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ORIGINAL RESEARCH

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Evaluation of the Bond Strength and Fracture Resistance of Different Post Systems

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ABSTRACT

Aim: To compare the bond strength and the fracture resistance of different post systems.

Materials and methods: Endodontically treated 60 mandibular incisor and 60 mandibular premolar teeth were used for the bond strength and fracture resistance test respectively. For each test, three groups (n = 20) were formed according to the posts used zirconia posts (ZR post), individually formed glass fiber reinforced composite posts with an (Interpenetrating Polymer Network—IPN post) and cast metal posts. Then groups were randomly assigned into two subgroups according to the post design: 1-parallel sided and 2-tapered (n = 10/group). All posts were luted with a self-adhesive luting agent. For push-out test two 1 mm thick horizontal root sections were obtained and subjected to push-out test. For fracture resistance test, the specimens were loaded vertically at 1 mm/min crosshead speed. The push out test data were analyzed with Kruskal-Wallis and Dunn's test. Analysis of variance (ANOVA) and Tukey significant difference tests were used to compare the fracture resistance.

Results: Cast metal posts showed the highest retention ($p < 0.05$); however, IPN and zirconia posts showed similar results. No significant difference was found between parallel sided or tapered designs of post groups in terms of bond strength ($p > 0.05$). In terms of fracture resistance, IPN post groups showed lowest fracture resistance ($p < 0.05$). No significant difference was found between parallel sided or tapered posts in terms of fracture resistance, except zirconia post ($p > 0.05$). There was no relationship between the bond strength and fracture resistance of the post systems ($r = -0.015$, $p > 0.700$).

Conclusion: Post type had effect both on the fracture resistance and retention of the posts used. However, post design had effect only on the fracture resistance of the post systems.

Clinical significance: Superficial treatment of the post used can improve the retention of post systems.

Keywords: Bond strength, Fracture resistance, Post systems.

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INTRODUCTION

Most endodontically treated teeth suffer massive reduction in their structural stability because of the great loss of significant coronal part of the tooth structure caused by fractures, caries and access preparations.[1] For reconstruction of root canal treated teeth before final restoration, several post systems are generally indicated to restore missing tooth structure.[2] The selection of most suitable post system is challenging. Different post systems are recommended depending on the amount of remained tooth structure.[3] Until recently, root canal treated teeth have been traditionally restored with metal or cast post and core systems because of their superior mechanical properties.[4] But metal prefabricate or cast post systems can negatively affect the all ceramic restoration by altering the light transmission.[5] An increase in demand for metal-free restorations has resulted in the advent of nonmetallic post systems, such as glass fiber reinforced composite resin posts and yttrium stabilized zirconia (Y-TZP)-based ceramic posts.[6]

Fiber posts were developed in the early 1990s to restore endodontically treated teeth with severe loss of coronal tooth structure. Fiberglass posts have a high flexural strength and their elastic modulus is close to that of dentin, minimizing the transmission stress to the canal walls and reducing the risk of root fracture.[7] On the other hand, Y-TZP-based ceramic posts have high flexural strength and fracture toughness,[8] besides they are extremely radiopaque[9] and biocompatible.[10]

The post design or shape of post systems evaluated by many studies.[11-13] Post type, design, dimensions, surface roughness all have been shown to affect fracture resistance and retention of post systems.[12] It has been reported that post design could influence its retentive capability, at least when metallic and zirconia posts are used.[11,12] The fracture resistance and bond strength of several post systems have been assessed in many *in vitro* studies.[1,13] But to our knowledge, there is no study that compares the effect of post designs on the bond strength and fracture resistance of different post systems together. Therefore, we purposed to evaluate the bond strength and fracture resistance of parallel sided and tapered CAD/CAM zirconia post (ZR post), an individually formed glass fiber reinforced composite post (Interpenetrating Polymer Network—IPN post) and cast metal post.

MATERIALS AND METHODS

Tooth Selection and Preparation

All experiments were performed under a protocol approved by the Human Subjects Ethical Review Committee of Hacettepe University (Project No. 10/07-4). For push-out bond strength test freshly extracted 60 single rooted mandibular incisors, and for fracture resistance test 60 single rooted mandibular premolars with approximately the same dimensions were selected and stored in distilled water until they were used. To standardize procedures and materials, mesiodistal and buccolingual dimensions were obtained from the specimens at 16 mm from the apex. The means were calculated, and specimens that showed 10% deviation from the mean, were discarded. All specimens were examined under magnification and fiber optic lighting to ensure that there were no cracks or craze lines in the teeth.

To standardize the root canal lengths at 16 mm, teeth were decoronated using a low-speed diamond saw (Isomet 1000, Buehler, Lake Bluff, IL, USA) under copious water cooling. The working length of each root was determined to be 1 mm less than the length by a ISO size-10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was passively introduced into each canal until its tip was just visible at the apical foramen. Root canal shaping procedures were performed by using ProTaper rotary instruments (Dentsply Maillefer) up to an apical preparation with size #30 (F3). Root canals were irrigated with 1 ml 5.25% sodium hypochlorite (NaOCl) between instrument changes, 5 ml 17% ethylenediaminetetraacetic acid (EDTA) for 1 minute as final rinse, and 10 ml distile as final flush water to avoid the prolonged effect of EDTA and NaOCl solutions. Then the canals were obturated with single 0.06 taper size 30 gutta-percha cones (Dentsply-Maillefer) in conjunction with AH 26 sealer (Dentsply DeTrey GmbH, Konstanz, Germany). After the completion of endodontic treatment, cervical root canal openings were filled with a temporary restorative material (Cavit-G; 3M ESPE AG, Seefeld, Germany) and samples were stored in 100% humidity for 7 days to allow the sealer to set.

Post Space Preparation

Gutta-percha was removed with heated endodontic pluggers (Sybron Dental Specialties, Romulus, MI), maintaining at least 5 to 6 mm of filling material in the apical third creating a standard post space of 10 mm from the apical surface.

Endodontically, treated teeth were divided into three groups in order to place ZR posts, IPN posts and cast metal posts (n = 20/per group). These post groups were assigned into two subgroups according to the post design: (1) parallel sided and (2) tapered posts (n = 10/per group). To obtain parallel post space, 24 peeso reamer no. 5 were used in the study. One reamer was used for five post space preparation. The conical apical parts of the reamers were flattened with 180-grit SiC papers under water irrigation.[19] For obtain tapered post space, after removal of gutta-percha by heated pluggers no preparation was performed. Post holes were checked radiographically for any residual gutta-percha. The post spaces were finally flushed with 2 ml distile water; root canals were then dried with absorbent paper points.

Preparation of Parallel Sided and Tapered Post Systems

Zirconia Posts

For push out and fracture resistance test a total of 40 ZR posts were fabricated 10 mm in height and 1.2 mm in coronal diameter (n = 20/per test). For each test half of the 20 posts were fabricated in parallel shape, and the other half were in tapered shape (n = 10). Zirconia posts manufactured from pre-sintered Y-TZP disk shaped blocks (Noritake Alliance, Noritake Co., Inc. USA) by using computer-aided design/computer-aided manufacturing (CAD-CAM). Posts were sintered to full density in a high-temperature furnace (Protherm, B&D Dental Origin Milling, UT, West Valley) at 1450°C for 2 hours according to the manufacturer's instructions. All of the ZR posts received an airborne-particle abrasion with 50 μm silicatized aluminum oxide particles (Al_2O_3) (S-UAustral, Schuler Dental, D-7900 ULM Eberhard-Finckh-Str. 39, Almanya) distance of 10 mm for 20 seconds.

The specimens were then cleaned in distilled water under ultrasonic vibration. Thereafter, Monobond-plus primer (Ivoclar Vivadent, Schaan, Liechtenstein) was applied on the post surfaces according to manufacturer's recommendations.

Individually Formed Glass Fiber Reinforced Composite Posts

Interpenetrating Polymer Network post (EverStick, Sticknet Ltd., Turku, Finland) posts were sectioned to 10 mm in height by a sharp scissor through the manufacturer's recommendations. To obtain tapered IPN posts, parallel IPN posts diminished by a sharp scissor from apical part until it goes full length of the post space. Stick^{TM} resin (Stick Tech Ltd. Turku, Finland) was applied on the parallel sided and tapered IPN post surface according to manufacturer's recommendations then IPN posts were kept in darkness until use.

Preparation of Cast Metal Posts

Parallel sided and tapered post patterns was carried out using polymerizing acrylic resin (Duralay; Reliance Dental Fg Co., Worth, IL) in the root canal. Then the patterns were invested and cast in nickel–chrome alloy (Wirobond C, Bego Bremer Goldschägerei wilh. Herbst GmbH & Co., Bremen, Germany) using an induction casting machine. The castings were examined under 10× magnifications to detect casting defects. Each casting was placed on the respective tooth to verify its fit. Finally, cast posts were sandblasted with 50 µm Al_2O_3 and then were cleaned in distilled water under ultrasonic vibration. All posts were luted with a self-adhesive luting agent (RelyX U100, 3M ESPE, Seefeld, Germany) according to the manufacturer's instructions. The seating procedure was performed by the same operator for all posts. Following placement of the posts with slight pressure, in all groups, excess luting cement was removed. The luting agent was light cured with a LED light-curing unit (Elipar S10, 3M ESPE, St Paul, MN) for 20 seconds in each of four directions. The samples were subjected to thermocycling, 6000 cycles in a 5 to 55°C water bath.[14]

Push-out Bond Strength Test

Specimens were embedded along their long axis in self-curing acrylic blocks and were cut into two slices (1 ± 0.1 mm thick) with a precision cutting machine under water cooling (Isomet 1000; Buehler, Lake Forest, IL, USA) (n = 20/group). Each slice was marked on its apical side with an indelible marker and the thickness of each specimen was measured and recorded by a digital caliper (Liaoning MEC Group, Dalian, China) with an accuracy of 0.01 mm. Push-out force was applied from apical to coronal direction on the post by using a 0.76 mm diameter custom stainless steel cylindrical plunger mounted on a Lloyd LRX universal testing machine (Lloyd Instruments Ltd., Fareham, UK). Each slice was placed ensuring that the apical surface faced the plunger and plunger centralized and avoided its contact with dentin during testing. Micro push-out testing was performed at a crosshead speed of 1 mm/min until bond failure occurred. The bond strength at failure was calculated in megapascals (MPa) by dividing the load in Newtons (N) by the area of the bonded interface. The bonded area of each section was calculated by using the following formula:[15]

Area = $2\pi rh$, where π was the constant value 3.14, r was the radius of the post radius and h was the height (mm).

The data were analyzed statistically by using Kruskal-Wallis, Dunn's tests at $p < 0.05$.

Fracture Resistance Test

Each apical root end was embedded along their long axis in self-curing acrylic blocks, leaving 9 mm of the root exposed and 7 mm embedded. The specimens were mounted in a universal testing machine (Lloyd LRX; Lloyd Instruments Ltd., Fareham, UK) for evaluation of fracture resistance. A loading fixture was mounted with its spherical tip (r = 2 mm) aligned with the center of the canal opening of each specimen. A compressive force was applied at a crosshead speed of 1 mm/min until fracture occurred. The forces necessary to fracture each root were recorded in Newtons (N).

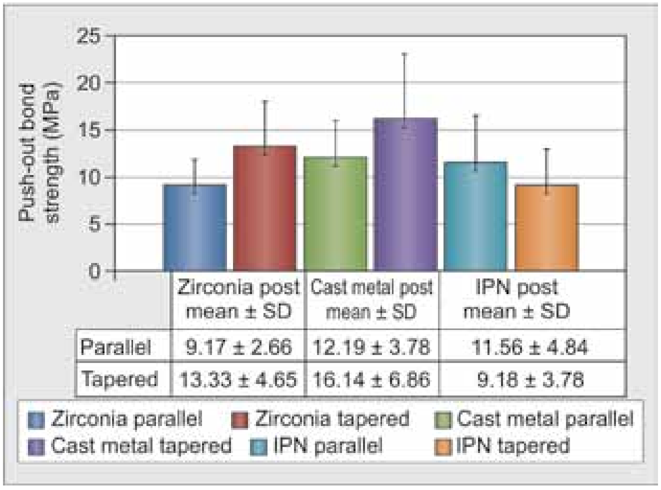
The data were analyzed statistically by using one way analysis of variance (ANOVA) and Tukey tests at $p < 0.05$. Spearman's correlation analysis was performed to determine the relationship between the bond strength and fracture resistance tests.

RESULTS

The mean push-out bond strength values, standard deviations and the differences within the groups are presented in Graph 1. The fracture resistance values (N) are presented in Table 1 as mean and standard deviations.

According to results, it was shown that the factor 'post type' significantly affected the push-out bond strength and fracture resistance of the posts used. However, the factor 'post design' had no affect on the push-out bond strength, and also on the fracture resistance of post systems, except zirconia posts.

According to the bond strength results, there was a significant difference between groups ($p < 0.05$). Cast metal posts showed the highest retention; however, IPN



Graph 1: Push-out bond strength values of post groups. No statistically significant difference between parallel sided and tapered post systems ($p < 0.05$)

Table 1: Fracture resistance values (N) of test specimens presented as mean ± standard deviation

*Groups**	*Fracture resistance values (N)*
1A: Zirconia parallel sided post	981.44 ± 306.87
1B: Zirconia tapered post	638.28 ± 155.87
2A: Cast metal parallel sided post	789.26 ± 219.38
2B: Cast metal tapered post	716.28 ± 220.14
3A: IPN parallel sided post	486.14 ± 178.17
3B: IPN tapered post	395.81 ± 117.44

*Statistically significant difference between zirconia parallel sided and tapered post group ($p < 0.05$). IPN post groups showed the lowest fracture resistance ($p < 0.05$).

posts showed the lowest. No significant difference was found between parallel sided or tapered designs of post groups in terms of bond strength ($p > 0.05$).

In terms of fracture resistance the results revealed that there was a significant difference between the groups ($p < 0.05$). Interpenetrating Polymer Network post groups showed the lowest fracture resistance ($p < 0.05$). No significant difference was found between parallel or tapered designs of post groups, except zirconia post group ($p > 0.05$).

The Spearman's correlation analysis showed that there was no relationship between the bond strength and fracture resistance of the post systems ($r = -0.015$, $p > 0.700$).

DISCUSSION

The purpose of this investigation was to evaluate the retention and fracture resistance of various parallel sided and tapered post systems. For testing the adhesion of various post systems, the micro push-out technique was used since it has been generally accepted for the bond strength evaluation.[15]

The results of this study showed that the highest push-out bond strengths were observed for cast metal tapered posts (group 2B), while zirconia parallel sided and IPN tapered posts (groups 1A and 3B) showed the lowest mean bond strength values.

With regard to post retention, it has been stated that the dislocation resistance of the posts proceeds from the some factors: (1) micromechanical interlocking, (2) chemical bonding, and (3) sliding friction.[16] Consequently, any factor influencing this mentioned factors could have influenced the push-out bond strength performance of the posts. In this present study the relatively superior fitting of cast posts might enhance the friction level between post and tooth structure when compared with zirconia and IPN posts, consequently this may increased bond strength of cast metal posts.[17] Another explanation of higher bonding values might be due to the surface roughness of the post systems. Studies showed that rough surface is more retentive than polished ones.[18] In this study cast metal posts were air-particle abraded, which increased both the roughness and surface area, and it may be speculated that because of this surface treatment, the bond strength values of cast posts are higher than IPN posts.

In the present study, ZR posts had similar bond strength values with IPN posts. Zirconia posts received airborne-particle abrasion with 50 µm Al_2O_3 particles before cementation. Thus, for ZR post specimens, the major portion of bond strength might be related with the micro-retention of the surface roughness formed by the Al_2O_3 particle. These results are in accordance with a previous study.[19] Egilmez et al[19] reported that the mean micro push-out bond strength values of ZR post and IPN post were similar and there was no significant differences between these groups. For a satisfactory resin bond to zirconia, airborne-particle abrasion is a treatment choice to create micromechanical interlocking between a composite resin and ceramic surface.[20] In addition to these factors, low bond strength values obtained with IPN post could be attributed to different cross-sections of this post, which was not always symmetrical and round, as opposed to the ZR post.[19] There have been varied outcomes from studies comparing parallel and tapered designs of posts effect on the bond strength. Previous authors indicated the superior retention of parallel sided posts when compared with tapered ones.[11,12] In a retrospective clinical study,[21] it was found that tapered posts had a higher failure rate than parallel posts, although there was no statistically significant difference between them. In contrast, Naumann et al[22] reported a failure rate for parallel posts three times higher than for tapered posts.

It should be pointed out that, in all of these studies, the results might be related with the different luting cements, luting procedures, and surface treatment of different post systems. In the present study, no significant difference was found between the bond strength values of tested posts for those designs. It seems that some superficial treatment carried out, could improve the interaction between the posts and the cement, so that the design became secondary for the retention.

With regard to fracture resistance, the results demonstrated that zirconia and metal posts had the highest fracture resistance, whereas IPN posts had the lowest. These results are in agreement with previous results.[13,23] Toksavul et al[23] reported that less fracture resistance and more catastrophic root fractures were associated with glass fiber posts when compared to zirconium posts. Stockton and Williams[24] suggested that fiber post flexibility might cause stress redirection toward the post-tooth interface, and thus increase the failure rate. Nevertheless other previous studies showed better fracture resistance of teeth restored with fiber-reinforced resin posts (which had a similar rigidity to dentin) when compared with metal or zirconia posts (which had a much higher modulus of elasticity than dentin).[25] Cast posts and cores were frequently associated with deep catastrophic root fractures.[11,26]

In the present study, cast posts had higher fracture resistance when compared to IPN posts. This result might be related to the high rigidity of cast posts. It was suggested that posts with a high elastic modulus could improve the bending resistance of post-restored teeth.[27] The teeth with more rigid cast NiCr post and cores were more resistant to the bending forces and exhibited higher failure loads. It might also be explained by the type of intraradicular retention of the metallic post. It has been reported that poorly fitted posts might create levers within the root canal, making the tooth more liable to fracture.[28] Close adaptation of posts to the canal walls was found to increase the fracture resistance of restored teeth significantly.[29] Marchi et al[30] reported that cast metal had higher fracture resistance because of is higher retention in root canal. In accordance with these results in our study cast metal posts had higher bond strength and fracture resistance mean values.

According to results, the post design did not significantly affect the fracture resistance of post systems except zirconia post. In zirconia post group, parallel sided posts showed significantly higher facture resistance than tapered posts. Although there was no significant difference between post designs of IPN and cast metal post systems, parallel sided posts had higher fracture resistance mean values than tapered ones. It was reported that tapered metal posts cause greater cervical stress concentration than parallel sided posts. This was attributed to the wedging effect introduced by tapered posts. A higher incidence of root fracture was reported when tapered posts were used.[29]

In the setup of this study, the test methodology was limited to the root, the crowns were not included to exclude other variables, such as ferrule design and remaining coronal dentin. In this way, we could solely test the effect of the post design and type, whilet excluding any strengthening effect of the core build-up and the crown on the tooth.

This *in vitro* study has some limitations in respect to its clinical relevance, and cannot indicate precise results. Therefore, further evaluations, mainly clinical investigations and *in vivo* studies are required to support these *in vitro* results.

CONCLUSION

Taking into account, the limitations of this laboratory study, the following conclusion can be drawn:

- Post design does not affect the retention of post systems. Parallel sided and tapered post systems had similar retention.
- In all groups parallel sided posts showed higher fracture resistance than tapered posts.
- There was no relationship between the bond strength and fracture resistance of the post systems.

CLINICAL SIGNIFICANCE

Superficial treatment of the post used can improve the retention of post systems.

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