Bond Strength of Fiber Posts to Intraradicular Dentin After the Use of Ultrasonically Actived Irrigants

Egídia Maria Moura de Paulo Martins Vieira, Roberta Tarkany Basting, Fabiana Mantovani Gomes França, Flávia Lucisano Botelho do Amaral, Cecilia Pedroso Turssi

Division of Cariology and Restorative Dentistry, São Leopoldo Mandic Institute and Dental Research Center, Campinas, São Paulo, Brazil

Abstract

Aim: This study evaluated the bond strength of glass-fiber posts (GFP) to intrarradicular dentin in cervical, middle and apical thirds, after using ultrasonically activated irrigants. Methods: One hundred and twenty lower premolars sectioned and distributed into 10 groups (n=12), according to irrigant and ultrasonic treatments. The groups were 2.5% NaOCl (HS), 2% chlorhexidine digluconate (CL), 17% EDTA, saline (SF) distilled water (AD), plus or minus ultrasonic instrumentation, and posts were cemented whith RelyX ARC. Results: The bond strength was evaluated by means of the push-out test. Repeated measures three-way analysis of variance and Tukey test revealed that compared to EDTA 17%, CL and SF significantly reduced the bond strength of GFP, regardless of ultrasonic instrumentation and also independently from root third (p=0.015). The most prevalent failure type was adhesive between the dentin and cement for the EDTA and HS groups, followed by mixed failure for the CL and HS groups. GFP bond strength was not affected by ultrasonic instrumentation (p=0.114), nor was it different between root thirds (p=0.280). Conclusion: The GFP bond strength to root dentin was influenced by the irrigant used, being the greatest values obtained with 17% EDTA when compared to CL and SF with or without passive ultrasonic instrumentation.

Key Words: Ultrasonic, Root canal irrigants, Root canal posts, NaOCl, Chlorhexidine

Introduction

Endodontic treatment is related to the loss of dental structure owing to the presence of caries lesions, old restorations, fractures or access for endodontic preparation. In this context, in order to provide retention for the restoration in the dental element, the use of glass-fiber posts is recommended, which, as they have a high resistance to flexion and modulus of elasticity similar to that of dentin, has made it possible to achieve success rates of between 90% and 99% [1].

Nonetheless, in order to achieve success with rehabilitation procedures, it is also essential that, for endodontic treatment, the remains of the vital and necrotic pulp tissue have been removed, as well as microorganisms and microbial toxins from the root canal system [2]. In this context, it is of paramount importance that irrigants are used which act as cleaning agents during the biomechanical treatment, with the removal of microorganisms, of products associated with tissue degeneration and organic and inorganic residue, ensuring the elimination of the contaminated dentin and permeability along the entire length of the canal [3].

At this time, there are no irrigants available that combine all of the ideal characteristics, even when used with a lower pH, have a higher temperature or are added to surfactants [4]. There is no single irrigant that has shown itself capable of dissolving organic pulp material and demineralizing the wall of the root canal [5].

Among the auxiliary chemical substances used in endodontics during the chemical/mechanical preparation of the root canals, NaOCl (NaOCl), in a variety of concentrations (0.5% to 6%), is the one most frequently used [6]. Despite its wide spectrum of antimicrobial action and the property of dissolving organic tissue, its penetration into the dentin tubules is limited [7]. However, it should be stressed that in high concentrations NaOCl has cytotoxic effects, while in low concentrations it is ineffective against *Enterococcus Faecalis* [8].

The complete cleaning of the root canal system requires the use of irrigants that dissolve both organic and inorganic material. As NaOCl is only active on organic material, another substance may be used to supplement the removal of the smear layer [9]. EDTA has been used for this purpose but, on the other hand, it has little or no effect on organic tissue and has no antibacterial activity [5]. As a chelating agent, EDTA can accelerate the effect of the NaOCl and help to diffuse the hydroxyl ions through the dentin tubules [10]. However, EDTA alters the physical and chemical properties of dentin and increases the adherence of enterococcus faecalis, a significant bacteria linked to post-endodontic treatment infections [8,11,12].

Chlorhexidine digluconate at 2% (CHX) has also been suggested as an irrigant for endodontic treatment [13], due to its antimicrobial properties and substantivity [14]. The chlorhexidine gel is an auxiliary chemical substance that does not interfere with the collagen present in the organic matrix of root dentin or the effectiveness of the filling and restoration [15].

Throughout the history of endodontics, efforts have focused on developing more effective systems for applying and agitating irrigant solutions in the canal system [3]. These systems can be divided into two categories of agitation techniques: manual and mechanical [16]. The latter includes the use of simultaneous irrigation with rotating canal instrumentation, pressure switching devices as well as sonic and ultrasonic systems [14]. All of these appear to improve canal cleaning when compared to irrigation with a conventional syringe and needle [14].

The use of ultrasound for irrigation procedures results in a more efficient cleaning of the canals, improves the

Corresponding author: Cecilia Pedroso Turssi, Division of Cariology and Restorative Dentistry, São Leopoldo Mandic Institute and Dental Research Center, Campinas, São Paulo, Brazil, Tel: +55-19-32113600; E-mail: cecilia.turssi@gmail.com

dissociation of the irrigant in the canal system, provides a softening of the dentin debris and removes bacteria and smear layer. In view of the conflicting, barely explored outcomes, there is a need to conduct studies to investigate the effectiveness of the ultrasound apparatus and its impact on the outcome of treatment [17]. This is even more important if we consider the associated presence of the irrigant.

Bearing in mind the above aspects, this study aims to contribute to the understanding of the influence of endodontic irrigating solutions, with and without ultrasonic instrumentation, on the bond strength of fiber posts cemented with resinous agent to the root dentin of human teeth. The null hypothesis tested was that the use of irrigants, both with and without passive ultrasonic instrumentation, does not affect (i) the bond strength between glass-fiber posts and intraradicular dentin, (ii) in either the cervical, middle or apical regions.

Materials and Methods

Experimental design

This study followed a randomized complete-block design, with repeated measures, in a 5x2x3 factorial scheme, the factors studied being as follows:

Irrigation solution, at five levels (distilled water, saline solution, 2% chlorhexidine digluconate solution, 2.5% NaOCl and EDTA 17%);

Ultrasound, on two levels (present and absent);

Root third, on three levels (cervical, middle and apical).

The experimental units consisted of 120 roots of human lower premolars randomly divided into ten groups, according to the irrigation solution and the use, or not, of ultrasound (n=12). Three cross-sections were obtained from one single experimental unit corresponding to the cervical, middle and apical root thirds. The qualitative response variable was push-out bond strength of the glass-fiber posts cemented to the root canal, measured in MPa. The bond failure mode was a qualitative response variable.

Ethical aspects

The protocol for this research study was submitted to the Human Research Ethics Committee at the São Leopoldo Mandic Dental Faculty, which approved the use of 120 single-rooted human teeth (lower premolars), donated by the Tooth Bank at the São Leopoldo Mandic Dental Faculty.

Sectioning of teeth and acquisition of specimens

The premolars were cleaned with scalpel blades, polished using pumice stone and a low-rotation Robinson brush and maintained at 4ºC in a solution of 0.1% thymol. The teeth were sectioned at the cementoenamel junction using a low-speed diamond saw, under refrigeration (Isomet 1000); Buehler Ltd., Lake Bluff, IL, USA), in order to obtain 120 roots with a length of 16 mm, the measurement of which was performed using a digital caliper (MIP/E – 103, Mitutoyo Sul Americana Ltda., Suzano, SP, Brazil). The following exclusion criteria were applied: roots with excessive curvature, open root apex and the presence of more than one root canal, assessed by radiographic examination of the teeth.

Biomechanical preparation and filling

The root canals were prepared using the step-back technique with K-Files (Dentsply/Maillefer, Petrópolis, Rio de Janeiro, RJ, Brazil). The cervical and middle thirds were enlarged using Gates-Glidden drills (Dentsply/Maillefer, Petrópolis, Rio de Janeiro, RJ, Brazil), prior to canal preparation.

Depending upon the group to which the roots belonged, the canal was irrigated using the following vehicles: distilled water, saline solution, solutions of 2% chlorhexidine digluconate, 2.5% NaOCl or EDTA (Biodinâmica, Ibiporã, PR, Brazil), both with and without the use of ultrasound (Microssonic, Driller, Carapicuíba, São Paulo, Brazil) using the PUI technique, namely Passive Ultrasonic Irrigation. Ultrasound was used for one minute after instrumentation with the aid of special inserts to cause the irrigant to vibrate. The root canals were irrigated using 20 mL of each solution during the cleaning and instrumentation, and were filled using calcium hydroxide-based cement (Sealer 26, Dentsply, Rio de Janeiro, RJ, Brazil), using the lateral compaction technique.

The bed for the cementation of the posts was prepared at 14 mm using glass-fiber posts (Exacto #1, Angelus, Londrina, PR, Brazil). Special drills were employed supplied by the manufacturer of the system of posts, in order to remove the fillings from the canal, resulting in 2 mm of apical sealing.

Preparation and cementation of the glass-fiber posts

Prior to cementation, the glass-fiber posts (Exacto #1, Angelus, Londrina, PR, Brazil) were cleaned in 70% alcohol for 1 minute, and then dried. Afterwards, silane agent (Exacto, Angelus, Londrina, PR, Brazil) was applied using disposable microbrushes (Cavibrush 2, FGM, Dentscare, Joinville, SC, Brazil) for 1 minute and then air-dried.

Prior to cementation, the root dentin was etched using 37% phosphoric acid (Condac 37, FGM, Joinville, SC, Brazil) for 15 seconds. After washing, it was dried with absorbent paper (Dentsply/Maillefer, Rio de Janeiro, RJ, Brazil). The adhesive system was applied (Adper Scotchbond Plus, 3M ESPE, St. Paul, MN, USA), with disposable microbrushes (Cavibrush 2, FGM, Dentscare, Joinville, SC, Brasil) and, following the manufacturer's recommendation, a layer of primer was applied (Adper Scotchbond Plus, 3M ESPE, St Paul, MN, EUA) and dried for 5 seconds. Then, a layer of catalyst was applied in the root canal (Adper Scotchbond Plus, 3M ESPE, St Paul, MN, EUA) and dried for 5 seconds. Finally, a catalyst layer (Adper Scotchbond Plus, 3M ESPE, St Paul, MN, USA) was applied to the conduit, being the excesses removed with absorbent paper # 80 (Dentsply/Maillefer, Petrópolis, RJ, Brasil) after each application.

Conventional dual-cure resin cement (RelyX ARC, 3M ESPE, St. Paul, MN, USA) was manipulated following manufacturer's recommendations, and inserted into the root canal and the post, with the aid of a periodontal probe with millimeter markings. The posts were then placed inside the canal, using finger pressure, for 3 minutes, the excess cement being removed. The light-activation was then carried out through the post in the occluso-apical direction for 40 seconds, with a light-activation unit (GNATUS, Ribeirão Preto, SP, Brazil). The samples were stored at 100% relative humidity at 4ºC.

Acquiring the samples' slices

The specimens were fixed to acrylic plates with wax for sculpting (Kota, São Paulo, SP, Brazil) such that the long axis of the post was parallel to the plate surface and perpendicular to one of its edges and then sectioned in a precision saw (Isomet 1000, Buehler Ltd., Bluff, IL, USA), using a high-concentration diamond cutting wheel (Buehler Ltd., Bluff, IL, USA). Cuts were made in the buccolingual direction of the root, so as to obtain sections 1 mm thick for each of the thirds, cervical, middle and apical.

Once the specimens were obtained, the diameters of the canal on the cervical and apical surfaces were measured and the height was measured using a digital caliper (MIP/E – 103, Mitutoyo Sul Americana Ltda., Suzano, SP, Brazil).

Push-out bond strength test

The push-out bond strength test was conducted using a universal testing machine (EZ-LX, Shimadzu Corporation, Suzhou, Jiamgsu, China), at a speed of 0.5 mm/min, attached to a 500 N load cell. The slices were placed in a device such that the force was applied in the apical-cervical direction by means of a metal piston measuring 1 mm in diameter, until the post was dislodged.

The bond strength values, in MPa, were obtained by dividing the force used to provoke the failure (in Newtons) by the bonded area (in mm^2). To calculate the glued surface area, taking into account the conical shape of the posts, the following formula was applied:

Area=π (R + r) [h2 + (R - r)2]0.5, where:

R – radius in the cervical portion (mm)

r – radius in the apical portion (mm)

h – slice thickness (mm)

Evaluation of failure mode

An analysis of the failure pattern at the dentin-cement-post interfaces was performed using a stereoscopic magnifier (EK3ST, Eikonal Equip. Ópticos e Analíticos, São Paulo, SP, Brazil), at a magnification of 40x. Failure types were classified as:

a) adhesive between cement and dentin;

b) adhesive between cement and post;

c) cohesive: dentin;

d) mixed, with cohesive and adhesive fracture

Statistical analysis

The bond strength values were evaluated for compliance with the assumptions of normality and homoscedasticity, by means of the Shapiro-Wilk and Levene tests, respectively. Square root transformation was applied for variance stabilization.

The transformed data were subjected to a repeated measures three-way analysis of variance and the Tukey test for multiple comparisons.

The statistical calculations were performed using the software SPSS 20 (SPSS Inc., Chicago, IL, USA), using a level of significance of 5%.

Results

Table 1 shows the descriptive analysis, in terms of means and standard deviations, of the push-out bond strength values of glass-fiber posts to the intraradicular dentin, subjected to irrigation with different agents, whether or not associated with the use of ultrasonic agitation, and by root third.

The Repeated measures three-way analysis of variance showed that there was no significant interaction between the factors being studied, Irrigation solution, Ultrasound and Root third (p=0.220). The dual interactions Irrigant x Ultrasound (p=0.384), Irrigant x Root third (p=0.870) and Ultrasound x Root third (p=0.125) were also not significant.

Regardless of whether or not PUI was used and of root third, it was found that bond strength was influenced by the irrigating agent (p=0.015). The Tukey test identified that, when irrigation was carried out using 2% chlorhexidine digluconate and with saline solution, significantly lower bond strength values were found for the glass-fiber post to the root canal versus the groups in which irrigation was conducted with EDTA at 17%. As for the groups where the irrigating agent was 2.5% NaOCl and distilled water, it was found that bond strength did not differ significantly from that found in the groups irrigated with EDTA at 17%, chlorhexidine digluconate at 2% and with saline solution (*Table 1*).

The Repeated measures three-way analysis of variance also showed that, for any of the irrigating agents used and location of the root third, the PUI did not have any effect on the bond strength of the glass-fiber post to the radicular dentin (p=0.114).

Finally, through The Repeated measures three-way analysis of variance also showed. No significant difference was found for bond strength values obtained in the cervical, middle and apical thirds (p=0.280).

Table 1. *Means and standard deviations of push-out bond strength values of glass-fiber posts to dentin, according to irrigating agent, ultrasonic agitation and the root third.*

Irrigant agent	Ultrasonic instrumentation	Root third	Push out bond strength	Grand mean
Distilled water	Absent	Cervical	19.05 (6.93)	16.05 AB
		Middle	11.04 (6.11)	8.83
		Apical	11.25 (9.40)	
	Present	Cervical	25.76 (10.98)	
		Middle	14.71 (5.30)	
		Apical	15.71 (6.06)	
2% chlorhexidine digluconate	Absent	Cervical	18.05 (7.13)	15.05 B
		Middle	11.21 (7.80)	8.55
		Apical	14.99 (7.63)	
	Present	Cervical	18.83 (10.75)	
		Middle	14.33 (10.71)	
		Apical	11.91 (3.51)	
17% EDTA	Absent	Cervical	20.46 (10.31)	19.54 A
		Middle	17.09 (6.72)	10.76
		Apical	11.08 (7.60)	
	Present	Cervical	24.91 (12.94)	
		Middle	26.10 (12.36)	
		Apical	19.17 (8.40)	
2.5% NaOCl	Absent	Cervical	16.82 (6.88)	17.10 AB
		Middle	11.79 (5.62)	9.9
		Apical	13.75 (13.95)	
	Present	Cervical	24.46 (11.77)	
		Middle	17.30 (7.02)	
		Apical	19.38 (9.68)	
Saline solution	Absent	Cervical	16.31 (7.57)	14.89 B
		Middle	9.99 (3.31)	8.55
		Apical	10.13 (5.89)	
	Present	Cervical	21.23 (13.40)	
		Middle	18.46 (7.18)	
		Apical	14.38 (7.88)	
Grand means followed by different capital letters indicate significant difference between irrigants, regardless of the ultrasound instrumentation and root third.				

Figure 1 shows the fracture modes exhibited by the samples after the push-out bond strength test and indicates that the adhesive failure between the dentin and cement was the most prevalent failure mode when using the irrigants EDTA at 17% and 2.5% NaOCl, regardless of whether or not PUI was performed. This was followed by mixed failure whose highest index occurred when using the irrigants 2% chlorhexidine digluconate and 2.5% NaOCl. Failures of the post-cement adhesive type and cohesive type in dentin demonstrated the lowest indices, had been performed.regardless no matter whether or not PUI and of the apical third.

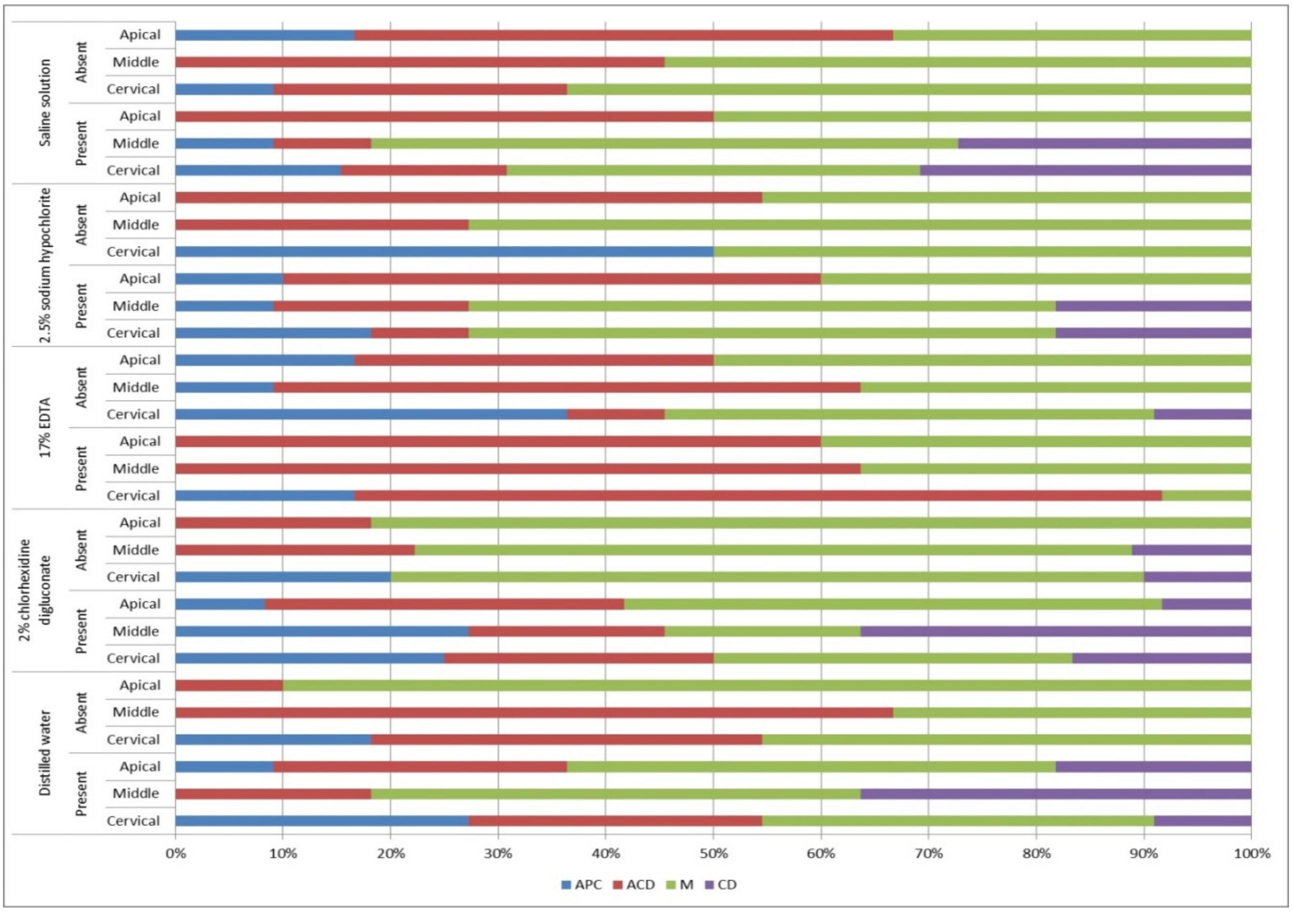

Figure 1. *Diagram of frequency of fracture modes after the push-out bond strength test, according to irrigation agent, instrumentation type and root third.*

Discussion

In the present study, it was found that bond strength was influenced by the irrigation agent, no matter whether or not passive ultrasonic instrumentation was performed, thereby rejecting the null hypothesis. Irrigation with EDTA at 17% provided significantly higher bond strength values than when carried out with 2% chlorhexidine digluconate and saline solution. This result may be explained by the fact that EDTA is effective in removing the smear layer in root canals, providing a dentin surface free from residue and wider open dentinal tubules [17-20], facilitating the penetration of the resin cement after preparing the space for the cementation of posts in endodontically treated teeth [20-23].

Moreover, it has been reported that EDTA is the best solution for removing the smear layer during the use of both sonic irrigation [24-26] and ultrasonic irrigation [19,27,28], provided it is used for no longer than one minute, as over longer periods of time it could result in excessive dentin erosion [29], which justifies the use of ultrasonically activated EDTA, for one minute, in the present study. On the other hand, [19], used EDTA 17% after instrumentation for three minutes, ultrasonically activated and prior to the final irrigation with solutions of 2.5% and 5.25% NaOCl, saline solution and 2% chlorhexidine gel, respectively, obtaining a lower bond strength in the group irrigated with 5.25% NaOCl and the use of the self-adhesive resin cement RelyX U100, which differs from the present study in that there was no statistically significant difference between the groups, either with or without ultrasonic activation, when using dual-cure resin cement RelyX ARC. The difference in outcomes may be associated with the fact that the aforementioned researchers used the cement RelyX U100 which, due to its relatively high viscosity, combined with its low demineralizing capacity, may have contributed to low infiltration of the monomer into the dentin, thereby reducing micromechanical retention [30].

Distilled water and the 2.5% NaOCl solution were no different from either EDTA at 17% or 2% chlorohexidine digluconate solution and saline solution. 2.5% NaOCl has a wide spectrum of antimicrobial action and the property of dissolving both organic and inorganic tissue, although it is not effective in removing the smear layer and dentin debris from the root canal walls, which could affect the bond strength of the glass-fiber post [7,9]. Combined with these factors, NaOCl breaks down into sodium chloride and oxygen [31]. It has been reported that this release of oxygen inhibits the polymerization of resin cements, leading to a reduction in bond strength [20]. In this study, the fact that NaOCl did not result in lower bond strength values when compared to the other irrigants employed is probably attributable to the concentration applied (2.5%), a finding which corroborates the results of [19], who highlighted that NaOCl in the aforementioned concentration did not interfere with the bonding capacity of resin materials to the intraradicular dentin.

In this study, irrigation with chlorhexidine digluconate did not result in an improvement in bond strength, in agreement with the results of earlier studies, probably due to its inability to dissolve organic and inorganic material, making it difficult to clean the root canal walls; in other words; the presence of debris and smear layer create a physical barrier, obstructing the dentinal tubules, preventing the penetration of the adhesive system and reducing the interaction of the resin cement with the dentin surface [32-34].

Another factor which must be taken into consideration in this study is that the PUI had no effect on the bond strength of the glass-fiber post to the intraintraradicular dentin, regardless of the irrigation agent employed and the root third. One explanation for this finding may lie in the fact that PUI does not significantly improve the removal of smear layer on the dentin [23]. In fact, despite the fact that PUI is better than irrigation with needles, it is reported that the smear layer was not completely eliminated [22]. It should be stressed, however, that in this study the solution of NaOCl used had more than double the concentration of that used by the aforementioned authors, being applied for 60 seconds, six times greater, which may explain the fact there was no significant difference between the groups in which ultrasound was or was not used.

In terms of the removal of smear layer, several studies have produced conflicting results, probably due to the different concentrations of irrigation solutions and the length of time activated inside the canal [35]. As far as this aspect is concerned, the literature advocates between 30 seconds and 3 minutes of ultrasonic activation of the irrigant [36], but there is still no consensus concerning application time [37]. In the present study, the decision was taken to use the ultrasound for 60 seconds and it was found that, regardless of irrigation solution and root third, PUI of the irrigant did not interfere with the bond strength of the glass-fiber post. This result may be attributable to ultrasound's inefficiency in improving removal of the smear layer and providing the opening of the dentinal tubules [26,35]. However, other researchers have reported that PUI had a favorable effect on the removal of smear layer during endodontic treatment [27,38,39], in this study, the explanation for the fact that PUI did not have a significant effect can be due to the fact that, although the elliptic-shaped teeth were replaced by others with more circular conformation, the fiber post did not present juxtaposed in all the roots. As a result, there was a greater thickness of resin cement and, consequently, a possible benefit generated by the use of ultrasonic activated irrigants became insignificant due to the inherent variability of the resistance values.

Given that ultrasonic vibration leads to the agitation of the irrigation solution in all directions, it is important to evaluate if there is any risk of apical infiltration and consequent damage to periodontal tissue and alveolar bone. In the present study, there was no extrusion of the irrigant due to the root canal models having had a solid foramen, sealed with composite resin. However, Tasdemir T [37] reported that the risk of irrigation solution overflowing into the periapical region is reduced when PUI is used, due to the direction of oscillation of the tip being lateral and not longitudinal.

In the present study, there was no significant difference between bond strength values obtained from the cervical, middle and apical thirds. This discovery corroborates the findings of other studies in that there was a statistically significant difference compared to the irrigation solution, though not among the root thirds [29,40].

With regard to fracture analysis, it should be pointed out that the predominant type of failure was the adhesive between the dentin and the cement when using the irrigant EDTA at 17%, regardless of the canal region (cervical, middle or apical) and of the use, or not, of PUI which, clinically, would be expressed in the decementation of the post. However, bearing in mind that the bond strength values for the group irrigated using EDTA exceeded those found with the use of chlorhexidine and saline solution, up to the point of decementation, a greater force would be required for this event to occur. Mixed failures were more prevalent when using the irrigants 2% chlorhexidine digluconate and 2.5% NaOCl, a result which was also observed in the group treated with saline solution. Failures of the post-cement adhesive type had lower frequencies, regardless of whether PUI was performed or not, or of the root third, this finding probably being due to the fact that silane was used. Cohesive fractures in dentin were also less frequent, which may be explained by the fact that fragility of the bond occurs at the interfaces [29].

Based on the results of this study, it was concluded that the bond strength of the glass-fiber post at the different depths of root dentin was influenced by the irrigating agent, regardless of whether or not PUI was used. It is noteworthy that there is evidence that the association of EDTA and NaOCl provides optimized endodontic results with respect to the bond strength of fiber posts to the root canal [29]. In this sense, it would be interesting to evaluate the effect of these associated agents, considering the use of PUI. In addition, there is a need for further investigations, regarding in terms of the length of time the passive ultrasonic irrigation in used and the bond longevity of fiber posts when the PUI is used.

Conclusion

The bond strength of the glass-fiber post to intraintraradicular dentin, whether cervical, middle or apical, was influenced by the irrigating agent, the best results being obtained using EDTA at 17%, when compared with 2% chlorhexidine digluconate and saline solution, regardless of the PUI.

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