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In Vitro Effects of Chlorhexidine and Isopropyl Alcohol Conditioning Agents on Immediate and Late Bond Strength of Fiber Posts to Dentin

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ABSTRACT

Objectives: This study assessed the effect of chlorhexidine (CHX) and isopropyl alcohol (IA) on immediate and late pushout bond strength (PBS) of fiber posts to dentin.

Materials and Methods: In this in vitro study, 54 single-canal premolars were endodontically treated, and randomly assigned to 3 groups (N=18) for root dentin conditioning with distilled water (control), 2% CHX, and 70% IA after post space preparation. Fiber posts were cemented with TheraCem self-adhesive cement, and each group was subdivided into two subgroups (N=9) for PBS measurement immediately after bonding, and after 5000 thermal cycles (5-55°C). The roots were then sectioned, and their PBS was measured. The mode of failure was evaluated under a stereomicroscope at ×40 magnification. Data were analyzed by repeated measures ANOVA and Tukey's test (alpha=0.05).

Results: The highest PBS was noted in the IA group (21.12 MPa) after 24 hours and the lowest PBS belonged to the control group after thermocycling (7.48 MPa). The immediate and post-thermocycling PBS were significantly lower in the control group than the CHX group ($P<0.05$). The PBS in both the control and CHX groups was lower than that in the IA group ($P<0.001$). Regardless of the type of detergent, a significant reduction in PBS was observed after thermocycling ($P<0.003$). The PBS significantly decreased from the cervical towards the apical region in all groups ($P<0.001$).

Conclusion: According to the results, application of IA before the self-adhesive cement effectively improved the immediate and late PBS, and was significantly more effective than CHX.

Keywords: Chlorhexidine; 2-Propanol; Dentin; Root Canal Therapy

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INTRODUCTION

The quality of coronal restoration is an important parameter in reconstruction of endodontically treated teeth, and provision of an optimal-quality restoration is often a challenging task [1]. Currently, a variety of tooth-colored intracanal post systems such as fiber posts are available for reconstruction of endodontically treated teeth [2]. Most clinical fractures of fiber posts are due to poor occlusal adjustment and subsequent fracture in the space between the root and intracanal post. A number of factors may affect post retention such as the shape and design of the post, the length and diameter of the post, type of cement, and crown preparation design after cementing the post [3]. In restorative procedures, chlorhexidine (CHX) as an antimicrobial agent is commonly used for treatment and conditioning of root canal dentin to prevent the collapse of collagen fibers [4].

According to Durski et al, [5] CHX inhibits endogenous factors such as matrix metalloproteinases, and stabilizes the dentin-composite hybridization as such. They also reported significantly higher pushout bond strength (PBS) when CHX was used in the root canal system before cementation of intracanal post compared with no application of CHX [5]. Nonetheless, no consensus has been reached in this regard. Other chemicals, such as alcohols, are used for dentin treatment to control its moisture level, improve the penetration depth of resin monomers, prevent the collapse of collagen fibrils, and subsequently improve adhesion [6,7]. Isopropyl alcohol (IA) has less polarity than ethanol, and therefore removes less moisture from the dentinal tubules, which in turn improves the degree of conversion and adhesion [8].

Durability of bonding is usually assessed by measuring the bond strength of resin cements to dentin over time by applying aging methods such as thermocycling [9]. Self-adhesive cements are one-step application cements with reportedly equal or even superior bonding efficiency than other resin-based cements [5]. The manufacturers suggest that the dentin surface should not be too dry when applying self-adhesive cements. However, number of studies on optimal dentin preparation protocol for application of such cements is limited [10]. Moreover, there is a gap of information about the effects of CHX and IA before the cementation of fiber posts. Thus, this study aimed to assess the effect of CHX and IA on immediate and late PBS of fiber posts to dentin. The null hypothesis of the study was that no significant difference would be found in PBS of fiber posts to dentin following the application of distilled water, CHX and IA.

MATERIALS AND METHODS

This in vitro experimental study evaluated 54 single-rooted and single-canal mandibular premolars. The study protocol was approved by the ethics committee of the university (IR.IAU.DENTAL.REC.1399.021).

The sample size was calculated to be 9 in each of the 6 subgroups according to a study by Lecardelli et al, [1] using ANOVA power analysis feature of PASS 11 considering alpha=0.05, beta=0.2, mean standard deviation of PBS to be 9.1, and effect size of 0.52. The required sample size was smaller by using the factorial formula. The teeth were decoronated perpendicular to their longitudinal axis and parallel to the cementoenamel junction (CEJ) by a cylindrical diamond bur (Dia, Italy) and high-speed hand-piece under water spray. The root canals were instrumented with ProTaper rotary system (Dentsply Sirona, NC, USA) by using SX, S1, S2, F1, and F2 files by the crown down technique [5]. The root canals were rinsed with 2.5% sodium hypochlorite and 17% EDTA (Vista Dental, Racine, WI, USA). Finally, the canals were obturated with gutta-percha (ProTaper F2; Dentsply DeTrey GmbH, Konstanz, Germany) and AH26 epoxy resin-based sealer (Dentsply DeTrey, Konstanz, Germany) by the lateral compaction technique [4]. After root canal obturation, the orifice was temporarily sealed with Cavit (3M ESPE, St. Paul, MN, USA), The teeth were incubated (E55CM Gostar Azma Fan Co., Tehran, Iran) at 37°C and 100% humidity for 48 hours .Subsequently, Peeso reamers #1, #2, and #3 (Angelus, Londrina, PR, Brazil) were used at low speed (500-800 rpm) to prepare the post space with 7 mm length as measured from the CEJ. The roots were then randomly assigned to 3 groups (N=18) of control, CHX, and IA.

To measure the PBS, each group was subdivided into two subgroups (N=9) of immediate PBS (after 24 hours) and late PBS measured after thermocycling. In the CHX group, the post space was irrigated with 2% CHX (Maquira Dental Products, Maringá, PR, Brazil). Distilled water was used for this purpose in the control group, and 70% IA (Nova, Iran) was used in the IA group. A 27-gauge needle was used for irrigation, and irrigation was performed for 60 seconds in all groups. The root dentin of the post space was then dried with gentle air spray and paper points. Next, #2 fiber posts (Angelus Brazil, PR, Londrina) were cut to 3 mm above the CEJ with a double-sided diamond disc (Diatech, Germany), cleaned with 70% ethanol, and completely air-dried.

TheraCem self-adhesive cement (Bisco Inc, Schaumburg, Ill) was used to cement the fiber posts to root canal dentin according to the manufacturer's instructions. After cementation, all teeth were light-cured (Optilux 500; Kerr, Orange, CA, USA) for 60 seconds from the occlusal surface with a minimum light intensity of 800 mW /cm^2 [5,11].

Core build-up was performed by composite resin (Estelite Sigma Quick; Tokuyama Dental, Tokuyama, Japan) applied with 3 mm thickness to cover the dentin and fiber post, and the teeth were then incubated in a dark chamber containing distilled water at 37°C for 24 hours [12].

Thermocycling was then performed to simulate the aging process. The groups underwent 5000 thermal cycles (Dorsa, Tehran, Iran) between 5°-55°C with a dwell time of 10 seconds, to simulate 6 months of clinical service [5]. The roots were mounted in metal molds containing self-cure acrylic resin (Acropars, Iran). Next, three sections with 1±0.1 mm thickness were made perpendicular to the longitudinal axis of each root 1 mm below the CEJ under water coolant by using a high-speed cutting machine (CNC, Nemo, Iran) [1].

A universal testing machine (STM 20; Santam, Iran) with a punching pin was then used to measure the PBS in the cervical (1 mm), middle (0.9 mm) and apical (0.8) sections by applying 500 N force in an apico-cervical direction with a cross-head speed of 0.5 mm/minute. The force was applied to the center of each specimen until the fiber post was detached from dentin. The following formula was then used to calculate the PBS in megapascals (MPa) [13,14]:

$A= \pi(r_1+r_2)[(r_1+r_2)^2+h^2]½$

Where A is the lateral surface area of the post, F is the maximum force required for debonding of the post, r_1 is the radius of the coronal part of the root, r_2 is the radius of the apical part of the post, and h is the slice thickness in millimeters. The mode of failure was evaluated under a stereomicroscope (Olympus SZ51; Olympus Corp., Tokyo, Japan) at ×40 magnification, and classified into 5 categories of adhesive between the post and cement (no cement seen around the post), mixed 1 (0%-50% of the post surface covered with the cement), mixed 2 (50%-100% of the post surface covered with the cement), adhesive between the cement and dentin (enveloped post), and cohesive within the cement [1]. Data were analyzed by repeated measures ANOVA and Tukey's test. P<0.05 was considered statistically significant.

RESULTS

The effects of CHX and IA on immediate and late PBS of fiber posts to dentin were evaluated in 54 single-canal mandibular premolars (6 subgroups of 9). Table 1 shows the mean PBS of the groups after 24 hours and following

Table 1. Mean pushout bond strength (PBS) values (MPa) of fiber post to dentin in different root sections

Group			Minimum	Maximum	Mean	SD
Control	Immediate PBS (24 hours)	Coronal	12.70	18.64	16.66	1.91
		Middle	7.65	15.87	12.80	2.44
		Apical	5.58	13.15	7.73	2.35
	Late PBS (after thermocycling)	Coronal	11.07	18.97	13.22	2.41
		Middle	7.21	12.06	9.61	1.70
		Apical	6.25	9.12	7.48	1.20
Chlorhexidine	Immediate PBS (24 hours)	Coronal	10.41	20.40	17.75	2.97
		Middle	8.60	18.90	14.34	3.13
		Apical	5.40	15.44	10.75	2.63
	Late PBS (after thermocycling)	Coronal	14.98	18.97	17.04	1.19
		Middle	9.89	15.85	14.13	1.81
		Apical	6.37	14.70	10.04	2.41
Isopropyl alcohol	Immediate PBS (24 hours)	Coronal	19.25	23.08	21.12	1.54
		Middle	14.70	22.99	19.40	2.29
		Apical	9.87	18.90	15.80	3.23
	Late PBS (after thermocycling)	Coronal	18.81	22.98	20.25	1.48
		Middle	14.52	22.53	19.45	2.27
		Apical	12.34	20.41	15.30	2.86

SD: standard deviation

Table 2. Frequency of different failure modes in the study subgroups (N=9)

Groups	PBS measurement time	Failure mode				
		Adhesive CP	Mixed 1	Mixed 2	Adhesive CD	Cohesive
Control	After 24 hours	-	5	3	16	3
	After thermocycling	1	7	4	13	2
Chlorhexidine	After 24 hours	4	6	6	8	3
	After thermocycling	4	6	5	9	3
Isopropyl alcohol	After 24 hours	5	5	7	9	1
	After thermocycling	4	7	5	10	-

PBS: pushout bons strength; Adhesive CP: adhesive cement-post); Mixed 1: 0%-50%; Mixed 2: 50%-100%; Adhesive CD: adhesive cement-dentin

thermocycling in all three groups. The highest PBS was noted in the IA group (21.12 MPa) after 24 hours, and the lowest PBS belonged to the control group after thermocycling (7.48 MPa). The Tukey's test showed that the immediate (24 hours) and late (after thermocycling) PBS values in all root sections in the IA group were significantly higher than the values in the CHX and control groups ($P<0.001$).

Repeated measures ANOVA showed a significant reduction in PBS after thermocycling in all three groups and in all root sections, irrespective of the type of conditioning agent used ($P<0.003$). Pairwise comparisons between the root sections in all samples showed that the mean PBS significantly decreased from the cervical towards the apical region regardless of the type of conditioning agent and thermocycling ($P<0.001$).

Regarding the failure mode, inspection under a stereomicroscope at x40 magnification revealed that the most common failure mode was adhesive between the cement and root dentin (post covered by cement, enveloped). Table 2 shows the frequency of different failure modes in the study groups.

DISCUSSION

This study assessed the effect of CHX and IA on immediate and late PBS of fiber posts to dentin. The null hypothesis of the study was that no significant difference would be found in PBS of fiber posts to dentin following the application of distilled water, CHX and IA. According to the results, the null hypothesis of the study was rejected since both the immediate and late PBS of fiber posts to root dentin were significantly different among the three groups and were significantly higher in the IA group than the CHX and control groups.

In the present study, dual-cure self-adhesive cement was used for cementation of fiber posts. Self-adhesive cements with mild acidic properties cause demineralization and limited hybridization of dentin. Several studies have reported higher bond strength values provided by these cements than multi-phase cements [17,18]. The reason may be the chemical reaction of the cement with dentin hydroxyapatite in use of self-adhesive cements. Also, they are easy to use and have a one-step application. Higher number of procedural steps in multi-stage cements can cause errors such as air retention in the cement layer and development of defects. The setting reaction of self-adhesive cements is an acid-base reaction in aqueous media. For this reason, adhesive manufacturers recommend avoiding over-drying of dentin surface. Thus, controlling the desired dentin moisture by IA is more important in self-adhesive cements [17,18].

The structure of the dentin matrix is composed of type 1 collagen and non-collagenous proteins. Due to the hydrophilicity of the fibers, hydrolytic degradation of the hybrid layer progresses over time. However, complete removal of moisture from dentin significantly decreases the bond strength, as water is essential to maintain the integrity of the collagen network, which in turn allows adequate penetration of resin monomers. Bitter et al, [15] and Cecchin et al. [7] used ethanol to control the moisture content of dentin, and a higher bonding durability was observed in the ethanol group than the CHX and distilled water groups. Controlling the dentin moisture by using chemical methods to dehydrate dentin (such as application of ethanol) is a promising technique that has shown good results in terms of bond strength and durability [19].

Lecardelli et al. [1] showed that IA was more successful than CHX and distilled water in improving the bonding durability after 24 hours and 6 months of storage. According to this study, better penetration of resin monomers into the dentinal tubules occurs when the dentin substrate has optimal moisture before cementation. IA has less polarity than ethanol, and therefore, removes lower amounts of water from the dentinal tubules and increases the dentin wettability. As a result, the degree of conversion of resin monomers and subsequently the strength and durability of the bond increase [1,6,23].

In the current study, the bond strength of fiber posts to dentin after 24 hours and also after thermocycling was significantly higher in the IA group than the CHX and distilled water groups. This finding was consistent with the results of Bitter et al, [15] and also Lecardelli et al, [1] regarding the effect of IA and CHX on the bond strength of fiber posts to dentin over time. However, some other studies found no significant difference in bond strength of IA and CHX groups [2,7]. Such contradictory results are probably due to the differences in the methodology of studies, different aging protocols, and different adhesive systems used [16].

Matrix metalloproteinases (MMPs) are calcium- and zinc-dependent endopeptidases present in the dentin matrix. CHX inhibits the activity of MMPs in the hybrid layer and preserves the bond strength. For this reason, several studies have suggested the use of CHX as a MMP inhibitor [5,20]. Moreover, CHX can also increase dentin wettability and improve adhesion due to properties such as highly positive ion charge and tendency to bond to phosphate groups, high affinity for bonding to tooth structure, and increasing the surface free energy of enamel and dentin [5,20]. Therefore, the PBS in the CHX group was higher than that in distilled water control group in the present study. According to the current results, both IA and CHX were successful in increasing the PBS of fiber posts at both 24 hours and after thermocycling compared to distilled water. But in use of self-adhesive cements that do not require dentin etching, it appears that CHX is not as effective as when used on etched dentin. Formation of chlorine compounds as a result of the reaction between CHX and hydroxyapatite phosphate ions has been mentioned as one of the possible causes of the decreased effect of CHX on bond strength [21]. It appears that optimal level of dentin moisture obtained by the application of IA is more effective than CHX application in improving the bond strength and preserving the quality of the hybrid layer over time [1,9].

Another finding of the present study was that in all specimens, regardless of the type of root canal conditioning agent and conduction of thermocycling, the PBS decreased from the cervical towards the apical region. This result was consistent with the findings of Durski et al, [5] and Conte et al, [22] that reported the highest bond strength in the cervical third of the root, followed by the middle third, and the minimum bond strength in the apical third of the root.

Limited access to the apical region, incomplete removal of the smear layer, incomplete penetration of cement, and limited light penetration for complete and ideal polymerization of cement, as well as differences in the distribution and density of dentinal tubules in different parts of the root are the reasons for this reduction in bond strength [5,23].

The bond strength values decreased in all groups after thermocycling regardless of the type of conditioning agent. Another study reported the same result regarding the effect of CHX on bond strength after aging [16]. A possible explanation for this reduction is the effect of hydrolysis between cement and dentin [5,24]. Although a reduction in bond strength was observed in all groups after thermocycling, this decrease was greater in the control group than the CHX and IA groups in the current study. This finding is probably due to inhibition of the activity of MMPs by CHX, which decreases after 12 months according to an in vitro study [11]. The long-term effects of CHX are still unclear; a clinical study reported that application of 2% CHX effectively increased the bond strength for up to 6 months [25]. Optimal efficacy of IA is due to removal of excess moisture from dentin substrate, which prevents hydrolytic degradation of the adhesive layer, and increases the lifespan of the adhesive in the hybrid layer and the bonding durability [1,7,11,26].

In the present study, the frequency of adhesive failure between the cement and root dentin was consistent with many studies [1, 27, 28]. The most common mode of failure was failure at the cement-dentin interface. Factors such as cleaning the post surface before cementation or using silane decrease the frequency of failures at the post-cement interface [29].

This study had an in vitro design. Thus, generalization of results to the clinical setting should be done with caution. Future studies are required on the effect of a combination of CHX and IA on the PBS of fiber posts to dentin. Also, the effect of conditioning agents on cements with different bonding systems should be investigated.

CONCLUSION

The present results revealed that application of IA before the application of a self-adhesive cement effectively improved the immediate (24 hours) and late (after thermocycling) PBS, and was significantly more effective than CHX.

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CONFLICT OF INTEREST STATEMENT

None declared.

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