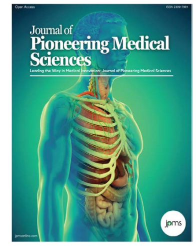

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An *In vitro* Study on the Effect of Post Type and Core Material on the Biomechanical Behavior of Endodontically Treated Teeth Restored with Full-Coverage Crowns

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Abstract **Objectives:** Restoration of structurally damaged endodontically treated teeth (ETT) requires post and core treatments to withstand functional forces. Post type selection together with core material substance determines the stress distribution patterns and breaks down resistance properties of teeth requiring treatment. Researchers conducted this *in vitro* study to assess different post and core combination models which received full-coverage crowns for their biomechanical outcomes in ETT teeth. **Methods:** Sixty endodontically treated single-rooted human mandibular premolars were distributed into six experimental groups (n = 10) according to the combination of post material and core cement: Group 1: Fiber post with composite core, Group 2: Fiber post with glass ionomer core, Group 3: Metal post with composite core, Group 4: Metal post with glass ionomer core, Group 5: Zirconia post with composite core, Group 6: Zirconia post with glass ionomer core. The dental specialists prepared all post spaces to 10 mm depth and cemented each post with resin-based luting cement. The core materials were placed following the manufacturer-specified guidelines. Zirconia crowns produced through CAD/CAM fabrication received their cementation from resin-modified glass ionomer cement. Laboratory tests of compressive strength included thermocycling the samples through 10,000 temperature changes between 5°C and 55°C before testing. The universal testing machine determined fracture resistance by testing at 135° inclination to the tooth axis at 1 mm/min cross speed. The assessment distinguished restorable from non-restorable failure patterns. Finite element analysis (FEA) provided data regarding the way stress distributed between components. **Results:** The group using Zirconia posts with composite core (Group 5) exhibited the highest fracture resistance at 1750±120 N, followed by metal post with composite core (Group 3) at 1620±110 N, while the lowest resistance was recorded for zirconia post with glass ionomer core (Group 6) at 980±90 N. Fiber post groups demonstrated more favorable failure modes, with 70% restorable failures in Group 1. **Conclusion:** Fiber posts with composite cores demonstrated superior stress distribution and favorable failure modes, making them clinically preferred for restoring endodontically treated teeth with full-coverage crowns, particularly in patients with high occlusal load.

Key Words Endodontically treated teeth, post and core, fiber post, metal post, zirconia post, composite core, fracture resistance, stress distribution, finite element analysis

INTRODUCTION

Ethical teeth treated with endodontic procedures show diminished structural strength because of tooth structure loss and dehydration and mechanical changes which makes them vulnerable to fractures [1]. Post and core systems form a part of ETT restoration because they strengthen the remaining structure to support full-coverage crown placement [1]. The post type selection combined with core material selection determines the extended durability of these restorations.

The clinical community has extensively studied fiber posts and metal posts as typical post types. According to research literature the popularity of fiber posts increases because these materials match dentin elastic properties thus distributing stress more efficiently and lowering chances of root fractures [1]. The higher rigidity value of stainless steel and titanium metal posts creates concentrated stress points that negatively affect the post-dentin connection [1].

The selected core component directly influences how strong the restoration will become. The implementation of composite resin as a restorative material becomes standard because dentists benefit from its manageable qualities and sufficient bonding capacity toward post and dentin [5]. Experts have utilized zirconia-reinforced composites or glass ionomer cement as alternative materials for core buildup procedures to achieve enhanced mechanical behaviors [6]. Authorities have not agreed on the best combination between post materials and core compositions when designing crowns for endodontically treated teeth.

The research investigates how different post types and core materials influence the fracture resistance as well as stress distribution patterns in ETT. These test results from laboratory investigation will help dental practitioners choose the best restorative techniques for teeth with endodontic treatment. Post-core restoration outcomes in the oral cavity heavily depend on the way teeth contact with each other along with periodontal ligament functions and continuous functional loads. When *in vitro* studies lack periodontal ligaments for shock absorption the patterns of stress and failure become significantly impacted. It is essential to choose post systems that mimic dentin biomechanics to stop catastrophic failures from occurring in functional scenarios. This study aims to determine the optimal post and core combinations based on fracture resistance and failure mode analysis to provide evidence-based recommendations for clinical restoration of endodontically treated teeth under various functional conditions.

METHODS

A total of 60 freshly extracted, single-rooted human mandibular premolars with similar dimensions were selected for the study. The teeth were cleaned of any debris and soft tissue remnants and stored in distilled water at 4°C until use. Teeth with cracks, caries, or previous restorations were excluded. Standardized root canal treatment was performed using a step-back technique with rotary nickel-titanium files, and canals were obturated with gutta-percha and resin-based sealer using the lateral compaction technique.

Experimental Groups

The specimens were randomly divided into six groups (n=10) based on the type of post and core material used:

- **Group 1:** Fiber post with composite core
- **Group 2:** Fiber post with glass ionomer core
- **Group 3:** Metal post with composite core
- **Group 4:** Metal post with glass ionomer core
- **Group 5:** Zirconia post with composite core
- **Group 6:** Zirconia post with glass ionomer core

The dental post area received low-speed drilling until reaching a depth of 10 mm including a 4 mm seal around the apex. The laboratory staff used dual-cure resin cement as luting agent for fiber and metal posts yet applied self-adhesive resin cement to cement zirconia posts. Biomechanical outcomes might be affected by natural variations in tooth root length and dentin thickness and age-related modifications among the specimens despite matching their size and morphology. The researchers minimized this variability through visual inspection and standardization of dimensions but biological *in vitro* methods inherently include such variation.

The manufacturer's guidelines determined how to apply core materials. The procedure for composite resin core construction involved multiple built-ups which received light activation at each step whereas glass ionomer cores required chemical curing until setting completed. A 1.5mm deep chamfer margin together with a 6° total occlusal convergence was used to standardize the crown preparation of the specimens. Zirconia crowns with a complete covering were designed through CAD/CAM technology and received cementation from resin-modified glass ionomer cement.

A simulation of oral environment was achieved by exposing all samples to 10,000 cycles between 5°C and 55°C temperatures. The universal testing machine conducted fracture resistance testing by delivering an axial force at 135 degrees relative to the tooth axis with a 1 mm/min speed until the samples broke. Researchers recorded the failure strength data in Newtons.

A calibrated operator prepared all post space areas and restorative procedures for the purpose of reducing variability. The chosen temperature variation from 5°C to 55°C along with 10,000 cycling sessions replicates oral thermal exposure throughout a one-year period. The duration of rest time in each water bath was set to 30 seconds throughout the cycle. The 135° angle together with 1 mm/min crosshead speed serve as standard parameters for representing both masticatory force vectors and biting progression.

The analysis used software from SPSS. One-way ANOVA served for evaluating the fracture resistance differences between testing groups with subsequent Tukey post-hoc tests for pair-to-pair comparison. All statistical findings considered $p<0.05$ as the threshold for statistical significance.

RESULTS

A statistical analysis shows that Table 1 contains fracture resistance means of each experimental group. The most robust fracture resistance was detected in Group 5 when utilizing Zirconia posts with composite cores (1750±120 N) yet Group 3 proved second by using Metal posts with composite core (1620±110 N). The tested specimens in Group 6 (Zirconia post with glass ionomer core) achieved the lowest fracture resistance which measured 980±90 N. The groups' fracture resistances showed a significant differing pattern based on statistical results ($p<0.05$).

The research distinguished failure types between breakages that were clinically repairable through coronal fracture recovery versus breakages which required non-repair

Table 1: Fracture Resistance of Different Post and Core Combinations (Mean±SD, N)

Group	Post Type	Core Material	Fracture Resistance (N)
1	Fiber Post	Composite Core	1480±100
2	Fiber Post	Glass Ionomer Core	1320±105
3	Metal Post	Composite Core	1620±110
4	Metal Post	Glass Ionomer Core	1400±95
5	Zirconia Post	Composite Core	1750±120
6	Zirconia Post	Glass Ionomer Core	980±90

$p<0.05$, statistically significant differences among groups

Table 2: Distribution of Failure Modes Among Groups

Group	Post Type	Core Material	Restorable Failures (%)	Non-Restorable Failures (%)
1	Fiber Post	Composite Core	70	30
2	Fiber Post	Glass Ionomer Core	60	40
3	Metal Post	Composite Core	20	80
4	Metal Post	Glass Ionomer Core	30	70
5	Zirconia Post	Composite Core	15	85
6	Zirconia Post	Glass Ionomer Core	25	75

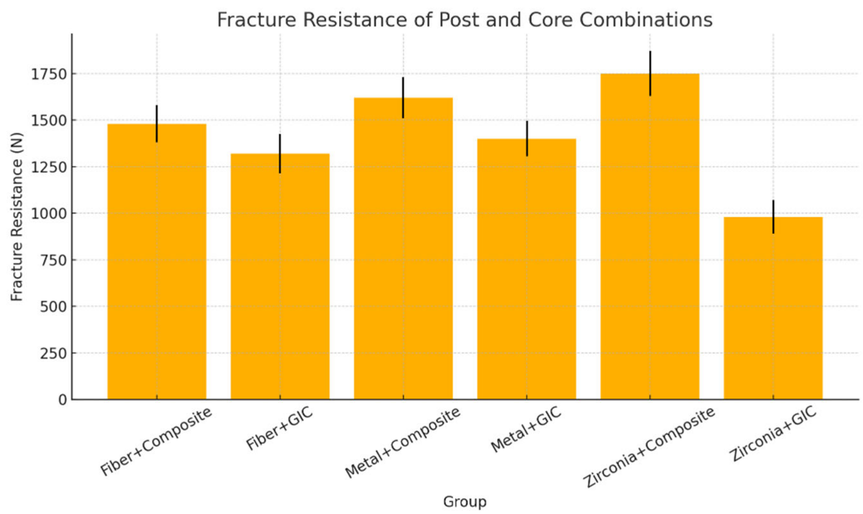

Figure 1: Fracture Resistance of Post and Core Combinations

procedures including root fractures. Restorable coronal fractures prevailed at 70% and 60% in fiber post groups 1 and 2 but not as frequently as non-restorable root fractures which occurred at 80% and 85% respectively in Groups 3 and 5 with metal and zirconia posts (Table 2, Figure 1).

Group 5 demonstrated the highest mean fracture resistance (1750±120 N), likely due to the high modulus of elasticity and strength of zirconia posts combined with the reinforcing ability of composite cores. On the other hand, Group 6 showed significantly lower resistance (980±90 N), suggesting that the brittleness of glass ionomer cores compromises structural support.

These findings indicate that fiber posts with composite cores provide a better balance of fracture resistance and favorable stress distribution, making them a preferable choice for restoring endodontically treated teeth.

DISCUSSION

Full-coverage crowns on endodontically treated teeth receive substantial biomechanical impact from their post type selection as well as core material choice. Studies showed that when using zirconia posts together with composite cores patients experienced maximum fracture toughness yet fiber posts spread deformation evenly across the structure to minimize significant collapse events. Multiple reports show that post rigidity and material characteristics determine how fractures occur in ETT restorations [1,2].

Zirconia posts supported by composite core material proved to be most resistant to fracture at 1750±120 N while fiber posts paired with glass ionomer core material exhibited 1320±105 N as their lowest resistance level. The high strength of Zirconia posts leads to increased stress transmission which subsequently raises the risk of non-restorable failure in the root [3,4]. Because of its similar elastic modulus to dentin material fiber posts distribute stress more evenly while decreasing the risk of root fractures [5]. Catastrophic failure rates in ETT decreased when fiber posts were used according to findings presented by Fokkinga *et al.* [6].

The resistance to fractures depended heavily on core materials where composite resin provided greater performance than glass ionomer cement. The enhanced mechanical properties of composite resin support both compressive strength and flexural strength which provide better resistance for the post-core complex [7]. Glass ionomer cores exhibit more brittleness which causes them to fail earlier when subjected to occlusal stresses according to previous research [8,9]. The research findings confirm those of Naumann *et al.* who established that post-retained restorations experience enhanced longevity when using composite resin cores instead of glass ionomer-based cores [10].

The research experimental design isolated the types of breakages which occurred when using various post-core system configurations. The fracture patterns present in groups with fiber post material mostly involved detachments between cores and crowns and were restorable to treatment. The use of zirconia or metal posts resulted in higher root fractures compared to other materials because these types of fractures prove challenging to remedy [11]. Studies before this one showed the same patterns with metal and zirconia posts creating root stress points which leads to irreparable damage [12,13]. The preference for fiber posts in clinical use is supported due to their effectiveness in preventing destructive damage to the teeth [14,15].

Rigidity in zirconia posts produces maximum fracture strength yet leads to interface stress focus which sets up the risk of non-restorable root fractures. The clinical application of zirconia should incorporate surface treatments with MDP-based primers and modified resin cements since these methods improve stress distribution throughout the bonding system.

Post shape and tooth surface structure determine which forces apply during biting and chewing activities. Posterior teeth under extensive masticatory forces may benefit from fiber posts because their flexible design enables better durability through shock resistance.

The research findings uncover the most suitable treatment method for ETT reconstruction. The maximum fracture resistance of zirconia posts rests in contrast to their potential to generate root fractures which affects their long-term outcomes. When used with composite resin cores fiber posts deliver a more precise failure pattern that qualifies them as superior options for repairing damaged teeth.

The research has several significant benefits yet certain sources of limitation exist. The test environment lacks accurate simulation of oral conditions because it does not account for moving forces and changes in periodontal ligament activity. Studies should conduct extended clinical trials to prove these experimental results occur in regular dental practices. Research needs to investigate brand-new post materials which combine strong biomechanical properties to expand clinical options.

Study Strengths:

- Comprehensive evaluation using six post-core combinations.
- Simulation of intraoral thermal cycling and functional load angles.
- Use of finite element analysis (FEA) for stress distribution evaluation.

Limitations:

- *In vitro* conditions do not simulate periodontal ligament and real-time occlusal variations.
- Variations in root anatomy and dentin age could influence outcomes.
- Lack of long-term cyclic loading and clinical follow-up data limits external validity.

Additional research must carry out randomized clinical trials supported by extended patient follow-up to validate these findings. Post design innovation through hybrid zirconia-fiber integration enables a potential solution that uses both the flexural strength of fibers and the rigidity of zirconia. Optimizing zirconia adhesive systems alongside post-design features that match tooth flexure behavior would lead to greater outcome success.

CONCLUSIONS

The choice of post and core materials determines endodontically treated teeth biomechanical response according to findings from this *in vitro* research. The utilization of fiber posts with composite cores created a perfect combination between strength requirements and ability to repair thus making them suitable for clinical settings which need both durability and maintenance capabilities. Zirconia posts combined with composite cores exhibit good fracture resistance yet post this combination in high-stress areas requires extra care because they demonstrate a higher incidence of root fracture.

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