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Retentive strength of different intracanal posts in restorations of anterior primary teeth: an *in vitro* study

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Objectives: To determine the retentive strength and failure mode of undercut composite post, glass fiber post and polyethylene fiber post luted with flowable composite resin and resin-cement. ***Materials and Methods:*** Coronal parts of 120 primary canine teeth were sectioned and specimens were treated endodontically. The teeth were randomly divided into 6 groups ($n = 20$). Prepared root canals received intracanal retainers with a short composite post, undercut composite post, glass fiber post luted with flowable resin or resin-cement, and polyethylene fiber post luted with flowable resin or resin-cement. After crown reconstruction, samples were tested for retentive strength and failure mode. Statistical analysis was done with one-way ANOVA and Tukey tests ($p < 0.05$). ***Results:*** There were statistically significant differences between groups ($p = 0.001$). Mean bond strength in the undercut group was significantly greater than in the short composite post ($p = 0.030$), and the glass fiber post ($p = 0.001$) and the polyethylene fiber post group luted with resin-cement ($p = 0.008$). However, the differences between the undercut group and the groups with flowable composite as the luting agent were not significant ($p = 0.068$, $p = 0.557$). Adhesive failure was more frequent in the fiber post groups. ***Conclusions:*** Although the composite post with undercutting showed the greatest resistance to dislodgement, fiber posts cemented with flowable composite resin provided acceptable results in terms of retentive strength and fracture mode. (*Restor Dent Endod* 2013;38(4):215-221)

Key words: Dental restoration; Fiber posts; Primary teeth; Resin cement

Introduction

Although parents prefer restoration of anterior primary teeth in their children rather than replacing the teeth with appliances following extraction, restoration remains a challenge for pediatric dentists.[1] The teeth are small with short crowns, and may be extensively destroyed by caries.[2] Under these circumstances, effective bonding to the remaining tooth structure by tooth-colored restoration materials may be compromised.[3] Therefore, intracanal posts and retainers have been suggested for use after tooth pulpectomy. Among the types of retainers that have been used to increase restoration retention are nickel-titanium and other metallic posts, orthodontic wires, biological posts, short composite resin posts, fiber-reinforced composite (FRC) posts such as polyethylene ribbon fiber posts, and glass fiber posts.[4-18]

The use of a short composite resin post is a simple technique to compress the composite into the canal and create a tapered post.[8,9] A similar technique, called the mushroom-shaped resin post, involves creating an undercut around the root canal walls and building up the composite within the entire canal. This method results in better retention than short composite posts alone.[8]

Prefabricated tooth-colored FRC posts are an alternative to metal posts for tooth restoration.[9,18] One improved new system is a hybrid of unidirectional and braided polyethylene fibers known as Ribbond Triaxial.[19-21] Glass fiber is another type of FRC post composed of unidirectional glass fibers embedded in a resin matrix for added strength.[21,22] EverStick is a flexible pre-impregnated glass fiber post that adapts to the canal. Both types of flexible fibers improve the aesthetic results, increase fracture resistance of the composite resin restoration and have a modulus of elasticity similar to that of dentin.[20,21,23] A number of studies have documented the clinical and laboratory success of polyethylene fiber and glass fiber posts in restoring primary teeth.[10-18]

The choice of luting cement as well as post selection are important factors that influence the bond strength of post retention.[23] In primary teeth, flowable composites are used most frequently as the luting agent.[11-18] However, other materials such as resin cements have also been introduced mainly for use in permanent teeth. The new generation of resin luting cements provides high retention of intracanal posts. Dual-cured resin cements were developed to take advantages of the benefits of both self- and light-cured compounds. Polymerization starts with light-curing and is assumed to continue even in the absence of light. However, the technique is sensitive and the cement is highly viscous.[23,24] Variolink II is a dual-cured resin cement with good mechanical properties due to high load of fillers. The cement attains favorable characteristics with low light intensity.[24] Several studies have reported successful results with resin cements for posts in permanent teeth.[25-28]

Most studies to date have assessed bond strength in different kinds of posts and luting cements in permanent teeth, whereas few have evaluated the resistance to removal of different aesthetic posts luted to primary teeth. To investigate the effect of resin cement on post retention, this study was designed to compare the retentive strength of composite posts versus two aesthetic fiber posts cemented either with flowable composite or resin cement in anterior primary teeth. The hypothesis was that the resin cement would provide increased retentive strength with polyethylene or glass fiber posts.

Materials and Methods

After the research protocol for this study was approved by the Human Ethics Review Committee of the School of Dentistry, Shiraz University of Medical Sciences, 120 sound maxillary primary canine teeth extracted for orthodontic treatment were selected for this study. All the patients' parents were informed about the purpose of the research and how the extracted teeth would be used for *in vitro* research.

Root canal preparation

To remove debris, the teeth were scaled, cleaned with fluoride-free pumice and a prophylaxis brush, and immersed in 0.1% chloramine T solution for 2 weeks for disinfection, and then stored in distilled water. None of the teeth showed any signs of external root resorption. All the surfaces were examined with an explorer to rule out any teeth with enamel defects, cracks or caries. The crown of each tooth was sectioned transversally 2 mm above the cementenamel junction.

After a standard coronal access cavity was prepared, the working length of each canal was recorded as the length of the initial file at the apical foramen minus 1 mm. Then the root canals were prepared with K-files (Mani INC., Utsunomiya Tochigi, Japan) and obturated with zinc-oxide eugenol paste (ZOE, Kemdent, Swindon, UK) with a packing and injection techniques. Then the apex of the root was covered with red wax and the apical parts of the roots (from 2 mm below the cementenamel junction) were placed in the center of cold-cured acrylic resin blocks measuring 1 × 1 × 1 cm. Then the specimens were divided randomly into six groups of 20 teeth each. Before crown construction was begun, about 4 mm of paste in the coronal part of the canal was removed with a diamond fissure bur.[5,11,17,18] The presence of eugenol in the ZOE is known to interfere with composite resin polymerization. Therefore a thin layer (approximately 1 mm) of polycarboxylate cement (Durelon, 3M ESPE, St Paul, MN, USA) was placed over the ZOE. After all the paste was completely removed from the root canal walls, pretreatment was done as described below.

Crown reconstruction

Group 1. Short composite resin post group (control). The tooth structure and root canal walls were etched with 37% phosphoric acid (3M ESPE) for 15 seconds followed by rinsing for 15 seconds and gentle drying with a weak air stream. During the procedure, surface moisture was maintained as recommend for wet bonding techniques. Then a 2-step etch-and-rinse adhesive system (Tetric N-Bond, Ivoclar Vivadent, Schaan, Liechtenstein) prepared according to the manufacturer's instructions was placed in the preparation, thinned by applying a weak air stream, and light-cured for 20 seconds with a halogen light curing unit (Coltolux, Coltène/Whaledent AG, Altstätten, Switzerland) at a power density of 600 mW/cm^2. The crown was reconstructed with a nanohybrid composite resin (Tetric N-Ceram, Ivoclar Vivadent) with an incremental technique to reduce polymerization shrinkage and void formation during composite placement.[17] At first, the entrance of the

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root canal and the canal were filled with composite resin, and then the crown was built up with the same composite to about 5 - 6 mm in diameter and 6 mm in length. Each increment was less than 1.5 mm, and was light-cured for 20 seconds with a light curing unit. Light intensity was monitored with a radiometer (Model 100 Optilux Radiometer, SDS Kerr, Danbury, CT, USA) before each use.

Group 2, Short composite resin post with undercut. A mushroom-shaped undercut (1 × 0.7 mm) was prepared around the root canal walls about 3 mm below the cementenamel junction of the tooth. The undercut was made with a round bur (no. 4) while the bur was held parallel to the long axis of the tooth to prevent canal perforation.[8] Before etching, each tooth was examined to rule out any teeth with lateral canal perforation. Then the tooth surfaces were etched and a thin layer of adhesive (Tetric N-Bond) was applied as in group 1. The canal and crown were constructed as in group 1.

Group 3, Glass fiber post + Resin cement group. The tooth surfaces were etched and a dual-cured adhesive (ExciTE F DSC, Ivoclar Vivadent) was applied, thinned and cured for 10 seconds. A glass fiber post (everStick, StickTech Ltd., Turku, Finland) 1.5 mm in diameter was cut to a length of 6 mm to insert 3 mm inside the canal and leave the remaining 3 mm to reinforce the core. Placement of fiber post to a depth of 3 mm in the root canals did not interfere with normal root canal resorption.[5,11,17,18] Fiber post length was measured with a scored probe and checked in the canal before cementation. The tweezers used to handle fiber posts and the operator's fingers never touched the fibers post. Two pastes (base and catalyst) of a dual-cured resin cement (VariolinkII, Ivoclar Vivadent) were mixed according to the manufacturer's instructions, and the fiber post was coated with the mixture, and placed into the canal. Excess material was removed and the complex was cured for 60 seconds. Finally the crown was constructed as described above.

Group 4, Glass fiber post + Flowable composite resin group. All procedures were as described above for group 3 except that the glass fiber post was cemented with a flowable composite resin. After etching, applying the adhesive (Tetric N-Bond) and curing, a thin layer of flowable composite (Tetric N-Flow, Ivoclar Vivadent) was applied in the canal and the fiber post was inserted, fitted by finger pressure, and cured for 120 seconds to ensure polymerization of the composite inside the root canal. The crown was built as described above.

Group 5, Polyethylene fiber post + Resin cement group. The tooth surfaces were prepared as in group 1. A tape-shaped Ultra High Molecular Weight Polyethylene (UHMWPE) triaxial fiber (Ribbond, Seattle, WA, USA Triaxial) 3 mm in diameter was selected and manipulated according to the manufacturer's instructions. The length of the fiber post was the same as in groups 3 and 4. The fiber post was wetted with an unfilled resin (Resist, Biodental Technologies, Sydney, Australia) to increase adhesion between the fiber post and composite, and to facilitate handling. After excess resin was removed, the fiber post length was checked inside the canal and the fiber wetted with resin was cured for 10 second. Then the fiber post was coated with resin cement as in group 3. Finally the crown was built as described above.

Group 6, Polyethylene fiber post + Flowable composite group. The procedures were performed as described above for group 5 except that a flowable composite was used as the luting agent. The procedure for fiber post placement with flowable composite was the same as described above for group 4, and the crown was build as in the other five groups.

The composition of the materials and instructions for use are shown in Table 1.

Tensile bond strength

A piece of orthodontic wire 2 mm in diameter and 12 cm length was cut and bent into a 5 - 6 mm long U shape using orthodontic pliers (No. 139). During crown reconstruction, the wire was embedded in the composite and covered with a layer of composite. This method is preferable to making holes in the polymerized composite with a bur, which may create a source of stress within the composite.[17] It also provides better control of the position of the wire, and reduces damage to the core and post materials by the bur.

After all the samples were prepared, the teeth were placed in distilled water for one week at 37℃. Resistance to removal of the restoration was measured as tensile bond strength by placing the tooth in an Instron testing machine and twisting the free ends of the wires together. To apply tension, the mounted tooth was placed on the lower crosshead of a universal testing machine (Zwick-Roell, Zwic, Ulm, Germany), while upward force was applied through the wire by the upper part of the machine. The load (force) required to dislodge the restoration was measured at 1,000 N at a speed of 4 mm/min. The force was applied to the long axis of the tooth and increased in 0.1 g steps until the restoration was dislodged.

Mode of fracture

Under blind conditions, two observers examined the teeth under a digital microscope (Dino Lite, Taipei, Taiwan) at 25× magnification and recorded the types of bond failure as follows,

1. Adhesive fracture at the cement-post interface
2. Adhesive fracture at the cement-dentin interface
3. Cohesive fracture: only core bulk fracture[17,24]

Table 1. Materials and application procedures used in this study

Material	Chemical composition	Procedures	Manufacturer
Phosphoric acid gel (37%)		Apply for 15 sec, rinse 15 sec, air-dry for 10 sec	3M ESPE, St. Paul, MN, USA
Durelon, Polycarboxylate cement	Powder: zinc oxide Liquid: polyacrylic acid	Mix powder and liquid (1 : 1) for 30 sec	3M ESPE, St. Paul, MN, USA
Tetric N-Bond	Phosphoric acid acrylate, HEMA, bis-GMA, urethane dimethacrylate, ethanol, catalysts stabilizers	Apply and leave for 10 sec, dry gently, light-cure for 20 sec	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric N-Flow	Dimethacrylates, TEGDMA, barium glass, ytterbium trifluoride, silica, mixed oxide,stabilizers, pigments	Apply inside the canal, light-cure for 120 sec	Ivoclar Vivadent, Schaan, Liechtenstein
Tetric N-Ceram	Dimethacrylates, barium glass, ytterbium trifluoride, mixed oxide, copolymers, catalysts, stabilizers, pigments	Apply in layers of 1.5 mm maximum, light-cure for 20 sec	Ivoclar Vivadent, Schaan, Liechtenstein
Ribbond Fiber	Polyethylene fiber		Ribbond, Seattle, WA, USA
EverStick	Polymer (PMMA), impregnated (bis-GMA), glass fiber post		StickTech Ltd., Turku, Finland
Variolink II	Bis-GMA, urethanedimethacrylate, triethylene glycol dimethacrylate, barium glass, ytterbium trifluoride, Ba-Al-fluorosilicate glass, catalysts, stabilizers, pigments	Mix base paste and catalyst at a 1 : 1 ratio for 10 sec, light-cure for 60 sec	Ivoclar Vivadent, Schaan, Liechtenstein
ExciTE F DSC	HEMA, dimethacrylate, phosphonic acid acrylate, silicone dioxide, initiators, stabilizers, potassium fluoride, alcohol solution	Apply and leave for 10 sec, dry gently, light-cure for 10 sec	Ivoclar Vivadent, Schaan, Liechtenstein

HEMA, 2-hydroxyethyl methacrylate; Bis-GMA, bisphenol-A-diglycidyl methacrylate; TEGDMA, triethyleneglycol dimethacrylate; PMMA, polymethylmethacrylate.

Consistency between the examiners was ensured by having them examine 10 dislodged teeth and comparing their ratings before the evaluation started.

Statistical analyses were done with one-way ANOVA to compare all subgroups and the Tukey test for paired comparisons. A p value of < 0.05 was considered significant.

Results

Statistical analysis with one-way ANOVA detected significant differences among all groups ($p = 0.001$). Table 2 shows the mean and standard deviation of retentive strength in all the groups. *Post-hoc* analysis with the Tukey test showed that the mean retentive strength in group 2 (undercut) was significantly higher than in group 1 (control, $p = 0.030$), group 3 (glass fiber post + resin cement, $p = 0.001$) and group 5 (polyethylene fiber post + resin cement, $p = 0.008$). However, the differences were not significant between group 2 and the other groups with a flowable composite as the luting agent (group 4, glass fiber post + flowable cement, $p = 0.068$; group 6, polyethylene fiber post + flowable cement, $p = 0.557$) (Table 2). The results of failure mode tests showed that cohesive failure was the most frequent in group 2. However, mean retentive strength was the highest in this group. In the groups with a fiber post-reinforced restoration (groups 3 - 6), adhesive bond failure was more frequent than cohesive fracture. Table 2 shows the frequencies of the different fracture modes in all 6 groups.

Discussion

Fracture and particularly dislodgment of tooth-colored restorations are the main causes of failure after the reconstruction of extensively damaged anterior primary teeth. Therefore better retention of the restoration is desirable, and evaluations of resistance to dislodgment with laboratory tests such as retentive strength are of interest to clinicians. Among the available tooth-colored materials, composite resin is a common choice for restoring anterior teeth due to its strength, resistance to wear and aesthetic results.[2] Nevertheless, new materials and techniques may

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Table 2. Mean tensile bond strength of experimental groups (Unit, MPa; n = 20) and frequency of failure modes of fractures in each group

Groups	Tensile bond strength	Failure mode		
		Adhesive fracture (at cement-post junction)	Adhesive fracture (at dentin-cement junction)	Cohesive fracture
1. Short composite post	127.96 ± 46.98	-	7	13
2. Undercut short composite post	175.70 ± 53.24	-	2	18
3. Glass fiber post + Resin cement	113.12 ± 40.43	5	8	7
4. Glass fiber post + Flowable resin	132.71 ± 63.59	4	11	5
5. Polyethylene fiber post + Resin cement	121.31 ± 44.65	1	11	8
6. Polyethylene fiber post + Flowable resin	149.95 ± 40.07	1	9	10

offer dentists alternative options for improving the results of treatment.

Intracanal posts have been used to increase crown restoration retention, especially when a significant part of the crown has been lost.[21] Fiber-reinforced composite posts made of polyethylene and glass fiber provide the best aesthetic results and are widely used to restore permanent teeth. Ribbond polyethylene fiber increases the flexural characteristics of the composite resin, thus providing high fatigue resistance, preserving the architectural shape, and maintaining fiber orientation during application.[19,20] Glass fiber posts such as everStick are also used to reinforce weakened roots without increasing the likelihood of root fracture. The flexible post is easy to handle and provides maximum support for the crown. In addition, the composition of the fiber post favors adhesion to the luting cement and composite core.[22,25]

In the current study, group 2, in which the mushroom-shaped undercut technique was used, had the highest mean retentive strength. This characteristic can contribute to both mechanical and micromechanical bonding to the tooth structure. The successful use of undercut techniques has been reported in previous studies, but the technique increases the risk of lateral root perforation and root weakening, especially in young children with thin dentinal root canal walls.[8] Therefore the technique has been modified to incorporate a short composite resin post (as in group 1). This is a rapid and straightforward method.[9] However, it obviates the problems of the undercut method, it provides less retention against crown dislodgment in straight anterior root canals.[8,17] In the present study the crown reconstructions in group 1 (control) had lower retentive strength than in group 2, most likely because of providing mechanical retention in the undercut group.

Groups 4 and 6, which used fiber posts cemented with a flowable composite, also had higher retentive strength although the values were lower than in group 2 (undercut). This result may be related to the low viscosity of flowable composite resins and their good adaptation to root canal walls.[29,30] However, during light-curing, polymerization shrinkage may occur toward the curing light, away from the dentinal wall, and toward the posts. Using dentin adhesives can reduce the contraction gap along the dentin-luting interface.[31] In addition, inserting a fiber post helps the composite to resist pull-away toward the light source and thus improves marginal adaptation.[29] Moreover, fiber posts used in associated with a flowable composite can modify interfacial stress, resulting in better integrity of the bonded interface.[30]

Despite the high polymerization shrinkage stress of flowable composite resins with an unfavorable configuration factor (C-factor), this appears not to compromise tensile bond strength. The low intrinsic rigidity of flowable composites enhances the stress-relieving behavior of these compounds.[30] In agreement of our result, Gujjar *et al.* showed that the tensile bond strength of glass fiber posts was greater than composite posts or orthodontic wires when a flowable composite was used as the luting agent.[17] However, according to Pithan *et al.* there were no significant differences in tensile bond strength between orthodontic wire, composite and glass fiber posts when they were cemented with a composite resin.[18] The same results were obtained by Pinherio *et al.*, who compared orthodontic wire, composite and dentin posts fixed with a dual cured adhesive material.[7] The type of post, tooth and luting cement may explain the differences between our results and other studies.[17]

Some studies that used resin cement with a glass fiber post reported high bond strength in permanent teeth especially by using self cured adhesive and resin cement than light cure of them.[23,25,26,32] Nevertheless, in the present study, Variolink II (groups 3 and 5) provided less resistance to crown dislodgment in comparison to the flowable luting agent (groups 4 and 6). This result may be due to the high viscosity of the cement, which may interfere with complete adaption of the post in the root canal.[25,33] In addition, greater void formation may decrease the adhesion of these cements to the dentin. The presence of voids may result from mixing the two pastes of the cement, or from covering the post with cement before inserting the fiber post into the canal.[23,34] When this is the case, using elongation tip to inject cement is recommended.[27] With regard to the high C factor, there is no free area to provide relief from polymerization shrinkage. This phenomenon reduces bond strength between the cement and dentin and may lead to gaps at the cement-dentin interfaces.[35] One of the potential limitations of the present study was the effect of variations in root canal size, which may affect luting agent thickness and therefore bond strength. Other factors that may influence the results include short working time, technical sensitivity and operator experience.[25]

In the present study, cohesive failures were mostly observed in groups 1 and 2, in which composite posts were used as the retainer. In contrast to other groups which used a fiber post for core reinforcement, adhesive failures were more frequent than cohesive failures because of the low bond strength between the luting cement and the dentin. This finding is in agreement with Gujiar *et al*. and Ayes *et al*., and suggests that the fiber post reinforces the core.[17,23] The groups that used a composite post, only retention of the post inside the canal increased, with no gain in reinforcement of the core. As a result, the load applied during testing in groups 1 and 2 led to fracture of the crown mostly at the cervical margin (cohesive failure). Unfortunately, fracture and failure of this type of restoration are more difficult to repair than teeth that were restored with a fiber post. Our study shows that glass fiber posts were more resistant to fracture at the cervical margin. Glass fiber posts are easy to use, and unlike polyethylene fiber posts, they do not need to be impregnated with resin. Thus using a glass fiber post together with a flowable composite may be a potentially useful alternative for the restoration of primary teeth.

Our results show that the type of cement had a greater effect on retentive strength than the type of post. In agreement with our results, Braga *et al.* reported that the type of post did not affect the force needed to dislodge the core.[36] Kim *et al.* concluded that the type of post did not affect fracture resistance or fracture level in restored permanent teeth.[28] Moreover, Pithan *et al.* reported that the adhesion of the materials to dentinal root canal walls was more important than the type of post used as a retainer.[18] Additional clinical studies are necessary to document the performance and success of different materials used to restore anterior primary teeth.

Conclusions

The mushroom-shaped undercut technique led to a significantly higher retentive strength than restorations prepared with a fiber post fixed with resin cement. Crowns reinforced with fiber posts showed adhesive failure more frequently than teeth reinforced only with a composite as the post and core. Restorations created with a glass fiber post cemented with a flowable composite can be considered as an alternative treatment for restoring anterior primary teeth due to its retentive strength and mode of fracture.

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