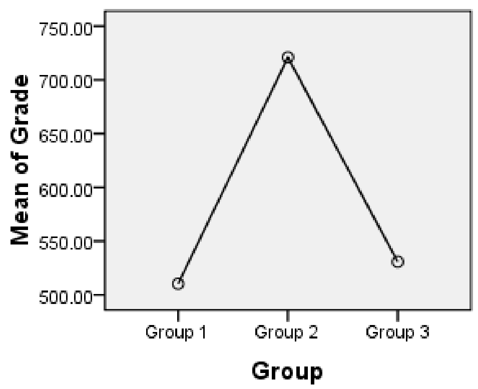

Figure 2 Mean value of load bearing capacity (N) of the teeth in 3 groups

The ANOVA test revealed that restoration technique significantly affected the load bearing capacity. No statistical difference was found between groups 1 and 3. All the failure in group 1 was between the remaining part of the tooth and restored edge. In group 2, most of the failure was on the remaining part of the tooth. In group 3, the most failure was seen in the restored edge. The difference between the groups is shown in table 3.

Table 3 Comparison between failure mode of the groups

Group	Group (J)	Mean Difference (I-J)	Std. Error	Sig
Group 1	Group 2	-210.47273*	72.84552	.019
	Group 3	-20.47273	72.84552	.957
Group 2	Group 1	210.47273*	72.84552	.019
	Group 3	190.00000*	72.84552	.036

Group1: PFC Group2: PFC+ one position of fiber
Group3: PFC+2 positions of fiber

Discussion

Direct composite resin is commonly used for small anterior restorations and is not recommended for large restorations in the regions with high masticatory forces [5-6]. On the other hand, FRC is a group of materials having high toughness and strength that has been used in many applications in dentistry. In addition, bond strength of chairside-fabricated FRC to dental tissue is as good as that of PFC [18]. This in-vitro study was designed and conducted to restore the fractured incisor teeth with different techniques using the same bonding agent and PFC. but fiber was used in two different positions in order to reinforce the restoration. The data reveal a substantial improvement in the load bearing capacity of a reinforced tooth-restoration. A previous study about the effect of FRC on the load bearing capacity of cusp-replacing composite restoration of premolars was inconclusive [19]. FRC combined with PFC is intended to provide better mechanical properties to restore the incisal edge by distributing the forces to a wider surface area. This diminished the stress at the interface and created a larger bonding area, probably being beneficial under repeated loading. FRC substructure could reinforce PFC restoration for use in high stress bearing areas [20].

In this study, the failure mode observed with conventional technique without using fiber was debonding of all restorations at the bonding joint. It revealed the stress concentration at the interface of the restoration and tooth [20]. In the restored teeth reinforced with fiber in the central part of the palatal surface, most fracture occurred on the remaining part of the tooth. This could explain the high strength of FRC, which exceeds the load bearing capacity of the tooth, especially in the teeth with thin roots. Stress was diminished at the interface of the tooth and restoration and distributed in larger area. In the restorations reinforced with two positions of the fiber, most failures were seen in the restored edges. This might be the effect of fiber volume that may reduce the strength of the composite. It seems that increasing the fiber volume in the restoration of the fractured anterior tooth may have adverse effects [12, 21].

Sharafeddin, et al. reported that the fiber could increase the fracture load in the posterior fractured teeth restored with FRC with fiber use in two different positions of the occlusal surfaces [22]. In that study, the larger area of the occlusal surface of the posterior tooth with a larger volume of composite resin between fibers withstood the load better in comparison with small restorations in the anterior teeth with two part fibers. It seems that the volume of composite resine between the fibers is an important factor in the fracture load of FRC restorations; this can be investigated in future studies. Somewhat different failure modes of restoration with conventional techniques were reported by other researchers [23-25]. These differences may partly be explained by differences in the loading technique. In some studies, the tooth was loaded at a 90-degree angle [8, 26-27], whereas in this study, the tooth was loaded to a more closely simulated clinical condition.

Conclusion

The position and volume of the fiber are important factors of load bearing capacity of the fiber reinforced composite restorations in the anterior teeth. This might help to optimize the properties of directly made composite restorations in the anterior teeth. The fracture mode revealed that the volume and position of the fiber in the central part of the palatal surface have better effects on the distribution of stress and increase in the strength of restoration.

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