

## Push-Out Bond Strength of Different Esthetic Post: An *In-Vitro* Study

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### Abstract

**Purpose:** This *in-vitro* study measured push-out bond strength of different posts as function of radicular regions.

**Statement of Problem:** In non-circular or excessively flared root canals, prefabricated posts may not fit well, increasing cement thickness and bubbles at coronal level which may alter its mechanical performance causing impaired post retention. Push-out bond strength test in different radicular thirds of posts will detect location of failure in bonded esthetic posts.

**Methods:** 40 sound extracted human central incisors were used in this study. All teeth were endodontically treated and decoronated 2 mm above CEJ. Then were randomly divided into 4 groups of 10 each regarding type of post used: group 1 (PD): Polymer infiltrated ceramic, Paradigm MZ 100 (3M-ESPE); group 2 (FRC) Fiber post, Postec Plus (Ivoclar Vivadent); group 3 (ZR): Lava Zirconium dioxide blocks (3M-ESPE); group 4 (CP): Cosmo Post, Zirconium dioxide (Ivoclar Vivadent). All posts were luted with Panavia 21 (Kuraray Noritake, Japan). Push-out tests were performed to evaluate the bond strength of different posts at different radicular regions. Data were statistically analyzed using one way (ANOVA) and Scheffe test made pairwise comparison ( $\alpha = 0.05$ ).

**Results:** FRC group recorded the highest mean bond strength value ( $11.78 \pm 0.79$ MPa). PD group showed higher results ( $10.10 \pm 1.12$ MPa) than ZR ( $9.56 \pm 0.85$  MPa) and CP ( $7.93 \pm 0.89$  MPa) and the 2 latter groups were not significantly different from each other  $p \leq 0.05$ . Regardless to post type, it was found that middle region recorded highest bond strength means value, then apical region, meanwhile the lowest mean bond strength values were recorded at cervical regions  $p \leq 0.05$ .

**Conclusions:** Within limitations of this study the following can be drawn: 1- Push-out mean bond strength of different esthetic posts are significantly affected by the type of its materials and manufacturing; FRC recorded the highest bond strength values, ZR and CP showed the least values ( $P \leq 0.05$ ). 2- Regardless type of the post, the middle radicular region (as Fiber Reinforced Composite) recorded the highest bond strength then the apical region, meanwhile the cervical region (as Cosmo Post) showed the lowest bond strength values  $P \leq 0.05$ .

**Keywords:** Push-Out Bond Strength; Esthetic Post

### Introduction

Partially yttrium-stabilized zirconium-oxide post systems were introduced in mid 1990s by various researchers [1,2]. Pure zirconia material shows polymorphic phase transformation from a cubic, to tetragonal, to monoclinic phase, accompanied by a high volume change when cooling down after sintering, which makes the sintered body unstable. Therefore, dental zirconia material contains 3 to 6 weight % Yttria-stabilized zirconia as an additive to stabilize the ceramic in the tetragonal phase which is usually

not stable at room temperature [3]. Zirconium-oxide posts demonstrate high fracture resistance due to high flexural strengths, which is comparable to that of cast gold posts and cores or titanium posts [4,5]. Fractures of teeth restored with zirconium-oxide posts are often unrestorable, whereas *in vitro* studies on fracture strengths of FRC posts showed less catastrophic failures due to a modulus of elasticity that is closer to that of dentin [6].

Different resin luting agents and corresponding bonding systems have been proposed for cementing tooth-colored posts and

can be generally divided into conventional bis-GMA-based resin luting agents and so-called adhesive resin luting agents containing functional monomers such as 10-Methacryloyloxydecyl hydrogen phosphate (10-MDP) or 4-methacryloxyethyl trimellitate anhydride (4-META) [7]. Several *in-vitro* studies reported controversial results regarding bond strengths of different luting agents to endodontic posts and root canal dentin [8].

Bonding to zirconium-oxide ceramics requires different pretreatment procedures compared to glass ceramics [9].

High-strength zirconium-oxide ceramics are not silica based; therefore, chemical silica-silane bonds cannot be established [10]. Moreover, the application of acidic agents such as phosphoric or hydrofluoric acid to zirconium-oxide ceramic will not create a sufficiently roughened surface for enhanced micromechanical retention [11]. Thus, various pretreatment procedures have been recommended [11]. Airborne-particle abrasion with alumina particles changes the structure of the surface by plastic deformation and roughening, resulting in an increased surface area and a volume loss of material [12].

There are many structural differences between radicular and coronal dentin, as well as problems related to presence of endodontic sealers, provisional cements and irrigant solutions violating the bond between post and radicular dentin [13]. When mismatch exists between post size and post space diameter, the resin cement layer would be excessively thick and bubbles are likely to form in it, thus predisposing to bonding failure [14].

For large, non-circular or tapered canal, post systems that rely on use of a cylindrical prefabricated post may not achieve the intimate adaptability of the post to the canal, possibly compromising the retention of the post [15]. When these factors are assessed, a custom made milled posts and cores would be an alternative treatment option in some clinical cases. Butz., *et al.* [15] reported that survival rates and fracture strengths of prefabricated zirconia posts with composite cores are significantly lower than custom made milled post and core, so this combination are not recommended for clinical use.

Dentin is a heterogeneous material. Its characteristics vary widely among individuals, even within the same individual [16]. Age plays a decisive role because dentin undergoes age-associated changes [16]. Young dentin has wide and open tubules [16]. With increasing age, the number of tubules decreases and tubular diameter becomes narrower as a result of sclerotic processes and the deposition of secondary and tertiary dentin [16]. This process results in reduced bond strength because the penetration of resin into and around the dentinal tubules is responsible for nearly 40%

of the bond strength [17]. There is no *in-vitro* or *in-vivo* evidence of the long-term stability of dentin bonding procedures [16]. It has been reported that bond strength decreases over time under the influence of water, temperature changes, and dynamic loading [18].

Dietschi., *et al.* [19] conducted an *in-vitro* fatigue test and reported that the interface between adhesive posts and dentin exhibited substantial defects after intermittent loading and thermal cycling. Also, poor bonding of composite resin to the zirconia post was reported [19]. In addition to problems of bonding to dentin in general, there are difficulties associated with the use of adhesive systems in root canals [19]. There are structural differences between radicular dentin and coronal dentin as well as problems related to the presence of provisional cements, endodontic sealers, and rinsing solutions in a canal with limited access [13-20]. Radicular dentin can be divided into apical, middle, and coronal thirds [21]. In the middle and coronal thirds, significantly lower values for the bonding strength have been measured [22]. Conventional cements offer advantages over resin cements, including lower costs and less complicated procedures with less opportunities for procedural error, meanwhile resin cements offer high mechanical properties and insolubility [23,24].

Different resin luting agents and corresponding bonding systems have been proposed for cementing tooth-colored posts and can be generally divided into conventional bis-GMA based resin luting agents and so-called adhesive resin luting agents containing functional monomers such as 10-Methacryloyloxydecyl hydrogen phosphate (10-MDP) or 4-methacryloxyethyl trimellitate anhydride (4-META) [25]. Several *in vitro* studies reported controversial results regarding bond strengths of different luting agents to endodontic posts and root canal dentin [25,26].

### Aim of the Study

The aim of this study was to measure the push-out bond strength of different esthetic posts in the three different radicular regions. Push out bond strength test in different radicular thirds of posts will detect location of failure in bonded esthetic posts. The null hypothesis of this study include the following: 1- No difference in bond strength values between different types of posts. 2-Different radicular regions have the same bond strength to different posts.

### Materials and Methods

A total of forty sound freshly extracted upper central incisors were selected from surgery department (Modern Sciences and Arts University), extractions of samples were processed due to periodontal considerations (experimental procedures are ap-

proved by ethical committee of Modern Sciences and Arts University) after proper inspection to ensure the absence of any defects. All teeth were decoronated 2 mm above cemento-enamel junction and prepared using rotary files (ProTaper, Dentsply, Switzerland).

**Sample size:** According to previous studies [27,28,41,52]. 10 samples of each group will be tested to implicate statistical significance.

The canals were enlarged to size F4 file, irrigated with 2.5% sodium hypochlorite solution and obturated using F4 tapered single cone with eugenol-free resin sealer (AH26, Dentsply).

Methyl methacrylate cylinders were fabricated for this study and received 18 mm deep standardized drill holes with a diameter of 3.5 mm. The holes were filled with self cure methyl methacrylate (Technovit 4071; Heraeus Kulzer, Hanau, Germany).

Subsequently, post space preparations with a length of 13 mm were prepared with dedicated drill provided by the post manufacturer (Reamer 1.7mm #572712; Ivoclar Vivadent) (Figure 1).



**Figure 1:** Reamers for post space preparation.

### Types of posts used in this study

Zirconium oxide posts (CosmoPost; Ivoclar Vivadent, Schaan, Liechtenstein).

Glass-fiber-reinforced composite posts (FRC Postec; Ivoclar vivadent) (coronal diameter 2.0 mm; size 3) FRC posts contain unidirectional silane-coated glass fibers (61.5% weight), which are embedded in a polymer matrix of triethylene-glycol-dimethacrylates (TEGMA) and urethane - dimethacrylates (UDMA) in combination with highly dispersed silicone dioxide.

Polymer infiltrated ceramic, 3M Paradigm MZ100 Block Cerec (Sirona, Germany) contains 85% ultrafine zirconia-silica ceramic particles that reinforce a highly cross linked polymeric matrix. The polymer matrix consists of bisGMA (Bisphenol A diglycidyl ether dimethacrylate) and TEGDMA (triethylene glycol dimethacrylate) and employs a patented ternary initiator system.

Zirconium dioxide blocks-Dentsply (Sirona, Germany).

According to previous studies [27,28], impression of post and core spaces were taken with C type light and heavy viscosity silicone based impression material (Zeta Plus; Zhermack, Badia Polesine, Italy) mixed and applied inside root canals.

After taking the impressions, dies were prepared and scanned by laser in laboratory for acquiring and transmitting information. Full Digital impressions were made with an extra-oral scanner (inEos X5; Sirona, Germany) to generate virtual models. Special software (in Lab SW 4.2.1.61068, Sirona Dental Systems, Bensheim, Germany) was used to design the post and core restorations.

Thermocycling was done for all samples, 5000 cycles (5 - 55°C) every 30 seconds.

Samples were sectioned horizontally perpendicular to their long axis with a slow speed diamond blade (Isomet 1000, Buehler Ltd.) under water cooling. Three horizontal sections ( $2 \pm 0.1$  mm) thick were obtained from coronal, middle and apical regions of each root. Every root slice was secured in a custom made loading fixture.

Each sample was mounted in custom made loading fixture (Figure 2) and subjected to compressive loading via computer controlled testing machine and loaded at crosshead speed of 0.5 mm/min. The load applied by plungers size of (1, 0.75 and 0.5 mm) in an apical coronal direction because of the convergence of the root canal sections. Selected diameter of the plunger was positioned so it only contacts the filling to displace it down ward. This guaranteed that root dentine was sufficiently supported during loading process (Figure 2).



**Figure 2:** Push-out test.

Maximum failure load was recorded in N and converted into MPa. Bond strength was calculated from the recorded peak load divided by surface area as follows:  $\text{Bond} = F/A$   $A = \pi h (r_1+r_2)$ ,

Where  $\pi$  is the constant 3.14,  $r_1$  is apical radius,  $r_2$  coronal one, and  $h$  is the thickness of sample in millimeters.

Failure was manifested by extrusion of filling material and confirmed by sudden drop along load-deflection curve recorded by computer software (Nexygen; Lloyd Instruments Ltd). All data were collected, tabulated and statistically analyzed.

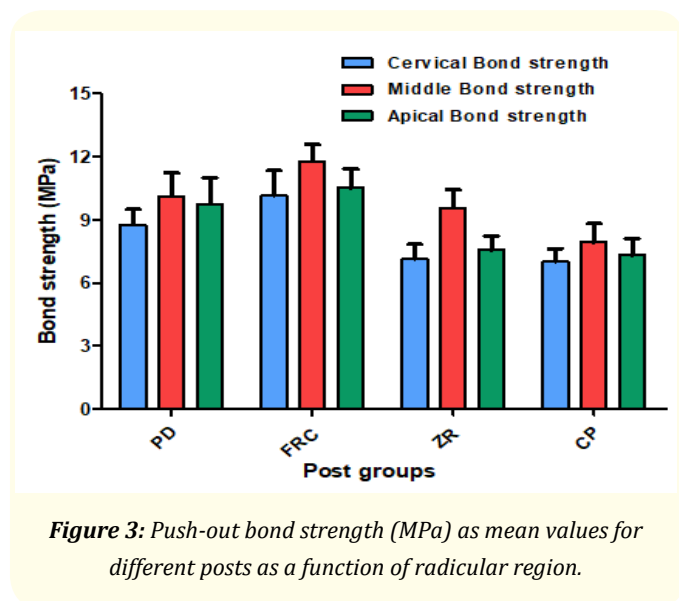
SPSS version 23.0 was used for data management. Mean and standard deviation described mean push out bond strengths. One way ANOVA made comparisons between groups and Scheffee test made pairwise comparisons. P value always 2 tailed and significant at 0.05 level.

### Results

Descriptive statistics for the push-out mean bond strength measured in (MPa) for the four types of posts in three different radicular regions are presented in table 1 and figure 3. It was found that FRC posts recorded the highest mean bond strength than PD. ZR and CP showed the least results with no significant difference.

Radicular region	Study groups				P value
	PD	FRC	ZR	CP	
Cervical	8.77 ± 0.73 b	10.15 ± 1.19 a	7.12 ± 0.72 c	7.01 ± 0.61 c	< 0.001
Middle	10.10 ± 1.12 b	11.78 ± 0.79 a	9.56 ± 0.85 b	7.93 ± 0.89 c	< 0.001
Apical	9.76 ± 1.22 a	10.52 ± 0.88 a	7.56 ± 0.66 c	7.31 ± 0.81 c	< 0.001

**Table 1:** Comparison of push-out bond strength as mean ± standard deviation for different post as a function of radicular region. P value is significant ≤ 0.05. Groups sharing same letter within same raw (or region) are not significantly different.



Regarding bond strength to radicular regions; the middle recorded higher results than apical region. Cervical region showed the least bond strength values as shown in figure 1.

### Discussion

Results of this *in-vitro* study, support rejection of null hypothesis of this study, push-out bond strength were significantly affected by different types of posts and different radicular regions.

Superior results of fiber posts can be explained in the light of adhesion and chemical bonding between composite and the fiber post, that are essentially composite materials composed of fibers of silica surrounded by a matrix of polymer resin. This results agreed with previous studies [29,46,48].

The push-out test was utilized for bond strength testing in 75% of literatures published from 2007 to 2016 as it provides a practical tool for assessment the interfacial shear strength between post and root canal walls as has the benefit of more simulating the clinical condition [30]. The push-out test is easy to perform and has less cohesive failures in test and small standard deviations [31]. Push-out tests also showed more homogenous stress distribution by finite element stress analysis. The push out test is an indicative to retention of fiber post in root canal as it mimics the forces that act on the post in apico-coronal direction [31].

The Low results of Cosmo-Posts in this study, may be explained due to increase thickness of resin cement than in custom made that may involve bubbles, voids and other defects and act as crack centers and decrease post retention [32].

Regarding results at different radicular regions; the middle third showed the highest then apical and cervical showed the lowest results, this agreed with Mannocci, et al. [33] who reported that middle and apical radicular dentin showed the lower densities of dentinal tubules and found to be more resistant to tension than the coronal third, when other possible factors as cement thickness are stable.

Malyk, et al. [34] stated that intraradicular dentin in the coronal level presents a larger number of tubules and therefore less intertubular dentin, which is usually associated with higher bond strength as reported by Giannini, et al. [35] and Bitter, et al. [36] who stated that the bond to root dentine inversely related to tubules diameters and directly related to the percentage of solid dentine i.e. intertubular dentin and the increase in the number of resin tags is not directly proportional to the bond strength. Daleprane, et al. [37] defended this hypothesis that although the dentin in the apical third may be more likely to present residues of endodontic treatment [38], the bond strength appears to be enhanced by the

technical sensitivity of the luting system. The lower volume of cement at apical level may have reduced the polymerization shrinkage stress, thus increasing bond strength values of all resin cements to root dentin [39].

Results of bonding at apical third were less than middle third in different groups as apical region is devoid tubules, presence of irregular secondary dentin, cementum like tissue on the root canal wall and numerous accessory canals [35]. Also, the decrease in degree of resin cements conversion in deepest areas of the cavity due to inaccessibility of curing irradiation [40]. Even with dual cured material, deeper portions of cement are inaccessible to light, rendering the material dependent on chemical curing. This can reduce the degree of conversion of the cement and consequently affect its mechanical properties [41]

Moreover, it has been reported that the root canal dentin walls after post space preparation are covered with remnants of gutta-percha and sealer, rough debris and a thick smear removed [42]; thus may limit the adhesion.

On the contrary to the previous hypothesis, Gaston, *et al.* [43], Bitter, *et al.* [44] and Daleprane, *et al.* [37] reported significant higher bond strength at the apical third.

Induced micro-roughness from milling tools to Zirconium dioxide blocks enhanced the bond strength between posts and resin cement and this may explain the higher bond strength achieved in this group compared to smooth Cosmo-post zirconium dioxide [45].

In case of retreatment, fiber posts are easily removed by a drill, while ceramic posts, even using a diamond bur, hardly can be removed [46], they are very stiff with no plastic behavior [47]. Stiffness of ceramic posts can be less favorable clinically than fiber posts in respect to risk of root fracture. In fact a number of *in vitro* studies demonstrated that fracture type is more benign with fiber posts than when ceramic posts were used [48].

Cementation technique also has an important effect upon eventual retention and stress distribution of the post [49]. According to several studies [50,51], the introduction of cement into the root canal is essential to achieve a uniform bubble-free layer of cement that distributes stresses evenly through the entire root canal.

Of all the methods investigated [52,53], the use of lentulo spiral to place cement in the canal is superior, as it gives better spinning and spreading of cement because of centrifugal dispersion of cement. This method also reduces voids and increases the contact of cement with the walls [53].

During cementation, the post space should be free of any residue, as it has been reported that even a small nodule on the post surface or temporary cement residue in the canal can generate enough force to cause root fracture during and after post cementation.

## Conclusion

Within limitations of this study the following can be drawn: 1- Push-out bond strength of different esthetic posts are significantly affected by the type of its materials and manufacturing. 2-FRC recorded the highest bond strength value, PD recorded intermediate value, ZR and CP showed the least values with no significant difference between them ( $P \leq 0.05$ ).

## Clinical Implications

Fiber reinforced composite posts showed significantly higher *in-vitro* bond strength values than zirconium-oxide posts. Therefore, FRC posts may be suitable to resist the loss of retention of endodontic posts.

## Conflict of Interest

No conflict of interest.

## Source of Support

This experiment was totally self-funded by the author. Equipment units and some consumables were provided by research center, Faculty of Dentistry, Modern Sciences and Arts University.

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