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Push-out bond strength of different intracanal posts in the anterior primary teeth according to root canal filling materials

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ABSTRACT

Background: This study was carried out to evaluate the effect of root canal filling on the bond strength of three intracanal posts in the primary incisors.
Materials and Methods: Sixty primary incisors were prepared and then divided into two groups (n = 30). The first group canals obturated with zinc oxide eugenol (ZOE) and Group 2 canals obturated with Metapex. Further, the two group categories were divided into three subgroups (n = 10): (1) short composite post (SCP), (2) glass fiber posts (GFPs) cemented with flowable composite, and (3) GFP with glass ionomer cement (GFP + GIC). The push-out test was performed with a universal testing machine. The results were statistically analyzed with two-way analysis of variance.(α = 0.05).
Results: The mean bond strength of the first group obturated with ZOE was lower than that of the second group obturated with Metapex (P = 0.046). Moreover, from a statistical point of view, in all three subgroups, the correlation of mean push-out bond strength between SCP and GFP coated with flowable composite was not substantial at P = 0.97. However, the mean bond strength of SCP was in fact significantly greater than that of the GFP coated with GIC since P = 0.034.
Conclusion: Using ZOE resulted in the significant reduction of the mean bond strength of the intracanal posts when utilized in the primary anterior teeth. Likewise, SCP and GFP coated with flowable composite showed higher push-out bond strengths for restoring primary anterior teeth.

Key Words: Composite dental resin, Metapex, post and core technique, primary tooth, zinc oxide eugenol cement

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INTRODUCTION

Restoration of severely decayed primary anterior teeth is often considered as a great challenge for a pediatric dentist.[1,2] This problem is frequently seen among children with nursing bottle caries and involved in the maxillary anterior teeth. Progression of nursing caries may affect growth adversely and affects body weight and quality of life in preschool children.[3] The esthetic restoration of severely destructed primary anterior teeth has been a challenge for the pediatric dentist because of existing materials and the children who need these restorations are usually uncooperative. Furthermore, these teeth

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usually have short and narrow crowns, and bonding to primary tooth structure is more difficult than permanent teeth. In many cases, because of entire crown destruction, only root dentin is available for crown reconstruction. Hence, many of these teeth were conceived unrestorable and extracted.[4] Early loss of carious primary incisors may lead to matters regarding esthetic, speech, masticatory function, and abnormal tongue habits and may also lead to malocclusion.[2] Accordingly, different intracanal posts and retainers have been used for restoration of such teeth after carrying out pulpectomy. Numerous methods have been developed to increase restoration retention are metallic posts, alpha or gamma shape orthodontic wires, short composite resin posts, biological posts, fiber reinforced composite (FRC) posts such as polyethylene ribbon fiber posts, and glass fiber posts (GFPs).[2,5-10]

Short composite post (SCP) is used in a way to pack the composite within the canal and make a tapered post.[5,11] The primary function of a post is to retain the coronal restoration in an endodontically treated tooth, which also has signs of excessive destruction in crown structure. The base composition of FRC posts includes carbon, quartz, or glass fibers embedded in a matrix of epoxy or methacrylate resin. Many clinical studies have revealed that post debonding is known to be most frequent failure mode encountered in retained fiber post restorations.[12] Further, clinical and laboratory use of polyethylene fiber post and GFPs in restoring primary anterior teeth has been successful as shown in studies carried out by Eshghi *et al*., Pithan *et al*., and Pinheiro *et al*.[5-9] Since fiber posts are passively fixed into the root canal, the success of the adhesive cement and the luting procedure plays an important role in clinical performance of the restorations.[12] In primary teeth, most frequently, flowable composites are used to cement fiber posts.[5-9] However, different cements such as resin cements and glass ionomer cements (GICs) have frequently used in the permanent teeth.[12,13]

GIC provides practitioners with several clinical benefits when dealing with cementation of GFP, such as providing a chemical and micromechanical bond to tooth structure and saving time, as a cementation process can be carried out without the need for tooth preparation. Other advantages of GIC include the presence of their viscoelastic properties that lowers polymerization shrinkage and improves adaptation between the root canal walls and materials.[13,14]

As to the interpretation of traditional procedures, pulp therapy has always been used before any full coronal restoration of anterior primary teeth is carried out.[10] In the 1930s, zinc oxide eugenol (ZOE) paste was the first root canal filling material (introduced by Sweet) to be used for the primary teeth.[15] It is also well known that ZOE paste is the most commonly used filling material for primary teeth in the United States. With that in mind, other relevant studies have been published in Japan on calcium hydroxide ($Ca(OH)_2$) and iodoform mixture (Vitapex, Neo Dental Chemical Products, Tokyo). In accordance with findings of Machida *et al*. (1990), $Ca(OH)_2$-iodoform mixture meets the criteria for an ideal primary tooth filling material. Furthermore, the use of an iodoform base or materials containing $Ca(OH)_2$ as a substitutes for ZOE has received great attention in recent years.[16]

Root canal filling material has a tendency to inhibit adhesion taking place between resin, filling material, and dentinal surfaces.[17] Thus, research studies have concluded that eugenol-containing sealers do not have an inhibitory effect on the bond strength of fiber posts cemented with resin.[18-23] Nonetheless, other studies have shown that eugenol-containing sealers, in fact, prompts a negative effect on the bond strength of fiber posts with resin cements.[24-27] However, the effect of eugenol on bond strength of intracanal posts has been remained unclear.[17]

Bond strength to root dentinal walls has been determined using conventional shear, micro-tensile, and push-out tests. Moreover, studies claimed that a push-out test provides better results than that of a conventional shear test when considering measurement of bond strength. This is mainly to do with fractures which can occur parallel to the dentin–bond interface. This also results in a more favorable condition within a clinical setting.[17]

The purpose of this study is to compare the push-out bond strength of different root canal filling materials (ZOE and Metapex) using three different intracanal posts. In here, the null hypothesis is used to conclude the relationship between that of a push-out strength and root canal dentin in anterior primary teeth, which are affected by root canal filling material and type of intracanal posts.

MATERIALS AND METHODS

In this *in vitro* study, sixty extracted primary central and lateral incisors were selected. Teeth were extracted within 2 months and disinfected in 0.5% chloramine and stored in distilled water at 37°C. All considered teeth measured at least two-third of root length and satisfied the criteria; for having at least one-third of their crown remaining. The crown of each tooth was sectioned transversally at 1 mm above the cementoenamel junction. The complete pulpectomy was performed with K-files (MANI, Utsunomiya Tochigi, Japan) to a size #45, then further irrigated with normal saline, and dried with paper points. The specimens were divided into two groups (n = 30). In Group 1, canals were obturated with ZOE paste (ZOE BP, Kemdent, Swindon, UK) with lentulo spiral #25 (Dentsply, Maillefer, Johnson city, TN) on low speed hand piece and packing technique. In Group 2, canals were obturated with Metapex (Metapex, Meta dental, Korea) with tip of syringe and packing technique. Further, approximately 4 mm of paste in the coronal part of the canal was removed with a round bur on a low speed hand piece, and a base of zinc polycarboxylate cement (Z^{25}, Hanse Dental Gmbh, Germany) with 1 mm thickness was placed over the ZOE and Metapex. From this, roots in each group were assigned to three subgroups in accordance with the type of post used [Table 1].

Thus, the following methods were carried out for each subgroup:

- Group 1: SCP group. Root canal walls were etched with a 35% phosphoric acid etchant (Scotchbond Etchant, 3M ESPE) for 15 s, rinsed with water for a further 10 s, and then gently dried with cotton pellets. In the meantime, surface moisture was thoroughly maintained during the course of the wet bonding procedure. Further, two layers of etch and rinse adhesive system (Adper Single Bond, 3M ESPE, St. Paul, Minn., USA) was applied with a micro-brush, and each layer was dispersed by applying a weak air stream and then light cured with a light emitting diode curing unit (Bluephase C5, Ivoclar vivadent clinical, Austria) for 20 s. The root canals were filled with a Z250 composite resin (3M ESPE, USA) via the incremental

Table 1: Characteristics of materials used in the study

Material	Manufacturer	Composition*	Application*
Zinc oxide eugenol cement	Kemdent, UK	Powder: Zinc oxide, rosin, zinc acetate Liquid: Eugenol	Powder and oil hand mixed and placed in canal with lentulo spiral
Metapex	Meta Dental, Korea	Calcium hydroxide, iodoform, silicon oil	Used with syringe and the paste is injected into the canal
GFP	Over fibers S.R.I, Italy	Reinforced composite + S type glass fibers + epoxy resin matrix	Clean the post surface with ethylic alcohol or phosphoric acid, clean the post from the etching Apply the adhesive to the post, wait at least 60 s, then dry it with air blast Fill up the root canal by self-curing or dual-curing cement and insert completely the post into the canal
GC Fuji I cement	GC, Japan	Powder: Fluoroaluminosilicate glass Liquid: Polyacrylic acid + distilled water	One level scoop Level scoop powder to 2 drop liquid Hand mix: Using the plastic spatula, add all the powder to the liquid Mixing time: 20 s Working time: 2 min
Adper Single Bond plus adhesive	3M ESPE, MN, USA	BisGMA, HEMA, dimethacrylates, ethanol, water, Vitrebond™	Apply etchant 15 s Rinse 10 s Drying with cotton pellets Apply 2-3 layers of bonding agents Gently air thin for 5 s Light cure for 10 s
Filtek Z350 XT flow	3M ESPE, MN, USA	Nanocomposite, flowable Matrix: BisGMA, TEGDMA, Procrylat resins Filler: Ytterbium trifluoride, silica filler, zirconia/silica cluster filler	Place and light cure in increments For shade A2, increment depth 2 mm, 20 s cure time
Filtek Z250 universal restorative	3M ESPE, MN, USA	Microhybrid universal composite Filler zirconia/silica Matrix: BisGMA, UDMA, BIS-EMA, TEGDMA	Place in cavity in increments and light cured 20 s for each 2.5 mm thickness (shade A2)

*Chemical composition and application methods of materials was obtained from the manufacture's safety data sheet, instructions and technical profiles. BisGMA: Bisphenylglycidyl dimethacrylate; UDMA: Urethane dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; BisEMA: Ethoxylated bisphenol-A dimethacrylate; HEMA: 2-hydroxyethyl methacrylate; GFP: Glass fiber post technique to reduce polymerization shrinkage. Therefore, each layer was approximate 2 mm in length and light cured for 40 s. Root canals were filled with composite until reaching the orifice. This method was appropriate since only 1 mm section were needed to perform the push-out tests.

- Group 2: GFP and flowable composite group. The root canal preparation in Group 2 was carried out in the same manner as Group 1. Each GFP (HI-Rem Post, Overfibers S. R. I, Italy) was sections in three parts using fissure bur on a high speed hand piece with water spray. Fiber post lengths in canals did not exceed more than 3 mm, ensuring no interference with normal root resorption. Hence, before cementation was carried out, fiber post lengths were measured with a probe, and post fitment checks were carried in the canals. Moreover, GFPs with sizes 1 and 2 were used based on their dimensions relative to the canals. Post surface treatment was done according to the manufacturer's instructions and immersed in ethyl alcohol and rinsed. This was followed by performing acid etching for 60 s, rinsing for 30 s, and drying with airflow until it became matt white. Furthermore, fiber posts were wet treated with adhesive as to further strength their adhesion between the utilized composites. A thin layer of flowable composite (Filtek Z350XT, 3M ESPE, USA) was applied in the canal and the fiber posts were inserted accordingly, in the post space, with applied finger pressure. Finally, the canals and posts were cured for nearly 40 s from incisal direction[28,29]
- Group 3: GFP and GIC group. In this group, no preparation was done on the root canal walls. Also, post treatment was performed following the same steps carried out in Group 2. GIC (GC FUJI Ⅰ, Luting and Lining, GC Corp. Tokyo, Japan) was mixed according to the manufacturer's instructions (one manufacture's spoon powder + two drop liquid) and applied to the post. It was then carefully inserted into the canal with finger pressure.

All teeth were stored in normal saline solution before testing commenced.

Push-out test procedure

All teeth were mounted with cold cure acrylic resin blocks. Then, using a water-cooled diamond blade on an abrasive cutting machine (Labcut 250B Benchtop, T201A, Perci, France), each tooth was sectioned, with 1 mm thickness, perpendicular to its long axis. Finally, a single slice was obtained from the 3 mm post space between each tooth.

A piston with a circular cross-section and a round head was attached to a universal testing machine (Zwick/Roell Z05, Ulm, Germany) and positioned at the apex, which aligned directly with the center of the post [Figure 1]. The load test was performed at a controlled speed of 0.5 mm/min until the post was fully extruded. The maximum load value was recorded in Newton and was then converted into megaPascal by dividing the recorded load value that caused fatigue with the measured surface area (A) of the post in the piston. The surface area of each post specimen was measured using a photograph taken by a handheld camera (Canon, model EOS600D, Japan) at a fixed distance from each specimen. Each photograph was exported in a CAD package (AutoCAD, version 2013, Autodesk, California, USA) and scaled accordingly to output true dimensions for each specimen [Figure 2]. As such, apical and coronal areas of all samples were calculated using the equation shown below.

$$(A1+A2) \times (h/2)$$

The push-out test data were analyzed with 2-way ANOVA analysis.

RESULTS

The mean push-out bond strengths with standard deviations, minimum and maximum bond strengths (MPa) are all presented in Table 2. The two-way ANOVA showed that the

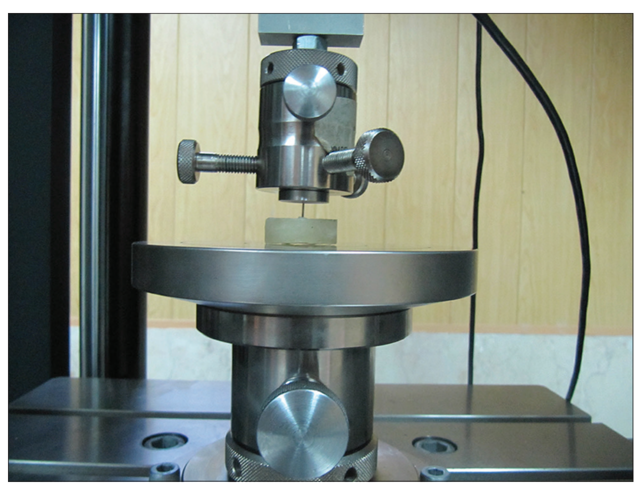

Figure 1: Specimen in universal testing machine for the push-out test.

Table 2: Mean push-out bond strength and standard deviations for different intracanal posts according to root canal filling materials (MPa)

Root canal filling material	Post	Mean±SD	Minimum	Maximum
Zinc oxide eugenol	Composite post	12.26±4.47	4.01	17.40
	Flowable composite+post	11.87±6.48	5.24	25.83
	GI cement + post	8.31±1.64	6.05	12.25
Metapex	Composite post	14.74±6.04	7.51	25.74
	Flowable composite+post	14.28±5.07	6.76	23.57
	GI cement + post	11.11±4.03	5.25	19.65

GI: Glass-ionomer; SD: Standard deviation

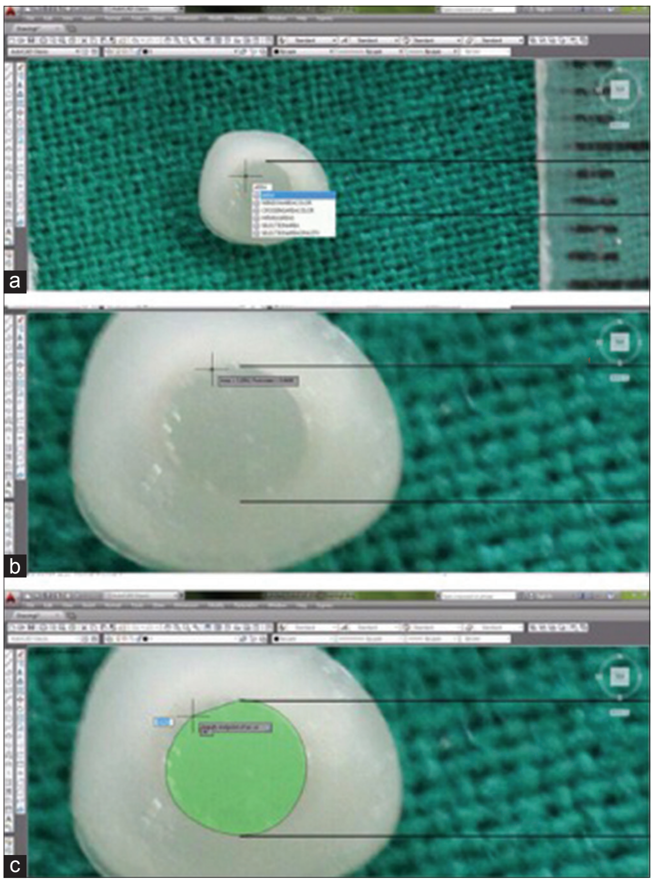

Figure 2: The specimens' cross-section measurements using the AutoCAD software. (a) The scale of each specimen was configured accordingly, using the dimensional tools in AutoCAD and a consistent scale of 1:1 was achieved. (b) Points were determined for measuring the area. (c) Then, utilizing the area tool, the desired sections were selected as to retrieve the precise area for each section.

interaction between the post and cement was not significant (P = 0.99). The mean push-out bond strength for all groups having ZOE as the root canal filling material (Group 1: 12.26 ± 4.47, Group 2: 11.87 ± 6.48, Group 3: 8.31 ± 1.64) came to be lower compared with the groups using Metapex (Group 1: 14.74 ± 6.04, Group 2: 14.28 ± 5.07, Group 3: 11.11 ± 4.03) (P = 0.046).

When considering different intracanal posts, the mean push-out bond strength of Group 1 (SCP) was higher (14.74 ± 6.04 MPa) in comparison with other groups. The mean bond strength of Group 1 was significantly higher than the Group 3 (GFP and GIC) (P = 0.034). However, the difference between Group 1 and Group 2 (GFP and flowable composite) was not significant (P = 0.097). Although the calculations of mean bond strength of Group 2 showed higher value than that of Group 3, the difference was not significant (P = 0.93).

DISCUSSION

The aim of this study was to determine the effect of root canal filling material on the bond strength of different intracanal posts and to also compare the push-out bond strength of different intracanal posts.

As to the interpretation of the null hypothesis, it was established that the root canal filling material has an effect on the bond strength of intracanal posts in primary teeth. It was also confirmed that the mean bond strength of all intracanal posts in the first group (utilizing ZOE) was considerably lower in comparison with other groups using Metapex. The evidence presented so far supports the findings in similar studies investigating the effect of root canal sealers on the bond of intracanal posts.[18-23] In the literature, eugenol has been associated with having adverse effects on resin compounds since its phenolic ingredients interfere with the polymerization of resins. This adversely affects their adhesion. Eugenol residues remaining on the dentin has a tendency to interfere with the polymerization of adhesive resins, and because of their penetrating potential in dentin, they can lead to a significant reduction in the adhesion and also decrease the bond strength of the resin cements.[22] Markowitz *et al*. reported that a chelation reaction occurs when zinc oxide is mixed with eugenol. Further, the formed particles of zinc oxide absorbed in a zinc eugenolate matrix practically make it possible for the eugenol to be released.[24] However, due to the presence of fluids inside the dentinal tubules, this reaction becomes reversible meaning; the eugenol is released and then permeates into dentin and finally becomes concentrated at the tooth–adhesive interface.[22]

Other studies with different results concluded that the eugenol content in endodontic sealer cements had no influence on the bonding process to the dentin.[25-27] A possible explanation for these differences in results may be entirely due to the assigned methods, canal preparation, canal irrigation and time between root canal obturation and post cementation.[24,26,27,30,31] In the studies which the post was cemented after a period of 7 days, inhibitory effect of eugenol on the polymerization process was decreased.[18,25,27] In this study, the cementation process was carried out immediately after the root canal filling was performed. This procedure might reduce the risk of coronal and apical leakage and restorative procedure could be performed in one session.[20] This has also been seen in the case of restoration of anterior primary teeth in younger children, under general anesthesia, in which the treatment procedure usually is accomplished in a single session. Based on the used methodology and the results obtained, it was concluded that, when posts are to be cemented immediately after root canal filling in anterior primary teeth, Metapex is much more suitable in comparison with ZOE.

As we pointed out in the introduction to this paper, Group 1 (SCP) had the highest mean push-out bond strength (14.74 MPa). Thus, the current method is endorsed among practitioners for being swift and easily implementable, which is proven to be the case in numerous laboratory and clinical research studies.[5,8,11] When considering cases with severe tooth destruction, intracanal posts have been used to increase crown retention. Moreover, fiber posts have the advantage of having a favorable bio-mechanical behavior, modulus of elasticity similar to dentin and good esthetic.[13,28,29] In primary teeth, flowable composites are mostly used as the luting agent for fiber posts.[5-10] The calculated bond strength for Group 2 (fiber post and flowable composite) was similar to Group 1, and statistically, no difference was noticeable between the two groups. This result may be because of the low viscosity of flowable composite resins and their good adaptation to root canal walls.[5] Flowable resin composite liners also work really well as flexible intermediate layers. They are advantageous in relieving stresses during polymerization shrinkage of restorative resin.[32] According to Hooke's law,[33] stress is related to elastic modulus of material. Polymerization shrinkage can initially increase stress along the tooth–adhesive interface. Nonetheless, the low modulus of elasticity of low viscosity composites allows them to flow during polymerization. This opposes the stress developed and aids in maintaining the marginal seal of the restoration.[34]

The mean bond strength of 14.74 retrieved in SCP group was comparable with Afshar *et al*. mean bond strength (13.6 MPa), which was carried out to estimate the effects of different bonding formations on push-out bond strength of SCPs in the anterior primary teeth.[35] Further, the results gathered in this study were compatible with other studies which primarily dealt with permanent teeth.[17-22]

In the all studies reviewed, the results gathered in this study matched closely with the work of Memarpour *et al*.[5] and Pithan *et al*.,[7] which showed that the tensile bond strength of GFPs luted with flowable composite are in fact similar to that of SCPs. In accordance with the studies carried out on permanent teeth, canal diameters were shaped by employing drills as to achieve a uniform canal diameter. However, in primary teeth, due to thin dentin composition, it was not possible to use drills, thus canal diameters were calculated from photographs of each specimen and using state of AutoCAD software package as illustrated in Figure 2. Hence, the difference between canal diameters did not affect the bond strength and push-out bond strength was precisely calculated for each specimen.

Finally, the mean push-out bond strength of Group 3 (GFP and GIC) was lower in comparison with other groups. The difference in results was much more significant when compared against Group 1, but not so much when compared with Group 2. The outcomes of results gathered in this study were similar to research findings that also assessed bond strength of GIC to dentin. In these results, the average bond strength of GIC were in the range of 3–4 MPa and bond strengths above 5 MPa was rarely obtained.[36-39] The low strength of GIC was due to its initial brittleness, contamination, and sensitivity to dehydration and greater void formation.[35,36,40] Such an outcome could be the result of lower bond strength in Group 3 when compared with other groups as a part of this study.

Additional clinical studies are encouraged to be carried out for evaluating effect of root canal filling materials on bond strength of intracanal posts in the primary anterior teeth. Further suggestions are made for them to be compared with different intracanal posts. As part of this study, no root canal irrigants were used, and it is beneficial to conduct research in future studies to understand and evaluate the effect of root canal irrigants on intracanal posts bond strengths in the primary teeth.

CONCLUSION

ZOE significantly reduces the mean push-out bond strength of intracanal posts in primary anterior teeth. SCPs and GFPs luted with flowable composite have acceptable mean push-out bond strength for restoring anterior primary teeth.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial, or nonfinancial in this article.

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