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THE BOND STRENGTH OF ADHESIVE RESIN CEMENT: TIME DIFFERENTIAL BETWEEN CEMENTATION AND FINISHING OF CAST DOWEL-CORES

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THE BOND STRENGTH OF ADHESIVE RESIN CEMENT: TIME DIFFERENTIAL

BETWEEN CEMENTATION AND FINISHING OF CAST DOWEL-CORES

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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Finally, my ultimate thanks to my Creator and to my mother for the gift of life and the courage to pursue my dreams.

Table of Contents

Page

List of Tables

Page

List of Figures

Page

Abstract

THE BOND STREGTH OF ADHESIVE RESIN CEMENT: TIME DIFFERENTIAL BETWEEN CEMENTATION AND FINISHING OF CAST DOWEL-CORES

By Purnima Joan Shahani, D.D.S., M.S.

A Thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Dentistry at Virginia Commonwealth University.

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This study compared the retention of cast dowel-cores cemented with Panavia® 21 subjected to immediate versus delayed high-speed finishing. Conventionally, finishing is delayed for 24 hours to one week to allow for optimal setting and ultimate strength of the cement. Forty-five recently extracted human maxillary canines were used. Teeth were divided among 3 groups: a control group (n=15, no finishing), an immediate finishing group (n=15, high-speed cutting of the cores performed five minutes after cementation) and a delayed finishing group (n=15, high-speed finishing performed 48 hours post-cementation). Tensile load to failure was applied using an Instron® at a crosshead speed of

0.05 inches/minute. A statistical test of equivalence was performed. The average retention force associated with failure after immediate finishing was not found to be inferior to delayed finishing failure force. In fact, post-hoc comparisons indicated that immediate finishing has statistically significant greater mean retentive force when compared to this force for delayed finishing at $p = 0.00001$.

Introduction

Cast dowel-cores are the treatment of choice for extensive loss of coronal tooth structure combined with sound radicular tooth structure.[1-6] Following routine endodontic therapy, gutta percha is removed to within five millimeters of the radiographic apex and a custom wax dowel-core pattern fabricated, invested, and cast.[7-9] There is an abundance of literature showing that serrated, parallel-sided posts are more retentive than tapered posts.[10-15] Therefore, an acceptable technique for direct cast dowel fabrication combines the use of a parallel-sided segment in the more apical portions of the canal with customization of the coronal segment. The function of the dowel is to retain the core.[9, 17] As a logical consequence, and based on studies demonstrating their superior bond to tooth structure, the adhesive resin cements have become increasingly popular for cementation of cast dowel-cores.[18-24] Panavia® 21 (Kuraray America Inc. 101 East 52nd Street, 26th Floor, New York, NY 10022) is one such adhesive resin cement. It is a filled BIS-GMA composite resin in which a phosphate ester (4-META) is added to the monomer. This phosphate ester addition differentiates the conventional resin cements from the adhesive resin cements and allows for chemical adhesion to teeth and dental alloys.[20, 25] According to the manufacturer's recommended protocol for cementation of cast post and cores, the operator can "continue with normal abutment and crown procedures" approximately four minutes after cementation. This study proposes to analyze whether or not the time lapse between dowel-core cementation and high-speed finishing techniques affects the bond strength of Panavia® 21. No evidence-based studies were found to support the controversial clinical recommendation that immediate refinement of the core should be avoided as the vibration can disturb the setting of the cement, permanently diminishing its bond strength and likely contributing to premature restoration failure. Only one textbook reference was found that clearly supported this view, but was not specific for Panavia® 21 cement.[26a, 26b] Another textbook failed to indicate any controversy on the subject, was also not specific for Panavia® 21 cement and recommended immediate finishing after cementation of dowel-cores, followed by making of the master impression.[6] Only one study was found that examined the effect of core preparation on retention of cast dowel-cores, but the cement used was zinc phosphate, and the sample sizes were too small to draw reliable conclusions.[27] A review of the literature revealed a recommended technique for removal of fractured dowel-cores cemented with zinc phosphate that involved the application of an ultrasonic force to the remaining portion.[28-31] A single study was found that analyzed the effect of ultrasonic force application on removal of prefabricated titanium ParaPosts® cemented with Panavia® 21.[32] Interestingly, the vibration was found to increase the dowel retention, an effect the authors could not explain.

Materials and Methods

Forty-five recently extracted human maxillary canines with intact roots were used for this study. These teeth were chosen as their canals are roughly ovoid in cross section and therefore can be conservatively prepared to allow close adaptation to a parallel post.[33] The teeth were stored in a 1 to 10 dilution of 5% sodium hypochlorite to water after extraction. They were maintained in a moist environment throughout the study. Prospective test teeth were discarded if their canal morphology showed anomalies such as dilaceration or excessive curvature. Also, an attempt was made to match the lengths of the tooth roots by rejecting any specimens longer or shorter than 2 mm from the mean maxillary canine root length.[34] Two endodontic operators performed root canal therapy. A standard protocol was employed such that rotary files were used to size 40/.06, with a crown down technique. The more coronal aspect of the canals was flared using #5, 4, 3 and 2 Gates Glidden burs. No obturation was performed as this study wished to eliminate the disputed effects of eugenol in the sealer on the strength of the cement bond.[35-39] Post space preparation was achieved using the ParaPost® (Coltène/Whaledent Inc. 750 Corporate Drive Mahwah, NJ 07430 USA) system. The post diameter was standardized to 0.045” for all specimens.

Each tooth root was then notched in two places on both the buccal and lingual root surfaces using a football shaped diamond bur to create wedge shaped cuts. This enhanced retention of the specimens in an acrylic base. Each tooth was measured and the shortest tooth determined how much the coronal portion of each specimen needed to be removed in order to standardize the post spaces. A standardized post length of 13 millimeters was at least two thirds[40] the average length of the specimen roots. The shank of the 0.045" ParaPost® drill was fastened in the vertical arm of a dental surveyor. Each tooth specimen with its prepared canal was then suspended from the drill, which was gently guided to its maximum prepared depth in the tooth. A surveyor table was leveled (bubble level) and a custom reusable Teflon mold in the shape of a hollow cylinder was fastened on it. The open base of the mold was closed using masking tape prior to its attachment to the surveyor table. The suspended post-tooth complex was centered within the mold. An acrylic resin base (TrayResin®, Dentsply/Austenal, Trubyte Division, 570 W. College Avenue, York, PA 17405) was poured into the mold. The surveyor arm with the suspended post-tooth complex was gently lowered into the fluid resin until flush with the top edge of the acrylic mold. In this way, the resin base was made perpendicular to the path of removal of the future dowel. When the resin had reached complete set, the acrylic cylinder with its embedded specimen was pushed out of the mold from below, after removal of the masking tape. The superior aspect of the tooth/acrylic base was subsequently sectioned using precision machining with a diamond lathe, at 1 millimeter beneath the orifice of the tooth/acrylic complex. Using this strategy, a planed edge perpendicular to the post space was created. The overall purpose of this mounting method was to increase the likelihood of applying a pure tensile force along the root and allow for a reliable bond strength test of the cement, without the introduction of torquing forces on the tooth or core. The core pattern for each tooth was a standardized rectangular parallelopiped that provided excess to remove at the finishing stage. In order to standardize the core pattern, a novel custom Teflon mold was designed (Fig.1).

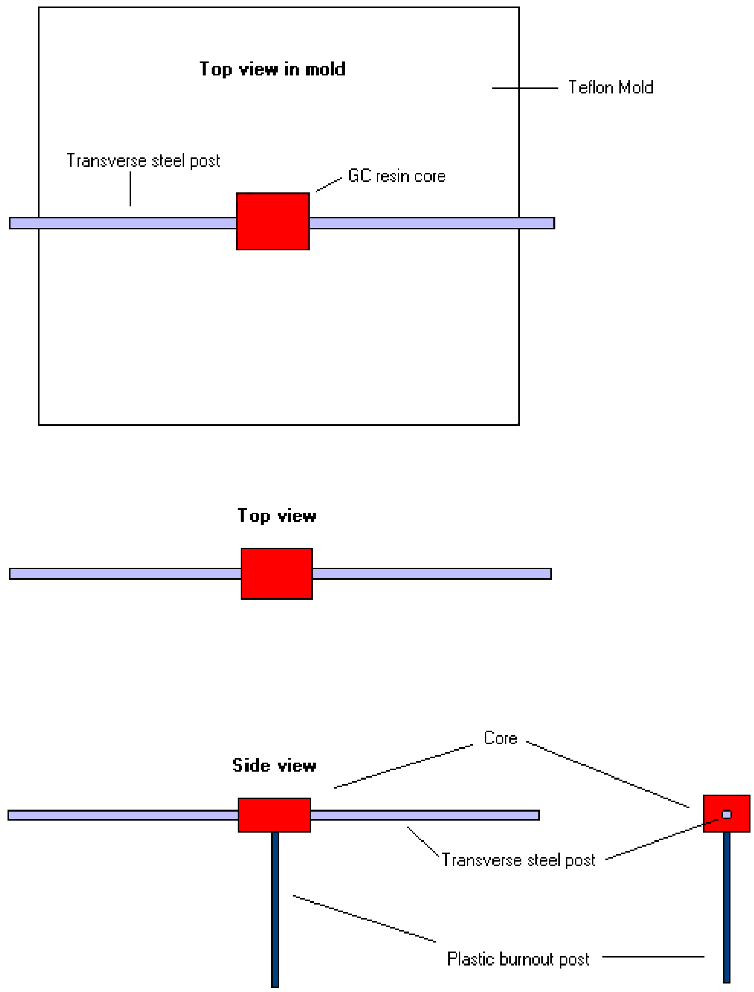

Figure 1 Illustration of Custom Teflon Mold for Dowel-Core Fabrication

To facilitate the attachment of the Instron® to the cemented dowel-cores, a stainless steel dowel (1" length, 1/16" diameter) pin (McMaster-Carr Supply Company, 6100 Fulton Industrial Blvd, Atlanta, GA 30336) was placed lengthwise (mid-coronally) through each core and perpendicular to the dowel. The custom mold allowed for the placement of the transverse steel post first, with GC Pattern Resin® (GC America Inc. 3737 W. 127th St. Alsip, IL 60803) then placed around it. The custom mold also facilitated the placement of the 0.045" plastic burnout post perpendicular to the transverse post, by providing an appropriately positioned pilot hole on its undersurface. This pilot hole then guided an appropriately sized drill, used to a depth of 2 mm, into the hardened GC Pattern Resin® core (Fig2).

A ParaPost® burnout post, matched in size to the 0.045" drill, could then be press fit into the core at right angles to the undersurface of the core and the transverse steel post. In this way the dowel core pattern was fabricated almost to completion. Three milliliters of sodium hypochlorite (1:10 dilution) in an irrigating syringe was used to cleanse the specimen root canals of any debris from previous manipulations. Each canal was lubricated minimally with water soluble SurgiLube® (Altana Inc., 60 Baylis Rd. Melville, NY 11747) and GC Patern Resin® was then used to customize the shape of the more coronal aspect of the canal, according to standard protocols. The completed pattern with retained transverse steel post, was then immediately invested (Hi-Temp®, Whip Mix Corp. P.O. Box 17183, Louisville, Kentucky, USA 40217), cast in Option® PFM alloy (Dentsply Ceramco, 6 Terri Lane, Burlington, NJ 08016) and prepared for cementation according to standard protocols.

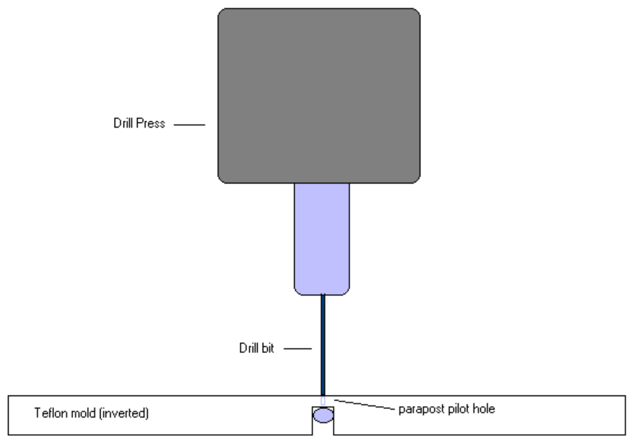

Figure 2 Drilling Pilot Hole for Plastic Burnout Post Placement

Each dowel-core was then tried in its tooth specimen, with adjustment of the fitting surface as necessary to achieve a passive fit within the root canal and complete seating. At this stage, the teeth were randomly allocated into a control group and two test groups all having 15 teeth each.

Group 1 (the control group) had dowel-cores cemented with Panavia®21 following the manufacturer's recommended protocol for treatment of the root canal and the dowel. This included sandblasting followed by tin-plating of the cast dowel and undersurface of the cores. After tin-plating, the cast dowel-cores were ultrasonically cleansed in a non-ionic soap solution for five minutes. Thereafter, care was taken not to handle or in any way contaminate, the bonding surfaces of the castings. Just prior to commencing the Panavia® 21 cementation process, the root canal of each specimen was irrigated using 5 ml ordinary tap water in an irrigating syringe and dried with paper points. A standardized bonding area confined to tooth structure was defined at the coronal aspect of each specimen. To achieve this, a 6 mm biopsy punch was used to remove a circular portion from a piece of 3M MagicTape®. The piece of tape was large enough to cover the 5/8" diameter acrylic resin surface of each specimen. It was pressed onto the superior aspect of the tooth/acrylic cylinder, such that the punched hole was positioned symmetrically around the root canal orifice. The tape provided a barricade between the excess cement (expressed from the canal during cementation) and the mounting acrylic. To ensure standardized seating forces during cementation, a ring stand was used that facilitated placement of fifteen pounds on each core for one minute. Cementation time was determined by precisely following the manufacturer's recommendations for clinical use of Panavia® 21. After cementation, teeth in Group 1 were returned to moist storage in ordinary tap water at room temperature.

Each tooth in Group 2 (the immediate preparation group) had its dowel-core cemented following the same procedures as for Group 1. After five minutes, the core portions were refined using water-cooling in a high-speed hand piece (KaVo® model #846, 420,000 r.p.m.) at 40 p.s.i air pressure. A new medium grit chamfer diamond (Size 014,

856, Brasseler USA®, 1 Brasseler Blvd., Savannah, GA 31419) was used to prepare only five cores before it was exchanged for another. The handpiece was kept in contact with, and moved along, the entire “occlusal” face, “buccal” face, “lingual” face and all four corners of the square core for eleven complete passes on each surface to simulate extensive clinical core refinement. A single operator performed core refinement after two independent calibration sessions. A high-speed handpiece was used to prepare a test core that was held in a device attached to the Instron® (Instron Corp, Canton, MA). The forces applied to the core during instrumentation were recorded using the Instron® graph. On the two independent sessions, there was minimal force variation and the assumption was made that the same operator would prepare test specimens with similar and consistent forces. The teeth in Group 2 were returned to storage after preparation. Group 3 teeth (the delayed preparation group) were treated as for Group 2 teeth, except that the elapsed time prior to finishing was 48 hours. All teeth remained stored in a moist environment at room temperature for exactly one week post-cementation, prior to testing on the Instron®.

At the time of testing, the mounted specimens were placed in a custom jig attached to the Instron®. The transverse steel post cast into each core was engaged on both ends from above the core by a second custom device (a modified bicycle chain). The latter was used to apply straight-line tensile force. The crosshead speed used was 0.05 inches/ minute. Failure was recorded (tensile unseating force in pounds) at the first decrease in the load curve on the Instron® chart. This was considered representative of fracture of the cement seal that clinically would result in a gap at the cast dowel-core-tooth interface resulting in loosening, followed by an increased potential for microleakage, decay at tooth-restoration interface and clinical failure.

Results

Three experimental groups were considered as follows: Group 1- No Finishing; Group 2-Immediate Finishing, cores refined after 5 minutes of cementation and Group 3-Delayed Finishing, cores refined 48 hours after cementation. Outcomes were tensile retentive force in pounds, where larger values represented a more favorable result. Table 1 summarizes the observed retention force for the three groups. This data is also plotted in Figure 3. 95% confidence intervals (C.I.) are included: it can be assumed that intervals

Table 1
Data Summary

Group	N	Mean (lbs)	SD	Range (lbs)	95% C.I.
Control	15	74.77	25.02	30 – 115	(60.91, 88.62)
Immediate	15	91.15	21.79	62 – 138.4	(79.08, 103.21)
Delayed	15	65.67	22.78	39.3 – 113	(53.06, 78.29)

derived in this manner contain the true mean 95% of the time. One popular practice is that of delayed finishing. The goal of this study was to show that immediate finishing

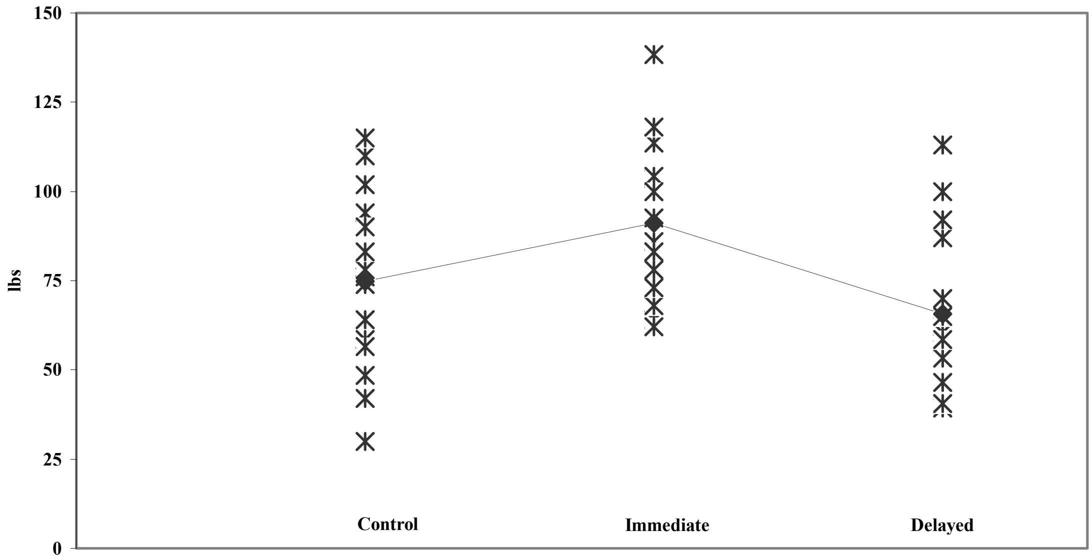

Figure 3: Observed Retention Force. (Group mean values are bolded and connected)

is equivalent to delayed finishing. This is commonly referred to as a noninferiority analysis.[41,42,43] We sought to demonstrate that the mean outcome for the immediate group was at least similar to the delayed group, i.e. the difference in the means for the delayed and the immediate was less than a clinically meaningful difference. The first step in applying this type of analysis is to determine what would be a meaningful clinical difference (Δ) in the outcomes. By convention, this value is set at 20% of a control.[43]

To summarize in conventional statistical terms: the alternative hypothesis (Ha) is what this study would like to demonstrate, i.e. that the average for Group 2 (Immediate Finishing) is not less than that of Group 3 (Delayed Finishing) by more than a Δ. The null hypothesis (H_0) states the controversial view, i.e. that the average for Group 3 (Delayed Finishing) is greater than that for Group 2 (Immediate Finishing) by more than the clinically meaningful value Δ. The null and alternative hypothesis are given as:

H_0: $\mu_d - \mu_i > \Delta$ (immediate group is not equivalent to the delayed group)

Ha: $\mu_d - \mu_i < \Delta$ (immediate group is equivalent to the delayed group)

where μ_d = mean for the delayed group

μ_i = mean for immediate group

For this study:

Δ = 0.20(74.77 lbs) = 14.95 lbs

$\mu_d - \mu_i$ = 65.67 lbs - 91.15lbs = (-)23.48

Note that if, in fact, the immediate group is greater than the delayed group then $\mu_d - \mu_i < 0$ and consequently, if the absolute value $[\mu_d - \mu_I] < \Delta$. then the immediate group is judged superior.

A one-sided t-test was applied and the resulting p-value was p = 0 .00001. Since the p-value was so small, we reject H_0 and accept Ha, i.e. we can conclude that the immediate group is equivalent to the delayed group. By examining the confidence intervals about the observed means some further conclusions can be drawn. Since the intervals for the immediate finishing and delayed finishing groups do not intersect, it can be concluded that the means for these two groups are significantly different. A one-sided p-value associated with the t-test is p = 0.0020, implying the mean for the immediate group is in fact significantly greater than the delayed group. For completeness, comparisons of the delayed and immediate groups to the controls were considered. Two-sided t-tests were used to determine if the means of the groups compared to the control varied. All p-values are summarized in Table 2. In conclusion, the average retention force associated with immediate finishing was found to be equivalent to that for delayed finishing. In fact, post-hoc comparisons indicated that immediate finishing has significantly greater mean bond strength when compared to delayed finishing.

Table 2
Statistical Summary

Test	t	df	p-value	Conclusion
Equivalence test Delayed vs immediate H_0: $\mu_d - \mu_i > \Delta$ Ha: $\mu_d - \mu_i < \Delta$ $\Delta = 14.95$	-4.968	28	<0.0001	Reject H_0 and assume the mean for the immediate group is equivalent to the delayed group.
Determine if immediate superior to delayed H_0: $\mu_d - \mu_i > 0$ Ha: $\mu_d - \mu_i < 0$	-3.130	28	0.0020	Reject H_0 and assume the mean for the immediate group is greater than for the delayed group.
Compare immediate and control H_0: $\mu_c - \mu_i = 0$ Ha: $\mu_c - \mu_i \neq 0$	-1.912	28	0.0662	Fail to reject H_0 and assume the data does not support a difference between the control and the immediate.
Compare delayed and control H_0: $\mu_c - \mu_d = 0$ Ha: $\mu_c - \mu_d \neq 0$	1.041	28	0.3068	Fail to reject H_0 and assume the data does not support a difference between the control and the delayed.

Discussion

Immediate core finishing was found to be at least equivalent to delayed core finishing and post-hoc analyses indicated that it was superior, with respect to the mean retentive force required to dislodge dowel-cores cemented with Panavia®21. The manufacturer's recommendations for Panavia® 21, an anaerobic cement, stipulate that the dowel should be coated and no cement should be introduced into the root canal. Oxygen inhibition in the canal promotes faster set of the cement and may result in failure to completely seat the dowel. Turner[44] demonstrated that placement of zinc phosphate cement into the root canal space versus placement only on a preformed dowel (whether parallel-sided or tapered) resulted in a more uniform cement distribution. Goldman et al[45] verified these results in a similar study. In addition, it was found that greater tensile forces were required to dislodge prefabricated dowels where cement had been placed both on the dowel and into the canal, than for dowels coated with cement only. Reel et al[46], using custom cast dowels, demonstrated that there was a significant difference in retention when zinc phosphate cement was placed only on the dowel versus only into the root canal. The retention was higher for the latter group. Since Panavia®21 should not be placed in the root canal, the advantages of this technique realized with zinc phosphate would not apply. It may be that the application of vibration can be compensatory as it may cause the unset cement to flow and lock into irregularities and minor undercuts in the root canal space. This offers a possible explanation for the unexpected experimental outcome obtained.

Only one other somewhat related study on this topic was found in the literature. This was by Bergeron et al [32], who investigated the effect of ultrasonic vibration on the force required to remove prefabricated parallel-sided Paraposts cemented with zinc phosphate and Panavia®21. The ultrasonic force was applied two weeks post-cementation. Interestingly, they found that with both cements, the groups subjected to vibration were significantly more retentive than those in which no vibration was applied. The authors could not explain this finding. They mentioned that they elected not to use water coolant during the application of ultrasonic vibration to the dowels and stated that this might have allowed significant heat formation in the dowel and cement. The heat could have increased the degree of reaction of monomer resin of Panavia but it is not likely to affect zinc phosphate cement.

It may be hypothesized from examination of failure modes and retentive strengths in this study that deliberate placement of undercuts at specific locations in the root canal just prior to cementation of dowels is a clinically desirable technique that could increase dowel retention. The downsides of such a technique would be an increased difficulty in removing the dowel-core if it becomes necessary to replace it, for example due to recurrent decay and an increased risk of perforation of the root canal.

Great care was taken in this study to minimize torquing forces during removal of the dowel-cores from the canals of the specimens. We attempted to apply a pure tensile force along the dowel-cores in an effort to examine the true shear bond strength of the adhesive resin cement Panavia®21, and to eliminate scatter. The standard deviations obtained in the three study groups were comparable to that seen with other similar-sized studies in the literature that used prefabricated dowels and Panavia®.[47,48] It is difficult to compare actual values for retentive force obtained in this study with other studies that examined retention of dowels cemented with Panavia®21. Several factors are known to affect dowel retention including type of dowel-core (custom vs prefab; parallel vs tapered vs parallel-tapered combination; serrated vs smooth), dowel diameter, canal morphology of type of tooth specimen used (for example: ovoid vs ribbon-shaped) and length of dowel used. The dowel length selected in the current study was 13 mm, which was generally longer than the range from 7 to 12 mm seen in comparable papers.[49, 22, 47, 35, 50, 18] The exception to this was the study by Lund and Wilcox [27] in which 13 mm dowels were also used.

Panavia®21 manufacturer's recommended protocol for the treatment of the root canal does not include irrigation with 5% sodium hypochlorite, as is routinely used during endodontic therapy. However, several clinicians will do this, their rationale being that the hypochlorite will rid the canal of any remnant debris that may interfere with the bond strength of Panavia®21 to dentin. There are also references in the dental literature that support this practice when an adhesive resin cement is used. They indicate that shear bond strengths obtained during dowel removal are higher than for dowels cemented into non-hypochlorite irrigated canals.[51,52,53,54] As this represents an area of ambiguity and controversy, and is not recommended by the Panavia®21 manufacturer, sodium hypochlorite irrigation was not used in the present study. This avoided any possible disturbance of the dentin smear layer and possible negative effects on shear bond strength of the cement.

As mentioned in the results, the statistical design used for this study was an equivalence analysis. With this type of analysis, by convention, the value that is taken to represent a clinically meaningful difference is set at 20% of a control value. This is based on examples in the medical literature where equivalence limits were derived empirically from the clinical judgment of investigators in the defined area of research.[43] What was found in this study, expressed in clinical terms, indicates that tensile bond strength of Panavia®21 following immediate core finishing is superior to that of delayed core finishing by at least 20%. Taken on its own, this finding is reason enough to challenge the clinical paradigm of delaying core refinement for at least twenty-four hours after cementation with Panavia®21. However, it becomes even more desirable when the time and cost benefits to both the patient and dental professional are considered. For instance, a patient requiring one to several cast dowel-core-crown restorations could conceivably have master impressions for the definitive restorations made at the same appointment as delivery of the dowel-cores. The procedure could be completed in a much more clinically efficient fashion and save the patient/dentist an extra visit to the dental office. In addition, the technical difficulties involved in attempting to refine a cast core just prior to its cementation can be avoided. Such refining is usually necessary to allow reseating of provisional restorations without opening the patient's occlusion.

The findings of this study are relevant and clinically significant, therefore, attempts should be made to replicate the results. Future studies could include larger sample sizes and investigate the benefits of placing deliberate undercuts into the root canal just prior to cementation of a dowel-core.

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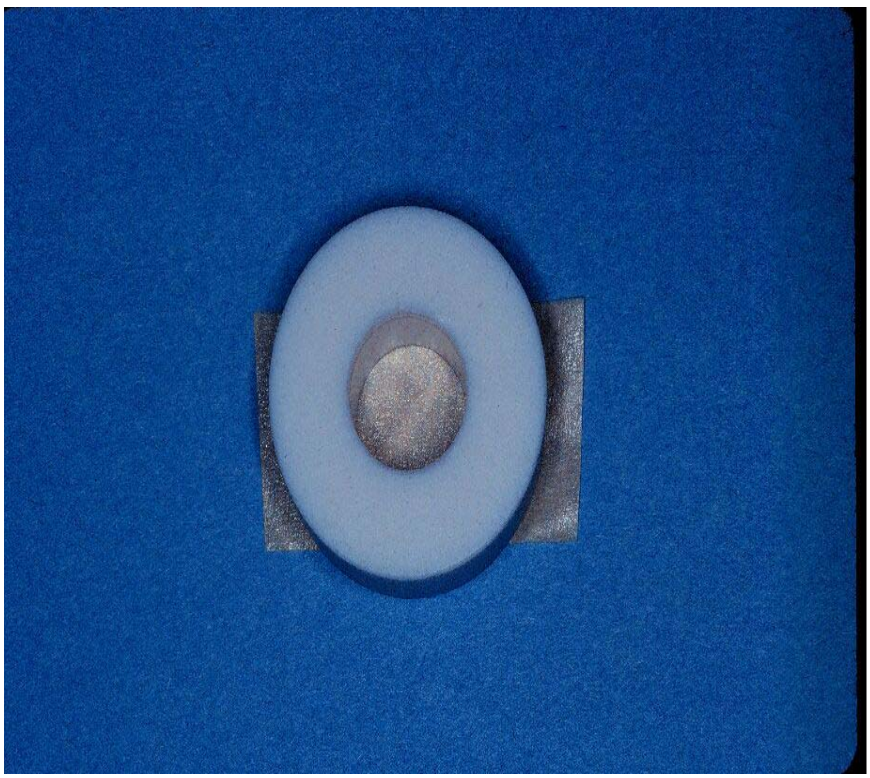
APPENDIX A

Customized GC Resin®/ParaPost®burnout post pattern. Transverse steel post in place.

APPENDIX B

Customized Teflon Mold for Mounting Specimens: closed at base with masking tape



VITA

Purnima Joan Shahani was born on December 11, 1968 in Port-of-Spain, Trinidad, West Indies. She attended St. Joseph's Convent in Trinidad, from which she received Ordinary (1985) and Advanced Level Certificates (1987). She then attended the University of the West Indies School of Dentistry in Trinidad, where she received a D.D.S With Distinction in 1994. Subsequently, she left the island to attend the University of Missouri-Kansas City, where she did a General Practice Residency (1995-1996), and earned a Certificate in Oral Medicine and a Master of Science in Oral Biology in 1998. In the summer of 1998, she was invited to join a research mission investigating O-variant HIV in Cameroon, West Africa. She then began a PhD at UMKC but discontinued it in order to pursue a specialty in Prosthodontics at Virginia Commonwealth University. She received a Certificate in Prosthodontics and a Master of Science degree from Virginia Commonwealth University in 2003. Grants awarded to her include: A Reinhart Foundation grant, UMKC Dental School: for Masters' Research; The UMKC Women's Council: for research mission to Africa; UMKC Chancellor's Interdisciplinary Ph.D. Award: for tuition and travel; Alexander Fellowship, VCU School of Dentistry: for Masters' Research and a Greater New York Academy of Prosthodontics grant: for Masters' Research.