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Effect of Ultrasound on Bond Strength and Penetration of Resin and Ionomeric Cements Used for Fiberglass Post Cementation

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Abstract

Objective: The objective of this study was to evaluate the bond strength of fiberglass posts (Reforpost ®) cemented with RelyX U200 and RelyX Luting 2, with (A) and without (WA) ultrasonic activation in the root canal of bovine teeth. The penetration of the cements into dentine tubules was also assessed. Methods: Forty bovine incisors were selected and endodontically treated, and then divided into 4 groups (n = 10). Fiberglass posts were cemented with RelyX U200 and RelyX Luting 2 and activated with an ITSMO ultrasound insert in 2 groups; the other two groups received no ultrasonic activation. After 24 hours of cementation, the roots were sectioned into slices of approximately 1 mm each. Confocal microscopy and push-out test were performed, and all specimens were subjected to 200× magnification optical microscopy for mode of failure evaluation. Statistical analysis was done with three-way ANOVA, followed by the Fisher's test ($\alpha = 0.05$). Results: There was no difference among the root thirds in the RelyX Luting 2 group while a difference was found among the thirds in the U200 group. In addition, the bond strength of the U200 cement group was higher than the RelyX Luting 2 group, in all thirds. The U200 cement also showed a greater penetration than the RelyX Luting 2 cement, in all thirds, with and without activation. The ultrasound activation caused a greater penetration only in the cervical and middle thirds in the RelyX Luting 2 group, and in the middle third of the U200 group. Conclusion: The U200 cement presented higher bond strength and penetration compared to the RelyX Luting 2 cement and ultrasonic activation improved the penetration of the RelyX Luting 2 in the middle and cervical root thirds and of the U200 cement in the middle root third. A significant correlation between bond strength and penetration was verified in all groups. Clinical relevance: Ultrasound can promote a better penetration of resin cements used in fiberglass post cementation, reaching the most difficult anatomical areas in the root canal.

Keywords: Confocal microscopy; Fiberglass post; Resin cements; Push Out; Ultrasound

Introduction

Preventive and conservative procedures have been increasingly emphasized in dentistry, indicating that despite the evolution of restorative materials, the dental structure remains irreplaceable. This philosophy has influenced all restorative techniques, including for teeth extensively destroyed, in which restorations should conserve as much as possible the remaining tooth structure [27].

The literature informs that restorations of endodontically treated teeth deserve special care because the biomechanical and morphologic changes due to loss of tooth structure by caries, fractures, cavity preparation, as well as access and instrumentation of the root canal [21] lead to a more fragile tooth.

A rapid, simple and effective way to place a crown in an endodontically treated tooth is by using anchored fiberglass posts [5, 14] A fiberglass post is defined as a segment of the dental restoration that can be placed inside the root canal with the purpose of retaining and stabilizing a crown [15]. The function of the post, in addition to retaining the coronary portion, is also to prevent fracture of the tooth that has been endodontically treated, providing support and internal resistance [13].

An advantage of the fiberglass post is the masticatory stress distribution under a wide surface area, increasing the load level and reducing root fractures [20]. Some studies indicate that the root canal can be influenced by previous endodontic treatment cementation post, root canal dentin type, the types of resin cement and dental adhesives, and cementation line [2, 3, 5, 11, 20] Therefore, the mechanical and adhesive characteristics of the cement are important factors in treatment success when using posts. The ideal cement should have a lower modulus of elasticity than the other components of the fiberglass post-root canal ensemble, which is about 7 GPa. In addition, it should be resilient and elastic, allowing the distribution of forces in the root canal, specifically in the region of greatest tension, the post-dentine interface [8].

Recently, dual resin cements have become popular due to their enormous benefits in adhesive procedures. However, some studies conflicting results regarding the behavior of the various options of cementing agents. The best results in bond strength have not always been attributed to dual resin cements, and researchers have linked this finding to the presence of residual eugenol from endodontic sealer inside the root canal; eugenol affects the acid etching of the dentin, interferes in the conversion degree of the dual resin cement, and decreasing the strength bond of fiber post [27].

The new self-adhesive resin cements such as the RelyX U200 have as main advantage an easier and more convenient application, with fewer clinical steps. One of the causes for the high frequency of fiberglass post failures is adhesive failure at the dentine-cement interface [5, 9, 20]

Ultrasound has been widely used in medicine since 1957, and in recent years, its use in different stages of endodontic therapy, including root canal sealing, has increased [18]. Ultrasound can be applied in canal cleaning and preparation [23, 24] in line with the concept of minimally invasive tooth preparations [16].

The high frequency ultrasound used today facilitates the access to the root canal, the search for calcified canals, and the removal of root canal obstructions (fractured instruments, intracanal posts, and broken metal posts). In addition, it increases the distribution of irrigating substances, and aids gutta-percha condensation during sealing. Moreover, procedures such as MTA placement and paraendodontic surgery are easier to perform with the use of ultrasound [18].

However, few studies have been found [4, 25] regarding the use of ultrasound during the sealing of the root canal through the classical technique. Most results show that ultrasound favors cement penetration, increases sealing ability at the dentinal tubules level and improves retention of the intracanal post.

Thus, the aim of this study was to evaluate the penetration of resin and glassionomeric cements in the dentinal tubules and the bond strength of cemented fiberglass posts in root canals with or without the use of ultrasound.

Material and Methods

Experimental Design

For this study, three factors were evaluated: cement (RelyX U200 and RelyX Luting 2), root thirds (cervical, medium and apical) and activation (with and without ultrasound activation) by means of two response variables: penetration of cement in dentinal tubules evaluated by confocal laser microscopy and bond strength assessed by the push-out test.

Selection and Preparation of Samples

Forty freshly extracted bovine incisors with intact roots, complete apices and less than 5° of curvature were selected. The teeth were cut at the cement-enamel junction with a low-speed saw (Isomet, Buehler, LakeBluff, IL, USA) under constant irrigation with deionized water to obtain 18-mm-long roots. The working lengths were established by visualization of a K file N° 30 in the apical foramen (Dentsply Maillefer, Ballaigues, Switzerland) and subtracting 3 mm. Mechanical preparation was made towards the apex crown. The preparation of the cervical and middle thirds was made with the conventional micromotor instrument LA Axxess 45/06 (SybronEndo, California, USA) up to 6 mm short of the working length. For the apical preparation, K-files (Maillefer-Dentsply, Ballaigues, Switzerland) up to 45 ISO size were used. Throughout the procedure, canal irrigation was performed after each file using a syringe with a 30-diameter needle (Navitip; Ultradent Products Inc. South Jordan, USA) with 5 mL of 1% NaOCl. Next, the canals received a final irrigation with 2 mL of 17% EDTA (pH 7.7) for 3 minutes. Finally, the canals were irrigated with 5 mL saline, aspirated with Capillary Tips suction tips (Ultradent, Utah) and dried with absorbent paper points (Dentsply Maillefer, Tulsa, USA).

Root Canal Obturation

The root filling was performed with the main #45 gutta percha cone, taper 0:02 (Dentsply Maillefer, Switzerland). The canals were filled by the lateral condensation technique. The canals were filled by the lateral condensation technique. With the aid of a # 30 lentulo (Dentsply Maillefer, Switzerland), Sealer 26 cement (Dentsply Maillefer, Switzerland) was applied to the root holding the instrument 4 mm from the apex using a silicone stop. The canals were then filled with cement, and M side cones were inserted (Dentsply Maillefer, Switzerland). After filling, a #60 McSpadden (Dentsply Maillefe, Switzerland) was used for compaction. The teeth were sealed with Cotosol (Coltène, Switzerland) and stored in moist gauze for 72 hours at 37 °C and 100% humidity.

The root canal sealing material was removed with a #2 Gates-Glidden drill (Dentsply/Maillefer, Rio de Janeiro, RJ, Brazil). Each root canal was enlarged with the low-speed drill provided by the post system manufacturer. The post space from the cement-enamel junction was 18 mm in depth and 1.5 mm in diameter, resulting in 4 mm of apical sealing.

Cementation of Fiberglass Post

The roots are distributed randomly into 4 groups according to the cementing agents and ultrasound activation (Table 1).

Groups		Cement		Ultrasound activation
Group 1		RelyX U200		With
Group 2		RelyX U200		Without
Group 3		RelyX Luting 2		With
Group 4		RelyX Luting 2		Without

Table 1: Groups according to techniques and material on this study

The fiberglass posts were cleaned with ethanol and subsequently silanized (silane primer-Angelus, Londrina, PR, Brazil), allowing it to dry for a minute. To facilitate fluorescence in the confocal laser microscopy, fluorescein dye was added to the cement in a concentration of about 0.1% [6] after mixing. Before cementing the post, the canals were cleaned using 1% sodium hypochlorite.

In Group 1, the Relyx U200 cement was introduced in the canal with the aid of a N° 30 K-file (Dentsply Maillefer, Baillanges, Switzerland). After filling, the canal was energized for 20 seconds, in mesial-distal and buccal-lingual directions, using the ultrasound device (Jet-Sonic Four Plus, Gnatus, Ribeirão Preto, Brazil), operating in Endo function (10% of power) equipped with Itsmo ultrasound cutting-edge (Helse, Brazil). A Reforpost Exacto fiberglass post was then inserted (Angelus Industry Dental Products S/A, Londrina, PR, Brazil), and the cement was light-cured with LED light (Optilight Max, GNATUS) for 40 sec. The teeth from Group 2 followed the same procedures but were not energized by ultrasound, and they served as a control group.

In group 3, the root canal was preconditioned in polyacrylic acid 11.5% (conditioner-vitro new DFL, Rio de Janeiro, RJ, Brazil) for 12 seconds. The RelyX Luting 2 was mixed and introduced with a N° 30 K-file (Dentsply Maillefer, Ballaigues, Switzerland). After filling, the canal was energized with ultrasound as described above. The Refortpost Exacto fiberglass post was inserted. The teeth from Group 4 followed the same procedures but were not energized by ultrasound, and they served as a control.

Preparation of the Samples for Microscopic Evaluation

The teeth were identified and incubated for 1 week at 37 °C and 100% humidity. The teeth were cut transversely into 1.5 mm-thick slices in an Isomet cutter (Isomet, Buehler, Lake Bluff, Illinois, USA), using a 0.3 mm-thick diamond disc at 200 rpm and continuous irrigation with deionized water. Nine specimens were obtained from each root: 3 coronal, 3 middle and 3 apical. The sections were placed on an acrylic base, fixed with dental wax and were later polished in a polishing machine (AROTEC, Cotia, SP, Brazil) with the use of 600, 900 and 1200 grit water sandpaper in a 320 mm diameter disc.

Confocal Laser Microscopy Evaluation

The cement/dentine interface was analyzed with a Leica TCS-SPE model confocal laser (Leica Microsystems GmbH, Mannheim, Germany) in fluorescence mode. The wavelengths of absorption and fluorescence emission were 488 to 590 nm. The different sections were displayed 500 µm in depth with 10× magnification. These images were recorded at a resolution of 1024 × 1024 pixels and saved in TIFF format. To measure the area of cement penetration in the dentinal tubules, the images were evaluated with the Image J V1.46r software program (National Institutes of Health, USA). The scale given by the confocal microscopy images (500 µm) are provided by the Image J software. The total perimeter of the canal and of the segment with cement penetration into dentinal tubules were measured in millimeters, and percentage of cement penetration into the tubules for all measured sections were calculated.

Bond Strength Test (Push-Out)

After the storage period, the specimens were submitted to the bond strength (push out) test. The specimens were placed in a stainless steel support having a central bore of 1 mm in diameter. Due to the conical shape of the post, the load was applied in the apex--coronal direction at the apical surface so that the post was pushed toward the wider portion of the canal.

The load was applied only on the surface of the post by means of a tip with 1.2 to 0.9 mm diameter attached to a universal testing machine (Instron Co., Canton, MA, USA) with a load cell of 500 kg (50 N) and a speed of 0.5 mm/min without touching the adhesive interface. The values were recorded in Kgf and later converted to Mpa.

Conversion Values

For the calculation of bond strength, the following formula was used: α = F / A, where F, in MPa, is the force required for pin displacement and A is the area. Since specimens had a conical shape, the diameters of the post fragments (coronal and apical) and their thickness were measured with a digital caliper (Messen Sensor Technology Co, Guangdong China), and the total area in mm was calculated using the following formula: a = π (R2 + R1) [h2 + (R2-R1) 2] 0.5, where π = 3.14; R2 = coronal radius of the cement area; R1 = apical radius of the cement area; h = height of the slice.

Optical Microscopy Analysis

The posts were examined by an optical microscope (DINO-LITEplus digital microscope, AnMo Electronic Corporation, Hsinchu, China), with 200× magnification to evaluate the fracture mode according to Albashaireh et al., 2010.

Statistical Analysis

The three-way ANOVA and Fisher's LSD test were used for comparison among groups, with a significance level of 5% ($p < 0.05$).

Results

There was a statistically significant difference in bond strength only for material and root third factors, but not for the activation factor. However, material and root third presented a significant interaction. There was no difference among thirds for the RelyX cement while all thirds in the U200 cement were different, with the apical third having the lowest value, followed by the middle third; the cervical third had the highest bond strength. In addition, values of all U200 cement specimens were found to be significantly above those of the RelyX Luting 2 cement, and this difference was present in all root thirds (Table 2).

Regarding cement penetration, there was a statistically significant difference in all single factors, with an interaction between all factors combined two by two and among all 3 factors studied (activation, material and third). The multiple comparison analysis showed that the U200 cement always showed a higher penetration than the RelyX Luting 2 cement in all conditions (all thirds, with and without activation). The ultrasound activation resulted in greater penetration only in the cervical and middle thirds cemented with RelyX, and in the middle third cemented with U200; in all the other situations the ultrasound activation did not yield significant differences.

Regarding canal thirds, there was a smaller cement penetration in the apical third in almost all situations except with RelyX cement and no activation (Table 2).

Cement	Ultrasound Activation	Third	Penetration(%)	Bond Strength(Mpa)
Relyx L	With	Apical	$18(5.35)_{a}$	$1.02(0.73)_{A}$
Relyx L	Without	Apical	$17.5(6.17)_{a}$	$1.17(1.48)_{A}$
Relyx L	With	Cervical	$26(7.69)_{b,d}$	$1.53(1.31)_{A}$
Relyx L	Without	Cervical	$19.2(5.7)_{a,c}$	$1.68(1.17)_{A}$
Relyx L	With	Middle	$23.1(4.32)_{b,c}$	$0.71(0.37)_{A}$
Relyx L	Without	Middle	$16.6(4.89)_{a}$	$1.14(0.90)_{A}$
U200	With	Apical	$22.8(7.31)_{b,c}$	$3.38(2.51)_{B}$
U200	Without	Apical	$25.1(8)_{b,d}$	$3.53(3.51)_{B}$
U200	With	Cervical	$32(12.8)_{e,f}$	$7.13(5.77)_{D}$
U200	Whitout	Cervical	$34.1(8.42)_{e}$	$6.63(5.66)_{D}$
U200	With	Middle	$35.8(10.49)_{e}$	$5.37(4.52)_{C}$
U200	Without	Middle	$28.2(8.77)_{d,f}$	$5.51(4.88)_{C}$

Table 2: Means and standard deviations (SD) for cement penetration and bond strength of fiberglass posts using the tested cements, with or without ultrasound activation and in different thirds of the root canal. Different letters mean significant differences ($p < 0.05$).

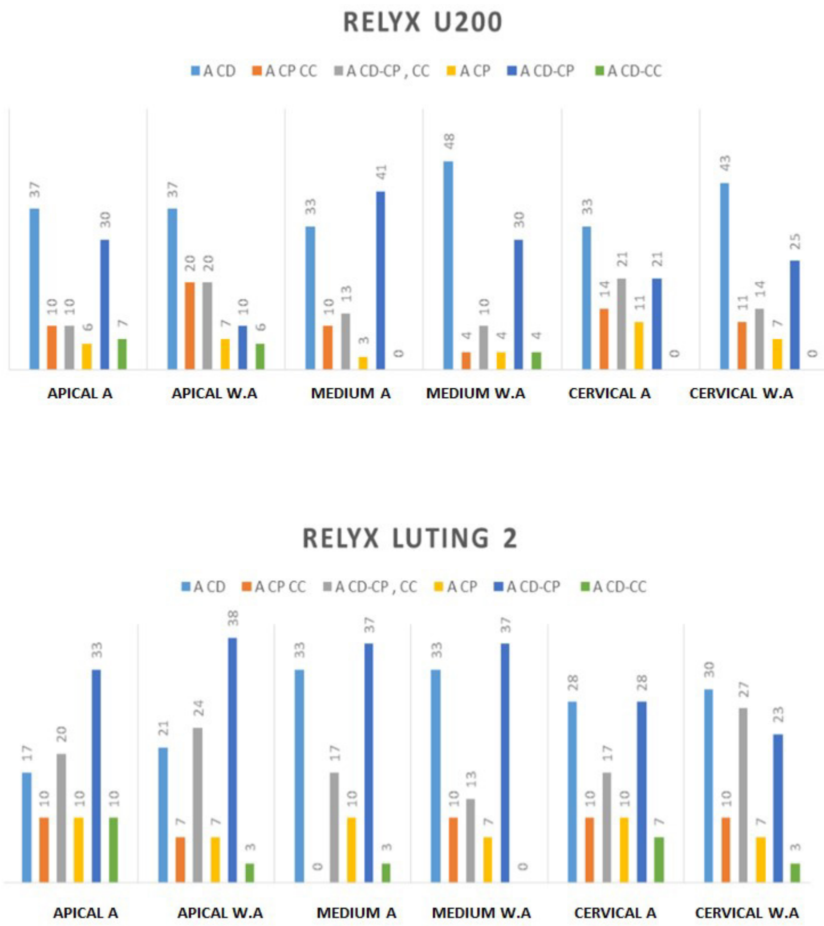

Figure 1: Fracture modes for RelyX Luting 2 and U200 according to Ultrasound Activation and root canal thirds (apical, middle and cervical).

Failure modes in the graph:

1) Adhesive failure - CD (cement - dentin) and CP (cement - post)

2) Mixed failure (adhesive failure and cohesive failure) - CD (cement - dentin), CP (cement - post) and CC (cement - cement).

In all cases, a significant correlation was verified between penetration area and bond strength factors. Table 3 shows the correlation values considering the study factors separately and in a general analysis.

	Area of penetration							
	All groups	ACTIVATION		MATERIAL		THIRD		
		Yes	No	Luting 2	U200	Apical	Middle	Cervical
Bond strength	r= 0.58	r= 0.54	0.68	0.19	0.54	0.64	0.52	0.61
	p<0.001	p<0.001	p<0.001	p<0.010	p<0.001	p<0.001	p<0.001	p<0.001

Table 3: Pearson's correlation results between penetration area and bond strength (p<0.0001)

Discussion

After endodontic treatment, teeth have to be restored to reestablish their shape and function (JAYASENTHIL et al., 2016, 27, 21]. A fiberglass post can be used in direct or indirect restorations (PURTON et al., 2000) as this material has good mechanical properties such as fatigue and traction resistance, in addition to having a modulus of elasticity similar to dentin [2]. To cement the fiberglass post into the root canal, dual cure and chemically active cements are the most recommended because they allow an adequate control of the working time, present a wide choice of colors and opacities, good fluidity, and also allow polymerization in difficult areas.

In this study, the dual cure RelyX U200 cement and the chemically activated RelyX Luting 2 cement were used for the cementation of the fiberglass post. The push out test was selected because it is a suitable method to evaluate the bond strength of the intracanal posts, which were divided into thirds to compensate the structural variability of the dentin inside the root canal [5, 11]

We found that the RelyX U200 cement had higher bond strength compared to RelyX Luting 2, in line with the literature [3]. This can be due to a chemical interaction between the functional monomers of the dual cure adhesive cement and hydroxyapatite, as these monomers might be more important for the bonding process than the capacity to hybridize the dentin. In addition, the chemical bonding and the simplicity of the technique of the dual cure cement may contribute to the greater success. Moreover, the physical properties and lower contraction of the dual cement may result in greater contact with the walls of the root canal, thus increasing the bond strength compared to the chemically activated cements.

The resin-modified chemically activated cement RelyX Luting 2 obtained lower bond strength values compared to RelyX U200, as this cement is more resistant to compression than to traction. However, the use of resin-modified glass ionomer allows the formation of microcracks up to one year after cementation because of hygroscopic expansion [34].

The root dentin presents morphological differences along the canal extension [28, 29], such as the reduction in the density of dentinal tubules [30] and a decrease in tubules diameter in the apical region [28] which may compromise cement adhesion, leading to significantly lower bond strength values in this region when compared to the cervical third [29, 30]. In this study, the difference between the bond strength of the cervical and mid thirds can be explained by the increased difficulty of the cement to reach narrower tubules [29] partially due to the fluidity of the material. This was confirmed for RelyX U200 cement, in which there was a significant difference in bond strength between the apical, middle and cervical thirds.

The values of bond strength obtained in the present study corroborate the studies that describe higher values for the cervical third, intermediate values for the middle third and lower values for the apical third [3] . This is because the dual cure self-adhesive resin cements are mildly acidic and therefore promote demineralization and hybridization of the root dentin [11]. On the other hand, the resin-modified ionomer cement Relyx Luting 2 did not present a significant difference in bond strength among apical, middle and cervical thirds of the root canal. This was due to the chemical polymerization of the cement, which requires an initial acid conditioning step and therefore the level of root canal demineralization is provided by the operator [26].

The use of ultrasound in this study increased the area of cement penetration in the root dentinal tubules of the middle and cervical thirds for RelyX Luting 2 cement and in the middle third for RelyX U200 cement, probably due to the ultrasound vibration [22] In addition, the increase of the cement temperature caused by the ultrasonic motion may facilitate the flow of the resin cement into the dentinal tubules of the root canals [22].

Regarding fracture modes, both cement and dentin adhesive failures were found for RelyX Luting 2 and RelyX U200 cements, corroborating the results of Druck et al. However, as it is difficult to remove all the fillers used in endodontic treatment, residues from gutta-percha and endodontic cements might interfere with the bonding of fiberglass posts.

In order to better understand the role of ultrasound in the cementation of fiberglass posts, different studies and analyzes are recommended. For example, a horizontal displacement test would better resemble the clinical situation of posts inside the root canal. Also, the temperature increase induced by different ultrasound exposure times might modify mechanical and physical properties of the cement; in this study this could not be assessed because we used a single 20-second activation. Another suggested study is the measure of canal wear amount during preparation for fiberglass post cementation to eliminate endodontic sealing materials.

Thus, RelyX U200 cement presented better bond strength and penetration compared to RelyX Luting 2 cement. Ultrasound activation of the cements seems to be a promising step in the quest to improve the bond strength of fiberglass posts, as a significant correlation between penetration and bond strength was found.

Conclusion

The RelyX U200 cement obtained higher bond strength and showed greater penetration in all canal thirds, irrespective of ultrasound activation, compared to RelyX Luting 2 cement. A greater cement penetration was achieved in the middle and cervical thirds for the RelyX Luting 2 and in the middle third for the RelyX U200 when ultrasound activation was applied during cementation. In addition, a significant correlation between penetration and bond strength was observed. Thus, the use of ultrasound seems to be a promising step in the longevity of restorations using fiberglass posts.

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