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PUSH-OUT-BOND STRENGTH OF GLASS FIBER COMPOSITE POSTS CEMENTED USING TWO DIFFERENT ADHESIVE APPROACHES

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ABSTRACT

Purpose: To evaluate the push out bond strength of three glass fiber composite posts bonded to radicular dentin using either etch and rinse or self etch adhesive systems.

Methods: Forty-two single rooted extracted mandibular first premolars were decoronated. The roots were endodontically prepared and randomly divided into three main groups according to the type of glass fiber post (n=14): group I; electrical-glass (everStick, ES); group II, alkaline resistance-glass (RelyX, RX); group III, quartz-glass (Peerless, PL). Each group was further subdivided into two subgroups (n=7) according to the adhesive system used; in the first subgroup; Adper Single Bond 2 (ASB2) was used while in the second subgroup; Adper Easy Bond (AEB) was employed. Posts were cemented with dual cure resin cement (Rely X ARC). The roots were perpendicularly sectioned to obtain two discs from the coronal half of each root. In each subgroup 10 discs were submitted to a push-out test, while the remaining 4 discs for scanning electron microscopic examination (SEM). Data was analyzed using two way ANOVA and Tukeys post hoc test. **Results:** Groups; PL/ASB2 (17.1±1.4 MPa) and RX/ASB2 (14.59±5.9 MPa) yielded significantly the highest mean push-out bond strength values. Meanwhile, there was no statistically significant difference between the other groups; ES/ASB2 (8.28 ± 1.9 MPa), RX/AEB (9.36±1.5 MPa), PL/AEB (8.04±0.2 MPa) and ES/AEB (7.03 ± 2.9 MPa), respectively. **Conclusion:** Alkaline resistance (RX) and quartz glass (PL) fiber posts in conjunction with etch and rinse adhesive system (ASB2) showed prompt bonding to radicular dentin.

KEY WORDS: Composite glass fiber posts, etch and rinse adhesive system, self etch adhesive system, push out bond strength test.

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INTRODUCTION

Endodontically treated teeth are known to present a higher risk of biomechanical failure than vital teeth. Posts are generally indicated to restore missing tooth structure and pulpless teeth.(1) Cast metal posts and cores have been used for many years but due to their unfavorable esthetics and biomechanical properties various tooth-colored fiber reinforced composite post systems (FRC) were introduced.(2)

Glass fiber–reinforced resin post systems were introduced in 1992. (3) They gained wide popularity owing to their stress absorption and distribution capabilities, stemming from their dentin-like modulus of elasticity. (1,4) Glass fiber reinforced post systems contain a high volume percentage of continuous glass fibers embedded in a polymer matrix. They can be composed from different types of glass; electrical glass (E-glass), alkaline resistance glass (AR-glass), or quartz glass (Q-glass). E-glass fibers are composed from an amorphous phase of SiO_2, CaO_2, B_2O_3, Al_2O_3 and some other oxides of alkaline metals. AR-glass fibers are silica based alkaline resistant glass fibers containing high percentage of zirconium oxide. Meanwhile, the quartz fibers are pure silica in a crystallized form. (5,6) The matrix that hold the glass fibers together can be made from either fully or partially polymerized resinous matrix.(1,7) Thus the mechanical properties and bonding behavior of glass fiber composite posts are dictated by the type of glass fibers used and its matrix composition.

Theoretically, the remaining tooth, the fiber post and the resin composite cement should create a "monoblock" in which the loads are uniformly dissipated, providing a behavior similar to healthy teeth.(7) The success of this "monoblock" system depends, in part, on the cementation technique used to create a link between the post and root canal dentin. Therefore, the selection of the appropriate adhesive and cementation procedure for bonding endodontic posts to root canal dentin is a further challenge.

Contemporary resin cements could be coupled to dentin using either etch and rinse or self etch adhesive systems. Self-etching adhesive approach offers a shorter adhesive application time and a reduced number of clinical steps. It is considered to be less technique-sensitive because the clinical assessment of optimal dentin wetness after rinsing the phosphoric acid, in the deep and narrow post space within a root canal, is avoided.(8,9) However, their efficiency at infiltrating smear layers produced during post space preparation remains a major concern.

Therefore, on the search on the most retentive glass fiber post system and most appropriate adhesive approach, this study was carried out to evaluate the push-out bond strength of three different glass fiber posts cemented to the root dentin using either etch and rinse or self etch adhesive system.

The null hypotheses tested were: First; there is no difference in the push-out bond strength between the three glass fiber post systems examined. Second; there is no difference in push-out bond strength between the etch and rinse and self etch adhesive systems when used in conjunction with the resin cement.

MATERIALS AND METHODS

Forty-two recently extracted human single canaled, mandibular first premolars, with straight canals and mature apices were collected. Selected teeth were cleaned and stored in an aqueous solution of 0.5% chloramine-T at 4°C until use (maximum of one month). Before canal instrumentation, decoronation of the teeth was performed by using a law-speed diamond disc to obtain approximately 14-mm long root segments. The working length was established by inserting K file #15 (Mani, Inc, Tochigi, Japan) to the root canal terminus and subtracting 1 mm from this measurement. The root canals were instrumented using ProTaper Universal files; S1, S2, F1, F2, F3, and F4 (Dentsply Maillefer, Ballaigues, Switzerland). Each canal was enlarged to size 40 at the working length. Irrigation was performed with 3 ml of 5.25% NaOCL after each file size. After instrumentation, the smear layer was removed from the canal by rinsing with 5ml of 17% ethylenediaminetetraacetic acid (EDTA) solution then 5 ml of 5.25% NaOCL. Finally, the canals were flushed with distilled water and dried with paper points. The root canals were filled using single cone technique with ProTaper gutta-percha size F4 (Dentsply Maillefer, Ballaigues, Switzerland) and AH plus root canal sealer (Dentsply, Detrey, GmbH, Germany).

The forty-two roots were randomly divided into three main groups (n=14) according to the post system used; group I; E-glass fiber post (everStick (ES), size # 2, stick Tech-Turku, Finland), group II**;** AR-glass fiber post (Rely X (RX), size # 1, 3M, ESPE, St Paul, USA) and group III; Q-glass fiber post (Peerless (PL), size # 1, SybronEndo, USA). Each group was further subdivided into 2 subgroups (A and B, n=7 each) according to the adhesive system used; subgroup A: Adper Single Bond 2 (ASB2, 3M, ESPE, St Paul, USA), an etch and rinse adhesive system and subgroup B**:** Adper Easy Bond adhesive, (AEB, 3M ESPE, St Paul, USA) a self etch adhesive. Materials, manufacturers and composition are presented in table 1.

TABLE (1) Materials used in the studys:

Materials		**Composition**	**Manufacturer**
Posts	Everstick fiber post	E-glass fibers, PMMA, Bis- GMA	Stick Tech-Turku, Finland
	Rely X fiber post	AR-glass fibers, epoxy-resin, zirconia filler.	3M, ESPE, St Paul MN,USA
	Peerless fiber post	Quartz fibers, epoxy resin matrix	SybronEndo. USA
Adhesive systems	Adper Single Bond 2 (etch and rinse adhesive system)	Scotchbond etchant: 35%phosphoricacid Adhesive: HEMA, Bis-GMA, dimethacrylates, ethanol, water, camphor-quinone, methacrylate functional copolymer of polyacrylic, silica filler and polyitaconic acids	**3M ESPE, St Paul MN,USA.**
	Adper Easy Bond (self etch adhesive system	HEMA, Bis-GMA, Methacrylated phosphoric esters, 1,6 hexanediol dimethacrylate, Methacrylate functionalized Polyalkenoic acid, silica filler, Ethanol, Water, camphorquinone Stabilizers	
Resin cement	RelyX ARC	Bis-GMA, TEGDMA, dimethacrylate monomer, zirconia/silica filler	
PMMA = Polymethylmethacrylate; Bis-GMA = 2, 2–bis (4-2-hydroxy-3- methacryloylxypropoxy) phenyl-propane; TEGDMA = triethylene glycol dimethacrylate; HEMA = 2-hydroxyethyl methacrylate			

Each post was marked at a point 10 mm from its apical end and cut to a 10 mm length with a water-cooled diamond rotary cutting instrument. Posts channel holes for post placement were prepared leaving 4 mm of gutta- percha as apical seal. For both RX and PL fiber posts analogue drills corresponding to the selected posts were used, meanwhile for the ES fiber post, the post space was prepared using the RX fiber post drill as it is an adjustable system that takes the shape of the post space and is not supplied with a corresponding analogue drill. After post space preparations, the root canals were rinsed with distilled water and dried using paper points after which, the root canals were ready to receive the bonding agents, which were applied according to manufacturer instructions.

In subgroups A, the root canal walls were etched with 37% phosphoric acid etchant (Scotch Bond Etchant, 3M, ESPE, St Paul, USA) for 15 seconds then rinsed with distilled water. Excess water was plotted using paper points. Immediately after blotting, 2 consecutive coats of the bonding system were attempted for 15 seconds followed by gentle air dryness for 5 seconds.

In subgroups B, the bonding agent was applied to the dentin walls of the post spaces and left for 20 seconds then gently air dried for 5 seconds. Finally, both adhesives were light cured for 20 seconds using Bluephase C5 LED light emitting diode curing unit at a light intensity of 500 mW/cm^2 (Ivoclar Vivadent AG, Schaan, Liechtenstein).

After application of the bonding agents in all subgroups dual polymerized resin cement (Rely X ARC, 3M, ESPE, St Paul, USA) was used for cementing all post systems according to the manufacturer's instructions. The mixed cement was lentulated inside the canal. The apical portion of the post was smeared with cement, and the post was seated into place. Excess cement was removed with a plastic instrument. The tip of the light curing unit was directly placed on the top of the cervical portion of the root to light cure the adhesive resin cement for 40 seconds. Specimens were stored in water for 24 hours.

Push-out-bond strength test

Each root was then embedded in self cure acrylic resin using a custom-made split-ring copper mold. The acrylic resin cylinders were mounted on a low speed cutting machine (Bronwill cutting machine, MAC, Saint Louis MO, USA) and sectioned under copious water using a diamond saw (MTI corporation, Valley Research Corp. Austin, Texas, USA). Two horizontal sections of 2±0.1 mm thickness were cut from the coronal half of each root. The thickness of each specimen was checked using digital caliper (Absolute Digimatic Caliper, Mitutoyo Corp., Japan). This resulted in 10 horizontal sections per each subgroup with a total number of 60 horizontal sections for the six experimental groups. Each section was coded and the apical and coronal diameters of the post area were measured using an Olympus Camedia C-5060 digital camera (Tokyo, Japan) attached to stereomicroscope. Each root section was then subjected to a compressive load via a universal testing machine (LIoyd LRXplus; LIyod Instruments Ltd, Fardham, UK) at a cross head speed 1mm/min using 1mm in diameter stainless steel cylindrical plunger. The plunger tip was positioned so that it only contacted the post area. The push-out force was applied in an apicocoronal direction until the post segment was dislodged from the root slice. The force was recorded by using Nexygen data analysis software (LIyod Instruments Ltd). The maximum failure load value was recorded in Newton (N) and converted into Megapascal (MPa), considering the bonding area (mm^2) of the post segments. Total bonding area for each post segment was calculated using the formula:

$\pi(R + r)[h^2 + (R-r)^2]^{0.5}$, where R represents the coronal post radius, r is the apical post radius and h is the thickness of the slice.[(4)]

Statistical analysis

Data were presented as mean and standard deviation values. A regression model with two-way analysis of variance (ANOVA) was used in testing significance for the effect of variables (post system) and (adhesive system) and their interactions. Tukey's post-hoc test was performed for pair-wise comparison between the means when ANOVA test was significant. The significance level was set at $P \leq 0.05$. Statistical analysis was performed with SPSS 16.0 (Inc., Chicago, IL, USA.).

Scanning electron microscopic examination

Four discs from each subgroup were prepared for scanning electron microscopic examination (SEM). The discs were wet polished with 600 grit silicon carbide abrasive papers. The polished surfaces were immersed in 6 mol/L HCL for 30 seconds to remove polishing smear layer, then immersed in 1% NaOCl for 10 minutes and washed in an ultrasonic bath of distilled water for five minutes. The specimens were dried, sputter coated and examined under SEM (Model Philips XL 30, Tokyo, Japan) at different magnifications to morphologically evaluate the bonded interfaces and possibly hybrid layer and resin tag formation.

RESULTS

Push-out test results

Push-out bond strength mean and standard deviation (SD) values were explored for normality using Kolmogorov-Smirnov and Shapiro-Wilk tests which showed that data were normally distributed. Levene test indicated homogeneity of variance between the groups. Regression model with two-way analysis of variance (ANOVA) revealed that both the post type ($F=8.434$, $P=0.002$) and the bonding systems examined ($F=23.599$, $P< 0.001$) had a statistically significant effect. The interaction of both variables was statistically significant ($F=4.456$, $P=0.23$).

The mean and standard deviation of the push out bond strength values are presented in table 2. Groups; PL/ASB2 (17.1±1.4 MPa) and RX/ASB2 (14.59±5.9 Mpa) showed the highest statistically significant mean push-out bond strength values, with no statistically significant difference between them. However, groups; RX/AEB (9.36±1.5 MPa), PL/AEB (8.04±0.2 MPa), ES/ASB2 (8.28±1.9 MPa) and ES/AEB (7.03±2.9 MPa) yielded lowest mean push-out bond strength values with no statistically significant difference among them.

SEM results

The scanning electron micrograph for ES/AEB group revealed a gap in numerous areas along the circumference of the resin dentin interface with discrete areas of gap free junction (Fig 1a). At a

TABLE (2) Mean and SD of push-out bond strength values of the tested groups (MPa):

	Everstick post	Rely-X post	Peerless post
Adper Single Bond 2	8.28 ^{b} ±1.9	14.59 ^{a} ± 5.9	17.10 ^{a} ± 1.4
Adper Easy Bond	7.03 ^{b} ± 2.9	9.36 ^{b} ± 1.5	8.04 ^{b} ± 0.2

Different letters indicate statistically significant differences according to Tukey's test higher magnification X500 (Fig 1b) complete union at the cement/post interface is evident with existence of a gap at the cement/dentin interface. On the other hand, the scanning electron micrograph for RX/ASB2 showed a gap free junction at the resin-dentin interface (Fig 2a). Higher magnification (X500) showed a gap at the cement/post interface. Whereas, at the resin/dentin interface a well defined hybrid layer and numerous resin tags having conical shape configuration with a wide base were evident (Fig 2b). The scanning electron micrograph for PL/ASB2 showed a gap free junction at the resin dentin-interface (Fig 3a). Surface serration of the post with macromechanical entanglement at the cement/post interface was obvious at a higher magnification X500 (Fig 3b). The scanning electron micrograph (Fig 4a) of the resin dentin interface using the AEB, showed a relatively thin hybrid layer with scarcely distributed slimy resin tags while with the ASB2 adhesive system (Fig 4b) numerous funnel shaped resin tags are evident which might promote the bonding mechanism.

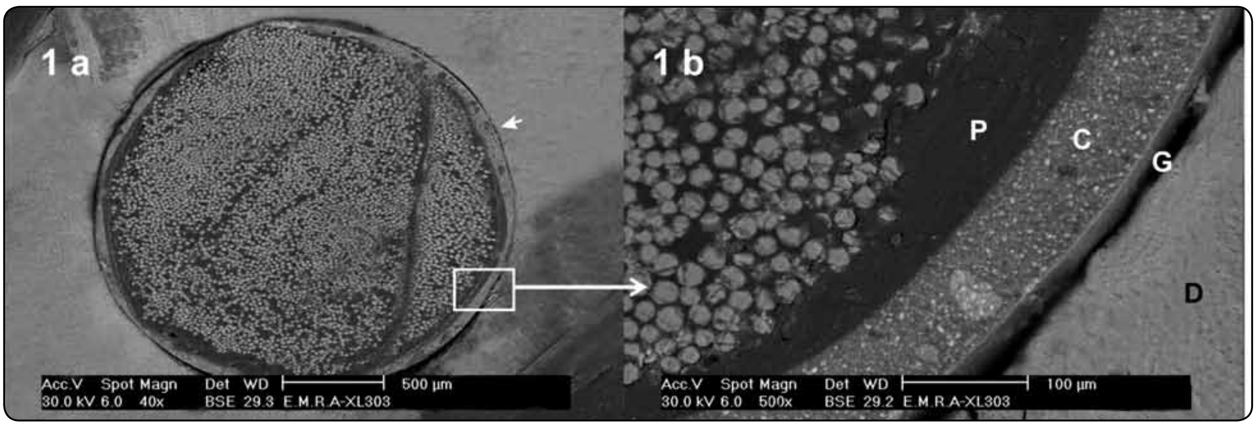

Fig (1) a :SEM of ES post in conjunction with AEB adhesive system, Arrow; gap free junction at the resin-dentin interface at few areas 1b: SEM at X500 denoting the complete union at the cement/post interface with existence of a gap at the cement dentin interface. (D: dentin, G: gap, C:cement, P:post)

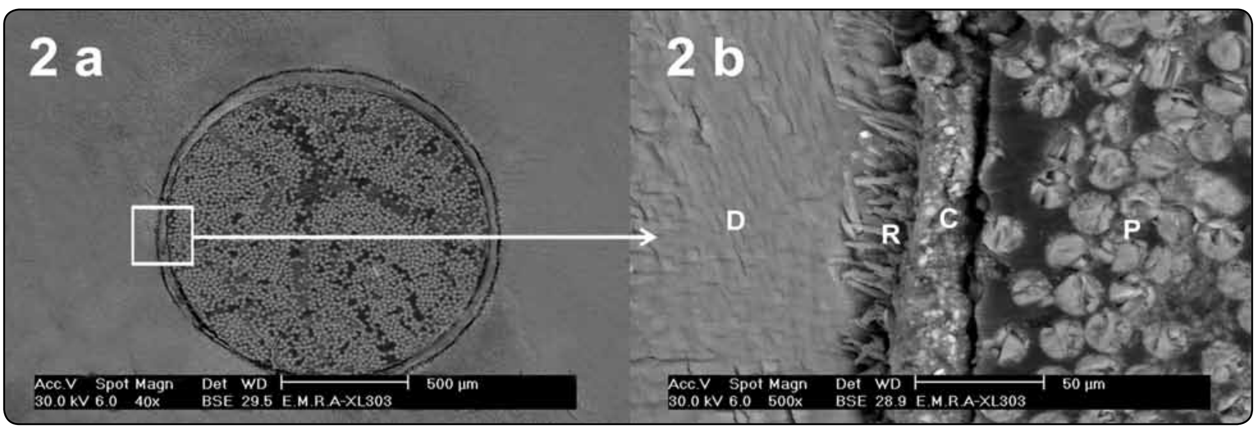

Fig (2) a: SEM of RX post in conjunction with ASB2 adhesive system, 2b: SEM at X500 denoting a gap at the cement /post interface with a well defined hybrid layer and numerous resin tags at the cement /dentin interface. (D: dentin, R: resin tags, C:cement, P:post)

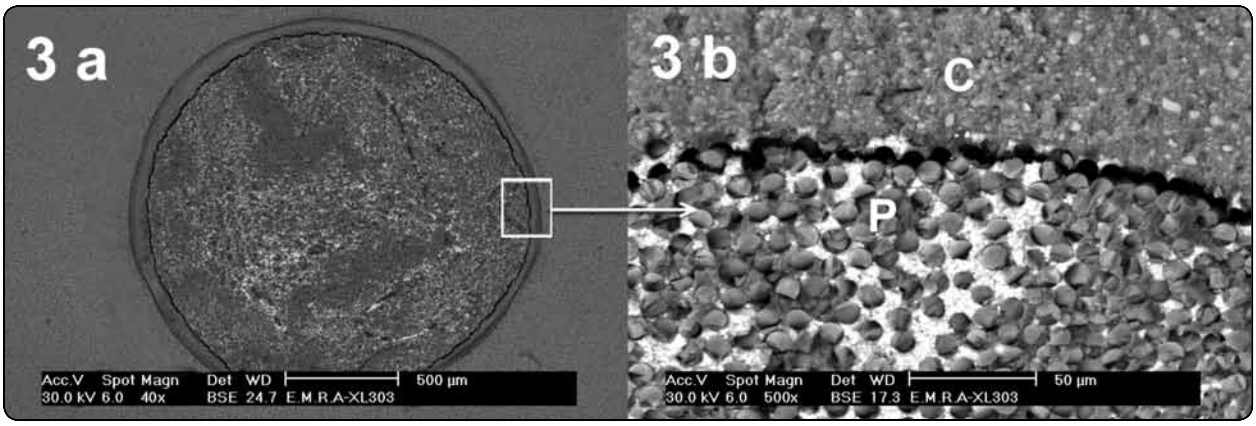

Fig (3) a: SEM of PL post in conjunction with ASB2 adhesive system showed a gap free junction at the resin/dentin interface 3b: SEM at X500 showing post surface serrations denoting the macromechanical interaction at the cement/post interface.

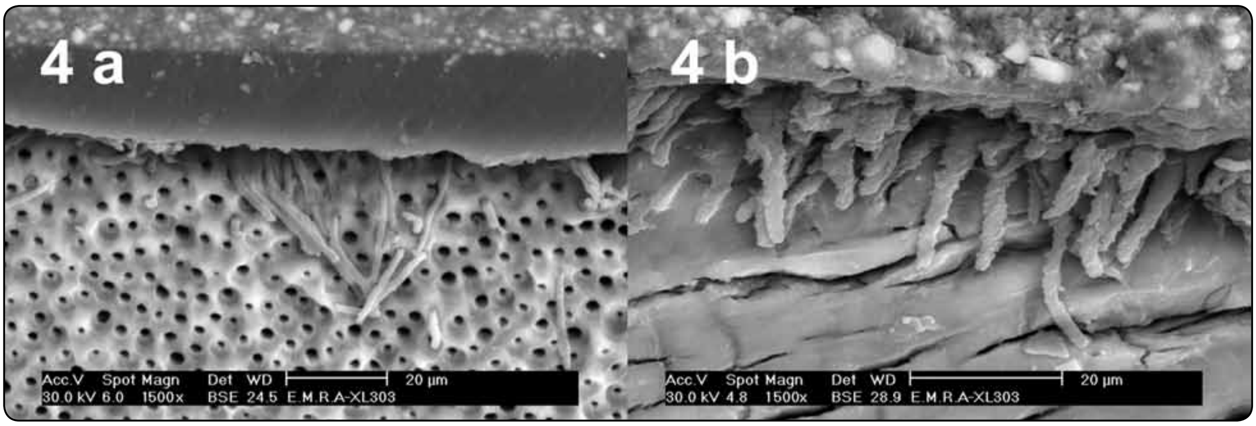

Fig (4) a: SEM of the resin/dentin interface using the AEB adhesive system scarcely distributed and slimy resin tags are evident, 4b: SEM of the resin/dentin interface using the ASB2 adhesive system, numerous and conical shaped resin tags are depicted.

DISCUSSION

Results of the present study revealed that there was statistically significant difference between the post systems examined thus the first null hypothesis is rejected, and extended to reject the second null hypothesis as there was significant difference between the adhesive systems examined.

Quantitative evaluation of the bonding efficacy was carried out in this study using push-out test. This test is considered a reliable and a more clinically relevant method in measuring the bond strength of fiber posts to root dentin, since it take in consideration the cavity configuration factor, which is a crucial factor that affects the bond strength.[10,11]

Interfacial analysis by the use of SEM represent an ideal complement to the pushout bond strength test, allowing assessment of qualitative aspects of bonding by looking into the clues of micro-and ultra-morphological appearances of the different attempts for successful bonding to human dentin.[12]

In the present study the ES post recorded the lowest push-out bond strength values irrespective to the adhesive system used. The ES post is a FRC posts composed of silanted glass fibers impregnated with an interpenetrating polymer network (IPN) resin matrix. In IPN, linear polymer phases (PMMA) and the cross-linked polymer phases (Bis-GMA) are not bonded chemically together as a single network. It has been claimed by the manufacturer that bonding of the FRC post with the IPN resin matrix to composite cements is by an interdiffusion bonding mechanism.[1] During the contact time of the resin cement to the surface of IPN resin matrix, the monomers of the resin cement diffuse into the linear phases of the IPN polymer matrix and after polymerization become interlocked.[13] For this reaction to proceed the solubility parameters of the resin cement should be close to that of PMMA.[14] The resin cement used in the study contains Bis-GMA and TEGDMA monomers. According to Mannocci et al, [14] the solubility parameter of those monomers are close to that of PMMA. This clarifies the ability of the used resin cement to penetrate into the structure of IPN posts giving the opportunity to establish a chemical adhesion to the ES post (Fig 1a and b). Since copolymerization occurred between the resin cement and the matrix of the ES post, shrinkage stresses are induced.

Shrinkage stress can be described as a vector, with a magnitude and a direction.[15] The magnitude of the shrinkage vectors is dependent in part on the volume of the resinous material and on the cavity configuration. Therefore, it can be assumed that a higher magnitude might have occurred with the ES post, as the shrinkage stresses generated is the resultant stresses of polymerization of resin cement and the resinous matrix of the FRC post. In addition the highly unfavorable C- factor (defined as the ratio of bonded to unbonded surface areas of cavities) inside the root canal maximize the polymerization stress of resin based materials that may be so intense creating interfacial gaps. [16-18]

Photo-elastic analyses have shown that the direction of force vectors during polymerization shrinkage flow is determined by the conditions at the boundary. [19] This direction is also supposed to be dependent on the bonding features of the material to substrate. [20] Thus ,it can also assumed that in case of ES post the shrinkage vectors of the resin cement were theoretically oriented toward the post. This would cause the resin cement to be pulled away from peripheral zones, toward the center, at the expense of optimal bond during polymerization (Fig 1b). On contrary, with RX and PL posts, the lack of chemical union with the resin cement (Fig 2b, 3b) might have allowed the flow of resin toward the dentin substrate allowing the formation of resin interpregnated dentin zone, with hybrid layer and resin tag formation (Fig 2b).

The RX and PL posts in conjunction with the etch and rinse adhesive system (ASB2) showed the highest push out bond strength values. This, in part, can be related to the surface macro-structure of both posts, and in another part, the ability of the etch and rinse adhesive system to establish a strong bond at cement/dentin interface. The microporous surface of RX fiber post (Fig 2b) and the surface serrations of the PL post resulted in surface indentations, which enhanced the mechanical interlocking with the resin cement (Fig 3b).

The current results are in accordance with Kececi et al, [21] who found that the electrical glass fiber post showed lower push out bond strength values compared to translucent quartz and opaque glass FRC post when used in conjunction with etch and rinse adhesive system. On contrary, Abo El-Ela et al, [7] found that ES glass fiber post showed the highest bond strength values compared to other glass fiber posts (Light post and Parapost fiber white). This contradiction might be attributed to the different post type examined (parapost without surface serrations) and bond strength test (microtensile) used.

The lower bond strength found with the self etch adhesive system compared to the etch and rinse alternative was contagious with SEM findings which revealed thinner hybrid layer with scarcely slimy resin tags in some areas making them weak candidates for promoting dentin adhesion (Fig 4a). Meanwhile with the etch and rinse adhesive the numerous funnel shaped resin tags were evident (Fig 4b). The results are in accordance with Marques de Melo et al,(22) and Radovic et al,(23) whom found that the self-etching approach may offer less favorable adhesion to root canal dentin in comparison with etch and rinse.

This might be attributed to several factors occurring simultaneously: first; the sclerotic nature of the root dentin, resulting in smear layer rich in mineral deposits thus the self etch adhesives might not be able solubilize the minerals, hampering hybridization in some areas.(22) In addition to the traditional smear layer produced manually or by rotary instrumentation, the subsequent preparation of the post space results in an additional and even thicker smear layer composed of debris and sealer remnants. This "secondary" smear layer, which is rich in sealer and gutta-percha remnants that are plasticized by the frictional heat of the drill might have diminished the penetration of self etch adhesives. (24)

Second; the intrinsic permeability of these adhesives compromise coupling with resin based cements used for post cementation. (25) The hydrophilic characteristics of these simplified systems increase their susceptibility to the effects of water, leading them to behave as semipermeable membranes after polymerization.(26,27) The movement of water through the adhesive–dentin interface is facilitated by the presence of a hypertonic layer. The high concentration of calcium and phosphate ions in the hypertonic layer together with the suboptimal polymerized resin blends leads to osmotic pressure gradient, which causes movement of water from an area with high water content to an area with low water content (the adhesive/cement interface). The water that has undergone transudation will accumulate at the interface, weakening bond strength in this area. Although, such scenario is expected to occur in vital dentin, Chersoni et al, (28) speculated that the same can occur in the intraradicular dentin of endodontically treated teeth. Water could have been partially derived from the residual water that is retained in these water-containing adhesives due to insufficient air drying which is increased by the difficulty of properly air drying an endodontic space and partially from the unbound water that is present in pulpless teeth.

King et al, (29) named the incompatibility between the simplified adhesives and dual cure resin cements due to its inherent permeability "apparent incompatibility" which masks the "true incompatibility" that might be the third factor compromising the bonding of self etch adhesives to dual cured resin cements. In this context the acidic groups from the outer layer of the adhesive that are not polymerized (because of the presence of oxygen) compete for peroxides with the tertiary amines of the resin luting agent. These results in an acid–base reaction between the adhesive system and the resin cement, which in turn prevents appropriate copolymerization and, as a result, the bonding between the adhesive and the luting agent is weak. (30)

The results are in contrary with Carlos et al, (31) whom found that the push-out strength for cementing fiber posts into root canals was not significantly influenced by the bonding strategy (etch and rinse adhesive system and self etch adhesive system). This contrary could be attributed to the difference in the adhesive systems used.

CONCLUSIONS

Under the limitations of the present study, the following conclusions can be drawn:

1- Post composition and macrostructure affects its retentive capacity to radicular dentin.

2- Prefabricated composite post systems based on quartz and alkaline resistance glass fibers embedded in a fully polymerized resinous matrix (Peerless and RelyX) in conjunction with etch and rinse adhesive system (Adper Single Bond 2) showed prompt bonding to radicular dentin.

3- The two step etch and rinse adhesive provides a retentive intraradicular bonded interface while the one step self etching adhesives should be avoided for post cementation.

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