

# Comparative Evaluation of Fracture Resistance and Failure Patterns Among All-Resin Post and Core Designs: In vitro Study

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**Purpose:** This in vitro study evaluated the fracture resistance of dual-cure resin cement and core build-up material (Core-X<sup>®</sup> Flow) used as all-resin posts of two different lengths, compared with conventional fiber-reinforced posts, and to analyze failure patterns.

**Material and Methods:** Thirty extracted human single-rooted mature teeth (premolars, canines, and maxillary central incisors) were endodontically treated and randomly assigned to three groups (n=10). Group A received a 10 mm fiber post with Core-X Flow, Group B received a 10 mm all-resin post with Core-X flow, and Group C received a 5 mm all-resin post with Core-X flow. Fracture resistance was evaluated under compressive loading using a universal testing machine, at a crosshead speed of 1 mm/min, and the failure patterns were assessed using a digital stereomicroscope. Data were analyzed using a one-way ANOVA (p>0.05).

**Results:** Fracture resistance did not differ significantly among the three groups (p>0.05). Mean values were 430.28 N for Group A, 422.16 N for Group B, and 434.56 N for Group C. Failure mode analysis showed that Group C (5 mm all-resin posts) exhibited the highest number of favorable (repairable) fractures, followed by Group A (fiber posts) and Group B (10 mm all-resin posts).

**Conclusion:** All-resin posts demonstrated fracture resistance comparable to fiber-reinforced posts. Shorter all-resin posts produced more favorable failure outcomes, suggesting that they may offer a conservative and clinically viable option for restoring endodontically treated teeth. These findings should be interpreted within the limitations of an in vitro design and small sample size.

**Keywords:** fiber reinforced posts, all resin post, post and core, fracture resistance, core-X flow

## Introduction

Endodontically treated teeth (ETT) differ from vital teeth in the amount of the remaining tooth structure and in their biomechanical behavior due to extensive hard-tissue loss from caries, trauma, or over-instrumentation.<sup>1,2</sup> Consequently, these teeth often require additional intervention to retain the core and the final restoration.<sup>3-5</sup> Restoring ETT also helps prevent reinfection of the root canal system, replaces lost tooth structure, and protects the remaining tooth structure.<sup>6</sup> As a result, these factors contribute to improving the long-term tooth survival.<sup>7</sup> Therefore, post-and-core systems were introduced as a standard treatment option for restoring structurally compromised teeth.<sup>1</sup>

Many types of post-and-core systems have been developed over the years, according to the post type, material, and design.<sup>8</sup> Recently, the emphasis on preserving tooth structure and improving esthetics has increased the use of tooth-colored, non-metallic posts.<sup>1</sup> Advances in adhesive dentistry have also shifted post-and-core concepts from mechanically retained restorations, toward systems that rely on adhesive bonding to enhance retention and stress distribution.<sup>7</sup>

Material selection plays a critical role in determining the performance of the post and the ability of the restored tooth to resist fractures.<sup>9</sup> Fiber-reinforced composite (FRC) posts have become an alternative to metal posts.<sup>1</sup> Because their modulus of elasticity is close to that of dentin, promoting more uniform stress distribution, thus decreasing the risk of



root fracture. Their favorable mechanical properties include adequate compressive and flexural strength, as well as thermal expansion. Moreover, FRC posts enhance aesthetics due to radiopaque quartz and glass particles, which further contribute to their clinical success.<sup>7</sup>

Despite their advantages, post space preparation is considered an invasive procedure, and clinicians debate whether a post is always necessary for restoring ETT. In contrast, core build-up materials offer simple clinical steps and conserve tooth structure.<sup>2</sup> Although fiber-reinforced posts have been extensively studied, evidence supporting the use of highly filled resin composites as a post-and-core monoblock is still limited, and the effect of different post lengths on fracture resistance, also failure behavior has not been clearly established.<sup>10</sup> These knowledge gaps provide the rationale for evaluating Core-X<sup>®</sup> Flow as an all-resin post in different lengths. Accordingly, the aim of this in vitro study was to evaluate the fracture resistance of the core build-up material (Core-X<sup>®</sup> Flow) as an all-resin post in two different lengths compared to conventional fiber-reinforced posts, and to identify the types of failure in each group. The null hypothesis was that no significant differences would be found in the outcomes of the compressive test nor in the failure modes when comparing the three different post-and-core systems.

## Materials and Methods

This in vitro study was conducted in the Faculty of Dentistry, King Abdulaziz University (KAUFD), Jeddah, Saudi Arabia. Ethical approval was obtained from the Research Ethics Committee of the KAUFD (No. 4598878). A total of 30 natural single-rooted teeth were collected from the Department of Oral and Maxillofacial Surgery Department at the KAUFD.

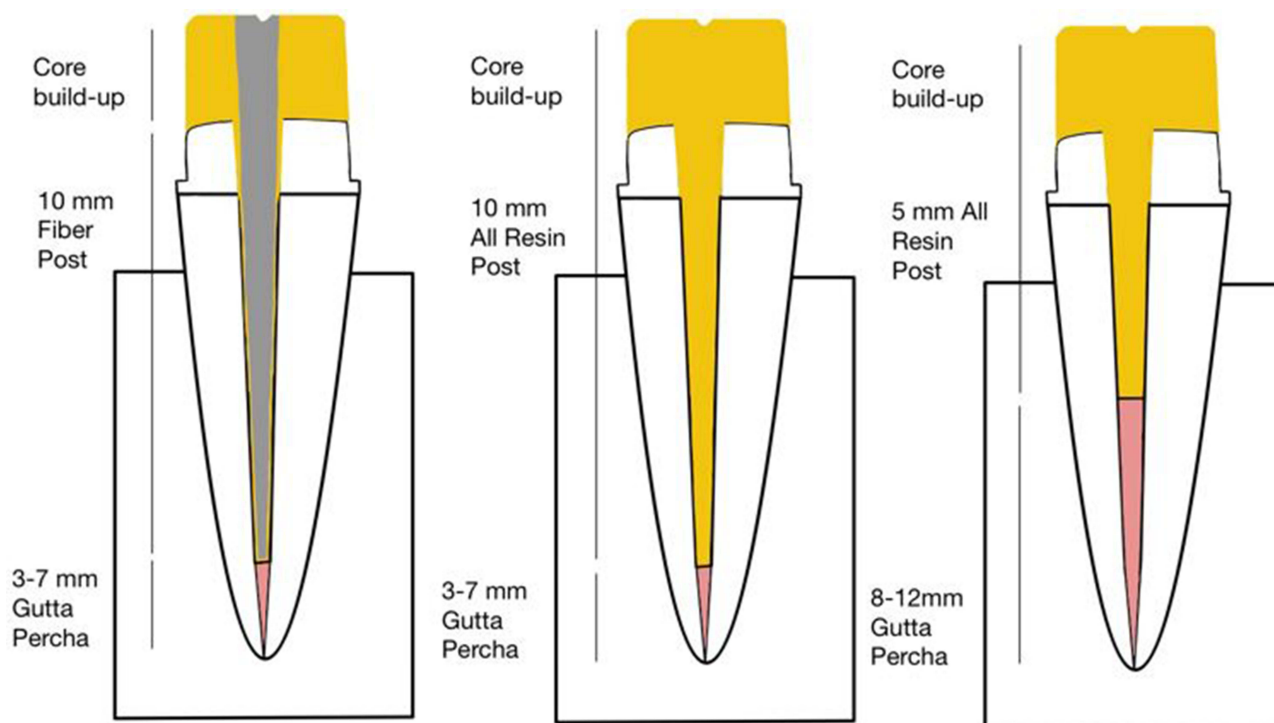
Inclusion criteria included mature premolars, canines, and maxillary central incisors extracted for orthodontic or periodontal reasons; free from caries, restorations, cracks, or pre-existing fractures as verified under magnification and transillumination. These single-rooted teeth were selected due to their similar root morphology, which allows standardized post-space preparation. Exclusion criteria included teeth from patients with infectious diseases, immature teeth, mandibular incisors, teeth extracted for reasons other than orthodontic/periodontal indications, and teeth of unusually small or large sizes. Teeth with unusually short or long roots were excluded to minimize anatomical variability. The specimens were cleaned to remove calculi and soft tissue remnants, rinsed, and stored in normal saline. Normal saline was used to preserve dentin hydration without altering tooth structure, as disinfectant solutions may modify mechanical properties. All samples were used within four weeks of extraction.

## Endodontic Treatment

Root canals were prepared using hand K-files up to size 30, followed by ProTaper Gold rotary files up to size F3 (Dentsply Sirona, Ballaigues, Switzerland). Irrigation was performed with 2.5% sodium hypochlorite, and obturation was performed using the lateral compaction technique with gutta-percha (Meta Biomed Co., Ltd., Chungcheongbuk-do, Korea) and a resin-based sealer (Adseal<sup>™</sup>, Meta Biomed). Post spaces were prepared using Gates Glidden drills (#2, #3) and a 1.6 mm post drill (RelyX<sup>™</sup> Fiber Post, 3M ESPE, St. Paul, MN, USA). Samples were numbered (1–30) and randomly allocated into three groups (n=10) using the Random Allocation Software (version 2.0). All samples were etched with 37% phosphoric acid and bonded using a single-component adhesive (Single Bond Plus; 3M, St. Paul, MN, USA).

## Post Placement and Core Build-up

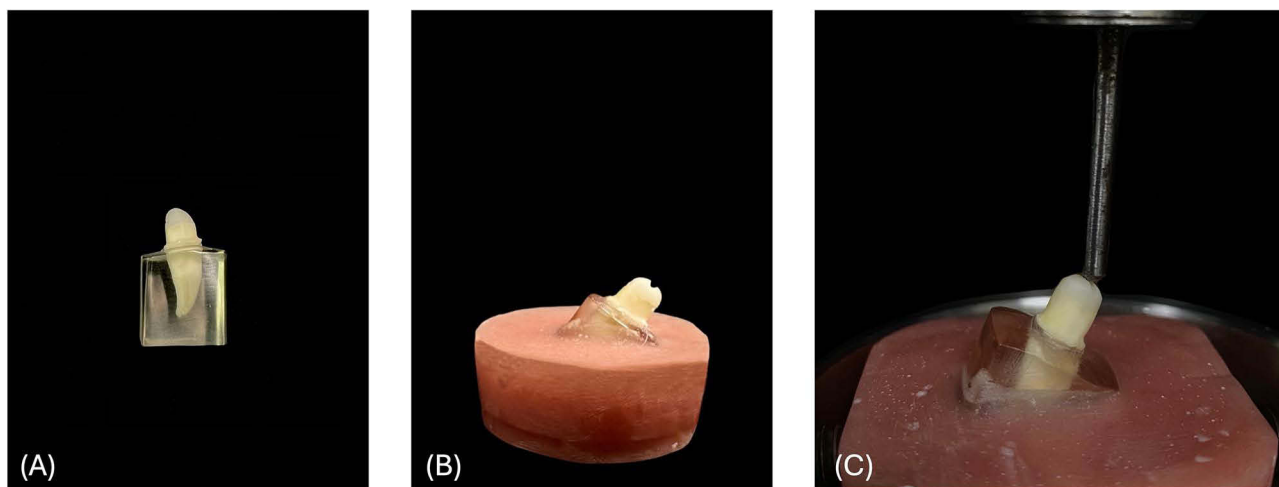
- Group A: Restored with a 10 mm fiber post (RelyX<sup>™</sup>, 3M ESPE) cemented and built with Core-X<sup>®</sup> flow (Dentsply DeTrey, Konstanz, Germany).
- Group B: Restored with a 10 mm all-resin post and core build-up using Core-X<sup>®</sup> flow without a fiber post.
- Group C: Restored with a 5 mm all-resin post and core build-up using Core-X flow without fiber post. The designs of the three post and core systems are shown in (Figure 1). Core-X<sup>®</sup> Flow is a dual-cure, highly filled composite resin containing urethane dimethacrylate, multifunctional methacrylates, and barium boron fluoroaluminosilicate glass, according to the manufacturer.



**Figure 1** Representative designs of all-resin post and core systems used in the study.

## Crown Preparation and Mounting

All specimens received standardized crown preparations with diamond burs (medium grit) maintaining a 2 mm ferrule. A mesiodistal groove was created to engage the loading rod during testing. Teeth were mounted in clear acrylic resin blocks and fixed at a 45° angle in cold-cure acrylic resin bases (PalaXtreme®, Kulzer GmbH., Hanau, Germany). To stabilize the specimens. Periodontal ligament simulation was not performed, consistent with similar in vitro fracture resistance studies. The mounting and testing setup is illustrated in (Figure 2).



**Figure 2** (A) Specimens mounted vertically in clear self-cure acrylic resin blocks. (B) Resin blocks further embedded at a 45° angle in pink cold-cure acrylic resin to simulate loading direction. (C) Mounted samples subjected to compressive loading using a universal testing machine.

## Fracture Resistance Testing

The specimens were subjected to compressive loading using a universal testing machine (Instron, Canton, MA, USA) until they fractured. A crosshead speed of 1 mm/min was used during all tests. All tests were performed at room temperature under dry conditions.

A schematic flow chart summarizing the experimental procedure is presented in (Figure 3)

## Failure Mode Analysis

Failure mode assessment was performed by an examiner blinded to the group allocation. Fracture patterns were analyzed using a digital stereomicroscope (RaySmart Technology Co., Ltd., Shenzhen, China). Fractures were classified as favorable (confined to the core, repairable) or unfavorable (extended into the tooth structure, nonrepairable). This assessment was qualitative in nature.

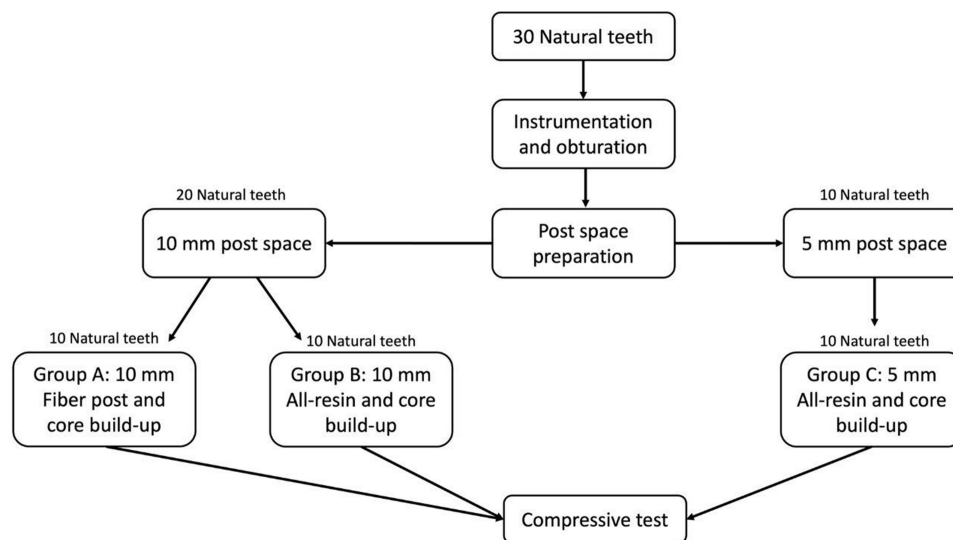
## Statistical Analysis

The data were recorded using Microsoft Excel (Microsoft Corp., Redmond, WA, USA). Normality and homogeneity of variances were assessed and confirmed prior to performing one-way ANOVA. The results were analyzed using one-way ANOVA with IBM SPSS Statistics for Windows (version 26.0; IBM Corp., Armonk, NY, USA). Effect size (eta squared) was calculated to describe the magnitude of group differences. Because ANOVA assumptions were met, non-parametric alternatives were not required. Statistical significance was set at  $p < 0.05$ .

## Results

All groups were tested under compressive strength using a universal testing machine. (Table 1) shows the mean and standard deviation of the applied force (failure point load) for the three groups. Group C exhibited the highest mean compressive strength resistance (434.56 N), followed by Group A (430.28 N) and Group B (422.16 N). One-way ANOVA revealed no significant difference in fracture resistance among the three groups ( $P > 0.05$ ) (Table 2).

Failure mode analysis was conducted using a Digital Camera Stereomicroscope to determine whether the outcomes were favorable (repairable) or unfavorable (unrepairable). Favorable fractures were defined as those occurring above the simulated bone level and considered restorable, whereas unfavorable fractures extended below this level and were deemed non-restorable. Group C displayed a higher number of favorable outcomes (7 samples) compared to Group A (6 samples) and Group B (5 samples). This corresponds to favorable fracture rates of 60% in Group A, 50% in Group B, and 70% in Group C, with unfavorable fractures occurring in 40%, 50%, and 30% of the respective groups. These data



**Figure 3** Flowchart illustrating the experimental methodology and specimen grouping.

**Table 1** Mean and Standard Deviation of Fracture Resistance Values in Newtons (N)

| Group | N  | Mean   | Std. Deviation | Std. Error | 95% Confidence Interval for Mean |             | Minimum | Maximum |
|-------|----|--------|----------------|------------|----------------------------------|-------------|---------|---------|
|       |    |        |                |            | Lower Bound                      | Upper Bound |         |         |
| A     | 10 | 430.28 | 39.58          | 12.52      | 401.97                           | 458.60      | 376.46  | 502.19  |
| B     | 10 | 422.16 | 40.26          | 12.73      | 393.37                           | 450.96      | 385.44  | 503.18  |
| C     | 10 | 434.56 | 47.71          | 15.09      | 400.43                           | 468.69      | 385.29  | 513.46  |
| Total | 30 | 429.00 | 41.51          | 7.58       | 413.50                           | 444.50      | 376.46  | 513.46  |

**Table 2** One-Way ANOVA Comparing Fracture Resistance (N) Among Groups

| Source         | Sum of Squares | df | Mean Square | F     | Sig.  |
|----------------|----------------|----|-------------|-------|-------|
| Between Groups | 792.91         | 2  | 396.45      | 0.218 | 0.806 |
| Within Groups  | 49174.87       | 27 | 1821.29     |       |       |
| Total          | 49967.77       | 29 |             |       |       |

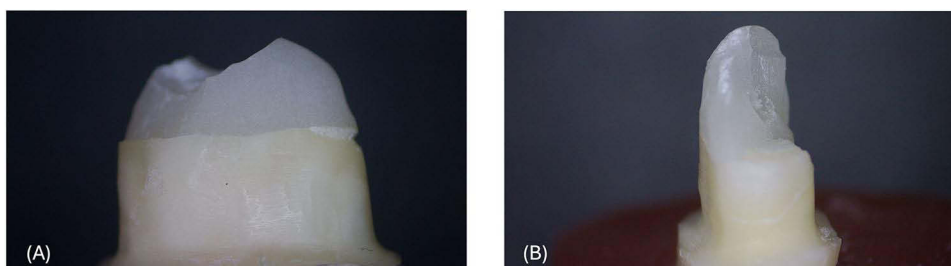
**Table 3** Distribution of Favorable and Unfavorable Failure Modes

| Group | Favorable (n) | Unfavorable (n) | Total (n) |
|-------|---------------|-----------------|-----------|
| A     | 6             | 4               | 10        |
| B     | 5             | 5               | 10        |
| C     | 7             | 3               | 10        |

are summarized in (Table 3). There were no statistically significant differences in failure mode distribution among the groups (Chi-square test,  $p > 0.05$ ). (Figure 4) represents a specimen of each type of failure.

## Discussion

A previous in vitro study explored the potential substitution of fiber posts with all-resin posts using epoxy resin blocks to simulate dentin strength by applying standardized measurements and techniques. Compressive strength testing was conducted on all samples positioned in an acrylic base at a 45-degree angulation using a universal test machine. The experimental results showed that the group of all resin posts with a length of 10 mm exhibited the highest mean compressive strength and maximum load, followed by all resin posts with a length of 5 mm and then prefabricated fiber posts with a length of 10 mm. Importantly, the results concluded that the use of the material was considered reliable because of the exclusion of multiple factors and the similar behavior under compressive strength testing in comparison to



**Figure 4** Stereomicroscopic evaluation of failure modes: (A) Core-only fracture with no damage to tooth structure, representing a repairable failure. (B) Fracture extending into the tooth structure, indicating a non-repairable failure mode.

fiber posts.<sup>10</sup> Currently, there is a growing demand for simple yet effective post-and-core systems.<sup>11</sup> According to Altassan 2024 et al, Core-X<sup>®</sup> flow stands out a promising option for post and core systems.<sup>10</sup>

This study replicated the previous measurements and techniques. However, in a previous study, bonding factors were excluded, relying solely on mechanical interlock for retention. In this study, bonding was incorporated as a retention method, in addition to the ferrule effect. An adequate ferrule should be at least 1–2 mm of the remaining tooth structure coronal to the finishing line to counteract functional lever forces, the wedging effect of tapered posts, and lateral forces during post insertion.<sup>12</sup> It is essential to study and determine fracture mechanics in structural engineering. This not only addresses the material's ability to resist fracture within itself but also predicts the failure of the loaded structure.<sup>13</sup> Notably, tooth fracture is one of the most common complications in endodontically treated teeth. Therefore, it is crucial to determine the fracture resistance of any restorative material in advance, as it provides a reference for evaluating material performance to replace natural tissue.<sup>14</sup>

For instance, metal alloys have been used as the gold standard, especially in curved canals or when a tremendous amount of coronal tooth structure is lost. However, using a material with a higher modulus of elasticity than that of dentin can produce unwanted stress, which consequently leads to root fracture or post-separation.<sup>14</sup> In addition, one of the most important factors affecting the fracture resistance of a cast post is its diameter; therefore, further preparation of the canal and extra removal of the dentin to accommodate thicker posts are required.<sup>15</sup>

When fiber posts with composite cores were compared to other types of posts, there was no statistical difference; however, it was evident that fiber posts with composite core teeth had a favorable fracture type, thus being more susceptible to retreatment.<sup>16</sup> Furthermore, Fiber-reinforced composite (FRC) posts have been used as a standard replacement for traditional metal posts. It is more resistant to microcracking and lower shrinkage owing to the presence of fibers in the resin.<sup>17</sup> Their modulus of elasticity is similar to that of natural dentin and is considered less stiff; thus, they exhibit better stress distribution along the root, resulting in a lower fracture incidence. However, there are insufficient data regarding its long-term clinical performance. The most reported failure mode is post dislodgement rather than tooth fracture.<sup>17,18</sup>

The dual-cure build-up and post-cement composite showed lower flexural strength and modulus of elasticity than the hybrid composite. In addition, it has a higher filler content, which improves hardness, stiffness, durability, and strength while minimizing polymerization shrinkage.<sup>19,20</sup> Namely, core-X<sup>®</sup> flow contain urethane Dimethacrylate, Di- and Tri-functional, methacrylates and Barium Boron Fluoroaluminosilicate Glass in form of base and catalyst and when mixed together produces a dual cured, highly filled, composite resin that has high compressive strength and “Cuts like dentine” according to the manufacturer. This material completely envelops the post through intra-oral tips without leaving gaps or voids and is also easy to cut and shape in addition to the absence of excessive hardness, which is often found in other core and restorative composite materials,<sup>21</sup> Using such materials minimizes canal preparation, offering less effort compared to traditional post types.

The post length significantly influences the stress distribution along the root.<sup>14</sup> Thakur et al investigated the impact of post length on two post types and found that longer posts correlated with higher fracture resistance, whereas shorter posts exhibited lower resistance. However, no statistical variance was noted between the two post lengths, a finding consistent with studies by Nissan et al and Chuang et al, which also reported no significant differences in post retention across varying lengths.<sup>22–25</sup> Consequently, despite differences in fracture load, post length did not notably affect fracture resistance in the endodontically treated teeth. This underscores the viability of fiber-reinforced composite (FRC) posts and cores as alternatives to the traditional metal options. The findings of this study are consistent with those of previous studies, showing no significant difference between the all-resin post systems at 5- and 10-mm length.

Failure mode analysis of the samples exhibiting either a repairable type, which describes the fracture site only to the core, or a non-repairable type, where the fracture extends to the tooth structure. No Significant differences in the failure modes across all post-designs were evident in the study results. However, following the experiment, a digital camera stereomicroscope was used to observe failure modes. Group C demonstrated a superior number of favorable outcomes, totaling seven samples, surpassing both Group A with six samples and Group B with five samples. The underlying causes of these failures include potential issues related to bonding, post-geometrical design, variations in core size, structural integrity, and tooth condition after extraction. The results suggest comparable outcomes among the tested post-system designs.

Owing to the nature of this *in vitro* study, several limitations are evident. The small sample size may have prevented the extrapolation of the results. The samples were mounted on a rigid acrylic support and subjected to compressive strength testing without the effect of the periodontal ligament. This can alter the stress distribution around the root, thereby altering the failure load and the fracture mode. Because the oral cavity is not a static environment, restorative materials are subjected to dynamic temperature and loading conditions. Additionally, to mimic chewing action and lateral glide, resin blocks were mounted at 45 °, although this was not feasible.

## Conclusion

All-resin post designs demonstrated fracture resistance comparable to that of fiber posts, with slightly more favorable failure patterns observed in the shorter all-resin post configuration. These findings suggest that all-resin posts may represent a conservative and clinically viable option for restoring endodontically treated teeth. However, the results should be interpreted within the limitations of this *in vitro* study, including the absence of periodontal ligament simulation, thermomechanical aging, and multidirectional loading, as well as the relatively small sample size. Further research under clinically simulated conditions is recommended to validate these findings.

## Ethics Approval and Consent to Participate

Ethical approval was obtained from the Research Ethics Committee at King Abdulaziz University, Faculty of Dentistry (KAUFD) (Approval No. 4598878; approval date: 28 January 2024). All patients whose extracted teeth were used in this research provided written informed consent, in accordance with the Declaration of Helsinki.

## Patient Consent Declaration

This study did not involve direct interaction with patients or the use of identifiable personal data; therefore, patient consent was not required.

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## Disclosure

All authors declare no conflicts of interest in this work.

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