ORIGINAL ARTICLE

The short-term effect of sodium ascorbate irrigation on push-out bond strengths of fiber posts

Sodyum askorbat irrigasyonunun fiber postların bağlanma kuvveti üzerindeki kısa süreli etkisi

Assoc. Prof. Zeynep Özkurt-Kayahan
Department of Prosthodontics, Yeditepe University, Faculty of Dentistry, Istanbul, Turkey.

Assoc. Prof. Haktan Yurdagüven
Department of Restorative Dentistry, Yeditepe University, Faculty of Dentistry, Istanbul, Turkey.

Prof. İdil Dikbaş
Department of Prosthodontics, Yeditepe University, Faculty of Dentistry, Istanbul, Turkey.

Prof. Mehmet Baybora Kayahan
Department of Endodontics, Okan University, Faculty of Dentistry, Istanbul, Turkey.

Prof. Ender Kazazoğlu
Department of Prosthodontics, Yeditepe University, Faculty of Dentistry, Istanbul, Turkey.

Prof. Mübin Soyman
Department of Restorative Dentistry, Yeditepe University, Faculty of Dentistry, Istanbul, Turkey.

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Corresponding author:
Zeynep Özkurt-Kayahan
Yeditepe University, Faculty of Dentistry Department of Prosthodontics, Bağdat cad. No: 238
34728, Goztepe, Istanbul, Turkey
email: zeynepozkurt@hotmail.com

SUMMARY

Aim: The aim of this study was to evaluate the push-out bond strength of fiber posts to root canal dentin after irrigation of post spaces, prepared shortly after root canal filling.

Materials and Methods: Thirty roots of maxillary central incisors and canines were divided into 3 groups (n=10) and irrigated with different solutions after post space preparations. In the first group that served as the control, only distilled water was used for irrigation. In the second group, 5.25% NaOCl, 17% EDTA and distilled water were used subsequently for irrigation. In the third group, 5.25% NaOCl, 17% EDTA and distilled water were used. Then, 10% sodium ascorbate was applied to root canal for 10 minutes. RelyX Fiber Posts were cemented with RelyX Unicem self-adhesive resin cement. Three slices from different root regions (coronal, middle, apical) were sectioned, and totally 90 slices were collected. The push-out test was conducted and the SEM analysis was performed to determine the failure modes. One-way ANOVA and Tukey HDS tests were used to analyze the data ($p<0.05$).

Results: The mean bond strength was found as 8.64±3.73 MPa in the control group, 8.37±2.88 MPa in the second group and 9.94±2.94 MPa in the third group. There were no statistically significant differences between the bond strength values of the groups related to irrigation procedures and root regions ($p>0.05$).

Conclusions: Sodium ascorbate application after post space preparation did not cause higher bond strength of fiber posts to dentin, compared to conventional NaOCl and EDTA irrigation.

Keywords: Sodium ascorbate, bond strength, fiber post.

ÖZET

Amaç: Bu çalışmanın amacı, kanal dolgusunun hemen ardından hazırlanan post boşluklarının irrigasyonundan sonra, fiber postların kök kanal dentinine push-out bağlanma kuvvetinin değerlendirilmesidir.

Gereç ve Yöntem: 30 adet tek kanallı üst kesici ve kanin dişleri 3 gruba ayrıldı (n:10). Kanal tedavileri tamamlandıktan ve post boşlukları hazırlandıktan sonra dişler farklı solüsyonlarla yıkandı. 1.gruptaki dişler distile suyla yıkandı ve kontrol grubu olarak belirlendi. 2.gruptaki dişler %5,25 NaOCl, %17 EDTA ve distile suyla yıkandı. 3.gruptaki dişler % 5,25NaOCl, %17 EDTA ve distile suyla yıkandı. Ardından, bu gruptaki dişlere 10 dk boyunca %10 sodyum askorbat solüsyonu uygulandı. RelyX fiber postlar RelyX Unicem self-adeziv rezin simanla yapıştırıldı. Köklerin kuronal, orta ve apikal olmak kaydıyla her bölümünden 3 adet kesit alındı ve toplamda 90 adet kesit elde edildi. Push-out bağlanma dayanımı testi ve kırık tiplerini belirlemek amacıyla SEM analizi yapıldı. İstatistiksel analiz için one-way ANOVA ve Tukey HDS testleri kullanıldı ($p<0.05$).

Bulgular: Ortalama bağlanma dayanımı değerleri kontrol grubunda 8,64±3,73 MPa, 2.grupta 8,37±2,88 MPa ve 3.grupta 9,94±2,94 MPa olarak bulundu. Kök bölgelerine ve kullanılan irrigasyon solüsyonlarına göre bağlanma dayanımı değerleri arasında anlamlı bir farklılık gözlenmedi ($p>0.05$).

Sonuç: Post boşluğu hazırlandıktan sonra uygulanan sodyum askorbat solüsyonu, NaOCl ve EDTA'ya kıyasla fiber postların dentine bağlanma kuvvetini arttırmamaktadır.

Key words: Sodyum askorbat, bağlanma kuvveti, fiber post.

INTRODUCTION

Fiber-reinforced composite (FRC) posts have been used successfully in endodontically treated teeth because they have similar elastic modulus to dentin that leads to decrease in the incidence of root fracture (1), they do not cause metallic allergies and they provide good esthetics especially in visible areas (2). On the other hand, removal of a FRC post is easy in retreatment cases (3).

FRC posts are cemented with adhesive resin cements. The success of FRC posts depends on the cementing agent and the success of the cementing procedure to root canal dentin (4). Debonding is considered as the main failure mode of FRC posts (5). Many factors may cause debonding. The dentin of endodontically treated teeth is generally contacted by mechanical instrumentation, irrigation, medication and temporary restoration. In a study conducted by Nikaido et al. (6), it was stated that the remnants of irrigation solution such as sodium hypochlorite (NaOCl) or hydrogen peroxide demonstrated negative effect on polymerization of the adhesive system, which caused reduction of bond strength. It has been suggested that this reduction might be caused by the damage of the organic matrix, mainly the collagen, leaving the mineralized surfaces of dentin by application of NaOCl (6). In addition, NaOCl breaks down to sodium chloride and oxygen. Oxygen from the chemical reaction causes strong inhibition of the interfacial polymerization of adhesive materials (7). Otherwise, there might be some reactive residual free-radicals in NaOCl treated dentin which might compete with the vinyl free radicals generated during light activation of the adhesive system. This results in premature chain termination and incomplete polymerization (8).

To achieve adequate bond strength, 10% sodium ascorbate was introduced to apply on the NaOCl treated dentin and followed by water rinsing (8, 9). The sodium ascorbate is a reducing agent that interacts with oxygen, which is by-product of NaOCl by redox reaction (9). According to Vongphan et al. (10) application of 10% sodium ascorbate on NaOCl treated dentin (40.5 MPa) significantly increased the bond strength of single bond on etched dentin compared to NaOCl treatment (21 MPa). This finding was in agreement with the other studies (9, 11, 12). They found that additional treatment with ascorbic acid or neutral sodium ascorbate increased bond strengths of resin cements.

Immediate restoration of endodontically treated teeth is of great significance both for clinicians and patients. This immediate approach may prevent microleakage (13). In addition, dental patients expect adequate esthetics and function shortly after the root canal treatment (14). Although it was indicated in a few studies (9-12) that sodium ascorbate irrigation restored the bond strength of resin cements, short-term effect of sodium ascorbate on bond strengths of FRC posts to root canal dentin has not been evaluated yet. Thus, the aim of this study was (i) to evaluate the push-out bond strength of self-adhesive resin cement to dentin surfaces which were treated with different irrigates, (ii) to evaluate the effect of sodium ascorbate irrigate on the bond strength of FRC posts shortly after applying the conventional NaOCl and EDTA (ethylenediaminetetracetic acid) irrigates, and (iii) to determine the bond strength of FRC posts according to regional differences of the root dentin. The hypothesis tested was that, sodium ascorbate irrigation would increase the push-out bond strength of FRC posts shortly after the root canal treatment, reducing the negative effect of NaOCl irrigate used during instrumentation and post space preparation of the roots.

MATERIALS AND METHODS

Thirty human maxillary central incisors and canines extracted for periodontal reasons, with straight single root canals, free of cracks, caries, and fractures, and fully developed apices, were selected for this study. External debris was removed and they were stored in tymol solution for surface disinfection until use. The crown of each tooth was removed from the cemento-enamel junction with a 0.15 diamond-wafering blade (Buehler Ltd., Lake Bluff, IL, USA) with a slow speed saw (Buehler Ltd., Lake Bluff, IL, USA) under water cooling, to achieve a uniform length of 16 mm. The pulp tissue was removed with a barbed broach. Canal patency was determined by passing a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) through the apical foramen. Canal working lengths were established 1 mm short of the apical foramen and the step-back technique was used for canal instrumentation. The 30 roots were randomly assigned to 3 groups (n=10). In group 1, which served as the control, root canals were copiously irrigated with distilled water during shaping procedure. In group 2 and group 3, root canals were copiously irrigated with 5.25% NaOCl between the instruments. At the end of shaping procedure, canals were thoroughly rinsed using 17% aqueous EDTA. Distilled water was the final irrigant. Following the irrigation, the canals were completely dried with absorbent paper points (Dentsply Maillefer, Ballaigues, Switzerland). Then the canals were obturated with cold lateral condensation technique. AHPlus (De Trey-Dentsply, Konstanz, Germany) was the sealer. After obturation, all access cavities were sealed with temporary filling material (Coltosol-F, Coltene-Whaledent, Switzerland) and the roots were stored in distilled water at room temperature for 24 hours. Then, the post spaces were all prepared to a depth of 10 mm with preparation drills (size 3, RelyX Fiber Post drill; 3M ESPE, Seefeld, Germany). Five mm of intact gutta-percha was left behind to preserve the apical seal. Post size 3 (RelyX Fiber Post, 3M ESPE, Seefeld, Germany, 0.9-mm diameter apically, 1.9-mm diameter coronally and 0.10 taper) was tried to ensure that the posts would reach the bottom of the post space. Presence of any residual gutta-percha in the walls of post space was checked by radiographic evaluation.

Before cementation of the posts, different irrigation procedures were performed. In the first group, only distilled water was used for irrigation (group 1). In the second group, after copious irrigation with 5.25% NaOCl, 17% EDTA and distilled water were used subsequently (group 2). In the third group, 5.25% NaOCl, 17% EDTA and distilled water were used followed by 10% sodium ascorbate irrigation for 10 minutes (group 3).

The post spaces were completely dried with absorbent paper points (Dentsply Maillefer, Ballaigues, Switzerland) and the surfaces of the posts were cleaned with alcohol and dried with air. For cementation of fiber posts, the dual-polymerized self adhesive resin luting agent (RelyX Unicem, 3M ESPE, Seefeld, Germany) was prepared according to the manufacturer's instructions. RelyX Unicem Aplicap was mixed for 15 seconds and the special elongation tip was inserted to RelyX Unicem Aplicap. The cement was applied into the orifice of root canals. The posts were inserted into the canal to full depth by using finger pressure, and excess was immediately removed. The light curing was performed for 40 seconds through the posts, the tip of the light unit (Optilux 501, Kerr, USA) directly in contact with the coronal end of the posts. All the post-cemented roots were placed in distilled water at room temperature for 24 hours.

Push-out test

Then, each root was sectioned perpendicular to the long axis with a low speed saw (Buehler Ltd., Lake Bluff, IL, USA) to create 1.00±0.05-mm-thick slices. For each root, 3 slices from each region (coronal, middle, apical) were sectioned and totally 90 slices were collected. Each slice was marked on its coronal side with an indelible marker. The thickness of the slices were measured with a micro-measuring device in which the minimum reading value was set at ±0.001 mm (Mitutoyo Digimatic Caliper, Mitutoyo Corp., Kawasaki, Japan), and the radius of the canals were measured by using stereomicroscope (Leica MZ16 FA, Houston, TX). The push-out tests were performed at a crosshead speed of 1 mm/min by using a universal testing machine (Instron, 3345, Instron Corp., Norwood, MA, USA). The push-out jig was placed on the test machine. Care was taken to center the push-out pin (1.0 mm in diameter) on the center of the post surface, without stressing the surrounding post space walls. The load was applied to the apical side of the root slice to avoid any limitation of post movement due to post space taper. The peak force at the point of extrusion of the post segment from the slice was taken as point of bond failure, and the values were recorded in Newton (N). To express the bond strength in MPa, the load values recorded in Newton were divided by the area of the bonded interface. It was calculated using this formula: $A=2\pi rh$ (A: bonded area, r: radius, h: thickness of the slices).

Push-out test

After testing the push-out bond strengths, all samples were analyzed under a scanning electron microscope (SEM) to determine the type of failure. Failure of fractured specimens were determined and classified in 5 categories, described by Perdigao et al. (15):

1: Adhesive failure between the post and resin cement, there is no cement around the post.

2: Mixed failure between the post and resin cement, there is resin cement 0-50% in percentage around the post.

3: Mixed failure between the post and resin cement, there is resin cement 50-100% in percentage around the post.

4: Adhesive failure between the dentin and resin cement, the post is surrounded with resin cement.

5 : Cohesive failure in dentin.

Failure mode analysis

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4: Adhesive failure between the dentin and resin cement, the post is surrounded with resin cement.
5: Cohesive failure in dentin.

Statistical analysis

Statistical analyses were performed to evaluate the differences between bond strengths. One-way analysis of variance (ANOVA) and Tukey HDS tests were used to analyze the data and the significance level was set at $p<0.05$.

RESULTS

Push-out bond strength

The push-out bond strength values are shown in Table 2. The bond strength for coronal region was found as 10.38±4.11 MPa in control group, 8.04±3.3 MPa in group 2 (NaOCl and EDTA) and 10.35±2.46 MPa in group 3 (NaOCl and EDTA and sodium ascorbate). The bond strength for middle region was found as 7.82±3.63 MPa in control group, 7.50±2.72 MPa in group 2 and 9.58±3.49 MPa in group 3. The bond strength for apical region was found as 7.73±3.12 MPa in control group, 9.57±2.42 MPa in group 2 and 9.89±3.06 MPa in group 3. There were no statistically significant differences between the bond strength values of the groups related to irrigation procedures ($p>0.05$). In addition, there were no statistically significant differences between the bond strength values of the groups related to different regions of the roots ($p>0.05$).

Material	Manufacturer	Composition	Lot number
RelyX Fiber Post	3M ESPE, Seefeld, Germany	Parallel oriented and equal distributed glass fibers, embedded into a composite resin matrix	113770907
RelyX Unicem Aplicap (self-adhesive resin cement)	3M ESPE, Seefeld, Germany	Powder: glass fillers, silica, calcium hydroxide, self-cure initiators, pigments, light-cure initiators Liquid: methacrylated phosphoric esters, dimethacrylates, acetate, stabilisers, self-cure initiators	357281

Table 1: *Materials used in this study*

		Mean (sd)
Coronal region	Group 1 (distilled water)	10.38 (4.11)
	Group 2 (NaOCl and EDTA)	8.04 (3.30)
	Group 3 (NaOCl and EDTA and sodium ascorbate)	10.35 (2.46)
	p	0.222
Middle region	Group 1 (distilled water)	7.83 (3.63)
	Group 2 (NaOCl and EDTA)	7.50 (2.72)
	Group 3 (NaOCl and EDTA and sodium ascorbate)	9.58 (3.49)
	p	0.331
Apical region	Group 1 (distilled water)	7.73 (3.12)
	Group 2 (NaOCl and EDTA)	9.57 (2.42)
	Group 3 (NaOCl and EDTA and sodium ascorbate)	9.89 (3.06)
	p	0.213
Total	Group 1 (distilled water)	8.64 (3.73)
	Group 2 (NaOCl and EDTA)	8.37 (2.88)
	Group 3 (NaOCl and EDTA and sodium ascorbate)	9.94 (2.94)
	p	0.134

Table 2: *Mean push-out bond strength values (sd) in MPa.*

Failure mode analyses

According to the SEM analysis, mixed failure between the post and resin cement which included 50-100% resin cement remaining around the post (failure type 3) was the most frequently observed failure type (45%, n=41). The cohesive failure in dentin (failure type 5) was the least observed failure type (n=2). Other failure types were determined as adhesive failure between the post and resin cement which included no cement around the post (failure type 1, n=7), mixed failure between the post and resin cement which included 0-50% resin cement around the post (failure type 2, n=22) and adhesive failure between the dentin and resin cement in which the post was surrounded with resin cement (failure type 4, n=18) (Table 3).

		Failure mode				
Groups	**Region**	**1**	**2**	**3**	**4**	**5**
Group 1	Coronal	0	5	5	0	0
	Middle	1	2	7	0	0
	Apical	2	0	8	0	0
Group 2	Coronal	2	1	2	5	0
	Middle	2	0	2	6	0
	Apical	0	2	5	3	0
Group 3	Coronal	0	3	5	1	1
	Middle	0	3	4	2	1
	Apical	0	6	3	1	0
Total		7	22	41	18	2

Table 3: *Distribution of the failure modes following the push-out test*

DISCUSSION

The dislocation resistance of the FRC posts is mainly related to the luting agent and the success of the luting procedure to dentin. Although clinical experiences give exact information of bonding effectiveness, laboratory researches provide first-hand information on newly introduced materials (16). For quantitative evaluation of adhesion reliability, bond strength tests suggest that the stronger the bond at the tooth-material interface, the better it will resist undesirable stresses (17).

Several bond strength tests have been developed to evaluate clinical performances of dental materials. When FRC posts were first introduced in the 1990s, conventional shear and tensile tests had been criticized by some researchers (18). The bond strengths were entirely depended on experimental conditions and this was a limitation of these methods (19). The microtensile bond strength testing was introduced because it has the ability to reflect the true bond strength, to measure adhesion to small surfaces, to assess local variations and to obtain multiple specimens from a single tooth (20).

The push-out test, first used in 1996, is a valid method to investigate the retention of posts. Factors affecting the retention such as root canal treatments, timing of post cementation, type of adhesive and polymerization mode, properties of the luting agent, and thickness of the cement layer have been evaluated with this method (21). Also the degree of bond maturation over time and bond degradation under fatigue loading has been studied with the push-out test (16). This test is involved sectioning the posted root into 1 mm thick slices, and loading the post within each slice with a plunger until failure occurs. It provides a better estimation of the bonding strength than the conventional shear test, because the fracture occurs parallel to the dentin-bonding interface (22). In addition, the push-out test has been considered more dependable than the microtensile test for bonded posts because of the high number of premature failures occurring during specimen preparation and the large data distribution associated with microtensile testing (23). Moreover, the push-out test simulates the clinical conditions more closely (18).

The adhesive systems that have been proposed for bonding FRC posts to root canal dentin can be divided into self-etching adhesives and etch-and-rinse systems (24). Recently, self-adhesive resin cement, RelyX Unicem, was introduced. The multifunctional monomers with phosphoric acid groups simultaneously demineralize and infiltrate enamel and dentin. The adhesion obtained with this agent is claimed to rely on micromechanical retention and chemical interaction between monomer acidic groups and hydroxyapatite (25). Self-adhesive cements do not require any pretreatment of dentin and this offers a shorter application time and reduced number of clinical steps (4). In this study, this cement is preferred to eliminate the variability depending on multiple steps.

Self-adhesive resin cements react with the hydroxyapatite of the dental hard tissues. However, they have limited capacity to diffuse and decalcify the dentin because of their high viscosity which increases the acid-base reaction (26). They are unable to dissolve the smear layer completely. Despite the initial acidic pH (2.1), RelyX Unicem does not produce any dentin demineralization and hybridization (27, 28). Behr et al (29). revealed that the adhesive interface appeared similar to established dual-cured luting agents.

The post space preparation and cementation can be performed immediately or later, after the endodontic treatment. In vitro studies reported less apical leakage in case of immediate post space preparation and post cementation (13, 30), and immediate approach is less time consuming (31). However, the timing of these procedures may affect the retention of the posts. Vano et al. (32) investigated the effect of immediate versus delayed cementation of the FRC posts on the retention and found that push-out bond strength obtained with immediate approach was significantly lower than those obtained with delayed approach (24 h and 1 week). This finding was attributed to poor adhesion caused by contamination of the post space walls with the unset eugenol sealer. In the present study, non-eugenol sealer was used to eliminate this factor. On the other hand, obturated roots were stored in distilled water for 24 hours before post space preparation and post cementation to allow the root canal fillings to set.

The preparation of the post space using post drills results in an additional and thicker smear layer, which is composed of both dentin debris and sealer or gutta-percha remnants, which would affect the FRC post adhesion (33). These remnants may decrease the penetration and chemical interaction of the bonding agents. Therefore, achieving a clean dental surface with irrigation the post space after drilling procedures is a critical step for optimal FRC post retention (34).

Surface treatments of root dentin with different agents may cause alterations in the chemical and structural composition of dentin, which may change its permeability and solubility (35). These alterations have the potential to affect the bonding of adhesive materials to the treated dentin surfaces (36). In the present study, a conventional irrigation procedure was followed during shaping the root canals. According to this procedure, the canals were irrigated with copious amounts of NaOCl. After shaping procedure, EDTA was used because of its smear-removing efficacy. As it was demonstrated that dental erosion was more evident with final flush of NaOCl (37, 38), distilled water was used for the final irrigation. The presence of the smear layer may be a weak link for self-adhesive cements similar to glass ionomers (28).

NaOCl is a nonspecific oxidizing and proteolytic agent which denatures the collagen components of the smear layer (39). The oxidizing properties of the NaOCl cause negative effect on the initiation of polymerization of the adhesive system, leading to lower bond strength (6). Vonghpan et al. (10) suggested that endodontically treated teeth which were irrigated with NaOCl can be acid-etched and bonded immediately, with the use of 10% sodium ascorbate without any adverse effect. They observed rougher surface and more clearly visible collagen fibrils on the intertubular dentine after treating with 10% sodium ascorbate. The increased bonding strength was attributed to this finding.

Sodium ascorbate is a salt of ascorbic acid, which is a water-soluble vitamin known as vitamin C. This solution has antioxidant properties. As vitamin C and its salts are non-toxic and are used in food industry, it seems that their use on dentine will create no adverse biological effect. It is reported that sodium ascorbate increases bonding strength of resins to dentin (40). Various results have been reported regarding the positive influence of sodium ascorbate solutions on the bond strengths of resin materials to dentine (9-12). In Morris et al.'s study (9), it was stated that irrigation with 5% NaOCl (7.7 MPa) decreased the bond strength of resin to dentin compared to distilled water (23.6 MPa). On the other hand, they applied 10% sodium ascorbate and found that this procedure increased the bond strength (27.7 MPa). Vongphan et al. (10) evaluated the microtensile bond strength of resin to dentin after treated with different irrigates and found that the bond strength of dentin irrigated with 5.25% NaOCl for 10 minutes was significantly lower (21 MPa) than the bond strength of dentin irrigated with 5.25% NaOCl and 10% sodium ascorbate for 10 minutes (40.5 MPa). Weston et al. (11) investigated the effectiveness of sodium ascorbate to increase bond strengths when used for less time (1 to 3 minutes) than recommended by the manufacturer (10 minutes) or at different concentrations (10%, 20%). They stated that there were no significant differences between those canals treated with 10% sodium ascorbate and those treated with 20% sodium ascorbate regardless of treatment time, and 1-min treatment (23.8 MPa) was just as effective as 10-min treatment (29.1 MPa). However, they found statistically significant differences among the all sodium ascorbate groups (22.0 MPa- 29.1 MPa) and 5.25% NaOCl groups (8.3 MPa) (11). Da Cunha et al. (12) compared 3 different irrigation procedures for the evaluation of push-out bond strength of FRC posts to dentin. They reported that application of 5% NaOCl for 10 minutes decreased the bond strength compared to distilled water and irrigation of 10 % sodium ascorbate for 10 minutes restored the bond strength (12). These results can be explained by the antioxidant ability of sodium ascorbate. In the present study, there were no statistically significant differences between the bond strength values of the groups, both related to irrigation procedures and the root regions. However, the mean bond strength values of the sodium ascorbate group (9.94 MPa) were numerically higher than the other groups. Similarly, the bond strength values of the NaOCl and EDTA group (8.37 MPa) were numerically lower than the other groups. A possible explanation for these findings could be that the post space preparations and the adhesive procedures were performed 1 day after the root-canal treatment. In the other studies (9-12), all these procedures were performed 1 week later. Reduction in bond strength may be related to changes in the physical and chemical properties of dentin after application of NaOCl and EDTA (41).

EDTA is a chelator agent that reacts with calcium ions in the hydroxyapatite crystals of dentin. It softens dentin especially in the middle and coronal peritubular dentin. It is very effective in smear layer removal. It is considered to improve the retention of the FRC posts by removing the smear layer, opening the dentin tubules and etching the intertubular dentin that leads to better contact between the resin cement and the dentin (42). In the present study, EDTA was used after NaOCl irrigate for the purpose of applying routine clinical irrigation procedure. Higher bond strength values were obtained in group 2 (NaOCl and EDTA) than expected, and this result can be attributed to the irrigation of root canals with EDTA.

The secondary aim of this study was to compare the regional differences on the bond strengths of FRC posts for all irrigation procedures. However, a statistically significant difference was not found between the coronal, middle and apical regions of the root canal dentin.

According to SEM evaluation of this study, mixed failures between post and resin cement (type 3) were observed frequently (66%) in group 1. Most of the dentinal tubules were closed probably because of the smear layer that could not be dissolved by rinsing distilled water. No hybrid layer or resin tag formation was observed in this group (Figure 1 and Figure 2)

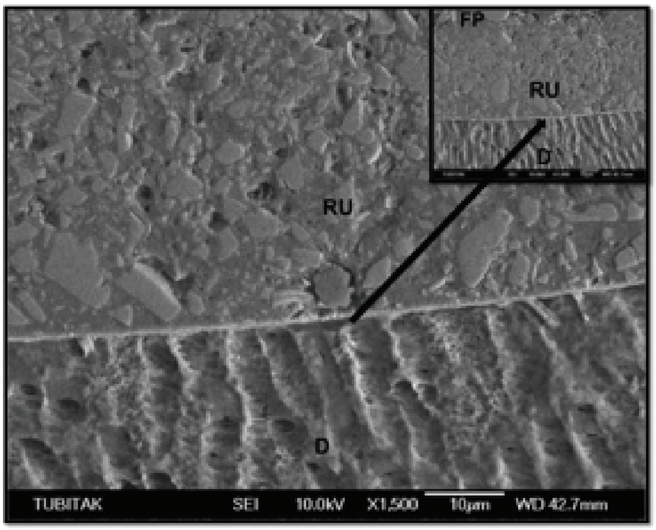

Figure 1: *Fe-SEM image of the Rely X Unicem dentin interface from the control group. At the cement-dentin interface a thin interaction zone with few resin tags were observed. (D: Dentin; RU: Rely X Unicem; FP:Fiber post).*

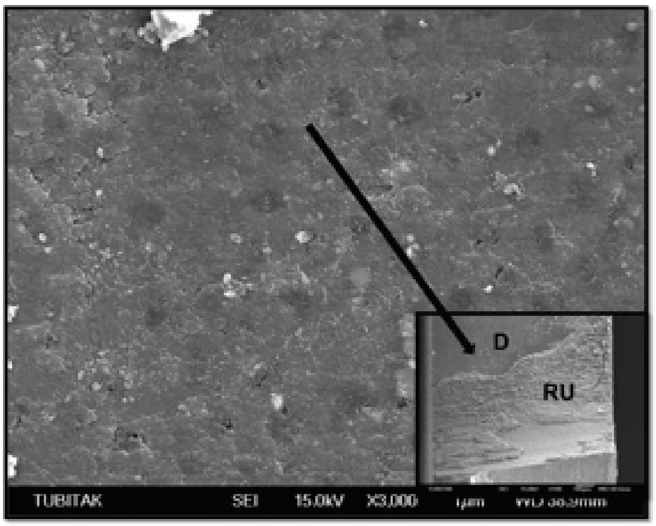

Figure 2: *Dentin side of a fractured push-out specimen from Rely X Unicem control group showing mixed failure mode with smear layer covered dentin (D) and resin cement (RU).*

In group 2, it was observed that the smear layer was removed completely from the NaOCl EDTA treated dentin, and an erosive surface occurred with large opened dentinal tubules and resin tags. Although resin tag formation was detected, no hybrid layer was observed in group 2. Adhesive failures between dentin and resin cement (type 4) were observed frequently (46%) and this may be related to lower bonding strength

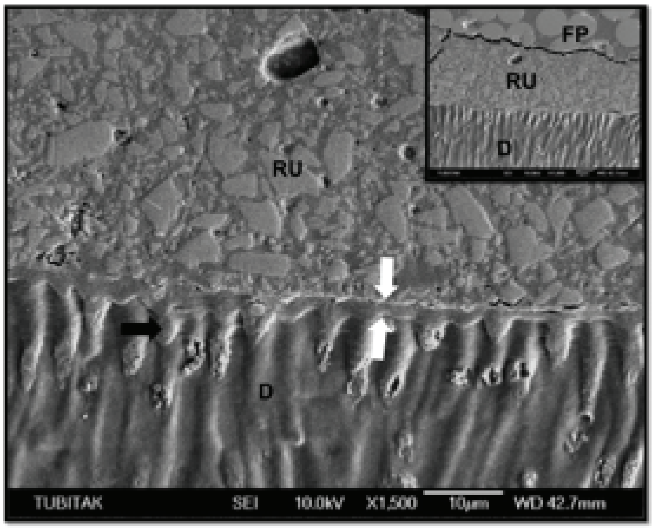

Figure 3: *: Fe-SEM image of Rely X Unicem and NaOCl, EDTA treated dentin interface. An interaction zone (white arrows) and large funnel shaped resin tags (black arrow) were detected. The interaction zone appeared to have a larger diameter compared to those observed in the control and in the NaOCl-EDTA-Sodium Ascorbat group. (D: Dentin; RU: Rely X Unicem; FP:Fiber post).*

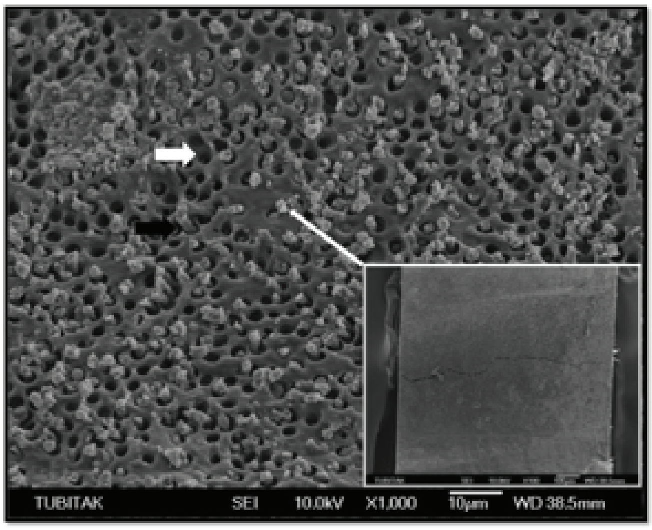

Figure 4: *Dentin side of a fractured push-out specimen from NaOCl and EDTA treated group showing adhesive failure mode. Most of the resin tags were pulled out of the tubules (black arrow) whereas infiltration into some tubules were not evident (white arrow).*

(Figure 3 and Figure 4).

In group 3, the application of 10% sodium ascorbate on the NaOCl EDTA treated dentin surface showed no obvious morphology change compared to group 2. Mixed failures between the post and resin cement (type 2 and 3) were detected frequently in this group (80%). Cohesive failures within the dentin were observed in 2 samples (Figure 5 and Figure 6).

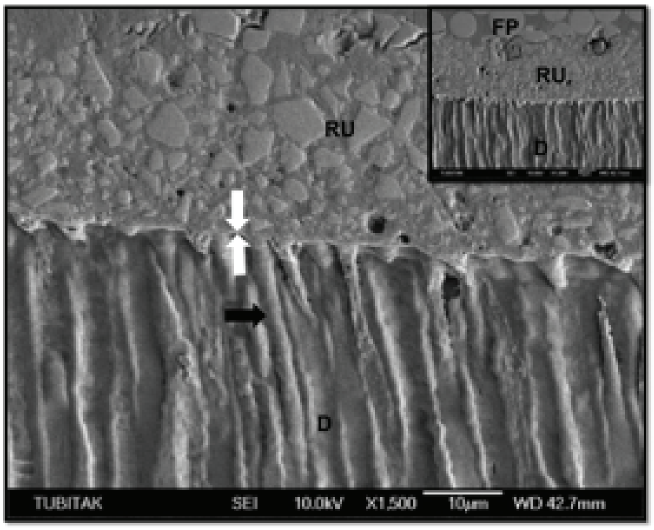

Figure 5: : Fe-SEM image of Rely X Unicem and NaOCl-EDTA-Sodium Ascorbat treated dentin interface. A thin interaction zone (white arrows) with a lot of resin tags (black arrow) were evident. (D: Dentin; RU: Rely X Unicem; FP:Fiber post).

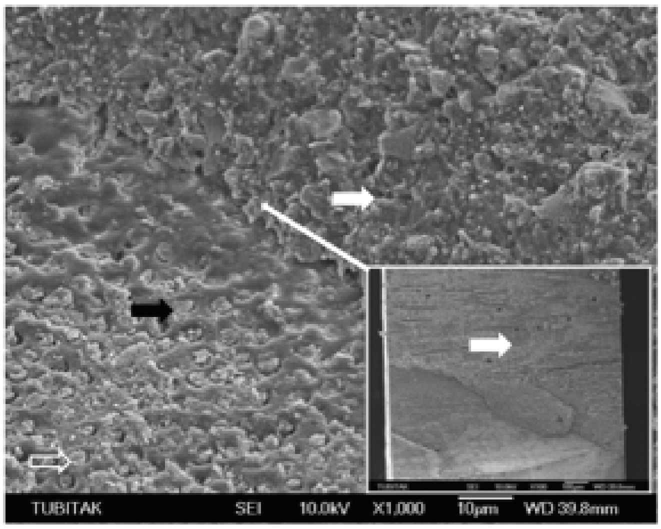

Figure 6: Dentin side of a fractured push-out specimen from NaOCl- EDTA- Sodium Ascorbat treated group showing mixed failure mode with fractured resin tags into the tubules (black arrow) and resin cement (white arrow).

CONCLUSIONS

The short-term effect of sodium ascorbate irrigation on the push-out bond strengths of FRC posts to root canal dentin was determined in vitro. The use of 10% sodium ascorbate after irrigation the dentin with NaOCl and EDTA improved the bond strengths but this difference was not statistically significant. The surface treatment of dentin with sodium ascorbate requires further investigation to determine appropriate timing or concentration for achieving optimal adhesion at the resin cement-dentin interface after exposure to NaOCl.

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REFERENCES

1. Sirimai S, Riis DN, Morgano SM. An in vitro study of the fracture resistance and the incidence of vertical root fracture of pulpless teeth restored with six post-and-core systems. J Prosthet Dent, 1999; 81:262-269.
2. Cheung W. A review of the management of endodontically treated teeth. Post, core and the final restoration. J Am Dent Assoc, 2005; 136: 611-619.
3. Cormier CJ, Burns DR, Moon P. In vitro comparison of fracture resistance and failure mode of fiber, ceramic, and conventional post systems at various stages of restoration. J Prosthodont, 2001; 10:26-36.
4. Radovic I, Mazzitelli C, Chieffi N, Ferrari M. Evaluation of the adhesion of fiber posts cemented using different adhesive approaches. Eur J Oral Sci, 2008; 116:557-563.
5. Cagidiaco MC, Goracci C, Garcia-Godoy F, Ferrari M. Clinical studies of fiber posts: a literature review. Int J Prosthodont, 2008; 21:328-336.
6. Nikaido T, Takano Y, Susafuchi Y, Burrow MF, Tagami J. Bond strengths to endodontically-treated teeth. Am J Dent, 1999; 12:177-180.
7. Rueggeberg FA, Margeson DH. The effect of oxygen inhibition on an unfilled/filled composite system. J Dent Res, 1990; 69:1652-1658.
8. Lai SCN, Mak YF, Cheung GSP, Osorio R, Toledano M, Carvalho RM, et al. Reversal of compromised bonding to oxidized etched dentine. J Dent Res, 2001; 80:1919-1924.
9. Morris MD, Lee KW, Agee KA, Bouillaguet S, Pashley DH. Effects of sodium hypochlorite and RC-prep on bond strengths of resin cement to endodontic surfaces. J Endod, 2001; 27:753-757.
10. Vongphan N, Senawongse P, Somsiri W, Harnirattisai C. Effects of sodium ascorbate on microtensile bond strength of total-etching adhesive system to NaOCl treated dentine. J Dent, 2005; 33:689-695.
11. Weston CH, Ito S, Wadgaonkar B, Pashley DH. Effects of time and concentration of sodium ascorbate on reversal of NaOCl-induced reduction in bond strengths. J Endod, 2007; 33:879-881.
12. Da Cunha LF, Furuse AY, Mondelli RF, Mondelli J. Compromised bond strength after root dentin deproteinization reversed with ascorbic acid. J Endod, 2010; 36:130-134.
13. Karapinar-Kazandağ M, Tanalp J, Bayrak OF, Sunay H, Bayirli G. Microleakage of various root filling systems by glucose filtration analysis. Oral Surg Oral Med Oral Pathol Oral Radiol Endod, 2010;109:96-102.
14. Villat C, Machtou P, Naulin-Ifi C. Multidisciplinary approach to the immediate esthetic repair and long-term treatment of an oblique crown-root fracture. Dent Traumatol, 2004; 20:56-60.
15. Perdigão J, Gomes G, Lee IK. The effect of silane on the

bond strengths of fiber posts. Dent Mater, 2006; 22:752-758.
16. Goracci C, Grandini S, Bossù M, Bertelli E, Ferrari M. Laboratory assessment of the retentive potential of adhesive posts: a review. J Dent, 2007; 35:827-835.
17. De Munck J, Van Landuyt K, Peumans M, Poitevin A, Lambrechts P, Braem M, et al. A critical review of the durability of adhesion to tooth tissue: methods and results. J Dent Res, 2005; 84:118-132.
18. Sudsangiam S, Van Noort R. Do dentin bond strength tests serve a useful purpose? J Adhes Dent, 1999; 1:57-67.
19. Versluis A, Tantbirojn D, Douglas WH. Why do shear bond tests pull-out dentin? J Dent Res, 1997; 76:1298-1307.
20. Pashley DH, Carvalho RM, Sano H, Nakajima M, Yoshiyama M, Shono Y, et al. The microtensile bond test: a review. J Adhes Dent, 1999; 1:299-309.
21. Patierno JM, Rueggeberg FA, Anderson RW, Weller RN, Pashley DH. Push-out and SEM evaluation of resin composite bonded to internal cervical dentin. J Endod Dent Traumatol, 1996; 12:227-236.
22. Drummond JL, Sakaguchi RL, Racean DC, Wozny J, Steinberg AD. Testing mode and surface treatment effects on dentin bonding. J Biomed Mater Res, 1996; 32:533-541.
23. Goracci C, Tavares AU, Fabianelli A, Monticelli F, Raffaelli O, Cardoso PC, et al. The adhesion between fiber posts and root canal walls: comparison between microtensile and push-out bond strength measurements. Eur J Oral Sci, 2004; 112:353-361.
24. Bitter K, Meyer-Lueckel H, Priehn K, Kanjuparambil JP, Neumann K, Kielbassa AM. Effects of luting agent and thermocycling on bond strengths to root canal dentine. Int Endod J, 2006; 39: 809-818.
25. Radovic I, Monticelli F, Goracci C, Vulicevic ZR, Ferrari M. Self-adhesive resin cements: a literature review. J Adhes Dent, 2008; 10:251-258.
26. De Munck J, Vargas M, Van Landuyt K, Hikita K, Lambrechts P, Van Meerbeek B. Bonding of an auto-adhesive luting material to enamel and dentin. Dent Mater, 2004; 20:963-971.
27. Yang B, Ludwig K, Adelung R, Kern M. Micro-tensile bond strength of three luting resins to human regional dentin. Dent Mater, 2006; 22:45-56.
28. Al-Assaf K, Chakmakchi M, Palaghias G, Karanika-Kouma A, Eliades G. Interfacial characteristics of adhesive luting resins and composites with dentine. Dent Mater, 2007; 23:829-839.
29. Behr M, Rosentritt M, Regnet T, Lang R, Handel G. Marginal adaptation in dentin of a self-adhesive universal resin cement compared with well-tried systems. Dent Mater, 2004; 20:191-197.
30. Solano F, Hartwell G, Appelstein C. Comparison of apical leakage between immediate versus delayed post space preparation using AH Plus sealer. J Endod, 2005; 31:752-754.
31. Saunders EM, Saunders WP, Rashid MY. The effect of post space preparation on the apical seal of root fillings using chemically adhesive materials. Int Endod J, 1991; 24:51-57.
32. Vano M, Cury AH, Goracci C, Chieffi N, Gabriele M, Tay FR, Ferrari M. Retention of fiber posts cemented at different time intervals in canals obturated using an epoxy resin sealer. J Dent, 2008; 36:801-817.
33. Goracci C, Sadek FT, Fabianelli A, Tay FR, Ferrari M. Evaluation of the adhesion of fiber posts to intraradicular dentin. Oper Dent, 2005; 30:627-635.
34. Boone KJ, Murchison DF, Schindler WG, Walker WA 3rd. Post retention: the effect of sequence of post-space preparation, cementation time, and different sealers. J Endod, 2001; 27:768-771.
35. Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod, 2010; 36:609-617.
36. Dogan Buzoglu H, Calt S, Gümüsderelioglu M. Evaluation of the surface free energy on root canal dentine walls treated with chelating agents and NaOCl. Int Endod J, 2007; 40:18-24.
37. Niu W, Yoshioka T, Kobayashi C, Suda H. A scanning electron microscopic study of dentinal erosion by final irrigation with EDTA and NaOCl solutions. Int Endod J, 2002; 35:934-939.
38. Grande CM, Plotino G, Falanga A, Pomponi M, Somma F. Interaction between EDTA and Sodium hypoclorite: Anuclear Magnetic Resonance Analysis. J Endod, 2006; 32:460-464.
39. Zhang K, Kim YK, Cadenaro M, Bryan TE, Sidow SJ, Loushine RJ, Ling JQ, Pashley DH, Tay FR. Effects of different exposure times and concentrations of sodium hypochlorite/ethylenediaminetetraacetic acid on the structural integrity of mineralized dentin. J Endod, 2010; 36:105-109.
40. Soeno K, Taira Y, Jimbo R, Sawase T. Surface treatment with ascorbic acid and ferric chloride improves the micro-tensile bond strength of 4-META/MMA-TBB resin to dentin. J Dent, 2008; 36:940-944.
41. Yiu CK, García-Godoy F, Tay FR, Pashley DH, Imazato S, King NM, Lai SC. A nanoleakage perspective on bonding to oxidized dentin. J Dent Res, 2002; 81:628-632.
42. Rasimick BJ, Shah RP, Musikant BL, Deutsch AS. Effect of EDTA conditioning upon the retention of fibre posts luted with resin cements. Int Endod J, 2008; 41:1101-1106.