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Fracture Resistance of Endodontically Treated Premolars Reinforced with Two Different Fibers -A Comparative In Vitro Evaluation

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Abstract:
Background: *Endodontically treated teeth are structurally weakened due to loss of tooth structure during endodontic procedures. Premolars are highly susceptible to fracture because of thin cuspal walls and reduced cervical dimensions, leading to cuspal deflection under occlusal forces. Composite resin restorations provide bonding but may not fully restore fracture resistance due to polymerization shrinkage and limited toughness. Fiber reinforced composites improve stress distribution and prevent crack propagation. This study aimed to evaluate and compare fracture resistance of endodontically treated premolars reinforced with polyethylene fibers and ultrathin glass fiber strips*.
Materials and Methods: *Sixty extracted mandibular first premolars were randomly divided into three groups (n = 20). Group I received composite resin, Group II polyethylene fiber reinforced composite, and Group III ultrathin glass fiber strip reinforced composite. Standardized root canal treatment and cavity preparation were performed. Fracture resistance was tested using a universal testing machine, and fracture load was recorded in Newtons. Data were analysed using one-way ANOVA and Tukey's post hoc test*.
Results: *Mean fracture resistance values were 855.15 ± 10.15 N (Group I), 899.90 ±7.25 N (Group II), and 916.75 ± 6.18 N (Group III). A statistically significant difference was observed ($p < 0.001$). Group III showed highest fracture resistance followed by Group II and Group I.*
Conclusion: *Fiber reinforcement significantly improved fracture resistance compared to composite alone. Ultrathin glass fiber strips demonstrated superior performance over polyethylene fibers. This indicates that fiber reinforcement, especially ultrathin glass fiber strips, is an effective conservative approach to enhance fracture resistance of endodontically treated premolars.*
Key Word: *Fracture resistance, Endodontically treated teeth, Polyethylene fiber, Glass fiber strip, Composite resin.*

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I.Introduction

The long-term success of endodontic therapy is not limited to the fact that the root canal system is well cleaned, shaped, and obturated, but also that the quality of the definitive coronal restoration is satisfactory. A well-sealed coronal restoration has an important role in the prevention of microbial leakage and reinfection into the root canal system which is essential for periapical healing and long term functional stabilization of the tooth.[1]

Endodontically treated teeth typically have a significant amount of structural loss from the removal of caries and the preparation of an access cavity and biomechanical preparation of the root canal system. Loss of marginal ridges and weakening of cuspal structures substantially decreases stiffness of teeth and predisposes to chemical fracture under mechanical functional loading.[2,3] Compared with vital teeth, endodontically treated teeth exhibit lower resistance to fracture as a result of loss of structural integrity rather than alteration in dentin properties.

Of the posterior teeth, the premolars are a special restorative problem. The anatomical features of the premolars, such as thin cuspal inclines, reduced cervical dimensions and relatively short roots, predispose them to cuspal flexure and fracture during function.[4] The reduced cervical diameter together with an unfavorable crown root ratio even further contributes to stress concentration within the tooth structure thus predisposing to catastrophic fracture of premolars after endodontic treatment.[5]

Premolars experience a complex pattern of occlusal forces, vertical compressive forces, lateral shearing forces, and oblique forces during the act of mastication and parafunctional activity. Because of the great cusp inclines and intercuspal anatomy such forces result in tensile stresses at the cervical region and tooth cusp deflection during functional loading.[4,5] Among these stresses, buccolingual splitting forces are especially important, since they have the tendency of separating weakened cusps, triggering the propagation of the crack and ultimately causing cuspal or vertical fractures.[6] The elimination of marginal ridges used for endodontic access preparation also leads to an increase in cuspal flexure and an enhancement of these splitting forces, which result in a significant reduction of fracture resistance.[6,7]

Traditionally, endodontically treated premolars have been recommended to be reinforced with full coverage crowns to improve fracture resistance.[6] Full coverage restorations offer protection of the cusps and aids in distributing the occlusal stresses more evenly. However, the crown preparation requires further removal of sound tooth structure which may possibly further reduce the remaining tooth structure and goes against the practice of minimally invasive dentistry.

Various restorative materials and techniques have been proposed that help for improving fracture resistance of endodontically treated premolars. These included cuspal coverage restorations, bonded composite restorations, indirect restorations, post and core systems, and fiber reinforced composite restorations for better stress distribution and reinforcement of the weakened cusps.[7,8] Adhesively bonded restorations are of special value as they give a monoblock effect and minimise cuspal deflection by internal splinting of the remaining tooth structure.[7]

With the coming of adhesive dentistry, there has been a general shift in the direction of minimally invasive and biomimetic restorative practices. Conservative post endodontic restorations using adhesive composite resins intention is to preserve the remaining tooth

structure while restoring a functional strength.[8] Adhesive composite restorations offer micromechanical bonding and internal splinting of cusps thus enhancing biomechanical behaviour of weakened teeth.

However, that is not always the case with composite resin, which on its own may not be sufficient to build the structural resilience of structurally compromised premolars. Polymerization shrinkage stresses, internal stress development and limited fracture toughness can lead to predisposing cuspal deflection and fracture of restored teeth8. Previous studies have shown that composite restorations without other means of reinforcement may not restore fracture resistance to levels that are similar to that of intact teeth.[9]

To overcome these limitations, fiber reinforced composite techniques have been introduced as an alternative technique for strengthening endodontically treated teeth. Fibers that are embedded into composite restorations serve as crack arresters, and enhance stress distribution through the tooth-restoration complex.[9]

Among the available reinforcement systems, polyethylene fibers have received wide investigation for post-endodontic restorations. Polyethylene ribbon fibers incorporated in a buccolingual orientation of composite restorations have been shown to have a significant influence in improving fracture resistance by splinting the weakened cusps and interfering with crack propagation.[10]

Glass fiber reinforcement has also been studied as an alternative reinforcement material. Composite impregnated glass fibers have shown benefit in their mechanical properties and enhanced resistance to fracture when used in teeth that have been endodontically treated.[11] However, some studies have reported on the fact that glass fibre bundles may fail to give significant reinforcement compared to composite restorations alone.[12]

Recently, ultrathin strips of glass fibers like DentaPreg UFM has been introduced for use of intracoronal reinforcement. These fibers have high adaptability and positive mechanical properties for the ideal distribution of the stress in the tooth-restoration complex. The ultrathin structure allows close adaptation to the cavity walls with a minimum of tooth structure being removed: thus they may be used for minimally invasive restorations.[13]

Several studies have compared different fiber reinforcement systems and have reported variations in reinforcing potential based upon type of fiber and placement technique .[14] Clinical studies have also shown good short-term performance of fiber reinforced composite restorations in endodontically treated teeth.[15]

In spite of the growing use of fiber-reinforced composite restorations, scarce data are really available about the reinforcing potential of ultrathin glass fiber strips compared with polyethylene fibers in endodontically treated premolars. Sparse literature is available evaluating the fracture resistance of the premolars reinforced with ultrathin glass fiber strips placed in a buccolingual orientation.[16,17]

Therefore, present in vitro study aimed to evaluate and compare the fracture resistance of the endodontically treated premolars restored with the composite resin reinforced with polyethylene fibres and ultrathin glass fibre strips.

II.Material And Methods

Study Design: The present investigation was conducted as an experimental, in-vitro, comparative, and quantitative study.

Study Location: Department of conservative dentistry and endodontics, The Oxford Dental College, Bengaluru, Karnataka, India.

Study Duration: January 2026 to March 2026.

Sample size: 64 human permanent maxillary premolars.

Sample size calculation: Using SPSS software in accordance with previous studies.

Subjects & selection method: 60 Human mandibular premolars

Inclusion criteria:
- Teeth extracted for periodontal or orthodontic reasons were included.
- Teeth with completely formed apices.

Exclusion criteria:
- Teeth with caries.
- Teeth with abrasions, erosions.
- Teeth with cracks, fractures.
- Teeth with previous root canal treated teeth.
- Teeth with resoprtion.

Procedure methodology:
A total of 60 intact mandibular first premolars, freshly extracted for orthodontic or periodontal reasons will be collected and stored in 0.1% thymol solution. Before starting the procedure, all teeth will be radiographed to rule out any fractures and cracks.

Root canal procedure:
The Access cavity will be prepared with no.4 round carbide bur. The cavity outline will be maintained 2mm bucco lingually and 1mm mesio distally to standardize all samples. De-roofing of pulp chamber will be done followed by buccolingual ovoid outline cavity. The length of the root canal will be obtained by inserting a size 10-k file (Dentsply Maillefer) into the canal until its tip is visible at the apical foramen. The working length will be determined by subtracting 1mm from this length. The root canals will be prepared using ProTaper NiTi rotary instruments (Dentsply Maillefer) up to master apical file F3. For canal irrigation, 20ml of 2.5% sodium hypochlorite (NaOCl) via 30G needle will be used. Final irrigation will be done by 2ml of a 17% ethylenediaminetetraacetic acid (EDTA) solution for 2 mins followed by 2ml of saline for 30sec and the canals will be dried with paper points.

Root canal obturation:
The canal will be obturated with gutta-percha points and sealed with bioceramic sealer (CeraSeal B, MAARC Dental Company, India) using single cone technique. The access cavity will be restored with (FILTEK Z 250) composite. Root of each tooth will be embedded in mass of acrylic resin so as to leave only the crown of the tooth exposed. This will be done using cylindrical two halves split Teflon Mold (2cm internal diameter and 1cm height).
All the samples will be stored at 37^0C in 100% humidity for 24 hrs in artificial saliva.
2mm wide and 1mm deep groove will be prepared from the buccal cusp tip to the lingual cusp tip using an aerotor handpiece with a long straight fissure diamond point. The diamond abrasives will be changed after every 10 cavity preparations. The dimensions of the cavity will be verified using a periodontal probe to standardize remaining tooth structure.
Subsequently the teeth will be divided into 3 groups with 20 teeth each.

- Group A - Control group (n= 20)
- Group B - Polyethylene fiber group (n= 20)
- Group C - Ultra thin glass fiber strip group (n= 20)

Group A - In the control group
Access cavity restored with composites.

Group B - In the polyethylene fibre group,
Tooth will be etched and bonded using waldent etchant and 3M ESPE bonding agent. Polyethylene fibre strip to cover the groove prepared will be adapted to the floor of the groove using a flowable composite (Filtek Flow; 3M ESPE), and the combination will be cured for 40 s using the pulse program. The exposed fibre surface will be filled with composite resin.

Group C - In the Ultrathin glass fiber strip group,
Tooth will be etched and bonded using waldent etchant and 3M ESPE bonding agent. Ultrathin glass fibre strip to cover the groove prepared will be adapted to the floor of the groove using a flowable composite (Filtek Flow; 3M ESPE), and the combination will be cured for 40 s using the pulse program. The exposed fibre surface will be filled with composite resin.

Testing of Samples:

The fracture resistance of the teeth will be measured using a universal testing machine under a compressive force at strain rate of 0.5mm per minute. A 5 mm diameter round stainless-steel ball will be positioned parallel to the long axis of the teeth and centered over the teeth until the bar just contacted the occlusal surface of the restoration and the buccal and the lingual cusps. The force needed to fracture each tooth will be recorded in Newtons. The samples will be submitted to statistical analysis.

Statistical analysis

One-way ANOVA test followed by Tukey's post hoc test / Kruskal Wallis Test followed by Dunn's post hoc test [Based on Data Distribution] will be used to compare the Fracture Resistance between 3 groups. The level of significance [P-Value] will be set at P<0.05

III.Result

One-way ANOVA analysis showed that there were statistically significant differences among the groups. The mean and standard deviations for the fracture strength of the test groups are shown in Table 1.

Comparison of mean Fracture Resistance (in N) b/w 3 groups using One-way ANOVA Test						
Groups	N	Mean	SD	Min	Max	p-value
Group 1	20	855.15	10.15	840.0	870.0	<0.001*
Group 2	20	899.90	7.25	890.0	914.0	
Group 3	20	916.75	6.18	904.0	927.0	

The test result showed the mean Fracture Resistance for Group 1 was 855.15 ± 10.15 N, Group 2 was 899.90 ± 7.25 N and Group 3 was 916.75 ± 6.18 N. The difference in the mean fracture Resistance between 3 groups was statistically significant at p<0.001. [Refer Fig no. 1]

Multiple comparison of mean difference in the Fracture Resistance b/w groups using Tukey's Post hoc Test					
(I) Groups	(J) Groups	Mean Diff. (I-J)	95% CI for the Diff.		p-value
			Lower	Upper	
Group 1	Group 2	-44.75	-50.86	-38.64	<0.001*
	Group 3	-61.60	-67.71	-55.49	<0.001*
Group 2	Group 3	-16.85	-22.96	-10.74	<0.001*

* - Statistically Significant

Multiple comparison of mean differences between groups showed that Group 3 showed significantly highest mean fracture Resistance as compared to Group 1 (with a mean
difference of- 44.75 N, with 95% CI of -50.86 to -38.64) and Group 2 (with a mean difference of -61.60 N, with 95% CI of -67.71 to -55.49), and the mean differences were statistically significant at p<0.001 respectively. This was then followed by Group 2 which showed significantly higher mean fracture resistance as compared to Group 1 (with a mean difference of -16.85 N, with 95% CI of 10.74 to 22.96) and the mean difference was statistically significant at p<0.001. This infers that the Group 3 demonstrated significantly highest mean fracture Resistance, followed by Group 2 and the least was observed in Group 1. [Refer Fig no. 2-5]

Fig no. 1 Mean Fracture Resistance (in N) b/w 3 groups

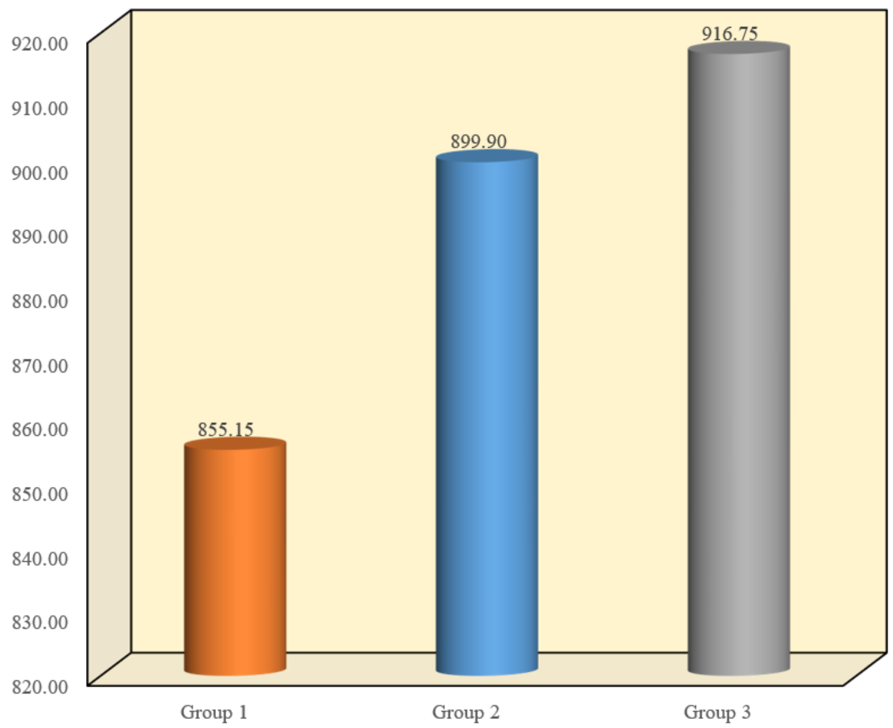


Fig no. 2 Mean Fracture Resistance (in N) b/w Group 1 & Group 2

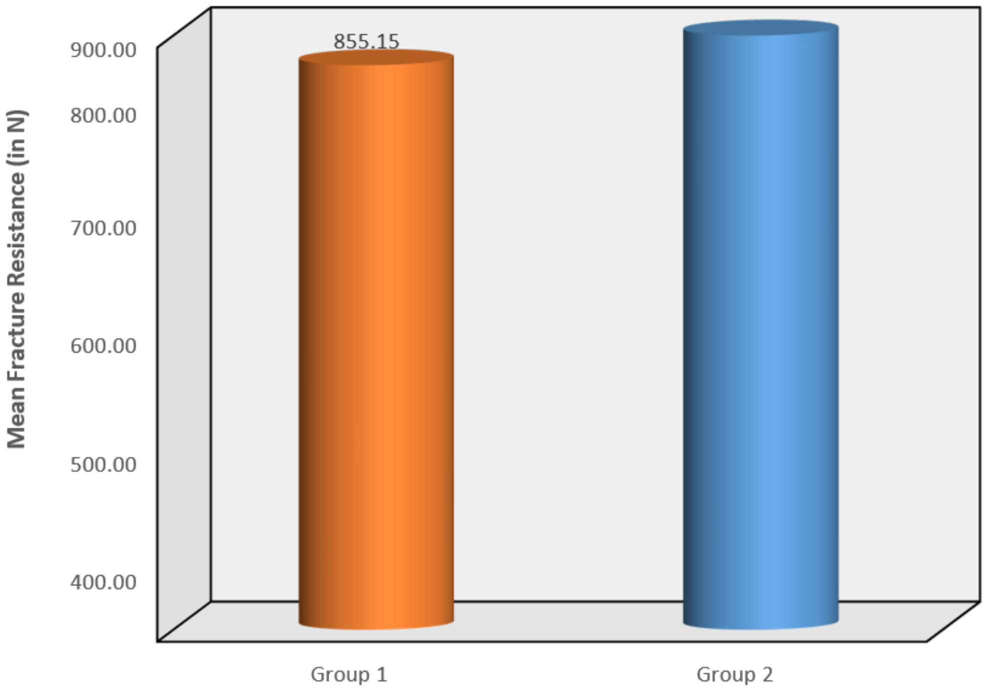


Fig no. 3 Mean Fracture Resistance (in N) b/w Group 1 &

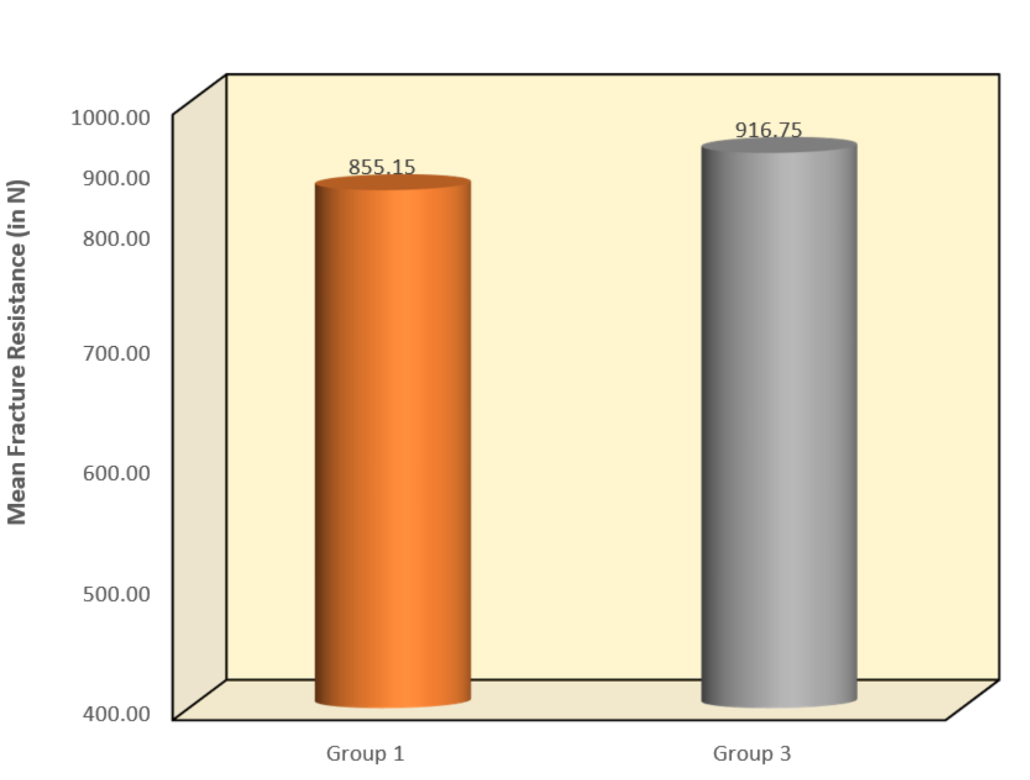


Fig no. 4 Mean Fracture Resistance (in N) b/w Group 2 &

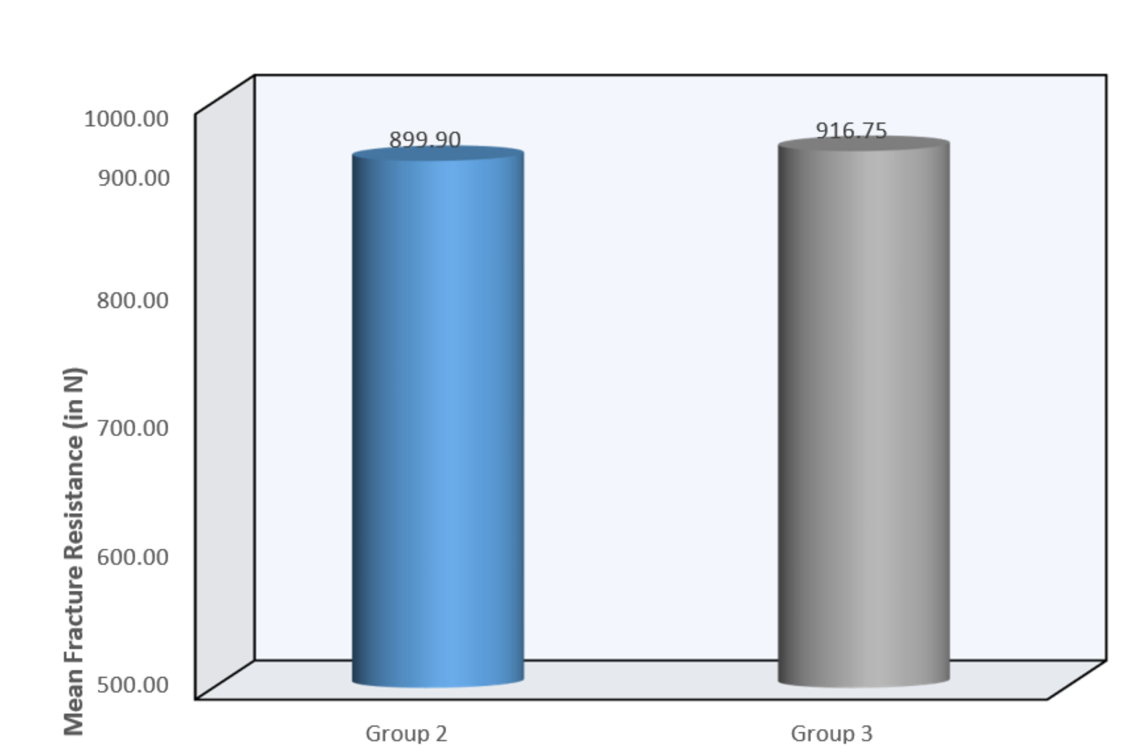
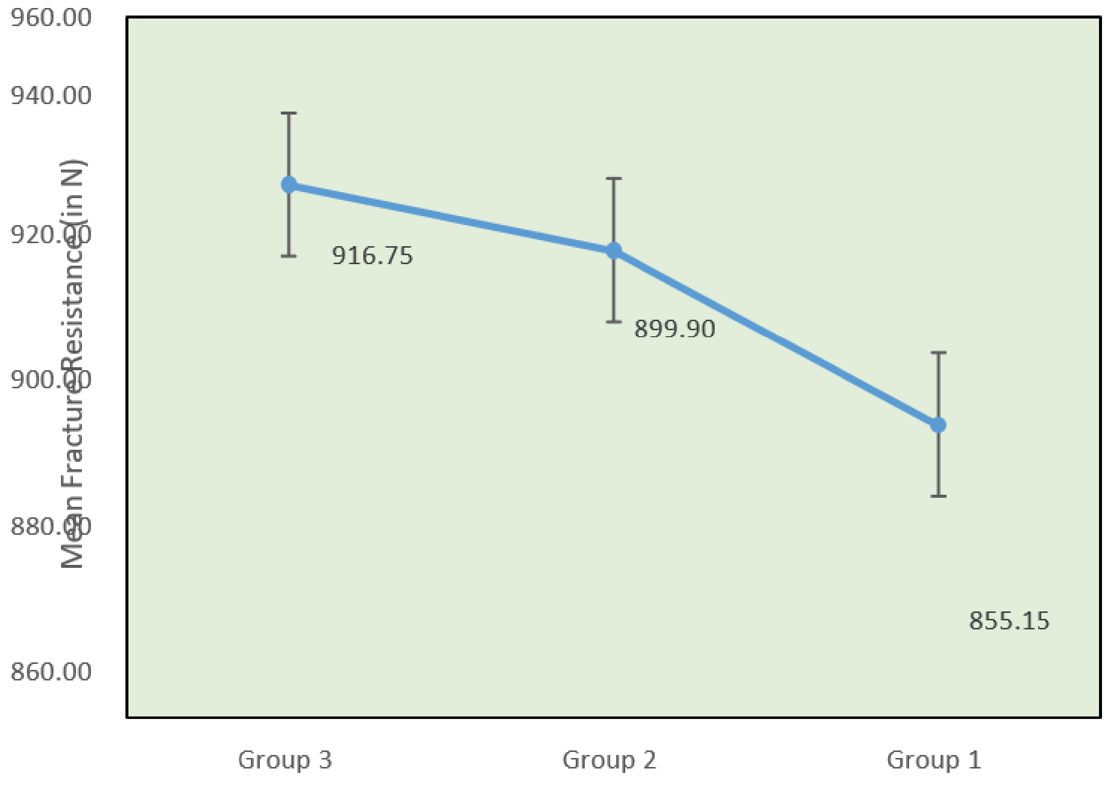


Fig no. 5 Mean Fracture Resistance (in N) b/w 3 groups



IV.Discussion

Endodontically treated teeth are structurally weakened because of the loss of tooth structure during caries removal, access cavity preparation, and root canal instrumentation. Premolars are particularly susceptible to fracture because of their thin cuspal walls and narrow cervical diameter, which predispose them to cuspal deflection under occlusal forces. Fiber-reinforced composite restorations provide a conservative approach by improving stress distribution and limiting crack propagation.

The present study was conducted with strict standardization to minimize methodological variations. Sixty intact mandibular first premolars were standardized with respect to access cavity dimensions, biomechanical preparation, obturation, restorative procedures, storage conditions, and fracture testing. Random allocation into three groups (n = 20) and controlled loading conditions enhanced the reliability and reproducibility of the findings.

The present study evaluated fracture resistance following restoration with composite resin (Group 1), polyethylene fiber-reinforced composite (Group 2), and ultrathin glass fiber strip-reinforced composite (Group 3). Group 3 demonstrated the highest fracture resistance, followed by Group 2 and Group 1. The mean fracture resistance values were 916.75 N, 899.90 N, and 855.15 N, respectively, with a statistically significant difference among the groups ($p < 0.001$). These findings demonstrate the beneficial effect of fiber reinforcement in improving the fracture resistance of endodontically treated premolars.

The lower fracture resistance observed in Group 1 may be attributed to the absence of internal reinforcement. Conventional composite restorations have limited capacity to resist cuspal deflection and crack propagation in structurally compromised teeth. In contrast, polyethylene fibers act as internal splints and improve stress distribution within the restoration. These findings are consistent with Belli et al. (2005), who reported increased fracture resistance with polyethylene fiber reinforcement.1 Yamada et al. (2004) and Rodrigues et al. (2010) similarly reported lower fracture resistance with composite restorations without fiber reinforcement.[26,5]

Group 3 showed significantly greater fracture resistance than Group 2. This may be related to the superior stiffness and modulus of elasticity of glass fibers, which facilitate efficient stress transfer and provide greater resistance to deformation. Although polyethylene fibers provide flexibility and multidirectional reinforcement, glass fibers offer greater rigidity and load-bearing capacity. Kumar et al. (2024) similarly reported superior fracture resistance with ultrathin glass fiber reinforcement compared with polyethylene fibers.[25]

The present findings are further supported by previous investigations. Polyethylene fiber reinforcement has been shown to improve fracture resistance through multidirectional reinforcement, stress absorption, and crack arrest.[8,12,27–31] Glass fiber reinforcement has similarly demonstrated improved fracture resistance because of its high tensile strength, stiffness,and ability to improve load distribution.[32–38] The biomechanical benefit of fiber reinforcement can be explained by the ability of fibers to function as stress-bearing elements within the composite restoration. They distribute occlusal forces, reduce stress concentration at the dentin-restoration interface, and interrupt crack propagation.34 Furthermore, the elastic modulus of fiber-reinforced composites can approximate that of dentin, facilitating more favorable stress distribution.[39]

Overall, the findings demonstrate that fiber reinforcement significantly improves the fracture resistance of endodontically treated premolars. Ultrathin glass fiber strips showed the highest fracture resistance, followed by polyethylene fibers and composite resin alone. These results support fiber-reinforced composite restorations as a conservative approach for reinforcing structurally compromised teeth and potentially reducing dependence on full-coverage restorations.

However, the in-vitro design limits direct extrapolation to clinical conditions, where teeth are subjected to cyclic loading, thermal changes, and saliva contamination. Absence of periodontal ligament simulation is another limitation. Future studies incorporating thermocycling, fatigue loading, and long-term clinical evaluation are recommended.

V.Conclusion

Within the limitations of the present in-vitro study, it can be concluded that incorporation of fiber reinforcement significantly improves the fracture resistance of endodontically treated premolars.

Among the restorative techniques evaluated, ultrathin glass fiber strip (DentaPreg UFM) reinforced composite restorations demonstrated the highest fracture resistance, followed by polyethylene fiber reinforced composite restorations, while composite restorations without fiber reinforcement showed the least fracture resistance.

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