

Full Length Research Paper

Effect of different adhesion strategies on push-out bond strength of fiber reinforced composite posts

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The aim of this study was to compare the bond strength of translucent fiber posts to root dentin, cemented with 4 adhesion strategies. Forty eight (48) sound human central incisors were decoronated and divided into 4 groups: Etch-and-rinse group, two-step self-etch group, one-step self-etch group, and self-adhesive resin cement group. The adhesion between the post and root canal walls was assessed using push-out test. Data was analyzed using one and two way ANOVA and a post hoc Tukey test ($P < 0.05$). There were significant differences in mean bond strength values between the etch-and-rinse group and the other groups ($P < 0.001$). Bond strength in the apical region was significantly different from those of the middle ($P = 0.018$) and cervical ($P = 0.014$) regions in etch and rinse group. The results were confirmed by scanning electron microscopy (SEM). Etch and rinse adhesive systems are more effective in bonding of fiber posts to post space dentin.

Key words: Adhesive system, bond strength, fiber post, root canal dentin.

INTRODUCTION

In recent years, foundation materials chosen for restoring endodontically treated teeth have changed from exclusively rigid materials (metal and zirconium posts) to materials having mechanical characteristics more closely resembling dentin (fiber posts and composite resin) (Asmussen et al., 1999). Fiber posts are chemically compatible with the bisphenol-glycidyl methacrylate (Bis-GMA) based luting agents, commonly used in bonding procedures, and they can be cemented with an adhesive technique (Sahmali et al., 2004). The retention of fiber posts in roots depends on the bond strength between the post material and resin luting agent, as well as the bond strength between the resin luting agent and post space dentin. Previously conducted scanning electron microscopy (SEM) studies have demonstrated a good bond between the resin matrix of the posts and resin luting agent (Mannocci et al., 1999; Vichi et al., 2002a). However, debonding along the dentin-resin luting agent interface has been identified as the most frequently

encountered mode of failure (Monticelli et al., 2003). The differences between coronal and radicular dentin should be considered and the appropriate adhesion strategy for adhesive cementation of endodontic posts, should be selected according to those variations (Ferrari et al., 2000). Originally, the use of 3-step dentin bonding systems was recommended for cementation of fiber posts (Vichi et al., 2002b). In an effort to simplify the bonding procedures, 2-component bonding agents that combine primer and bonding resin components in one solution have been introduced (Ferrari et al., 2002). A wet bonding procedure is essential for these adhesive systems to achieve an optimal hybrid layer and therefore improves the dentin bond strength (Molla et al., 2002).

Accordingly, use of 2-step self-etching primers with resin luting agents has been proposed (Foxton et al., 2003). Recently, 1-step self etch adhesives which have combined etchant, primer and bonding resin components in one solution was introduced. Rely X-Unicem is probably the first self-adhesive resin-based luting material designed to be applied without any dentin pretreatment (Van Meerbeek et al., 2003). Given the possibility of different reactions between each of the above mentioned bonding systems with the dual-cured

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resin cement predominantly used to cement fiber posts and the variable function of self-adhesive resin cement, the aim of this study was to evaluate the effect of different adhesion strategies using different bonding agents and a self-adhesive resin-based luting agent on the push-out bond strength of translucent fiber posts to root canal dentin. The null hypothesis was that the push-out bond strengths of fiber posts to root canal dentin using the above mentioned adhesion strategies are the same.

MATERIALS AND METHODS

Forty-eight maxillary central incisors with sound roots, which had been extracted for periodontal reasons were stored in 0.5% chloramine T solution until use. After cleansing the root surfaces, working length, and root canal morphology were determined radiographically. Teeth with any calcifications or obstructions inside the root canals or with working lengths exceeding 14 ± 1 mm were excluded from the study. The teeth were decoronated using a diamond saw (Diamant GmbH, D&Z, Berlin, Germany) in a low-speed straight handpiece (KAVO, Dental GmbH, Bismarckring 39, D-88400 Biberach/Riß, Germany) under continuous water spray.

The root canals were filed manually to the full working length using the step-back technique and #15 to #40 K-files (MANI, Tochigi, Japan) with #30 master apical file. The canals were then flared using #2, #3, and #4 Gates-Glidden drills (MANI), and were irrigated with normal saline. Subsequent to drying by paper points the canals were filled with gutta-percha (Guppudent co., Ltd, TianJin city, China) and AH-26 sealer (De Trey, Zurich, Switzerland) using lateral condensation technique.

In each tooth, 24 h after root canal treatment a 9 mm post space was prepared with a drill (#3 D.T. Light-Post Drill, RTD, St. Egreve, France) for translucent quartz fiber post (D.T. Light Post). The diameters of the fiber posts were 2.2 mm at the coronal end and 1.2 mm at the apical end. The posts had a tapered design with smooth surfaces and were 20 mm in length. Subsequently, the post spaces were irrigated with 3% NaOCl for 1 min and then were rinsed with 10% sodium ascorbate for 1 min to eliminate the detrimental effect of sodium hypochlorite on bond strength (Weston et al., 2007). Distilled water was used for final irrigation. Extra moisture was eliminated by paper points. Then the specimens were randomly divided into four (4) groups and prepared as follows:

In the etch-and-rinse group, Single Bond adhesive (3M ESPE, St Paul, MN, USA) was used according to manufacturer's instructions (Chemical compositions and application modes of adhesives used in the study are presented in Table 1). Subsequent to removal of the excess of resin with paper points, light-curing procedure was carried out using a quartz-tungsten-halogen light-curing unit (Degulux Soft Start, Dentsply, De Trey, GmbH, Germany) at a light intensity of 800 mW/cm^2 for 20 s by contacting the tip of the light conductor with the canal orifice. Then Rely X-ARC dual-cured resin cement (3M, ESPE) was placed inside the prepared canals by a lentulo spiral and the shortened quartz fiber post was coated with cement without any surface pre-treatment (according to manufacturer's instructions) and seated inside the prepared canal using finger pressure. Then the whole compartment was light-cured with the same light-curing unit for 20 s at a light intensity of 800 mW/cm^2 with the light conducting tip touching the end of the post.

In 2- and 1-step self-etching groups Adper SE Plus and Adper Easy Bond adhesives (3M, ESPE) were used according to manufacturer's instructions, respectively. Subsequently, fiber posts were cemented using Rely X-ARC similar to that in the etch-and-rinse group.

In the self-adhesive group, Rely X-Unicem (3M, ESPE), a self-

adhesive dual-cured resin cement, was used. Equal amounts of base and catalyst pastes were mixed for 20 s and spread in the canals. Then the post was coated with cement, placed in the canal and light-cured similar to that in the etch-and-rinse group. Twenty-four hours after completion of cementation procedures the specimens were fixed on the lab cut instrument using sticky wax and were horizontally cut under constant water spray so that each specimen yielded 3 post/dentin sections (cervical, middle and apical), each 3 mm thick. Therefore, each group yielded 36 samples, equally divided for cervical, middle and apical thirds.

Thirty samples from each group were fixed on the special jig using cyanoacrylate adhesive for the push-out test. The cervical part was placed toward the jig. Loading was carried out in the universal testing machine (Hounsfield Test Equipment, H5K-S, UK, England) using 1 mm diameter cylindrical piston which was exactly positioned at the center of the post without any contact with the post periphery. The force was applied in an apico-cervical direction, at a strain rate of 0.5 mm/min. The maximum force at the point of extrusion of the post segment from the test specimen was recorded in Newton (N). The push-out bond strength in MPa was calculated by dividing load at debonding (N) by the area (A) of the bonded interface. The surface area of the bonded interface was calculated by the formula: $A = \pi \times k (r_1 + r_2)$, in which r_1 represents the cervical post radius, r_2 represents apical post radius and k can be calculated using formula $[(h + (r_1 - r_2)^2)^{0.5}]$ where h is the thickness of the slice in millimeter (Akgungor et al., 2006).

The remaining 6 prepared specimens in each group were used for SEM observations of dentin-resin luting agent interface. They were kept in distilled water for 24 h and then immersed in 30% HCl for another 24 h to dissolve all tooth structures and reveal resin tags (Akgungor et al., 2006). Subsequent to rinsing in water and drying with air spray the samples were gold sputtered (Hummer Sputter Coater, Technics Inc, Alexandria, Va) and then, cervical, middle and apical parts of post surfaces were evaluated under SEM (Tescan Vega-II; Tescan, S.RO. Libusinia Trida, CZ) at $\times 1000$ magnification.

Two-way analysis of variance (ANOVA) was used to determine the effects of the adhesion strategies, post space region and the interaction between these two factors. A post hoc Tukey test was used for two-by-two comparisons. One-way analysis of variance (ANOVA) followed by Tukey test was used to compare the bond strength of post space regions in each study group using SPSS 16 software package. Statistical significance level was defined at $\alpha = 0.05$.

RESULTS

The means and standard deviations (SD) of bond strength values for post space regions in each adhesion strategy group are presented in Table 2. The results of two-way ANOVA revealed significant differences in relation to the adhesion strategies ($P < 0.001$), and the post space regions ($P = 0.001$). However, there was no noticeable interaction between these two factors ($P = 0.047$).

Two-by-two comparison of the groups by post hoc Tukey test showed that the bond strength in the etch-and-rinse group was significantly different from that in other groups ($P < 0.001$), while there were no significant differences between the other groups ($P \geq 0.51$). In addition, the differences between bond strength values of cervical and apical regions were significant ($P = 0.001$), but the differences between cervical and middle ($P =$

Table 1. Chemical compositions and application modes of adhesives used in the study.

Adhesive	Composition	Application mode
(Adper Easy One	HEMA, Bis-GMA, water, phosphoric acid-methacryloxy-hexylesters, ethanol, silane-treated silica, HDDMA, copolymer of acrylic and itaconic acid, DMAEMA, phosphine oxide, CQ	(1) Dispense one drop of the adhesive into a dappen dish and apply liberally with an applicator for 15 s using rubbing motion. (2) Gently air-blow until the liquid does not move anymore. (3) Light-cure for 10 s.
Adper SE Plus	Liquid A: water, HEMA, polyethylene–polypropylene, glycol, Rose Bengal dye. Liquid B: surface modified zirconium dioxide, Di-HEMA phosphate, TEGDMA, TMPTMA, diurethanedimethacrylate, 6-methacryloxyhexacryloxyphosphate, ethyl 4-dimethyl aminobenzoate, DL-camphorquinone.	(1) Dispense 1 drop of Liquid A into a dappen dish and apply so that a continuous red-colored layer is obtained on the surface. (2) Dispense 1 drop of Liquid B into second mix well and scrub into the entire wetted surface of the bonding area. The red color will disappear quickly. Continue scrubbing with moderate pressure for 20 s. (3) Air dry thoroughly for 10 s, the adhesive should remain in place and shiny in appearance. (4) Re-coat brush with Liquid B, and apply second coat to the entire bonding surface. Lightly air dry to obtain a thin adhesive layer. (5) Light-cure for 10 s.
Adper Single Bond	Ethyl alcohol, bis-phenol A diglycidyl ether, dimethacrylate, silane-treated silica, 2-hydroxyethyl methacrylate, glycerol, 1,3-dimethacrylate, copolymer of acrylic, and itaconic acids, diurethanedimethacrylate, water	(1) Etch: Apply Etchant to dentin. Wait 15 s. • Rinse for 10 s. • Blot excess water using a cotton pellet or mini-sponge. Do not air dry. • The surface should appear glistening without pooling of water. (2) Adhesive: • Immediately after blotting, apply 2-3 consecutive coats of adhesive for 15 s with gentle agitation using a fully saturated applicator. • Gently air thin for 5 s to evaporate solvent. (3) Light-cure: • Light-cure for 10 s
Rely X Unicem	Base paste (white): Methacrylate monomers containing, phosphoric acid groups, Methacrylate monomers, Silanated fillers, Initiator components, Stabilizers. Catalyst paste (yellow): Methacrylate monomers, Alkaline (basic) fillers, Silanated fillers, Initiator components, Stabilizers, Pigments.	No pretreatment is required

0.17) and/or middle and apical regions ($P = 0.16$) were not significant. The results of one-way ANOVA in each adhesion strategy group revealed

statistically significant differences in bond strength between post space regions ($P < 0.001$). Two-by-two comparison by post hoc Tukey test

demonstrated significant differences between the apical region and middle ($P = 0.018$) or cervical regions ($P = 0.014$) in the etch-and-rinse group.

Table 2. Means \pm standard deviations (SD) of bond strength values (MPa) in different regions of root dentin using different adhesion strategies.

Adhesion strategies	Root region	Bond strength \pm (SD)
Etch-and-rinse ^a	Cervical	63.69 \pm 13.21 ^c
	Middle	62.73 \pm 19.56 ^c
	Apical	35.74 \pm 25.27 ^d
2-step self-etch ^b	Cervical	28.55 \pm 8.94
	Middle	29.59 \pm 10.12
	Apical	26.20 \pm 13.33
1-step self-etch ^b	Cervical	41.53 \pm 24.4
	Middle	27.56 \pm 14.46
	Apical	22.29 \pm 11.37
Self-adhesive ^b	Cervical	31.25 \pm 12.22
	Middle	15.70 \pm 10.93
	Apical	21.40 \pm 13.50

However, there were no significant differences between the post space regions in the other groups ($P = 0.99$).

SEM micrographs of the resin tags are presented in Figure 1. The number and length of the resin tags in all the three regions of the post space dentin were higher in the etch-and-rinse group compared to other groups. However, the number and length of resin tags in the apical region of this group was lower than those in the cervical and middle regions. In the other groups, the number and length of resin tags in different regions of the root canal were relatively similar.

DISCUSSION

The efficacy of the bonds between fiber posts and root dentin may be evaluated by micro leakage testing (Mannocci et al., 2001), bond strength tests (Gaston et al., 2001), and SEM evaluations (Ferrari et al., 2000). According to the results of a study carried out by Gorraci et al. (2005a), push-out bond strength test is an appropriate test to evaluate the bond between endodontic posts and intra-canal dentin. Therefore, in the present study, push-out bond strength of fiber post to different regions of root canal dentin was evaluated using four different adhesion strategies.

The results of the present study demonstrated that the push-out bond strength of etch and rinse system is higher than 1- and 2-step self-etch adhesive systems and also self-adhesive luting agent. In other words, the null hypothesis of the study was refuted. These findings are consistent with the existing literature (Malyk et al., 2010; Gorraci et al., 2005b), which might be attributed to the capability of etch-and-rinse systems to etch dentin through the smear layer, facilitating hybridization and

formation of resin tags. In the etch and rinse system, the use of phosphoric acid as an etching agent removes the smear layer completely and paves the way for hybridization of decalcified inter tubular dentin, dentinal tubule walls and accessory canals. Self-etching primers, which have a weaker etching capability, do not result in complete elimination of the smear layer, and only a relative penetration through the smear layer may be seen (Ogata et al., 2002).

According to previous SEM studies adhesive bonding to root canal dentin is predominantly based on the formation of resin tags (Ferrari et al., 2002; Molla et al., 2002). Similar to the results of other studies (Gorraci et al., 2005a; Wang et al., 2008), SEM micrographs of the present study demonstrated more numerous and longer resin tags by the etch and rinse system in all the three regions of the root canal compared to the corresponding root regions in self-etch and self-adhesive luting agent groups. Therefore, the bond strength in the adhesive systems using a separate etching step is significantly greater than that in the systems without a separate etching step (Gorraci et al., 2005b). A possible chemical incompatibility between adhesive systems with low pH and resin materials of chemical and dual polymerization has been indicated (Suh et al., 2003). However, in another study self-etching primer and light-polymerized bonding agent has been recommended for luting of fiber post with a dual-polymerized resin luting agent (Akgungor et al., 2006).

Another important finding of the present study was that the bond strength to the apical region in the etch and rinse group was significantly less than that in the cervical and middle regions, which might be attributed to the number and length of the resin tags formed. The density of dentinal tubules significantly decreases in a cervico-

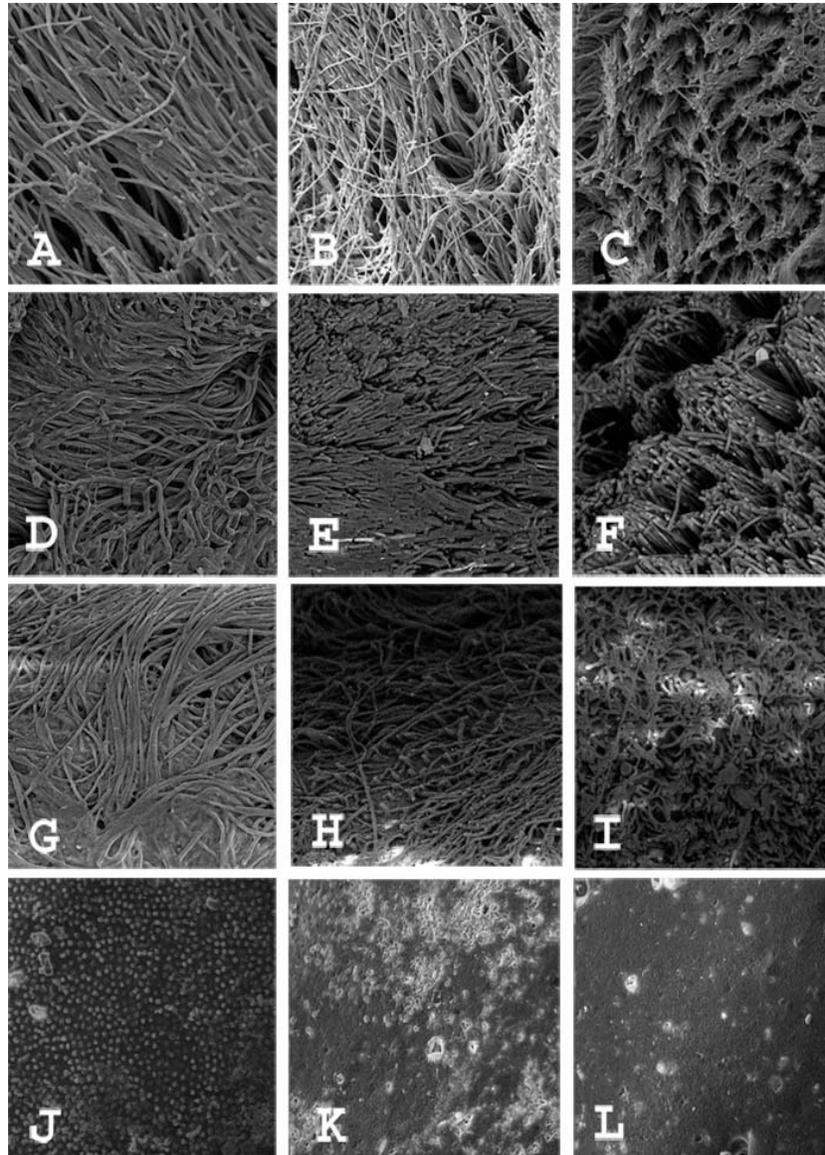


Figure 1. SEM micrographs of the resin tags formed in the study groups. (A) Cervical, (B) Middle, (C) Apical region of etch-and-rinse group, (D) Cervical, (E) Middle, (F) Apical region of 2-step self-etch group, (G) Cervical, (H) Middle, (I) Apical region of 1-step self-etch group, (J) Cervical, (K) Middle and (L) Apical region of self-adhesive resin cement group.

apical direction, which is consistent with bond strength pattern in the present study and other similar studies (Gorracci et al., 2005b; Kalkan et al. 2006). Problems related to manipulation and insufficient access to transfer or rinse the etching agent from the apical region should be taken into account. SEM micrographs in the present study confirm this finding. But there were no noticeable differences in the density and length of the resin tags formed by self-etching systems in different regions of the intra-canal dentin. It seems that the use of self-etching adhesives facilitates access to apical regions of root dentin, which is consistent with the result of previous

studies (Ogata et al., 2002; Abo El-Ela et al., 2009).

In the present study, low bond strength was observed with self-adhesive luting agent, which is consistent with the results of other studies (Gorracci et al., 2005b; Wang et al., 2008).

Similar to the results of previous studies (Monticelli et al., 2008; Behr et al., 2004) the SEM micrographs in the present study demonstrated no distinct resin tag formation by self-adhesive resin cement throughout dentin, and the interface produced was more like that produced by conventional luting agents. It seems the low decalcifying properties and low penetration of self-

adhesive resin cement into the underlying dentin results in a lower bond strength values. It has been demonstrated that removal of the smear layer with EDTA/NaOCl before post cementation results in better bonding of a self-adhesive resin cement to post space dentin (Zorba et al., 2010).

It should be pointed out that limitations may as well exist in direct application of the results of the present study to clinical situations. The bonding agents and self-adhesive resin cement used are only one of several available products for each adhesive strategy in the market; considering the chemical component variations, it is suggested to investigate retention properties of fiber posts using a broad range of products within each category.

Conclusions

Within the limitations of the present *in vitro* study, it can be concluded that etch-and rinse adhesive systems are more effective in bonding of fiber posts to post space dentin.

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REFERENCES

- Abo El-Ela OA, Atta OA, El-Mowafy O (2009). Micro tensile bond strength of nonmetallic dowels bonded to radicular dentin with self-etch adhesives. *J. Prosthodont.* 18: 167-171.
- Akgungor G, Akkayan B (2006). Influence of dentin bonding agents and polymerization modes on the bond strength between translucent fiber posts and three dentin regions within a post space. *J. Prosthet. Dent.* 95: 368-378.
- Asmussen E, Peutzfeldt A, Heitmann T (1999). Stiffness, elastic limit, and strength of newer types of endodontic posts. *J. Dent.* 27: 275-278.
- Behr M, Rosentritt M, Regnet T, Lang R, Handel G (2004). Marginal adaptation in dentin of a self-adhesive universal resin cement compared with well-tried systems. *Dent. Mater.* 20: 191-197.
- Ferrari M, Grandini S, Simonetti M, Monticelli F, Goracci C (2002). Influence of microbrush on bonding fiber posts into root canal under clinical conditions. *Oral. Surg. Oral. Med. Oral. Pathol. Oral. Radiol. Endod.* 94: 627-631.
- Ferrari M, Mannocci F, Vichi A, Cagidiaco MC, Mjor IA (2000). Bonding to root canal: structural characteristics of the substrate. *Am. J. Dent.* 13: 255-260.
- Foxton RM, Nakajima M, Tagami J, Miura H (2003). Bonding of photo and dual-cure adhesives to root canal dentin. *Oper. Dent.* 28: 543-551.
- Gaston BA, West LA, Liewehr FR, Fernandes C, Pashly DH (2001). Evaluation of regional bond strength of resin cement to endodontic surfaces. *J. Endod.* 27: 321-324.
- Goracci C, Fabianelli A, Sadek FT, Papacchini F, Tay FR, Ferrari M (2005a). The contribution of friction to the dislocation resistance of bonded fiber posts. *J. Endod.* 31: 608-612.
- Goracci C, Sadek FT, Fabianelli A, Tay FR, Ferrari M (2005b). Evaluation of the adhesion of fiber posts to intra radicular dentin. *Oper. Dent.* 30: 627-635.
- Kalkan M, Usumez A, Ozturk AN, Belli S, Eskitascioglu G (2006). Bond strength between root dentin and three glass-fiber post systems. *J. Prosthet. Dent.* 96: 41-46.
- Malyk Y, Kaaden C, Hickel R, Ilie N (2010). Analysis of resin tags formation in root canal dentine: a cross sectional study. *Int. Endod. J.* 43: 47-56.
- Mannocci F, Innocenti M, Ferrari M, Watson TF (1999). Confocal and scanning electron microscopic study of teeth restored with fiber posts, metal posts, and composite resins. *J. Endod.* 25: 789-794.
- Mannocci F, Ferrari M, Watson TF (2001). Microleakage of endodontically treated teeth restored with fiber posts and composite cores after cyclic loading: a confocal microscope study. *J. Prosthet. Dent.* 85: 284-291.
- Molla K, Park HJ, Haller B (2002). Bond strength of adhesive/composite combinations to dentin involving total-and self-etch adhesives. *J. Adhes. Dent.* 4: 171-180.
- Monticelli F, Grandini S, Goracci C, Ferrari M (2003). Clinical behavior of translucent fiber posts: a 2-year prospective study. *Int. J. Prosthodont.* 16: 593-596.
- Monticelli F, Osorio R, Mazzitelli C, Ferrari M, Toledano M (2008). Limited decalcification/diffusion of self-adhesive cements into dentin. *J. Dent. Res.* 87: 974-979.
- Ogata M, Harada N, Yamaguchi S, Nakajima M, Tagami J (2002). Effect of self-etching primer vs phosphoric acid etchant on bonding to bur-prepared dentin. *Oper. Dent.* 27: 447-454.
- Sahmali S, Demirel F, Saygili G (2004). Comparison of in vitro tensile bond strengths of luting cements to metallic and tooth-colored posts. *Int. J. Periodontics. Restorative Dent.* 24: 256-263.
- Suh BI, Feng L, Pashley DH, Tay FR (2003). Factors contributing to the incompatibility between simplified-step adhesives and chemically-cured or dual-cured composites. Part III. Effect of acidic resin monomers. *J. Adhes. Dent.* 5: 267-282.
- Van Meerbeek B, De Munck J, Yoshida Y, Inoue S, Vargas M, Vijay P, Van Landuyt K, Lambrechts P, Vanherle G (2003). Bonocore memorial lecture. Adhesion to enamel and dentin: current status and future challenges. *Oper. Dent.* 28: 215-235.
- Vichi A, Grandini S, Davidson CL, Ferrari M (2002a). An SEM evaluation of several adhesive systems used for bonding fiber posts under clinical conditions. *Dent. Mater.* 18: 495-502.
- Vichi A, Grandini S, Ferrari M (2002b). Comparison between two clinical procedures for bonding fiber posts into a root canal: a microscopic investigation. *J. Endod.* 28: 355-360.
- Wang VJ, Chen YM, Yip KH, Smales RJ, Meng QF, Chen L (2008). Effect of two fiber post types and two luting cement systems on regional post retention using the push-out test. *Dent. Mater.* 24: 372-377.
- Weston CH, Ito S, Wadgaonkar B, Pashley DH (2007). Effects of time and concentration of sodium ascorbate on reversal of NaOCl-induced reduction in bond strengths. *J. Endod.* 33: 879-881.
- Zorba YO, Erdemir A, Turkyilmaz A, Eldeniz AU (2010). Effects of different curing units and luting agents on push-out bond strength of translucent posts. *J. Endod.* 36: 521-525.