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Effect of Ultrasonic Vibration and Various Sealer and Cement Combinations on Titanium Post Removal

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The purpose of this study was to determine the effect of ultrasonic vibration on the force required to remove prefabricated posts. Ninety-six extracted human canines were divided into eight groups, which were prepared and obturated with gutta-percha and either a eugenol-containing (Roth's 801 Elite) or eugenol-free (AH26) sealer. Titanium #6 Parapost XH posts were cemented with either zinc phosphate or Panavia 21 resin cement. One half of the sample was subjected to ultrasonic vibration for 16 min at the post–dentin interface, whereas the other half received no vibration (controls). Each combination of sealer, cement, and vibration status was subjected to tensile load to failure using an Instron testing machine. Posts cemented in teeth obturated with gutta-percha and AH26 sealer demonstrated significantly greater resistance to dislodgement, compared with teeth obturated with gutta-percha and Roth's 801 Elite sealer. There was no statistical difference in retention of posts cemented with either zinc phosphate or Panavia 21, regardless of the sealer used. Additionally ultrasonic vibration increased post retention for both cements.

Removal of intraradicular posts has always been a clinical challenge with regard to endodontic retreatment, often steering the clinician toward a surgical approach. Nonsurgical retreatment, normally considered to be more conservative than periradicular surgery, can result in catastrophic consequences, such as root fracture or perforation in an attempt to remove a well-cemented post. The emergence of ultrasonics and its implementation into endodontics has provided clinicians with a useful adjunct for post removal. Ultrasonic energy has proven effective as an adjunct in removal of silver points, fractured instruments, and cemented posts in studies dating to 1981 (1). Subsequent research has attempted to demonstrate the significantly reduced amount of tensile force required to remove cemented posts following ultrasonic vibration. In 1994 Buoncristiani et al. (2) demonstrated that ultrasonics were significantly more efficient than sonic instrumentation in reducing the amount of time required to dislodge a cemented 4-mm-long prefabricated post under a constant tensile force. Berbert et al. (3) showed that significantly reduced tensile forces were required for in vitro removal of cast posts after ultrasonic vibration. In 1996 Johnson et al. (4) demonstrated that the force required to dislodge a cemented prefabricated post decreased by ~50% between 12 and 16 min of ultrasonic vibration, compared with the control. Yoshida et al. (5) found that simultaneous application of two ultrasonic tips on either side of the cemented post further decreased the amount of lateral vibration required to extract cemented dowel-retained cast cores under intermittent tension.

The previous studies used either prefabricated or cast posts cemented with zinc phosphate cement. The advent and popularity of resin cemented posts have presented a new challenge in post removal. No studies have been published to date regarding the efficacy of ultrasonics in reducing the tensile force required for successful removal of resin cemented posts. Buoncristiani et al. (2) have suggested that the viscoelastic nature of the plastic in resin cements tends to dampen vibrations and absorb ultrasonic energy transmitted to the post. Resin cements are less brittle and may not tend to microfracture like zinc phosphate. Should ultrasonics prove less useful in removal of resin-retained posts, clinicians might consider the earlier use of a post-pulling device or reconsider a surgical approach instead of nonsurgical retreatment.

A number of studies have investigated the effects of resin cement on post retention (6–10). Several investigators have reported higher retentive values with resin cement than with zinc phosphate or glass ionomer cements (6–8). Dentin adhesive agents have also been found to enhance retention when used with resin cements (9). Fogel (10) reported less microleakage around posts when resin cements were used with dentin adhesives than with zinc phosphate or glass ionomer cements. These results have led many to believe that resin cements generally provide greater post retention than other cements.

Schwartz et al. (11) implied that the idea that resin cements enhance retention of posts must be questioned, however, because some previous studies had omitted obturation as a critical clinical step and simply contaminated the post space with eugenol. Any effects of the filling materials or other sealer ingredients, in com-

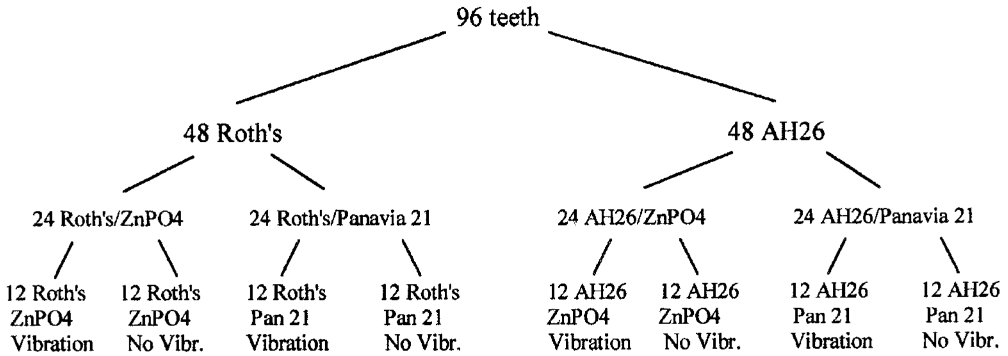

FIG 1. Experimental group design. $ZnPO_4$, zinc phosphate; Vibr., vibration; Pan 21, Panavia 21.

bination with eugenol, used in obturation were not accounted for by the results. This may prove important as many of the sealers used for obturation contain eugenol, which has been shown to inhibit the polymerization of resins (12, 13). However, free eugenol may have a far different effect than eugenol incorporated with the other components of a root canal sealer.

Schwartz et al. (11) found that, under the conditions of their study, although there was a trend toward a greater retention of posts cemented in teeth obturated with gutta-percha and AH26 sealer, a eugenol-containing sealer had no significantly negative effect on the retention of resin cemented prefabricated posts. Additionally zinc phosphate cement produced higher retention values than resin cement, regardless of the type of sealer used (11).

As no studies have investigated the effects of ultrasonics on resin cemented posts, the purposes of this study were to determine: (i) whether ultrasonic vibration reduces the amount of tensile force required to remove a prefabricated titanium post luted with a resin cement; and (ii) whether obturation with gutta-percha and a eugenol sealer compromises the retention of cemented posts, compared with teeth obturated with gutta-percha and a eugenol-free sealer control.

MATERIALS AND METHODS

Extracted human canine teeth were collected and stored in tap water. All teeth were measured for root length and screened preoperatively using a Schick digital radiography system (Schick Technologies, Inc., Long Island City, NY) to eliminate teeth with unusual morphology, pulp size, or dilaceration. Once the 96 experimental samples were selected, a stratified randomization scheme was devised based on length to allocate teeth into eight different test groups. The experiment was a complete $2 \times 2 \times 2$ factorial design evaluating the effects of sealer (Roth's 801 Elite vs. AH26), post cement (zinc phosphate vs. Panavia 21), and ultrasonics (Yes vs. No) on the magnitude of tensile force required to remove a cemented titanium post (Fig. 1). A single operator completed all experimental procedures.

The teeth were decoronated with a carbide bur perpendicular to the long axis at the level of the facial cementoenamel junction. Access to the pulp chamber was obtained with a #329 bur, and straight-line radicular access was established using #2 and #3 Gates-Glidden drills. Working length was established by placing a pathfinder file to the apical foramen and subtracting 1 mm. The canals were subsequently instrumented using Series 29, .04 taper Profile (Dentsply Tulsa Dental, Tulsa, OK) rotary instruments to an apical preparation size #8 (ISO 60) using 5.25% sodium hypochlorite as an irrigant. The canals were then dried and obturated with laterally condensed gutta-percha (Kerr/Sybron Corp, Romulus, MI) and one of two different sealers—Roth's 801 Elite Grade cement (Roth International, Chicago, IL), a sealer containing eugenol, or AH26 (Dentsply/Maillefer, Tulsa, OK), an epoxy resin sealer containing no eugenol. A heated plugger was used to vertically condense the coronal gutta-percha and subsequently prepare a 3-mm deep space for a provisional restoration. All obturated teeth were then temporized with Cavit (Espe, Norristown, PA) and stored at 37°C at 100% humidity.

After a minimum of 2 weeks, preparation and cementation of posts were performed. Using the Parapost series of drills, a 9-mm post space was created in each tooth for a #6 parallel-sided titanium Parapost XH (Coltene/Whaledent Corp., Mahwah, NJ). The post channels were then rinsed with sterile water and dried with paper points. EDTA 17% (Pulpdent Corp., Watertown, MA) was injected into the post space and left in place for 1 min to remove the smear layer. The post space was then rinsed and again dried with paper points. The teeth were then equally divided into two cement groups. Equal numbers of each sealer group (Roth's and AH26) had posts cemented with either Fleck's zinc phosphate cement (Mizzy, Inc., Cherry Hill, NJ) or Panavia 21 (J. Morita Corp., Irvine, CA), a self-curing resin cement that uses a dentin adhesive. The cements were manipulated according to the manufacturers' instructions, and a lentulo spiral was used to introduce cement into the preparation and coat the walls. A hemostat was then used to grip the posts at a point 9 mm from the tip to ensure accurate depth of embedment. The Paraposts were uniformly coated with cement and inserted to the depth of the prepared channels and maintained in place with finger pressure until an initial set took place. Excess cement was removed flush with the top of the tooth. The cemented Paraposts extended ~6 mm above the flat tooth surface. Since the set of Panavia 21 is retarded by the presence of oxygen, Oxyguard gel (J. Morita Corp., Irvine, CA) was injected around the post–tooth interface to cover and ensure the set of any exposed cement. Each cement was used with 48 teeth; thus, after the posts were cemented, all possible combinations of sealer and luting cement were available for testing (Fig. 1).

After an additional 2 weeks storage at 37°C and 100% humidity, the roots were notched on the facial and lingual surfaces with a carbide bur for retention and mounted in a cylinder with orthodontic acrylic (Dentsply Caulk, Milford, DE). A surveyor and specially constructed mounting jig were used during mounting procedures to ensure that the posts maintained the same alignment for tensile retention testing, minimizing lateral forces when the load was applied.

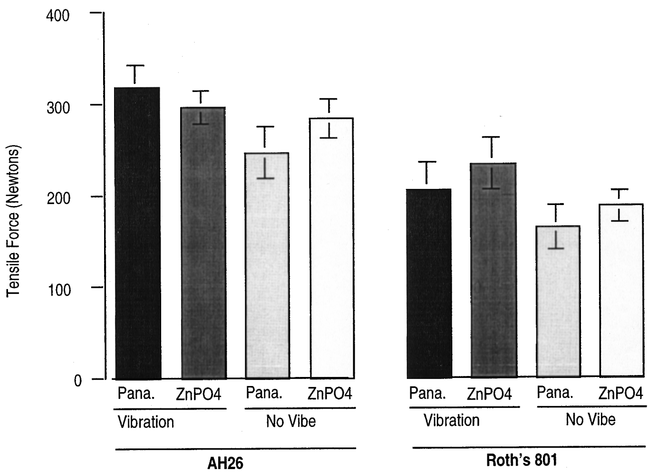

FIG 2. Mean tensile force required to dislodge Paraposts. Pana., Panavia 21; $ZnPO_4$, zinc phosphate; No Vibe, no vibration.

Ultrasonic energy was applied to the post–dentin interface at a 90-degree angle for a total of 16 min. A new Amadent P-5 ultrasonic unit with a Satelec blunt-ended vibration tip (Amadent Corp., Cherry Hill, NJ) was used at maximum power without water spray. The tip was placed on the mesial, distal, buccal, and lingual surfaces for equal periods of time (4 min each).

The subsequent tensile force required to dislodge each post was determined on an Instron Universal Testing Machine (Instron Corp.) using pneumatic grips with a constant loading rate of 0.5 cm/min until the cement bond failed. Posts that were vibrated were mounted on the Instron immediately following ultrasonic application.

An a priori power analysis to determine sample size used an estimated variance of 30% of the mean and an α-level of 0.05. Under these parameters, a sample size of 12 teeth/group was calculated to result in a power of 0.86 ($\beta = 0.14$). Forces required to remove the posts were recorded and statistically analyzed using a three-way factorial ANOVA at the 95% confidence level.

RESULTS

The results of tensile testing are summarized in Fig. 2. Three-way ANOVA indicated significant differences between groups, but no significant interaction of the variables. In assessing main effects, there was a significant difference in the forces required to dislodge the posts based on the sealer used. The use of AH26 significantly increased the retention of the posts, compared with groups in which teeth had been obturated with the Roth's sealer ($p < 0.0001$). Statistically significant differences in mean dislodgement forces were also noted when comparing test groups with or without ultrasonic vibration ($p < 0.05$). Interestingly the groups subjected to vibration exhibited higher values than those in which no vibration was used. The differences for cement were not statistically different ($p > 0.05$).

DISCUSSION

The results of this study may be addressed with regard to the three separate parameters that were evaluated (i.e. sealer, cement, and ultrasonic vibration). Concerning the effect of eugenol, there was a highly significant increase in retention with tensile load for those teeth obturated with gutta-percha and AH26 sealer, regardless of the luting cement used for the post. The use of a noneugenol containing sealer, such as AH26, has been advocated by several authors to prevent the potential negative interaction between eugenol and a resin luting agent (14, 15). Eugenol has been implicated in several studies in weakening resin cements used to lute preformed or cast posts due to residual eugenol associated with canals after obturation (7, 14, 15). Although previous studies reported a trend for the noneugenol-containing AH26 to yield a more retentive post, compared with eugenol-containing sealers after smear layer removal (11, 16), the present experimental conditions exhibited a statistically significant improvement with AH26, compared with Roth's sealer.

Some studies suggest that resin cements are superior when compared with zinc phosphate (6–8). Although three of the four post groups cemented with zinc phosphate in this study had mean failure loads that were greater than their Panavia 21 counterparts, cement was not found to be a statistically significant parameter for post retention. This is consistent with more recent investigations that show that zinc phosphate is at least as retentive as resin cement for post cementation (11, 17). Additionally Goldman et al. (6) were able to demonstrate that smear layer removal with EDTA enhances the tensile strength of posts luted with either resin cement or zinc phosphate.

The use of ultrasonics has been suggested to interrupt the integrity of the cement by vibration to facilitate post removal. Perhaps the most interesting finding in this study was the fact that ultrasonic vibration exhibited no mitigating effect on the retention of posts cemented with sealer/cement combinations used. Various studies have been able to demonstrate a reduction in tensile failure loads of intraradicular posts cemented with zinc phosphate cement after ultrasonic vibration (2–5). The initial intent of this study was to investigate whether such effects could be reproduced using a resin cement. Surprisingly, not only was the ultrasonic vibration ineffective in reducing retention of the cemented posts, but also there was a significant ($p = 0.01$) increase in mean failure loads for both cements.

Although we can offer no apparent explanation for the increase in tensile strengths after ultrasonic vibration, there may be several possible reasons why ultrasonics was unsuccessful in helping to dislodge these posts. A review of the literature on ultrasonic vibration for post removal consistently revealed that previous experimental designs used a mixture of cast or prefabricated posts, post lengths of 8 mm or less (only 4 mm in one instance), and post diameters of 1.10 mm or less. All but one of the reviewed studies used some form of constant or intermittent tension applied to the post simultaneously rather than vibration alone (2–5).

In the present study uniformly shaped, parallel, prefabricated, titanium Paraposts were used with a raised diamond retention pattern. It has been demonstrated that parallel-sided posts may resist tensile forces as much as 4.5 times more than tapered dowels (18).

Depth of post embedment was established at 9 mm creating a 2/3 ratio of exposed/cemented post. Increased post length results in increased retention. One study demonstrated as much as a 30% increase in post retention with as little as a 2 mm increase in post length (18). Robbins (19) suggests that a post should be as long as possible without encroaching on the remaining gutta-percha or causing perforation in a curved canal.

Large diameter posts (#6, 1.50 mm diameter) were selected to ensure an intimate fit at the post–dentin interface after precise mechanical canal enlargement. Consistently well-adapted posts were achieved with minimal cement film thickness. Multiple studies have shown retention is considerably influenced by fit of the post. A larger diameter, and therefore better adapted, post consistently requires a greater tensile force to break the cement seal and free the post (8, 18, 20). Additionally a well adapted post inherently minimizes the film thickness of cement. In fact the literature suggests that the ideal cement film thickness should be between 25 to 35 μm. A thicker layer is inconsistent with optimum cement tensile strength, causing reduced post retention (8, 20).

A large sample of canines was selected for this study to ensure similar canal morphology and a block design used in an attempt to reduce anatomical variability. Canines consistently provided relatively narrow canal diameters with circular to slightly ovoid shapes rather than ribbon configurations, as often found in other tooth types.

Only one other study has been published using pure ultrasonic vibration for post removal without constant or intermittent tension (4). That study used mandibular premolars and smaller sized (#4 stainless steel) Paraposts with only a 1.0 mm diameter, cemented with zinc phosphate to a depth of 8 mm and demonstrated that 16 min of ultrasonic vibration alone reduced post retention by ~50%. Whereas retentive strengths were reduced after 16 min of vibration, the posts were not dislodged, and additional mechanical force was still required for removal. Additionally no reduction in retention on tensile challenge before the 16-min point was noted (4). This may prove clinically impractical for many practitioners. Although Johnson et al. (4) did not attempt to remove the smear layer, Goldman et al. (6) have demonstrated that smear layer removal not only enhances the bonding strength of resin cement, but also can increase the tensile strength of posts cemented with zinc phosphate as well. The combination of a round, intimately adapted post, minimum cement film thickness, and adequate length may have contributed to the resistance to weakening of the cement bond by ultrasonic vibration. Greater depth and stability of posts may make them resistant to ultrasonic vibratory forces regardless of the cement used.

The use of a water coolant is sometimes used during ultrasonic vibration of posts. Johnson et al. (4) do not state whether a coolant was used in their investigation. We chose not to use a coolant. This may have allowed significant heat formation in the post and cement that could have affected the force required for post removal.

One final hypothesis may be suggested for the ineffectiveness of ultrasonics in reducing post retention. The posts selected for this study were composed of a titanium alloy. According to Buoncristiani et al. (2), "Conductance of vibratory forces down the post is proportional to the square root of the modulus of elasticity for the post material. Stiffer materials with a higher modulus of elasticity will tend to conduct the vibrations better. A material like titanium, which has a significantly lower modulus of elasticity than stainless steel, would tend to conduct the vibrations less efficiently. This may result in either a prolonged period of instrumentation or a higher energy requirement for removing posts of this type." A combination of factors, including lower modulus or less stiff post materials with dentin bonded cements, may significantly alter the effectiveness of post removal by an ultrasonic technique (2).

Nonsurgical endodontic retreatment of teeth with intraradicular posts can be a great source of anxiety for the clinician. Additionally titanium posts are less radiopaque than stainless steel, with a radiographic density similar to gutta-percha. This radiographic similarity can make detection of titanium posts difficult. The use of burs or even ultrasonics to remove either tooth structure or post material can lead to weakening of the root structure or misadventures such as root perforation or fracture. When posts are not particularly well adapted to the canal space and an avenue for troughing or probing alongside the post with files or instruments is possible, ultrasonic vibration may be a very useful adjunct in retrieving cemented posts. Additionally if the post is well adapted to the canal but an adequate amount of post extends superior to the orifice, a hemostat or alternate device may be used to transfer ultrasonic energy to the canal space while exerting simultaneous or intermittent tensile extraction forces. However, in cases where the post exhibits an intimate fit to the canal with adequate length and diameter, and limited accessible coronal post for grasping, the effects of ultrasonic vibration alone may be limited or even aborted. Based on the results of this study, in those situations the clinician may choose to consider other treatment options immediately, such as a Masserann, Gonon, or Ruddle post removal device. In certain cases surgical endodontics may in fact be the conservative choice of treatment for both patient and clinician.

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The Way It Was

John D. Rockefeller offered the following advice. “Don’t even think of temporary or sharp advantages. Don’t waste your efforts on a thing which ends in a petty triumph unless you are satisfied with a life of petty success.”

“It is very important to remember what other people tell you, not so much what you already know. Let the other fellow talk.”

So! Think big, talk little.

Well, he must have known something. He was a billionaire when there was only one billionaire in the whole world.

Zachariah Yeomans