Original Article

Evaluating Efficacy of Different Post Materials and Lengths on Bonding Strength Between Root Canal Dentin and Post Restorations: An Experimental Study

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Abstract

Background: During post restoration, different root structures require several types of posts to increase duration of their clinical use. Several materials have been investigated to enhance their quality and optimize their length according to the available root canal. **Aims:** The aim of this study was to determine the effect of zirconia, fiber, and ceromer posts with 3- and 6-mm post sizes on the bonding strength of them to root canal dentinal wall with the means of pull-out bond strength test. **Methods:** Forty-eight single-rooted mandibular human premolar teeth were collected and prepared for this *in vitro* study. With resin cement, 3- and 6-mm study posts including zirconia, fiber, and ceromer were luted to prepare teeth. For the retention testing, the pull-out force was applied to each specimen parallel to longitudinal axis of both the post and tooth. **Results:** Both type of materials and size of posts changed the value of bonding strength. In all the post types, 6-mm ones performed better. Overall, the best bonding strength was obtained with fiber posts and the better bonding strength was obtained with zirconia; however, ceromer provided the least bonding strength. **Conclusion:** Current experiments supported that 6-mm post size can increase the bonding between root canal dentin and studied posts. When considering post materials, fiber provided the best bonding strength in current laboratory setup. Second, zirconia had meaningfully acceptable bonding strength; however, the bonding strength of ceromer posts was not favorable. Further studies optimizing post fabrication techniques of root materials may increase the bonding strength of posts to human dentin to an acceptable clinical degree.

Keywords: *Dental prosthesis retention, dentin, post and core technique, shear force*

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Introduction

Retention of coronal structure and health of periodontal tissues should be provided with the restoration of root-filled teeth.[1,2] If more than 50% part of the coronal structure is damaged, post application is required to provide extra strength to the tooth.[3] Remaining coronal tooth tissue is mostly insufficient for supporting the restoration in anterior and premolar teeth without post applications.[4] The selection of post is dependent on the remaining root, its size, and shape.[5] For decades, cast metal posts have been used for treating of root-filled teeth. Even though these conventional posts have high retention and thin resulting cement film, they have a high elastic modulus and can result in root fractures.[6] Similar elastic modulus of fiber posts, resin cements, and dentin is beneficial to enhance the performance of restorations.[7] The advantages of ceramics and reinforced resins compared to metal alloys are the elimination of galvanic corrosion[8] and decrease of toxicity of metallic ions.[9,10]

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Production method, material type, and size of the post are important factors for the retention.[11,12] Optimal preparation of post space is essential to achieve adequate retention. The remaining short and curved root restricts the use of a longer dowel.[13] *In vitro* studies have revealed that cements reinforced with resin may be used to tolerate reduction of the length.[14] For the prosthetic treatment of root-filled teeth with major hard tissue loss, the use of fiber posts and self-adhesive resin cement is a popular treatment solution. In scientific literature, many studies have revealed that the successful clinical results of fiber posts were associated with mechanical stress and their superior retention values.[15,16] Elasticity modulus of fiber post and dentin are alike (resp., 18–22 GPa and 18 GPa); thus, this material is used to reduce the risk of root fracture.[17,18]

Zirconia posts are tooth-colored materials and generally used in anterior teeth for esthetic reasons.[19] Commercially available prefabricated zirconia posts may be preferred by the clinicians for the treatment of root-filled teeth. In addition, for the increasing the strength of the teeth with wide root canals, one-piece zirconia posts can be manufactured with CAD/CAM technology after taking impression from the root canal. Zirconia posts have some advantages including greater resistance,[20] greater toughness, and adequate esthetics.[21,22] However, elasticity modulus of zirconia material is not similar with dentin. This is a disadvantage of zirconia material that can cause vertical root fracture because of transmitting the chewing force directly from zirconia post to the root canal.[23] There are ceramic optimized resins/polymers (ceromers) among the advanced types of composite materials. The properties of ceramic fillers are also used to enhance the physical and mechanical properties of composites like improved mechanical strength and abrasion resistance.[24,25]

Survival of post restorations depends on retention to the root canal. Loss of retention is primary failure mode for post restorations and this was shown in both *in vivo* and *in vitro* studies.[26-28] However, there is still no consensus on the type of post regarding its material and size that can provide more superior long-term clinical retention of post-retained restorations. It was thought that dentinal wall needs to be improved with the investigation of suitable materials and the optimal size of posts in order to improve the bonding strength of posts to root canal. The purpose of this study was to assess the effect of zirconia, fiber, and ceromer posts with 3- and 6-mm post sizes on their bonding strength to root canal dentinal wall by pull-out bond strength test. The null hypothesis was that the pull-out strengths of zirconia, fiber, and ceromer with different post sizes to root dentin surface were similar.

Material and Methods

Approval from the Human Research Ethics Committee of our university was obtained (No: 2019-08/17). In this *in vitro* study, forty-eight single-rooted mandibular human premolar teeth that extracted with orthodontic or periodontal indications without any caries or previous restorations were used. Digital radiographs of teeth were taken from the buccal and proximal directions to determine the number and morphology of their canals. After dental plaque, calculus, and periodontal tissues were cleaned, they were kept at + 4°C in 0.9% saline solution during the whole study. The coronal part of the tooth was cut using diamond discs below the level of the cemento-enamel junction under cooling water to obtain a 14-16 mm length for each root. First, a 15-number K-File (Mani Inc., Japan) hand tool was used to enter the canal. Working length of the canal was determined by transmitting the file until it can be seen in the apical foramen. Then, the file was withdrawn 1 mm from the apex. Root canal preparation was performed with Protaper Universal (DentsplyMaillefer, Switzerland) system according to the crown-down technique by using an electric motor (Dentaports ZX, J. Morita Mfg. Corp., Japan). The root canals were irrigated with 1 mL of 5.25% NaOCl solution after the use of each file. Then, root canals were dried with paper points. Afterward, they were filled with lateral condensation technique using AH Plus (DentsplyMaillefer, Switzerland) and gutta-percha. For the preparation of post space, gutta-percha in the root canal was removed and space was created with a size #3 fiber post drill (D.T Light-Post, Bisco Inc., USA) for two post lengths: 3 mm and 6 mm.

For the production of zirconia post, 3D shape of post space was captured with light body (Elite HD+, ZhermackSpA, Italy) and putty (Elite HD+, ZhermackSpA, Italy) polyvinyl-siloxane impression materials. Light-body impression material was delivered into the post hole and a plastic-post was used as a carrier for this impression. The putty material was prepared by hand and applied to coronal part of the post restoration for facilitating its removal. After setting of the impressions, they were removed from the post space by ensuring that it extends to end of the prepared post space, it will not lock into any undercut, and it is free of any voids or defects. For digitalizing the impression, contrast spay (Calidia, Whitepeaks Dental Solutions Inc., Germany) was applied to the impression and scanned with model scanner (Dental Wings 7 Series; Dental Wings, Canada). Post and core structures were designed in software (DWOS, Dental Wings, Canada) [Figures 1 and 2] and subtracted from pre-sintered Y-TZP disc-shaped block (ST, Upcera, China) by using milling machine (DC40, Yenadent, Turkey). After computer-aided design (CAD) and computer-aided manufacturing (CAM) process, the samples were sintered to full density in a high-temperature furnace (Protherm; B and D Dental Origin Milling, USA) at 1480°C for 2 h according to the manufacturer's instructions [Figure 3].

For the production of ceromer post, individual molds were prepared for 3 mm and 6 mm groups separately using polyvinyl-siloxane impression material. For the preparing of individual mold, a fiber post was measured with scale (Endoring II, JordcoInc, USA) and placed into impression material before set of the impression. After setting, fiber post material was carefully removed from the impression; thus, appropriate space for the production of ceromer post was created. Then, ceromer material was placed into space and carefully adapted with a hand instrument (OP2X, Optident Ltd, UK). Ceromer material was polymerized for 20 s with a light-curing device for removing easily from the mold. After they were removed from the mold, they were subjected to a polymerization process according to manufacturer's instructions. First, ceromer posts were polymerized by Light Curing-300 device for 270 s. Then, final polymerization was performed with Heat-Curing-110 furnace for 15 min at 100°C–110°C.

After preparation of all post restorations, they were cleaned by using 95% ethyl alcohol and air-drying. For the cementation, a self-adhesive resin cement (G-Cem, GC Corp., Japan) was delivered into the post space with a lentulo spiral (Mani Inc., Japan). Post restorations were seated to post hole and held under moderate finger pressure for 10 s. The excess cement was gently removed using microbrush after the posts-core restorations were completely seated. The surfaces were light-cured for 40 s with a light-emitting diode light polymerizing unit (Smartlite, Dentsply, USA).

For pull-out testing, each specimen prepared for the study was embedded in autopolymerizing dental acrylic (Meliodent, Heraeus Kulzer, Germany) in aluminum cylinders with a diameter of 14 mm and a height of 12 mm. Thereafter, the specimens were stored in distilled water for 1 week at 37°C. For the retention testing, the pull-out force was applied to each specimen parallel to longitudinal axis of both the post and tooth by a universal test machine (Lloyd LF Plus, AmetekInc, UK) with a cross-head speed of 2 mm per minute. Maximum tensile force (N) was recorded for each specimen.

Statistical analysis

The data were expressed as mean ± SD. Statistical analysis of the data was performed using a Kolmogorov-Smirnov test to examine normality and then a one-way analysis of variance, Tukey *post hoc* tests, and t-test to compare the pull-out bonding strength data. A P value of less than 0.05 was used to describe significant differences.

Results

Figure 4 presents the values of pull-out bonding strength of zirconia, fiber, and ceromer posts sized 3 and 6 mm. ANOVA and t tests revealed that overall bonding strengths of studied specimens were significantly different. Both type of materials and size of posts changed the value of bonding strength. The bonding strength of 6-mm zirconia post was significantly higher than the bonding strength of the 3-mm zirconia post (8.40 ± 0.22 vs. 7.73 ± 0.20; $P < 0.05$). The bonding strength of the 6-mm ceromer post was significantly higher than the bonding strength of the 3-mm ceromer post (7.48 ± 0.21 vs. 7.10 ± 0.14; $P < 0.05$). Although the bonding strength of the 6-mm fiber post was higher than the bonding strength of the 3-mm fiber post, this difference was not statistically significant (8.75 ± 0.19 vs. 8.55 ± 0.17; $P > 0.05$).

The pull-out bonding strength test revealed that there was a significant difference between 3-mm fiber and zirconia posts regarding the bonding strength values (8.55 ± 0.17 vs. 7.73 ± 0.2; $P < 0.05$).The bonding strength of the 3-mm zirconia post was significantly higher than that of the 3-mm ceromer post (7.73 ± 0.2 vs. 7.10 ± 0.14; $P < 0.05$). The 3-mm fiber post had significantly higher bonding strength compared to the 3-mm ceromer post (8.55 ± 0.17 vs. 7.10 ± 0.14; $P < 0.05$). The bonding strength of the 6-mm zirconia post was significantly higher than the bonding

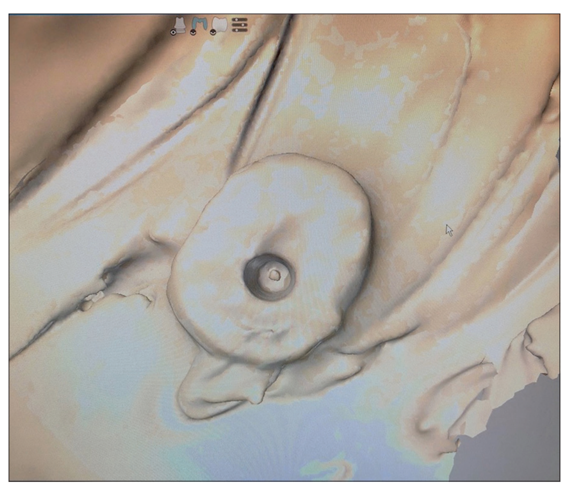

Figure 1: Representative images of the post hole on digital software

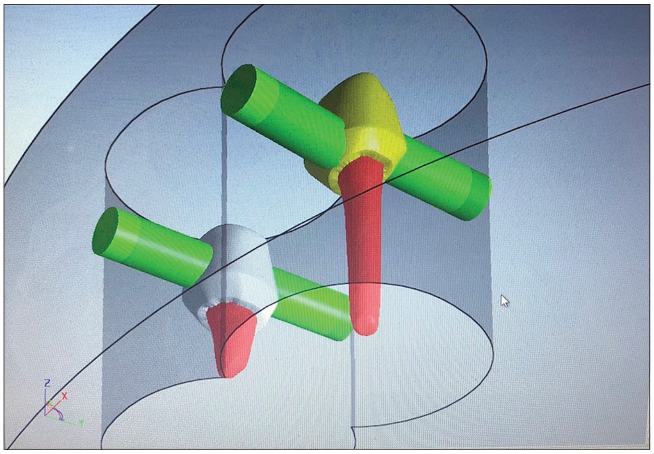

Figure 2: Computer-aided designed 3-mm and 6-mm post restorations

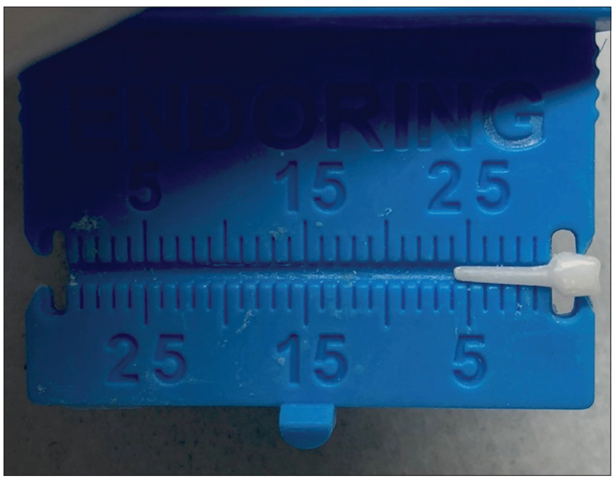

Figure 3: Image of final restoration of 6-mm zirconia post

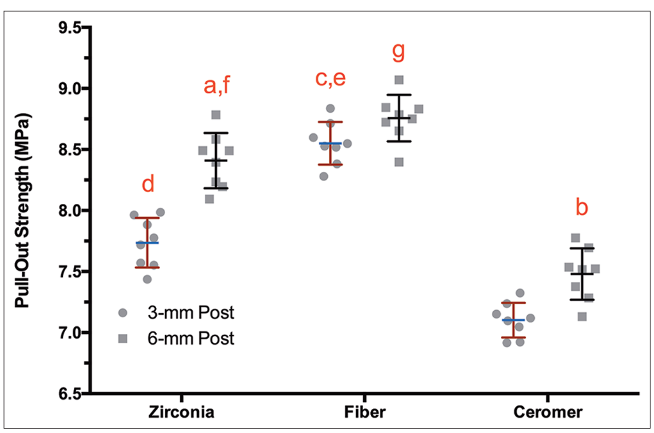

Figure 4: Values of pull-out bonding strength of zirconia, fiber, and ceromer posts sized 3 and 6 mm. The data were expressed as mean (midline) and SD (whiskers). $^{a}P < 0.05$, 6-mm zirconia post vs. 3-mm zirconia post. $^{b}P < 0.05$, 6-mm ceromer post vs. 3-mm ceromer post. $^{c}P < 0.05$, 3-mm fiber post vs. 3-mm zirconia post. $^{d}P < 0.05$, 3-mm zirconia post vs. 3-mm ceromer post. $^{e}P < 0.05$, 3-mm fiber post vs. 3-mm ceromer post. $^{f}P < 0.05$, 6-mm zirconia post vs. 6-mm ceromer post. $^{g}P < 0.05$, 6-mm fiber post vs. 6-mm ceromer post

strength of the 6-mm ceromer post (8.40 ± 0.22 vs. 7.48 ± 0.21; $P < 0.05$). The 6-mm fiber post provided a significant increase in the bonding strength compared to the 6-mm ceromer post (8.75 ± 0.19 vs. 7.48 ± 0.21; $P < 0.05$). Although the bonding strength of the 6-mm fiber post was higher compared to the 6-mm zirconia post, this difference was not statistically significant (8.75 ± 0.19 vs. 8.40 ± 0.22; $P > 0.05$).

Discussion

Our null hypothesis was not confirmed by the bonding strength data of the present *in vitro* study. The bonding strength data obtained with the pull-out test supported that the size of post was important to increase the bonding strength of zirconia, fiber, and ceromer materials to the root canal. In accordance with the increase of post size, there was an increase in the bonding strength. When considering the studied post materials of zirconia, fiber, and ceromer, significant differences were found between the bonding strength of posts prepared with these materials. The most favorable results in bonding strength measurements were obtained with fiber posts. Second, the considerably good results in bonding strength measurements were found with zirconia. The least favorable results in bonding strength measurements were recorded with ceromer. According to the type of material and the size of post, the optimal type of post was designed as 6-mm fiber post.

When considering specimen preparation methods used in this study, there may be some limitations in these experiments. During the preparation of fiber posts, a commercial set of fiber was used for post preparation. It was thought that this may help the optimization of adaptation between the post and root canal dentin. On the other hand, for the preparation of zirconia and ceromer posts, we need to use post preparation techniques as mentioned in the Methods. These specimen preparations may decrease the optimization of adaptation between the posts and root canal dentin. In further studies, analysis of space between post and root canal dentin by microscopy modalities and association of this finding with the bonding strength may shed light on the difference of bonding values of currently studied posts.

During post restoration in clinical practice, it is not easy to obtain a desired post length as suggested two-thirds of the root in some of the cases.[29] In addition, the post size necessary based on the tooth anatomy[30] and preventive measures should be taken into account during the process of post space preparation.[18] The results of the study by Holmes *et al*.[13] supported that the stress peak was observed adjacent to the post and increased by 57% when post length decreased from 13 mm to 8 mm. On the other hand, Yang *et al*.[31] stated that the stresses in the apical region increased when dowel length increased beyond two-thirds of the root and they suggested that extension of post length may be harmful to the root apical sealing. When considering the implications of those studies, there is a need to pay attention to maintain an apical seal of 4 to 5 mm of gutta-percha.[32] Braga *et al*.[33] suggested that in the presence of short and curved roots, it is logical to select an 8-mm post since they found no significant difference between 8- and 10-mm posts.

Christel *et al*.[34] observed that zirconia posts, introduced in the late 1980s, exhibited high resistance to fractures; additionally, Kwiatkowski and Geller[35] revealed that zirconia post can be used as bonded with a resin cement. This can be related to the smooth surface of zirconia after sinterization but this condition can be a negative contributor for the bonding quality of zirconia and resin cement. In a pertinent study, Al-Harbi and Nathanson[36] measured the retentive strength between composite and ceramic endodontic dowel systems and the tooth and its fabricated core. According to their results, the ceramic dowel systems were not successful compared to other studied system regarding bonding values. Concerning improvement of the bonding quality of ceramic posts, Kakehashi *et al*.[37] indicated a positive effect of airborne-particle–abrasion on the post surface to improve bonding level. In the current study, we did not use this technique, because of possible phase transformation of zirconia and its detrimental effect on its structure.[38,39]

Contrary to the results of the present study, Bottino *et al*.[40] conducted a study to determine the effect of cyclical mechanical loading on bond strength of a fiber and a zirconia post bonded to root dentin. In their study, the push-out bonding strength of zirconia post was higher compared to the fiber post but this difference was not significant. In the current study, we fabricated the zirconia post in the laboratory; however, in their study, zirconia specimens were prefabricated. This may be the cause of difference between the results of the study by Bottino *et al*.[40] and the present study.

Properties of fiber posts such as having elasticity modulus similar with dentin, greater retention values to root canal, and adequate esthetic properties can be related to the success with their long-term clinical use.[41] In the pertinent literature, there are several studies presenting the positive association of post length and retention[33,42-46] The results of Nergiz *et al*.[30] supported that dowel length was the most important factor for the retention of post compared to dowel diameter. They noted that this might be related to the increased surface area of the post. Another study also revealed similar results after artificial aging.[47]

In the literature, there are studies presenting results supporting the potential clinical use of short post.[29,30] The fact that the bonding performance of cement is more effective in cervical third than in the apical third may be the cause of advantage during the use of fiber posts for short roots or roots having a high degree of curvature.[48] Webber *et al*.[5] stated that the preparation of 1/2 of the remaining root can be preferred when 2/3 of the preparation of the remaining root was not performed. Borer *et al*.[45] explained that 10-mm posts requiring greater force to dislodge than their 5-mm counterparts also provided adequate retention.

During fabrication of ceromer material, different fillers to reinforce polymers, as an inorganic–organic hybrid polymeric material, can be used. These fillers can improve wear resistance and lifespan of these composites with the support of increased mechanical strength and abrasion resistance.[49,50]

In the present study, it was thought that it is possible to use ceromer as a test material for post development. For this purpose, some properties of ceromer can be helpful when they were used as a post material, including its content as polymer structure similar to that of resin cement and their potential compatibility; flexible structure reducing vertical root fracture; and tooth-colored surface increasing patient's satisfaction. However, in the current laboratory settings, ceromer was not performed well compared to other studied materials. This may be the result of complicated fabrication technique used in our laboratory.

In our laboratory setup, the pull-out bond strength test was preferred because it is a reliable and validated method of evaluating the performance of post specimens to resist shearing stresses. During this test, with applied forces, the stress was distributed better on the surface of post and this may increase the precision of measurements. When posts have higher retention with pull-out test, they are more resistant to dislodgement as a result of lateral occlusal stresses.[51,52]

The main idea of the present study was to include a variety of post materials including zirconia, fiber, and ceromer, to simulate clinically relevant conditions of post restoration, and to explore if the bonding strength between root canal dentin and customized zirconia, fiber, and ceromer posts would also be affected by different sizes of posts. Current experiments supported that post material and size can increase the bonding between root canal dentin and studied posts. In addition, to the best of authors' knowledge, this is the first attempt to measure the bonding strength of these materials with different sizes by pull-out test in the same laboratory settings, and the current experiments provided *in vitro* data about the suitability of ceromer as post material. Further studies may be helpful to explore the effect of their different sizes to optimize the potential merit of fiber posts for use during post restorations.

Conclusion

Based on the limitations of the present study, the following conclusions may be reached:

1. The bonding strength of the 6-mm zirconia, fiber, and ceromer posts was significantly higher compared to their 3-mm pairs.
2. The bonding strength of the 3- and 6- mm fiber posts was significantly higher compared to the 3- and 6-mm zirconia and ceromer posts.
3. The 3- and 6-mm ceromer posts provided the lowest values of bonding strength compared to other post types.

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Conflicts of interest

There are no conflicts of interest.

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