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Influence of sonic vibration and cement type on the bond strength of fiberglass posts after aging.

Influencia de la vibración sónica y el tipo de cemento en la fuerza de unión de los postes de fibra de vidrio después del envejecimiento.

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Abstract: Introduction: This study evaluated the influence of sonic vibration and thermocycling on the bond strength of fiberglass posts using conventional dual-cured and self-adhesive resin cements. **Material and Methods:** Ninety-six single-rooted endodontically treated teeth were divided randomly into eight groups according to the cement used (dual-cured or self-adhesive resin cement), use of sonic vibration during post accommodation, and aging conditions (24h in distilled water or 5,000 thermal cycles). The fiberglass posts (White Post DC1, FGM) were cleaned with alcohol, treated with silane and cemented with dual-cured (Allcem Core, FGM) or with self-adhesive resin cement (seT, SDI). For groups in which sonic vibration was used, the posts were accommodated, and sonic vibration was applied for 10 s using a special tip placed on top of the post (Sonic Smart Device, FGM). Pull-out tests were performed after storage in distilled water for 24h at 37°C or after thermocycling (5000 cycles, at 5°C and 55°C). The results were evaluated using three-way ANOVA and Tukey's test (α=0.05). **Results:** Significant differences were not observed between the bond strengths of dual-cured (87.93±41.81 N) and self-adhesive cement (82.53±41.43 N). Bond strength for the sonic vibration groups (100.36±42.35 N) was significantly higher than for groups without sonic vibration (70.13±34.90 N). There were significant differences between specimens subjected to thermocycling (98.33±39.42 N) and those stored for 24h in distilled water (72.16±39.67 N). **Conclusion:** It can be concluded that both sonic vibration and thermocycling significantly improved bond strength of fiberglass posts with the two evaluated resin cements.

Keywords: Post and core technique; fiberglass; dentin-bonding agents; resin cement; vibration; ultrasonic waves.

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Resumen: Introducción: Este estudio evaluó la influencia de la vibración sónica y el termociclado en la fuerza de unión de los postes de fibra de vidrio utilizando cementos de resina autoadhesivos y de curado dual convencionales **Material y Métodos:** Se dividieron aleatoriamente noventa y seis dientes tratados endodónticamente de raíz única en ocho grupos según el cemento utilizado (cemento de resina de curado dual o autoadhesivo), el uso de vibración sónica durante la acomodación posterior y las condiciones de envejecimiento (24 horas agua destilada o 5.000 ciclos térmicos). Los postes de fibra de vidrio (White Post DC1, FGM) se limpiaron con alcohol, se trataron con silano y se cementaron con cemento de curado dual (Allcem Core, FGM) o con cemento de resina autoadhesivo (seT, SDI). Para los grupos en los que se utilizó vibración sónica, se acomodaron los postes y se aplicó la vibración sónica durante 10 s utilizando una punta especial colocada en la parte superior del poste (Sonic Smart Device, FGM). Las pruebas de extracción se realizaron después del almacenamiento en agua destilada durante 24 horas a 37°C o después del termociclado (5000 ciclos, a 5°C y 55°C). Los resultados se evaluaron mediante ANOVA de tres vías y la prueba de Tukey (α = 0.05). **Resultados:** No se observaron diferencias significativas entre las resistencias de adhesión del cemento de curado dual (87,93 ± 41,81 N) y el cemento autoadhesivo (82,53 ± 41,43 N). La fuerza de unión para los grupos de vibración sónica (100,36 ± 42,35 N) fue significativamente mayor que para los grupos sin vibración sónica (70,13 ± 34,90 N). Hubo diferencias significativas entre los especímenes sometidos a termociclado (98,33 ± 39,42 N) y los almacenados durante 24 h en agua destilada (72,16 ± 39,67 N). **Conclusión:** Se puede concluir que tanto la vibración sónica como el termociclado mejoraron significativamente la fuerza de unión de los postes de fibra de vidrio con los dos cementos de resina evaluados.

Palabra Clave: *Técnica de perno muñón; fibra de vidrio; recubrimientos dentinarios; cementos de resina; vibración; ondas ultrasónicas.*

INTRODUCTION.

Luting fiber posts inside the root canal is a challenge for clinicians because it is difficult to work with bonding materials in this particular area, due to cavity configuration, poor access and visualization of the post space, and difficulties in moisture control.[1] Bubbles and artifacts present at the cement/post interface can negatively influence the performance of post-and-core restorations and decrease their clinical longevity.[2] The presence of bubbles or voids represent areas of weakness within the material and are thought to occur in lower percentages in thin, uniform cement layers.[3]

There are several ways to improve cement insertion for fiberglass post luting, such as the use of Lentulo drills, Centrix syringes, and elongation tips. It has been reported that the use of one of these alternatives tends to create more homogeneous cement layers, with less bubbles.[4] Also, it has been shown that the use of Centrix syringe for cement application during post cementation positively influences the bond strength to root dentin in comparison to the conventional application technique.[5] Therefore, the homogeneity and quality of the cement layer is influenced by the technique used to apply the resin cement.

The use of sonic vibration has also been proposed to improve the bond of the resin cement to fiberglass posts, favoring the flow of the cement and post accommodation.[6] Studies have suggested that sonic application of etch-and-rinse adhesives can increase the bond strength to coronal dentin because sonic devices transfer energy to the resin monomers, facilitating diffusion of the monomers and evaporation of the solvents.[7,8] Other studies also reported the use of sonic devices[9-11] and ultrasonic equipment 12 for the luting of fiber posts, but in these cases the sonic vibration was used in the phosphoric acid and adhesive layer application. Few studies reported the effect of sonic application directly on the post to improve the bond strength when compared with manual accommodation.[6,13] It has been reported that a sonic device for accommodating posts during the luting procedure resulted in more homogeneous films, with less defects and bubbles.[6]

The Smart Sonic Device is a vibrating sonic energy-generating device that would be able to improve the diffusion and accommodation of different dental materials used in direct and indirect restorations.[7,8,14] It is indicated for use in several clinical procedures, such as the application of adhesive systems in direct restorative procedures and the cementation of fiber posts. However, sufficient studies have not been found to establish a protocol with the use of sonic vibration in the application of dental adhesives in coronary and radicular dentin and for the accommodation of glass fiber posts.[6-8,14]

Sonic devices are already used in endodontics for cleaning the root canal systems, improving debridement and disinfection.[15-18] For the purpose of fluid activation, sonic energy generates mechanical agitation on the tip of files.[15-18] It has been shown that the use of irrigant agitation methods improved canal cleanliness and be more successful in reducing intratubular viable bacteria when compared with conventional syringe needle irrigation;[16,18] and sonic irrigant activation also improved sealer penetration into the dentinal tubules.19 In this way, sonic energy could be used not only in endodontic therapy for irrigant agitation, but also for the accommodation of fiberglass posts during the restorative phases.

Thus, the aim of the present study was to evaluate the pull-out bond strength of fiberglass posts bonded to root dentin with two resin cements with and without the use of sonic vibration after thermocycling. The hypotheses tested were:

i) the type of resin cement (conventional dual-cured or self-adhesive) would influence the bond strength of fiberglass posts;

ii) the use of sonic vibration applied during post accommodation would increase the bond strength of fiberglass posts; and

iii) thermocycling would negatively affect the bond strength values of fiberglass posts.

MATERIALS AND METHODS.

Ninety-six recently extracted human unirradicular teeth were collected, cleaned and immersed in chloramine-T 0.5% at 4°C until use. All teeth were single-rooted with fully developed root apex, free of decay, fractures or root anomalies, and without endodontic treatment. The study was approved by the Institutional Review Board (CAAE n. 51271315.0.0000.0093 and approval n. 1.392.571).

The crowns were removed to create a standard access to the root canal and root portions of 13 mm. The same operator performed the root canal preparations with rotary Protaper universal files (Dentsply Maillefer; Ballaigues, Switzerland). The irrigants used were 2.5% sodium hypochlorite and 17% EDTA. After the final irrigation, the canals were dried with paper points (Roeko paper points; Coltene/ Whaledent, Cuyahoga Falls, Ohio, USA) and obturated with gutta-percha and AHPlus (Dentsply Maillefer; Ballaigues, Switzerland) using the Tagger's Hybrid technique.

After 24 h, the post spaces were prepared using Gates-Glidden drills and number 1 drills of the White Post DC system (FGM, Joinville, SC, Brazil), maintaining an apical seal of 4 mm. The post spaces were irrigated with distilled water and dried with paper points. The specimens were randomly divided into eight groups (n = 12) according to the resin cement used (conventional dual-resin cement, Allcem Core; FGM, Joinville, SC, Brazil) or self-adhesive cement (seT; SDI, Bayswater, Victoria, Australia), conventional post accommodation or sonic vibration of the post during accommodation (Smart Sonic Device; FGM, Joinville, SC, Brazil), and aging condition (24h in distilled water or 5000 thermal cycles).

The fiberglass posts were cleaned with 70% alcohol and dried with an air jet, followed by silane application (Prosil; FGM, Joinville, SC, Brazil) for 60 s. The groups cemented with a dual-cured resin cement (AllCem Core) were etched with 37% phosphoric acid (Condac 37; FGM, Joinville, SC, Brazil) for 15 s, rinsed with water, dried with absorbent paper points, and one layer of the adhesive system (Ambar; FGM, Joinville, SC, Brazil) was applied and light-cured. A LED curing light (Poly Wireless; Kavo, Joinville, Brazil), with irradiance of 1100 mW/cm2 was used throughout the experiment.

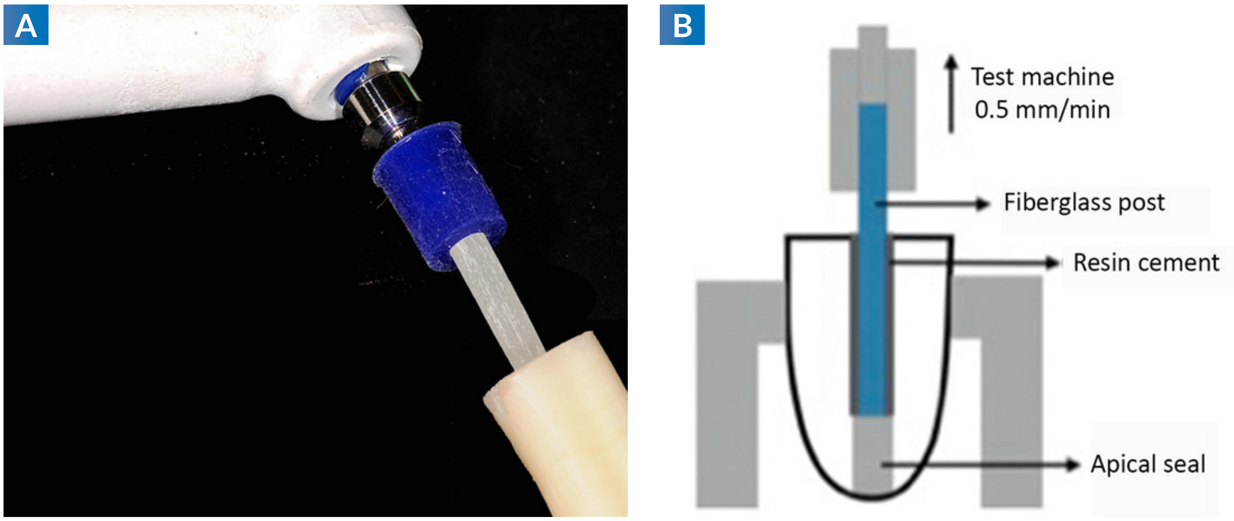
In the groups cemented with self-adhesive resin cement (seT), the post spaces were cleaned with distilled water and dried with absorbent paper points. Posts were coated with cement and slowly seated by finger pressure, and the excess cement was immediately removed. For groups in which sonic vibration was used, the posts were accommodated, and sonic vibration was applied for 10 s using a special tip placed on top of the post with a frequency of 241 Hz (Figure 1A).[6,20] The cement was light-cured for 40 s.

Afterward, the samples were stored in water at 37°C for 24h or subjected to thermocycling (OMC200; Odeme, Luzerna, SC, Brazil) with 5000 cycles at temperatures of 5°C and 55°C with a dwell time of 30 s. Pull-out tests were performed on all samples using a universal testing machine (DL2000; EMIC, São José dos Pinhais, PR, Brazil) at a crosshead speed of 0.5 mm/min (Figure 1B). The data were statistically analyzed using three-way ANOVA (luting material, use of sonic vibration and aging) and Tukey's test (α=0.05).

The post surfaces were analyzed using a stereo-microscope at 10× to 57× (SZX9; Olympus, Tokyo, Japan) to determine areas with cement after the pull-out test.

The surfaces of each post were classified according to the percentage of cement. Surfaces ≥50% covered with cement were scored 1, and surfaces with <50% coverage were classified as score 2.[6,21]

Figure 1. Sonic vibration and schematic configuration used in tests.



A: Sonic vibration (for 10 s) was applied with a specific tip placed on top of the post. **B:** Schematic configuration of the pull-out tests, performed using a universal testing machine at a crosshead speed of 0.5 mm/min.

Figure 2. Failure surface classification after pull-out bond strength test.

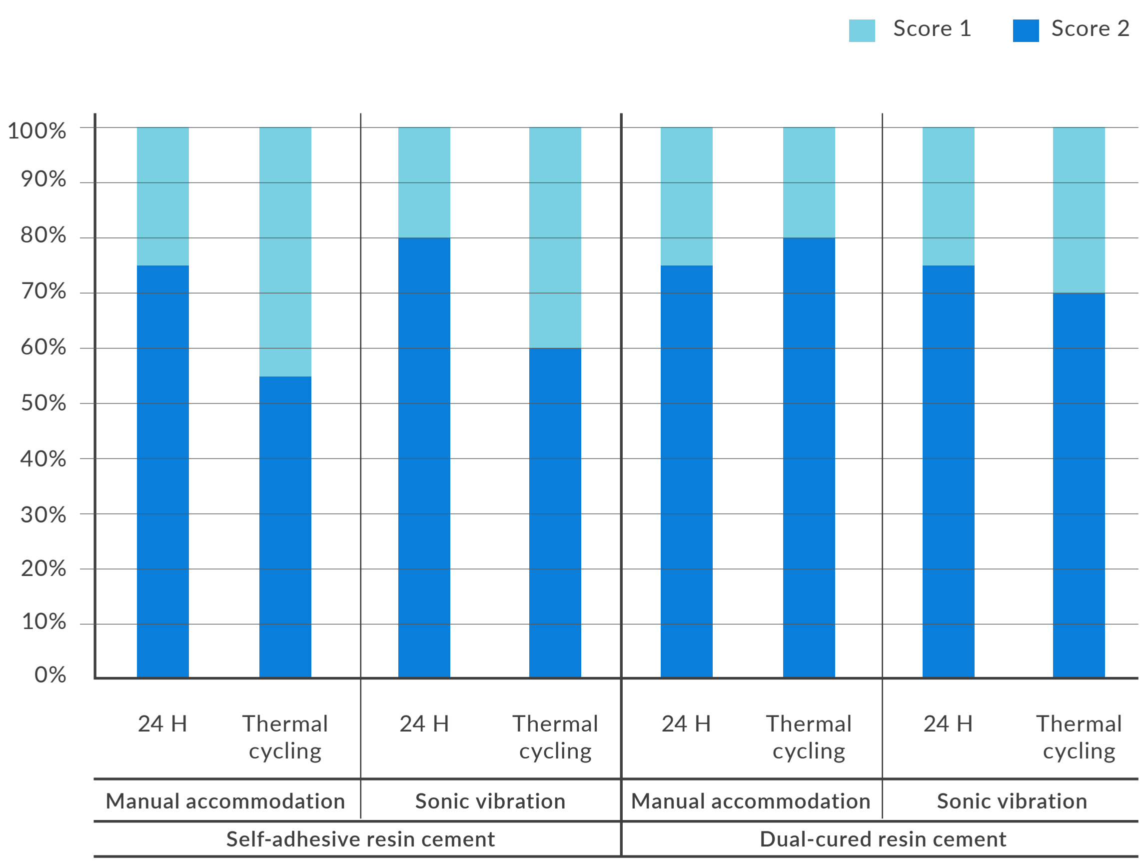


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Table 1. **Means and standard deviations for bond strength of fiberglass posts according to resin cement, use of sonic vibration and aging.**

Luting material	Sonic vibration	Bond strength (N)	
		Distilled water for 24 h	After thermocycling
Dual-cured resin cement	No	60.31 ± 19.95[ab]	84.68 ± 39.62[ab]
	Yes	90.57 ± 47.29[ab]	92.46 ± 36.96[ab]
Self-adhesive resin cement	No	43.09 ± 15.35[b]	107.79 ± 33.32[a]
	Yes	94.59 ± 43.79[ab]	108.47 ± 47.22[a]

Values followed by the same superscript letter are statistically similar (p>0.05).

RESULTS.

The mean values and standard deviations of the pull out bond strength are shown in Table 1. There were statistically significant differences for use of sonic vibration (p<0.001) and aging (p=0.002), but there were no significant differences regarding luting materials (dual-cured resin cement: 87.93 ± 41.81 N; self-adhesive resin cement: 82.53 ± 41.43 N).

Significantly higher bond strength values were observed in groups subjected to sonic vibration (100.36 ± 42.35 N) than in groups with conventional accommodation (70.13 ± 34.90 N). Significantly higher bond strength values were observed after thermocycling (98.33 ± 39.42 N) than for 24h-water storage (72.16 ± 39.67 N). Double and triple interactions were not statistically significant (p>0.05). All groups exhibited a predominance of score 1 failures, indicating prevalence of adhesive failure between the resin cement and dentin (Figure 2).

DISCUSSION.

Different methods can be used to evaluate the bond strength of fiberglass posts in endodontically treated teeth. Push-out tests require cutting of several slices of the root and can be more difficult to execute than the pull-out test; however the root thirds can be individually evaluated.[22,23] The pull-out method is widely recognized in the literature for assessing the bond strength of posts.[24] Among its advantages, it has a better stress distribution and is considered accurate to measure the bond strength between root dentin and post.[25] Also, it is more suitable than the push-out tests to measure the post retention force along the canal,[26] because shear forces are generated parallel to the adhesive interface, providing a better estimation of the bond strength.[27]

In the present study, conventional dual-cured and self-adhesive resin cements were evaluated and the results showed similar bond strength performance. Therefore, the first hypothesis, that the type of resin cement would influence the bond strength of fiberglass posts, was rejected. Conventional dual-cured resin cements are usually used to lute fiber posts, but the number of operative steps makes the adhesive technique difficult and more complex. On the contrary, self-adhesive cements are unable to demineralize the underlying dentin layer, interacting only superficially with the substrate; however, acidic monomers effectively bind calcium present in the dental tissue, establishing a chemical bond between dentin and cement.[28] Other studies have also reported similar bond strength results between conventional and self-adhesive resin cements for post cementation,[29-31] reinforcing that self-adhesive cements are well indicated for the adhesive luting of fiber posts.

The bond strength of resin cements has been reported in the literature, as well as the degree of conversion of these materials.[32,33] However, little is known about the behavior and deformations that occur in situ during polymerization, especially in the luting of intracanal posts. One of the possible explanations is the difficult to adapt the measuring instruments in the small dimensions of the root canal. However, despite the difficulties, Pulido *et al*.,[34] evaluated in situ the deformations that occurred during polymerization and the degree of conversion of resin cements in root canals using micro-Raman spectroscopy.

The authors reported that the dual-cured resin cement (RelyX ARC) showed higher degree of conversion (87.5%) when compared with the self-adhesive (RelyX U200, 55.9%); and for both of the resin cements, the degree of conversion values was higher at the cervical region than at the apical region of the root canal.[34] It is worth mentioning that only one study evaluated the in situ degree of conversion of simplified etch-and-rinse adhesives applied manually or with a sonic vibration device before fiber post cementation.[14] But, in this case, the evaluation was performed on the adhesives, not on the resin cement.

The present study showed that the use of sonic vibration during cementation of fiberglass posts increased the bond strength to root dentin, so the second hypothesis, that sonic vibrations during post accommodation would increase the bond strength of fiberglass posts, was accepted. In the present study, the use of sonic vibration during the cementation procedure increased the bond strength when compared to conventional luting. One of the possible explanations is that sonic vibrations reduced the formation of defects in the cement film. In theory, the more homogeneous the resin cement film, the higher the bond strength. Mushashe *et al*.,[6] evaluated the use of a sonic device for accommodating posts during the luting procedure. Despite the lack of statistical differences between the groups regarding bond strength, it was observed microscopically that the samples where sonic vibration was used showed more uniform cement films in all thirds as compared to the control group.

The sonic vibration was performed with a specific tip of the device placed on the top of the post, in its coronary portion. The idea behind this methodology is not to directly vibrate the cement, so as not to accelerate the setting and interfere with the insertion of the fiber post. Therefore, after inserting the post in the post space, the vibrations on the post would reach the cement line, reducing the viscosity of the luting material, eliminating bubbles and increasing homogeneity.[6,10] Regarding resin cements, especially self-adhesive cements, there is a recommendation to not use Lentulo spirals to insert the cement into a root canal as this will accelerate setting excessively. For this reason, the device's specific tip was used to vibrate the post, avoiding excessive vibration in the cement. This methodology, vibrating the post instead of the resin cements, has been previously described in the literature.[6,20]

Sonic vibration devices used either for endodontic irrigation or restorative procedures should allow the use in different situations and clinical applications, in a way that the clinician does not have to buy more than one equipment with similar principles and functionalities. The two most known sonic activation irrigation systems are EndoActivator (Dentsply Maillefer, Ballaigues, Switzerland) and EDDY (VDW, Munich, Germany).

EDDY uses a flexible polyamide tip and is activated with 5000 to 6000 Hz by an air-driven handpiece (Air Scaler).[35] EndoActivator, on the other hand, is a cordless sonic handpiece to activate highly flexible polymer tips, with a frequency of 33–167 Hz.[35] Considering the frequencies of these two devices, EndoActivatior has a lower frequency range than Smart Sonic Device (170 - 241 Hz), used in the present study to accommodate the posts.

Even though *in vitro* studies cannot exactly simulate the conditions present in the oral cavity, it is possible, to some extent, to simulate some of the oral cavity environment through artificial aging procedures. In this way, laboratory studies can predict similar outcomes when compared to those obtained in clinical situations.[36] Considering the available protocols for artificial aging, thermal cycling seems to be a valid method to accelerate the aging of restorative materials, and it has been proposed that 10,000 cycles approximately represent one year of clinical service.[36,37] In the present study, 5,000 thermal cycles were performed, as well as in other previous studies that also evaluated the bond strength of fiber posts to root dentin after shorter thermocycling periods.[38-42]

In this study, the results were higher after thermocycling than in groups immersed in water for 24 h. Therefore, the hypothesis that thermocycling would negatively affect the bond strength values of fiberglass posts was rejected. Previous studies have also found similar results, showing higher bond strength values after thermocycling for the luting of fiberglass posts.[38,41,43,44]

Thermal stresses act as stimuli for finalizing the chemical reaction of the cements, increasing the bond strength of the materials overtime.[41] Finally, this result can also be explained by the fact that the chemical polymerization reactions of dual and self-adhesive resin cements extend over periods longer than 24 h and can extend up to 7 days.[45]

The failure mode most frequently found in the present study was adhesive between the cement and dentin, for both self-adhesive and dual-cured resin cements. This finding corroborates the well-known statement that the dentin-cement interface is the most critical for the luting of fiber posts, because in this area there is greater stress contraction.[46]

Finally, it is important to mention the limitations of the present study, which include the use of few luting agents (one of each type of resin cement, which may not reflect the behavior of all the materials of these groups) and a short period of aging. Further research on fiberglass post cementation using sonic vibration is necessary to validate its use with different cements and techniques. In addition, studies of sonic vibration associated with longer storage periods and different aging methods are fundamental to validate the technique and to verify whether the results observed here can be extrapolated to other materials and to clinical situations.

However, it is important to emphasize that although both resin cements presented similar bond strength results, self-adhesive cements have important clinical advantages for post cementation. Because they do not require dentin pretreatment, technique sensitivity and the number of application steps are considerably reduced, shortening the overall clinical treatment time. Therefore, for the luting fiber posts, self-adhesive resin cements can be considered the best option, since they provide easy application and good bond strength performance.

CONCLUSION.

Sonic vibration during post accommodation and aging with thermocycling significantly improved bond strength of conventional dual-cured and self-adhesive resin cement between fiberglass posts and root dentin. Both resin cements presented similar bond strength values.

Conflict of interests: The authors declare that they have no competing interests.

Ethics approval: The study was approved by the institutional review board of Universidade Positivo, Curitiba, Brazil (CAAE: 51271315.0.0000.0093 and approval number: 1.392.571).

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