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Effect of Chlorhexidine on Bond Strength Between Glass-Fiber Post and Root Canal Dentine After Six Month of Water Storage

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Abstract - *Aim of this study was to assess the influence of chlorhexidine digluconate (CHX) application on bond strength of glass fibre reinforced composite (FRC) posts to root dentine using adhesive luting systems. Forty extracted human mandibular premolars were endodontically treated and root canals were prepared. Teeth were divided into 2 groups according to luting system as SuperBond C&B (etch-and-rinse/chemical cure) and FuturaBond DC (self-etch/dual cure). Each group was further divided in 2 subgroups (n=10) according to whether CHX was applied or not. Group Futura/CHX: FuturaBond DC + CHX; group Futura: FuturaBond DC; group Super/CHX: Super Bond C&B + CHX; group Super: SuperBond C&B + CHX. Mean and standard deviation (in parenthesis) values of bond strength in MPa were: group Futura/CHX: 8.86 (1.96), group Futura: 7.65 (1.01), group Super/CHX: 17.47 (2.93), group Super: 12.41 (3.83). Bond strength values were affected by the type of luting agent and CHX irrigation (p=0.001, two-way ANOVA). There were statistically significant differences among the groups according to one-way ANOVA (p<0.001). Significant differences were observed in bond strength between groups Super/CHX and Super (p=0.023), between groups Futura/CHX and Super/CHX (p<0.001). Application of CHX before luting procedure with etch-and-rinse/chemical cure luting agent of glass FRC post improved long-term bond strength between glass FRC and root dentine.*

KEYWORDS: adhesive luting, bond strength, chlorhexidine digluconate, fibre post, matrix metalloproteinas

INTRODUCTION

In the course of fixed prosthodontic rehabilitation planning, glass FRC posts are generally the first choice of treatment for many endodontically treated teeth that exhibit extensive structural defects resulting from caries, cavity access and excessive removal of radicular dentine[1]. Glass FRC post systems compose of unidirectional glass fibres in the resin matrix that strengthen the structure of the post without compromising the modulus of elasticity[2]. The main advantage of glass FRC posts is their modulus of elasticity which is close to that of dentine[3]. In addition, they can be easily removed from the root canal when treatment fails.

Adhesive luting systems are used to achieve the bond between glass FRC posts and root canal dentine[1]. It was reported that unfavourable polymerization contraction stress of light-cured composite resin luting agents due to high configuration factor (C-factor, ratio of bonded to unbonded surface), may cause inferior bond strengths in the root canal[4]. Therefore, dual-cure or chemical-cure resin luting cement and dentine bonding agents should be preferred during luting of glass FRC posts into the root canal in order to achieve complete and slow polymerization especially at the apical part.

Durability of bond between FRC posts and root canal dentine is an important issue for providing long-term clinical success[5]. However; the most common cause of clinical failure for FRC posts is the post's debonding in root canal[6]. Adhesion along root canal dentine is difficult, particularly owing to the difficulties in achieving complete dryness in the root canal[7]. Additionally, degradation of denuded collagen fibrils exposed in incompletely infiltrated hybrid layers that is attributed to an endogenous proteolytic mechanism involving the activity of matrix metalloproteinases (MMPs) found in radicular dentine results in loss of adhesion between dentine bonding agent and dentine surface over time[8].

It was stated that incomplete infiltration of hydrophobic resins to demineralized dentine surface after acid etching in etch-and-rinse adhesive luting system may activate MMPs and cause adhesive and collagen degradation[7]. The investigators have reported that, in addition to its good antimicrobial properties and adhesion to root canal dentine surface, the application of CHX in root canal improves the longevity of hybrid layer by inhibition of MMPs[9]. Therefore application of CHX is of importance especially when etch-and-rinse dentine bonding agent is used.

In spite of above mentioned advantages, limited information is available on the long-term effect of CHX on the adhesion of fibre posts in root canals in combination with various adhesive cements. Therefore, the aim of this study was to investigate the effect of 2% CHX and 2 different adhesive luting systems, SuperBond C&B (chemical-cure) (etch-and-rinse) and Rebilda DC/FuturaBond DC (dual-cure, self-etch) on bond strength of glass FRC post to root dentine after 6-month period. It was hypothesized that:

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1. Bond strength to root canal dentine does not vary among luting agents after 6-month period.
2. Application of CHX into root canal improves bond strength between glass FRC post and root canal dentine after 6-month period.

MATERIALS AND METHODS

According the power calculation the number of specimens for each group was determined as 9.7 in order to detect a difference of 1.5 MPa with a power of 80% and an error probability of 0.05.

A total of 40 human mandibular premolars free of cracks, caries and fractures were used. All external debris was removed with an ultrasonic scalar and the teeth were stored in 0.9% saline solution at 4°C and used within 3 months following extraction. Teeth with curved roots and wide or atypically shaped root canals were excluded.

The coronal section of each tooth was removed below the cemento-enamel junction to obtain a 14-mm long root using a slow speed diamond saw (Isomet) under distilled water cooling and perpendicular to the long axis of the teeth. Endodontic treatment was performed through filing with reamers and Hedstrom files up to International Standards Organization (ISO) size 60. Distilled water was used for the irrigation during endodontic treatment. The root canals were dried with paper points (Roeko) and all roots were obturated with laterally condensed gutta-percha No. 60 (VDW) and a sealer (AH Plus). The roots were stored at 37ºC in distilled water for 1 week.

The endodontic posts used in this study were prefabricated conical shape glass FRC posts (Rebilda Post). Gutta-percha was removed from the root canals with Gates Glidden burs, leaving 4 mm of root canal filling in the apical portion. Subsequently, roots were prepared with the drill of the same diameter and same shape as the post that was available in the Rebilda Post system. The length of the post hole in root canal for each group was 10 mm. The post-holes were rinsed with distilled water and dried with paper points until the last paper point drawn out was dry. The teeth were randomly divided into 2 groups according to the luting resin used for post cementation: SuperBond C&B and FuturaBond DC. Each group was further divided in two subgroups (n=10) according to whether 2% CHX (Consepsis) was applied into the root canal or not. Chemical composition of the resin luting systems used in this study are presented in Table 1.

In group Futura/CHX, the surface of prefabricated glass FRC post was silanated with a silane coupling agent (Ceramic Bond) for 60s and air-dried for 10s. 2% CHX was applied into root canal for 15s and then dried with paper points. The single-dose and dual-cure self-etch dentine bonding agent (FuturaBond DC) was activated and applied onto root canal dentine for 20s and air dried for 5s. Dual-cure composite resin (Rebilda DC) base and catalyst were mixed on the mixing pad with a plastic spatula, and applied onto the post surface according to the manufacturer's instructions. Post was placed with slight vibration into the prepared root canal. Initial light-polymerization was performed for 10s. Excess cement was removed with a dental probe. Luting agent was polymerized from coronal

Table 1 *Materials used in the study*

Material	*Manufacturer*	*Batch #*	*Material Composition*
		Luting Systems	
Rebilda DC/ FuturaBond DC	Voco, Cuxhaven, Germany	FuturaBond DC (Dual-polymerizing single-bottle bonding agent): 1023106	Bis-GMA, HEMA, BHT, ethanol, fluorides, CQ, siliciumdioxide nanoparticles
		Cement base: 1016004 Cement catalyst: 1016004	Bis-GMA, UDMA, TEGDMA, BHT, BPO, silica, bariumborosilicate glass ceramic
		Silane (Ceramic Bond): 1015493	Polyfunctional methacrylates, silanes
SuperBond C&B	Sun Medical, Tokyo, Japan	Monomer:RX1	MMA, 4-META
		Catalyst:RW2	TBB, acetone
		Polymer: RW1	PMMA
		Green activator: RT1	Citric acid, $FeCl_3$
		Silane (Porcelain Liner M)	
		Liquid A:TE1	5% 4-META in MMA
		Liquid B: TE1	4% TMSPMA in MMA

4-META: 4-methacryloxyethyl trimellitate anhydride
MMA: methyl methacrylate
TMSPMA: 3-trimethoxysilylpropyl methacrylate
TBB, tri-*n*-butylborane
PMMA,poly(methylmethacrylate)
HEMA, hydroxyethyl methacrylate
Bis-GMA, bisphenol A-glycidyl dimethacrylate
BHT, butylated hydroxytoluene
UDMA, urethane dimethacrylate
TEGDMA, triethylenglycoldimethacrylate
BPO,benzoilperoxide

direction using visible light with an irradiance of 480 mW/cm^2 (Optilux 501) for 40s. The core build-up was made with a light-cured composite in three layers, light-cured for 40s each.

In group Futura, prefabricated glass FRC posts were luted as in group A without CHX irrigation.

In group Super/CHX, the surface of prefabricated glass FRC post was silanated with a silane coupling agent (Porcelain Liner M) for 60s and air-dried for 10s. Green activator was applied for 10s onto the root canal dentinal surface. After that, the root canal was rinsed off for 10s with distilled water and dried with paper points. Then 2% CHX irrigation was applied into root canal for 15s. The root canal dentine surface was dried with paper points. The monomer and catalyst S were then mixed and the mixture was applied into post space. Finally, the polymer powder was added to the mixture and put into the root canal with the help of a lentulo spiral, the glass FRC post was seated and excess luting material was removed. The luting material was left during 8 minutes for chemically polymerization.

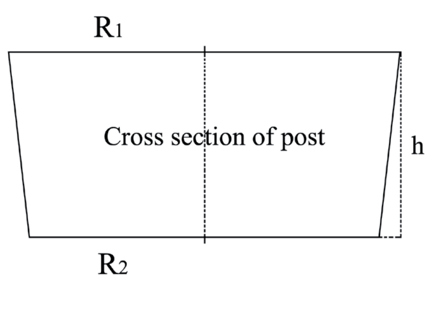
In group Super, prefabricated FRC posts were luted as in group C without CHX irrigation.

A composite built-up was placed onto all specimens to ensure the tight sealing of the root canal and specimens were then stored in distilled water at 37°C for 6 months prior to the sectioning procedure.

Push-out test

The most coronal tip of each composite built-up on each specimen was stabilized using sticky wax on a fixator with vertically moving rods. Specimens were then embedded in autopolymerizing acrylic resin (Meliodent) surrounded by plastic mould. The specimens were removed from the plastic mould after the first signs of polymerization.

Six slices of 1 mm thickness from coronal tip of each root to apical tip were obtained by sectioning the root with a slow speed diamond saw under distilled water coolant. Thus, a total of 60 slices were obtained for each group. The thickness of each slice was measured using a digital caliper to the nearest 0.01 mm to confirm accuracy and the value was recorded. Each section was fixed with cyanoacrylate adhesive to a stainless steel platform with a central circular perforation. This assembly was placed under a 1 mm diameter metallic plunger used to displace the post. The push-out bond strength was measured using a Shimadzu Universal Testing Machine with a crosshead speed of 0.5 mm/min. The load was applied apicocoronally on the apical surface of the slices due to conical shape of the glass FRC post. The load at failure after 6-month period was recorded in Newtons by Labtech Notebook software version 6.3. Bond strength value of each slice after 6-month period was calculated and expressed in MegaPascals (MPa). For this purpose, bond strength value in Newtons of each slice was divided by bond surface area. The apical and cervical diameters of the root canal of each slice were measured using a digital caliper to calculate the bond surface area. The bonding surface was calculated using the Formula of a conical frustum (Fig. 1) [10]. Thereafter, a mean bond strength value for each tooth and then a mean for each group was calculated.



$$\pi(R_1 + R_2)\sqrt{(R_1 - R_2)^2 + h^2}$$

Figure 1. *Bonding area and formula of conical frustum*

Failure mode evaluation

Specimens were evaluated to determine the type of failure after the bond strength test using the Optical Microscope (Nikon ECLIPSE ME 600) at X20 magnification and the images were analysed with the Image Analyzer lucia 4.21 (Labtech). Failures were classified as follows: (a) mixed, with resin cement covering 25% to 75% of the post surface; (b) adhesive between resin cement and root canal (post enveloped by resin cement); (c) Cohesive fracture of cement; (d) adhesive between resin cement and root canal (post enveloped by resin cement); or (e) Cohesive fracture of post.

Statistical analysis

Mean value for each specimen was calculated using six values obtained from six slices. Statistical analyses were then performed using mean values. All discs were analysed separately for the failure mode analysis. After checking the normality of data distribution and homogeneity of group variances, two-way analysis of variance (ANOVA) was used to examine 2 factors, luting agent and CHX irrigation and their interactions on bond strength. One-way analysis of variance (ANOVA) and Dunnett T3 post hoc test using SPSS 19.0 for Windows were performed for the comparison of bond strength of 4 groups. For the surface analysis data of fracture sites, the Chi-Square test was used. All tests were performed at a 95% confidence level.

RESULTS

None of the prepared specimens failed prematurely. Bond strengths in MPa (Mean and Standard deviation) after 6-months period for the four groups are presented in Table 2. Type of luting agent and application of CHX was significantly effective on the micro push-out bond strength according to the two-way ANOVA ($p=0.001$; Table 3). There were statistically significant differences among the groups according to the One-way ANOVA ($p<0.001$). A statistically significant difference was observed in bond strength between groups Super/CHX and Super ($p=0.023$), with group Super/CHX having higher values than group Super. Super/CHX had higher push-out bond strength values than group Futura/CHX ($p<0.001$), according to the Dunnett T3 test.

Table 2. *Mean bond strength (MPa), standard deviations (S.D.), and the modes of failure for all groups after 6-month period*

Group	*Failure mode*					*Bond strength*	
	Adhesive failure between dentine and cement	*Adhesive failure between post and cement*	*Mix*	*Cohesive failure composite*	*Cohesive failure post*	*Mean*	*S.D.*
Futura/CHX	54	-	6	-	-	7.6	1
Futura	39	3	17	-	1	8.8	1.9
Super/CHX	6	-	35	-	19	17.4	2.9
Super	15	-	10	1	34	12.4	3.8

Table 3. *Results of two-way ANOVA*

Source	*Df*	*Mean square*	*F*	*Significance*
Luting agent	1	446.759	63.477	.000
CHX	1	37.133	5.276	.028
Luting agent, CHX	1	98.157	13.946	.001
Error	36	7.038		

The modes of failure observed in different luting resins applications after 6-month period are presented in Table 2.

DISCUSSION

The mechanism of the luting systems used in the present study is different in the fact that while FuturaBond DC is a self-etch dual-cure luting system, SuperBond C&B is an etch-and-rinse chemical-cure luting system. Since micro push-out bond strength of glass FRC post luted with etch-and-rinse adhesive luting system to root dentine was higher than that of glass FRC post luted with self-etch adhesive luting system after 6-month period, the first null hypothesis must be rejected. Because micro push-out bond strength between root dentine and glass FRC post was not affected after applying CHX for self-etch adhesive luting system after 6-month, we must partially reject the second null hypothesis.

A variety of methods have been used to evaluate the bond strength in root dentine, including pull-out, microtensile and bond strength techniques[11]. The use of bond strength test for studying bonding to root canal dentine was reported in 1996[12]. Bond strength technique offers some advantages over the microtensile technique, since specimens are rarely lost. Conversely, pretesting failure commonly occurs with microtensile technique during specimen cutting and higher standard deviations are obtained. The bond strength test provides a better estimation of the bond strength than the conventional shear test because with the bond strength test the fracture occurs parallel to the dentine-bonding interface, which makes it a true shear test[12]. Additionally, bond strength test has been considered more dependable than the microtensile test for bonded posts[13].

The root canals were rinsed using distilled water instead of NaOCl during post-space preparation. Chemical irrigants such as solutions of NaOCl have been used in previous studies to clean the post-space. However, the influence of NaOCl as an irrigation agent on the retention of fibre posts remains controversial. A negative effect of NaOCl irrigation on the adhesion of resin cement to intraradicular dentine has been shown in a recent study[14]. NaOCl breaks down into NaCl and oxygen and it has been suggested that the liberation of oxygen may inhibit the polymerization of resinous bonding materials and interfere with resin infiltration into demineralized dentine[14]. A recent study reported that although the dentine surface was clean and the dentinal tubules had opened widely after irrigation with EDTA/NaOCl, the push-out strength of the EDTA/NaOCl group was not significantly different from that of the control group (water irrigation) [15]. The investigators did not recommend a single irrigation with an EDTA/NaOCl as a post-space treatment when luting a fibre post[15].

Thin slices (1mm) were obtained before the bond strength test in the present study. The use of thicker discs increases the area of friction and may lead to an overestimation of the bond strength[13]. The risk of friction is also higher with cylindrical versus conical posts[16]. Rebilda posts used in the present study have conical shape and thus the friction is minimized by directing the axial force from the smallest to the largest diameter.

The difficulty of moisture control and the lack of direct vision into the root canal have negative influences on all bonding procedures. Long-term clinical success of the adhesive-dentine bond is directly related to the integrity of the uncovered collagen and hybrid layer[17]. The uncovered collagen activates MMP in coronal dentine, leading to degraded bond interfaces[18]. According to a recent investigation, host-derived MMPs in root dentine after clinical function negatively influence bonding to root canal dentine in long-term clinical use[19]. MMPs can also be activated after application of acid etch onto dentine surface[19]. This procedure of etch-and-rinse dentine bonding system activates latent MMPs in dentine matrix due to low pH environments. This was the reason to compare the bond strength of an etch-and-rinse adhesive luting system with that of a self-etch one after 6-month period in the present study. Several studies indicated that MMPs should be inactivated to obtain stable hybrid layer for long-term period[20].

The polymerization contraction stress has a negative effect on adhesive-dentine interface. Configuration factor is very high for post restoration due to long narrow root shape. High degree of polymerization contraction stress occurs due to high configuration factor[7]. As a result, disruption of the sealing and formation of gaps occur at the cement-dentine interface. In the present study, glass FRC posts luted with etch-and-rinse/chemical cure luting system showed higher bond strength than ones luted with self-etch/dual-cure luting system. The use of light polymerization for dual-cure luting system that used in this study may cause gap formation at the cement-dentine interface. This may be the reason of lower bond strength for self-etch luting system that used in this study after 6 months of water storage. The adhesive system bonds to root canal dentine by diffusion of the hydrophilic bonding agent into the collagenous layer, after elimination or incorporation of the smear layer. It has been reported that thick smear layers and other debris retained on root canal walls after acid-etching might prevent adhesive infiltration and that self-etching primer might not be able to etch through thick smear layers[21]. This may be another reason of lower bond strength for self-etch adhesive luting system.

CHX is accepted as an effective MMP inhibitor[22-24]. Application of CHX into root canal prior to post luting did not have a negative effect on bond strength after 6 month of water storage in the present study. CHX could decrease debonding between resin cements and dentine for cement using etch-and-rinse adhesive system, while cement using with self-etch adhesive system CHX had no effect on push-out bond strength. In a recently published in vitro study, it was reported that prefabricated glass FRC posts exhibited higher bond strength to root dentine after application of 2% CHX[25]. However in an in vitro study it was reported that CHX application following application of acid-etch to root dentine did not improved bond strength between root dentine and glass FRC post for 6 months period[26].

CONCLUSIONS

Within the limitations of this in-vitro study, the first null hypothesis must be rejected. The bond strength of glass FRC post to root dentine obtained with etch-and-rinse dentine bonding system was higher than that obtained with self-etch dentine bonding system after 6-month period. The second null hypothesis must be partially rejected. Application of CHX after conditioning of root dentine with acid-etching agent improved bonding performance between root dentine and glass FRC post for etch-and-rinse dentine bonding system after 6-month period water storage. However, bond strength between root dentine and glass FRC post was not affected after applying CHX for self-etch dentine bonding system after same period of water storage.

MANUFACTURERS' DETAILS

- SuperBond C&B, Sun Medical, Tokyo, Japan
- Rebilda DC/FuturaBond DC (dual-cure, self-etch) (Voco, Cuxhaven, Germany)
- Isomet; Buehler, Lake Bluff, IL, USA
- Roeko, Langenau, Germany
- VDW, Munich, Germany
- AH Plus; Denstply, Konstanz, Germany
- Rebilda Post, Voco
- Consepsis, Ultradent, Salt Lake City, UT, USA
- Ceramic Bond, Voco
- Optilux, Kerr, Danbury, CT, USA
- Porcelain Liner M, Sun Medical
- Green activator, Sun Medical
- Catalyst S, Sun Medical
- Polymer powder, Sun Medical
- Meliodent, Bayer Dental, Newbury, United Kingdom
- Digital caliper, Mitutoyo Corp, Kanogawa, Japan
- Shimadzu Universal Testing Machine, Model AG-50kNG, Shimadzu, Kyoto, Japan
- SPSS 19.0, SPSS Inc., Chicago, IL, USA

ADDRESS FOR CORRESPONDENCE

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