ORIGINAL RESEARCH

# *In vitro* Study Comparing Fracture Resistance of Nanocomposites with and without Fiber Reinforcement with Different Cavity Designs Used for Obliquely Fractured Incisal Edge Restoration

Gayatri Galyan[1], Bhupinder Kaur Padda[2], Taman Preet Kaur[3], Mehak Sharma[4], Ishita Kapur[5], Sunpreet Kaur[6]

## Abstract

**Aim:** The aim of the study is to evaluate fracture resistance of nanocomposites with and without fiber reinforcement with different cavity designs used for obliquely fractured incisal edge restoration.

**Materials and methods:** In the present study, 60 sound extracted maxillary central incisors were mounted on autopolymerizable acrylic resin up to the cementoenamel junction, out of which, 10 intact teeth were kept as control (group 1) and the remaining 50 samples were reduced incisally in an oblique manner up to 3 mm. All incisally reduced samples were divided into five groups ($n$ = 10) based on the restoration techniques as follows: group 2 (conventional bevel), group 3 (single central palatal slot on the incisal edge), group 4 (single palatal slot with central 2 mm fiber), group 5 (two palatal slots on the incisal edge with a distance of 0.5 mm to 1 mm between them), and group 6 (two slots on the incisal edge with two 2 mm fibers). All samples were built incrementally with nanocomposites followed by finishing and polishing. All samples including control were then stored in distilled water before their fracture resistance was measured using a universal testing machine. Failure modes were visually examined and the results were subjected to statistical analysis.

**Results:** The mean fracture resistance among the experimental groups was observed, group 4 with single fiber in the central position had the highest (832.68 N) followed by group 3 (490.84 N), group 5 (446.175), and group 2 (270.1359), and the least in group 6 (223.443). The mean fracture resistance of group 4 is comparable to intact teeth, i.e., group 1 (1096.40). The mean of all samples was compared using the one-way Anova test, and it was found that there is statistically significant difference in fracture resistance among groups ($p < 0.001$**).

**Conclusion:** Fibers certainly have the reinforcing effect and the position of fibers determines their reinforcing effects. A single central slot with fiber (Ribbond) showed maximum fracture resistance almost equivalent to natural teeth. Modifying conventional beveled cavity design with an additional slot in the center also increases the fractural strength of restoration.

**Clinical significance:** Nanocomposites reinforced with single fiber in the central palatal slot used for restoring fractured incisors provide strength almost equivalent to natural teeth. In case when the fiber is not available for preparing a single palatal slot also, we can increase the fracture resistance.

**Keywords:** Fiber-reinforced composite, Incisal edge fracture, Nanocomposites, Ribbond.

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## Introduction

A beautiful smile further enhances the personality of an individual and the maxillary central incisors are the teeth which are most visible during phonetics. Any injury to these prominent elements will be crucial for the look of any individual and more so for teenagers. As epidemiology of dental injuries has shown, children and adolescents are more commonly affected by the anterior crown fracture. Among these, the majority of fractures are uncomplicated type, i.e., involves crown of teeth with dentin exposure but no pulpal exposure. Unsightly look of these fractures lowers the self-esteem of patients and, hence, there is a sense of urgency for its immediate restoration.[2] If the fractured segment is available, then reattachment provides the best esthetic result but the problem of such restoration is their tendency to refracture or debond.[3–5] Various other treatment modalities, such as fused ceramic porcelain, full coverage crown, and laminate veneers, are also available but they cause unnecessary removal of a healthy tooth structure and need multiple appointments.[6] In such esthetic emergency, composite resins with higher fracture resistance are materials of choice. Nanocomposites with properties, such as easy handling, high fracture resistance, and excellent polish ability, are used for such a high-impact stress situation.[7] Along with the material used, the cavity design used for composite restoration also affects

[1,5,6]Department of Conservative Dentistry and Endodontics, M.M. College of Dental Sciences and Research, Mullana, Ambala, Haryana, India

[2]Department of Conservative Dentistry and Endodontics, Hazaribag College of Dental Sciences and Hospital, Hazaribag, Jharkhand, India

[3,4]Department of Conservative Dentistry and Endodontics, Swami Devi Dyal Hospital and Dental College, Barwala, Haryana, India

**Corresponding Author:** Taman Preet Kaur, Department of Conservative Dentistry & Endodontics, Swami Devi Dyal Hospital and Dental College, Barwala, Haryana, India, Phone: +91 9646615855, e-mail: drtamanpreet@gmail.com

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the strength of restored crown; hence, various modifications in preparation techniques, such as butt joint margins, bevel, feather edge margin, and chamfer, were recommended to obtain greater fracture resistance and retention.[8–10] However, in spite of employing all these techniques, a fracture resistance of 50 to 60% was achieved as compared to intact tooth.[11–13]

The use of fiber-reinforced composites (FRC) is growing in dental practice from splinting to fixed partial denture and strengthening of restoration.[14,15] Although much is known about the properties of FRC, less work is available on the properties of a material combination of FRC and particulate filler composite (PFC). Different fiber types, such as glass fibers, carbon fibers, polyethylene fibers, and Kevlar fibers, have been added to composite materials to improve their physical and mechanical properties.[16,17] The objective of this study was to determine the best cavity design for restoration of fractured anterior teeth in single visit and the role of fiber (Ribbond) in strengthening it.

## Materials and Methods

The present *in vitro* study was conducted in the Department of Conservative Dentistry and Endodontics, Swami Devi Dyal Hospital and Dental College, Barwala, to compare fracture resistance of nanocomposites with and without fiber reinforcement for obliquely fractured incisal edge restoration.

For this study, 60 freshly extracted intact human permanent maxillary central incisors were collected from the Department of Oral and Maxillofacial Surgery of Swami Devi Dyal Hospital and Dental College, Panchkula, private clinics, and civil hospital. Teeth which were caries free and without any visible cracks were included in study. The teeth were cleaned mechanically to remove adherent soft tissue, debris, and stored in 100% humidity. The teeth were mounted on an acrylic block (a diameter of 2.5 cm) at the cementoenamel junction using autopolymerized acrylic resin, out of which, 10 intact teeth were kept as control (group 1) and the remaining 50 samples were cut incisally.

For incisal fracture, a straight line was drawn at 3 mm from the incisal edge, then using a diamond wheel at a constant speed with air water as a coolant, oblique incisal reduction was done starting 3 mm from one side to the other side. Teeth in which pulp got exposed or any crack appeared during reduction were excluded from study. The samples, thus, prepared were further divided into five groups ($n = 10$) namely group 2 to group 6 for the restoration of the fractured incisal portion. Hence, the following groups of teeth were defined:

### Group 1: Control Group

Ten intact teeth were kept as control.

### Group 2: Build with Nanocomposites

Bevels (1 mm wide) were given all around the fracture line equally involving both sides of the fracture line with flame-shaped bur (Mani Inc. diamond bur). The prepared tooth surface was etched with 37% phosphoric acid gel for 15 seconds, the gel was rinsed thoroughly, and the tooth structure was gently air-dried. Adper Single bond 2 adhesive (3 M ESPE, USA) was applied according to the manufacturer's instructions and polymerization was carried out using the LED curing unit (Translux Blue) at a wavelength of 440 to 480 nm for 20 seconds. The lost tooth structure was incrementally built freehand with nanocomposites (Filtek™Z350 XT, 3 M ESPE). Each increment was polymerized for 30 seconds and then for another 20 seconds after completion from the labial and the lingual side. Crown lengths were adjusted to the same level as originally.

### Group 3: Single Slot in the Centre on the Incisal Edge

A palatal slot of 5 mm width, 0.5 mm depth, and 1 mm length was prepared in the center of the oblique fracture line with a fine diamond bur using air water as the coolant (Fig. 1). After that, the fracture line was beveled and etched, and bonding agents were applied as per the manufacturer's instruction. The remaining portion was built incrementally with nanocomposites similarly to that in group 2.

### Group 4: Single Slot with Fibers in the Centre

Samples were prepared the same as in group 3 with all margin beveled and palatal slot in the center of similar dimension. Etching and bonding agents were applied as in group 2. Then, a layer of flowable composite was applied in the slot and before curing 2 mm of polyethylene fiber (Ribbond), which was placed in a bonding agent for 1 minute, was gently placed in the slot with the portion of fiber protruding from fractured margin and remaining portion built incrementally as in group 2 (Figs 2A and B).

### Group 5: Two Slots on the Incisal Edge

Two small slots were prepared on the palatal surface adjacent to the incisal margin with a 0.5 to 1-mm distance between them and 1 mm tooth structure left on each side with diamond bur using air water coolant (Fig. 3). The remaining margins were beveled. After that, the same procedure was followed as in group 2.

### Group 6: Two Slots with Two Fibers

Samples were prepared in a similar fashion to that in group 5 with two palatal slots and beveled margins. Etching and bonding agents were applied in the same way as in group 2. Then, 2 mm of two polyethylene fibers (Ribbond), which were placed in the bonding agent for 1 minute, were gently placed in slots with a layer of flowable composite with a portion of fiber protruding from fractured margin and remaining portion built incrementally as in group 2 (Fig. 4).

All restored samples were finished and polished using superfine flexible disks (Soflex, 3 M ESPE). All samples including the control group were stored in distilled water before testing.

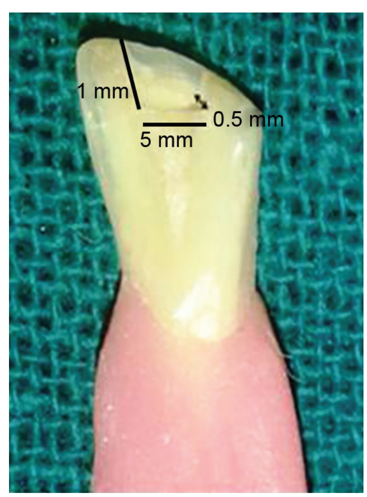
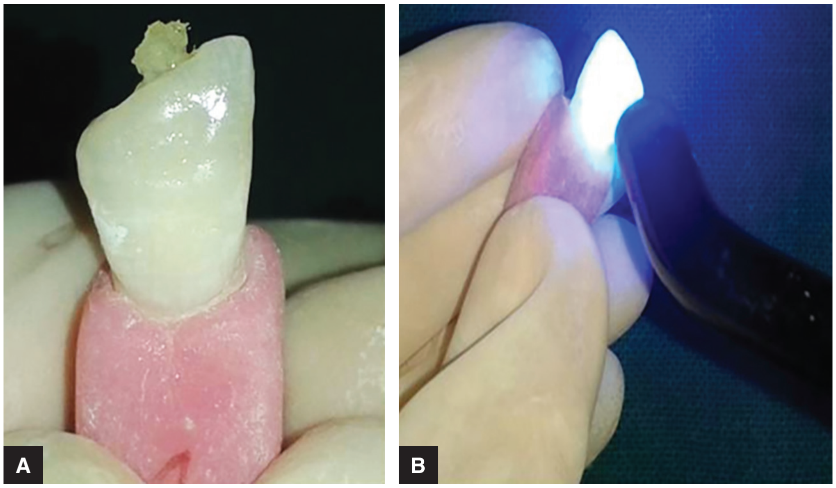



**Fig. 1:** In group 3, palatal slot prepared on samples with above-depicted dimensions




**Figs 2A and B:** (A) In group 4 with a layer of flowable composite Ribbond placed in slot; (B) Remaining portion built incrementally with nanocomposite

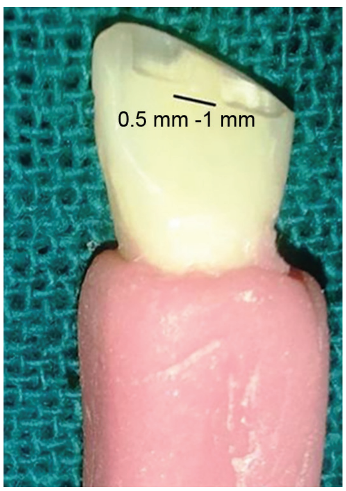



**Fig. 3:** In group 5, two slots prepared on the sample with above-depicted dimensions

**Fig. 4:** In group 6, two fibers placed in slots with a layer of flowable composite

### Fracture Load Test to Measure Fracture Resistance

Compressive load was applied on all samples with a universal testing machine at a speed of 1 mm/min. The samples were fixed

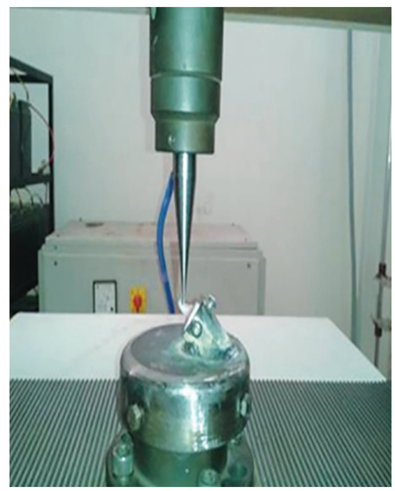


**Fig. 5:** Sample fixed on universal testing machine

on a custom-made inclined metal base (104 diameter with 25 mm height) having a metal ring fixed to provide 45° angle between the palatal surface of tooth and the spherical loading tip of 2 mm (Fig. 5). Force was applied just below the cingulum on samples. The load was applied until failure occurs and machine stops automatically. Fracture resistance of each sample was measured. The failure mode of each specimen was visually analyzed.

## Results

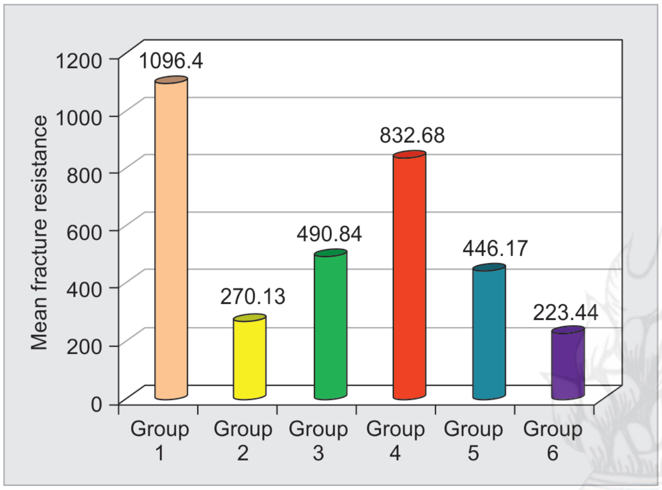
Results were analyzed by using the one-way Anova test and post hoc multiple comparison tests. Data and graphical presentation revealed that after control, among the experimental groups, group 4 with a single fiber in the central position had the highest mean fracture resistance (832.68 N) followed by group 3 (490.84 N), group 5 (446.175), and group 2 (270.1359), and the least in group 6 (223.443) (Table 1 and Graph 1). Although difference was present in fracture resistance of groups 2, 3, 5, and 6, but statistically the difference was not significant. There was no statistically significant difference between groups 1 and 4; thereby implying that group 4 behaved in a way similar to natural teeth. Hence, group 4 was found to be superior to all other groups.

After fractural loading, failure modes were visually analyzed that showed the extent of the fracture line in all samples. All fractures in group 2 involved both tooth and restoration. In group

**Table 1:** Mean fracture resistance of all groups

| *Groups* | *No.* | *Mean* | *SD* |
|---|---|---|---|
| Group 1 | 10 | 1096.40 | 117.7 |
| Group 2 | 10 | 270.13 | 126.29 |
| Group 3 | 10 | 490.84 | 255.84 |
| Group 4 | 10 | 832.68 | 456.19 |
| Group 5 | 10 | 446.17 | 186.55 |
| Group 6 | 10 | 223.44 | 81.34 |
| ANOVA | *F* value | 13.571 | |
| | *p* value | <0.001*** S | |

One-way ANOVA, ANOVA, analysis of variance; S, significant
***Highly significant




**Graph 1:** Mean fracture resistance of different groups

3, majorities of samples' fracture line extended in tooth above cementoenamel junction (CEJ). In group 4, the mode of fracture was variable: 40% of samples involved fracture of both tooth and restoration while remaining samples involved fracture of tooth only. In group 5, samples also showed a variable fracture mode. In group 6, the majority of samples showed fracture in tooth out of which 50% were below CEJ.

## Discussion

Traumatic dental injuries are one of the most common dental health problems among the youth. Andreason Jo also mentioned that the majority of traumatic dental injuries occurred in the younger age group and most of them involved anterior teeth.[1] So, most of the affected teenagers become very conscious about their facial aesthetic and seek an immediate solution.

Direct composite resin is material of choice for small anterior restoration only, but not recommended for restorations that are subjected to direct occlusal loading.[18,19] Continued effort in reducing the size of fillers to improve properties has led to the development of dental composites based on nanotechnology. Nanocomposites use nanoparticles throughout the resin matrix due to which they provide excellent aesthetics along with high strength and wear resistance. Despite evolution of these new modern composite materials, their applications are still being questioned in clinical situations of greater stress. Hence, for further enhancing mechanical properties of composite, its reinforcement with fiber has been proposed. The reinforcing capacity of fiber is influenced depending on the type and length of fiber, adhesion to resin, and orientation of fiber in matrix.[20] Sharafeddin et al. also found that the choice of fiber and the type of composite have a significant positive influence on the flexural properties of the FRC.[21]

FRC is a group of materials having high strength and toughness with multiple uses in dentistry. Various studies showed substantial improvement in load-bearing capacity of reinforced tooth restoration system as compared to that of conventional restoration.[22] In market, different types of fibers are available for reinforcement. Among them, Ribbond has been used in this study due its patented leno weave design with a lock-stitch feature. This unique design effectively transfers forces throughout the weave without transferring back into the resin and acts as an integral strength member of the restoration.[23] This *in vitro* study was designed to determine the best method for restoration of fractured anterior teeth in single visit using nanocomposite and fiber-reinforced composite with different cavity designs. Among all experimental groups, maximum fracture resistance was observed in group 4 which is almost equivalent to natural teeth. This increase in the fracture resistance may be result of transfer of stress from the weak polymer matrix to fibers that have a high tensile strength which dissipates the tension lines and prevent the failure of restoration at masticatory force. In a similar study, Sufyan et al. also found the maximum fracture resistance while using single fiber in the central slot.[24] Though it has been suggested in the literature that more the bulk of fiber, better will be the fracture resistance. But contrary to belief, in the present study, group 6 which had two fibers placed in two slots gave the minimum fracture resistance. Sharafeddin et al. also found that samples with two fibers in two slots had lesser fracture resistance compared to a single fiber.[25] It seems that centrally placed fiber is closer to the long axis of tooth, hence, will distribute forces uniformly in larger area of tooth but when it is away from center, the force is distributed unevenly to other parts. It seems that in the case of two fibers in two slots, interface created allowed stress transfer further down the restored structure to the cementoenamel junction and resulted in lower fracture resistance due to root fracture. This also explains the mode of fracture seen in group 6. Slot preparation without fiber placement also showed improved fracture resistance. This improvement in fracture resistance may be attributed to an increase in the bonding area due to slots (group 3 have one slot and group 5 having two slots) and it is a known fact that slots always increase retention. Variable fracture mode observed in groups 3 and 5 may be attributed to the fact that two slots which were prepared were not of the same size as the single slot and lesser intact tooth structure was left at edges of the fracture as well as in between two slots. This fact may also be responsible for lower mean fracture resistance of group 5 than group 3 and for variable mode of fracture because dissipation of forces is always dependent on sites of adhesion which varies in groups 3 and 5. Furthermore, because of two slots, the numbers of joints in restoration were also increased. Fracture resistance of both these groups is within the range of normal masticatory load; hence, it can be the modality of restoration when fiber is not available to clinician. Somehow different failure modes of restoration were reported by other researchers, which can partly be explained by differences in the loading technique. In some studies, the tooth was loaded at a 90° angle, whereas in this study, the tooth was loaded to a more closely simulated clinical condition.[26,27] Further studies with larger sample size and simulations of oral conditions are warranted to draw a definite conclusion.

## Conclusion

From this study, we can conclude that

- Fibers certainly have the reinforcing effect on restoration of fractured anterior teeth. This might help to optimize properties of directly made composite in anterior teeth.
- The position of fiber is an important factor to determine the reinforcing effects of fibers.
- Polyethylene fiber (Ribbond) in the central palatal slot has a better effect on the distribution of stress and increases the strength of restoration. By using this technique, one can achieve strength almost equivalent to natural teeth.
- During restoration of fractured anterior teeth by preparing a single slot in addition to conventional beveled design, the load bearing capacity of tooth is also enhanced.

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