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ORIGINAL RESEARCH

Effect of Fiber-Reinforced Composite Placement Site on Fracture Resistance of Premolar Teeth: An in vitro Study

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Background: This study aimed to investigate the fracture behavior of upper premolars with deep MOD cavities that were restored with Ribbond resin-reinforced fibers (FRCs) placed in different orientations.

Methods: A total of 54 extracted maxillary premolars were randomly divided into nine groups. The experimental groups underwent MOD cavity preparation with or without root canal treatment, followed by FRCs placed in the pulpal floor, proximal walls, or both. Fracture resistance was tested using an Instron Machine. The samples were visually inspected to analyze the fracture mode.

Results: The highest fracture resistance was observed in intact teeth (1299.98 ± 284.66 MPa). Placing Ribbond fibers in the pulpal floor (1155.86 ± 244.21 MPa) or the proximal walls (1077.56 ± 260.60 MPa) significantly improved fracture resistance ($p = <0.05$), compared to cavities restored with only resin composite (804.58 ± 93.34 MPa). However, placing Ribbond fibers in both the pulpal and proximal walls did not enhance fracture resistance. In the MOD-RCT groups, fracture resistance was improved only when Ribbond fibers were placed in the pulpal floor and the proximal walls. Fracture mode analysis revealed a combined fracture in most of the groups.

Conclusion: This study concluded that using FRCs significantly improved the fracture resistance of MOD cavities in premolars and revealed that the placement site could be a determinant factor.

Plain Language Summary:

- This study investigated the fracture behavior of upper premolars with deep MOD cavities restored with Ribbond resin-reinforced fibers (FRCs) placed in different orientations.
- Placing Ribbond fibers in the pulpal floor or the proximal walls significantly improved the fracture resistance of premolars with deep MOD cavities.
- In the MOD-RCT groups, fracture resistance was improved only when Ribbond fibers were placed in the pulpal floor and the proximal walls.
- Fracture mode analysis revealed a combined fracture in most of the groups.

This study concluded that using FRCs significantly improved the fracture resistance of MOD cavities in premolars and revealed that the placement site could be a determinant factor.

Keywords: fracture resistance, compressive strength, resin composite

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Introduction

Restorative dentistry faces a significant challenge when restoring a tooth with marginal ridge loss, as it leads to a 46% reduction in tooth stiffness.[1] Excessive loss of the marginal ridge is commonly observed in endodontically treated teeth, which are more prone to fracture.[2] This tendency can be attributed to the biomechanical changes that enamel and dentin

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undergo during endodontic therapy, as well as the loss of tooth structure during caries removal and cavity preparation.[3] Despite the lower fracture toughness of resin composite compared to dentin, its use in tooth restoration has become increasingly popular, especially as a core for endodontic-treated teeth.[4] Apart from reduced fracture toughness, resin composite restorations exhibit significant drawbacks, such as debonding and polymerization shrinkage.[5] The placement of resin composite as a core restorative material for compromised premolars faces challenges due to these factors.[6]

In recent years, fiber-reinforced composites (FRCs) have gained wide usage to improve the performance of adhesive restorative materials.[7] Various types of fiber reinforcement exist in the restorative field, including glass, kevlar, carbon, Vectren, and polyethylene fibers.[8–10] Among these, glass and polyethylene fibers are the most utilized.[8–10] In 1992, Ribbond, an example of non-impregnated polyethylene fibers, was introduced in dentistry. It consists of bondable reinforced ultra-high-strength polyethylene with a high molecular weight and coefficient of elasticity, which makes it highly resistant to distortion and capable of absorbing and redistributing occlusal forces in high-stress areas.[8,9] Ribbond fibers also exhibit excellent adaptability to tooth morphology, reducing microleakage and polymerization shrinkage.[11]

Ribbond fibers can be placed either under or within a restoration or circumferentially inside the cavity. The combination of aesthetics, strength, and bond ability offered by Ribbond fibers allows for a wide range of dental applications, such as being splints for periodontally compromised teeth, stabilizing traumatized teeth, and the fabrication of provisional fixed partial dentures.[8–10,12] In operative dentistry, Ribbond fibers are used to reinforce resin composite strength, particularly in restoring missing walls and endodontically-treated teeth with extensive tooth damage.[13]

Few investigations explored the potential of FRCs to improve the fracture resistance of teeth with missing marginal ridges. One in vitro study demonstrated that FRCs improved fracture resistance in mesio-occlusal-distal (MOD) cavities, with no significant difference observed between fiber types.[14] A recent literature review concluded that FRCs significantly increased fracture resistance in both endodontically and non-endodontically treated teeth, with variations between fiber types, while no significant difference was found in reducing microleakage.[9] Additionally, one investigation displayed that FRCs exhibited greater fracture resistance in premolars with MOD cavities extending toward the palatal cups compared to traditional direct techniques with no FRCs.[15] Moreover, another study demonstrated that premolars with compromised palatal cusps and endodontic cavities exhibited improved fracture resistance when restored with FRCs.[16]

To the best of our current understanding, no investigation has explored the fracture characteristics of FRCs when used to restore the proximal wall of deep MOD cavities in upper premolars, particularly in various fiber orientations. This includes scenarios where Ribbond fibers could be positioned in the pulpal floor, proximal walls, or both. Therefore, this study aimed to evaluate the impact of FRCs orientation on the fracture behavior of upper premolars with deep MOD cavities with and without root canal treatment (RCT).

Materials and Methods

Sample Size Calculation, Ethical Approval, and Study Design

The minimum sample size for each group in this study was determined based on previous studies,[7,9,14,15] considering a power of 80% and an effect size of 1.6. As a result, a total of six samples per group were deemed necessary, which was confirmed following our statistical analysis. This randomized laboratory study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Ethical approval was obtained from the IAU Institutional Review Board (IRB-2023-02-313) to approve the use of fifty-four extracted upper first premolars. The selected samples for this research were extracted teeth for orthodontic reasons after patient approval. The teeth were placed immediately after extraction in 0.1% thymol solution until use. Before using the specimens, a scaler handpiece was used to remove soft tissue remanent. Only intact teeth with no defects were included. Teeth with cracks, wear facets, crowns, resorption, or previous endodontically treated teeth were excluded. To minimize variation between the selected teeth, only premolars with a crown length of 8.5 ± 1 mm, buccolingual length of 9 ± 1 mm, and mesiodistal width of 7 ± 1 mm were included.

Groups Distribution

Teeth were categorized into nine groups, with six teeth per group. Figure 1 and Table 1 describe the group distribution according to the cavity preparation and the Ribbond fiber orientation. The groups were categorized as the following:

Group 1: Sound teeth with no intervention (Control).

Group 2: Teeth with MOD cavity preparation restored with resin composite only (MOD)

Group 3: Teeth with MOD cavity preparation restored with Ribbond fiber placed in the pulpal floor and resin composite (MOD Ribbond-pulpal).

Group 4: Teeth with MOD cavity preparation restored with Ribbond fiber placed in the proximal walls and resin composite (MOD Ribbond-proximal).

Group 5: Teeth with MOD cavity preparation restored with Ribbond fiber placed in the pulpal floor and proximal walls, and resin composite (MOD Ribbond-pulpal-proximal).

Group 6: Teeth with MOD cavity preparation and endodontic access opening restored with resin composite only (MOD-RCT)

Group 7: Teeth with MOD cavity preparation and endodontic access opening restored with Ribbond fiber placed in the pulpal floor and resin composite (MOD-RCT Ribbond-pulpal).

Group 8: Teeth with MOD cavity preparation and endodontic access opening restored with Ribbond fiber placed in the proximal walls and resin composite (MOD-RCT Ribbond-proximal).

Group 9: Teeth with MOD cavity preparation and endodontic access opening restored with Ribbond fiber placed in the pulpal floor and proximal walls, and resin composite (MOD-RCT Ribbond-pulpal-proximal).

Cavity Preparation

All teeth except those in Group 1 (Control) were prepared with standardized MOD cavity preparation using the cylindrical diamond bur (medium grit, 010 diameters), which was replaced every 10 prepared teeth.

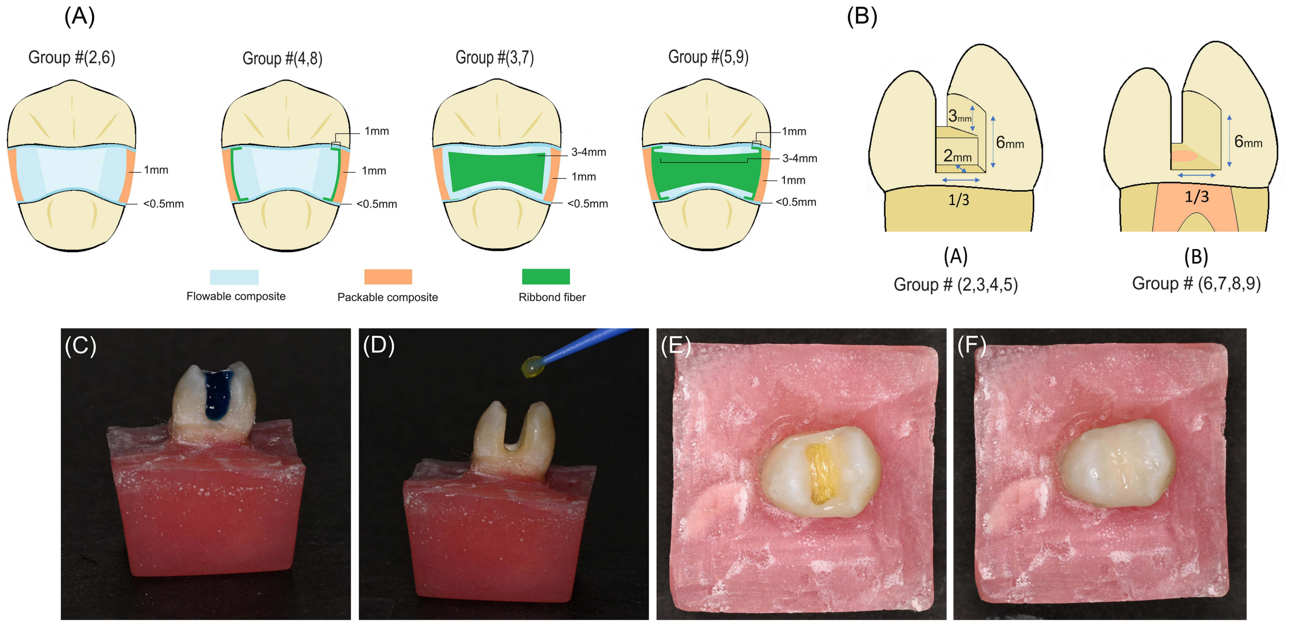

Figure 1 Schematic diagrams illustrating sample preparation procedures. (**A**) The diagram depicts the different tested groups. Groups #2 and #6 represent the mesio-occluso-distal (MOD) groups with and without root canal treatment (RCT) but no involvement of fiber-reinforced composite (FRC). Groups #4 and #8 indicate the placement of FRC in the proximal walls, while groups #3 and #7 represent the conditions where FRC was placed in the pulpal floor. Lastly, groups #5 and #9 demonstrate situations where FRC was placed both in the pulpal floor and the proximal walls. (**B**) The diagram showcases the dimensions of the cavity. One-third of the intercuspal distance was involved. In terms of depth, the MOD cavities in groups without RCT were reduced by 3 mm toward the pulpal floor and 6 mm toward the gingival floor. For the groups with RCT, an equivalent reduction of 6 mm in depth was applied. Diagrams (**C**–**F**) present the step-by-step laboratory procedures for one of the groups. It begins with cavity preparation and etching (**C**), followed by the application of bonding agent (**D**), flowable composite, build-up of the proximal walls and placement of FRC (**E**), and concludes with the restoration of the entire cavity using packable resin composite (**F**).

Table 1 Description of the Included Groups in the Study

Steps	Control	MOD	MOD Ribbond-pulpal	MOD Ribbond-proximal	MOD Ribbond-pulpal-proximal	MOD-RCT	MOD-RCT Ribbond-pulpal	MOD-RCT Ribbond-proximal	MOD-RCT Ribbond-pulpal-proximal
RCT						*	*	*	*
MOD		*	*	*	*	*	*	*	*
Etching and Bonding		*	*	*	*	*	*	*	*
Placement of Flowable Composite		*	*	*	*	*	*	*	*
Placement of Ribbond Fiber on pulpal floor			*		*		*		*
Placement of Ribbon Fiber on Proximal wall				*	*			*	*
Placement of Packable Composite		*	*	*	*	*	*	*	*
Depth of Cavity to the pulpal floor (mm)		3	3	3	3	6	6	6	6
Depth of Cavity to the gingival floor (mm)		6	6	6	6	6	6	6	6

Note: *symbol indicates that the steps were performed in a particular group.
Abbreviations: MOD, Mesio-occluso-distal; RCT, Root canal treatment; mm, millimeter.

1. Group 2 (MOD) preparation: Premolars with MOD cavities were prepared with a depth of 3 mm toward the pulpal floor and 6 mm toward the gingival floor. The width of the cavity was 1/3 of the inter-cuspal distance. The preparation was achieved using the cylindrical diamond bur with a high-speed handpiece and water coolant spray. Then, Tofflemire matrix was applied. Total etch (3M™ ESPE™ Scotchbond™ Universal Etchant, 3M, St. Paul, MN, USA) was applied in enamel for 30 seconds and dentin for 15 seconds, followed by rinsing and drying. Then, a bonding agent (3M^{TM} Single Bond Universal Adhesive, 3M, St. Paul, MN, USA) was placed. Excess adhesive was removed using the air of the three-way syringe; then, the adhesive was light cured for 20 seconds. After that, the cavity surfaces were coated with less than 0.5 mm layer of low viscosity flowable resin composite resin (Premise Flowable, Kerr, Scafati, Italy) in the buccal and lingual dentin walls and the pulpal floor to achieve an immediate dentin seal. Then, the cavity was restored with nanohybrid packable resin composite (Filtek Z250 XT, 3M ESPE, Paul, MN, USA) using an incremental technique and each increment was cured for 30 seconds following the manufacturer recommendation using quartz-tungsten-halogen (QTH, Ivoclar Vivadent LEDition, Schaan, Liechtenstein). The radiant power of the QTH device was verified using Bluephase Meter II (Ivoclar Vivadent, Schaan, Liechtenstein).
2. Group 3 (MOD Ribbond-pulpal) Preparation: Steps for group 3 preparation were similar to Group 2. However, the proximal walls (mesial and distal) in this group were built with 1 mm thickness of nano-hybrid packable resin

composite, Ribbond fiber (Ribbond THM, Seattle, WA, USA) of 4 mm width was placed in the pulpal floor only. The remaining cavity was restored with the same type of packable resin composite using an incremental technique and each Increment was cured for 30 seconds following the manufacturer's recommendations.

3. Group 4 (MOD Ribbond-proximal) Preparation: Steps were similar to Group 3. The only difference is that the Ribbond fiber of 4 mm width was placed in the inner proximal walls of the cavity, instead of the pulpal floor, by wallpapering technique from the base to 1 mm below the marginal ridges with an extension of 1 mm in the buccal and lingual walls.
4. Group 5 (MOD Ribbond-pulpal-proximal) Preparation: Steps were similar to Group 2. However, in this group, the Ribbond fiber of 4 mm width was placed in the inner proximal walls of the cavity by wallpapering technique from the base to the 1 mm below the marginal ridges with an extension of 1 mm in the buccal and lingual walls combined with Ribbond fiber placed on the pulpal floor.
5. Group 6 (MOD-RCT) Preparation: Endodontic-treated premolars with MOD cavities with a depth of 6 mm were prepared. The width of the cavity was 1/3 of inter-cuspal distance. The premolars were prepared using the cylindrical diamond bur with a high-speed handpiece and water coolant spray. Following the endodontic access opening, a size 10 K-file was inserted in each canal to set the working length at 0.5 mm away from the apical foramen. Cleaning and shaping were carried out using ProTaper rotary system (ENDO-MATE DT NSK, Dubai, UAE) following the manufacturer's guidelines of the crown-down technique. The canals were irrigated with 2.5% sodium hypochlorite solution and dried with absorbent ProTaper paper points 2% (Sure-endo, Gyeonggi-do, South Korea). The master cone was size 30/0.2. The teeth were filled with bioceramic-impregnated Gutta-Percha (Sure-endo, Gyeonggi-do, South Korea), and the AH Plus Jet sealer (Dentsply Sirona, Charlotte, NC, USA) using the lateral condensation technique. GP was cut at the cemento-enamel junction level then covered with low-viscosity flowable resin composite (Tetric N-Flow, Ivoclar Vivadent, Schaan, Liechtenstein). Tofflemire matrix was applied. Total etch (3M™ ESPE™ Scotchbond™ Universal Etchant, 3M, St. Paul, MN, USA) in enamel for 30 seconds and dentin for 15 seconds, rinse and dry. Subsequently, a bonding agent applied, excess adhesive was removed using the air of a three-way syringe and cured for 20 seconds (3M^{TM} Single Bond Universal Adhesive, 3M, St. Paul, MN, USA). After that, the cavity surfaces were coated with less than 0.5 mm layer of low viscosity flowable resin composite (Premise Flowable, Kerr, Scafati, Italy) in the buccal and lingual dentin walls and the pulpal floor to achieve an immediate dentin seal. Then, the cavity was restored with nanohybrid packable resin composite (Tetric N-Cream, Ivoclar Vivadent, Schaan, Liechtenstein) using an incremental technique and each increment was cured for 30 seconds following the manufacturer's recommendation using quartz-tungsten-halogen (QTH, Ivoclar Vivadent LEDition, Schaan, Liechtenstein).
6. Group 7 (MOD-RCT Ribbond-pulpal) Preparation: The steps were similar to what was mentioned in Group 6. However, in this group, Ribbond fiber of 4 mm width was placed in the pulpal floor only. The remaining cavity was restored with the same type of packable resin composite using the incremental technique and each increment was cured for 30 seconds.
7. Group 8 (MOD-RCT Ribbond-proximal) Preparation: Steps were similar to what was mentioned in Group 6. However, in this group, Ribbond fiber of 4 mm width was placed in the inner proximal walls of the cavity by wallpapering technique from the base to the 1 mm below the marginal ridges with an extension of 1 mm in the buccal and lingual walls. The remaining cavity was restored with the same type of packable resin composite using the incremental technique, and each increment was cured for 30 seconds.
8. Group 9 (MOD-RCT Ribbond-pulpal-proximal) Preparation: The steps were similar to what was mentioned in Group 6. However, in this group, Ribbond fiber of 4 mm width was placed in the inner proximal walls of the cavity by wallpapering technique from the base to the 1 mm below the marginal ridges with an extension of 1 mm in the buccal and lingual walls combined with Ribbond fiber placed on the pulpal floor. The remaining cavity was restored with the same type of packable resin composite using the incremental technique, and each increment was cured for 30 seconds.

Load Testing and Mode of Fracture

Careful mounting and precise vertical orientation of specimens was done; dual-cure methacrylate resin was used to mount the specimens. All specimens were loaded using (Instron Machine) with a vertical application of steel indenter that had a round metal tip with 6 mm diameter, which was centered at the occlusal surface; continuous application of load was done until fracture occurred. Each load of 5 kN was gradually moved 1 mm\min. The force necessary to fracture each tooth was recorded in newtons for each sample.[1] After a fracture occurs, a magnification loop (4.5×) was used to identify the type of fracture, whether cohesive, adhesive, or combined fracture. A fracture was considered cohesive when the material failed by breaking internally, within its own bulk structure, and adhesive when the fracture happened at the interface between two different materials. The fracture was considered mixed fracture when it exhibited characteristics of both cohesive and adhesive fractures. Besides, the fracture was considered restorable when it happened coronal to the cementoenamel junction, and unrestorable when it happened apical to the cementoenamel junction.

Statistical Tests

Sigma version 28.0 statistical package software (IBM Corp., Armonk, NY, USA) was used for statistical analyses. Statistical analysis for the fracture resistance values was performed using the one-way ANOVA test. After that, the Tukey post hoc test was used for pairwise comparisons between group means. A P-value of <0.05 is considered statistically significant.

Result

Table 2 and Figure 2 describe the fracture resistance of the tested groups. The highest fracture resistance was observed in the control resin composite of sound teeth (1299.98 ± 284.66 MPa). When the MOD cavity, with no RCT, was restored with resin composite only, the fracture resistance (804.58 ± 93.34 MPa) was significantly reduced (p= 0.002; power of analysis =100%). Using the Ribbond fiber in the pulpal floor (MOD Ribbond-pulpal) significantly improved the fracture resistance (1155.86 ± 244.21 MPa), which was comparable to the control of sound teeth (p= 0.937; power of analysis= 100%). The same trend was observed when the Ribbond was placed in the proximal walls (MOD Ribbond-proximal), as the fracture resistance value (1077.56 ± 260.60 MPa) was comparable to the control (p= 0.586; power of analysis= 100%). Placing the Ribbond fiber in the pulpal and proximal walls (MOD Ribbond-pulpal-proximal) did not improve the fracture resistance (826.81 ± 178.88), but surprisingly, reduced it to be even comparable to the MOD group with no Ribbond fiber (p= 0.275; power of analysis= 100%).

In the MOD-RCT groups, restoring the MOD cavity with root canal treatment (MOD-RCT) with resin composite only Resulted in the least fracture resistance in this study (735.50 ± 198.34 MPa), which was highly significant compared to the control of sound teeth (p< 0.001; power of analysis =100%). Adding Ribbond fiber in the pulpal floor (778.64 ± 86.20 MPa) or the proximal walls (792.66 ± 113.94 MPa) did not improve the fracture resistance of the MOD-RCT group

Table 2 Mean and Standard Deviation (Mean ± SD, N= 6) Concerning the Fracture Resistance of the Tested Groups

Group	Fracture Resistance (MPa)
Control	1299.98 ± 284.66 ^{a}
MOD	804.58 ± 93.34 ^{bc}
MOD Ribbond-pulpal	1155.86 ± 244.21 ^{ab}
MOD Ribbond-proximal	1077.56 ± 260.60 ^{abc}
MOD Ribbond-pulpal-proximal	826.81 ± 178.88 ^{bc}
MOD-RCT	735.50 ± 198.34 ^{c}
MOD-RCT Ribbond-pulpal	778.64 ± 86.20 ^{c}
MOD-RCT Ribbond-proximal	792.66 ± 113.94 ^{bc}
MOD-RCT Ribbond-pulpal-proximal	965.17 ± 207.67 ^{abc}

Notes: a, b, and c as unsimilar letters indicate a statistically significant difference.
Abbreviations: MOD, Mesio-occluso-distal; RCT, Root canal treatment.

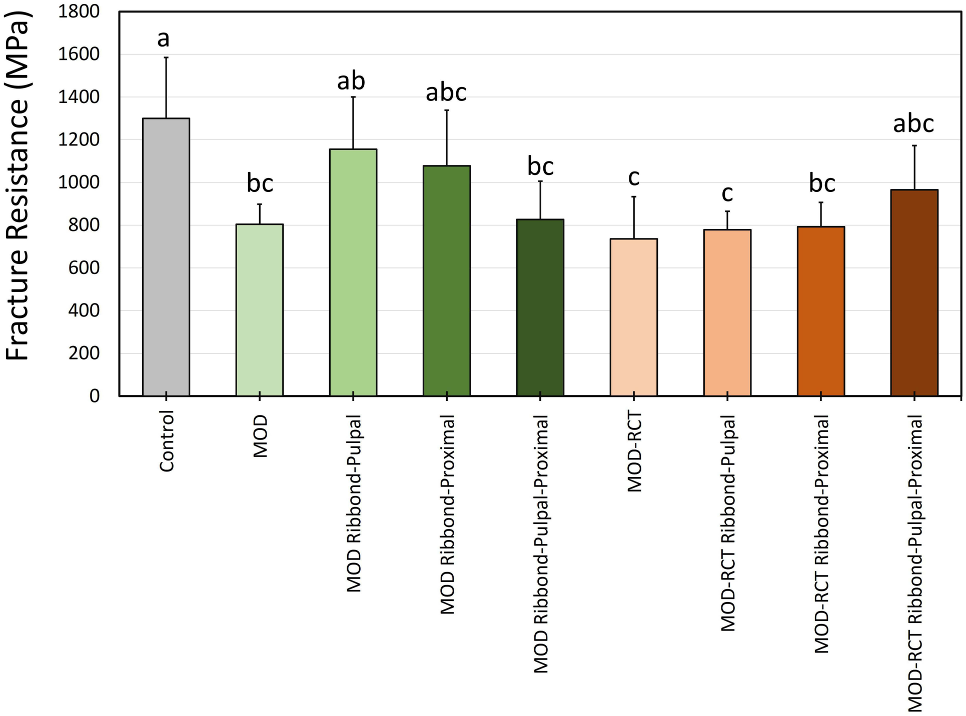

Figure 2 The fracture resistance of the tested groups (mean ± SD, n= 6). Unsimilar letters "a, b, and c" indicate a statistically significant difference.

($p>0.05$; power of analysis= 100%). However, when the Ribbond fibers were placed in the pulpal floor and the proximal walls (MOD-RCT Ribbond-pulpal-proximal), the fracture strength (965.17 ± 207.67 MPa) was improved compared to the MOD-RCT group with no Ribbond fiber by around 24%, but this was statistically insignificant ($p=0.544$; power of analysis= 100%).

Figure 3 illustrates the fracture mode of the included groups. In this study, most of the fracture modes were combined, followed by adhesive, then cohesive fractures. Combined fractures dominated all the MOD groups with no RCT. For MOD-RCT groups, all the groups were dominated by combined fractures, except when the Ribbond fiber was placed proximally, as most of the fractures were adhesives.

Figure 4 shows the tooth restorability outcomes after the fracture resistance test. All the control sound teeth were categorized as restorable. In comparison, the teeth that underwent root canal treatment (RCT) were more likely to experience unrestorable fractures. Interestingly, the placement of Ribbond fiber both pulpally and proximally resulted in more restorable fractures compared to teeth where the Ribbond was placed at only one site. These findings suggest that the location of Ribbond fiber reinforcement may influence the restorability of teeth following fracture.

Discussion

The preparation of cavities substantially impacts the compressive strength and stress distribution within the tooth.[17] Therefore, clinical approaches that can improve the fracture resistance of compromised teeth and improve the clinical longevity of dental restorations are critical to improving the quality of dental service. Most approaches in dental literature involve modifying the chemical composition of resin composite or performing a placement technique, such as an incremental technique, to minimize the clinical consequences of shrinkage stress.[5] Recently, FRCs have been investigated extensively due to their potential to improve the fracture resistance of compromised teeth.[4] In this study, we intended to explore if Ribbond fiber placement location may affect the fracture resistance of the restored teeth, and we found that placing Ribbond fiber in the pulpal floor or the proximal wall can improve the fracture resistance of premolars. Such findings may provide clinicians with some flexibility when adapting Ribbond fibers in their cavity design when restoring premolars.

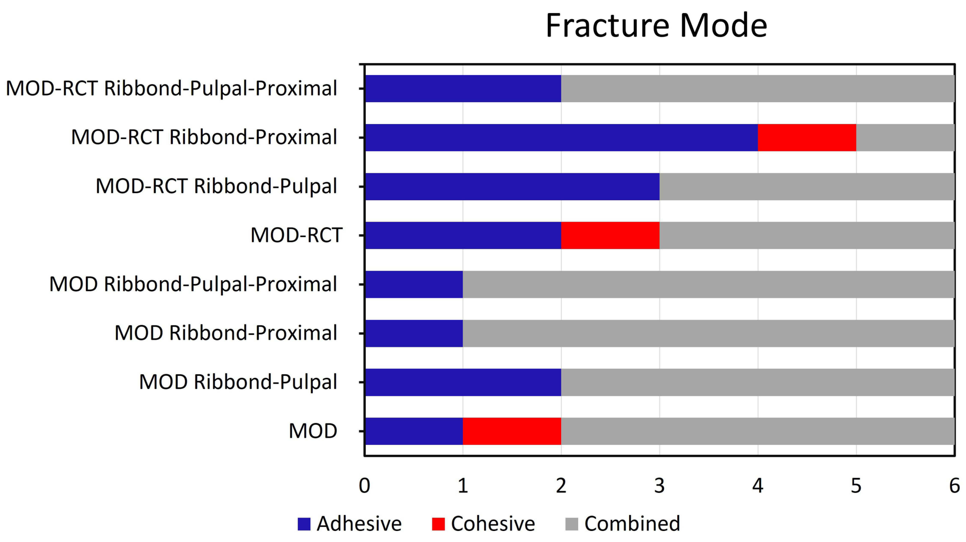

Figure 3 Mode of fracture in premolar teeth with different fiber-reinforced composite placement sites.

Considering the high vulnerability of maxillary upper premolars to lateral forces,[18] we chose them as our present study's focus. The MOD cavity preparation in a premolar is associated with a significant reduction of 54% in fracture resistance when compared to intact premolars.[19] To enhance the evaluation of fracture resistance, we carefully selected sample preparation dimensions that compromised the fracture resistance of the samples, thereby reflecting the clinical situations. In the current research, it is revealed that premolars restored with a combination of resin composite and Ribbond fiber either in the pulpal floor (1155.86 ± 244.21 MPa), the proximal wall (1077.56 ± 260.60 MPa), or both in endodontically treated teeth (965.17 ± 207.67 MPa) demonstrated significantly enhanced fracture resistance compared to teeth restored solely with resin composite restorations. No significant improvement was noticed among other groups, and surprisingly, when Ribbond was applied to both the pulpal and proximal walls of non-endodontically treated teeth, the resulting compressive strength was lower than teeth restored with traditional, non-fiber-reinforced restorations. One

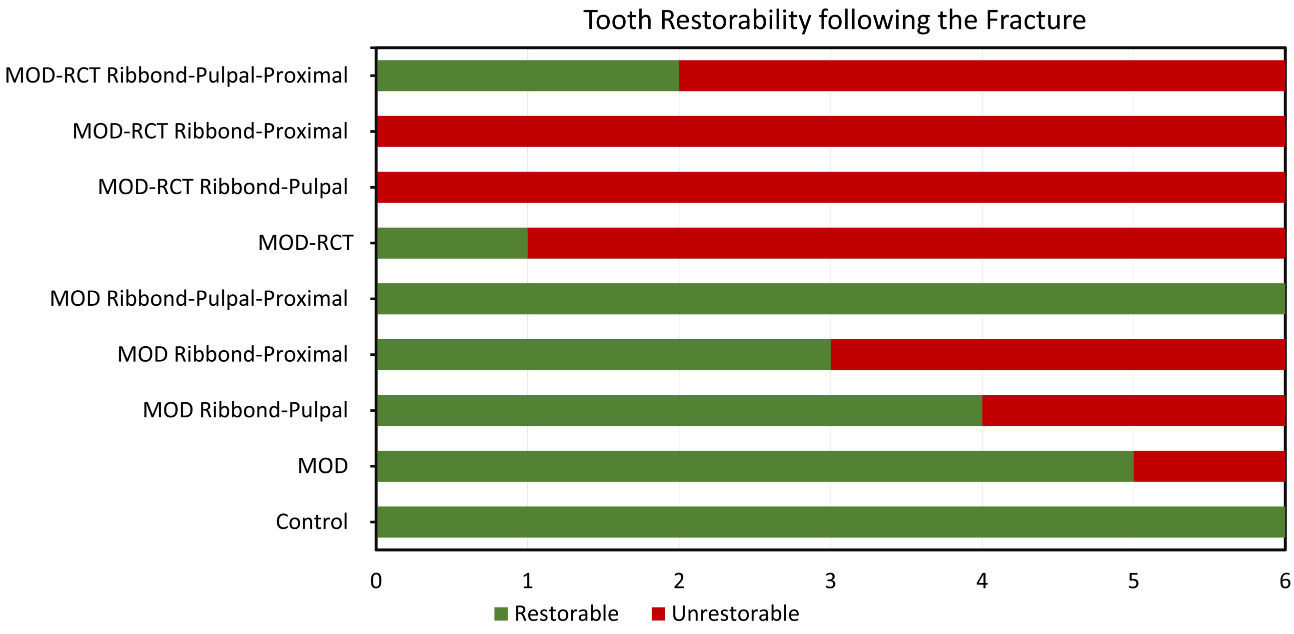

Figure 4 Restorability of the teeth following the fracture resistance test.

potential explanation for this unexpected outcome could be the high Ribbond-to-composite ratio, which might inversely impact the adaptation of the Ribbond and, subsequently, the overall integrity of the restoration.

In this investigation, the predominant fracture mode was combined across the tested groups. This aligns with the findings of a recent publication.[20] Catastrophic fractures are more likely to affect multiple components of the tooth-restoration interface, leading to diverse fracture patterns involving the restoration, bonding interface, and the tooth structure itself. This explains why the combined fracture dominated the fracture mode in this study. Notably, when the Ribbond fiber was placed in two different orientations, the teeth exhibited greater fracture resistance and more favorable fracture modes. This suggests that this dual placement technique may offer better clinical outcomes compared to Ribbond fiber placement at a single location.

The capability of FRCs in improving the fracture resistance is attributed to their ability to minimize cuspal deflection by holding the cavity walls and minimizing the combined compressive-tensile stress.[21,22] In dental restorations, cuspal deflection is a significant concern. This biomechanical phenomenon refers to the interactions between the polymerization shrinkage stress of the resin composite and the compliance of the cavity wall.[23] The deflection can lead to a weakened structure, potentially resulting in fracture or failure of the restorative material.[24] In the case of MOD (Mesial-Occlusal-Distal) restorations, the issue becomes even more pronounced due to the extensive loss of tooth substance involved.[23] The results of our study show that the use of polyethylene fiber (Ribbond) might be promising in mitigating the issue of cuspal deflection. Ribbond acts as a reinforcement within the restoration, providing additional structural stability. The material's unique characteristics allow it to bond securely with the resin composite, essentially creating a composite "bridge" within the tooth that helps distribute forces more evenly across the restoration.[21,22]

The configuration factor, or C-factor, refers to the relationship between the bonded and unbonded surfaces in a dental cavity that has been prepared for restoration.[25] The importance of the C-factor cannot be overstated, as it can greatly influence the long-term success and stability of the restoration.[25] In particular, a high C-factor can lead to stress during the polymerization of the resin composite material, resulting in possible complications such as marginal leakage, postoperative sensitivity, and secondary caries.[26,27] When the resin composite material undergoes polymerization, it contracts, and this shrinkage can put stress on the bonded interfaces. This stress can be particularly problematic in situations with a high C-factor, where the bonded surfaces outnumber the unbonded ones.[28] The stress from shrinkage can be so great that it exceeds the bond's strength, leading to gap formation and potentially bacterial infiltration and recurrent caries.[29] One approach to mitigating these effects involves the use of Ribbond reinforcement fibers in the resin composite restoration. These fibers, often composed of materials like polyethylene or glass, can serve as stress breakers within the resin composite, helping to distribute and lessen the forces created during polymerization.[30] This helps lower the localized stress that might otherwise harm the bonded interfaces and degrade the restoration's durability and lifespan.[30]

Besides the use of FRCs, preventing resin composite fracture in premolars involves several key considerations and techniques. Conservative tooth preparation techniques help preserve more natural tooth structure and reduce the risk of fracture.[31,32] In addition, resin composite restorations should be built up using an incremental layering technique. This involves applying the resin composite material in thin layers and curing each layer individually. Incremental layering allows for better polymerization and reduces the effects of polymerization shrinkage, which can lead to internal stresses and potential fracture.[31,32] Achieving adequate polymerization of the resin composite material is crucial for its strength and longevity.[33] Ensure proper light curing techniques, including using a high-quality curing light, appropriate light intensity, and sufficient curing time for each layer of resin composite. Insufficient polymerization can result in a weaker resin composite and increased susceptibility to fracture.[33]

After restoration placement, accurate occlusal adjustments are necessary to ensure proper occlusal force distribution and minimize excessive stress on the resin composite restoration.[34] Patients need to be informed about the limitations of resin composite restorations, provided instructions on proper oral hygiene practices, and encouraged to avoid habits such as chewing hard objects or biting on non-food items, as these can increase the risk of resin composite fracture.[35] It is important to note that the clinical success of FRC restorations depends on proper case selection, appropriate material handling, and following established protocols for bonding and placement.[4,22] Dentists should also consider the limitations and contraindications associated with FRCs when determining their suitability for a particular case.[4,22] In this study, we implemented the immediate dentin sealing (IDS) technique for restoring the tested premolars, even though the potential clinical benefits of this approach could not be achieved in extracted teeth. IDS involves the application of a hybrid layer on freshly prepared dentin to minimize contamination from saliva and bacteria, with the aim of enhancing the bonding effectiveness of the final restoration.[36]

This laboratory study yielded significant findings regarding the influence of the placement site of FRCs on the fracture resistance of the restored tooth. However, there are limitations that should be addressed. Teeth mounted in acrylic eliminate the impact of periodontal ligaments as a shock absorber. Accordingly, it is expected that the fracture resistance of teeth with supporting periodontium will be greater. Even though selecting teeth with comparable size was attempted in this study, standardizing the exact size and configuration as well as their mineral contents is impossible.[37,38] Most importantly, this study is an in vitro investigation; therefore, the obtained findings should be validated through randomized clinical trials, as various patient-related factors can impact the fracture behavior of such teeth. Additionally, premolars that have undergone root canal treatment should be fitted with full-coverage indirect restorations to reinforce the remaining tooth structure.[39] Future studies could investigate the fracture resistance of indirect restorations with and without FRCs as a core material.

Conclusion

Based on our findings, FRCs demonstrate superior force distribution compared to conventional resin composite restorations. Consistent with previous studies, Ribbond FRCs exhibited higher fracture resistance than conventional restorations in compromised upper premolars. This study specifically observed that placing Ribbond fibers in the pulpal floor or the proximal wall resulted in improved fracture resistance. The combination of placing the Ribbond fiber in these two locations demonstrated enhanced strength exclusively in endodontically treated teeth. Overall, FRCs present a promising alternative in dentistry due to their improved mechanical properties, aesthetic flexibility, and biocompatibility. Ongoing research and development in this field continue to enhance performance and broaden the applications of FRCs in dental practice.

Ethical Statement

This randomized laboratory study was conducted in accordance with the principles outlined in the Declaration of Helsinki and was approved by the IAU Institutional Review Board (IRB-2023-02-313).

Data Sharing Statement

Available upon request from the corresponding author.

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Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Disclosure

The authors report no conflicts of interest in this work.

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