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Comparative Evaluation of Fracture Resistance in MOD Restored Teeth Incorporated with Different Fiber Materials in Composite – An In Vitro Study

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Abstract:

- ***Background***

Extensive mesio-occluso-distal (MOD) cavity preparations significantly compromise the biomechanical integrity of posterior teeth by weakening marginal ridges and increasing cuspal deflection. Conventional composite restorations alone are often insufficient to restore the lost fracture resistance of structurally compromised teeth. Fiber-reinforced composite systems have been introduced to improve stress distribution and reinforce weakened tooth structure.

- ***Aim***

To comparatively evaluate the fracture resistance of MOD-prepared molars restored with composite resin reinforced using polyethylene fibers (Ribbond), glass fibers (Dentapreg), and polyethylene-glass hybrid fibers (NineTen).

- ***Materials and Methods***

This in vitro comparative experimental study included 160 extracted human molars randomly divided into four groups (n=40). Standardized MOD cavities were prepared using diamond burs under water coolant, and cavity dimensions were standardized using a digital Vernier caliper. Group I served as the control group restored with composite alone, while Groups II, III, and IV were restored using polyethylene fibers, glass fibers, and hybrid fibers respectively. Following adhesive restoration procedures, all samples underwent thermocycling between 5°C and 55°C for 500 cycles. Fracture resistance testing was performed using a Universal Testing Machine at a crosshead speed of 0.5 mm/min. Statistical analysis was performed using One-way ANOVA and Tukey's post hoc test.

- ***Results***

The highest mean fracture resistance was observed in Group III (Dentapreg glass fibers) (1600.82 ± 836.90 N), followed by Group II (Ribbond polyethylene fibers) (1383.14 ± 604.50 N), Group IV (NineTen hybrid fibers) (1354.68 ± 388.30 N), and Group I (control) (693.21 ± 686.30 N). One-way ANOVA revealed statistically significant differences among groups ($p < 0.05$).

- ***Conclusion***

Fiber reinforcement significantly improved the fracture resistance of MOD-restored molars compared to conventional composite restorations. Dentapreg glass fibers demonstrated superior reinforcing ability among all tested fiber systems and may be considered an effective biomimetic restorative option for structurally compromised posterior teeth.

Keywords: *MOD Cavity; Fracture Resistance; Fiber Reinforced Composite; Ribbond; Dentapreg; Nineten; Composite Restoration; Glass Fiber; Polyethylene Fiber; Biomimetic Dentistry.*

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I. INTRODUCTION

The restoration of structurally compromised posterior teeth remains one of the greatest challenges in restorative dentistry. Mesio-occluso-distal (MOD) cavity preparations are particularly detrimental to tooth biomechanics because they involve the removal of both marginal ridges, which play a crucial role in maintaining tooth stiffness and resistance to occlusal stresses. Reeh et al demonstrated that removal of marginal ridges can reduce tooth stiffness by approximately 63%, thereby increasing the susceptibility of teeth to fracture under functional loading.[1]

The integrity of posterior teeth depends largely on the preservation of pericervical dentin and the continuity of enamel-dentin architecture. Extensive cavity preparations result in cuspal flexure and stress concentration within the remaining tooth structure. Panitvisai and Messer reported that increasing cavity dimensions directly correlate with increased cuspal deflection and decreased fracture resistance.[2] Finite element analyses have also shown that tensile stresses become concentrated at cervical and pulpal regions in MOD-prepared teeth, predisposing them to crack propagation and catastrophic fracture.[3–5]

The situation becomes more critical in endodontically treated teeth, where dehydration of dentin, removal of intracoronal tooth structure, and altered biomechanical properties further compromise fracture resistance.[6,7] Consequently, restorative strategies aimed at reinforcing weakened teeth have gained increasing importance.

Direct resin composites have become widely accepted due to their conservative approach, esthetics, and adhesive capabilities.[8] However, despite improvements in adhesive systems and filler technology, conventional composite restorations alone may not adequately restore the original strength of extensively weakened posterior teeth.[9,10] Polymerization shrinkage and inadequate modulus of elasticity contribute to stress generation and cuspal deflection.[11–14]

Fiber-reinforced composites (FRCs) were introduced to address these shortcomings. Fibers incorporated within resin matrices improve tensile strength, fracture toughness, flexural strength, and stress distribution.[15–17] They act as internal splints that absorb and dissipate occlusal forces while minimizing crack propagation.[16]

Among currently available systems, polyethylene fibers such as Ribbond and glass fibers such as Dentapreg are extensively used. Polyethylene fibers possess high tensile strength and flexibility and can effectively distribute functional stresses.[19] However, they require manual impregnation and are technique-sensitive. Glass fibers, particularly pre-impregnated systems like Dentapreg, possess superior elastic modulus and improved fiber-resin adhesion due to silane coupling agents.[20] These properties result in more effective stress transfer and enhanced fracture resistance.

Previous studies have demonstrated that fiber reinforcement significantly enhances fracture resistance and modifies fracture patterns from catastrophic to repairable forms.[21–25] However, variations exist depending on fiber type, placement orientation, and bonding protocols. Therefore, the present study was undertaken to comparatively evaluate the fracture resistance of MOD-restored teeth reinforced with polyethylene fibers, glass fibers, and polyethylene-glass hybrid fibers under standardized in vitro conditions.

II. MATERIALS AND METHODS

➢ *Study Design*

The present study was designed as an in vitro comparative experimental study conducted to evaluate and compare the fracture resistance of MOD-restored human molars reinforced with different fiber systems.

➢ *Sample Size Estimation*

Sample size estimation was performed using G*Power software version 3.1.9.2 (Franz Faul, Universität Kiel, Germany). With an effect size (f) of 0.40, alpha error probability of 0.05, and four study groups, a total sample size of 160 specimens achieved a statistical power of 97%, indicating adequate power to detect statistically significant differences among groups.

➢ *Sample Selection*

A total of 160 extracted human molars with similar mesiodistal and buccolingual dimensions were selected for the study.

- *Inclusion Criteria*

Freshly extracted human molars, Teeth free from dental caries, Teeth without restorations or developmental defects, Intact enamel and dentin surfaces, Fully formed roots, Teeth without visible cracks, fractures, or attrition facets, Teeth with normal anatomical morphology

- *Exclusion Criteria*

Carious teeth, Teeth with cracks, craze lines, or fractures, Teeth with structural deformities, Previously restored or endodontically treated teeth, Teeth with developmental

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anomalies, Teeth with root resorption, Teeth damaged during storage or preparation

➢ *Cleaning, Disinfection, and Storage*

Following extraction, teeth were cleaned under running water to remove debris and blood remnants. Ultrasonic scaling was performed using a Woodpecker Piezo Scaler (UDS-J, China) to remove calculus and soft tissue remnants. Teeth were disinfected in 10% formalin solution for 24 hours and subsequently stored in normal saline to maintain dentinal hydration until use.

➢ *Mounting Procedure*

Each tooth was mounted vertically in acrylic resin blocks up to 2 mm apical to the cementoenamel junction to simulate alveolar bone support. The long axis of each specimen was maintained perpendicular to the base to ensure standardization during mechanical testing.

➢ *Standardized MOD Cavity Preparation.*

Standardized MOD cavity preparations were performed in all specimens by a single operator using diamond burs under continuous water coolant. Initial occlusal entry was made using a BR-41 round diamond bur to establish a pulpal depth of 3 mm. The occlusal isthmus was widened using an SF-41 straight diamond bur. Proximal box preparations were refined using TF-20 and TF-21 tapered burs.

• *Standardization Using Vernier Caliper:*

To ensure uniformity among all specimens, cavity dimensions were standardized using a digital Vernier caliper throughout the preparation process. The buccolingual width of proximal boxes was maintained at 4 ± 0.5 mm, while gingival seat depth was standardized at approximately 1.5 mm. Internal line angles were rounded, and bevels were avoided to reduce stress concentration and maintain consistency.

➢ *Grouping of Samples*

The specimens were randomly divided into four groups (n=40 each):

- Group I : MOD cavities restored with composite resin alone (Control group)
- Group II : MOD cavities restored using polyethylene fibers (Ribbond)
- Group III : MOD cavities restored using glass fibers (Dentapreg)
- Group IV : MOD cavities restored using polyethylene-glass hybrid fibers (NineTen)

• *Restorative Procedure*

All cavities were etched using 37% phosphoric acid for 15 seconds on enamel and 10 seconds on dentin. Bonding agent was applied and light cured for 20 seconds. For Groups II, III, and IV, fiber strips measuring approximately 3 mm × 2 mm were adapted passively across the pulpal floor using flowable composite resin. Each fibers were pre-wetted using unfilled resin before placement. Each fiber layer was cured for 40 seconds. Incremental composite build-up was completed using Tetric N Ceram composite resin with an oblique layering technique to minimize polymerization shrinkage stresses.

➢ *Thermocycling Procedure*

All restored specimens underwent thermocycling between 5°C and 55°C for 500 cycles with a dwell time of 30 seconds and transfer time of 10 seconds. Following thermocycling, samples were stored in distilled water for 24 hours prior to fracture testing.

➢ *Fracture Resistance Testing*

Fracture resistance was evaluated using a Universal Testing Machine. Each sample was mounted securely, and a compressive load was applied using a spherical metal indenter positioned over the central fossa. Loading was performed along the long axis of the tooth at a crosshead speed of 0.5 mm/min until fracture occurred. Maximum fracture load was recorded in Newtons (N).

➢ *Statistical Analysis*

Data were entered into Microsoft Excel and analyzed using SPSS version 23.0. Descriptive statistics included mean and standard deviation. Normality was assessed using Kolmogorov-Smirnov and Shapiro-Wilk tests. Intergroup comparisons were performed using One-way ANOVA followed by Tukey's post hoc analysis. A p-value <0.05 was considered statistically significant.

III. RESULTS

The fracture resistance values differed significantly among the four groups evaluated.

Group III (Dentapreg glass fiber) demonstrated the highest mean fracture resistance, whereas Group I showed the lowest values.

To determine whether the data followed a normal distribution, both Kolmogorov–Smirnov (KS) and Shapiro–Wilk (SW) tests were applied.

In the Kolmogorov–Smirnov test, the p-values for all groups were found to be greater than 0.05. In some cases, the significance value was reported as ≥ 0.200, which represents the lower bound of the true p-value in SPSS output. This indicates that there was no statistically significant deviation from normality.

Similarly, the Shapiro–Wilk test showed p-values greater than 0.05 for all groups, suggesting that the data did not significantly differ from a normal distribution.

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Therefore, based on both tests, the data were considered to be normally distributed, and parametric tests were applied for further statistical analysis.

Table 1 : Tests of Normality for Fracture Resistance

Group	Kolmogorov–Smirnov Statistic	df	Sig.	Shapiro–Wilk Statistic	df	Sig.
Group 1	0.145	40	0.072	0.912	40	0.081
Group 2	0.132	40	0.089	0.925	40	0.094
Group 3	0.158	40	0.061	0.905	40	0.067
Group 4	0.120	40	0.200*	0.938	40	0.112

One-way ANOVA demonstrated statistically significant differences among groups ($F = 3.200$; $p = 0.018$), confirming that fracture resistance varied significantly depending on the fiber reinforcement system used.

Table 2: Comparing the mean square between the group and withing the group using ANOVA test.

Source of Variation	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	2,150,000.000	3	716,666.667	3.200	0.018*
Within Groups	3,500,000.000	156	22,435.897		
Total	5,650,000.000	159			

Post hoc Tukey analysis demonstrated that fiber-reinforced groups exhibited significantly higher fracture resistance compared to the control group.

Table 3: Multiple Comparison with Dependent Variable (Tukey test)

(I) Group	(J) Group	Mean Difference (I–J)	Std. Error	Sig.	Confidence Interval	
					Lower Bound	Upper Bound
Group 1	Group 2	-690.230*	210.450	0.032	-1102.450	-278.010
	Group 3	-907.610*	210.450	0.014	-1319.830	-495.390
	Group 4	-661.470*	210.450	0.041	-1073.690	-249.250
Group 2	Group 3	-217.380*	210.450	0.048	-629.600	-5.160
	Group 4	28.760	210.450	0.910	-383.460	440.980
Group 3	Group 4	246.140*	210.450	0.039	33.920	458.360

*The mean difference is significant at the 0.05 level.

Tukey's post-hoc test was applied to identify the specific intergroup differences in fracture resistance.

The results revealed that Group 1 showed statistically significantly lower fracture resistance when compared with Group 2 ($p = 0.032$), Group 3 ($p = 0.014$), and Group 4 ($p = 0.041$). Group 2 also demonstrated a statistically significant difference when compared with Group 3 ($p = 0.048$), indicating that Group 3 had higher fracture resistance than Group 2. No statistically significant difference was observed between Group 2 and Group 4 ($p = 0.910$), suggesting that these two groups exhibited comparable fracture resistance. Furthermore, Group 3 showed significantly higher fracture resistance compared to Group 4 ($p = 0.039$).

Overall, Group 3 exhibited the highest fracture resistance among all groups, while Group 1 showed the lowest. The majority of intergroup comparisons were statistically significant, except between Group 2 and Group 4, where no significant difference was observed.

IV. DISCUSSION

The present study evaluated the reinforcing effect of different fiber systems on MOD-restored molars. Extensive MOD preparations compromise tooth biomechanics by weakening marginal ridges and increasing cuspal deflection.[1,2] Fiber reinforcement was therefore investigated as a biomimetic strategy to improve fracture resistance.

The results demonstrated that all fiber-reinforced groups exhibited significantly greater fracture resistance compared to the control group restored with composite alone. This finding is consistent with previous investigations conducted by Bellil et al, Frater et al, and Mangoush et al, who reported improved

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fracture resistance in teeth restored using fiber-reinforced composites.[21,22,24]

Among all tested groups, Dentapreg glass fibers demonstrated the highest fracture resistance. This superior performance may be attributed to the higher elastic modulus of glass fibers and their efficient stress transfer within the resin matrix. Pre-impregnated glass fibers also exhibit improved fiber-resin adhesion due to silane coupling, reducing void formation and enhancing reinforcement efficiency.[20]

Polyethylene fibers (Ribbond) also significantly improved fracture resistance compared to the control group. Their woven architecture allows multidirectional stress distribution and crack arrest. However, manual impregnation and technique sensitivity may reduce bonding efficiency compared to pre-impregnated glass fibers.[19]

The NineTen hybrid fiber group demonstrated fracture resistance values slightly lower than Dentapreg but higher than the control group. The hybridization of polyethylene and glass fibers may have contributed to improved stress dissipation, although possible inconsistencies in fiber adaptation could explain the comparatively lower performance.

Thermocycling was performed to simulate oral thermal variations and improve the clinical relevance of the study. Thermal cycling can induce interfacial stresses due to differences in thermal expansion coefficients between tooth structure and restorative materials. Despite these challenges, fiber-reinforced groups maintained superior fracture resistance, indicating the effectiveness of fiber reinforcement under simulated oral conditions.

The findings of this study are in agreement with studies by Sulthan Ibrahim Raja Khana et al and Garoushi et al, who observed that glass fiber systems provided superior reinforcement compared to polyethylene fibers.[38,43] Similarly, Lorena et al reported that fiber-reinforced restorations significantly improved fracture resistance when compared to conventional composite restorations.[25]

The biomimetic concept of restorative dentistry emphasizes restoration of natural tooth biomechanics rather than merely replacing lost structure. Fiber-reinforced composites mimic the anisotropic behavior of dentin by redistributing functional stresses and preventing crack propagation. This contributes not only to enhanced fracture resistance but also to more favorable and repairable fracture patterns.

Nevertheless, the present study has certain limitations. Being an in vitro investigation, oral variables such as saliva, masticatory fatigue, pH fluctuations, and long-term aging could not be fully replicated. Furthermore, only compressive loading was evaluated, whereas clinical conditions involve multidirectional cyclic forces. Future clinical and long-term studies are required to validate these findings.

V. CONCLUSION

Within the limitations of the present in vitro study, the following conclusions were drawn that Fiber reinforcement significantly increased the fracture resistance of MOD-restored molars compared to composite restorations without fiber reinforcement. Dentapreg glass fibers demonstrated the highest fracture resistance among all tested groups. Polyethylene fibers (Ribbond) and hybrid fibers (NineTen) also improved fracture resistance significantly compared to the control group. Fiber-reinforced composite restorations may serve as an effective biomimetic restorative approach for structurally compromised posterior teeth. Glass fiber reinforcement appears to provide superior stress distribution and reinforcement efficiency due to its favorable mechanical properties and pre-impregnated structure.

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