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In Vitro Evaluation of Push-Out Bond Strength in Three Different Post Systems

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Abstract

Background and objectives: Intimate adaptation to the canal walls is accomplished by custom-made posts which leave an even thickness of cement layer. Therefore, this study has been conducted for assessing the strength of push-out bond among prefabricated fiber posts, relined fiberglass posts, and zirconium posts using resin cement of self-adhesive and adhesive. The mode of failure was also assessed.

Materials and Methods: Sixty uniradicular teeth were endodontically treated. According to the kind of post system and cement utilized (n=10), the specimens were separated randomly into six groups. Zirconium oxide post, customized glass fiber post, and glass fiber post were used. The roots were divided into three discs: apical, middle, and cervical sections. After that, the discs were put through a push-out test, and the fracture mode was examined using a stereomicroscopic loupe.

Results: The highest push-out value was recorded for the relined post (8±2.83 MPa), and the lowest was registered with no significant differences for the prefabricated post (7.27±3.76 MPa). There were no significant differences in strength bond across the various posts and root regions (P>.05). Adhesive failure at the dentin-cement interfaces for the prefabricated and relined post was (60, 57) % respectively, and zirconium oxide post was (22%).

Conclusions: Relined posts may be a suitable clinical situation as a post material selection with reduced clinical steps. When posts are joined using self-adhesive and adhesive resin cement, the root region has no important influence on the strength of the bond.

Key words: Bond strength; Fiber post; Relined post; Resin cement; Zirconium oxide post.

Introduction

Despite current improvements in dentistry, such as the inclusion and improvement of new restoration materials and procedures, there are still significant obstacles in the reconstruction of endodontically treated teeth, especially when the root canal is large and/or fragile.[1] Cast metal cores were formerly thought to be the best alternative for restoring such teeth with poor crown structure.[2] Nevertheless, in addition to being unattractive, the core sends a significant portion of the masticatory forces received straight to the root, which can lead to fractures because of the metal's high coefficient of elasticity in comparison to that of root dentin.[3] Given the growing demand for cosmetic restorations and the need to develop the fracture resistance of teeth repaired with a post-and-core system, researchers have concentrated on post materials.[4] In certain clinical conditions, such as the presence of caries or oval-shaped roots with a greater cervical third, an increase of the post space width is required to achieve close contact with the canal walls, resulting in excessive tooth structure removal.[5] However, it's been suggested that the match in the drill and

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fiber posts size may not allow adequate space for the resin cement to reach its full strength.[6] Surface configuration, shape, diameter, post length, and therefore the luting agent are all important determinants in their retention. The most frequent reason for fiber post-failure is debonding, which may be caused by a lack of adaptability between the fiber post's form and diameter and the prepared root canal.[7] Zirconium-oxide ceramics of custom-made high-strength, which are not silica-based and so do not form chemical silica-silane linkages, are one method for achieving excellent adaptation.[8] Surface preparation using acidic chemicals such as phosphoric acid, on the other hand, will not provide enough roughness to increase micromechanical retention.[9] As a result, a variety of pretreatment methods are suggested. The structure of the surface is affected by airborne- abrasion particles of alumina, which causes plastic roughening and deformation, resulting in enhanced amount and volume of material loss.[10] Relining the fiberglass post with composite resins before cementation is one method of modifying it to improve its adaptability to the root canal walls. Therefore, the percentages of structural deformity creation in the cement layer declined since this approach assists the post in adapting to the anatomical space of the root canals, leading to a thinner cement layer.[11] Nevertheless, nothing is known regarding the relined fiberglass post` performance that has been luted with various resin cement necessitating further research to address these challenges. For cementing tooth-colored posts, various systems of corresponding bonding and agents of resin luting have been suggested, which can be grouped into traditional agents of bis-GMA-based resin luting and well-known agents of adhesive resin luting involving functional monomers including 10-Methacryloyloxydecyl hydrogen phosphate (10-MDP) or 4-methacryloxyethyl trimellitate anhydride (4-META).[12] Various in-vitro experiments on the binding strengths of various agents of luting to root dentin and endodontic posts have shown conflicting findings.[13] As a result, this study used a resin cement of self-adhesive and adhesive to test the push-out bond strength of prefabricated fiber posts, zirconium posts, and relined fiberglass posts. The mode of failure was also determined. The null hypothesis was that: first, the bond strength values of three distinct kinds of posts utilizing two distinct kinds of cement are the same. Second, the various radicular regions have identical bond strength to distinct posts and resin cement.

Materials and methods

Sixty freshly extracted single-root human teeth for orthodontic purposes were chosen in this research, and verbal consent was obtained from patients. The roots had a comparable straight shape at the apical third. The root surfaces were cleaned gently from soft tissue remnants and then disinfected with 0.5% chloramine for 48 h. By radiological evaluation, the teeth were evaluated for the existence of a single canal with no prior calcifications, resorptions, or endodontic treatment. Samples were decoronated with a disc of double-faced diamond in a slow straight handpiece apical from the cementoenamel junction to get (14mm) length which was determined by a digital Vernier (China) and marker. The pulp residuals were removed by a barbed broach. Samples were put into a block of chemically cured acrylic resin (Brazil, Pirassununga, and VIPI) with 4 mm of the coronal region left exposed. The resin block and the teeth' long axis was aligned perpendicular to the ground and parallel to each other using a dental surveyor. A single operator carried out all of the dental preparation procedures. For standardization, during instrumentation, the samples were fixed by bench vice (China) in such a way that the mesial side always faced the hand of the operator. Utilizing a size 15 K type file, the working length of all canals was recorded by 1 mm from the measured working length (Dentsply, Mallifer, Switzerland). Every canal was instrumented utilizing a crown-down method with rotary ProTaper. Next instruments (Dentsply, Tulsa, dental, Tulsa, Oklahoma) driven at 250 rpm with 2 N/cm torque (X Smart Dentsply, Maillefer) up to size X3, using 17% ethylenediaminetetraacetic acid (EDTA)and 10 mL of 3% sodium hypochlorite (Na OCl) as an irrigate. The last rinse was done with 10 mL of 0.9% normal saline. With sterile paper point size X3, every canal was dried, and radiographs were taken using an X3 master cone. After the application of sealer (AH Plus, Dentsply, Germany), obturation has been conducted through the lateral condensation method of gutta-percha points. Openings of the cervical root canal were temporarily closed with a temporary filling material when endodontic therapy was completed. Then, the samples were preserved for 7 days at 100 percent humidity and 37 ˚c to enable the complete set of sealers. Post space for each sample was prepared of a similar size of Peeso drill up to number 3 to remove the coronal gutta-percha and post drill (HS Maxima, USA) of size 2 was used to drill 10 mm length leaving 4 mm apical gutta-percha to prevent the variations in dimension which may affect the strength of push-out bond values. The post space was irrigated once again, and with paper points, the canals were dried. Radiographs were done to see whether there was any gutta-percha left in the root canal walls along with the post space. Based on the kind of post and luting cement utilized, the samples were randomly separated into six groups (n=10): Group1= prefabricated fiber post/RelyX U200(PP -U200), Group 2= prefabricated fiber post/ RelyX Ultimate (PP -UL), Group 3= relined post/ RelyX U200 (RP -U200), Group 4= relined post/ /RelyX Ultimate (RP -UL), Group 5= zirconium oxide post/ RelyX U200 (ZP - U200) and Group 6= zirconium oxide post/ RelyX Ultimate (ZP -UL). With 70% alcohol, prefabricated fiber posts in groups 1 and 2 (HS Maxima, USA) were cleaned and treated with silane (Ultradent, USA) for 1-minute before cementation. To obtain relined fiberglass posts in (groups 3 and 4), the single bond adapter universal (ESPE, 3M, USA) with a light intensity of 1.100 mW/cm was utilized and light-cured for 20 s with a light-emitting-diode curing unit (Radii Cal, SDI, Bayswater, Australia) [2]. The resin composite (Filtek Z250; 3M ESPE) was adapted to the selected post and then seated in the canal that was previously lubricated with water-based gel (K-Y gel, Johnson & Johnson, Sa˜o Jose´ dos Campos, SP, Brazil) to reproduce the canal anatomy. This relined post was first light-cured inside the canal for 5 seconds using a 1200 mW/cm2 from the occlusal surface, then light-cured for 40 seconds outside the canal and reinserted for verifying the adaptation. For 15 secs, every relined post was etched with phosphoric acid 37% then dried and treated with silane before cementation. To fabricate the zirconium oxide post (group 5 & 6), an impression of definitive with materials of polyvinyl siloxane (Aquasil Ultra LV, Aquasil Ultra XLV; Dentsply Sirona) was taken conventionally. With a scanner of blue light, the impression was scanned (Identica Blue; Medit Corp) which is subjected to a spray of nonreflecting scan (Diascan spray; Diaswiss SA). Using a CAD software inlay module, a perfectly formed post and core were created (Dental System 2014 2.9.9.5; 3Shape Inc). The design was sent to a machine of 5-axis milling (Arum 5X-200; DoowonID Co), which produced a zirconium oxide block (AlphaZ; DMAX Intl). In a furnace (Austromat mSiC; Dekema Dental-Keramiköfen GmbH), the milled zirconium oxide post and core were sintered. Lastly, 50 m Al2O3 particles were abraded in the air for 13 seconds at

0.28 MPa at a distance of 10 mm. The zirconium oxide posts were then treated with silane before cementation. Table (1) summarizes the luting techniques.

Table (1): Cementation procedures of three types of posts

Groups	Dentin pretreatment	Luting agent application
G1	The canals of root were rinsed with 2 ml of distilled water excess water was removed with cones of absorbent paper (Dentsply Maillefer).	On a paper pad, the cement of self-adhesive resin was mixed properly and utilized for the post. The post was inserted and twisted until seated to remove air bubbles, 2.5 N static load was applied, lied and later, cement excess was eliminated using a micro brush, before proceeding waiting for 3 minutes, for 40 seconds with photoactivation, 10 seconds on each face.
G2	The root canals were washed and dried as in G1. Then root canals were etched for 15 seconds with 36% phosphoric acid, rinsed for 15 s, and slowly air-dried. By absorbent paper cones, the excess was eliminated. Single bond adapter universal (ESPE, was used in the root canal with a micro brush of suitable size and for 5 s air-dried, removing access with an absorbent paper point. The prepared post was also coated with the bond.	The cement of adhesive resin was mixed and applied the same as in G1.
G3	G1's description applies here.	G1's description applies here.
G4	G2's description applies here.	G2's description applies here.
G5	G1's description applies here.	G1's description applies here.
G6	G2's description applies here.	G2's description applies here.

After storing the specimens for 24 hours at 37˚C, with an Isomet (Buehler) machine and a diamond disc (thickness of 0.03 inches and diameter of 7 inches) underwater cooling, the cuts were made perpendicular to the root's long axis, for producing three radicular discs with (2±0.1) mm thickness (apical, middle, and cervical) per sample. Using a digital Vernier, the precise thickness was assessed. Then, with a marker of indelible, each disc was marked on its apical side, one spot for the apical segment, two for the middle, and three for the apical disc. Digital images were captured for the cervical and apical side of the discs through a digital camera (Q-Color5, Olympus) associated with a stereomicroscope loupe (SZ61, Olympus America Inc., PA, USA) by 40x magnification Figure (1).

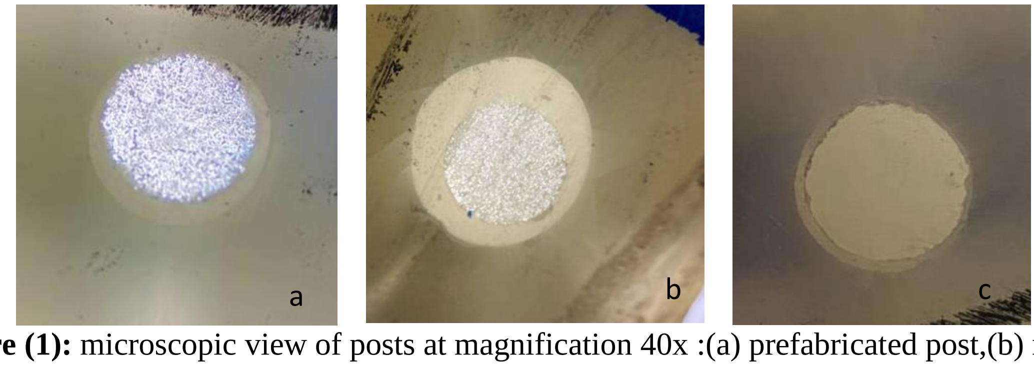

Figure (1): microscopic view of posts at magnification 40x :(a) prefabricated post,(b) relined post,(c) zirconium oxide post.

The images were entered into ImageJ software (v. 1.44o; National Institutes of Health, Bethesda, MD) to measure the root canals' apical and cervical diameters. The discs were subjected to force of push-out from apical to cervical end using different diameter cylindrical plunger of custom stainless steel (0.5 and 1 mm) on a universal testing machine (TERCO, MT 3037, Sweden) with 0.5 mm/min crosshead speed until bond failure. The load at failure was noted in Newton (N). By dividing the load value by the interfacial area (A) of the post fragment, which matched the bonded area in square millimeters, the retentive strength of the post fragment was given in MPa (mm^2). The below formula was applied to compute the interfacial area: A= (R+r) [(h) 2+(R-r) 2]0.5, where h = thickness of root slice, r = radius of the apical post, and R = radius of the coronal post, where h = thickness of root slice, r = radius of the apical post, and R = radius of the coronal post. After the test was established, the deboned discs were inspected using a stereomicroscope (SZ61, Olympus America Inc., PA, USA) at 40x magnification and the failure types were classified as follows: adhesive between post and dentin, adhesive at the post, and cement, cohesive in the cement, mixed (cohesive and adhesive combination) Figure (2).

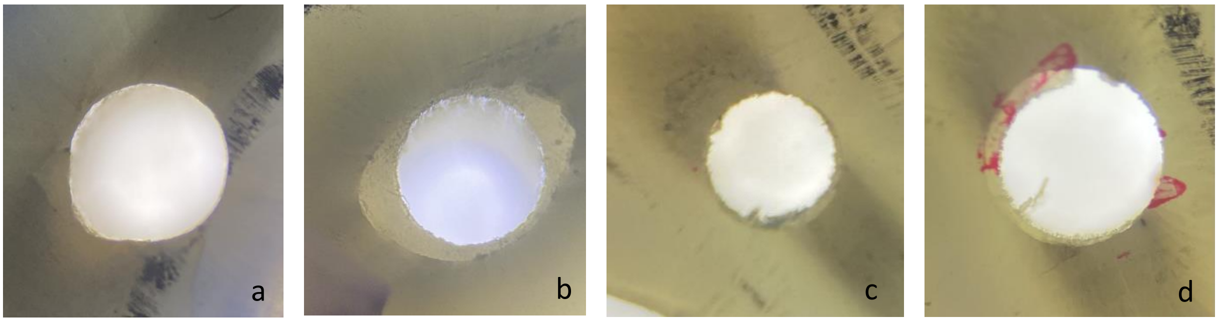

Figure (2): Microscopic views of failure specimens (a) adhesive failure at dentin and post interface. (b) Adhesive at post and cement. (c) Cohesive within the cement. (d) Mixed of adhesive and cohesive.

The push-out test was statistically analyzed using a two-way analysis of variance (ANOVA) (IBM SPSS Software; IBM, Armonk, NY, USA). The threshold of significance was fixed at 5%.

Results

The descriptive statistics for all post and cement types used in this study with standard deviation; mean values in MPa, and variance had been shown in Table (1).

Table (1): Descriptive statistics for all post and cement types.

Cement type	N	Min	Max	Mean	SD	variance
Prefabricated post / RelyX U200	30	1.51	14.24	6.74	3.47	12.09
Relined post / RelyX U200	30	3.85	12.24	7.06	2.22	4.94
Zirconium oxide post / RelyX U200	30	2.2	12.25	5.66	2.38	5.66
Prefabricated post / RelyX Ultimate	30	2.95	15.01	7.8	4.01	16.13
Relined post / RelyX Ultimate	30	1.18	14.53	8.93	3.1	9.63
Zirconium oxide post / RelyX Ultimate	30	1.17	12.15	6.32	3.16	10.04
Prefabricated post	60	1.51	15.01	7.27	3.76	14.15
Relined post	60	1.18	14.53	8.00	2.83	8.05
Zirconium oxide post	60	1.17	12.25	5.99	2.79	7.83
RelyX U200	90	1.51	14.24	6.49	2.78	7.76
RelyX Ultimate	90	1.17	15.01	7.68	3.58	12.82

The relined posts; showed higher mean values of strength of push-out bond in MPa than the other kind of posts Table (1). Regarding the cement type, groups cemented with RelyX Ultimate had higher mean values than RelyX U200 Table (1). By using the ANOVA test, there were no significant differences between post types and cement types Table (2).

Table (2): ANOVA test for difference between post & cement types

ANOVA	Sum of square (SS)	DF	Mean square (MS)	F statistic	p-value
Post-cement types	62.8924	2	7.0742	1.0961	0.4173
	32.7585	2	31.715		
	5.8149	4	6.4542		
error	6243.588	342	18.1355		
TOTAL	6345.054	350	18.0163		

There were no significant differences between every post kind of apical sections, middle, and mean values of coronal at P> 0.05. As a consequence, there is no probability of rejecting the null hypothesis (Mean values are identical); therefore, the posts in the apical, middle, and coronal regions were conducted similarly. The same results were also applied to cement types Table (3).

Table (3): ANOVA test for difference among root sections regarding post and cement type.

ANOVA	Sum of square (SS)	DF	Mean square (MS)	F statistic	p-value
Post types	14.14	2	7.0742	1.0961	0.4173
	63.43	2	31.715		
	25.8169	4	6.4542		
error	6202.3271	342	18.1355		
TOTAL	6305.7224	350	18.0163		
Cement types	14.0286	2	7.0143	0.4922	0.6701
	32.7585	1	32.7585		
	28.4993	2	14.2496		
error	6269.7677		18.0166		
TOTAL	6345.054		17.9747		

Detailed descriptive statistics for a mode of failure had been shown in Table (4), where the adhesive type was more prominent.

Table (4): Descriptive statistics for a mode of failure percentage

	Adhesive	Adhesive		Cohesive	Cohesive		Mixed
		Post/ cement	Cement/ dentin		Dentin	Post	
PP- U200	90%	27%	63%	0%	0%	0%	10%
PP- UL	90%	29%	61%	0%	0%	0%	10%
PP	90%	30%	60%	0%	0%	0%	10%
RP- U200	83%	17%	66%	0%	0%	0%	17%
RP- UL	87%	37%	50%	3%	0%	3%	10%
RP	85%	28%	57%	2%	2%	0%	13%
ZP- U200	100%	0%	0%	0%	0%	0%	0%
ZP- UL	60%	53%	7%	7%	7%	0%	33%
ZP	80%	58%	22%	3%	3%	0%	17%
U200	91%	37%	53%	0%	0%	0%	9%
UL	79%	40%	39%	3%	3%	0%	18%

Discussion

A significant amount of coronal tooth loss after endodontic treatment presents challenges for the clinician in rehabilitating such teeth. Endodontically treated teeth often need utilizing a post within the root canal that increases the retention of a core for a definitive full-coverage restoration. These teeth must be restored in a way that they can withstand vertical, lateral, and oblique forces without being fractured.[14] During the early 1990s, posts of the fiber-reinforced composite were produced with an extensive loss of tooth structure to rebuild endodontically treated teeth.[15] Isidor et al. observed favorable fractures which are often reparable because fiber-reinforced composite posts more evenly distribute occlusal stresses in root dentin.[16] Kadam et al. reported that for fiber-reinforced composite posts, the most prevalent failure mode is debonding. A bond failure that occurred due to the strain generated at the interface of dentin and post is related to the difference in the flexing of the bonding materials.[17] Kwiatkowski and Geller reported that to silane and resin cement, zirconium oxide posts have a strong bonding capacity.[18] It has been reported that the mechanical bonding between the resin cement and post surface is limited in untreated zirconium oxide posts due to their relatively smooth surface.[19] Various surface treatments are used for increasing the strength of the bond at the interface. Chemical, mechanical, and mechanical-chemical combination bonding are some surface treatments available.[20] To increase mechanical bonding, we employed a surface sandblasting treatment with 50-µm $Al_2 O_3$ particles. Boudrias et al. discussed the usage of anatomic post for decreasing the layer thickness of resin cement and its drawbacks.[21] The fiber post is relined into the root canal using this procedure, which replaces the resin cement with composite resin, which has improved physical and mechanical qualities. Laboratory studies[22-25] have shown that anatomical post methods have a considerable performance. The relined fiberglass post reduces resin cement thickness inside the root canal and applies pressure on the resin cement to conform to the dentinal walls.[26] Because of RelyX U200's thixotropic nature, applying pressure reduces its viscosity and enhances its adaptability to root canal walls.[27] If a system of etch-and-rinse adhesive was used inside the canal, the smear layer was eliminated by etching the dentinal walls, resulting in a stronger adhesion between the dentin and the cement.[28] This improvement in bond strength may be able to counteract the increased shrinkage and stress caused by polymerization. Several mechanical testing techniques were utilized for determining the binding strength of fiber post to intra-radicular dentin, including tests of push-out, pull-out, and micro tensile. The test of push-out offers a more accurate estimate of the bond stronger than the other tests since the fracture occurs parallel to the interface of dentin-adhesive.[29] This study used fiberglass post, relined fiberglass post, and zirconium post and cemented with resin cement of self-adhesive dual-cure (RelyX U200) and adhesive dual-cure (RelyX Ultimate) resin cement. Higher bond strength values were recorded with relined glass fiber posts in comparison to that of the prefabricated and zirconium posts but with non-significant differences. So, the null hypothesis was accepted. This result with relined posts may be attributed to the presence of a slim and even resin cement layer. Therefore, because of their form after relining with composite resin, they are better modified to fit the post spaces, improving the retention.[30] Also, in relined posts, a different interaction of the adhesive and self-adhesive resin cement with the surface of the relined post (composite interface) occurred compared with the prefabricated glass fiber posts and zirconium posts. Regarding the prefabricated post, the epoxy resin matrix of the glass fiber post is highly crosslinked, [31] and resin cement and composite resins cannot form strong chemical bonds with the post surface. Therefore, in the case of prefabricated posts, failure is more likely to occur at the post-cement interface. While for the relined posts, better bond strength may be gained between resin cement and composite resin, on the other hand, there may be a larger possibility of failure between the post and the composite resin used for customization. However, in this study, no failures were identified between fiber post and composite resin, demonstrating an effective bond. For all experimental groups, the greatest number of failures occurred at the resin cement/ post and resin cement/ dentin interfaces. Nevertheless, it must be noted that this research applied a fiber post with relining for maximum reduction of the thickness of resin cement as in zirconium post with the advantage of fewer steps, readily available materials at the dental clinic, giving a post that can fit over the prepared post space along its complete length. This technique is comparatively easy; except some additional steps are needed when compared to those required for luting a traditional fiber post. Posts of indirect customized zirconium were stated to have excellent mechanical properties, [22] while their fabrication needs more time and it is of high- price because of the requirement of a laboratory step. The assessment of failure modes demonstrated that almost all of the failures with customized and prefabricated posts occurred at dentin–luting cement interface (57%, 60%) respectively with non-significant differences. Rocha et al.[32] when studying the effect of anatomical customization in extracted human teeth found that the foremost failure modes are at the dentin and self-adhesive resin cement interface (72.2%) in comparison to prefabricated fiberglass post (77.8%). This could be due to occurring of polymerization stress at the interface of cement–dentin, which affects the adhesion between root dentin and cement and makes it difficult which could be impacted by the geometry of the root canal, which has the responsibility of its high configuration factor (C-factor).[17] While bond failure in this study with zirconium post occurs at the interface of zirconium resin/post cement and it was 58 %, Dündar Yılmaz and İzgi[33] reported that the bond failure was at the agent interface of zirconium post/luting (62.5%) in every group with different surface treatments of the zirconium oxide post (control, CoJet, sandblasted+ laser, and laser) and cemented with self-etch, dual-cure cement (Panavia F2.0). Amulet et al.[34] found that at the post-luting agent interface, adhesive failure was seen in 75% of RelyX ARC cement and zirconium oxide posts cemented with zinc phosphate, whereas mixed failure was observed in 75% of posts cemented with RelyX Unicem cement. In this study, it was also found that the root region has no important impact on the strength of push-out bond posts in all experimental groups. This result was also reported in other studies.[23, 34, 35] This study revealed that cement type does not have any impact on bond strength in all experimental groups. In the same way, it was found by Almufleh et al. ,[34] that there were no significant differences in strength using the push-out test between zirconium oxide posts cemented with zinc phosphate luting agents, self-adhesive resin (RelyX Unicem), or conventional resin (RelyX ARC). In other studies when testing zinc phosphate and RelyX ARC cement (P<.001) in cementing prefabricated fiber posts, investigations demonstrated that resin cement of RelyX Unicem self-adhesive had a much greater bond strength.[12, 36] This result is due to differences in the kind of cement and the methodology of application of the cement. The present study was carried out on human single-rooted teeth and despite all the steps taken to find matching samples, variations in the morphology of the canals were unavoidable; consequently, the results presented a large standard deviation. Future investigations should be performed to clarify the relationship between bond strength and adaptation of post after aging cycles.

Conclusions

With the limitation of this study, relined posts may be a suitable clinical situation as a post material selection with reduced clinical steps. The type of luting agent and the root region did not affect the push-out bond strength of custom-made and ready-made posts.

Conflicts of interest

The author reports no conflicts of interest.

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