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ORIGINAL ARTICLE

Structural integrity of extracted teeth restored using three different post-and-core systems: An in vitro comparative study

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KEYWORDS

Customized post-and-core;
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Strain fracture resistance;
Zirconia support

Abstract *Aim:* The objective of the study was to assess the in vitro fracture resistance of endodontically treated teeth restored using different post-and-core materials.

Materials and methods: Extracted human mandibular premolars (n = 36) were extracted teeth and equally distributed into four (4) treatment groups: cast metal post-and-core, milled zirconia post-and-core, pre-fabricated post with composite resin core and control group. These samples were then each subjected to the load to fracture test using a universal testing machine. Fracture resistance data were compared among groups by analysis of variance and Fisher's exact test.

Results: The highest mean fracture resistance value was observed in the zirconia post-and-core treatment group (1567.26 ± 317.66 N), followed by the cast metal (1355.92 ± 621.56 N) and lastly the pre-fabricated post with composite resin core (725.67 ± 251.05 N) treatment group. Differences among groups were not statistically significantly different (P = 3.77).

Conclusion: Endodontically treated mandibular premolars with a zirconia post-and-core system exhibited the highest robustness against structural failure based on its mean fracture resistance value. In addition, extracted teeth restored with cast post-and-core resisted a greater stress load than those restored with fiber-reinforced posts. Zirconia showed a more favorable fracture mode than the other restorations.

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1. Introduction

Dental restoration of structurally compromised extracted teeth is usually achieved by using a post, core, and crown. The extent of the remaining tooth structure defines the appropriate treatment plan, along with other considerations, such as the vitality of the tooth, periodontal status, and endodontic treatment (Schwartz and Robbins 2004). Additionally, dehydration and the stiffness of non-vital teeth contributed in root fracture (Makade et al. 2011, Khasnis et al. 2014). Thus, dental posts constructed from materials possessing similar properties as dentin are used in order to endure normal occlusal stress (Steele 1973).

Cast metal post-and-core systems have gained in popularity, due to their high success rates, favorable long-term prognoses, easy manipulation, and low cost. Furthermore, since these posts are custom-made, they reproduce the morphology of the canal with good accuracy (Habibzadeh et al. 2017). In contrast, reports of adverse reactions and chances of corrosion and root fracture, along with their negative effects on the esthetics of the teeth, have prompted a search for alternative techniques for structurally enhancing endodontically treated teeth (Habibzadeh et al. 2017).

Advancement in dental posts with identical tooth color have enhanced the appearance of post-and-core-treated teeth (Sidoli et al. 1997). The success rates of fiber-reinforced post restorations (90%) are higher than those of cast metal post-restorations (84%) (Ferrari et al. 2000). However, the fracture resistance of anterior teeth restored by customized, ready-made, and fiber-resin dental posts were not statistically significantly different (Raygot et al. 2001).

Many studies have investigated the resistance of fracture mechanic of endodontically treated teeth. The mechanical properties, stability, and dynamics of these application enhancing performances have yet to be established (Ozkurt et al. 2010). Hence, the present study compared the root fracture resistance of extracted teeth that were restored using glass-fiber, cast metal, or zirconia posts. The experimental hypothesis was that the three post-and-core treatment systems would show statistically significantly different resistance towards root fracture in an in vitro tensile and compression testing model.

2. Materials and methods

The study protocol was reviewed and approved by the Clinical Research Ethics Committee, Dental College Princess Norah bint Abdurrahman University with an IRB Log Number 17-0172.

2.1. Specimen preparation

Newly extracted, intact human teeth with the following dimensions and root lengths were collected:

Cementoenamel junction to apex distance:	14 mm
Faciolingual-width dimension:	6–8 mm
Mesiodistal dimension:	4–6 mm

The digital calliper was used to meaure the distence from Cementoenamel junction to apex distance. Teeth with very long or very short teeth with severe curvaturewere excluded from the study, as were teeth with any cracks or caries.

The teeth were immersed in a 0.9% physiological salt solution under ambient temperature. Radiographs taken in two buccolingual and mesiodistal dimensions were used for detection of any calcification, internal resorption, open apex and accessory canals; teeth showing these features were also excluded.

The included teeth (n = 36; mandibular first premolars) were then equally distributed into four groups (n = 9 per group) and then soaked for 5 min in 5% aqueous sodium hypochlorite to remove organic materials from the root surfaces. Root canal treatment was performed, and all roots were calibrated uniformly. The anatomic root length was 1 mm longer than the distance from the coronal reference point to the furthest point of canal preparation and obturation. Root canals were prepared with anF3 rotary file (ProTaper ® Universal, Switzerland) and flushed intermittently with copious amounts of 5% aqueous sodium hypochlorite. Absorbent paper points were used to dry the root canals prior to filling with a single F3 gutta-percha cone and AH26 Sealer (Dentsply DeTrey Gmblt 78,467 Konstanz, Germany) via lateral condensation. Obturated teeth were maintained submersed in 0.9% sodium chloride solution, at 37 °C, throughout the study. A silicone impression material (Imprint™ II Garant light-body, 3 M™ ESPE™, Maplewood, MN) was spread thinly onto the root surface prior to embedding the teeth in resin, to mimic the periodontal ligament. The teeth were then individually placed upright in a resin cube (2.8 cm × 2.8 cm × 2.8 cm, RAPID REPAIR, Dentsply) with the cementoenamel junction positioned 2 mm above the acrylic surface. The blocks were modified as necessary to mount them to a retention platform in the universal testing machine.

2.2. Post space preparation

The post space of an individual tooth setup (9-mm orifice depth, size 1–4, and apical seal of 3–4 mm) in the treatment groups was accomplished using a Gates Glidden drill instrument set at 2000 rpm.

Control group included No posts were installed with the applied core material as the control. The gutta-percha was removed, and 3–4 mm of gutta-percha was left as an apical seal. The dentine was etched with 37% aqueous phosphoric acid gel (Total Etch, Ivoclar Vivadent, Schaan, Liechtenstein) for 15 s, prior to washing the surface with water. The core was dried with paper points followed by application of the bonding agent, EXCITE F (Ivoclar Vivadent, Switzerland). Finally, the multicore Flow (Ivoclar Vivadent, Liechtenstein, Switzerland) material was inserted into the etched chambers with the core reconstructed to the preferred dimensions employing the same material.

Cast metal post-and-core group included a root canal impression, which was achieved using a plastic speedy point technique (a direct technique for post and core build up). The post-and-core system was then built via investment casting of the base metal alloy (4all, Ivoclar Vivadent) in Beauty-Cast

(Whip Mix Corp., Louisville, KY) withoutring liners. The resulting customized metal support was fine-tuned and subjected to air abrasion with 50-µm aluminum oxide. Zinc phosphate (Dentsply DeTrey Zinc Phosphate Powder) was applied as cement after adequate etching and irrigation.

Fiber-glass post group included a fiber-glass post of the appropriate size (RelyX, Fiber 3 M ESPE), as confirmed by radiography, was selected and cemented with dual cure resin-bonding agent (G-CEM™ Capsule, GC Dental Products Corporation, Tokyo, Japan). The core was a dual cure core build-up material (MultiCore, Ivoclar Vivadent).

Custom-built zirconia post group included the casting method described for Group B used in this group. The post-and-core system was then build up using and CAD/CAM (Opera system, Zirkonzahn, Gais, Italy). Cast zirconia, cemented with resin cement (G-CEM™ Capsule), was utilized to reestablish the structural integrity of the root.

2.3. Fracture resistance test

Endodontically treated tooth samples in the control and treatment groups were subjected to increasing stress loads until structural failure, by means of a universal testing machine (Instron 3369, Norwood, MS).Test samples were positioned at a 90-degree angle to the long axis of the tooth, with the stress load applied equidistant amid the lingual and buccal cusps. Chisel shaped Stress load with 12 mm width, expressed in Newtons, were applied at a constant speed of 0.01 cm/min and load application was continued until the mode/s of failure were determined (Abduljabbar et al., 2012). Fracture modes were digitally captured, recorded and it was related to the tooth structure level. Structural failure above the acrylic margin were classified as restorable while those beneath it were treated as non-restorable (Makade et al. 2011) (Fig. 1).

2.4. Statistical analysis

Fracture resistance, defined as the maximum load-to-failure, was assessed across the three treatment groups using analysis of variance (ANOVA). In addition, Fisher's exact test was used to measure consistency in the mode of fracture.

3. Results

In the present study, the fracture resistance of zirconia posts (1567.26 ± 317.66 N) was higher than that of metal cast posts (1355.92 ± 621.56 N). Fiber post-and-core systems exhibited the weakest fracture resistance among the three techniques investigated (725.67 ± 251.05 N) (Fig. 2). Differences in the fracture resistance values (maximum load-to-failure) detected in the occluso-gingival and bucco-lingual dimensions of the crowns and roots were not statistically significant among the treatment groups, based on ANOVA (p-value = 3.77).

In Custom-built zirconia post group, five fractures occurred vertically to a point beneath the acrylic resin, and four horizontal fractures occurred above the acrylic margin. Five fractures were considered non-restorable and four were restorable. In the cast metal post group, six structural failures occurred vertically to a point below the acrylic margin and, thus, were considered non-restorable, while three horizontal fractures occurred above the margin and were considered restorable. In the fiber-glass post group, seven non-restorable vertical fractures occurred, and two restorable horizontal fractures occurred. Zirconia and fiber-glass posts exhibited statistically similar fracture resistance, based on Fisher's exact test (0.17). However, the number of restorable fractures differed statistically significantly between the zirconia treatment group and the cast metal post group (0.05) (Table 1).

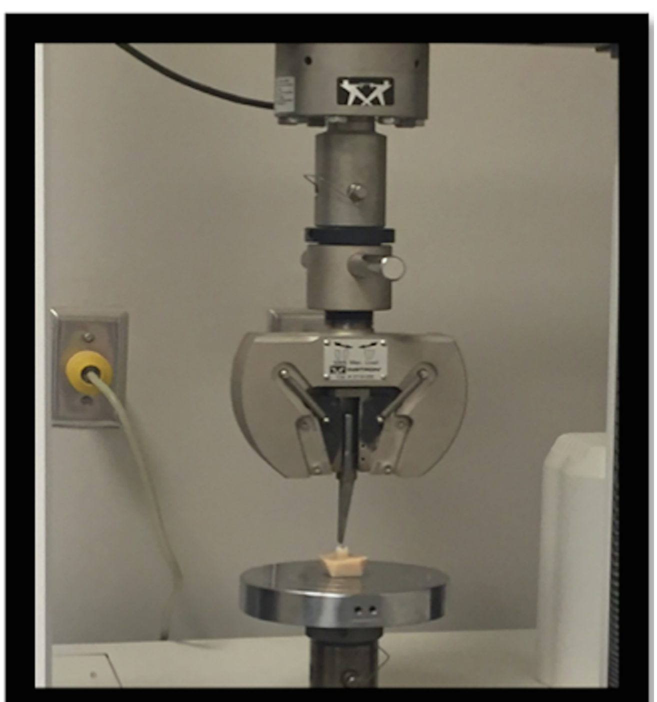

Fig. 1 The universal testing machine (Instron 3369).

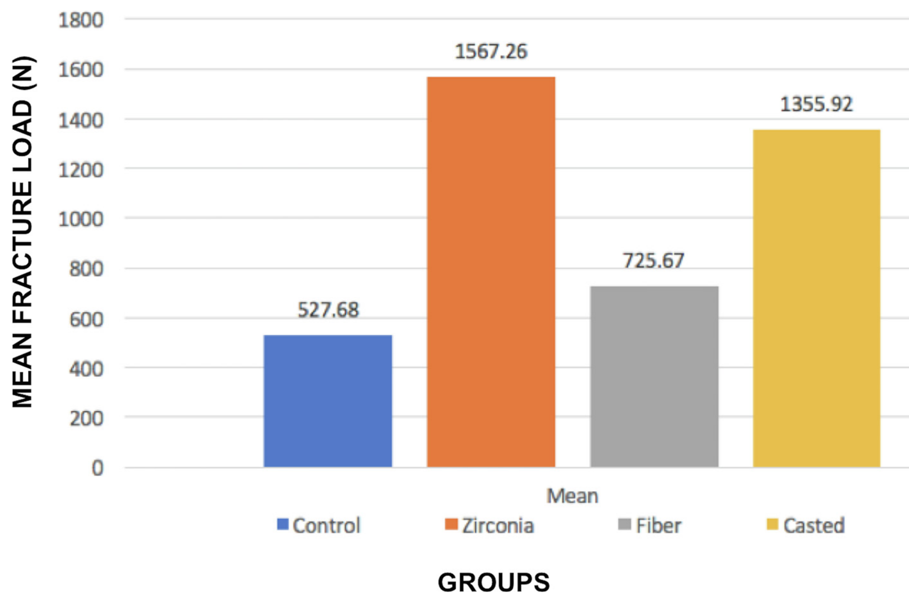

Fig. 2 The mean fracture load among the three groups studied.

Table 1 P-values for comparison between the fracture modes in the three groups of specimens.

	Fiber	Zirconia	Cast metal
Fiber	–	0.1667	–
Zirconia	–	–	0.0476*
Cast metal	0.0833	–	–

4. Discussion

The capacity of restorative supports to tolerate, transfer, and disperse stress load is essential in order to inhibit structural failure effectively. The present study presented three different post-and-core treatment systems that are extensively used for restoration of endodontically treated teeth (fiber-glass, zirconia, and cast metal posts) (Al-Wahadni and Gutteridge 2002, Ottl et al. 2002) and assessed their capacity to resist fracture. The customized zirconia post-cores showed significantly higher mean values for fracture resistance; these values were lower for fiber-glass posts. However, this difference in fracture resistance was not significant in comparison with the cast metal group.

Previous studies have reported contradictory results regarding the influence of posts in restoring structural integrity of endodontically treated teeth (Pereira et al. 2006, Buttel et al. 2009). A number of factors were shown to influence fracture resistance, including crowning the samples, the extent of remaining tooth tissue, the expanse of the collar support or dental ferrule, the rate and direction of load application, the material utilized for restoration, the bonding type, and the post dimensions. In the current study, teeth were not crowned, based on the recommendation of Friedel and Kern (Friedel and Kern 2006, Santos Pantaleon et al. 2018). They evaluated the fracture resistance properties of various zirconium posts systems for endodontic treated tooth with and without receiving crowns, and concluded that, when a crown is placed over the tooth, the post-and-core systems do not contribute to fracture resistance. In addition, the roots of natural teeth were used in our study, as this has been recommended in a number of previous studies. Using artificial roots diminish stress values leading to fracture, because they lower the influence of physical disparities between natural teeth and the post system (Santos Pantaleon et al. 2018).

In the present study, the load applied to fracture zirconia posts was greater than that required to fracture fiber and cast metal post systems. This could be attributed to the higher flexural strength (900–1200 MPa) and superior mechanical properties of zirconia, as reported previously; in addition, the vertical direction of load application may have had an effect. On the other hand, the high elastic modulus of zirconia posts (200 MPa) makes them very strong and stiff, and prevents them from showing plastic behavior (Piconi and Maccauro 1999, Sen et al. 2011). Forces applied to endodontically treated teeth restored with fiber-glass post are thought to be predominantly absorbed by the post itself, thus reducing stress on the root and leading to a lower probability of fracture (Pfeiffer et al. 2006, Stricker and Gohring 2006, Barcellos et al. 2013). Several studies have supported this hypothesis (Stricker and Gohring 2006, da Silva et al. 2010). As noted previously, the elastic modulus of fiber-glass posts is 3–4 $\times$ 10^{10}N/m^2, which is more similar to dentin than is that of either cast metal or zirconia posts (Gu et al. 2007). Consequently, using these posts to reinforce endodontically treated teeth facilitates the normal bending actions of the tooth, leading to less pressure accumulation at the edges, and as a result, the tooth–restoration complex shows a biomechanical behavior comparable to that of an undamaged tooth (Cohen et al. 1996). However, in this study, the fiber-glass posts exhibited lower resilience against fracture due to the vertical direction of the force.

Freedman stated that, due to the greater stress accumulation in the apical area, cast metal post-and-core systems caused more vertical root fractures than did other systems (Freedman 2001). Akkayan and Gülmez also observed that quartz fiber and fiber-glass posts are more resistant to catastrophic fracture failure than are titanium and zirconia posts. They hypothesized that titanium and zirconia, which are characterized by high rigidity and high elastic modulus, completely transfers the stress load to the tooth, without dissipating it, and thus, causing tooth fractures (Akkayan and Gulmez 2002). Raygot et al reported that teeth restored with cast metal, prefabricated, or fiber-reinforced posts showed no significant difference in fracture resistance, similar to the findings of our study (Raygot et al. 2001).

Comparative studies on fracture resistance of zirconia-composite and zirconia-ceramic post-and-core systems have been reported. Posts with ceramic cores demonstrated higher fracture resistance than those with composite cores (Ferrari et al. 2000). These results were congruent with current study.

In the present study, a tensile and compression testing machine (Instron®) was employed to measure, in a static manner, the fracture resistance of endodontic teeth with post-and-core systems. Moreover, custom-milled zirconia posts were utilized instead of prefabricated zirconia (Heydecke et al. 2001). However, the use of a chewing simulator and cyclic loading of the samples may better simulate the clinical situation, and further in vitro studies with larger sample sizes may be better. Moreover, a prospective clinical study with a long-term follow-up of 5or more years would be useful to evaluate the effectiveness of zirconia as a restorative material for endodontic posts.

5. Conclusion

Within the scope of the study, zirconia yielded a higher mean fracture resistance value than that of a cast metal post system. Among the different systems investigated, fiber-glass posts were most vulnerable structurally. Zirconia showed a more favorable fracture mode than the other groups. This study showed that fiber-glass post has a greater variability in fracture resistance than ceramic posts or metal posts; accordingly, it would be preferable to use fiber-glass posts in a clinical setting.

6. Author declaration

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We understand that the Corresponding Author is the sole contact for the Editorial process (including Editorial Manager and direct communications with the office). She is responsible for communicating with the other authors about progress, submissions of revisions and final approval of proofs. We confirm that we have provided a current, correct email address which is accessible by the Corresponding Author and which has been configured to accept email from (asaldegheishem@pnu.edu.sa).

Ethical statement

The consent and ethical clearances for the study were obtained from the institution ethical committee, College of Dentistry, PNU and all the Participants signed the consent form in the beginning.

This material has not been published in whole or in part elsewhere.

The manuscript is not currently being considered for publication in another journal.

All authors have been personally and actively involved in substantive work leading to the manuscript and will hold themselves jointly and individually responsible for its content.

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