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Fracture Resistance of Endodontically Treated Teeth Restored with Composite Systems and Polyethylene Fibers: An In Vitro Study

Keywords
Endodontically treated teeth; Fracture resistance; Fiber-reinforced composite; Ribbond; EverX Posterior.

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ABSTRACT

Aim: To evaluate and compare the fracture resistance of endodontically treated premolars restored with nano-ceramic composite, nanocomposite, and short fiber-reinforced composite systems combined with woven polyethylene (Ribbond) fiber. **Materials and Methods:** Forty freshly extracted human single-rooted premolars were included in this in vitro study. Ten intact teeth served as the control group, while thirty teeth underwent endodontic treatment and standardized mesio-occluso-distal cavity preparation. The specimens were randomly divided into four groups (n = 10): Group 1: intact teeth (control); Group 2: nano-ceramic composite (Neo Spectra ST) with Ribbond fiber; Group 3: nanocomposite (Filtek Z350 XT) with Ribbond fiber; and Group 4: short fiber-reinforced composite (EverX Posterior) with Ribbond fiber. All restorations were occlusally capped with Filtek Z250 XT. Specimens were thermocycled, mounted in acrylic blocks, and subjected to compressive loading using a universal testing machine at a crosshead speed of 1 mm/min and a 30° loading angle until fracture occurred. Fracture loads were recorded in Newtons and fracture patterns were evaluated using a dental operating microscope. **Results:** The control group showed the highest fracture resistance (938.85 ± 91.28 N). Among restored groups, EverX Posterior + Ribbond showed the highest fracture resistance (786.49 ± 68.54 N), followed by Neo Spectra ST + Ribbond and Filtek Z350 XT + Ribbond. Significant differences were observed among groups ($p < 0.001$). **Conclusion:** EverX Posterior combined with Ribbond fiber demonstrated superior fracture resistance and favorable fracture patterns, suggesting its potential as a conservative restorative approach for structurally weakened premolars.

INTRODUCTION

The long-term success of root canal treatment depends not only on effective cleaning, shaping, and obturation of the root canal system but also on the quality of the definitive coronal restoration placed after endodontic therapy. Following endodontic treatment, teeth frequently lose substantial amounts of hard tissue due to caries removal, access cavity preparation, and the removal of existing restorations. This cumulative loss of structural integrity significantly alters the biomechanical behavior of the tooth, reducing its resistance to functional stresses. Consequently, endodontically treated teeth are generally more susceptible to fracture compared with vital teeth, particularly in posterior regions where occlusal forces are greater.[1]

The structural weakening of endodontically treated teeth necessitates restorative strategies that not only provide an adequate coronal seal but also reinforce the remaining tooth structure. Intracoronal reinforcement techniques aim to redistribute occlusal forces, minimize stress concentration within the remaining dentin, and improve the mechanical stability of weakened teeth. Such reinforcement becomes particularly important in teeth with extensive cavity preparations, especially mesio-occluso-distal (MOD) cavities, where the removal of marginal ridges significantly compromises the

structural support of the tooth.[2] The loss of marginal ridges increases cuspal flexure and stress concentration within the residual dentin, thereby predisposing the tooth to crack formation and eventual fracture.[3]

To address these biomechanical challenges, fiber-reinforced restorative materials have been introduced to enhance the fracture resistance of weakened teeth. Among the available reinforcing systems, woven polyethylene fibers such as Ribbond have gained attention due to their high tensile strength, fracture toughness, and modulus of elasticity comparable to dentin.[4] When incorporated into resin composites, these fibers form a reinforcing network that distributes occlusal stresses and inhibits crack propagation, thereby improving the mechanical performance of restorations in structurally compromised teeth.[5] Surface modification techniques such as cold plasma treatment further improve the adhesion between polyethylene fibers and the resin matrix, enhancing stress distribution and reducing the likelihood of interfacial failure.[6]

Fracture remains one of the most common complications associated with endodontically treated teeth.[7] Fracture resistance, defined as the ability of a structure to resist crack initiation and propagation under functional loading, is therefore a critical factor influencing the longevity of restorations placed in such teeth.[8] Fiber-reinforced composite systems have been developed to mimic the stress-dissipating characteristics of natural dental tissues and to improve the mechanical performance of restorative materials used in extensive cavity preparations.[9] Additionally, these materials may reduce polymerization shrinkage stress and cuspal deflection while improving the toughness and flexural strength of composite restorations.[10]

Based on this background, the present in vitro study was designed to evaluate and compare the fracture resistance of endodontically treated teeth restored with three different composite systems—nano-ceramic composite, nanocomposite, and short fiber-reinforced composite—each combined with woven polyethylene fiber (Ribbond) reinforcement. The specific objectives of this study are to evaluate the fracture resistance of endodontically treated teeth restored with nano-ceramic composite and Ribbond fiber, nanocomposite and Ribbond fiber, and short fiber-reinforced composite and Ribbond fiber, and to compare the fracture resistance among these restorative systems. The null hypothesis tested in this study is that there is no significant difference in the fracture resistance of endodontically treated teeth restored with the three different composite systems combined with woven polyethylene fiber reinforcement.

Materials and Methods

Study Design and Sample Selection

This in vitro experimental study was conducted after institutional approval Department of Conservative Dentistry and Endodontics in collaboration with the Department of Dental Materials, Yenepoya Dental College. Forty freshly extracted human permanent premolars with a single root and single canal were selected for the study. The teeth were extracted for orthodontic or periodontal reasons and were anonymized prior to use.

The teeth were examined visually and radiographically to confirm the presence of a single canal and absence of structural defects. Teeth presenting with caries, fractures, calcified canals, bifurcated canals, or extensive restorations were excluded. Only teeth with a mesiodistal width of approximately 7 mm were included to ensure dimensional standardization.

The selected specimens were stored in 0.9% saline solution at room temperature until use to prevent dehydration.

Sample Size Estimation

Sample size calculation was performed using G*Power software based on the study conducted by Soto-Cadena et al. (2023). Considering an effect size of 0.5, a statistical power of 80%, and a confidence level of 95%, the required sample size for comparison among four groups using one-way analysis of variance (ANOVA) was calculated to be 40 specimens. The specimens were therefore divided into four groups of 10 teeth each.

Simulation of Periodontal Ligament and Mounting

To simulate the periodontal ligament, the root surfaces were coated with a 0.2-mm layer of aluminum foil and covered with petroleum jelly. The foil was subsequently replaced with polyvinyl siloxane impression material. Each tooth was then mounted vertically in autopolymerizing acrylic resin blocks leaving approximately 1.5 mm of the root surface exposed apical to the cementoenamel junction (CEJ) (Figure 1).

Figure 1 : **Tooth Mounted in acrylic resin**

Endodontic Procedure

Standard access cavities were prepared using an endodontic access bur in a high-speed airotor handpiece with water coolant. Working length was determined using stainless steel K-files and confirmed radiographically. Cleaning and shaping of the root canals were performed using hand K-files (#10–#25) followed by rotary nickel–titanium instruments (ProTaper Gold; Dentsply Sirona, Switzerland) up to size F3 (ISO size 30) according to the manufacturer's instructions.

During instrumentation, canals were irrigated with 3% sodium hypochlorite between each file. Final irrigation was performed with 17% EDTA followed by saline. The canals were then dried using sterile paper points.
Obturation was performed using ProTaper gutta-percha cones and epoxy resin-based sealer (AH Plus; Dentsply Sirona, Germany). Excess gutta-percha was removed to the level of the cementoenamel junction using a heated plugger. Radiographs were obtained to verify the quality of obturation (Figure 2). The pulp chamber floor was then sealed with resin-modified glass ionomer cement.

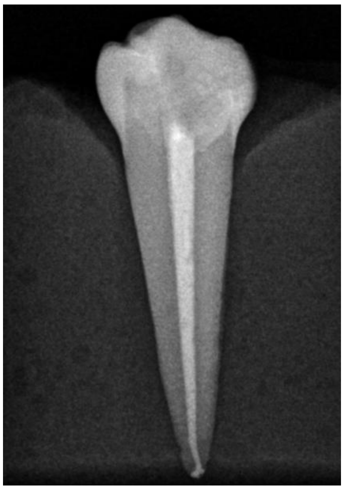

Figure 2 : **Radiographic evaluation of endodontic treatment**

Standardization of Cavity Preparation

Standardized mesio-occluso-distal (MOD) cavities were prepared in the specimens. The cavity dimensions were standardized to approximately 5 mm bucco-palatal width, 5 mm depth, and 7 mm mesiodistal width. The buccal wall thickness was maintained at 2 mm at the occlusal level and 2.5 mm at the CEJ, while the palatal/lingual wall thickness was maintained at 1.5 mm. Measurements were verified using a periodontal probe and digital calipers to ensure uniformity among all specimens.

Group Allocation

The specimens were randomly divided into four groups (n = 10 per group):

Group 1 (Control Group): Intact teeth with no restorative procedure performed.

Group 2: Endodontically treated teeth restored with nano-ceramic composite (Neo Spectra ST; Dentsply Sirona) reinforced with woven polyethylene fiber (Ribbond; Ribbond Inc.).

Group 3: Endodontically treated teeth restored with nanocomposite (Filtek Z350 XT; 3M ESPE) reinforced with woven polyethylene fiber.

Group 4: Endodontically treated teeth restored with short fiber-reinforced composite (EverX Posterior; GC) reinforced with woven polyethylene fiber.

Figure 3 : **Neo spectra ST, Filtek Z 350 , and ever X posterior**

Restorative Procedure

Prior to restoration, the cavity surfaces were etched with 37% phosphoric acid for 15 seconds, rinsed with water, and gently air-dried. A bonding agent (Ivoclar Vivadent) was then applied according to the manufacturer's instructions and light-cured.

A thin layer of flowable composite resin was placed on the cavity floor, and pre-cut woven polyethylene fiber (Ribbond) was embedded within the flowable composite along the buccal wall, pulpal floor, and lingual wall of the cavity (Figure 4). The fiber was adapted carefully to ensure intimate contact with the cavity surfaces. In Group 2 and Group 3, the cavities were restored incrementally using nano-ceramic composite and nanocomposite respectively, while in Group 4 the cavity was restored using short fiber-reinforced composite (Figure 5).
A final occlusal layer of composite resin (Filtek Z250 XT; 3M ESPE) was placed in increments of approximately 1.5 mm thickness. Each increment was light-cured according to the manufacturer's instructions. (Figure 6).

Figure 4: **Ribbond fiber embedded in the flowable Composite**

Figure 5 : **Placement of everX posterior**

Figure 6 : Final incremental layering done using filtek Z 250 XT

Fracture Resistance Testing

Fracture resistance of the restored specimens was evaluated using a universal testing machine (Tec-Sol, India) (Figure 7).

Each specimen was positioned in a custom-made metal jig. A compressive load was applied to the occlusal surface at an angle of 30° to the long axis of the tooth at a crosshead speed of 1 mm/min until fracture occurred. The maximum load required to fracture each specimen was recorded in Newtons (N).

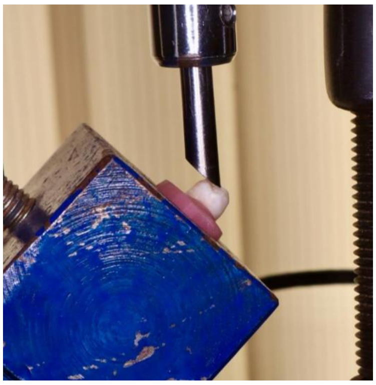

Figure 7 : **Evaluating the fracture resistance of samples using universal testing machine**

Fracture Pattern Evaluation

Following fracture testing, the fracture patterns were examined under a dental operating microscope at 20× magnification to determine the type and location of fracture (Figure 8-11).

Figure 8: Favourable fracture pattern of Group 1 (control group) [20x magnification in dental operating microscope]

Figure 9 : Unfavourable fracture pattern of Group 2 (Neo spectra ST) [20x magnification in dental operating microscope]

Figure 10 : Unfavourable fracture pattern of Group 3 (Filtek Z 350 XT) [20x magnification in dental operating microscope

Figure 11 : Favourable fracture pattern of Group 4 (EverX Posterior) [20x magnification in dental operating microscope

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics version 27. The normality of the data distribution was assessed using the Shapiro–Wilk test. Since the data followed a normal distribution, comparisons among groups were performed using one-way analysis of variance (ANOVA). Post-hoc multiple comparisons were performed using the Bonferroni test when significant differences were detected. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The control group (intact teeth) demonstrated the highest mean fracture resistance with a value of 938.84 ± 91.28 N. Among the restored groups, specimens restored with EverX Posterior reinforced with Ribbond fiber exhibited the highest mean fracture resistance (786.49 ± 68.54 N), followed by Neo Spectra ST reinforced with Ribbond fiber (684.50 ± 59.66 N). The lowest mean fracture resistance was observed in specimens restored with Filtek Z350 XT reinforced with Ribbond fiber (590.36 ± 49.36 N). The minimum and maximum fracture resistance values ranged from 514.75 N to 1051.86 N across the study groups. One-way analysis of variance revealed a statistically significant difference in fracture resistance among the groups ($p < 0.001$) (Table 1).

Group	Mean (N)	SD	95% CI (Lower–Upper)	Minimum	Maximum
Control	938.84	91.28	873.55 – 1004.14	795.71	1051.86
Neo Spectra ST	684.5	59.66	641.82 – 727.18	628.6	836.11
Filtek Z350 XT	590.36	49.36	555.05 – 625.67	514.75	684.6
EverX Posterior	786.49	68.54	737.46 – 835.52	693.13	920.84
One-way ANOVA: *$p < 0.001$*					

Table 1 : Descriptive statistics and one-way ANOVA comparison of fracture resistance among the study groups

To determine the pairwise differences among the groups, Bonferroni post-hoc multiple comparison analysis was performed. The results demonstrated that the control group had significantly higher fracture resistance compared with Neo Spectra ST, Filtek Z350 XT, and EverX Posterior ($p < 0.001$). Among the restorative groups, Neo Spectra ST showed significantly greater fracture resistance than Filtek Z350 XT ($p = 0.025$). EverX Posterior also demonstrated significantly higher fracture resistance than Filtek Z350 XT ($p < 0.001$). Furthermore, EverX Posterior exhibited significantly greater fracture resistance than Neo Spectra ST ($p = 0.013$). These findings indicate that among the restorative materials evaluated, EverX Posterior reinforced with Ribbond fiber provided superior fracture resistance compared with the other composite systems (Table 2).

Comparison	Mean Difference (N)	95% CI (Lower–Upper)	p value
Control vs Neo Spectra ST	254.35	168.23 – 340.46	<0.001*
Control vs Filtek Z350 XT	348.49	262.38 – 434.60	<0.001*
Control vs EverX Posterior	152.36	66.25 – 238.47	<0.001*
Neo Spectra ST vs Filtek Z350 XT	94.14	8.03 – 180.26	0.025*
Neo Spectra ST vs EverX Posterior	−101.99	−188.10 – −15.88	0.013*
Filtek Z350 XT vs EverX Posterior	−196.13	−282.24 – −110.02	<0.001*

Table 2: Bonferroni post-hoc pairwise comparison of fracture resistance among study groups

Favorable fracture patterns were predominantly observed in the control group and in specimens restored with EverX Posterior reinforced with Ribbond fiber. In contrast, specimens restored with Neo Spectra ST and Filtek Z350 XT reinforced with Ribbond fiber predominantly demonstrated unfavorable fracture patterns. These observations suggest that the restorative material used may influence the mode of fracture in endodontically treated teeth restored with fiber reinforcement (Table 3).

Group	Material	Predominant Fracture Pattern
Control	Intact tooth	Favorable
Group 2	Neo Spectra ST + Ribbond	Unfavorable
Group 3	Filtek Z350 XT + Ribbond	Unfavorable
Group 4	EverX Posterior + Ribbond	Favorable

Table 3: Distribution of Predominant fracture pattern observed among the study groups

Discussion

The present in vitro study evaluated the fracture resistance and fracture patterns of endodontically treated premolars restored with three different composite systems—nano-ceramic composite (Neo Spectra ST), nanocomposite (Filtek Z350 XT), and short fiber-reinforced composite (EverX Posterior)—each combined with woven polyethylene Ribbond fibers. The results demonstrated that intact teeth exhibited the highest fracture resistance, followed by teeth restored with EverX Posterior reinforced with Ribbond fiber, Neo Spectra ST with Ribbond fiber, and Filtek Z350 XT with Ribbond fiber. Although all restored groups showed lower fracture resistance than intact teeth, the EverX Posterior–Ribbond combination withstood significantly higher loads compared with the nanoparticulate composite systems. Furthermore, specimens restored with EverX Posterior predominantly demonstrated favorable fracture patterns, suggesting a more repairable mode of failure.

The reduced fracture resistance observed in restored teeth compared with intact teeth is consistent with previous studies reporting that extensive mesio-occluso-distal (MOD) cavity preparations significantly weaken premolars due to the removal of marginal ridges and pericervical dentin. These anatomical structures play a critical role in distributing occlusal forces and maintaining structural rigidity. Oskoee et al. reported that fiber reinforcement in MOD cavities could partially restore fracture resistance, although the effectiveness depends on fiber composition and placement within the cavity.[1] Similarly, Zotti et al. demonstrated that Ribbond fibers are most effective when integrated into a continuous tooth–fiber framework rather than used as isolated reinforcements.[2] Patnana et al. further observed that polyethylene fiber-reinforced composites could withstand higher fracture loads than particulate-filled composites, highlighting the reinforcing potential of woven polyethylene fiber networks.[3]

The superior performance of EverX Posterior observed in the present study may be attributed to its composition as a short fiber-reinforced composite (SFRC). SFRC materials contain randomly oriented glass fibers that act as crack-arresting elements within the resin matrix, allowing stresses to be distributed more evenly throughout the restoration. This mechanism improves fracture toughness and reduces crack propagation under occlusal loading. Soto-Cadena et al. reported that combining short fiber-reinforced composites with polyethylene fibers significantly increased fracture resistance in endodontically treated premolars, supporting the synergistic reinforcement mechanism observed in the current investigation.[4] Similarly, Selvaraj and Krithikadatta demonstrated that EverX Posterior-restored teeth exhibited higher fracture resistance and predominantly favorable fracture patterns compared with conventional composite restorations.[9] These findings support the concept that fiber-reinforced restorative systems can mimic the stress-absorbing behavior of natural dentin.

The biomechanical advantages of fiber-reinforced restorations have also been demonstrated in studies evaluating various reinforcement techniques. Nilavarasan et al. reported that intracanal fiber posts significantly influenced compressive strength and structural stability in endodontically treated teeth.[5] Aslan et al. observed that horizontal fiber reinforcement or occlusal Ribbond placement increased fracture resistance compared with composite restorations alone.[6] Likewise, Badakar et al. found that fiber-reinforced composite restorations in anterior teeth resisted higher fracture loads than conventional composites.[8] Collectively, these studies support the concept that fiber reinforcement redistributes occlusal stresses, improves load-bearing capacity, and enhances the overall mechanical performance of restorations placed in structurally compromised teeth.

Another important factor influencing fracture resistance is the orientation and placement of reinforcing fibers within the restoration. Albar and Khayat demonstrated that positioning Ribbond fibers along axial walls and pulpal floors significantly increased fracture resistance compared with non-reinforced restorations.[11] Prasanthi et al. showed that wallpapering techniques using polyethylene or glass fibers around pericervical dentin improved fracture resistance and shifted fracture patterns coronally.[12] Similarly, Ibrahim et al. reported that occlusal splinting with Ribbond fibers produced the highest fracture resistance among different fiber configurations.[13] These findings indicate that fiber reinforcement is technique-sensitive and that strategic placement along areas of maximum tensile stress is essential for optimal reinforcement.

Systematic reviews have also highlighted the reinforcing potential of fiber-reinforced restorative systems. Alvarado Orozco et al. concluded that polyethylene fiber-reinforced restorations generally demonstrate higher fracture loads and a greater proportion of favorable fracture patterns compared with non-fiber restorations.[14] Bijelic-Donova et al. reported that both short glass fiber-reinforced composites and polyethylene fiber systems significantly enhance fracture resistance in structurally weakened teeth.[15] These observations are consistent with the results of the present study, where fiber-reinforced restorations showed improved biomechanical performance compared with conventional nanoparticulate composites. An additional observation of the present investigation was the difference in fracture patterns among the restorative materials. Favorable fractures were predominantly observed in intact teeth and in the EverX Posterior group, whereas unfavorable fractures occurred more frequently in the Neo Spectra ST and Filtek Z350 XT groups. Favorable fractures are clinically desirable because they typically occur above the cementoenamel junction and are therefore repairable. Shadman et al. reported similar findings in premolars restored with fiber-reinforced materials, where reinforcement shifted fracture lines coronally and increased the likelihood of restorable failures.[16] Mohammadipour et al. also observed that combining short fiber-reinforced composites with polyethylene fibers increased fracture resistance while promoting more favorable fracture patterns.[17]
The experimental protocol used in the present study also followed established laboratory methods for evaluating fracture resistance. A universal testing machine was used to apply compressive loading at a controlled crosshead speed and angle until fracture occurred, allowing standardized and reproducible

evaluation of mechanical performance. Soto-Cadena et al. similarly used universal testing machines to assess fracture resistance in endodontically treated premolars restored with fiber-reinforced composites, demonstrating the reliability of this testing method.[4] In addition, fracture pattern evaluation using a dental operating microscope enabled accurate identification of favorable and unfavorable fracture modes, thereby enhancing the clinical relevance of the findings.

From a clinical perspective, the results of this study suggest that combining short fiber-reinforced composites with polyethylene fiber reinforcement may provide a biomimetic restorative approach for structurally compromised endodontically treated premolars. Such restorations may improve fracture resistance, redistribute occlusal stresses, and promote repairable fracture patterns. These characteristics support the principles of minimally invasive dentistry, in which adhesive fiber-reinforced restorations may serve as conservative alternatives to more invasive restorative procedures in selected clinical situations.

Despite these promising findings, certain limitations should be acknowledged. As an in vitro study, the experimental design could not fully reproduce the complex biological conditions of the oral environment, including saliva, thermal changes, periodontal ligament dynamics, and cyclic masticatory loading. The sample size was limited and only single-rooted premolars with standardized MOD preparations were evaluated, which may restrict the generalizability of the results. Furthermore, fracture resistance was assessed using a single load-to-failure test, which does not completely replicate the fatigue behavior of restorations subjected to long-term functional stresses.

Conclusion

The findings of this in vitro study indicate that the restorative material used in combination with polyethylene fiber reinforcement significantly influences the fracture resistance of endodontically treated premolars. Among the materials evaluated, short fiber-reinforced composite (EverX Posterior) combined with woven polyethylene (Ribbond) fiber demonstrated greater fracture resistance than nano-ceramic composite (Neo Spectra ST) and nanocomposite (Filtek Z350 XT) reinforced with Ribbond. Additionally, this combination produced more favorable, restorable fracture patterns, suggesting its potential as a conservative restorative approach for premolars with extensive MOD cavity preparations.

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