Original Article

DOI: 10.7860/JCDR/2026/88641.24764

Dentistry Section

Fracture Resistance of Different Fibre-reinforced Composite Restorations in Cervical Lesion-directed Access Cavities of Mandibular Premolars: An In-vitro Analysis

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ABSTRACT

Introduction: Endodontically Treated Teeth (ETT), especially mandibular premolars, are prone to fracture due to structural weakening and cervical lesions. Conventional straight-line access often results in excessive coronal dentin removal, further compromising strength. This study investigates a novel cervical lesion-directed access approach and evaluates the effect of Polyethylene Fibres (PF), Glass Fibres (GF) and their combination on fracture resistance.

Aim: To compare the fracture resistances of different fibre-reinforced combinations as access cavity restorative materials in cervical access cavities.

Materials and Methods: The current in-vitro study was conducted at the Department of Conservative Dentistry and Endodontics, Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India from October to December 2025. Sixty extracted human mandibular premolars with single canals and intact crowns were selected from the 18-40 years age group, irrespective of gender distribution. Cervical lesion was mimicked by preparing uniform wedge-shape cavities in Cemento-Enamel-Junction (CEJ) of buccal surfaces of all teeth, followed by Cervical Lesion-Directed Access Cavity (CLDAC) preparation and root canal preparation with ProTaper Gold rotary files up to F3. Canals were obturated and samples were randomly allocated into six groups (G1-G6, n=10 per group): G1 (control group)-intact teeth, G2- ETT without restoration, G3- ETT restored with nanohybrid composite, G4- ETT restored with composite and PF, G5- ETT restored with composite and GF, and G6- ETT restored with composite and combined PF and GF. Specimens mounted in acrylic resin did undergo fracture resistance testing in a Universal Testing Machine (UTM). Statistical analysis was performed using One-way Analysis of Variance (ANOVA) and Tukey's post-hoc test ($p \leq 0.05$).

Results: The highest fracture resistance was observed in intact teeth (994.00 N), followed by GF-reinforced composite (846.00 N), combined fibre reinforcement (793.00 N), PF reinforcement (746.00 N), and composite alone (594.00 N). The lowest values were recorded in unrestored teeth (280.00 N). All intergroup differences were statistically significant ($p<0.001$).

Conclusion: GF reinforcement showed the highest strengthening effect. Using fibres in combination produced a synergistic benefit, while PF offered moderate improvement compared to composite alone. Overall, GF-reinforced composite appears to be the most effective restorative option for CLDAC.

Keywords: Composite resin, Endodontics access cavity preparation, Glass fibres, Polyethylene fibres

INTRODUCTION

The ETT are structurally weakened due to factors such as caries, trauma, parafunctional habits, and endodontic procedures. Endodontic procedures involve removal of pulp tissue and infected dentin, along with mechanical and chemical processes that alter the natural stress-strain distribution of the tooth, thereby increasing the risk of failure [1]. The biomechanical behaviour of ETT is further influenced by the loss of hard dental tissue from carious and non-carious lesions, previous cavity preparations, and the size of the access cavity. Removal of the pulp chamber roof and deepening of the cavity increase flexure of the vertical coronal walls, making them more susceptible to fracture [1].

Moreover, cleaning and shaping of the root canal reduce tooth stiffness in proportion to the amount of dentin removed, with additional effects from chemical and structural alterations caused by irrigants. Sodium hypochlorite, though widely used for its tissue-dissolving and antimicrobial properties, degrades the organic components of dentin through its proteolytic action. Chelating agents such as Ethylenediaminetetra-Acetic Acid (EDTA) act on the inorganic component by removing calcium, leading to dentin softening and erosion, and affecting non-collagenous proteins [1].

Additionally, pre-existing tooth defects combined with eccentric occlusal forces generate tensile stresses at the CEJ, resulting in separation of enamel and dentin. This process contributes to the formation of abfraction lesions-wedge-shaped defects most commonly observed on the buccal aspect of the CEJ, particularly in mandibular premolars [2].

Traditionally, a straight-line access from occlusal aspect has been employed in root canal treatment to ensure operator convenience and minimise procedural errors. However, in teeth with deep cervical lesions, this conventional method often necessitates excessive removal of coronal dentin, further compromising structural integrity and increasing fracture risk [2].

In response to the growing emphasis on minimally invasive dentistry, a novel CLDAC approach has been proposed. This method allows direct access to root canal structure through the cervical lesion, lessening removal of healthy coronal dentin. This study is one of the first to investigate the effect of this innovative access approach on fracture resistance [2].

In oral cavity, restorations are subjected to complex functional forces including bending, shear, fatigue, and fracture [3]. Fracture resistance reflects a material's capacity to resist crack initiation and propagation. Various restorative materials and techniques have

therefore been developed to enhance the durability and strength of restorations [4].

Nanohybrid composites materials are widely used in contemporary restorative dentistry owing to their enhanced mechanical properties, making them suitable for restoring posterior teeth. Nanohybrid resin composites have nano-sized diameter fillers (0.02-0.05 µm) in a prepolymerised filler form. They can withstand greater mastication forces [3].

In recent years, Fibre-reinforced Composites (FRCs) have gained popularity in restorative dentistry. Available in various forms such as glass, polyethylene, Kevlar, carbon, and Vectran fibres [3]. GF and PF are the most widely used [5-8]. The incorporation of fibres into composite restorations can help offset the negative effects of polymerisation shrinkage by reducing stress transmission to both the restoration and the surrounding tooth structure, while simultaneously enhancing the mechanical properties of the composite material [9,10]. PFs consist of aligned low-density polymer chains that provide high impact strength and toughness. E-Splint, made of tightly woven medical-grade PFs, enhances fracture resistance by offering multidirectional reinforcement and excellent resin permeability [9,11,12]. Interlig contains braids of GF impregnated with composite resin that improves both aesthetics and strength. The resin-coated fibres act as crack stoppers by redirecting and dissipating stresses, reducing fracture risk. Its braided structure allows better adaptation to tooth surfaces, distributes forces evenly, and helps control polymerisation shrinkage and occlusal loads [9,13].

Despite their benefits, the use of FRCs in ETT with CLDAC remains underexplored [2]. Hence, the current study was aimed to compare the fracture resistances of different fibre-reinforced combinations as access cavity restorative materials in cervical access cavities. The null hypothesis stated that there is no statistically significant difference in the fracture resistance of ETT in mandibular premolars with CLDAC's restored using nanohybrid composite alone, composite reinforced with PF, GF, or a combination of both fibres.

MATERIALS AND METHODS

This in-vitro study was conducted in the Department of Conservative Dentistry and Endodontics at Sibar Institute of Dental Sciences, Guntur, Andhra Pradesh, India from October to December 2025. The study obtained ethical clearance from the Institutional Ethics Board under reference number (Pr.679/IEC/SIBAR/2025).

Inclusion and Exclusion criteria: Intact mandibular premolars possessing fully formed roots, a single canal, and no visible cracks, caries, fractures, restorations, or previous endodontic treatment-extracted for orthodontic or periodontal reasons were included. Mandibular premolars that were decayed, restored, exhibited developmental anomalies, or showed signs of root resorption were excluded.

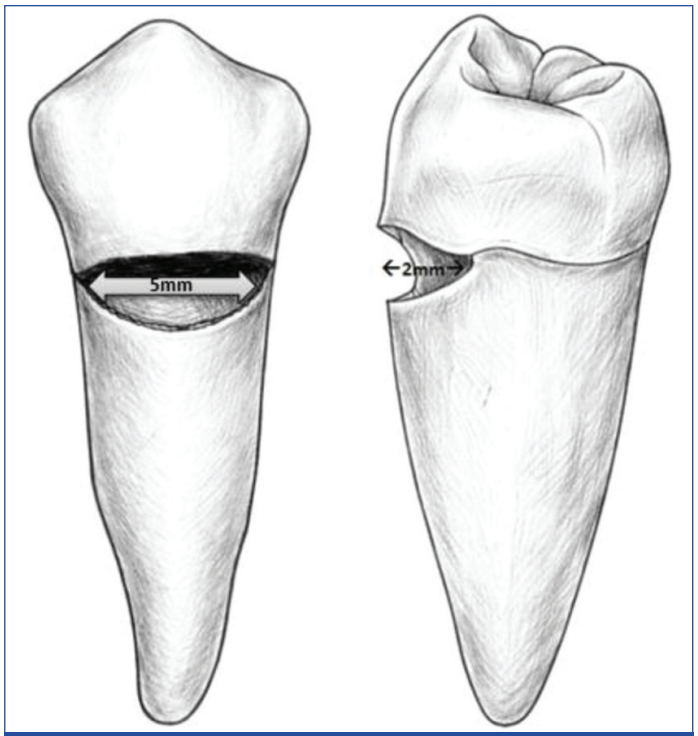
Sample size determination: Sample size estimation was done using G*Power software (version 3.1.9.4) with an effect size of 0.50, an alpha level of 0.05, and a power of 80%. The minimum required sample size was 60, with 10 specimens per group. The allocation ratio was 1:1.

Blinding protocol: Although the operator could not be blinded to the intervention protocol, the fracture testing evaluator and outcome assessor were blinded.

Study Procedure

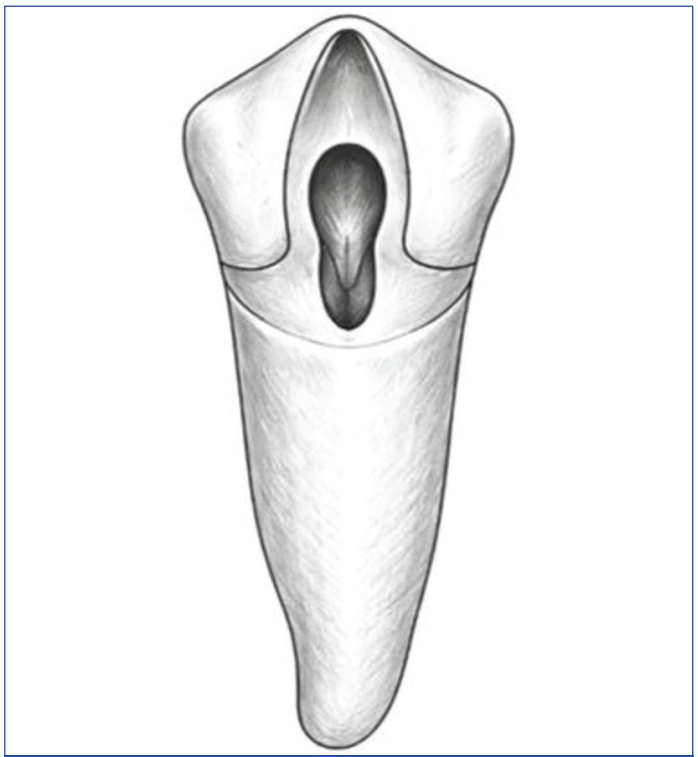
Sixty extracted human mandibular premolars were selected based on predefined criteria from individuals aged 18-40 years, irrespective of gender, and were cleaned using an ultrasonic scaler (Coltene Biosonic S1L Portable Scaler, Switzerland) to remove debris and calculus and stored in 200 mL of 0.1% thymol solution (Sigma Aldrich, US). Preoperative radiographs (mesiodistal and buccolingual direction) were taken to confirm single canals and exclude anatomical variations.

Cervical lesion creation: Cervically, a standardised wedge-shaped cavity was made on the buccal surface at the CEJ using a tapered fissure bur (Mani Inc., Japan). The cavity measures 2 mm in depth, extending three-fourths into the crown and one-fourth into the root with a mesiodistal width of 5 mm. All preparations were carried out using a high-speed air-rotor handpiece (W and H, Austria) under continuous water coolant [Table/Fig-1] [2].



[Table/Fig-1]: Cervical defect (dimensions 5 mm wide and 2 mm deep).

Endodontic treatment: Access to the pulp chamber was achieved through the prepared cervical lesion using a cervical lesion-directed approach. A round bur (BR 46, Mani Inc., Japan) was inserted perpendicular to the buccal surface and advanced until a drop into the pulp chamber was detected. A safe-end bur (EX 24, Mani Inc., Japan) was used to deroof the pulp chamber and create a buccal groove to allow straight-line canal access [Table/Fig-2].



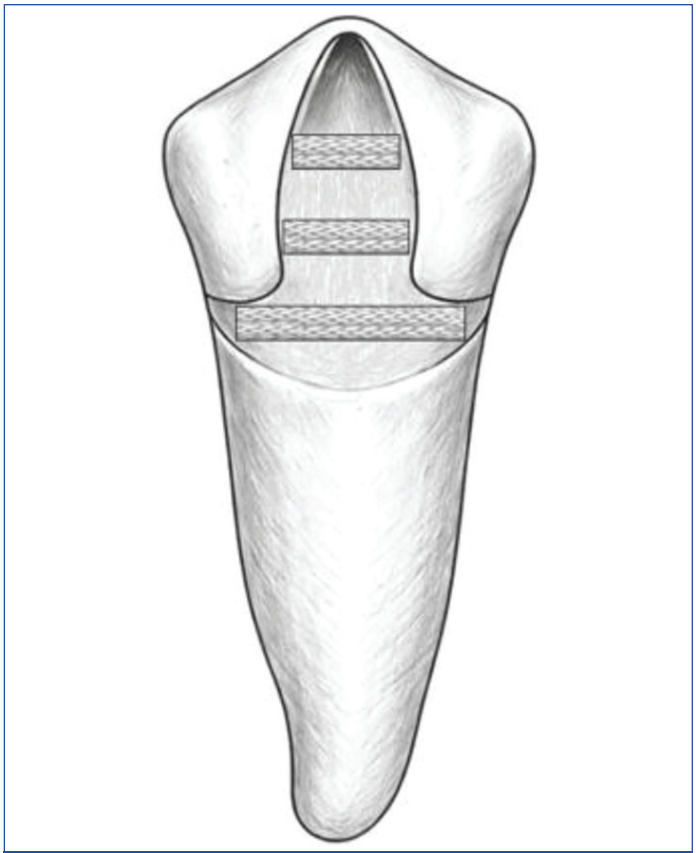
[Table/Fig-2]: Access to the pulp chamber was achieved through the prepared cervical lesion using CLDAC approach.

A #15 K-file (Mani Inc., Japan) was introduced up to Apical Foramen (AF) to be just visible after the AF. The working length was established 1 mm short of the AF. Canal cleaning and shaping was performed using stainless steel K-files (ISO sizes 10-25), after which rotary instrumentation with ProTaper Gold rotary files (Dentsply Maillefer, Switzerland) up to size F3 was performed. Irrigation was continued using 5 mL of 5.25% NaOCl (Vishal Dento Care Pvt., Ltd., India) and 5 mL of 17% EDTA (Anabond Stedman Pharma Research Ltd., India) after each file change, ending with a final rinse of saline. Obturation was completed using guttapercha cones (Dentsply Sirona Maillefer, Switzerland) matched to the final file size and a resin-based sealer (AH plus, Dentsply Sirona, North Carolina).

Sample allocation: Sixty prepared mandibular premolars were randomly allocated into six groups (G1-G6) (n=10 per group) based on the access restoration technique employed. The groups included a positive control (intact teeth, G1), a negative control (unrestored, G2), and four experimental groups (G3-G6). A computer-generated random sequence was used for randomisation and allocation concealment was performed by an independent person who is blinded to the experimental protocols.

- **G1 (Positive control):** Intact teeth.
- **Rest of the groups contained ETT with CLDAC restored with-**
- **G2 (Negative control):** Unrestored.
- **G3:** Nanohybrid composite.
- **G4:** Nanohybrid composite reinforced with PF.
- **G5:** Nanohybrid composite reinforced with GF.
- **G6:** Nanohybrid composite reinforced with combination of GF and PF.
- **Access cavity restoration:** Etching and bonding protocol (G 3-6): All cavity surfaces were etched using 37% phosphoric acid (Prime Dental Products, Pvt., Ltd., India) for 15 seconds, rinsed thoroughly with water, and air-dried gently. A universal bonding agent (3M ESPE, Germany) was applied as per manufacturer's guidelines and light-cured for 20 s using an LED curing unit (Woodpecker Mini S light cure LED, China).
- **G3 - Nanohybrid composite:** The cavity was incrementally restored using nanohybrid composite (Synergy, Coltene, Switzerland) in 2 mm layers. Each layer was cured for 20 s. The restorations were later finished and polished.
- **G4 - Nanohybrid composite reinforced with PF:** PF strips (E splint, Kids-e-dental, India) embedded in flowable composite were placed across the mesiodistal cavity width at three levels: cervical third, middle third, and the junction of middle and coronal thirds [Table/Fig-3]. Each fibre layer was light-cured prior to further build-up. Subsequently nanohybrid composite was layered and cured until whole cavity was filled and the restoration was finished and polished.
- **G5 - Nanohybrid composite reinforced with GF:** This group followed the same protocol as Group 4, substituting GF strips (Interlig, Angelus, Brazil) for PFs.
- **G6 - Nanohybrid composite reinforced with combination of GF and PF:** This group followed the same protocol as Group 4, with combination of both fibres. In this group, reinforcement was achieved using both polyethylene and GF strips placed alternately within the cavity.

Fracture resistance testing: The restored specimens were vertically entrenched in self-cure acrylic resin blocks, leaving 3 mm of the tooth structure exposed apical to the CEJ. The samples were preserved at 37°C under humidity of 95% for 24 hours in a humidifier (Remi Instruments Ltd., India). Each specimen was then positioned in a Universal Testing Machine (UTM) (Matrix Testing and Technologies Pvt., Ltd., India) and subjected to vertical compressive loading onto the occlusal surface at a crosshead speed of 1 mm/min until samples fracture. The peak load at which the fracture occurred was recorded in Newtons (N) [Table/Fig-4].



[Table/Fig-3]: Levels of placement of fibres (three levels: cervical third, middle third, and the junction of middle and coronal thirds).



[Table/Fig-4]: The specimens were tested for fracture resistance using a Universal Testing Machine (UTM) under compressive loading at a crosshead speed of 1 mm/min.

STATISTICAL ANALYSIS

Data analysis was executed using Statistical Package for the Social Sciences (SPSS) software version 26.0 (SPSS Inc., Chicago, USA). Intergroup comparisons were carried out using one-way ANOVA, followed by Tukey's post-hoc test for multiple pairwise comparisons. Statistical significance at a p-value of ≤0.05 was set.

RESULTS

One-way ANOVA revealed a statistically significant difference in the mean maximum load values among the groups ($F=88.377$, $p<0.001$), indicating that the tested groups differed significantly in their fracture resistance. G1 demonstrated the highest fracture resistance

value (994.00±59.66 N), followed by G5 (846.00±68.67 N), G6 (793.00±63.79 N), G4 (746.00±77.77 N), and G3 (594.00±41.15 N). G2 exhibited the lowest mean maximum load (280.00±40.00 N) [Table/Fig-5].

Groups	Mean (n=10)	Standard deviation	F value	p-value
Group 1	994.00	59.666	88.377	<0.001*
Group 2	280.00	40.000		
Group 3	594.00	41.150		
Group 4	746.00	77.775		
Group 5	846.00	68.670		
Group 6	793.00	63.795		

[Table/Fig-5]: Descriptive and comparative analysis of mean differences in fracture resistance (N) within each group using One-way ANOVA.
*p≤0.05 considered statistically significant; TEST: One-way ANOVA

To identify specific intergroup differences, Tukey's post-hoc test was performed. Group 1 showed statistically significant differences when compared with all other groups (p<0.05), confirming its superior maximum fracture resistance. G2 differed significantly from all remaining groups (p=0.001), indicating the weakest performance among the tested groups. Comparisons involving G3 revealed statistically significant differences with all other groups (p<0.05). G4 showed significant differences when compared with Groups 1, 2, 3, and 6 (p<0.05); however, the difference between G4 and G5 was not statistically significant (p=0.17). Similarly, no statistically significant difference was observed between G5 and G6 (p=0.99) [Table/Fig-6].

Groups	Groups	Mean difference	p-value
Group 1	Group 2	714	**<0.001***
	Group 3	400	**<0.001***
	Group 4	248	**<0.001***
	Group 5	148	**0.04***
	Group-6	128	**0.02***
Group 2	Group 1	-714	**<0.001***
	Group 3	-314	**<0.001***
	Group 4	-466	**<0.001***
	Group 5	-566	**<0.001***
	Group 6	-586	**<0.001***
Group 3	Group 1	-400	**<0.001***
	Group 2	314	**<0.001***
	Group 4	-152	**0.03***
	Group 5	-252	**<0.001***
	Group 6	-272	**<0.001***
Group 4	Group 1	-248	**<0.001***
	Group 2	466	**<0.001***
	Group 3	152	**0.03***
	Group 5	-100	0.17
	Group 6	-120	**0.04***
Group 5	Group 1	-148	**0.04***
	Group 2	566	**<0.001***
	Group 3	252	**<0.001***
	Group 4	100	0.17
	Group 6	-20	0.99
Group 6	Group 1	-128	**0.02***
	Group 2	586	**<0.001***
	Group 3	272	**<0.001***
	Group 4	120	**0.04***
	Group 5	20	0.99

[Table/Fig-6]: Multiple pairwise comparisons within each group using Tukey's post-hoc test.
*p≤0.05 considered statistically significant; Test: Tukey's Post-hoc test

DISCUSSION

The restoration of ETT is a crucial final phase in ensuring the long-term success of root canal therapy [14]. It is an established fact that ETTs exhibit poor mechanical properties compared to vital teeth [15]. Loss of water content and key anatomical structures, such as the roof of pulp chamber, renders root canal-treated teeth highly susceptible to fracture [16]. In ETT with cervical defects, the marginal ridges often remain intact, whereas significant loss of cervical tooth structure occurs as a result of caries or Non-Carious Cervical Lesions (NCCLs). NCCL is the loss of tooth structure near to the neck of the tooth, most often on the vestibular surface due to functional stresses. These lesions are increasingly common and may cause discomfort and functional problems. Mandibular premolars were selected for this study because they show a high prevalence of cervical lesions [17]. On finite element analysis, increased stress concentrations have been demonstrated in the cervical regions of such teeth compared to intact teeth [15].

The mean fracture resistance of intact lower premolars in the present study was highest (994.00 N) compared to all other groups. The highest reduction in fracture resistance (280.00 N) was seen in ETT with CLDAC's when left unrestored. The One-way ANOVA revealed a statistically significant difference in mean fracture resistance among the six groups (F=88.377, p=0.00; p≤0.05), leading to rejection of the null hypothesis and indicating that the type of restorative reinforcement significantly influences fracture resistance, with FRC groups demonstrating superior performance compared to composite alone.

This study employed the CLDAC approach, followed by endodontic treatment, as an alternative to the conventional occlusal access cavity technique for managing cervical defects. The CLDAC design provides biomechanical advantages by preserving more coronal and cervical dentin, resulting in higher fracture resistance and more favourable, repairable fractures. The self-supported dentin in CLDAC efficiently dissipates occlusal stress, while the use of FRC's enhances fracture resistance through crack-bridging and deflection. Additionally, CLDAC minimises polymerisation shrinkage stress, supports adhesive restorations, and eliminates instrument fractures due to heat-treated files, thereby optimising the structural integrity and longevity of ETT [2].

The advent of FRCs has marked a significant advancement in metal-free esthetic dentistry by providing materials with improved mechanical and aesthetic properties [7].

In the present study, FRCs, PF and GF reinforced composites-demonstrated superior fracture resistance compared to nanohybrid composites. Several studies have evaluated the fracture resistance of FRC in comparison with conventional hybrid composites in ETT [7-9,14]. While a few investigations reported that, root canal-treated teeth restored with FRCs and conventional hybrid composites exhibited no significant difference in fracture resistance [16,18]. On the other hand, majority of the studies consistently demonstrated superior fracture resistance with FRCs [8,14,19]; Kumar A and Sarthaj S reported that teeth restored with FRC exhibited greater fracture resistance (821.93 N) than those restored with conventional composite (761.20 N) [20]. FRCs offer key advantages for restoring ETT by effectively distributing functional stresses and reinforcing the remaining tooth structure. The embedded fibres help prevent crack initiation and propagation, making more favourable fracture patterns, often coronal to the Cementoenamel Junction (CEJ), which aids in easier restoration and better tooth preservation. FRCs enhance the biomechanical performance and longevity of restorations in compromised teeth [21].

Glass and PFs provide distinct mechanical advantages in reinforcing composite restorations of ETT, and their effectiveness is strongly influenced by fibre placement and orientation. In the present study,

fibre strips embedded in flowable composite were positioned horizontally across the mesiodistal width of the cavity at three strategic levels, namely the cervical third, middle third, and the junction of the middle and coronal thirds, to maximise reinforcement. This horizontal configuration allowed coverage across the cavity walls, increasing the effective contact area and facilitating more uniform stress distribution, thereby improving fracture resistance. Preservation of the Interlig™ fibre structure, rather than chopping, likely enhanced their reinforcing efficiency, while the increased fibre quantity, when well adapted to the gingival floor, contributed to reduced polymerisation shrinkage stress and improved structural support. Consistent with the observations of Khan S et al., fibre orientation was critical, with fibres placed perpendicular to compressive forces significantly enhancing restoration strength, whereas fibres aligned parallel to these forces offered limited reinforcement due to potential matrix failure [13].

Among the materials evaluated, GF-reinforced composite demonstrated superior improvement in fracture resistance, attributable to the high modulus of elasticity (21.6±1.4 GPa) [22] and flexural strength of GFs, which provide rigidity, resist deformation under functional loads, and enable efficient stress transfer through strong chemical bonding with the resin matrix, although this effect remains technique-sensitive [23]. In contrast, PFs, owing to their flexibility and woven architecture, adapt closely to cavity walls and dissipate functional stresses more evenly, reducing stress concentration and limiting crack initiation and propagation [8]. Luthria A et al., showed that composite restorations reinforced with GFs (600.49 N) had higher fracture resistance than those reinforced with PFs (514.64 N) in ETT [23].

Under clinical conditions, fibres are typically used in conjunction with flowable composite and adhesive resin, which increases the elastic modulus of the reinforced complex to approximately 23.6 GPa. This higher elastic modulus, along with a lower flexural modulus of the fibre, is thought to produce a stress-modifying effect at the tooth-restoration interface. The interwoven architecture and multidirectional yarns of the fibres create multiple load pathways, facilitating broader redistribution of occlusal forces within the restorative material, thereby limiting crack propagation and enhancing fracture resistance [24].

In this in-vitro study, composite reinforced with a combination of polyethylene and GFs exhibited greater fracture resistance than PF alone but remained inferior to GF-reinforced composite, though the difference was non-significant. This intermediate performance may be attributed to hybrid fibre architectures creating multiple load paths that enhance stress redistribution and delay crack propagation, although they do not provide the same stiffness as GFs. Systematic evidence further supports that while different fibre types can improve fracture resistance by acting as stress modifiers, the extent of reinforcement depends on fibre material and configuration [19].

Limitation(s)

This study has certain limitations. Despite standardisation, operator variability during cavity preparation, fibre placement, and restoration procedures may have introduced minor inconsistencies and potential bias. As an in-vitro investigation, it does not fully replicate the oral environment, lacking factors such as thermal fluctuations, moisture, periodontal ligament simulation, and cyclic masticatory forces, with fracture resistance assessed only under static loading. The use of only mandibular premolars with standardised cervical lesions also limits generalisability to other clinical scenarios. Furthermore, the long-term performance of fibre-reinforced restorations under ageing and repeated loading was not evaluated. Future studies should incorporate cyclic loading, periodontal ligament simulation, and long-term clinical assessment to better reflect in-vivo conditions.

CONCLUSION(S)

Despite its limitations, this in-vitro study demonstrated that restoring root canal-treated mandibular premolars with CLDACs significantly improved fracture resistance compared with unrestored teeth. GF-reinforced composite exhibited the highest mean fracture resistance, closely followed by the combination of glass and PFs; however, the difference between these two groups was not statistically significant. PF reinforcement also improved fracture resistance compared with composite restoration alone, while the lowest fracture resistance was observed in unrestored teeth. These findings suggest that GF reinforcement, either alone or in combination with PF, provides effective reinforcement of CLDAC-restored mandibular premolars.

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PLAGIARISM CHECKING METHODS: [Jain H et al.]
- Plagiarism X-checker: Mar 19, 2026
- Manual Googling: Aug 04, 2026
- iThenticate Software: Aug 06, 2026 (6%)

ETYMOLOGY: Author Origin

EMENDATIONS: 7

AUTHOR DECLARATION:
- Financial or Other Competing Interests: None
- Was Ethics Committee Approval obtained for this study? Yes
- Was informed consent obtained from the subjects involved in the study? NA
- For any images presented appropriate consent has been obtained from the subjects. NA

Date of Submission: **Feb 28, 2026**
Date of Peer Review: **May 01, 2026**
Date of Acceptance: **Aug 08, 2026**
Date of Publishing: **Dec 01, 2026**