Effect of Cementation Materials and Sonic Application on Push-Out Bond Strength of Fiber Posts to Root Canal Dentin

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Abstract

The purpose of this study was to evaluate the effect of a sonic application on the bond strength of fiber post to root canal dentin luting with two materials.

Twenty mandibular premolars were endodontically treated and divided into four groups according to the cementation materials and post insertion techniques; RelyX Unicem/conventional technique, RelyX Unicem/sonic application, Multicore flow/conventional technique, Multicore flow/sonic application. After post cementation and 24 hour-storage, the roots were sectioned into six slides (two-coronal, two-middle, two-apical region) and the push-out test was performed. The failure mode was evaluated. The result was analyzed using Mann-Whitney U test, Kruskal-Wallis and Dunn's test were performed.

The results revealed that the sonic application did not affect the push-out bond strength of the fiber post in either of the luting materials but tended to yield better results in the resin composite core material group. The resin cement showed a significant higher bond strength, irrespective of the mode of application. Regional factor affected the bond strength only in resin cement group. There was a predominance of adhesive failure in all groups.

The sonic application did not significantly improve the adhesion to the fiber post. Luting fiber post with resin cement provided the better result compared to resin composite core material.

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Introduction

Endodontically treated teeth with excessive loss of the tooth structure were traditionally restored with *post and core* systems. Currently, fiber posts are being popularly used in the restorative treatment of endodontically treated teeth as they offer many advantageous properties, such as favorable esthetic outcomes, easy operation, and a modulus of elasticity that is similar to dentin, providing favorable and repairable fractures.[1,2] Nevertheless, the failure of fiber post restoration could occur. The most common mode of failure associated with the fiber posts was post debonding, which occurred between the post-cement, cement-dentin interface, or cohesive failure of cement.[3]

Several procedures for improving the bond strength of fiber posts have been recommended in various literature. Fiber post surface treatment, as well as cement application techniques, appeared to have a significant impact on fiber post retention to root canal dentin.[4,5,6,7] For cement application methods, it was reported that significantly higher bond strength was obtained when cement was applied only into the root canal compared with the application of cement both into the root canal and around the fiber post.[4] In order to enhance the fiber post retention, a lentulo spiral instrument has been reported as a tool for cement application that improved bond strength values of post-cement-dentin complexes.[8] However, using the lentulo spiral instrument should be concerned about premature polymerization of dual-cure resin cement prior to fiber post insertion due to the increased energy input.[9,10] Therefore, some manufacturers do not recommend this method.

Sonic and ultrasonic applications have been used in dentistry for a variety of purposes, including eliminating smear layers, activating root canal sealers, and improving the effectiveness of root canal cleaning for root canal treatment.[11,12,13] In restorative dentistry, the use of sonic and ultrasonic

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applications has been introduced for seating inlays or veneer restoration to alter the viscosity of resin-based luting cement, which is a thixotropic material changed from a solid to a liquid state. This technique could enhance the surface wettability or surface energy and increase the flow capacity of the luting material, consequently decreasing the film thickness.[14,15] The sonic application technique was utilized to apply the adhesives inside the root canal prior to fiber post insertion to decrease viscosity. The low viscosity provided superior wettability and promoted deeper penetration of the adhesives, resulting in superior bond strength between fiber posts and intraradicular dentin.[16,17,18] In addition, one study revealed that sonic vibration during the post accommodation showed homogeneous resin cement films.[19] Another study found that using a sonic device in the application of self-adhesive resin cement promoted an increase in bond strength value.[20]

For fiber post cementation, resin-based luting agents consisting of resin cement and resin composite core material were used. The resin composite core material has a modulus of elasticity close to that of dentin and fiber post. It has become popular since it provides convenience for clinicians in using a single material for both cementation of fiber post and core-build up, thereby reducing the number of interfaces among the materials to establish a monoblock.[21] One study revealed higher bond strength of using resin composite core material over resin cement.[22] However, resin composite core material has a higher viscosity than resin cement. The low viscosity resin cement would be easier to inject into the root canal and provide good wettability that could be in intimate contact with the root canal dentin and fiber post.

Since the viscosity of material could be changed by energy input like sonic vibration and it consequently promote resin cement flow during luting. The vibration process may increase the bond strength of the post to root canal dentin. Moreover, the air bubbles that occur during cementation might be reduced with this method. However, the flow characteristic of luting materials may be affected by the types of materials as well. High viscosity luting resins such as resin composite core material and low viscosity luting resins such as resin cement may response differently to the sonic vibration technique. The study regarding the use of sonic application for fiber post cementation process is still very limited.

The purpose of the present study was to evaluate the effect of sonic application on the push-out bond strength of the fiber posts to different regions of root canal dentin when luting with self-adhesive resin cement and resin composite core material. The null hypothesis was that sonic application, types of luting materials, and region did not affect the push-out bond strength of fiber posts to root canal dentin.

Materials and methods

Specimen preparation

Twenty human mandibular premolars with one straight root canal and a root length was in between 14.0 – 16.0 mm measured from root apex to cementoenamel junction were used in this study. All teeth did not have crack lines, had no root caries, and had fully developed apices. The crowns were sectioned above the cementoenamel junction by 2 mm perpendicular to the long axis of the teeth. The length of the root canal was determined by the no. 10 K-file until it was presented at the point of apical foramen. The working length was obtained by subtracting 1 mm from the root canal length. The endodontic treatment started with the no. 15 K-file. ProTaper Gold rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) were sequentially used, S1, S2, F1, F2, and F3, to the full working length. After every instrument change, the canals were irrigated with 2.5% sodium hypochlorite and finally rinsed with 17% EDTA, followed by 2.5% sodium hypochlorite. All preparation canals were obturated using gutta-percha and Grossman's sealer with the warm vertical condensation technique. Specimens were stored at 100% humidity for one week. All the post spaces were then prepared to a depth of 11.0 mm using D.T. Finish drills No.3 supplied by the manufacturer of the used fiber post system. The post spaces were irrigated with normal saline solution and dried with absorbent paper points. After canal preparation, all roots were embedded in an autopolymerizing acrylic resin.

Twenty quartz fiber posts, size no.3 (D.T. Light-post Illusion X-RO, RTD, St-Egreve, France) were used in this study. To create the optimal bonding between the fiber posts and luting materials, all fiber post surfaces were treated with 4.5% hydrofluoric acid (Ivoclar Vivadent, Schaan, Liechtenstein) for 60 seconds followed by rinsing and air drying, and then the single component silane coupling agent (Monobond S, Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the entire post surfaces for 60 seconds and dispersed with a strong stream of air. The material used in this study and their chemical compositions are presented in Table 1.

Material	Manufacturer	Composition
D.T. Light-post Illusion X-RO	RTD, St-Egreve, France	60% quartz fiber, 40% epoxy resin
N-etch	Ivoclar Vivadent, Schaan, Lichtenstein	37% phosphoric acid
IPS Ceramic Etching Gel	Ivoclar Vivadent, Schaan, Lichtenstein	4.5% hydrofluoric acid gel
Monobond S	Ivoclar Vivadent, Schaan, Liechtenstein	ethanol, [3-(methacryloyloxy)propyl] trimethoxysilane
Excite DSC	Ivoclar Vivadent, Schaan, Liechtenstein	37% H_3PO_4, HEMA, phosphoric acid acrylate, dimethacrylates, silica, ethanol, catalysts, stabilizers, fluoride
Multicore flow	Ivoclar Vivadent, Schaan, Liechtenstein	dimethacrylates, 71% inorganic fillers (barium glass, Ba-Al-fluorosilicate glass, silicon dioxide, and ytterbium trifluoride)
RelyX Unicem	3M ESPE, St. Paul, MN, USA	55%-65% glass powder 15%-25% methacrylated phosphoric acid esters 10%- 20% TEGDMA 1%-5% Silane-treated silica 1%-5% Sodium persulfate

Table 1. Materials, composition, and manufacturer of product used in the study.

The root canal dentin was treated with 37% phosphoric acid (N-etch, Ivoclar Vivadent, Schaan, Lichtenstein) to remove the smear layer and endodontic remnant for 15 seconds, followed by rinsing and drying with cotton pellets and absorbent paper points.[23] For the bonding procedure, specimens were randomly divided into four groups of five teeth each, according to the cementation materials and post insertion techniques. Two post insertion techniques were applied in this study; a conventional technique without post vibration and a post vibration technique using sonic application. Two cementation materials were used for luting fiber posts; self-adhesive resin cement, RelyX Unicem (3M ESPE, St. Paul, MN, USA) and dual-cure resin composite core material, Multicore flow (Ivoclar Vivadent, Schaan, Liechtenstein). The experimental groups were as follows: (1) RelyX Unicem/conventional technique (RC), (2) RelyX Unicem /sonic application (RS), (3) Multicore flow/conventional technique (MC), (4) Multicore flow/sonic application (MS).

For the groups MC and MS, dual-cure adhesive (Excite DSC, Ivoclar Vivadent, Schaan, Liechtenstein) was applied to the entire etched surface and excessive adhesive was removed with absorbent paper points. Light-curing was performed from the coronal direction for 20 seconds (Elipar Trilight; 3M ESPE, St. Paul, MN, USA). Multicore flow was injected into the root canal using an automix cartridge attached with an elongation tip. A fiber post was then inserted centrally into the canal. For the groups in which the sonic device (Xiaomi PINJING EX3: Sonic Electric Toothbrush) was used, the sonic device tip was applied on the top of the fiber post for a period of 10 seconds and frequency of 31,000 times/min. Then light-curing was performed, in which the tip of the LED light-curing unit was placed directly on the post for 40 seconds. Specimens from all groups were subsequently stored at 100% humidity for 24 hours.

Push-out bond strength test

After 24-hour storage, each specimen was sectioned horizontally with a low speed cutting machine (Isomet 1000; Buehler Ltd., Lake Bluff, Illinois, USA). Two mm of the coronal third of the root was initially cut out. Then the roots were serially sectioned to obtain six 1±0.1 mm thick slices. The thickness of each slice was verified and recorded using a digital caliper (Mitutoyo CD15, Mitutoyo Co., Kawasaki, Japan).

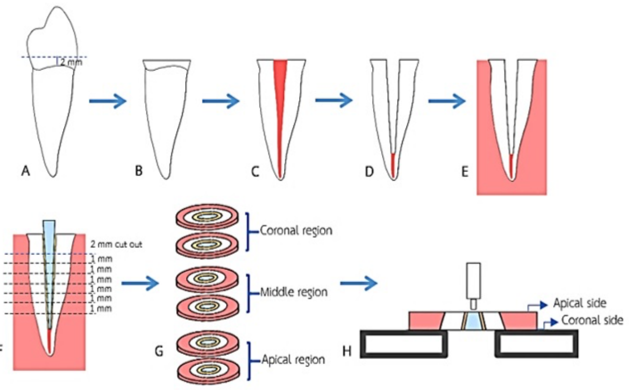

Figure 1. Specimen preparation and testing apparatus for push-out test. A: Lower premolar. B: Decoronation above CEJ 2 mm. C: Endodontic treatment. D: Post space preparation. E: Specimen embedded in acrylic resin. F: Fiber post cementation. G: Six 1-mm thick slices. H: Push-out test apparatus.

The first two slices were termed as coronal region, the next two slices were termed as middle region and the last two slices were termed as apical region. The push-out test was performed with a universal testing machine (Lloyd instruments, LRX-Plus, AMETEK Lloyd Instrument Ltd., Hamphshire, UK) with a 0.4 mm diameter metallic loading plunger at a crosshead speed of 0.5 mm/min. The plunger was positioned at the center point of the post, close to the specimen surface without contact. The load was applied from the apical to coronal direction until the post was dislodged (Figure1).

The maximum load was recorded in Newton (N) and the push-out bond strength in megapascals (MPa) was then calculated by the formula F/A, in which F is the maximum load (N), and A is the bonded surface area (mm^2), which was calculated as follows: $A = \pi(R+r)\sqrt{(R-r)^2 + h^2}$, in which R is cervical failure area radius (mm), r is apical failure area radius (mm), and h is slice thickness (mm). The radius was measured with a stereoscopic microscope (SMZ1500, Nikon Instech Co.,Ltd., Tokyo, Japan).

Determine the mode of failures

After push-out testing, all specimens were examined under a stereoscopic microscope. The failure modes at the apical side of specimens were classified into four groups: (1) adhesive failure between post and cement; (2) adhesive failure between root canal dentin and cement; (3) cohesive failure of cement; and (4) mixed failure. The failures were categorized with a decision that more than 70% surface area of those failures was observed.

SEM observation

Four teeth were prepared with the same protocol as each push-out bond strength experimental group to represent specimens for scanning electron microscope observation. Each specimen was sectioned into six slices. One slice from each region of the root, consisting of coronal, middle, and apical regions, was observed using a scanning electron microscope (QUANTA 400, Thermo Fisher Scientific, Czech Republic). The bonded interfaces were observed, and SEM micrographs were taken.

Statistical analyses

The push-out bond strength (PBS) values of two coronal specimens were considered to represent the coronal region of the post space, two middle specimens represented the middle region, and two apical specimens represented the apical region. Therefore, the sample size (n) of each experimental group in each region was ten. Since normal data distribution and homogeneity of variance (Levene's test) were not indicated, non-parametric statistics were used to compare the data. A Mann-Whitney test was used to compare the PBS mean rank between conventional and sonic application techniques and between RelyX Unicem and Multicore flow. Furthermore, the Kruskal-Wallis test was used to test the effect of the regions on the PBS data. Dunn's test for pairwise multiple comparisons of the ranked data was performed as a post hoc test. All statistical testing was performed at a 95% level of confidence.

Results

Table 2 shows the means and standard deviations of PBS for each experimental condition. For fiber posts bonded with RelyX Unicem, the conventional technique provided similar bond strengths to the sonic application technique at the middle (P=.55) and apical regions (P=.94). However, at the cervical region, the conventional technique provided significantly higher bond strength compared with the sonic application (P=.028).

Experimental conditions	Bond strength (MPa) Conventional	Sonic
RelyX Unicem		
Coronal	6.29 ± 4.61 †	2.84 ± 1.77 †, ‡
Middle	5.62 ± 3.06 *	4.70 ± 2.52
Apical	9.51 ± 3.74	*9.38 ± 2.22 * *
Multicore flow		
Coronal	1.77 ± 1.37	2.45 ± 1.55 ‡
Middle	1.12 ± 0.86	1.65 ± 1.21
Apical	1.67 ± 1.20	2.98 ± 2.67

Table 2. Means and standard deviations of push-out bond strength for each experimental condition. * Indicates significant difference between regions (*P* < 0.05),
† Indicates significant difference between techniques (*P* < 0.05), ‡ Indicate no significant difference between RelyX Unicem and Multicore flow.

When comparing bond strength between root regions, the results revealed that bond strength at apical regions was statistically higher than that at coronal and middle regions for both post-application techniques (P< 0.05), and there were no significant differences in bond strength between coronal and middle regions (P > 0.05). For the group bonded with Multicore flow, the average PBS with sonic application techniques was higher than that of conventional technique for all three regions, however, no significant difference in bond strength was noted among the two post application techniques (cervical-P=0.15, middle-P=0.17, apical-P=0.20). There were no significant differences in PBS among the three regions when the posts bonded with Multicore flow for both techniques (P > 0.05).

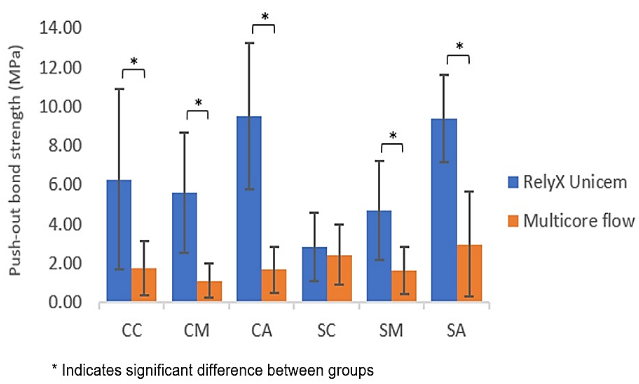

Figure 2. Bar graphs comparing PBS between two materials.

Figure 2 presents bar graph comparing PBS between two materials when the same techniques and regions were considered, RelyX Unicem provided significantly higher PBS compared to Multicore flow ($P < 0.05$), except for using sonic application in the coronal region, where no significant difference between cementation materials was observed.

Experimental conditions	Failure mode *							
	Conventional				Sonic			
	Ad:P/C	Ad:D/C	Co	Mixed	Ad:P/C	Ad:D/C	Co	Mixed
RelyX Unicem								
Coronal	0	5	0	5	0	7	0	3
Middle	0	7	0	3	0	4	0	6
Apical	0	2	0	8	0	1	0	9
Total	0	14	0	16	0	12	0	18
Multicore flow								
Coronal	5	5	0	0	4	6	0	0
Middle	3	7	0	0	5	5	0	0
Apical	2	8	0	0	4	5	0	1
Total	10	20	0	0	13	16	0	1

Table 3. Failure mode frequency for each experimental group *Ad:P/C = Adhesive failure between post and cement, Ad:D/C = Adhesive failure between root canal dentin and cement, Co = Cohesive failure of cement, Mixed = Mixed failure.

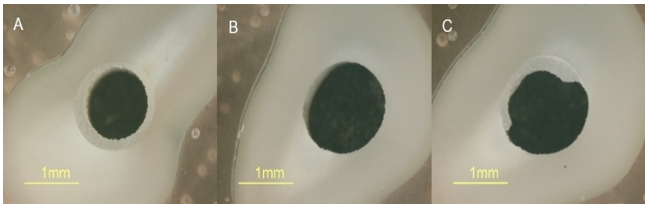

Figure 3. Representative stereo microscopic images of failure modes. A: Adhesive failure between post and cement, B: Adhesive failure between root canal dentin and cement, C: Mixed failure**.**

Table 3 shows the number of failure modes of debonded specimens in each experimental group. There were two main modes of failure in the RelyX Unicem group: dentin/cement adhesive failure (Figure 3B) and mixed failure (Figure 3C). For the Multicore flow group, the specimens presented predominantly dentin/cement adhesive failure, and approximately one third of the specimens failed as post/cement adhesive failure (Figure 3A) for both application techniques. Figure 4 presents SEM photographs of the fiber post/cement and the cement/dentin interfaces. The fiber post/cement interface demonstrates better intimate adaptation than the cement/dentin interface. With sonic application, smaller gaps were detected at the dentin and post interface.

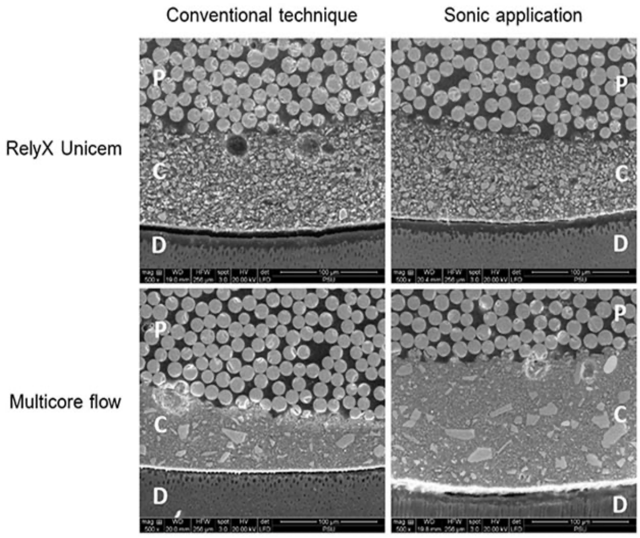

Figure 4. Scanning electron micrographs of representative bonded interfaces of coronal specimens (P is post, C is cement, and D is dentin).

Discussion

For improving bond strength between fiber post and root canal dentin, the present study proposed the sonic vibration as an alternative technique to use in fiber post cementation procedure. Regarding the difference in fiber post insertion techniques in this study, the results showed that technique possibly did not affect the bond strength of fiber post because there was no statistically significant difference between the two techniques in all groups except the cervical region in the RelyX Unicem group, where sonic application statistically significantly decreased the push-out bond strength compared with conventional technique. The type of luting material affected the bond strength. Fiber post bonded with RelyX Unicem provided a higher push-out bond strength value than Multicore flow regardless of techniques. In addition, regional factor affected the bonding to the root canal when RelyX Unicem was used. Therefore, the null hypothesis in this study was rejected.

Based on our preliminary findings, the ultrasonic device has been attempted to be used for fiber post cementation. Due to the high consistency of Multicore flow and the high frequency of ultrasonic. It can be noticed that ultrasonic vibration had no effect on cement flow. As a result, the sonic vibration was utilized in this study because it has a low frequency and a wide wavelength, which was supposed to correspond to the luting material with a high consistency. To avoid a premature polymerization of cement prior to adequate fiber post seating, the sonic application was applied on top of the post after the fiber post had already been properly seated.

When the RelyX Unicem, which is a self-adhesive resin cement, was used, the results showed that sonic application did not affect the push-out bond strength, except in the cervical region where a statistically significant decrease in push-out bond strength was obtained compared with the conventional technique. Since the self-adhesive resin cement has a low molecular weight and consistency, the sonic vibration might not affect this type of luting material in general. In the controversy, the strong vibration of sonic application possibly disturbed the bonding or adaptation to the fiber post in the coronal region. These findings are in accordance with one previous study which found that the use of sonic to apply resin cement did not promote an increased bond strength value, but it did provide more homogeneous and less bubbled cement films.[19] In contrast, another study demonstrated that using sonic application increased the bond strength values of self-adhesive resin cement.[20]

The resin composite core material has a high molecular weight and consistency. It was apparently less fluid than self-adhesive resin cement. When sonic application was used in the Multicore flow group, it had a tendency to increase the push-out bond strength of fiber posts, especially in the apical region, where a nearly twofold bond strength value was presented, but a statistically significant difference was not found between the two techniques possibly due to the large standard deviation.

When the push-out bond strength was compared between two luting materials, there was a statistically significant difference in all groups except one that used sonic application in the cervical region. Thus, the properties of the material itself might have more effect on the bond strength than techniques. RelyX Unicem generally showed much higher push-out bond strength values than Multicore flow. The low viscosity of RelyX Unicem might create better adaptation to the post and root canal surface, especially in a properly fitted canal. However, in the flare canal, which has a thick layer of luting resin, the strength of the luting materials may be compromised. Therefore, selection of luting materials needs to be concerned with various factors, such as cement space and remaining tooth structure. Although the low viscosity material is easier to handle and a higher bond strength was presented, its strength may be compromised. According to previous studies, resin composite core materials with a higher filler content tended to promote fracture resistance, flexural strength, and a reduction in water sorption.[24,25]

In the RelyX Unicem group, the push-out bond strength of the apical region was significantly higher compared with the coronal and middle regions. If the bond strength was correlated with resin tag formation, the bond strength value in the coronal region should increase as the density of dentinal tubules and the amount of dentin surface available for bonding increased, but the results of this study showed that when RelyX Unicem was used, the bond strength was significantly higher in the apical region. [26] It might be assumed that the root canals in the cervical region are wider, requiring a greater amount of resin cement, consequently increasing stress at the interface during polymerization shrinkage. That could explain why the bond strength of the cervical region was lower than the apical region. On the other hand, regions of the root canal had no effect on the bond strength when Multicore flow was used. The previous study revealed that the core material demonstrated significantly lower polymerization shrinkage than self-adhesive resin cement.[25]

There was a predominance of adhesive failure in all groups, with debonding between dentin and cement being more common than between post and cement since the fiber posts in this study were treated with hydrofluoric acid followed by a silane coupling agent to improve the bond strength between the fiber post and the luting material.[27,28]

These results were in accordance with the SEM evaluation. The fiber post/cement interface appeared to have better intimate contact than the cement/dentin interface (Figure 4). However, Multicore flow had a higher rate of adhesive failure between fiber post and cement than RelyX Unicem and a lower bond strength was presented. It might be considered that Multicore flow, which has a high viscosity, has poor adaptation to fiber posts, as revealed by SEM analysis.

According to the findings of the present study, sonic application had no effect on the push-out bond strength of fiber post, but it tended to produce better results in resin composite core material due to its high viscosity. While statistically significant differences in bond strength were found between resin cement and resin composite core material. The bond strength of resin cement was higher. However, previous studies have shown that resin composite core material has a higher fracture resistance.[24,25] Further research is needed to identify other techniques that are able to increase the bond strength of high viscosity luting resin to obtain both optimal adhesion and fracture resistance of the radicular restored teeth.

Conclusions

Within the limitations of this study, it could be concluded that sonic application of fiber post cementation with resin cement or resin composite core material did not improve the bond strength of fiber posts to the root canal dentin but trended to yield higher average bond strength in resin composite core material. Regardless of application technique, resin cement presented a higher bond strength compared with resin composite core material. Regional factor affected the bond strength of self-adhesive resin cement but not for resin composite core material.

Declaration of Interest

The authors report no conflict of interest.

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