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Evaluation of The Cleaning Protocol of Post Space on Bond Strength of Glass Fiber Posts

Evaluación del Protocolo de Limpieza del Conducto Radicular sobre la Resistencia de la Unión de Postes de Fibra de Vidrio

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ABSTRACT: This study aimed to compare the effect of four irrigation solutions for post space cleaning on the bond strength between glass fiber post and root dentine. Forty bovine roots were root-filled and randomly divided into four groups (n=10), according to the irrigation solution: CG (Control Group): saline solution; SH (Sodium Hypochlorite Group); CLX (Chlorhexidine group) and EDTA (ethylenediaminetetraacetic acid group). Specimens were submitted to mechanical aging and push-out test. Statistical analysis (ANOVA two-way and Tukey test; $p<0.05$) was performed. A stereomicroscope was used for failure mode classification. EDTA showed higher bond strength values, differing statistically from SH and CG ($p<0.05$). Adhesive failure between dentin and resinous cement was predominant, followed by mixed failures. SEM images showed pronounced smear layer removal in the EDTA group. 17 % EDTA was better than other solutions for cleaning of post space when using glass fiber posts.

KEY WORDS: dentin-bonding agents, EDTA, materials testing, glass fiber post, smear layer.

INTRODUCTION

Glass fiber posts are an effective alternative for restoration of root-filled teeth, since requiring relatively simple technique, demand less clinical time and may be luted in a single session. Combined with a resinous system, they present biomechanical properties that resemble the dentin structure and favor a stress distribution, minimizing the risks of root fracture. Further, they require a conservative preparation of dental structure, does not suffer corrosion, and present a good aesthetic result (Ferrari *et al*., 2007; Junqueira *et al*., 2017).

The use of a suitable post system, providing bond strength with the cement, is one of the greatest challenges of restorative dentistry, and post retention plays a crucial role in the rehabilitation process. The wide variety of products for fiber post luting available, along with the intrinsic difficulties of bonding inside the root canal, may difficult the selection of an appropriate luting strategy (Bitter *et al*., 2012; Renovato *et al*., 2013).

Bonding of glass fiber posts to the root dentin can be compromised by the presence of remnants of filling material, not removed during the post space preparation (Perdigão *et al*., 2007). Therefore, it is important to investigate cleaning protocols to effectively remove such remnants, to promote adequate luting, and to ensure good adhesion (Zhang *et al*., 2008; Bitter *et al*.; Bohrer *et al*., 2018).

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Although previous studies have demonstrated good behavior on the values of bond strength for teeth restored with glass fiber posts (Ferrari *et al*., 2000; Monticelli *et al*., 2003; Zicari *et al*., 2008; Kul *et al*., 2016), little is discussed about the behavior of this set concerning root canal cleaning protocols prior to cementation and its influence on bond strength values between the fiberglass post and root dentin. Thus, the aim in this ex vivo study was to evaluate the bond strength of glass fiber posts after cleaning post space with different irrigation solutions.

MATERIAL AND METHOD

Forty bovine incisors were selected and decoronated under water refrigeration, resulting in roots of 18 mm in length. The roots whose canal diameter was larger than that of the 2 mm posts used in the study (White Post DC #2; FGM, Joinvile, SC, Brazil) were discarded and replaced by others, meeting this criterion (Junqueira *et al*.). The amount of dentin around the canal was also measured with the same digital caliper to ensure a 2 mm thickness on the buccal, lingual, mesial, and distal aspects. Such measurements ensured the inclusion of similar roots in the study.

The canals were prepared using Gates-Glidden drills and hand files (Dentsply/Maillefer, Petrópolis, RJ, Brazil). As irrigant, a 1 % sodium hypochlorite solution (5 mL) was used, and the root filling was performed with gutta-percha cones and AH Plus sealer (Dentsply/Maillefer) by lateral condensation. A temporary restorative material was used to seal the access cavities (Cavit G, 3M ESPE). For periodontal ligament simulation, the roots were coated of polyether (3M/ESPE; Impregum Soft, Sumaré, SP, Brazil) around the root surface, to a depth of 2 mm below the cemento-enamel junction, producing a 0.3 mm thick wax layer. Then, they were embedded in a PVC tube containing polyurethane (F16 – Axson, Cercy, France) to simulate alveolar bone (Junqueira *et al*.). After 7 days of storage at 37°C and in 100 % humidity, the temporary restoration was removed. The post spacepreparation (12 mm in depth) was performed with the bur recommended by the manufacturer (White Post DC #2, FGM, Joinvile, SC, Brazil) in all roots.

The specimens were randomly divided into four groups, according to the solution used for cleaning of post space: CG (control group) – Saline solution; SH – 2.5 % Sodium hypochlorite; CLX – 2 % Chlorhexidine; EDTA – 17 % EDTA.

In all groups, 10 mL of each solution was dispensed for 60 seconds with a syringe (Injex - Produtos Cirúrgicos, São Paulo, SP, Brazil). Then, the contents were removed with an endodontic aspiration cannula (CapillaryTips - Ultradent, USA). Finally, post spaces were washed with 5 mL of distilled water and dried with absorbent paper tips (Dentsply/Maillefer)

The glass fiber posts (White Post DC # 2, FGM, Joinvile, SC, Brazil) were treated with 37 % phosphoric acid (15 s), washed with distilled water (60 s), and dried with air (15 s). Then silane-bonding agent (Prosil, FGM) was applied throughout the surface, the posts were left on a glass plate for four minutes and dried with air (15 s).

For dentin surface treatment, a two-step total acid etching adhesive system was used. Initially, the canal was conditioned with 37 % phosphoric acid (Condac, FGM) for 15 s, washed abundantly with distilled water (60 s), and dried with absorbent paper points. Then, the dentin adhesive (Ambar, FGM) was applied using a microbrush (Cavibrush, FGM), its excess was removed with absorbent paper and light-cured for 30 s (Radii Cal, SDI, Melbourne, Victoria, Australia). A conventional dual resinous cement (Allcem, FGM) was used for luting of all posts, following the manufacturer's recommendations: after cement insertion with a Lentulo drill (Destpsly/Maillefer), the post was inserted and kept under compression for 60 s to promote overflow of the excess and prevent bubble formation. The excess was removed, and the cement was light-cured for 40 s (Radii Cal, SDI) by the occlusal surface of the post.

For the coronal reconstruction, the dentin was conditioned for 15 s with 37 % phosphoric acid (Condac 37, FGM), washed with water, and dried with absorbent paper. The dentin adhesive (Ambar, FGM) was applied and light-cured for 30 s (RadiiCal, SDI). Direct composite resin (Opallis, FGM) was inserted in standardized silicone matrices, previously obtained from a model of human maxillary canine (8 mm in height), and placed over the cervical margin of the root. Then, light activation (Radii-cal, SDI) was performed for 20 s per surface (Junqueira *et al*.). Ultrafine diamond bur (3118F; KG Sorensen), abrasive paper discs (Sof-Lex; 3M ESPE, St Paul, MN, USA) and silicone tips (Poligloss, Microdont, São Paulo, SP, Brazil) were used for finishing (Bergoli *et al*., 2014).

For mechanical aging, the specimens were placed in a mechanical cycler (ER model 11000NG; Erios, São Paulo, SP, Brazil) and subjected to a load of 90 N with 4 Hz frequency, totaling 1 200 000 cycles. The load application piston had spherical tip 4 mm in diameter and was placed on the lingual surface of the crowns 3 mm from the incisal edge. During aging, all the specimens were kept immersed in water at 37 °C.

After cycling, the roots were sectioned horizontally with a water-cooled, low-speed diamond disk (Isomet 1000; Buehler Ltd, Lake Bluff, USA). Six slices were obtained (2 coronal, 2 middle and 2 apical), and each slice was approximately 1 mm thick. A push-out test was applied to slices 2, 4, and 6 at 0.5 mm min-1 with a 0.8 mm diameter metallic plunger from the apical to the coronal direction until failure. The push-out bond strength was measured with a universal testing machine (EMIC DL 2000, São José dos Pinhais, PR, Brazil). The bond strength was calculated in MPa by dividing the load at failure (N) by the area of the bonded interface. The area of the bonded interface was calculated as follows: A = 2pr 9 h, where A is the area of the bonded interface, p = 3.14, r is the radius of the post segment (mm) and his the thickness (mm) of the post segment (Kul *et al*.; Renovato *et al*.).

Table I. Mean (± SD) of the bond strength values according to the irrigation solution.

Groups (n = 10)	Mean (±SD) (MPa)†
CG (saline solution)	4.80 (1.21) [a]
SH (2.5 % Sodium hypochlorite)	4.69 (1.16) [a]
CLX (2 % Chlorhexidine)	5.78 (1.13) [ab]
EDTA (17 % EDTA)	7.07 (1.58) [b]

† Different letters mean statistical difference between groups (p <0.05).

To determine failure mode, all specimens were air-dried and analyzed in a stereomicroscope (30X; Discovery V20 – Zeiss, Munich, Germany). The failure mode was classified according to Renovato *et al*., as follows: (i) adhesive between resinous cement and root dentin; (ii) adhesive between the post and resinous cement; (iii) mixed between post, resinous cement, and root dentin; (iv) cohesive in dentin; (v) cohesive in the post and (vi) cohesive in cement.

The bond strength values were submitted to one-way ANOVA and post hoc Tukey's test to evaluate statistical differences among the experimental groups. The frequency of failure modes was compared using chi-square tests. The significance level was 5 %.

One extra root of each group was instrumented and filled. The post space was prepared and irrigated with respective solutions. Then, the roots were sectioned in mesiodistal direction, dehydrated in alcohol, and metalized for qualitative scanning electron microscopy (SEM) observation.

RESULTS

Statistically significant results ($p<0.05$) were found between the different solutions used to the post space cleaning (Table I), where EDTA presented higher bond strength values when compared to CG and SH. There was no significant difference ($p>0.05$) between the values of bond strength among the regions (coronal, middle, and apical) of the root (Table II).

Table II. Mean (± SD) of bond strength values according to root canal regions.

Region	Mean (±SD) (MPa)†			
	CG	SH	CLX	EDTA
Coronal	4.66 (1.20) [a]	3.66 (1.68) [a]	5.42 (1.15) [a]	7.88 (1.28) [a]
Middle	3.82 (1.90) [a]	5.14 (1.39) [a]	6.57 (1.00) [a]	6.90 (1.01) [a]
Apical	5.72 (1.28) [a]	5.23 (1.28) [a]	5.51 (1.06) [a]	6.51 (1.56) [a]

† Different letters mean statistical difference between different root regions (p <0.05).

Table III. Frequency of failure mode between groups.

Groups	Failure mode					
	(i)	(ii)	(iii)	(iv)	(v)	(vi)
CG	25 %	25 %	30 %	6,6 %	13,4 %	-
SH	33,3 %	26,7 %	20 %	3,3 %	16,7 %	-
CLX	41,7 %	23,3 %	8,3 %	1,7 %	25 %	-
EDTA	56,7 %	30 %	5 %	-	8,3 %	-

(i) adhesive between resinous cement and root dentin; (ii) adhesive between the post and resinous cement; (iii) mixed between post, resinous cement and root dentin; (iv) cohesive in dentin; (v) cohesive in post and (vi) cohesive in cement.

The frequency of failure mode is shown in Table III. Adhesive failure was predominant between dentin and resinous cement, followed by adhesive failures between post and resinous cement, mixed and cohesive.

Figure 1 shows the surface of root dentin in each group, after de post space irrigation procedures. There was more exposition of dentin tubules on dentin walls when 17 % EDTA and 2 % CLX were used.

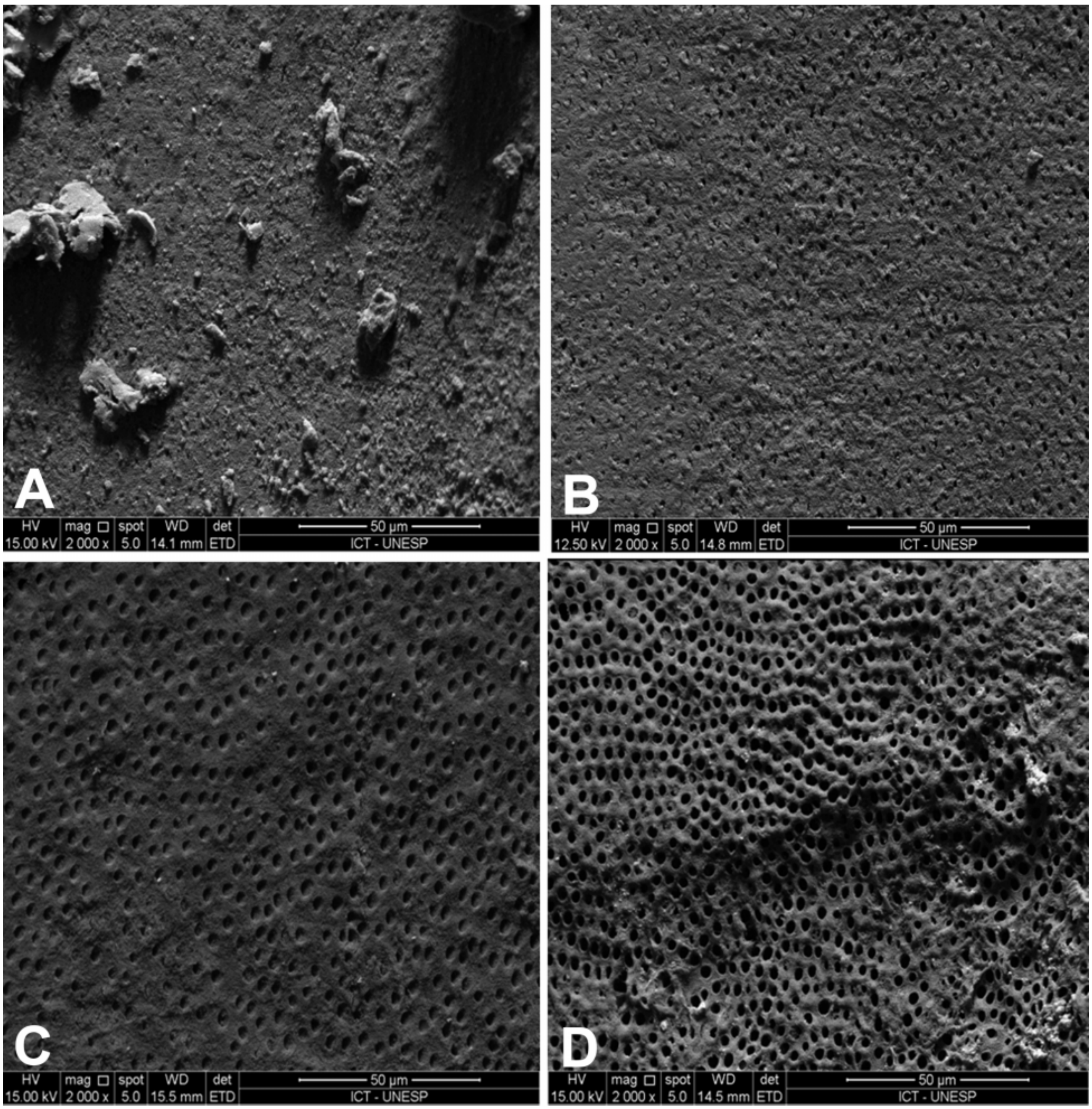

Fig. 1. Surface feature of root dentin in scanning electron microscopy after cleaning with saline solution (a); 2.5 % sodium hypochlorite (b), 2 % chlorhexidine (c) and 17 % EDTA (d).

DISCUSSION

According to the literature, the smear layer is a reflection of the composition of the dentin matrix, containing organic and inorganic substances, microorganisms, and necrotic material (Alaghemand *et al*., 2013). Upon preparing the post space, a new smear layer is produced in root-filled teeth. The penetration and chemical reaction of the adhesive system used in the luting of glass fiber posts can be compromised by the cumulative effect of these layers (Alaghemand *et al*.). Therefore, it is important to evaluate the effectiveness of different solutions to remove the smear layer when preparing the post space.

In order to allow a satisfactory adhesion of the post to the root dentin, the smear layer must be removed effectively, since it may prevent the penetration and adaptation of the resin-based cements to the dentinal tubules, decreasing the bond strength values (Monaco *et al*., 2003). To obtain a more effective cleaning of the canal, different solutions for dentin surface cleaning are proposed, such as Ethanol, Ethylene Acetate, Chlorhexidine Gluconate, Sodium Hypochlorite (NaOCl) and Ethylenediamine Tetraacetic Acid (EDTA). Their use and effectiveness during root canal preparation are well established, but after post space preparation, remains unclear in the literature.

EDTA is a bivalent cationic material used to chelate calcium ions in endodontics and to remove the smear layer in restorative procedures, selectively removing hydroxyapatite and non-collagenous proteins (Carvalho *et al*., 2000). It exhibits a low decalcification ability and less influence on the dentin so that the functional monomer of the adhesive system presents a greater chemical interaction. This solution also provides a thinner hybrid layer without collagen denaturation due to the presence of more residual apatite crystals left in the collagen matrix, leading to greater penetration of the resinous agent (Alaghemand *et al*.). Gu *et al*. (2009a) reported that irrigation with EDTA for 5 minutes would lead to severe root dentin erosion, whereas irrigation for less than 1 minute could significantly decrease smear layer removal. Present results showed a better performance of EDTA (7.07 ± 1.58) in removing residues and increasing bond strength values, when compared to the saline solution (4.80 ± 1.21) and NaOCl (4.69 ± 1.16), agreeing with Gu *et al*. (2009b). The exposure of dentinal tubules on the post space surface through SEM analysis can also illustrate the irrigating actions (Fig. 1).

According to Zhang *et al*., NaOCl has a negative effect on resin adhesion to intrarradicular dentin. The break of NaOCl releases sodium chloride and oxygen into the canal, which can interfere with the complete polymerization of adhesive systems and diffuse into the dentinal tubules. Sodium Hypochlorite also has the potential for collagen degradation, which could affect the bond strength in root dentin (Renovato *et al*.). However, in the present study, no decrease in bonding values was observed when this solution was used.

Saline solution does not have chelating or antimicrobial properties and cannot dissolve organic tissue. Thus, it is often associated with other solutions in the preparation of the root canal. Differently from the present study, Barreto *et al*. (2016) found higher bond strength values for saline solution compared to EDTA. However, the authors did not perform the cycling of the samples, as reported in the present study. In addition, they used ultrasonic irrigation, which results in the removal of debris from dentin, microorganisms, and organic tissue present in the canal (van der Sluis *et al*., 2007).

Chlorhexidine gluconate has been used as an irrigant in endodontic treatments, due to its good antimicrobial properties and to potentialize adhesion to intrarradicular dentin. Due to its substantive activity, it restricts the penetration of bacteria into the dentinal tubules. While irrigation with NaOCl alone or followed by EDTA may reduce the immediate bond strength of the composite resin to root dentin, irrigation with chlorhexidine gluconate does not have this effect (Lindblad *et al*., 2010). However, in the present study, 2 % chlorhexidine gluconate showed similar bond strength values in comparison with other groups. The absence of significant differences in the bond strength values when compared to the distilled water, had already been reported previously (Bitter *et al*.; Kul *et al*.).

The push-out test was chosen to provide a better estimate of bond strength than the conventional shear test at the dentin-adhesive interface. In addition, it was considered more reliable than the micro-tensile test for the evaluation of the bond strength of posts and allows the measurement of such values among different root regions (Ferreira *et al*., 2015). The adhesion to radicular dentin can be a challenge due to root anatomy and the particular handling of adhesive systems (Ferrari *et al*., 2007). There is a predominance of failures in the cement-dentin interface, which represents a more critical interface (Zicari *et al*.). In the current study, such failure was predominant, followed by mixed ones.

A decrease in bond strength values from the coronal to the apical region was expected (Gu *et al*., 2009a). However, no significant difference was observed in the values according to the root region. These results corroborate with reported by Kul *et al*. and differ from Ferreira *et al*. and Zhang *et al*., who attributed their findings to the morphological differences in root dentin and the sensitivity of intrarradicular adhesive procedures. The application of a meticulous protocol and the use of a dual resinous cement demonstrated efficiency in overcoming these difficulties, once different bonding mechanisms related to a dual resinous cement can contribute particularly to different regions of the root.

Further studies should be performed to evaluate the long-term effects of the different variables existing in root canal cleaning protocols, prior to cementation, on the mechanical behavior of glass fiber posts.

CONCLUSIONS

The bond strength values between glass fiber posts and dentin after mechanical cycling varied according to the irrigating solution used prior to cementation. EDTA was better than other solutions for cleaning of post space when using glass fiber posts. The different regions of the root canal presented similar bond strength values, even when submitted to different irrigation solutions prior to cementation.

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RESUMEN: Este estudio tuvo como objetivo comparar el efecto de cuatro soluciones de irrigación para la limpieza del espacio del poste sobre la fuerza de unión entre el poste de fibra de vidrio y la dentina radicular. Se rellenaron cuarenta raíces bovinas y se dividieron aleatoriamente en cuatro grupos (n = 10), según la solución de riego: CG (Grupo Control): solución salina; SH (Grupo de hipoclorito de sodio); CLX (grupo clorhexidina) y EDTA (grupo ácido etilendiaminotetraacético). Las muestras se sometieron a una prueba de envejecimiento mecánico y de expulsión. Se realizó análisis estadístico (ANOVA bidireccional y prueba de Tukey; p <0,05). Se utilizó un microscopio estereoscópico para la clasificación del modo de falla. EDTA mostró valores de fuerza de unión más altos, difiriendo estadísticamente de SH y CG (p <0,05). Predominó la falla adhesiva entre dentina y cemento resinoso, seguida de fallas mixtas. Las imágenes SEM mostraron una eliminación pronunciada de la capa de frotis en el grupo de EDTA. El EDTA al 17 % fue mejor que otras soluciones para la limpieza del espacio de los postes cuando se utilizan postes de fibra de vidrio.

PALABRAS CLAVE: agentes adhesivos de dentina, EDTA, ensayo de materiales, poste de fibra de vidrio, frotis.

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