The impact of endodontic irrigating solutions on the push-out shear bond strength of glass fiber posts luted with resin cements

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Resin-based restorative materials, widely used to cement posts, may be influenced by irrigants used during endodontic chemical-mechanical preparation. This study evaluated the impact of endodontic irrigating solutions and adhesive cement systems on the push-out shear bond strength of glass fiber posts to root dentin. Ninety-six bovine incisors were divided into 12 groups (4 irrigants × 3 resin cements; n = 8). Prepared canals were irrigated with saline solution, 2.5% sodium hypochlorite (NaOCl), 5.25% NaOCl, or 2% chlorhexidine gel, and posts were cemented with RelyX ARC, Panavia F, or RelyX U100. The bond strength was evaluated by means of the push-out test, and results were subjected to analysis of variance. The mean bond strength observed for the combination of 5.25% NaOCl irrigant and RelyX U100 cement was significantly lower (8.82 MPa) than the values found for the other groups ($P < 0.05$). The other combinations of irrigating solution and resin cement had no adverse effect on the bond strength of the glass fiber posts to dentin.

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The remaining coronal structure of endodontically treated teeth often is inadequate to retain restorative materials, making a post necessary to provide the required retention.[1,2] Glass fiber posts are indicated for this purpose, since they have a modulus of elasticity similar to that of dentin, affording a more balanced distribution of masticatory forces.[3,4]

Resin cements are increasingly used to lute posts in endodontically treated teeth. However, adhesive failures have been reported in connection with these cements.[1] Several factors may be associated with these failures, including the type of agent used to condition the substrate, the polymerization stress of the resin cement, the chemical and physical properties of the posts, and the effects on dentin collagen of the irrigating solutions used during endodontic preparation.[5,6]

The irrigating substances most commonly used during endodontic preparation are sodium hypochlorite (NaOCl) and chlorhexidine (CHX). Studies have reported that NaOCl may adversely affect the adhesion process, reducing bond strength between the post and the root.[7,8] The underlying explanation is that root dentin is adversely affected by the proteolytic action of NaOCl.[9] On the other hand, a positive effect of CHX on adhesion to dentin has been associated with its inhibiting effect on metalloproteinases.[10] Nevertheless, there is little information available on the interactional effect between irrigating solution and resin cement on the bond strength of glass fiber posts.

The aim of this study was to analyze the effect of different endodontic irrigants (saline solution, 2.5% NaOCl, 5.25% NaOCl, or 2% CHX gel) on the bond strength to dentin of glass fiber posts luted in the root canal of bovine teeth using various resin cement systems (RelyX ARC [RelyX], Panavia F [PaF], or RelyX U100 [U100]).

Materials and methods

Ninety-six recently extracted mandibular bovine incisors with mature apices and similar size, form, and canal orifice diameter (approximately 1.0 mm) were stored in a 0.1% thymol solution (Fórmula & Ação) before the experiment. The roots were randomly divided into 12 groups (n = 8) according to the irrigant used during instrumentation and the system employed for cementing the posts (Tables 1 and 2). A single experienced operator conducted the experiment.

Endodontic preparation of the specimens

Each tooth was decoronated with a double-faced diamond disc (KG Sorensen) so that the specimens were standardized at 17 mm in length. The root canals were prepared to 1 mm short of the apex with a modified step-back technique.[11] K-type hand files (DENTSPLY Maillefer) were used for apical preparation up to file No. 60 and programmed 1-mm step-back with files No. 70 and 80. Next, No. 6, 5, and 4 Gates-Glidden drills (DENTSPLY Maillefer) were used for cervical flaring of the canals.

During the entire preparation procedure, each root was irrigated with 20 mL of the irrigant designated for each experimental group, with the exception of the groups irrigated with 2% CHX, which received an application of 5 mL of CHX gel and subsequent irrigation with 20 mL of saline solution.

Once the instrumentation was completed, the specimens from each group were irrigated for 3 minutes with 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) solution (Fórmula & Ação) applied with ultrasonic vibration (frequency of 30,000 Hz) from an ET-20 tip (Satelec, Acteon North America). A second irrigation was performed with 5 mL of the irrigating solution studied, except in the CHX groups, in which the second irrigation was performed with 1 mL of 2% CHX followed by 5 mL of saline solution. The canals were dried with absorbent paper points (DENTSPLY International)

Table 1. Materials used to cement glass fiber posts for push-out shear bond strength testing.

Material	Manufacturer	Composition	Lot
Scotchbond Multi-Purpose (SMP)	3M ESPE	Primer: water, polyalkenoic acid copolymer, HEMA	6BC
		Adhesive: Bis-GMA, HEMA, photoinitiator	6PL
RelyX ARC (RelyX)	3M ESPE	Paste A: Bis-GMA, TEGDMA, zirconia silica filler, photoinitiators, amine, pigments	N47405
		Paste B: Bis-GMA, TEGDMA, benzoic peroxide, zirconia silica filler	
ED Primer (EDP)	Kuraray America, Inc	Primer A: HEMA, MDP, 5-NMSA, diethanol-*p*-toluidine, water	00207E
		Primer B: 5-NMSA, T-isopropylic benzenic sodium sulfinate, diethanol-*p*-toluidine, water	00086E
Panavia F (PaF)	Kuraray America, Inc	Paste A: MDP, hydrophobic dimethacrylate, hydrophilic dimethacrylate, benzoyl peroxide, camphoroquinone, colloidal silica	00245F
		Paste B: sodium fluoride, hydrophobic dimethacrylate, hydrophilic dimethacrylate, diethanol-*p*-toluidine, T-isopropylic benzenic sodium sulfinate, barium glass, titanium dioxide, colloidal silica	00024B
RelyX U100 (U100)	3M ESPE	Paste A: glass powder, silica, calcium hydroxide, pigment, substituted pyrimidine, peroxy compound, initiator	405969
		Paste B: methacrylates, phosphoric esters, dimethacrylates, acetate, stabilizers, self-cure initiators, light-cure initiators	405969

Abbreviations: Bis-GMA, bisphenol A glycidyl methacrylate; HEMA, 2-hydroxyethyl methacrylate; MDP, 10-methacryloyloxydecyl dihydrogen phosphate; 5-NMSA, N-methacryloyl-5-aminosalicylic acid; TEGDMA, triethylene glycol dimethacrylate.

Table 2. Push-out test groups of glass fiber posts cemented in bovine teeth (n = 8).

Group	Irrigant	Adhesive	Cement
1	SS	SMP	RelyX
2	2.5% NaOCl	SMP	RelyX
3	5.25% NaOCl	SMP	RelyX
4	2% CHX	SMP	RelyX
5	SS	EDP	PaF
6	2.5% NaOCl	EDP	PaF
7	5.25% NaOCl	EDP	PaF
8	2% CHX	EDP	PaF
9	SS	NA	U100
10	2.5% NaOCl	NA	U100
11	5.25% NaOCl	NA	U100
12	2% CHX	NA	U100

Abbreviations: CHX, chlorhexidine; EDP, ED Primer; NA, not applicable; NaOCl, sodium hypochlorite; PaF, Panavia F; RelyX, RelyX ARC; SMP, Scotchbond Multi-Purpose; SS, saline solution; U100, RelyX U100.

and filled with gutta percha cones (DENTSPLY International) and AH Plus endodontic sealer (DENTSPLY Maillefer), using the down-packing phase of the continuous wave condensation technique.[12]

After the canal was obturated, cervical removal of the filling material was performed with a No. 5 Largo drill (WL 12 mm, DENTSPLY Maillefer) to create space for the post used in all the groups: a glass fiber post with parallel form and a conical tip (Reforpost No. 3, Angelus Indústria de Produtos Odontológicos S/A). Finally, the canals were irrigated for 1 minute with 1.0 mL of saline solution to remove debris and sealer residue and dried with absorbent paper points.

Preparation of the glass fiber posts

The posts were cleaned by immersion in 70% alcohol (Fórmula & Acão) for 1 minute, covered with 37% phosphoric acid for 15 seconds, and washed with water. In the ED Primer (EDP) + PaF groups, a silanization agent (Silano, Angelus Indústria de Produtos Odontológicos S/A) was applied for 1 minute with a microbrush. In the Scotchbond Multi-Purpose (SMP) + RelyX and SMP + U100 groups, Porcelain Primer (3M ESPE) was used in accordance with the manufacturer's instructions.

Preparation of root dentin and post cementation

The surface of the intraradicular dentin was prepared according to the instructions provided by the manufacturer of each material.

Groups 1-4 (SMP + RelyX)

The canal was conditioned with 37% phosphoric acid for 15 seconds, washed with water for 15 seconds, and dried with absorbent paper points. The activator was applied with a paper point, and the excess was removed gently with another paper point. Next, the primer was applied in the same way, and the catalyst was applied to the post and the dentin. The RelyX ARC cement was spatulated according to the manufacturer's instructions and inserted into the canal through a Centrix syringe with a needle-type point (Centrix, Inc). The post was positioned in the root canal up to the total length of the post space, and excess material was removed with a microbrush. The cement was then photoactivated cervically for 80 seconds (40 seconds buccally and 40 seconds lingually) with 1200 mW/cm^2 of power (Radii-Cal, SDI [North America], Inc).

Groups 5-8 (EDP + PaF)

One drop of ED Primer A was mixed with 1 drop of ED Primer B, and the resulting mixture was actively applied with a microbrush to the dentin of the post space for 20 seconds. Excess material was removed with an absorbent paper point. The PaF cement base and catalyst pastes were spatulated, and the resulting mix was introduced to the root canal through a Centrix syringe with a needle-type point. The positioning of the post, removal of excess material, and photoactivation of the cement were performed as described for groups 1-4.

Groups 9-12 (U100)

The cement was spatulated and inserted in the canal through a Centrix syringe with a needle-type point. The positioning of the post, removal of excess material, and photoactivation of the cement were performed as described for groups 1-4.

Push-out shear test

All the specimens were stored in an environment with 100% humidity at 37°C for 7 days before the tests were conducted.

Each root was sectioned transversally with a double-faced diamond disc (Arbor, Extec Corp) mounted on a precision cutter (IsoMet 1000, Buehler), used at low speed and under cooling, to obtain 1-mm-thick sections of each root third (cervical, middle, and apical).The specimens obtained were identified and kept in distilled water for 24 hours at 37°C in containers that did not allow the passage of light.

An axial compressive load of 100 kN (EMIC D 500 universal testing machine, EMIC Equipamentos e Sistemas de Ensaio, Ltda) was applied to the apical surface of the post section at a speed of 1.0 mm/min until the cross section of the post became separated from its respective root section. The kilogram-force values applied until separation were divided by the root canal area to convert results to megapascals.

Statistical analysis

The values obtained in the push-out shear test were tabulated and statistically analyzed by analysis of variance and a Tukey test for multiple comparisons ($P < 0.05$). SAS software (release 9.2; SAS Institute, Inc) was used for the statistical analysis.

Results

The bond strength values obtained for the experimental groups are presented in Table 3. The bond strength between intraradicular dentin and resin cement was significantly lower (8.82 MPa) in group 11 (5.25% NaOCl + U100) than in the other groups tested ($P < 0.05$).

Table 3. Mean (SD) push-out shear bond strengths (in MPa) of glass fiber posts, according to irrigant and cement.

	Irrigant			
Cement	CHX	2.5% NaOCl	5.25% NaOCl	SS
RelyX	12.19 (7.87)[Aa]	12.61 (7.85)[Aa]	13.92 (4.77)[Aa]	9.47 (9.86)[Aa]
PaF	11.11 (5.51)[Aa]	12.09 (5.02)[Aa]	9.47 (4.46)[Aa]	10.87 (5.57)[Aa]
U100	13.36 (8.34)[Aa]	15.29 (6.39)[Aa]	8.82 (4.12)[Bb]	14.00 (6.82)[Aa]

Abbreviations: CHX, chlorhexidine; NaOCl, sodium hypochlorite; PaF, Panavia F; RelyX, RelyX ARC; SS, saline solution; U100, RelyX U100.

Values with different uppercase letters per row and lowercase letters per column are significantly different ($P < 0.05$).

Discussion

The correlation between adequate coronal restoration and endodontic success has been stressed in various studies.[13,14] It is therefore necessary to undertake a continuous assessment of recently developed restorative materials, particularly those recommended for dental restoration after endodontic treatment.[15] Intracanal morphology and the specific characteristics of root dentin have adverse effects on adhesion and may represent factors limiting the success of the final restoration.[16] Another potentially adverse factor is the influence of the irrigating solution used in the chemical-mechanical preparation of the root canal on the bond strength of the restorative material.

Microtensile and push-out tests have been used to assess adhesion between intraradicular dentin and adhesive materials. Findings in the literature indicate that push-out tests are more efficient and reliable than the microtensile technique and result in fewer specimen losses.[17] In addition, push-out tests distribute stress more homogenously and produce less variability in the mechanical test results; therefore, they are recommended for determining the bond strength of fiber posts to root dentin.[18]

Bovine teeth have been used in research because they are easier to obtain, allowing researchers to select specimens that have a more standardized anatomy.[19] Moreover, studies have shown that human and bovine teeth have similar histologic and morphologic properties.[19,20]

Although NaOCl is a widely used endodontic irrigant, several studies have reported a strong tendency of this material to modify the structure of intraradicular dentin, which may adversely influence dentin adhesion of the materials used after endodontic preparation.[21,22]

The present study revealed that NaOCl in its more concentrated form (5.25%) had a significant adverse impact on the bond of fiber posts luted with RelyX U100 self-adhesive resin cement to dentin. These results agree with those obtained in a prior study.[23] Highly concentrated NaOCl acts as an oxidizing agent and may lead to the formation of an oxygen-rich layer on the surface of the dentin and to degradation of dentin organic matrix, possibly leading to a reduction in bond strength between dentin and resin cement.[7,23-25] In addition, residual 5.25% NaOCl solution may diffuse into dentin and adversely affect monomer polymerization, thus reducing bond strength.[23]

Another factor that could account for the lower bond strength obtained in group 11 is related to the properties of the resin cement used. According to the manufacturer, the adhesion provided by RelyX U100 is related to 2 factors: the ability of acidic monomers to hybridize dentin and the chemical interaction between cement and hydroxyapatite.[26] Although Bitter et al stated that the chemical interaction between self-adhesive resin cement and hydroxyapatite is effective within the canal and highlighted its ability to hybridize dentin as a factor favoring adhesion, the relatively high viscosity of U100, combined with its low demineralizing ability, may have contributed to low monomer infiltration into dentin, thereby reducing micromechanical retention.[26,27]

When the other irrigants—2.5% NaOCl, CHX, or saline solution—were combined with any of the cements tested, and when 5.25% NaOCl was combined with PaF or RelyX, there was no statistically significant reduction in bond strength. Similar findings were observed in a study conducted by Muniz & Mathias, who stressed that NaOCl in lower concentrations (2.5%) does not interfere with the bonding ability of resin materials.[28]

Owing to its antimicrobial action, 2% chlorhexidine is also recommended as an intracanal irrigant.[29] No interference by CHX with dentin adhesion was observed in the present study. The push-out shear strength values observed for the groups using CHX were practically identical to those of the other groups tested, with the exception of group 11. Similar findings were reported by White et al.[29]

Owing to its widespread use in endodontics, EDTA was used before final irrigation in all the groups tested. According to Lui et al, final irrigation with EDTA combined with ultrasonic vibration is an efficient procedure for cleaning root canal systems because it removes the smear layer from canal walls.[30] Current scientific evidence shows that 3 minutes' exposure to EDTA is sufficient to dissolve the inorganic particles in the smear layer without affecting the mechanical properties of dentin.[21] Noncutting ultrasonic tips were employed to help dislodge debris from the root canal surface and permit more direct and efficient EDTA action in the deeper recesses of the root canal system.[31]

The posts used in this study underwent a silanization process before cementation. This process was performed for the purpose of improving the chemical and micromechanical retention between post and resin compounds.[32] The role of silanization is still controversial. Some investigators, such as Wrbas et al, stated that this pretreatment has no clinical relevance, while others have reported that silane has a positive effect on the adhesion process.[17,32,33]

Another mechanism that may be involved in the present results is the dual polymerization reaction of the RelyX U100 cement. As part of the reaction, the calcium ions in the hydroxyapatite act as electron receptors, promoting a chemical bond between the acidic monomers and the hard tissues and resulting in the formation of calcium phosphates.[26] These links, however, have low energy. This factor, together with the surface oxidation caused by hypochlorite and the diffusion of byproducts into dentin, may have inhibited polymerization at the interface between dentin and cement, resulting in the lower push-out shear bond strength values observed for the 5.25% NaOCl + U100 group in the present study.

In addition to the influence of endodontic irrigation on the adhesion process, other factors may also influence bond strength, including the composition and structure of intracanal dentin in different thirds of the canal, polymerization of the adhesive and resin, number of steps required for the application of the adhesive system, quality of the materials, ambient humidity, and temperature. However, in light of the present study, some factors observed in the results require greater attention than the aforementioned, such as the techniques employed for bonding fiber glass posts, including comparison of dentin bonding with total-etch, self-etching, and self-adhesive cement systems. In the present study, only the self-adhesive cement was influenced by 5.25% NaOCl, which indicated that the different protocols for adhesive application, in the form of bonding with the dentin, did not influence the results. Therefore, only the group to which a greater concentration of NaOCl irrigant was applied exhibited some influence. Moreover, the design of the present study sought to minimize the variables (keeping in mind the protocols indicated by manufacturers), the teeth were evaluated before the study to ensure selection of teeth with similar anatomy, and a single operator with high levels of experience in the techniques used in this study was employed.[26]

Since the combination of 5.25% NaOCl with the other tested resin cements did not seem to interfere with bond strength, future studies are warranted to investigate the possible mechanisms of interaction between endodontic irrigants and RelyX U100, which could be responsible for the lower bond strength to dentin observed.

Conclusion

The combination of intracanal irrigation with 5.25% NaOCl and RelyX U100 cement had a negative impact on dentin bond strength. The other combinations of irrigating solution and resin cement had no adverse effect on the bond strength of glass fiber posts to dentin.

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