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Comparative Evaluation Of Fracture Resistance In Endodontically Treated Molars With Mod Preparation Using Three Different Post Techniques: An In Vitro Study

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Abstract:
Objective(s): *This study aims to evaluate the fracture resistance in endodontically treated molars with an MOD preparation using three different post techniques.*
Materials and Methods*: Eighty extracted mandibular molars were selected and divided into 4 groups of 20 teeth each. Group 1(**Composite**): MOD cavity restored with resin composite restoration. Group 2 (**Vertical Post**): MOD cavity restored with vertical fiber post and resin composite restoration. Group 3(**Horizontal Post**): MOD cavity restored with horizontal glass fiber post and resin composite restoration. Group 4 (**Ribbond**): MOD cavity restored with ribbond and resin composite restoration. Fracture resistance was evaluated using the Universal testing machine.*
Results: *Group 4 showed significantly higher (p value <0.05) with a greater fracture resistance followed by Group 3. No significant differences were observed.*
Conclusion: *Despite the limitations of the present study, it was concluded that ribbond fiber posts and horizontal fiber posts placed within the resin composite restoration showed improved fracture resistance.*
Key Word*: Fracture resistance, Horizontal post, Ribbond, reinforcement*

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I. Introduction

Endodontic treatment involves preparing the root canal mechanically and chemically to seal it effectively with biocompatible materials. However, the structural integrity of root canal-treated teeth can be compromised by various factors like caries, fractures, and previous restorations[1]. For instance, the loss of marginal ridges significantly reduces tooth rigidity, with MOD cavities causing up to a 63% decrease in strength[2].

Proper restoration post-endodontic treatment is crucial, with options including fiber posts and bonded restorations to minimize microleakage and enhance durability[3]. Incorporation of fiber posts within direct composite restorations has been explored to enhance fracture resistance. Within the radicular dentin, fiber posts help distribute stresses and loads applied to the composite restoration[4], reinforcing the structure even when sufficient residual coronal dentin is present

To enhance the strength of an endodontically treated tooth, horizontal fiberglass posts can be placed from the buccal to the lingual wall. A recent in vitro study by Scotti et al [4] . and Salameh et al[5] have shown that composite restorations reinforced with glass fibers offer significantly greater fracture resistance than conventional direct composite restorations.

The development of fiber-reinforced composite (FRC) technology has marked a significant milestone in the evolution of aesthetic dentistry. The matrix of FRCs consists of a light-cured thermoset BisGMA, which enables strong bonding due to its compatibility with commonly used dental adhesives. The fibers are precisely oriented, ensuring excellent coupling, followed by an initial polymerization stage. This initial polymerization keeps the matrix flexible and adaptable, allowing it to be easily contoured to the teeth and shaped before undergoing final polymerization.[6]. After shaping, a final curing process stabilizes the structure and enhances its mechanical properties, ensuring optimal strength and durability.[7]

II. Material And Methods

This in-vitro study was carried out in the Department of Conservative Dentistry and Endodontics, Jaipur Dental College and Hospital, Jaipur collaboration with I.T.S Engineering College, Greater Noida, Delhi.

Study Design: In-vitro study

Sample size: 80.

Sample size calculation: A power analysis was established by G*power, version 3.1.9.2 (Franz Faul universitat, Kiel, Germany). A sample size of 80 subjects (20 in each group) would yield 84% power to detect significant differences, with effect size of 0.40 and significance level at 0.05.

Inclusion criteria:
The selected teeth should be intact, extracted for periodontal reason and non-carious and fully mature apices.

Exclusion criteria:
The selected teeth should not have root caries or restorations, open apices, calcifications, fractures, or craze lines.

Procedure methodology

Eighty recently extracted caries-free mandibular molars, which were removed for orthodontic reasons, were selected and then stored in 5% formol/saline solution at room temperature The teeth were cleaned using a hand scaler and maintained at room temperature throughout the study.

Endodontic access cavities were prepared as small as possible by using a water-cooled air turbine handpiece and round burs. The working length during root canal preparation was established 1 mm short of the apical foramen. The working length was determined by #15k file and cleaning and shaping of the root canals were completed with HyFlex CM upto (#25/06) at a speed of 300 rpm using an X Smart endomotor (Dentsply Maillefer, Switzerland). Endomotor was calliberated according to the manufacturer's instructions. Sodium hypochlorite solution (3%) was used to irrigate the canals throughout instrumentation.

The root canals were dried using paper points (Dentsply-Maillefer), followed by the introduction of size 25 gutta-percha cones with taper 6% (Dentsply-Maillefer) as the master cone; the apical 5 mm of which were coated with sealer. The teeth were then stored in distilled water at room temperature for at least 72 hours.

After that, the teeth roots were embedded into an autopolymerizing resin extending up to 2 mm apical to the cementoenamel junction (CEJ). The MOD cavity preparation was performed to all teeth. MOD cavities had a width of one third of intercuspal distance for occlusal portion preparation, and one third of total buccopalatal dimension was used to determine the width of proximal boxes. A depth of 1 mm above CEJ was determined for cavity preparation. All internal line angles were smoothed and rounded upon completion of the preparation. The walls of MOD cavities were etched by using 37% phosphoric acid for 15 seconds, rinsed with water spray, and air dried. Then MOD cavities were bonded by using dentin bonding agent according to the manufacturer's instructions. Flowable composite. Then resin composite (FiltekZ250 XT; 3M/Espe) was applied and polymerized following the incremental technique procedure. Teeth were assigned to 4 groups of 20 specimens:

Group 1(Composite): MOD cavity restored with resin composite restoration

Group 2 (Vertical Post): Post spaces were prepared with peso reamer size #2 (head diameter 0.9 mm) to a depth 5 mm short of working length. The post were cleaned with an alcohol wipe and surface treated with silane. Glass fiber post (Tenax fiber post, Coltene) was luted with resin cement into the post spaces. The cavity was restored using resin composite.

Group 3 (Horizontal Post): Holes prepared at the centre of both buccal and palatal surfaces using round bur to receive 1.1 mm diameter post (Tenax fiber post, Coltene). Posts were luted using dual cure resin cement (NexCore). Excess post was trimmed using bur. Cavity restored with bulk fill resin composite (Filtek 350 XT).

Group 4 (Ribbond): The cavity surface was coated with flowable composite after bonding. Ribbond fiber (3mm long and 2mm width) was first saturated with unfilled bonding agent and placed in the base of the cavity. Light curing was done at 800mW/cm2 for 40 seconds. Incremental build up was done with composite (Filtek Z250XT , 3M ESPE) . The layers were placed at thickness of 1.5 mm and each layer was cured for 40 second.

Loading of the specimen:

All samples were quasi-statically loaded with a crosshead speed of 0.5 mm vertical to the long axis of the tooth in a universal testing machine(Instron Corp, Canton, MA) set and the load was applied on the centre of the restoration on the occlusal aspect until they were fractured. The maximum load at which each specimen fractured was documented. The results were tabulated after recording the maximum cargo at fracture for each sample.

Statistical analysis

Data normality was assessed using the Shapiro–Wilk test, which confirmed that the data followed a normal distribution. One-way ANOVA was used to compare fracture resistance means among the 4 groups,followed by multiple comparisons by using Tukey honestly significant difference (HSD) test (a = .05). The confidence level was 95%. Statistical analysis was performed with SPSS statistical software 23.0 Version (SPSS 23.0 for Windows;SPSS, Inc, Chicago, IL).

III. Result

The mean values of the fracture resistance and standard deviations are displayed in (Table 1) and in (Graph 1). They ranged from 2044.496 N to 2442.495 N. (Table 1) showed that the mean score 2442.495 N for fracture resistance was higher in Ribbond (Group IV) whereas lower for 2044.496 N in conventional vertical post (Group II). The data is normally distributed; hence, parametric tests have been considered for further analysis according to (Table 2).

(Table 3) showed that the mean square between groups (619,350.947) is much larger than the mean square within groups (7,014.947), suggesting that the group means differ significantly. This supports **rejecting the null hypothesis** — there is a **statistically significant difference** among the group means.

Table 1: Comparison of fracture resistance of different groups

Group	N	Mean	Std. Deviation	Median
Composite	20	2114.371	99.989	2108.62
Vertical Post	20	2044.496	48.730	2025.12
Horizontal Post	20	2141.740	59.613	2115.10
Ribbond	20	2442.495	110.298	2426.05

Graph 1: Comparison of fracture resistance of different groups

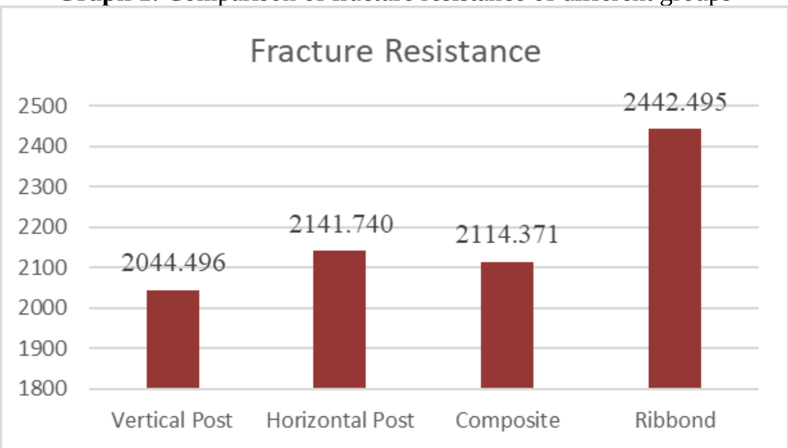

Table 2: Tests of normality

Group		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Fracture Resistance	Vertical Post	0.192	20	0.051	0.877	20	0.015
	Horizontal Post	0.208	20	0.024	0.877	20	0.016
	Composite	0.099	20	0.200*	0.971	20	0.766
	Ribbond	0.152	20	0.200*	0.939	20	0.232

Table 3: Comparing the mean square between the group and withing the group using ANOVA test

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1858052.842	3	619350.947	88.290	0.000
Within Groups	533135.975	76	7014.947		
Total	2391188.817	79			

Table 4: Multiple comparison with dependent variable (Tukey test)

(I) Group		Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Vertical Post	Horizontal Post	-97.24350*	26.486	0.002	-166.816	-27.671
	Composite	-69.87450*	26.486	0.049	-139.447	-0.302
	Ribbond	-397.99900*	26.486	0.000	-467.572	-328.426
Horizontal Post	Vertical Post	97.24350*	26.486	0.002	27.671	166.816
	Composite	27.36900	26.486	0.730	-42.204	96.942
	Ribbond	-300.75550*	26.486	0.000	-370.328	-231.183
Composite	Vertical Post	69.87450*	26.486	0.049	0.302	139.447
	Horizontal Post	-27.36900	26.486	0.730	-96.942	42.204
	Ribbond	-328.12450*	26.486	0.000	-397.697	-258.552
Ribbond	Vertical Post	397.99900*	26.486	0.000	328.426	467.572
	Horizontal Post	300.75550*	26.486	0.000	231.183	370.328
	Composite	328.12450*	26.486	0.000	258.552	397.697

IV. Discussion

Restoring endodontically treated teeth with MOD preparations presents a biomechanical challenge due to the substantial loss of tooth structure. The removal of both marginal ridges in MOD cavities can reduce the tooth's strength by as much as 63%. Mondelli et al., and Reeh et al.[8,9] emphasized that the greatest loss in tooth strength stems not from endodontic instrumentation, but from cavity and access preparations. Fiber posts, especially when used horizontally, act as internal splints, limiting cuspal deflection and redistributing occlusal stresses (Karzoun et al.) [10]. Studies have shown that a single horizontal fiber post significantly increases fracture resistance compared to composite restoration alone (Bromberg et al.) [11]. This reinforcement strategy mimics the natural bracing provided by marginal ridges.

Vertical posts, though effective for retention, have limited capability in counteracting lateral forces. Grandini et al.[12]noted that while vertical posts support coronal restorations, they may weaken the root structure due to excessive dentin removal. Moreover, rigid vertical posts can lead to root fractures due to unfavorable stress distribution (Mergulhao et al.)[13]

Ribbond, made from ultra-high molecular weight polyethylene fibers, provides enhanced reinforcement by creating a multidirectional, stress-distributing matrix. Belli et al.[14]and Rudo & Karbhari [15] demonstrated that Ribbond significantly improves fracture resistance and promotes favorable fracture patterns. Its design minimizes crack propagation and supports a monoblock effect with composite resins. Comparative studies (Gulve & Gulve, and by Saxena et al., [16] further confirm Ribbond's ability to shift failure modes from non-restorable to restorable fractures, making it a clinically valuable option. Its minimally invasive approach also aligns with the principles of conservative dentistry by preserving radicular dentin (Karbhari & Strassler)[17]

Overall, this study reinforces existing literature that supports the use of fiber reinforcement—especially Ribbond and horizontal posts—as effective, conservative techniques for improving the biomechanical performance of endodontically treated molars.

Limitations of the study:

While the study provides valuable insights, certain limitations should be considered in evaluating its conclusions Firstly, being an in vitro study, it does not fully replicate the complex oral environment encountered clinically. The absence of periodontal ligament simulation may have influenced stress distribution and fracture outcomes, thereby limiting the applicability of the findings to real-world clinical situations. Additionally, the use of a static loading protocol fails to mimic the dynamic forces of mastication, and the lack of long-term aging or thermocycling omits the impact of thermal and mechanical fatigue over time. The limited sample size may also reduce the statistical power and generalizability of the findings. Variability in tooth anatomy among specimens could have influenced outcomes, and the study did not assess the repairability of failure modes, which is clinically significant. Moreover, the findings are specific to the materials tested and may not apply to other systems. Lastly, procedural steps may be subject to operator dependency, potentially introducing variability in results

V. Conclusion

This in vitro study was conducted to comparatively evaluate the fracture resistance of endodontically treated mandibular molars with MOD cavities restored using three different post techniques: Ribbond fiber reinforcement, horizontal post, and vertical post systems. These systems not only improve fracture resistance but also tend to preserve the remaining tooth structure in the event of failure, which is a critical consideration for long-term prognosis and retreatment options. Ribbond fiber reinforcement demonstrated the highest fracture resistance, attributed to its stress-distributing ability and strong adhesion to dentin. The horizontal post technique showed comparable performance, offering better stress distribution and more restorable failure modes than the vertical post technique, which exhibited lower resistance and a higher rate of non-restorable fractures. Overall, fiber-reinforced systems like Ribbond and horizontal posts proved biomechanically superior for restoring endodontically treated molars with MOD cavities. The properties and orientation of post materials significantly influenced fracture resistance and failure patterns. These findings support the use of conservative, minimally invasive techniques that align with the tooth's natural biomechanics and simplify future retreatment.

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