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Original Research Article

Influence of the retropreparation ultrasonic insert type on the adhesive union of fiberglass posts within the root canal

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Abstract

Objective: To assess the displacement resistance of cemented fiberglass posts within the root canal, based on the type of ultrasonic retropreparation insert used during endodontic surgery. **Material and methods:** Thirty primary bovine incisor roots, measuring 17 mm in length, underwent endodontic treatment. After a seven-day period, the teeth were debrided and prepared to receive 13 mm posts. The roots were randomly divided into three groups, depending on the type of ultrasonic retropreparation insert used: GC – no retropreparation (control); GL – smooth insert; GD – diamond insert. The posts were cemented using RelyX U200® within the root canal. Subsequently, the roots were immersed in distilled water for 15 days and then sectioned to create specimens with an average thickness of 1.87 mm in each of the root thirds (cervical and middle). These specimens were subjected to a push-out test. Following the test, the fractured samples were examined under a stereomicroscope to determine the fracture pattern. The data obtained were analyzed using a one-way Anova test and non-parametric t-test (α = 0.05). **Results:** There were no statistically significant differences in the cervical third when comparing the tested ultrasonic inserts. However, in the analysis of the middle third, the use of a smooth ultrasonic insert had a significant impact on the adhesion of the intraradicular post ($P < 0.05$). **Conclusion:** The application of a smooth ultrasonic insert during endodontic retropreparation significantly influenced the displacement resistance of intraradicular fiberglass posts cemented in the middle third of the canal. In the cervical third, the type of ultrasonic retropreparation insert used did not affect post retention.

Introduction

Parendodontic surgery serves as an alternative treatment for clinical scenarios where endodontic retreatment has proven unsuccessful or is no longer a viable option. Common operative procedures carried out during endodontic surgery include apicectomy, retropreparation, and apical retrofilling.

Conducting endodontic surgical procedures on teeth that have been rehabilitated with intraradicular posts presents a significant challenge. The execution of such a procedure in this clinical context is hindered by several factors, notably the additional costs incurred by the patient for a new prosthesis and, more critically, the risk of tissue damage or accidents during attempts to remove the posts. Nonetheless, it remains unclear whether the utilization of ultrasonic inserts [20] for retropreparation during the surgical stages compromises the retention of the intraradicular post. These instruments, whether in contact with the post or not, induce vibrations within the root canal through a retrograde route.

Endodontically treated teeth with significant damage require restoration of both the intraradicular and coronal portions. For the intraradicular portion, options include cast metal cores or prefabricated posts [9, 10]. It's worth noting that metallic cores tend to offer lower resistance to fracture in endodontically treated teeth when compared to fiberglass and quartz fiber posts [1]. In contrast, fiberglass posts, aside from contributing to treatment aesthetics, exhibit properties similar to dentin, including an elastic modulus ranging from 18 to 47 Gpa [1]. Moreover, they possess a flexural modulus similar to dentin, a critical factor for ensuring the durability and resistance to fracture of the restoration. The flexural modulus is closely linked to the transfer and propagation of stresses from the post to the tooth structure [8, 25]. Another advantage of fiberglass posts is their capacity to bond effectively with resin cement [9, 15].

When using prefabricated posts, the most common types of failure are related to their retention, often resulting in detachment from the root canal [2]. It's important to note that resin cements, with their varying chemical compositions and application techniques, can yield different bond strengths. Self-adhesive cement, for instance, has been found to exhibit lower microtensile strength compared to conventional cements [24]. However, a study by Bergoli *et al.* [3] suggested that the use of self-adhesive resin cement may be a favorable alternative for bonding fiberglass posts when compared to conventional cements. This is due to the favorable values of bond strength and reduced polymerization stress. Additionally, this technique is less sensitive to external factors and offers a simpler and quicker application process.

In light of the aforementioned considerations, the primary objective of the present study is to assess whether the choice of a specific ultrasonic retro-preparation insert during endodontic surgery has an impact on the resistance to displacement of fiberglass posts that have been cemented within the root canal.

Material and methods

Sample selection and preparation

Thirty primary bovine incisors were carefully chosen for this study and underwent standardization procedures to ensure uniformity. Initially, the apical diameter of the root canal was adjusted to match that of a K-type #20 endodontic instrument (Dentsply/Maillefer Instruments S.A., Ballaigues, Switzerland). The root canals possessed circular cross-sections.

The dental crowns were then precisely sectioned at the cementoenamel junction, and the remaining root length was standardized to 17 mm. The working length (WL), which is the point where endodontic procedures are typically performed, was set to be 1 mm below this standardized measurement, resulting in a WL of 16 mm.

Endodontic preparation

All samples were subjected to manual preparation using K-type stainless steel endodontic instruments (Dentsply/Maillefer Instruments S.A., located in Ballaigues, Switzerland). The chemomechanical preparation followed a specific sequence of K-type instruments: #20, #25, #30, #35, #40, and #45, all of which were utilized along the WL.

During each instrument change, the root canals were thoroughly irrigated using a plastic syringe (BD Solumed, São Paulo, São Paulo, Brazil), equipped with 25 mm 30-gauge NaviTip needles (Ultradent, São Paulo, Brazil). The irrigation solution consisted of 2.5% sodium hypochlorite (Iodontec Industria e Comercio de Produtos Odontologicas Ltda. in Porto Alegre, Rio Grande do Sul, Brazil), with a standard volume of 2 ml applied each time.

After the root canal preparation, a final irrigation step was conducted using 17% trisodium EDTA (Biodinamica, Ibipora, Paraná, Brazil) for a duration of three minutes, with agitation using a #45 instrument. Subsequently, the root canals were thoroughly rinsed with distilled water (Iodontosul, Industrial Odontologica do Sul Ltda., Porto Alegre, Rio Grande do Sul, Brazil) and then meticulously dried using absorbent paper points (Tanari Industria Ltda., Manaus, Amazonas, Brazil).

For the endodontic filling procedure, the root canals were packed with gutta-percha cones and sealed using AH Plus® epoxy resin-based cement (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland). This was accomplished employing Tagger's hybrid technique and a #60 McSpadden® compactor (Dentsply/Maillefer Instruments SA, Ballaigues, Switzerland).

Following the filling procedure, all specimens were temporarily restored using Cimpat® restorative material (Septodont, located in Saint Maur des Fosses, France). They were then placed in a flask filled with distilled water, maintained at a temperature of 37°C, and maintained at 100% relative humidity for two days. This allowed for the complete curing and setting of the endodontic sealer.

Post cementation and specimen preparation

The root canals were meticulously cleared to create the necessary space for the post to be cemented. The removal of the root canal filling extended to a depth of 13 mm, with 3 mm of apical sealing left intact. The canals were then cleaned using kit drills that matched the diameter of the post intended for cementation within the root canal.

Following the unobturation of the canals, the posts were subjected to the cementation protocol in accordance with the manufacturer's recommendations. Prior to use, the posts were disinfected using 70% alcohol (Icarai, São Paulo, São Paulo, Brazil) and subsequently dried. Single Bond Universal® adhesive was applied for a duration of 20 seconds and then dried using air jets for 5 seconds.

The posts were affixed using self-adhesive cement (RelyX U200R, 3M ESPE, St. Paul, MN, USA). The resin cement was administered into the root canal using a centrix syringe (DFL, Rio de Janeiro, Rio de Janeiro, Brazil) equipped with a fine metal tip. The post was then carefully inserted into the root canal and filled with cement up to its most coronal portion to ensure a hermetic seal at the entrance. The cement was photoactivated using an EC450 device (ECEL, Ribeirao Preto, São Paulo, Brazil), boasting a light intensity exceeding 400 mW/cm2, for a duration of 20 seconds. Subsequently, chemical polymerization was carried out for 6 minutes to ensure proper setting.

Inclusion of teeth

The roots were enveloped with a single layer of aluminum foil and subsequently embedded in self-curing acrylic resin (Jet, Artigos Odontologistas Clássico, São Paulo, São Paulo, Brazil). They were securely placed within a square mold measuring 10 mm in length and 10 mm in width. This positioning ensured that the final 6 mm of the root portion remained outside of the resin, as depicted in figure 1.

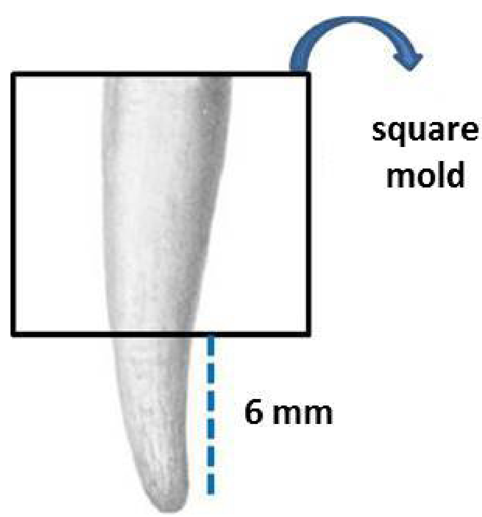

Figure 1 – Schematic drawing of the inclusion of the root in the square mold

Division of experimental groups

The teeth were allocated into three distinct experimental groups (as outlined in table I) through a simple random sampling process, facilitated using Microsoft Excel (Microsoft, USA).

Table I – Experimental groups

Groups	n	Retropreparation ultrasonic insert type
GC	10	Endodontic surgery was not performed
GL	10	Smooth ultrasonic insert
GD	10	Diamond ultrasonic insert

Plasty, retropreparation and apical retrofilling

Root apical resection was carried out by removing the final 2 mm of the root at a 90-degree angle to the tooth's long axis. This procedure was performed using a Zekrya high-speed bur (Dentsply/Maillefer Instruments S.A. in Ballaigues, Switzerland), coupled with a high-speed handpiece (Dabi Atlante, Ribeirão Preto, São Paulo, Brazil) and conducted with a cooling system in place.

The retrograde cavity was then prepared using specific ultrasonic inserts for each of the retrograde groups:
* GL: Employing the E11 smooth ultrasonic insert (WAK'S, São Paulo, São Paulo, Brazil).
* GD: Utilizing the P1M diamond ultrasonic insert (Helse Dental Technology, São Paulo, São Paulo, Brazil).

All inserts were uniformly inserted to a depth of 2 mm within the canal and were activated for 30 seconds using ultrasound, with continuous water cooling, set at power scale 5.

To conduct the apical retrofilling, the Bio-C Sealer material (Angelus, Londrina, Paraná, Brazil) was prepared in strict accordance with the manufacturer's guidelines. It was then carefully placed within the entire 2 mm depth of the retrograde cavity, utilizing a presser type Paiva No. 4 (Golgran Ind Com Instr Odontologicos, São Caetano do Sul, São Paulo, Brazil) for proper placement.

Push-out test

Initially, the roots were precisely sectioned perpendicular to their long axis. Using a cutting machine (Labcut 1010, Extec Corp., Enfield, CT, USA), two thick slices, measuring 1.87 mm ± 0.45 mm in thickness, were meticulously obtained. These slices were consistently obtained at distances of 5 mm (cervical third) and 10 mm (middle third) from the cervical edge of the root, as depicted in figure 2. They were then identified and stored within an oven set at 37ºC under conditions of 100% relative humidity for a period of 7 days.

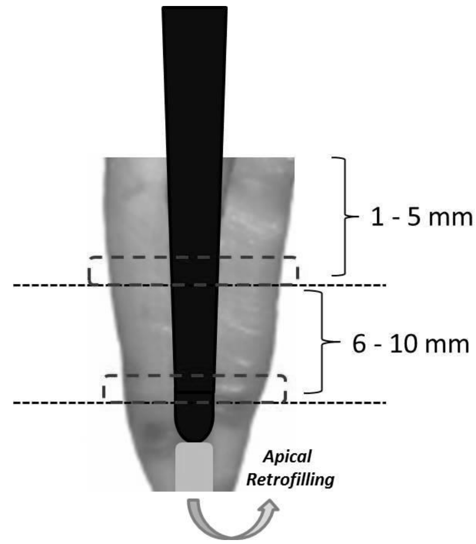

Figure 2 – Schematic diagram of root slices

Subsequently, the specimens were positioned on a stainless steel metal support featuring a central hole measuring 2 mm in diameter. Due to the conical shape of the posts, the load was applied in the apical-cervical direction, originating from the apical surface. This approach ensured that the post would be displaced toward the widest portion of the root canal.

The load was exclusively applied to the post surface using a tip with an approximate diameter of 1 mm, affixed to the EZ-SX universal testing machine (Shimadzu Corp., Kyoto, Kyoto, Japan). A load cell with a capacity of 500 kg (50 N) was selected, and the loading rate was set at 0.5 mm/min. The recorded values were in Newtons (N), and the displacement resistance was expressed in Megapascals (MPa).

To determine the canal's cross-sectional area and calculate resistance, measurements were taken of the diameters of the upper and lower circles of the canal, as well as the section's thickness (which represents the area of a truncated cone) [16].

Following the push-out test, the fractured specimens were meticulously examined using a stereomicroscope at 20x magnification (Stemi 2000, Karl Zeiss, Germany) to identify whether the failure pattern was adhesive, cohesive, or a combination of both.

Statistical analysis

The Shapiro-Wilk test was employed to evaluate the normality of the data. Subsequently, both a one-way Anova test and a non-parametric t-test were utilized to assess bond strength. The significance level was established at 5% ($P \leq 0.05$). All statistical analyses were conducted using GraphPad Prism 7 software (GraphPad Software Inc., San Diego, CA, USA).

Results

Table II presents the mean values of displacement resistance (MPa) for the various experimental groups in different regions of the canal. Concerning the cervical third, there were no statistically significant differences observed among the groups, indicating that the type of ultrasonic insert used for retropreparation did not significantly impact the adhesion of the intraradicular post. In the analysis of the middle third, it was noted that the smooth ultrasonic insert had a noticeable influence on the adhesion of the intraradicular post, with no significant differences observed between the GC and DG groups.

Table II – Bond strength in root segments in the push-out test and strength loss in relation to GC group

Experimental group	Root thirds				P
	Cervical		Middle		
	MPa (±SD)	Strength loss	MPa (±SD)	Strength loss	
GC	17.20^{Aa} ± (4.37)	-----	16.08^{Aa} ± (2.60)	-----	P = 0.494
GL	14.81^{Aa} ± (3.97)	13.86%	11.50^{Ba} ± (3.78)	28.48%	P = 0.072
GD	15.31^{Aa} ± (4.38)	10.98%	14.59^{Aa} ± (4.10)	9.26%	P = 0.711
P	P = 0.948		P < 0.05		

Means followed by different uppercase letters in the column differ significantly in the analysis of variance and means followed by different lowercase letters in the row differ significantly in the non-parametric t-tests, at a significance level of 5%

Figure 3 illustrates the percentage of failures in the samples within the cervical and middle thirds of the root. It's worth noting that a higher percentage of cohesive failures were observed in both the cervical and middle thirds across all groups. Adhesive failures, however, were not observed in any of the groups.

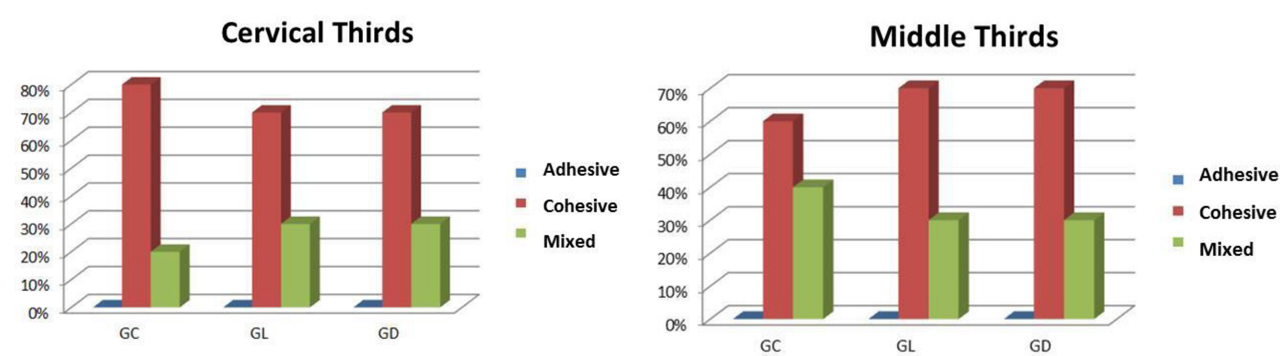

Figure 3 – Failure patterns (%) after tested protocols

Discussion

Endodontically treated teeth are more susceptible to fracture when compared to vital teeth [6]. This vulnerability stems from the reduced quantity and compromised quality of the remaining dental crown tissues [26]. Given this circumstance, the utilization of intraradicular posts often becomes essential in restorative treatments to evenly distribute masticatory forces [14]. Among the various types of posts available on the market, fiberglass posts offer certain advantages owing to their properties. Notably, their elastic modulus is akin to that of dentin, rendering them less prone to fracture [21].

Despite the high success rates reported in the literature, failures can still occur following the completion of primary endodontic treatment, primarily due to the presence of pathogenic microbiota [19]. There are two treatment modalities employed to address these infections, both intra- and extraradicular: endodontic retreatment or endodontic surgery. Surgical treatment is indicated when non-surgical retreatment efforts have proven unsuccessful or are deemed impractical [12]. A common scenario involves the presence of overly bulky and/or lengthy intraradicular posts, attempting to remove which may risk tooth fracture and consequently necessitate extraction.

The utilization of bovine teeth in the materials and methods section was motivated by their ready availability, ease of standardization, and their closely resembling human teeth in terms of the proposed testing methodology. Studies conducted by Krifka *et al.* [13] and Wegehaupt *et al.* [23] have demonstrated that bovine dentin can effectively substitute human dentin in shear resistance experiments.

Although certain drawbacks have been mentioned in the literature, such as non-uniform stress distribution, the push-out test was selected for this study due to its superior reliability compared to other techniques for assessing the displacement resistance of dentin fiber posts within root canals [7]. The testing of both the middle and cervical root thirds was undertaken to isolate variables and gain insights into the mechanisms underlying changes that occur during the interaction between the post and the cement.

In the analysis of the cervical third, this study observed that the vibration generated by the retropreparation ultrasonic insert did not produce a significant alteration in the retention force of the posts. The clinical retention loss ranged from approximately 10.98% to 13.86%, depending on the type of posts used. Consistent with the findings, research conducted by Souza *et al.* [22] indicates that the retention force of posts in the cervical third tends to be higher compared to the middle and apical thirds.

Furthermore, root morphology plays a role in determining the final bond strength outcome, as it affects the density of dentinal tubules, which decreases from the cervical third to the middle and apical thirds. Research by Mjör *et al.* [18] reveals that the tubule density in the cervical region is approximately 37.985/mm^2, declining to 31.028/mm^2 in the middle third and further to 26.042/mm^2 in the apical third. According to Malyk *et al.* [17] and Bitter *et al.* [4], a lower number of dentinal tubules results in less effective hybridization in that region, exerting a negative impact on bond strength and the overall durability of the restoration.

The transmission of vibratory forces through the post is directly related to the square root of the post material's modulus of elasticity. Stiffer materials with a higher modulus of elasticity are more efficient at conducting vibrations [11]. However, fiberglass posts, owing to their viscoelastic nature, tend to dampen vibrations and absorb the energy transmitted to the post.

Conversely, in the middle third, the use of a smooth insert during retropreparation resulted in reduced post adhesion resistance, leading to a clinical retention loss of approximately 28.48%. This decline in retention is a concerning issue in terms of the longevity we aim for in our tooth rehabilitation procedures involving posts. When ultrasound is employed, there's a risk that the insert may transmit vibrations directly to the post upon contact, potentially disrupting the surrounding cement layer and causing the post to lose its retention within the root canal. Clinical observations indicated that the smooth ultrasonic insert required more time to perform the retropreparation compared to the diamond insert, prolonging the period of vibration near the post.

According to Buoncristiani *et al.* [5], posts with greater depth and stability may be more resistant to vibratory forces within the power ranges of currently available instruments, making them less prone to dislodgement.

Conclusion

The adhesive bond strength of intraradicular cemented fiberglass posts was affected solely in the middle third of the canal when employing the smooth ultrasonic insert during endodontic retropreparation. In contrast, in the cervical third, there was no discernible influence on the adhesion of the retainer, regardless of the specific type of ultrasonic retropreparation insert utilized.

Conflict of interest

The authors deny any conflict of interest.

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