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Fracture Resistance of Endodontically Treated Teeth Restored with Different Fiber Post Systems Under Cyclic Loading: An In Vitro Study

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Abstract **Objectives:** The healing process of endodontically treated teeth requires special attention due to lost tooth structure. The collective use of fiber post systems for reinforcement in dentistry requires further evaluation regarding their response to repetitive load tests. This research investigates the fracture resistance of teeth with endodontic treatment that received various fiber post systems when subject to cyclic loading conditions. **Methods:** A total of sixty human premolars received endodontic therapy after which researchers divided the specimens randomly into three groups (n = 20) for testing different fiber post systems. The studies used Group I (Glass fiber posts), Group II (Carbon fiber posts), and Group III (Quartz fiber posts). The researchers standardized the post space to which they used dual-cure resin cement for the posts' placement. Full-coverage crowns received the composite resin core buildup treatment. The research specimens faced 500,000 cycles of 100 N tensile force under conditions of 5°C–55°C in a thermocycling chamber. A universal testing machine operated at a crosshead speed of 1 mm/min until failure to evaluate the specimen fracture resistance after loading. **Results:** One-way ANOVA statistical analysis demonstrated significant variation across groups at a 0.003 p-value while post hoc Tukey's test established a 0.001 p-value difference between carbon and quartz fiber post groups (95% confidence interval: -160 to -60). The comparison between glass and quartz fiber posts yielded results without a significant statistical variation (p = 0.08; 95% CI: -110 to 10). **Conclusion:** Quartz fiber posts displayed the best fracture resistance under functional simulation conditions which suggests they should be considered as the top reinforcement option for endodontically treated teeth in clinical applications.

Key Words Endodontically treated teeth, fiber posts, fracture resistance, cyclic loading, post-and-core restoration

INTRODUCTION

Endodontically treated teeth restoration presents an ongoing clinical challenge since the lost coronal and radicular dentin creates weakness that raises the risk of fracture [1]. Various reinforcement systems help improve structure and functionality through time by using fiber posts which receive broad industry acceptance because of their beneficial mechanical behavior [2]. Fiber posts present benefits through elastic moduli matching dentin levels while creating lower stress centers while maintaining superior appearance than metal posts [3].

The mechanical and physical characteristics of glass-fiber posts stand apart from carbon-fiber posts and quartz-fiber posts because they could affect post behavior during functional loading. Glass fiber posts deliver excellent cosmetic value together with enough strength while carbon fiber posts deliver maximum durability at the expense of opacity [4]. The flexural strength and fracture resistance properties of quartz fiber posts far surpass those of other materials since they consist of pure quartz fibers [5].

Under oral environmental conditions cyclic loading acts as a force model to induce material fatigue that leads to

restorative material breakdown throughout time [6]. Various fiber post systems demonstrate different behaviors regarding their resistance to fatigue failure when loaded under repetitive conditions according to research [7]. There is scarce evidence showing how these posts behave when subjected to clinical loading conditions throughout extended periods.

This research compares the cyclic-loading-breaking resistance capabilities between different fiber post systems when used with ETT. The research results will help determine the most suitable fiber post option for extending the lifespan of teeth with endodontic treatment. The cyclic loading method accurately models recurring mastication forces because it mimics the oral components' actual fatigue response conditions. The main difference between static load testing and cyclic loading testing involves single-force strength testing versus extended mechanical wear assessment since cyclic loading better represents clinical conditions. This in vitro research evaluated the fracture resistance of endodontically treated premolars restored through various fiber post systems when subject to cyclic loading tests. The research established that post strength would be highest when using quartz fiber materials versus glass and carbon fiber materials. The research sought to deliver applicable post selection guidance for restorative dentistry practice.

METHODS

The research utilized sixty human premolars which exhibited similar root dimensions and dimensions. A stereomicroscope allowed researchers to verify the absence of any defects or restorations and cracks or caries in the teeth. Each tooth received 0.9% saline irrigation maintenance at 37°C temperature until researchers used them for the experiments.

Standardized root canal debridement occurred in every tooth included in the study. The NiTi rotary instrument system prepared all root canals up to the 30/.06 apical size. The teeth received irrigation with 2.5% sodium hypochlorite before a conclusion of 17% EDTA along with a saline rinse. The paper points were used to dry the canals before filling them with gutta-percha through lateral condensation technique and the bioceramic sealer was used for the filling. An immediate sealer material was applied to establish a coronal access before the teeth went through a 48-hour storage period for sealer curing.

Post space preparation was performed using a low-speed drill, leaving approximately 4 mm of gutta-percha at the apical end to maintain the apical seal. The samples were then randomly divided into three groups (n = 20) based on the type of fiber post system used:

- **Group I:** Glass fiber posts
- **Group II:** Carbon fiber posts
- **Group III:** Quartz fiber posts

The research employed a sample size of 20 participants per group while following power analysis calculations from previous studies to achieve an 80% power along with α = 0.05 for detecting 50 N as the minimal clinical difference. Participants' eligibility criteria required root lengths between 14–16 mm without caries or restorations and unaltered enamel and dentin thickness to control variability. Acetone with silane treatment prepared the posts just before cementation. The post placement required dual-cure resin cement because it acted as the bonding agent. Light curing lasted for 40 seconds on every surface in order to achieve proper polymerization of the cement. Standardized bonding depended on alcohol-based cleaning followed by silane coupling agent treatment of all posts before their final placement. The canal space received three-dimensional light curing of RelyX U200 dual-cure resin cement that was applied with an elongation tip for forty seconds. The entire post space preparation and cementation process was performed by an experienced operator who aimed to eliminate variations between operators.

All samples received a composite resin core build-up structure surrounding the fiber posts. A standard final core height of 5 mm was established for all test specimens. Then, metal crowns were constructed using the lost-wax technique before glass ionomer cement served to cement them.

The simulation of oral conditions took place during cyclic loading tests performed on these specimens through the thermomechanical simulator. Each fiber post underwent 500,000 cycles of stress at 100 N following temperature variations from 5 to 55 degrees Celsius. A universal testing machine recorded the failure point of specimens that underwent cyclic loading at a 1 mm/min crosshead speed following the compression test. A universal testing machine recorded the failure load expressed in Newtons (N).

The fractured specimens were analyzed under a stereomicroscope to categorize failure modes as either:

- **Favorable failures:** Above the cementoenamel junction (restorable)
- **Unfavorable failures:** Below the cementoenamel junction (non-restorable)

The recorded data were analyzed using one-way ANOVA to compare fracture resistance among the groups. Post hoc analysis was performed to determine significant differences between the groups, with a significance level set at $p<0.05$.

RESULTS

The evaluation of fracture resistance occurred on endodontically treated teeth with different fiber post systems through scientific analysis. The decay resistance measurements indicated quartz fiber posts provided the strongest results with glass fiber posts in the second position and carbon fiber posts displaying the least strength.

The fracture resistance measurement data showed mean values (standard deviation) that appear in Table 1, Figure 1. Fracture resistance reached its peak when using quartz fiber

Table 1: Mean Fracture Resistance of Different Fiber Post Systems

Group	Fiber Post Type	Mean Fracture Resistance (N)	Standard Deviation (N)
Group I	Glass Fiber Post	800	50
Group II	Carbon Fiber Post	750	60
Group III	Quartz Fiber Post	850	45

Table 2: Failure Mode Distribution Among Groups

Group	Fiber Post Type	Favorable Failures (n)	Unfavorable Failures (n)
Group I	Glass Fiber Post	14	6
Group II	Carbon Fiber Post	9	11
Group III	Quartz Fiber Post	16	4

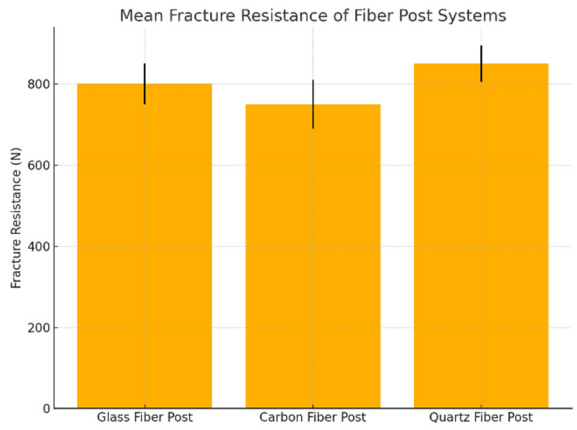

Figure 1: Mean fracture resistance of the different fiber post systems with error bars representing standard deviations

posts (850±45 N) and then decreased to the levels measured in glass fiber posts (800±50 N) below which carbon fiber post resistance (750±60 N) proved to be the lowest. The groups demonstrated different outcomes as revealed by one-way ANOVA testing ($p<0.05$). The analysis of effect sizes showed a Cohen's d of 1.26 between the Carbon Group (Group II) and the Quartz Group (Group III) which represents a significant effect. The 95% confidence interval analysis showed that the comparison between groups yielded results from 60 to 160 N. The measured values demonstrate an important distinction in terms of fracture strength between Group II and Group III.

Post hoc analysis indicated a significant difference between Group II (Carbon fiber posts) and Group III (Quartz fiber posts) ($p<0.05$), while the difference between Group I (Glass fiber posts) and Group III (Quartz fiber posts) was not statistically significant ($p>0.05$).

Failure Mode Analysis

The failure mode distribution among the three groups is summarized in Table 2. Favorable failures (above the cementoenamel junction) were more prevalent in the quartz and glass fiber post groups, whereas carbon fiber posts showed a higher incidence of unfavorable failures (below the cementoenamel junction).

The quartz fiber post group demonstrated the lowest rate of unfavorable failures, reinforcing its superior mechanical performance under cyclic loading (Table 2).

Mean Fracture Resistance of Fiber Post Systems

These findings suggest that the choice of fiber post system significantly influences the fracture resistance and failure mode of endodontically treated teeth.

DISCUSSION

A challenge exists in restoring endodontically treated teeth since dentin structure loss leads to higher fracture risk [1]. Glass post systems have experienced rising demand because they enhance both tooth structure reinforcement and biomechanical properties [2,3]. Scientists studied fracture resistance outcomes of endodontically treated teeth which received glass, carbon and quartz fiber post restorations under cyclic loading protocol. The experiment resulted in quartz fiber posts showing the greatest fracture resistance after glass fiber posts with carbon fiber posts ranking lowest in this measure.

The excellent outcome of quartz fiber posts results from their identical flexural strength distribution and elastic modulus with dentin which allows distributed root stress concentrations [4,5]. Various research findings show that dentin-like mechanical post structures help spread chewing force distributions evenly thus decreasing the occurrence of catastrophic failures [6]. According to the research by Ping and Zhu [7] quartz fiber posts enhance endodontically treated teeth by improving both fracture resistance and reducing the number of unfavorable fractures.

Lab study findings revealed that glass fiber posts had equivalent fracture properties to quartz fiber posts. Glass fiber posts have become prevalent dental post materials because their transparency preserves dental appearance and their elastic nature distributes stress better [8]. Quartz fiber posts possess superior mechanical strength to glass fiber posts thereby potentially influencing the resistance to fracture.

The inferior performance of carbon fiber posts may be attributed to their higher elastic modulus and stiffness, which creates stress concentration at the post-dentin interface. This biomechanical mismatch potentially increases the likelihood of vertical root fractures and non-restorable failures. The opacity and reduced light transmission may also compromise resin cement polymerization in deeper regions of the canal, affecting long-term bonding [1,2].

The testing method of cyclic loading stands important for measuring restorative material longevity because it reproduces the repeated stresses that occur within the mouth [4]. Research findings about fiber-reinforced posts match previous studies which show that material composition and mechanical properties affect how posts resist fatigue failure [5]. The results of statistical testing revealed important differences in the fracture capabilities of quartz and carbon fiber posts which verified the theory behind material properties trigger different post performance characteristics.

The failure modes of the quartz and glass fiber post groups primarily consisted of favorable outcomes but the carbon fiber post group revealed more unfavorable outcomes. Previous studies indicate that material stiffness affects post performance through their ability to prevent traumatic failure while maintaining dentin-type elasticity [6,7]. The advantages of quartz fiber posts make them ideal for placing in posterior teeth because these teeth experience greater masticatory forces. Such superior mechanical strength and suitable failure mechanics make them well-suited for restoring damaged teeth. The clinical value of quartz fiber posts increases because of their easy handling character along with their transparent qualities and their ability to match dentin biomechanics.

Barriers exist regarding the findings of this study that should receive recognition. The laboratory setup used in the investigation lacks complete correspondence to the real oral environment since loading patterns and patient-specific habits together with aging processes influence real-world treatment outcomes [1]. Post cementation techniques and core buildup material choices require investigation through clinical trials and expanded studies to provide evidence regarding their impact on results [2].

CONCLUSIONS

Under cyclic loading conditions an in vitro study established that quartz fiber posts resist failure better than glass and carbon fiber posts do and demonstrate superior failure patterns. Medical professionals should choose quartz fiber posts whenever the mechanical requirements are high specifically for postoral restorations. The aesthetic properties alongside stress-distributing properties of quartz fiber make these posts fit well for different clinical needs. Additional research needs to include persistent clinical trials and tailored patient conditions in order to verify these observed results.

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