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ORIGINAL ARTICLE/**ARTICOLO ORIGINALE**

Effect of chlorhexidine and isopropyl alcohol on immediate and delayed bond strength of glass fiber posts

Effetto della clorexidina e dell'alcool isopropilico sulla forza di adesione immediata e ritardata dei perni in fibra di vetro

KEYWORDS
Chlorhexidine, Isopropyl Alcohol, Post and Core Technique, Root Canal Irrigants, Root Canal Preparation

PAROLE CHIAVE
Clorexidina, alcool isopropilico, tecnica post e core, irriganti canalari, preparazione canalare

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Abstract

Aim: *To investigate the effects of dentinal treatment with chlorhexidine and isopropyl alcohol, alone or associated, on the bond strength and bond stability of glass fiber posts cemented with a self-adhesive resin cement.*

Materials and Methods: *Forty bovine teeth were endodontically treated and randomly distributed into four groups, according to the dentinal treatment after post space preparation: distilled water (Control); 2% chlorhexidine (CHX); isopropyl alcohol (ISO); 2% chlorhexidine + isopropyl alcohol (CHX+ISO). Glass fiber posts were cemented with a self-adhesive resin cement and after 24 h specimens were cut into six 1.5 mm-thick slices. One slice of each root third (i.e. apical, middle and coronal) was subjected to immediate push-out test and the other was stored in distilled water at 37 °C for six months for delayed push-out test. Bond strength was registered in megapascal (MPa). Failure mode was evaluated by a stereomicroscope, with 40x magnification. Data analysis was performed using Kruskal-Wallis and Friedman tests, with 5% significance level.*

Results: *No significant differences were detected between experimental groups or between root thirds in the same group in the immediate evaluation. After six months of aging, all groups showed a significant decrease in bond strength values, but ISO group presented higher bond strength than Control and CHX groups (p=0.0001). The most common type of failure for all groups was adhesive between resin cement and root dentine.*

Conclusions: *Dentinal treatment with CHX and ISO, isolated or combined, did not affect the immediate bond strength of glass fiber posts, but the ISO group presented better bond stability after six-month aging.*

Obiettivi: *studiare gli effetti del trattamento della dentina con clorexidina e alcol isopropilico, da soli o associati, sulla resistenza e sulla stabilità del legame dei perni in fibra di vetro cementati con un cemento resinoso autoadesivo.*

Metodologia: *quaranta denti di bovino sono stati trattati endodonticamente e distribuiti casualmente in quattro gruppi, in base al trattamento dentinale dopo la preparazione del post space: acqua distillata (controllo); 2% clorexidina (CHX); alcool isopropilico (ISO); Clorexidina al 2% + alcool isopropilico (CHX+ISO). I perni in fibra di vetro sono stati cementati con un cemento resinoso autoadesivo e dopo 24 ore i campioni sono stati tagliati in sei sezioni di 1,5 mm di spessore. Una porzione di ogni terzo è stata sottoposta a test di push-out e l'altra è stata conservata in acqua distillata a 37 °C per sei mesi per il test di push-up ritardato. La forza del legame è stata registrata in megapascal (MPa). Il tipo di fallimento è stato valutato da uno stereomicroscopio, con 40x di ingrandimento. L'analisi dei dati è stata eseguita utilizzando i test di Kruskal-Wallis e Friedman, con un livello di significatività del 5%.*

Risultati: *non sono state rilevate differenze significative tra i gruppi sperimentali o tra terzi dello stesso gruppo nella valutazione immediata. Dopo sei mesi di invecchiamento, tutti i gruppi hanno mostrato una significativa diminuzione dei valori di forza di legame, ma il gruppo ISO ha presentato una forza di legame superiore rispetto ai gruppi di controllo e CHX (p=0,0001). Il tipo più comune di fallimento riscontrato tra i gruppi era di tipo adesivo tra cemento resinoso e dentina radicolare.*

Conclusioni: *il trattamento dentinale con CHX e ISO, isolati o combinati, non ha influenzato la forza di legame immediata dei perni in fibra di vetro, ma il gruppo ISO ha presentato una migliore stabilità del legame dopo un invecchiamento di sei mesi.*

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Introduction

Quality of coronal restoration is an important factor for success in endodontically treated teeth. Furthermore, the rehabilitation of weakened teeth is still a challenge and there is a lack of consensus in the literature on the best way to restore them. In cases where there is total or partial loss of the dental crown, rehabilitation becomes even more complex and it may be necessary to use intraradicular posts to assist retention of restorative material (1, 2).

Glass fiber posts are an alternative to cast posts and core and have been widely used. In addition to the aesthetic advantages, this alternative is justified due to the similarity in the modulus of elasticity between the post and dentin, which allows a more homogeneous tension distribution in comparison to more rigid posts (3). Also, most of the clinical failures involving glass fiber posts occur by debonding of the cement/post assembly from the root canal walls (4). The literature demonstrates that adhesion of self-adhesive resin cements to root dentin can be affected by the moisture condition of dentin, with a partial moist being favorable to the adhesion mechanism of these cements (5). Manufacturer's instructions provide information on the proper use of these materials; however, there is no clear reference to the required dentin moisture condition or irrigation solutions to be used prior to the cementation procedures (6).

Several chemical substances, including alcohols in different concentrations, have been tested in the pre-treatment of dentin to control dentin moisture and promote effective adhesion (7, 8). The use of isopropyl alcohol (C_3H_7OH) has already shown a beneficial effect on the adhesive strength of endodontic sealers (9, 10) but has not yet been evaluated in relation to glass fiber post cementation.

NaOCl and chlorhexidine gluconate are the most used endodontic irrigants due to their antimicrobial capacity. They are also recommended as irrigating solutions prior to post cementation (11). A recent systematic review demonstrated that dentinal treatment is an important variable in the retention of fiber posts (12). Still, some studies have shown a negative effect of NaOCl on the adhesion of resin cements to intraradicular dentin when used alone (13), while chlorhexidine could enhance bonding stability through the inhibition of metalloproteinases (14).

Its beneficial effect was reported before the application of total-etch and also self-adhesive resin cements (15). Thus, the aim of this study was to evaluate the effect of dentin treatment with chlorhexidine and isopropyl alcohol, alone or associated, on the bond strength and durability of bonding of glass fiber posts cemented with a self-adhesive resin cement to the root dentin of bovine teeth, also considering root thirds. The null hypothesis tested was that different irrigating solutions would result in the same immediate or delayed bond strength of glass fiber posts, even at different root thirds.

Materials and Methods

Sample size calculation was based on previous studies (16, 17). Forty bovine incisors were selected for this study. Teeth were cleaned and stored in 0.5% chloramine T solution (Sigma-Aldrich Brasil LTDA, Duque de Caxias, RJ, Brazil) for disinfection. Crowns were removed using a slow-speed, water-cooled diamond disc (LabCut 1010; Extec Corp, Enfield, CT, EUA), and the length of the roots were standardized in 16 mm. Specimen preparation is illustrated in figure 1. A size 30 K file (Dentsply-Maillefer, Ballaigues, Switzerland) was used for canal exploration and removal of possible pulp remnants. The working length was set at 15 mm.

Chemomechanical preparation was performed with hand instrumentation using the crown-down technique. Cervical and middle thirds of root canals were enlarged with #5, #4 and #3 Gates Glidden drills (Dentsply-Maillefer, Petrópolis, RJ, Brazil), followed by instrumentation with K files in the apical third (Dentsply-Maillefer, Petrópolis, RJ, Brazil). Irrigation was per-

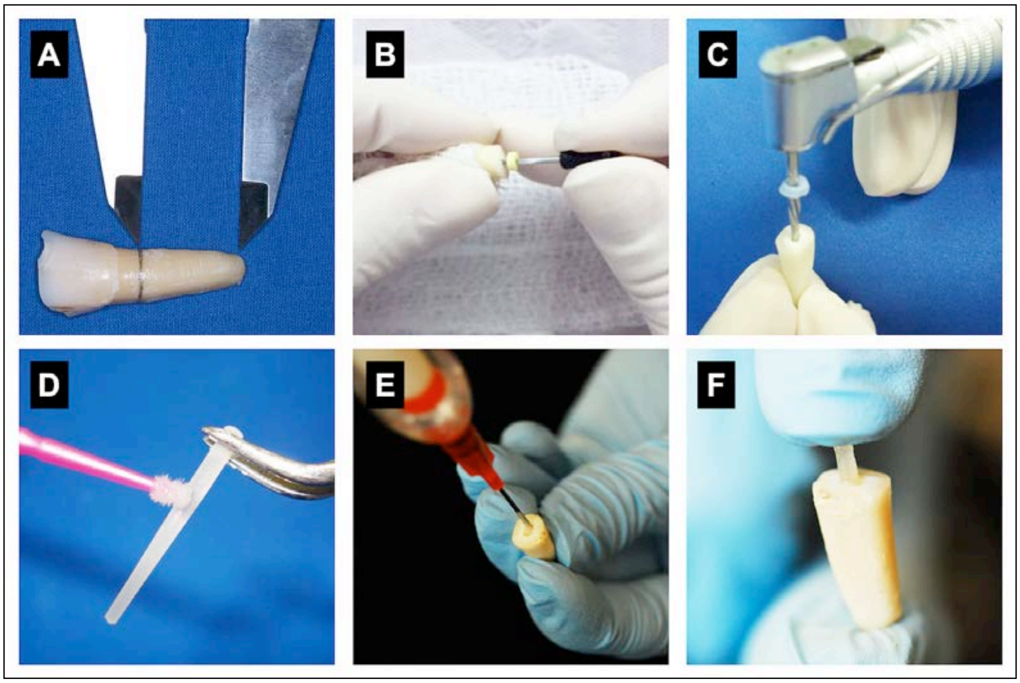


Figure 1
Specimen preparation: **(A)** Root length standardized in 16 mm; **(B)** Root canal preparation until a size 80 K-file; **(C)** Post space preparation with specific low-speed drill; **(D)** Silane application; **(E)** Resinous cement insertion with a Centrix syringe; **(F)** Cementation procedure followed by digital pressure.

formed with 2 mL of 2.5% NaOCl (Asfer, São Caetano do Sul, SP, Brazil) after the use of each instrument. The final apical size was 0.80 mm. To remove the smear layer, the root canals were irrigated with 5 mL of 17% EDTA (Asfer, São Caetano do Sul, SP, Brazil) for 5 minutes and finally flushed with 5 mL of 2.5% NaOCl. Root canals were completely dried with absorbent paper points (Tanari, Manacapuru, AM, Brazil) and filled using gutta-percha points and the epoxy resin-based endodontic sealer AH Plus (Dentsply DeTrey, Konstanz, Germany) in the lateral condensation technique. The coronal portion of the roots was temporarily sealed and stored in 100% humidity for a week.

Roots were prepared for post-placement using a low-speed drill (#2 Angelus, Londrina, PR, Brazil). A standardized 12 mm post-space was drilled in each root canal, and not less than 3 mm of apical seal was maintained. Specimens were randomly distributed into four groups (n=10) according to the irrigating solution used after post space preparation. Control group: distilled water; CHX group: 2% chlorhexidine; ISO group: isopropyl alcohol; CHX+ISO group: 2% chlorhexidine + isopropyl alcohol. Root canals were rinsed with 5 mL distilled water to remove the remaining debris, and then each group received 5 mL of the respective irrigant for one minute.

Glass fiber posts were previously cleaned with 70% ethanol and treated with silane (Angelus, Londrina, PR, Brazil). Root canals were dried with paper points and the resinous cement was inserted into the root canals with a Centrix syringe (DFL Indústria e Comércio SA, Rio de Janeiro, RJ, Brazil). Self-adhesive resin cement (RelyX U200 3M ESPE, Seefeld, Germany) was used for the cementation procedure according to manufacturer's instructions. After cementation, cervical dentin and post received a composite resin coverage and teeth were stored in distilled water at 37 °C for 24 h until bond strength specimen preparation.

Each root was horizontally cut with a slow-speed, water-cooled diamond disc (Isomet, Buehler Ltd., Lake Bluff, IL, USA) to produce two 1.5 mm-thick slices for each root third (i.e. apical, middle and coronal). The first coronal slice of 0.5 mm was excluded. Then, the six remaining slices were considered from each root canal (n=60 per group). One slice of each root third was considered for immediate push-out subgroup and the other was maintained in water storage 37 °C for six months for aged push-out subgroup (n=30).

The push-out test was performed in a universal testing machine (model DL-1000, EMIC Equipamentos e Sistemas de Ensaio Ltda., São José dos Pinhais, PR, Brazil). Root slices were positioned and then submitted to compression loading with a 1 mm-diameter metallic cylindrical plunger touching the cemented fiber-post center, in an apex-crown direction at a 1 mm/min speed with 1.000 N until dislodgment of the post. The bond strength (σ) in megapascal (MPa) was obtained as previously reported (16).
The following formula was applied:
$\sigma=F/A$
where
F=sample rupture load (N)
and
A=area of adhesion (mm^2)
To determine the adhesion area, a formula was used to calculate the lateral area of a straight circular cone with parallel bases, that is
$A=2\ \pi g\ (R1+R2)$
where
$\pi=3.14$
g=inclined height
R1=lower radius of the base
R2=largest base of the area
To determine sloping height, the following calculation was used
$g^2=(H2+[R1-R2]2)$
where
H=section height
R1 and R2 were obtained by measuring with a digital caliper (Mitutoyo, Suzano, SP, Brazil) the internal diameters of the smallest and largest base, respectively, which corresponds to the internal diameter of the root canal walls.
The failure mode was verified by using a stereomicroscope at 40x magnification (Stereo Discovery V20; Zeiss, Oberkochen, Germany). Failures were classified into five categories: 1) adhesive between post and resin cement (no resin cement visible around the post); 2) mixed, with resin cement covering 0%-50% of the post surface; 3) mixed, with resin cement covering between 50% and 100% of the post surface; 4) adhesive between resin cement and root dentin (post enveloped by resin cement); and 5) cohesive within the resin cement.
After push-out test, the mean values of bond strength were calculated for each root third (cervical, middle and apical) and for each tooth (average of three thirds) within each experimental group. Data were analyzed using the statistical software BioEstat 5.0 (CNPq, Brasília, DF, Brazil). For comparison between groups, the Kruskal-Wallis test was applied and for specimens of different root thirds, in the same group, the Friedman test was used. The comparison between immediate and after six months aged groups was performed with the Wilcoxon test. The significance level was set at 5% for all statistical analyses.

Results

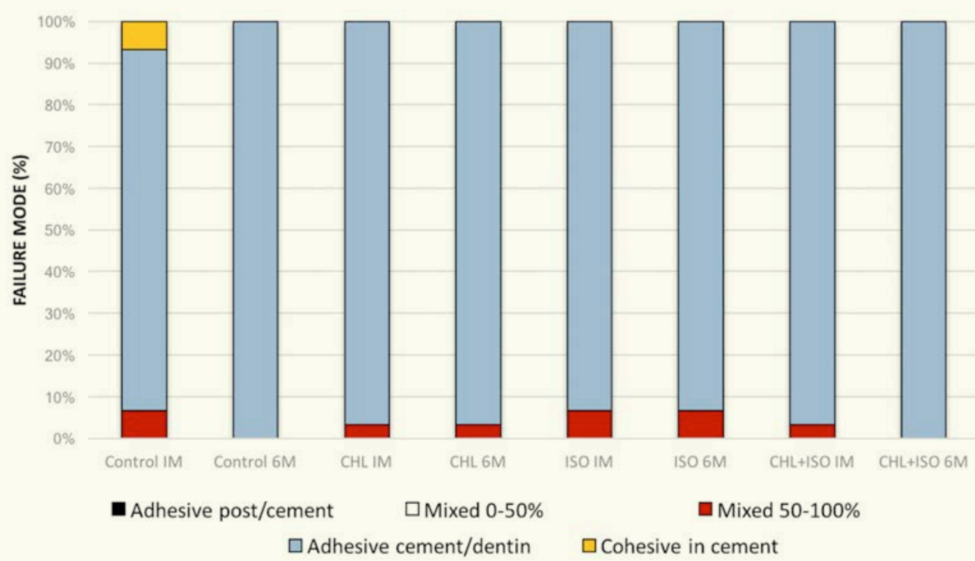
Mean bond strength and respective standard deviation are presented in Table 1. In the immediate evaluation, similar bond strength values were found for all dentinal

Table 1
Bond strength means and standard deviations (MPa) obtained in each experimental group and condition (n=30)

Groups	Irrigants	Immediate (MPa)	6-month aging (MPa)
Control	Distilled Water	2.57 ± 2.00^{Aa}	1.37 ± 0.93^{Ba}
CHX	2% Chlorhexidine	3.27 ± 2.36^{Aa}	1.35 ± 1.01^{Ba}
ISO	Isopropyl alcohol	4.04 ± 2.87^{Aa}	2.20 ± 0.91^{Bb}
CHX+ISO	2% Chlorhexidine + isopropyl alcohol	3.59 ± 2.28^{Aa}	1.90 ± 0.89^{Bab}

Means followed by different uppercase letters (row) or lowercase letters (column) are significantly different (p<0.05).

Figure 2
Failure mode distribution in the experimental groups and conditions. CHX: 2% Chlorhexidine; CHX+ISO: 2% Chlorhexidine + isopropyl alcohol; ISO: isopropyl alcohol; IM: immediate; 6M: six-month aging.



The five possible categories of failure mode in the chart legend are the most found in the literature. However, two of these categories were not observed in our samples.

treatments. However, after six months of aging, ISO group presented higher bond strength than Control and CHX groups (p=0.0001). In the intragroup comparisons, all dentinal treatments showed a significant decrease in bond strength values from immediate to six-month evaluation. The comparison between root thirds did not show statistical significant differences in any group in the immediate analysis: Control (p=1.00); CHX (p=0.90); ISO (p=0.27); CHX+ISO (p=0.67); and in the delayed analysis: Control (p=0.90); CHX (p=0.06); ISO (p=0.74); CHX+ISO (p=0.20). Figure 2 shows the failure mode distribution in the tested groups, being adhesive failures between root canal and resin cement (figure 3) the most frequent pattern obtained for all groups.

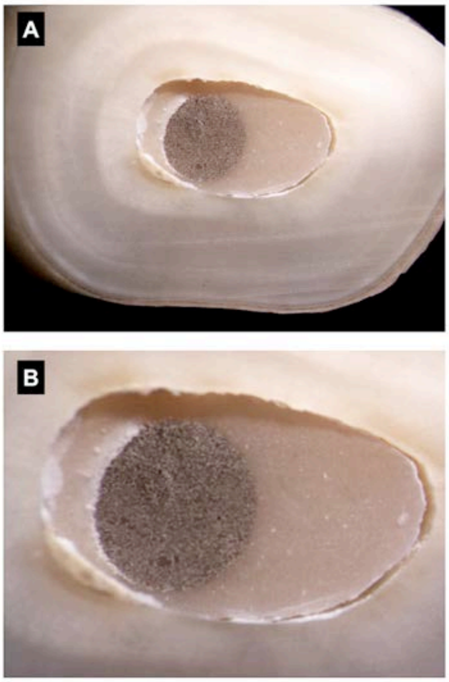


Figure 3
Stereomicroscope images illustrating an adhesive failure between root canal and resin cement at 15x **(A)** and 40x magnification **(B)**.

Discussion

There is a lack of consensus in the literature about the solution used prior to glass fiber post cementation. Scientifically based clinical protocols with standardization of these solutions for each type of cement are necessary to increase the bond strength of posts and consequently the longevity of restorations. The use of isopropyl alcohol was expected to control the excess water of the dentinal tubules. This has not happened immediately, although the bond strength values were slightly higher. However, isopropyl alcohol performed better than control and chlorhexidine groups after six months of aging. Also, all groups presented a significant decrease in bond strength values after the aging process. Thus, the null hypothesis was rejected.

Dias et al. (9) proposed a protocol to dry the canal with isopropyl alcohol and assessed its influence on the bond strength of an epoxy resin-based endodontic sealer prior to root canal filling. In their study, the use of this substance as an irrigating solution promoted higher bond values and greater penetration of the sealer in the dentinal tubules when compared to groups dried with paper points, corroborating our findings. Despite this, the direct comparison between endodontic sealer and self-adhesive resin cement is not possible, since the formulation and role played by these materials are different. Thus, to our knowledge, the present study is the first to use isopropyl alcohol in the intraradicular dentin cleaning protocol prior to glass fiber post cementation.

When a suitable control of dentin moisture is obtained, greater penetration of resin cement on dentinal walls should be expected (18). This way, the higher bond strength values of isopropyl alcohol group after aging could be explained due to its capacity of promoting a smaller water replacement of the dentinal tubules, increasing the wettability of the dentin and allowing more effective conversion of resin monomers (8).

Irrigation of post space using 2% chlorhexidine was proposed due to its beneficial effect prior to the use of total-etch and self-adhesive resin cements (15). However, its application did not alter the immediate bond strength when compared to the Control group in this study, which agrees with other studies using total-etch and self-adhesive resin cements (7, 17, 19, 20). After six months of aging, bond strength stability was not preserved in chlorhexidine groups (CHX and CHX+ISO). However, as reported in a published systematic review (21), there is high heterogeneity among studies where water-storage aging process was applied and the lack of bond strength stability could be addressed to the aging method.

Also, longer times of aging have already been evaluated and the results did not support bond strength stability when chlorhexidine was used as pre-treatment for post cementation, even after one year of aging in artificial saliva. Other authors even found a negative effect when using chlorhexidine prior to a self-adhesive resin cement (11, 22, 23).

These inconsistent findings may be explained by differences in the methodology, where a simple additional rinse with water after using the irrigating solution could remove a possible residual effect of the latter. Even knowing that self-adhesive resin cements adhere to tooth surface trough a chemical interaction with hydroxyapatite, it is important to understand that these methodological differences could be the main reason for discrepancies in the literature.

In the present study, the comparison between root thirds did not show statistical differences in any group. The explanation for this homogeneous behavior along the entire root canal length would be its dual-cure nature, which allows polymerization where the light does not reach (24). Some authors reported that RelyX Unicem (3M ESPE, Seefeld, Germany), the first self-adhesive resin cement released on the market, has behaved homogeneously along the root canal (25), as found in our study with U200. Another explanation would be the use of the Centrix syringe, which may have contributed to an adequate distribution of the cement on the apical root third (26).

The adhesive failure between resin cement and root dentin was the most common failure mode in all groups, as reported in past studies (27). They have shown that the bond strength in the cement/dentin interface is lower than in the cement/post assembly. Moreover, post cleaning and its pre-treatment with silane may have reduced possible failures within the cement/post interface (28).

Although well delineated, this laboratory study can only estimate an increase or reduction in bond strength performance in a period of six months, which should be complemented by long-term in vitro studies and further confirmed by clinical trials, to assess the clinical behavior of such irrigating solutions before adhesive cementation of glass fiber posts.

Conclusions

Despite the limitations of this in vitro study, the results confirm that regardless of the dentinal treatment applied, immediate bond strength values were not enhanced. However, considering the six-month aging period, the application of isopropyl alcohol as irrigant agent prior to glass fiber post cementation presented better bond strength stability.

Clinical Relevance

Dentinal treatment is an important variable in the retention of fiber posts. This study showed that isopropyl alcohol alone promoted better bond stability after six months when compared to chlorhexidine, alone or associated with isopropyl alcohol.

Conflict of Interest

All authors declare that they have no conflicts of interest. In addition, all authors have read and approved the manuscript as submitted, are qualified for authorship, believe the submission represents honest work and take full responsibility for the reported findings.

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