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Comparison of Adhesion of Gutta Percha/AH Plus<sup>®</sup> and Resilon/Epiphany<sup>®</sup>  
SE<sup>™</sup> After a Final Rinse with Different Concentrations of Ethanol

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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## Abstract

### COMPARISON OF ADHESION OF GUTTA PERCHA/AH PLUS® AND RESILON/EPIPHANY® SE™ AFTER A FINAL RINSE WITH DIFFERENT CONCENTRATIONS OF ETHANOL

By Suren Paravyan MD, DMD

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

Virginia Commonwealth University, 2011

Director: Karan J. Replogle, DDS, MS  
Department Chair, Department of Endodontics

The purpose of this study was to evaluate effect of final rinse of ethanol on bond strength in teeth obturated with Gutta Percha (GP)/AH Plus® or Resilon/Epiphany® SE™. Thirty-two extracted human anterior teeth were shaped to size 30, 0.06 taper and subjected to an identical irrigation protocol. Specimens were randomly divided into eight groups according to final irrigating solution (saline, 70%, 95%, 100% ethanol) and obturation material. Two millimeter thick slices were obtained by sectioning each obturated root. Bond strength was determined using micropush-out assay. Data was analyzed using Student's *t*-test.

Obturation with GP/AH Plus® formed a statistically significant stronger bond than Resilon/Epiphany® SE™. A final rinse with ethanol (irrespective of ethanol concentration) did not enhance push-out bond strength with GP/AH Plus®. Push-out bond strength of Resilon/Epiphany® SE™ decreases with increased ethanol concentration with



Resilon/Epiphany<sup>®</sup>SE<sup>™</sup>. Among Resilon/Epiphany<sup>®</sup>SE<sup>™</sup> groups, 70% ethanol resulted in strongest bond strength.

## Introduction

Apical periodontitis and root canal failure are caused by bacteria and their byproducts (1, 2). After invading the root canal space, bacteria can penetrate into the dentinal tubules 150 to 400  $\mu\text{m}$  (3, 4). The main objective of non-surgical root canal treatment is to eliminate bacteria and their byproducts from the canal space by chemo-mechanical cleaning and shaping. Recontamination of the root canal is prevented by three dimensional obturation of the canal space (5).

Instrumentation of root canal walls produces a dentinal smear layer that occludes normally patent dentinal tubules. Removal of the smear layer has generally been shown to increase bond strength to dentin for glass ionomer and resin based materials (6). Removal of the smear layer is reported to reduce microleakage for most sealers including AH26 (7, 8).

Presence of the smear layer prevents penetration of sealer into dentinal tubules (9). While root canal sealers do not bond to canal walls effectively, it is presumed that the penetration of sealer into the dentinal tubules enhances the retention of the obturation material within the canal. EDTA has been used for many years in endodontics for removal of the smear layer (10). Irrigation with 17% EDTA and 5.25% NaOCl has been shown to effectively remove the residual smear layer and allow sealer penetration deep into the dentinal tubules (11). Removal of the smear layer has additional benefit in infected teeth because the smear layer contains bacteria. Saleh et al showed that zinc

oxide eugenol sealer can penetrate into dentinal tubules up to 300  $\mu\text{m}$  and kill bacteria (12).

Regardless of the instrumentation and irrigation techniques, the effectiveness of irrigating solutions remains limited in the apical one third of a prepared canal. This is particularly true for curved root canals (13) and even on single-rooted teeth (14). Therefore, the improvement of irrigating protocols is essential during root canal treatment in order to achieve better cleaning efficiency especially in the very complex apical area. Currently, several techniques and systems are available and reported to improve final irrigation before obturation (15).

Among these protocols, passive sonic irrigation with Endoactivator system (Dentsply Tulsa Dental Specialties, Tulsa, OK) has shown promising results for debris and smear layer removal (16). The Endoactivator system (Dentsply Tulsa Dental Specialties, Tulsa, OK) has been purported to improve disinfection. This device uses a cordless sonic handpiece to activate strong, highly flexible polymer tips. Non cutting tips have tapers and terminal diameters that closely match the dimensions of the final root canal preparation. Mechanical oscillations are produced mainly at the tip of the activator with a frequency ranging from 1 to 10 kHz (17).

The goal for obturation is to obtain an adequate seal between the root canal system and the periradicular tissues. One of the most desirable properties of a sealer is the ability of the sealer to adhere to the core material and the root canal dentinal walls preventing leakage. Examination of the dentin-sealer interface is of interest. Disruption of the established seal due to mechanical stresses caused by tooth flexure is a primary concern. Restoration of an endodontically treated tooth may also involve procedures that

can loosen the root canal filling (18). The bond formed between the root canal filling material and the canal walls is of particular importance for long-term success of root canal therapy (19, 20).

Adhesion is a process in which two surfaces of different molecular compositions are bonded by chemical, physical or mechanical attraction forces (21). Mechanical adhesion occurs by entrapment of a material into another body, within natural or artificial cavities. Chemical adhesion may result from primary valence forces, such as covalent and metallic bonds. Physical adhesion, in turn, relies on secondary valence forces, like Van der Waals forces, London dispersion forces and hydrogen bonds (22). For adhesion to occur, it is necessary that the materials to be adhered are sufficiently close to each other. Therefore, a primary consideration factor is the wettability of the liquid on a solid surface (23), which will provide the required proximity between the materials, facilitating molecular attraction and promoting adhesion (21).

Surface wettability is dependent upon roughness, chemical composition, and hydration state of dentin (24). Water wettability is also specifically dependent on the hydration state of dentin. Dentin is a naturally hydrated biological composite and, if it is desiccated following partial demineralization, the exposed collagen matrix can re-orient and even collapse (24). This is thought to restrict adhesive penetration into the demineralized dentin surface, leading to restorations with lower bond strength and higher microleakage (25). This state is reversible, and rehydration can re-establish the hydrophilic exterior and/or opened collagen network, thus permitting adhesive penetration to occur (25). Therefore, changes in the dentin structure resulting from

demineralization, dehydration, and rehydration could influence wettability of various resin composite primers, particularly those that are water-miscible (23).

Current theory of dentin bonding was first described by Nakabayashi et al in 1982 (26). The process described is still used with today's adhesive materials. It is a three-step process that allows hydrophobic restorative materials to adhere to the wet dentin surface. The resin infiltrated dentinal collagen matrix is commonly referred to as the hybrid layer. The hybrid layer is 2 to 5  $\mu\text{m}$  thick. This process is called hybridization (20).

Hybridization is the primary process used today to bond hydrophobic restorative resin materials to dentin. Contrary to common belief, the dentinal tubules make only a minor contribution to dentin adhesion. The majority of the retention is provided by micromechanical retention from the collagen matrix in the intertubular dentin (27). The only current resin obturating sealer that utilizes dentin adhesive technology is Epiphany (Pentron Clinical Technologies, Wallingford, CT) (20).

Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> (Pentron Clinical Technologies, LLC, Wallingford, CT) is a thermoplastic synthetic polymer-based root canal filling material that has similar handling properties as of gutta-percha. Resilon is based on polymers of polyester. It has approximately 65% filler content by weight including bioactive glass, bismuth oxychloride, and barium sulfate. Epiphany<sup>®</sup> SE<sup>™</sup> system (the sealer) contains a self-etching primer and a dual-curable resin composite (28). Ethoxylated glycerolate dimethacrylate (BisGMA), urethane dimethacrylate (UDMA), and hydrophilic difunctional methacrylates make the resin matrix of Epiphany sealer. The fillers include calcium hydroxide, barium sulfate, barium glass, and silica that make up 70% by weight.

Penetration with a curing light is limited in the root canal system, therefore dual-

cured or self-cured resin adhesives must be used. Dual cured resins contain components that provide rapid light polymerization in those areas where the curing light penetrates effectively and a slower chemical polymerization in those areas where the light is not effective (20).

When Epiphany<sup>®</sup> SE<sup>™</sup> is used with Resilon, the manufacturers claim a “monoblock” is created between root canal dentin and the root-filling material. This is created by the adhesion of the Resilon cone to the resin based sealer, which adheres to dentinal walls and penetrates dentinal tubules (29). In their study, Shipper et al tested bacterial leakage of gutta-percha and AH26 sealer with Resilon/Epiphany<sup>®</sup> “monoblock” system by comparing their efficacy of preventing apical periodontitis after coronal microbial inoculation. The results showed that Resilon/Epiphany<sup>®</sup> “monoblock” system induced significantly less periapical inflammation providing greater resistance to microbial leakage (29). Therefore, Epiphany<sup>®</sup> SE<sup>™</sup> sealer is purported to adhere to root canal dentin.

AH26 is an epoxy resin-based sealer that is widely used as a root canal sealer with good sealing ability (30, 31, 32). Spangberg et al reported formaldehyde release after mixing AH26 with maximum release after two days (33). Other studies found AH26 to be highly cytotoxic in several different cell culture systems 34, 35). Recently AH26 was reformulated and sold as AH Plus<sup>®</sup>. The manufacturer of AH Plus<sup>®</sup> reports it has the same advantageous properties of AH26 but preserves the chemistry of the epoxy amines more effectively and does not release compounds such as formaldehyde which are not biocompatible (36). It is generally placed in the canal without any dentin preparation or dentin adhesive and can be used with any obturating technique. AH Plus<sup>®</sup> became

popular as a sealer due to the fact that it does not contain eugenol, which inhibits the polymerization of resins and can interfere with bonding (37).

Controversial results have been reported when push-out bond strengths of root canals filled with GP/AH Plus<sup>®</sup> are compared with those filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>. A number of studies show that GP/AH Plus<sup>®</sup> root fillings have much higher push-out bond strength than Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> fillings (38, 39, 40); while Skidmore et al reported high push-out bond strength in root canals filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> (41).

Enhancing sealer penetration may play a role in the bonding of the sealer to dentinal walls. Ability of a sealer to penetrate into dentinal tubules depends on its chemical and physical properties (9). Surface tension is an important property of a sealer that plays a critical role in the way sealer behaves. Surface tension of filling material and dental walls is critical factor for determining depth of penetration of the filling material into the dentinal tubules. Lower surface tension provides higher penetration of the filling material (42). Cunningham et al showed that ethanol reduces the surface tension of NaOCl which improves the ability of irrigants to spread in vitro (43). A final rinse prior to obturation with 70% isopropyl alcohol and 95% ethanol has been studied to determine if an increase in sealer penetration would result (44, 45). Engel et al showed that the use of a 70% solution of isopropyl alcohol was not shown to have any effect on the depth of sealer penetration or leakage (44). In contrast, Stevens et al studied use of 95% aqueous solution of ethanol as a final rinse and reported increase sealer penetration and decrease leakage (45).

The purpose of this study was to evaluate the effect of a final rinse of different concentration of ethanol on bond strength between dentinal walls and root canal filling materials in teeth obturated with Gutta Percha (GP)/AH Plus<sup>®</sup> (Dentsply, De Trey GmbH, Konstanz, Germany) or Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> (Pentron Clinical Technologies, LLC, Wallingford, CT).



## Materials and Methods

Thirty-two freshly extracted single-rooted, anterior human teeth with straight roots were selected for this study. All teeth collected would have been disposed of accordingly but were kept for the purpose of this study. Potential specimens for use in this study were radiographed using Dexis PerfectSize (Alpharetta, GA) digital system and evaluated by two operators. Only anterior teeth with straight roots and small canals were selected for the study. Teeth with large canals were eliminated in order to insure that the rotary file would touch all walls creating a similar, circumferential smear layer during instrumentation. All teeth were stored in Hank's Balanced Salt Solution (HBSS) (Thermo Scientific, Inc., Logan, UT) containing 0.2% sodium azide (Sigma Chemical Company, St. Louis, MO).

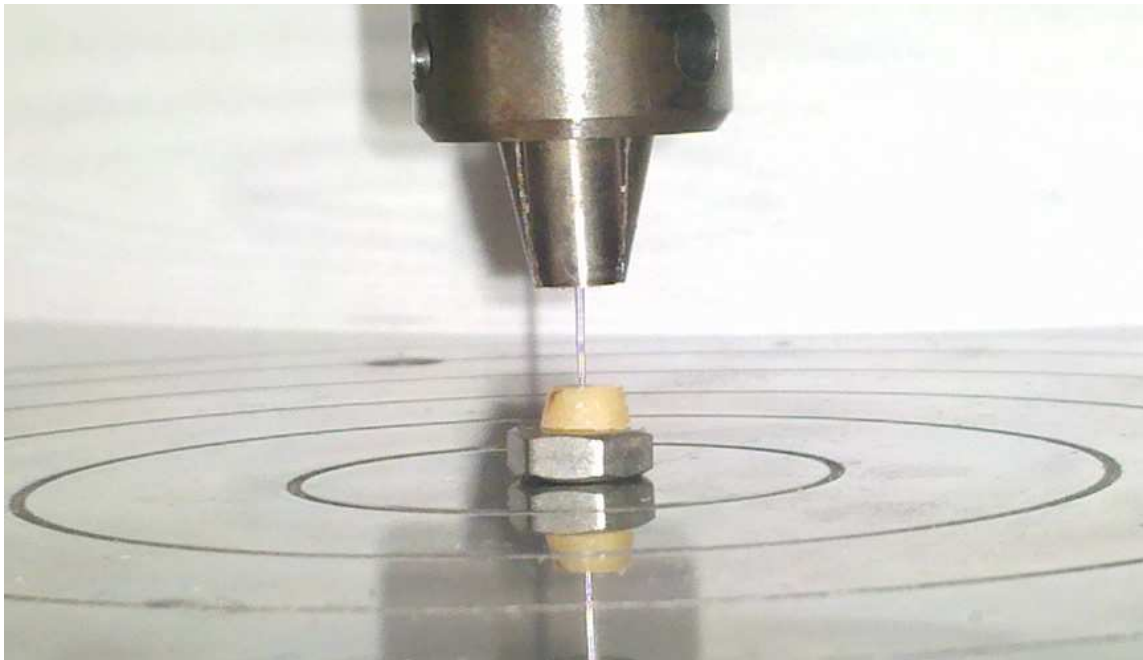
The teeth were accessed with a # 4 round bur in a high speed handpiece with water spray. The working length of all teeth was established by passing a #10 K-file (DENTSPLY Maillefer, Tulsa, OK) to the apical foramen then reducing the length by 0.5 mm from the actual canal length. Canals were prepared with the manufacturer's recommended sequence of ProTaper Universal NiTi rotary files S1, S2, F1 (Dentsply Tulsa Dental, Tulsa, OK) until the finisher F1 instrument achieved working length. The final shape was created with size 30 0.06 taper GTX NiTi file (Dentsply Tulsa Dental, Tulsa, OK) to the working length. The specimens were irrigated with 5.25% NaOCl via a #30 gauge blunt-tip needle between every other instrument.

Smear layer removal was accomplished via irrigation with 4ml of 17% EDTA (Endoco, Inc., Memphis, TN) followed by 4ml of 5.25% NaOCl. The EndoActivator System (Dentsply Tulsa Dental Specialties, Tulsa, OK) was used for thirty seconds using small tips following each irrigant. The canals were dried with paper points after each irrigant used. Specimens were randomly divided into eight groups of four teeth then divided based on obturation material. Each group received an additional 1ml rinse as follows: Group A and E 100% Ethanol, Group B and F, 95% Ethanol, group C and G, 70% Ethanol, and group D and H saline (control group). One additional tooth was prepared as in the control group and was left unobturated for scanning electron microscope analysis (46).

Teeth were obturated based on random group assignment using Gutta Percha (GP)/AH Plus<sup>®</sup> (Dentsply, De Trey GmbH, Konstanz, Germany) resin-based endodontic sealer or Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> (Pentron Clinical Technologies, LLC, Wallingford, CT) following manufacturer's guidelines. Sealer was placed on the apical ends of Gutta Percha or Epiphany cones then pumped several times to coat canal walls. Continuous wave heat plugger was used for downpack using System B (Analytic Technology, Redmond, WA) as heat source, 200°C for Gutta Percha and 160°C for Resilon. Canals were vertically compacted leaving 5-6mm in each canal and accesses were sealed with cotton pellet and 3mm of Cavit (3M ESPE, St Paul, MN). Specimens were stored separately in six-well tissue culture plates for a minimum of two weeks at 37°C in an oven containing water to allow sealer to set. A 2mm thick slice was obtained by sectioning each obturated root at 3mm and 5mm from the anatomic apex by using a low-speed saw (Isomet; Buehler, Ltd, Lake Bluff, IL) with a diamond disk under continuous

water irrigation. The thickness of each slice was measured with measuring calipers (Mitutoyo, Japan) and was within 0.1mm.

Slices were tested with a micropush-out technique (Fig. 1). This was accomplished by using 0.35mm cylindrical plunger that provided the most coverage of the root filling material without touching the canal walls. Specimens were loaded using universal testing machine (Instron Corporation, Canton, MA) at a speed of 0.5 mm/min in an apical-coronal direction to avoid any constriction interference that could be caused by root canal taper during push-out testing. The “debonding” recording operator was blinded as to which samples were tested. The bond strength was expressed in megapascals (MPa) and was calculated by dividing the load in Newtons by the area of the bonded interface (41). Statistical analysis for push-out bond strength data was derived using the Student t-test, with significance set at  $p < 0.05$ .



**Figure 1. Universal testing machine used for push-out test design.**

## Results

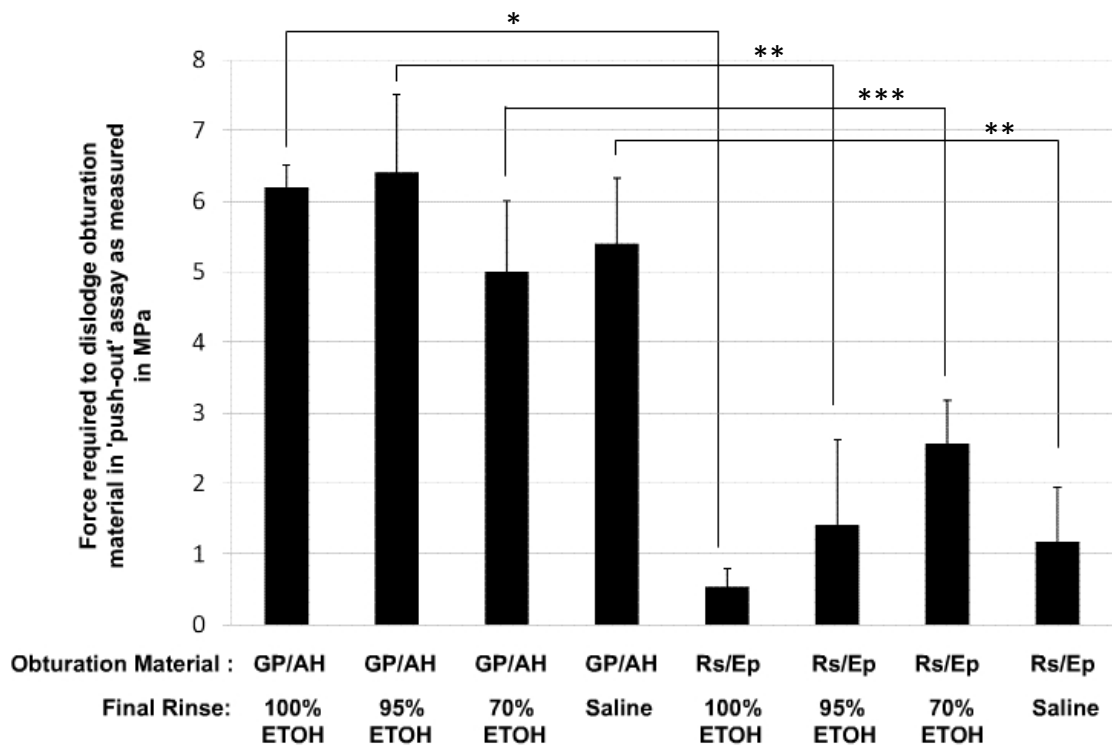
Push-out bond strength was measurable on all specimens. Push-out bond strength was measured in megapascals (MPa) (Table 1). The mean micropush-out bond strength of the GP/AH Plus<sup>®</sup> groups was 5.75 MPa (SD  $\pm$  0.85). The mean micropush-out bond strength of the Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups was 1.42 MPa (SD  $\pm$  0.71).

**Table 1. Mean push-out Bond Strength Value (MPa), Standard Deviation (SD), Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> (RE/SE), Gutta Percha/AH Plus<sup>®</sup> (GP/AH)**

<b>Group</b>	<b>Mean Bond Strength (MPa)</b>	<b>Standard Deviation (SD)</b>
Group A (GP/AH Plus <sup>®</sup> & 100% Ethanol)	6.2	$\pm$ 0.31
Group B (GP/AH Plus <sup>®</sup> & 95% Ethanol)	6.4	$\pm$ 1.12
Group C (GP/AH Plus <sup>®</sup> & 70% Ethanol)	5.0	$\pm$ 1.03
Group D (GP/AH Plus <sup>®</sup> & Saline)	5.4	$\pm$ 0.93
Group E (RE/SE & 100% Ethanol)	0.54	$\pm$ 0.25
Group F (RE/SE & 95% Ethanol)	1.42	$\pm$ 1.19
Group G (RE/SE & 70% Ethanol)	2.56	$\pm$ 0.61
Group H (RE/SE & Saline)	1.17	$\pm$ 0.78

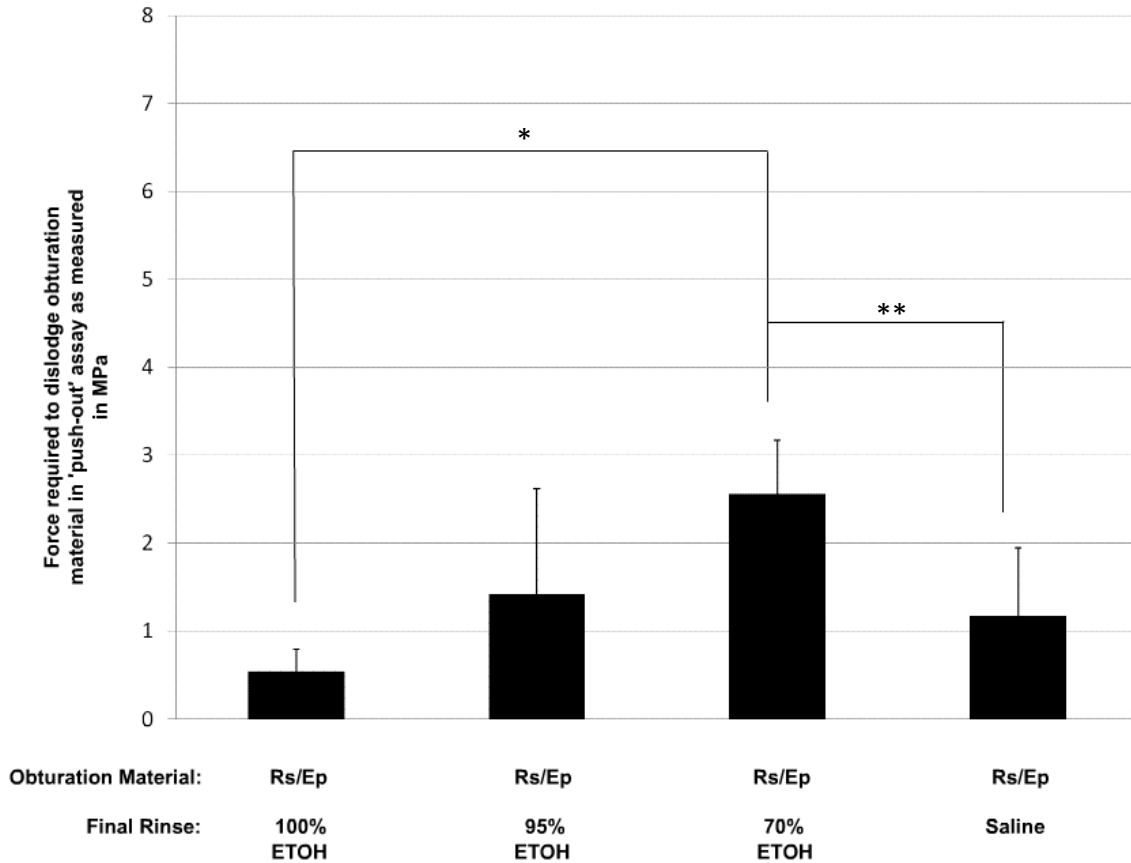
All groups with GP/AH Plus<sup>®</sup> root fillings showed significantly higher push-out bond strength than Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups (Fig. 2). GP/AH Plus<sup>®</sup> with a final rinse of 100% ethanol had a push-out bond strength of 6.2 MPa (SD  $\pm$  0.31) in contrast to Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> with 100% ethanol as a final rinse that had a push-out bond strength of 0.54 MPa (SD  $\pm$  0.25). Difference was statistically significant at  $p < .0001$ .

GP/AH Plus<sup>®</sup> with a final rinse of 95% ethanol had a push-out bond strength of 6.4 MPa (SD ± 1.12) in contrast to Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> with 95% ethanol as a final rinse that had a push-out bond strength of 1.42 MPa (SD ± 1.19). Difference was statistically significant at  $p < .001$ . GP/AH Plus<sup>®</sup> with a final rinse of 70% ethanol had a push-out bond strength of 5.0 MPa (SD ± 1.03) which was stronger than Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> with 70% ethanol as a final rinse that had a push-out bond strength of 2.56 MPa (SD ± 0.61) ( $p < .01$ ). Push-out bond strength after a final rinse with saline was measured as 5.4 MPa (SD ± 0.93) in GP/AH Plus<sup>®</sup> group in contrast to Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> at 1.17 MPa (SD ± 0.78). This difference also was statistically significant at  $p < .001$ .



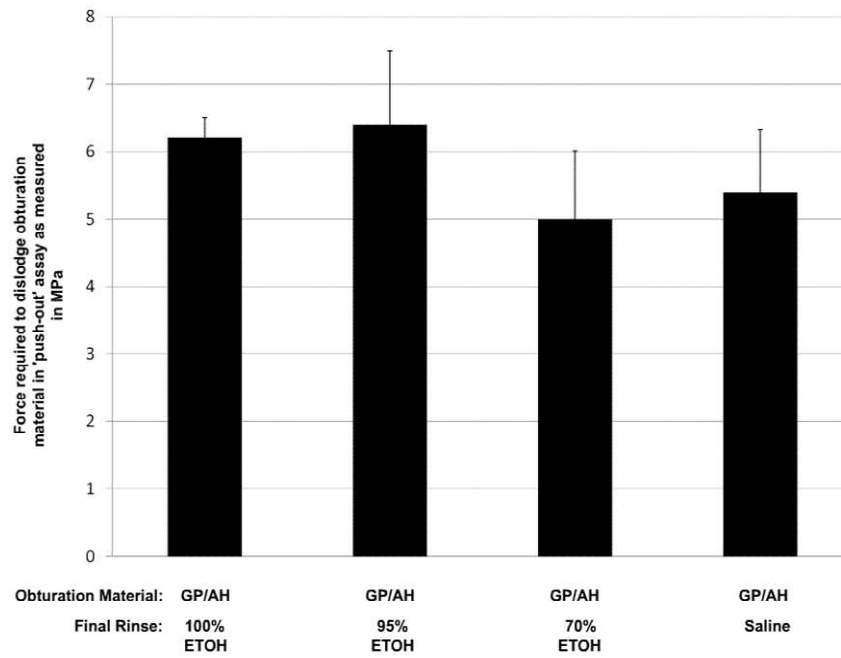
**Figure 2. Box plots of the push-out strength data showing statistically significant differences. GP/AH = Gutta Percha/AH Plus<sup>®</sup>, Rs/Ep = Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>, ETOH = ethanol. Ethanol concentration used as a final rinse represented as a %.**

Within the groups obturated with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>, there were statistically significant differences across the final rinse with different ethanol concentrations. A final rinse with 70% ethanol created push-out bond strength of 2.56 MPa (SD ± 0.61) when roots were filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>. This was statistically higher ( $p < .001$ ) than in Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> group with 100% ethanol as a final rinse and a push-out bond strength of 0.54 MPa (SD ± 0.25). Also, in the Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> filled groups with a final rinse with 70% ethanol, push-out bond strength was stronger than in the control group with saline as a final rinse ( $p < .05$ ). Push-out bond strength in the Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> group with saline as a final rinse was 1.17 MPa (SD ± 0.78) (Fig. 3).



**Figure 3. Box plots of the push-out strength data across Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups showing statistically significant differences. Rs/Ep = Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>, ETOH = ethanol. Ethanol concentration used as a final rinse represented as a %.**

Within the groups obturated with GP/AH Plus<sup>®</sup>, there was no statistically significant difference in push-out bond strength between different ethanol concentrations. Push-out bond strength in GP/AH Plus<sup>®</sup> groups with a final rinse of 100% ethanol was 6.2 MPa (SD ± 0.31); 95% ethanol was 6.4 MPa (SD ± 1.12); 70% ethanol was 5.0 MPa (SD ± 1.03); and saline was 5.4 MPa (SD ± 0.93) (Fig. 4).



**Figure 4. Box plots of the push-out strength data across Gutta Percha/AH Plus<sup>®</sup>, showing no statistically significant differences. GP/AH = Gutta Percha/AH Plus<sup>®</sup>, ETOH = ethanol. Ethanol concentration used as a final rinse represented as a %.**



## Discussion

The dentin-sealer bond strength is an important factor for maintaining the integrity of the seal in the root canal filling (47). The micropush-out test proved to be a reliable and effective method in this study to assess bond strength due to its ability to assess regional differences in the bond strength at different root levels (3mm and 5mm from the apex) and between two different samples (GP/AH Plus<sup>®</sup> and Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>) (48). While authors are aware that bond strength may also be assessed using tensile methodology (49), micropush-out test used herein resulted in statistically significant results. Other evaluation methodologies should include bacterial or other leakage material, light or electron microscopic evaluation, and resorbability. There is no evidence that any of these methodologies is the best one for measuring effectiveness of an endodontic obturation material.

In this study, the push-out bond strength was significantly higher (stronger) in GP/AH Plus<sup>®</sup> groups than in Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups ( $p < .001$ ). These findings are in accordance with other reports with similar studies that reported non-favorable results for the Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> root fillings (38, 39, 40, 50, 51).

The study by Gesi et al (40) compared the sealer-dentin push-out bond strengths of Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> and GP/AH Plus<sup>®</sup> using a similar methodology to study the interfacial strength achieved with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> to intraradicular dentin. The results showed that Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> was not superior to that of gutta-percha and

a conventional epoxy-resin sealer. De-Dues et al, Ungor et al, Gogos et al (39, 50, 51) conducted similar studies to assess push-out bond strength in root canals filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> and GP/AH Plus<sup>®</sup>. They also reported superior push-out bond strength in GP/AH Plus<sup>®</sup> group. These results also correlate with the results obtained in this study.

In contrast, one study reported higher push-out bond strength in Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> root fillings when compared to gutta-percha and Kerr Pulp Canal Sealer EWT (Kerr Corporation, Orange, CA) (41). Teeth were instrumented to size 40 0.06 taper and the smear layer was removed with 5.25% NaOCl and 17% EDTA. In their study, Skidmore et al stored samples in 100% humidity for only 24 hours. This may not have provided enough time for Kerr Pulp Canal Sealer EWT sealer to set. Authors herein, stored the teeth for a minimum of two weeks at 37°C in an oven containing water to allow sealer to set.

Fisher et al (38) used the same laboratory and similar methodology as Skidmore et al to evaluate push-out bond strength of root canals filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> and GP/AH Plus<sup>®</sup>. Their results did not correspond well with that of Skidmore et al. Fisher et al reported weaker push-out bond strength of root canals filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>. The only difference between these two studies was the obturation technique. Fisher et al used single cone technique, while Skidmore et al used vertical compaction technique (which was the same technique used in this study).

Other studies found no statistically significant difference in sealing ability of GP/AH Plus<sup>®</sup> and Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> (48, 50). Shipper et al reported that root canals filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> leaked less than root canals filled with GP/AH Plus<sup>®</sup>

fillings. Inconsistency between these studies illustrates the problematic nature of leakage studies in general and drawing conclusion from any leakage study is suspect.

Interesting in this study, a final rinse with 70% ethanol rinse showed statistically significant higher push-out bond strength than 100% ethanol rinse and 95% ethanol rinse for the Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups ( $p < 0.001$ ) (Fig 2). Surprising was the fact that in the Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups, the dentin-sealer bond strength in 70% group was even higher than in the control group where saline was used as a final irrigant ( $p < 0.05$ ) (Fig. 2).

An important advantage of Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>, according to the manufacturers, is its ability to bond to methacrylate-based resin sealers via the incorporation of dimethacrylates in the polyester-based material. Thus, it is rather surprising that Jordan et al (46) reported debonding between the Resilon and the Epiphany<sup>®</sup> SE<sup>™</sup> sealer, as resin composites normally couple well to dentin adhesives or resin cements. One possible reason could be the low concentration of dimethacrylates that is present in matrix component of Resilon. Another possible reason could be the absence of free radicals within the well-polymerized Resilon material for effective coupling with the Epiphany sealer (52)

The poor bond strength represented in Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups may be a product of the nature of dual cure resins. The geometry of the root canal system is unfavorable for resin bonding. It has extremely high configuration factors (C-Factor). C-Factor is the ratio of bonded to unbounded resin surfaces (48, 53, 54). The greater the percentage of unbounded surfaces, the less stress is placed on the bonded surfaces from polymerization contraction. The unbounded surfaces allow plastic deformation or flow

within the resin mass during polymerization. This may explain the results achieved in this and other studies where weak push-out bond strengths are reported at the Epiphany-dentin interface. It has been demonstrated that methacrylate-based materials, such as EndoRes, Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>, undergo volumetric shrinkage during the polymerization process (20). The unbonded surface area is very limited in the root canal to provide relief from the stresses created by polymerization shrinkage. It may be presumed that the sealer-dentin bond is not sufficient to resist the stress that develops during polymerization resulting in gap formation. For a dual cure resin sealer to truly create a strong sealer-dentin bond the C-factor limitations must be overcome. No bonding system to date has been able to do so.

Moisture is a very important factor for dentin bonding. It is difficult to create an effective bonding to such a wet substrate as root dentin (20). Manufacturers of Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> recommend not to desiccate canals with alcohol and avoid excessive drying that may adversely affect bonding to canal walls. No specific recommendations are made how moist canals should be before Epiphany<sup>®</sup> SE<sup>™</sup> placement. Ethanol has a drying effect and different concentrations may have different drying effects. A final rinse of 70% ethanol may have created the highest push-out bond strength in roots filled with Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>, because the 70% ethanol created the most favorable environment in the root canal system for dentin bonding.

Canals obturated with GP/AH Plus<sup>®</sup> demonstrated significantly greater push-out bond strength than did Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> regardless of whether a hydrating (saline) or dehydrating (ethanol) final rinse was used. The superior adhesiveness to root dentin shown by GP/AH Plus<sup>®</sup> may be due to a covalent bond created by an open epoxide ring

to exposed amino groups in the dentin collagen network (38). In this study, push-out bond strength was not statistically different in the GP/AH Plus<sup>®</sup> groups when different concentration of ethanol was used as a final rinse. It is likely that the results were not statistically different due to small sample size. The sample size in this study was sufficient to detect statistically significant difference in Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> groups because a final rinse with different ethanol concentrations had significant impact on push-out bond strength. In GP/AH Plus<sup>®</sup> groups, the push-out bond strength was different but not statistically significant. Farther studies with larger sample size may be conducted.

Skidmore et al stored samples in 100% humidity for only 24 hours and reported stronger push-out bond strength in Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> root filling (41). Another recommendation for a future similar study would be to store samples in 100% humidity to create similar environment.

Theoretically, introduction of dentin bonding technologies to Endodontics as root filling materials sounds promising but remains problematic. The challenges related to bond creation within a canal and wettability of the dentin walls have not been solved. None bonding conventional root canal sealers such as AH Plus<sup>®</sup> continue to be more practical considering their superior sealing, antibacterial, and adhesive qualities.

## Conclusion

Under the conditions of this study, the following conclusions were made:

- 1) GP/AH Plus<sup>®</sup> forms a stronger bond to root dentin than does Resilon/Epiphany<sup>®</sup> SE<sup>™</sup>;
- 2) A final rinse with ethanol prior to obturation does not appear to enhance push-out bond strength with GP/AH Plus<sup>®</sup>;
- 3) Push-out bond strength of Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> decreases with increased ethanol concentration in the final rinse;
- 4) 70% ethanol rinse creates highest dentin-sealer bond strength. It shows higher push-out bond strength than in the control group that was rinsed with saline.

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## Appendix

**Table 2: Raw Data Collection**

### GP/AH Plus<sup>®</sup> Groups

#### Group 1 ( GP/ 100% ethanol)

Specimen #	Bond Strength in MPa
1	5.91
5	6.36
9	5.97
13	6.56

#### Group 2 (GP / 95% ethanol)

2	5.51
6	5.38
10	7.47
14	7.28

#### Group 3 (GP/ 70% ethanol)

3	4.00
7	6.42
11	4.86
15	4.60

#### Group 4 (GP / saline)

4	4.79
8	4.47
12	6.16
16	6.29

Resilon/Epiphany<sup>®</sup> SE<sup>™</sup> Groups

Group 5 (Resilon / 100% ethanol)

17	0.31
21	0.89
25	0.45
29	0.52

Group 6 (Resilon / 95% ethanol)

18	3.09
22	0.72
26	1.44
30	0.42

Group 7 (Resilon / 70% ethanol)

19	2.26
23	2.90
27	1.86
31	3.20

Group 8 (Resilon / saline)

20	0.63
24	1.85
28	1.84
32	0.37

## Vita

Dr. Suren Paravyan was born on July 30<sup>th</sup>, 1970 in Vanadzor, Armenia. He is currently a citizen of the United States of America. Dr. Paravyan received a degree of Doctor of Medicine from Yerevan State Medical University (Yerevan, Armenia) in 1994. In 2008, he received a degree of Doctor of Dental Medicine from Medical University of South Carolina, Collage of Dental Medicine (Charleston, SC). Dr. Paravyan completed General Practice Advanced Residency Program at Tufts University School of Dental Medicine in 2009, prior to enrolling in the Advanced Specialty Program in Endodontics at Virginia Commonwealth University School of Dentistry. Dr. Paravyan is a member of the AAE, ADA. Dr. Paravyan will enter private practice in Fayetteville NC upon graduation. He will graduate from VCU with a Master of Science in Dentistry and a Certificate in Endodontics.