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Effect of ultrasonic tip designs on intraradicular post removal

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Objectives: To evaluate the effect of different ultrasonic tip designs on intraradicular post removal. ***Materials and Methods:*** The crowns of forty human canine teeth were removed, and after biomechanical preparation and filling, the roots were embedded in acrylic resin blocks. The post spaces were made, and root canal molding was performed with self-cured acrylic resin. After casting (Cu-Al), the posts were cemented with zinc phosphate cement. The specimens were randomly separated into 4 groups ($n = 10$), as follows: G1 - no ultrasonic vibration (control); G2 - ultrasonic vibration using an elongated cylindrical-shaped and active rounded tip; G3 - ultrasonic vibration with a flattened convex and linear active tip; G4 - ultrasonic vibration with active semi-circular tapered tip. Ultrasonic vibration was applied for 15 seconds on each post surface and tensile test was performed in a Universal Testing Machine (Instron 4444 - 1 mm/min). ***Results:*** G4 presented the highest mean values, however, with no statistically significant difference in comparison to G3 ($p > 0.05$). G2 presented the lowest mean values with statistically significant difference to G3 and G4 ($p < 0.05$). ***Conclusions:*** Ultrasonic vibration with elongated cylindrical-shaped and active rounded tip was most effective in reducing force required for intraradicular post removal. (*Restor Dent Endod* 2014;39(4):265-269)

Key words: Post removal; Tip design; Ultrasonic device

Introduction

After endodontic treatment, teeth with extensive coronal destruction require the use of intraradicular posts to retain fixed prostheses.[1] However, these posts can become an obstacle when endodontic retreatment is necessary, since their removal is considered difficult and complex depending on factors such as: material, shape and length of the post, type of cement used for fixation, interrelation of post with the canal walls, accessibility, as well as the skill of the professional and technical resources available for removal.[2-5]

Several techniques and devices have been suggested to remove intraradicular posts, such as drills to wear down the posts, post extractors, post pullers, the Masseran technique, among others.[5] With the advent of the ultrasonic device, this procedure has been considered easier and safer because of advantages such as minimal loss of tooth structure, faster working time, lower risk of perforation and root fractures, and easy application of the ultrasonic in any tooth.[6,7] Studies have reported the efficiency of ultrasonic on intraradicular posts removal, however, the number of studies regarding the effectiveness of different available tip designs on post removal remains limited.[8,9]

Therefore, the aim of this *in vitro* study was to evaluate the effect of three different ultrasonic tip designs on intraradicular posts removal. The hypothesis tested was that the different designs would not affect the force required for post displacement.

Materials and Methods

After obtaining approval from the Research Ethics Committee of the School of Dentistry of the Federal University of Amazonas, forty healthy single-rooted human mandibular canines, with complete root formation, were selected from the tooth bank from the same institution. The teeth were sectioned in the cervical portion close to the cemento-enamel junction with carborundum disk under cooling, thus, defining a standardized canal dimension of 13 mm in length. The roots were embedded in acrylic resin blocks using a rectangular aluminum mold, and they remained in distilled water until the time of the experiment. Biomechanical preparation was performed using the crown-down technique at the working length of 12 mm with K-type files (Dentsply Maillefer, Ballaigues, Switzerland) up to file size 50. The root canals were irrigated with 1.0 mL of 1% sodium hypochlorite solution at each instrument change. Filling was performed with gutta-percha and Sealer 26 (Dentsply, Petrópolis, RJ, Brazil) with the lateral condensation technique. The root canals were sealed with zinc oxide cement (Coltosol, Vigodent, Rio de Janeiro, RJ, Brazil) and stored in distilled water at 37℃ for 7 days.

After this time interval, the post spaces were prepared with Largo bur #6 (Dentsply Maillefer), mounted at low-speed handpiece (D700, Dabi Atlante, Ribeirão Preto, SP, Brazil) to standardize the length and diameter of the intraradicular portion of the post. This step was performed with the handpiece coupled to a parallelometer (B2, Bioart, São Carlos, SP, Brazil), so that the preparations remained parallel to the long axis of the roots. The post spaces were then washed and lubricated with silicone petroleum jelly (Rioquímica, São José do Rio Preto, SP, Brazil) to allow molding with self-curing Duralay acrylic resin (Reliance Dental, Worth, IL, USA) and prefabricated polycarbonate posts (Pin-Jet, Angelus, Londrina, PR, Brazil). After molding, the resin patterns were embedded in silicone rings with Termocast phosphate investment (Polidental, Cotia, SP, Brazil) and cast in copper-aluminum alloy (Duracast, DuraWear Corp., Birmingham, AL, USA) followed by airborne-particle abrasion treatment with 50 µm aluminum oxide particles for 20 seconds, at a pressure of 100 pounds, in a distance of 5.0 mm (Microjato Bioart, São Carlos, SP, Brazil). Zinc phosphate cement (SS White, Rio de Janeiro, RJ, Brazil) was applied to the post surface with a size 23 probe (SS White) and the post/cement was placed into the post space with light pressure until the cement has set. The set post/cement was placed into the post space with a light pressure until cement setting. The samples were stored at relative humidity of 100% and temperature of 37℃ for 3 weeks.

The specimens were then randomly separated into four groups ($n = 10$) according to the treatments to which they were submitted. These were G1 (Control) - no ultrasonic vibration, G2 - ultrasonic vibration using an elongated cylindrical-shaped and active rounded tip, G3 - ultrasonic vibration with a flattened convex and linear active tip, and G4 - ultrasonic vibration with active semi-circular tapered tip (Figure 1). All the tips were coupled to the Sonic Jet Plus Four appliance (Gnatus, Ribeirão Preto, São Paulo, SP, Brazil) and driven at maximum vibration under constant air/water cooling, placing each tip in a lateral direction on the buccal, lingual and proximal surfaces of the post for 15 seconds on each side, totaling 1 minute of application.

After this procedure, the test specimens were submitted to the tensile test in a Universal Testing Machine (Instron 4444, Instron Corp., Norwood, MA, USA). Each test specimen was coupled to the machine, and an increasing tensile load was applied to the post at a displacement

Figure 1. Ultrasonic tips used in the study. (a) Elongated cylindrical-shaped and active rounded tip (G2); (b) Flattened convex and linear active tip (G3); (c) Active semi-circular tapered tip (G4).

speed of 1 mm/min, until the post was fully detached from the root. The tensile strength was calculated using the following formula,

$\sigma = F/A$,

where σ = tensile strength (Newtons), F = tensile force (Newtons), and A = cementation area (mm^2). For cementation area calculation, the test specimens were radiographed, and the radiographs were digitized and analyzed using ImageLab Software (Softium Informatic Ltda., São Paulo, SP, Brazil). The cementation area was determined by calculating the percentage of the post space that was occupied by the post, and the free space. The normal distribution of data was tested by the Kolmogorov-Smirnov test and the values obtained in the tensile test were statistically compared (One-way ANOVA, Bonferroni, $p < 0.05$) with the aid of Minitab 14.1 Software (Minitab, State College, PA, USA).

After the tensile test, a light microsope (Carl Zeiss, Oberkochen, Germany) was used at x50 magnification to analyze the failure mode (adhesive, cohesive and mixed) that occurred in each specimen. Adhesive failure was considered when failure occurred between surfaces of different substrates (canal wall / cement / post), cohesive failure when it occurred between surfaces of same substrate (cement) and mixed when a combination of adhesive and cohesive failure modes occurred.

Results

The mean values obtained in the tensile test and their comparisons are shown in Table 1. G1 (Control) presented the highest mean values with statistically significant difference in comparison to the other groups ($p < 0.05$). With regard to groups that were submitted to the ultrasonic vibration, G2 presented the lowest mean values with statistically significant difference to G3 and G4 ($p < 0.05$). G4 presented the highest mean values, however, with no statistically significant difference when compared to G3.

Furthermore, after the tensile test, all test specimens showed the presence of zinc phosphate cement adhering to the posts and the canal walls, demonstrating that cohesive failure occurred in all samples.

Discussion

The aim of this *in vitro* study was to evaluate the effect of ultrasonic tip designs on reducing the force required to remove intraradicular posts. Based on the results obtained, it can be affirmed that the hypothesis tested was rejected, since the different tip designs affected the tensile force applied for posts removal. Although cast posts (Cu-Al) are not used currently, their removal is a common procedure in dental office prior to endodontic retreatment and aesthetic interventions.[10] Moreover, such procedure is considered difficult, complex, with high risk of injury and requires a great deal of time.[10-13] On the other hand, the use of ultrasonic devices promotes the safe and simple removal while reducing operating time.[4,5,8] Johnson *et al*. evaluated the time and force required to remove intraradicular posts using ultrasonic vibration and demonstrated that 16 minutes on average are needed to completely remove them.[14] On the other hand, Buoncristiani *et al*., have reported that time could range from 6 to 41.2 minutes.[15]

Another important clinical factor that should be taken into consideration by the professional is the heat produced during ultrasonic application.[16] The longer the time of ultrasonic application, the more heat is generated on the supporting tissues. The energy produced by ultrasonic vibration is dissipated from the device tip to the post and absorbed by dentin.[16] Heat is dissipated through the periodontal tissues and bone, causing irreparable damage such as bone resorption and ankylosis.[17-19] Ultrasonic devices produce mechanical waves at a frequency between 25 and 30 kHz.[16] Ultrasonic energy is produced by converting one form of energy into another. Magnetostrictive ultrasonic devices operate due to the application of an alternating current in the coils with ferromagnetic wire in the handpiece that cause it to vibrate.[7,19] The piezoelectric devices operate due to the oscillation of quartz plates coupled to the handpiece.[16,19] The oscillation generated, irrespective of the type of device used, produces heat that frequently affects the supporting tissues.[7]

In the present study, the authors have chosen to use an ultrasonic device with a reverse piezoelectric effect because it is considered more efficient than magnetostrictive-type

Table 1. Tensile forces required for post displacement (Unit, Newton; $n = 10$)

G1	G2	G3	G4
278.00 ± 27.32^a	136.97 ± 31.90^c	188.66 ± 45.06^b	207.55 ± 24.80^b

Different superscript letters indicate that the difference among groups is significant at the 0.05 level (One-way ANOVA, Bonferroni test, $p < 0.05$).

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devices due to the greater number of cycles per second (40 versus 24 kHz), and the specific tips operate in back-and-forth linear movements, which is ideal in endodontic practice.[5,20,21] Additionally, magnetostrictive-type devices generate more heat and require abundant and constant cooling, which complicates the surgical procedure.[19,21]

Besides the type of device selected, other factors also influence the effectiveness of posts removal procedure: the method of ultrasonic vibration application, the use or not of cooling during the process, diameter and height of the post, tip movement type, which may be continuous or alternating, and the design of the ultrasonic tips.[1,19,22-25] Several studies have reported techniques and devices that facilitate the removal of intraradicular posts. Braga *et al*. demonstrated that the simultaneous use of two ultrasonic devices is more effective than using one, irrespective of the application time.[6] This fact is explained by a phenomenon called constructive interference, which is the oscillation emitted simultaneously by two devices overlapping each other, weakening the bond strength at the post/cement and root interface, facilitating the post removal.

In the present study, the authors have chosen to use a method for ultrasonic application, in which the instrument tip is applied on all sides of the post, thus, reducing the application time, and consequently the heat generated.[26,27] Furthermore, the application time in the present study was 15 seconds on each surface, totaling 1 minute of application, which is extremely important since many studies apply ultrasonic forces for longer periods, sucha as 3 to 16 minutes of vibration.[25-27] It is known that the application of the ultrasonic tip for longer periods than 1 minute considerably increases temperature, which dissipates through the post/root interface causing several damages.[16] Only one type of ultrasonic device was used in the present study. It was found that G2 presented the lowest mean values in comparison to the other groups submitted to vibration. These results indicate that less tensile force was required for post removal. Such performance might be associated with the tip design, which has a higher contact surface due to its rounded shape, and allows an increase in energy transferred to the post surface, increasing the frequency at which the waves are transmitted, thus leading to greater removal efficiency.[28]

When removing posts, it is essential to promote rupture of bond between the luting cement used for fixation and the root canal wall.[5] The results of the present study demonstrated that vibration with elongated cylindrical-shaped and active rounded tip, in contact with the surface of the intraradicular post, is capable of transmitting energy produced by ultrasonic device on a larger scale, leading to the rupture of the adhesive interface and consequently promoting less tensile force to remove it. Findings show that it is possible to choose a more appropriate device for clinical practice, in order to decrease operating time and the risk of tissue damage. Cohesive failure occurred in all the tested specimens, confirming the results of previous studies. According to Garrido *et al*. and El-Mowafy and Milenkovic, cohesive failures occur more frequently in posts cemented with zinc phosphate cement than in posts cemented with resinous cements, which have mostly adhesive failures.[25,29] The results of the present study demonstrated that the tip design is an important technical issue which increases the efficacy of ultrasonic devices during intraradicular post removal. However, the authors believe that these findings cannot be extrapolated to clinical situation.

Conclusions

Within the limitations of this *in vitro* study, it could be concluded that ultrasonic vibration with an elongated cylindrical-shaped and active rounded tip was the most effective in reducing the tensile force required for intraradicular post removal.

Conflict of Interest: No potential conflict of interest relevant to this article was reported.

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