ENDODONTIC SEALERS-THEIR PROPERTIES AND EFFECTS ON FIBER POST RETENTION

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ABSTRACT

Zinc oxide eugenol sealers have been used clinically for several years. Glass ionomer sealers were introduced due to their adhesion to the dental hard tissues and excellent sealing ability.

During the process of endodontic treatment a post, core and final restoration is required for tooth restoration. Recently fiber reinforced composite posts have become more popular because of their mechanical properties and esthetics. However, fiber posts have to be adhesively cemented into root canal which can be affected by the endodontics sealers. The purpose of this study was to evaluate the effect of eugenol and non-eugenol containing sealers on the retention of fiber posts and to evaluate the apical sealing ability of both sealers.

Forty extracted human single rooted teeth were instrumented to simulate the conventional root canal therapy and divided into two groups (n=20); one was obturated with gutta-percha and zinc oxide eugenol and the other was obturated with gutta-percha and glass ionomer sealer. Gutta-percha was removed and a standardized post space was prepared. The fiber posts were cemented in each group either, with Rely X Unicem or Panavia F 2.0 and ED Primer II system. Each root was sectioned in to three parts. A
push-out test and SEM evaluation were applied for all groups. Bond strengths were analyzed using three-way ANOVA for the combination of the cement, sealer and sections.

The results showed no statistically significant difference in bond strength within the two resin luting systems and the tooth sections.

For microleakage, the apical third section of each root was covered with a nail polish. The specimens were immersed into 50% silver nitrate dye and cleared. The maximum dye penetration was measured and compared using T-test analysis. There was a statistically significant difference among the two sealers. Zinc oxide eugenol showed (2.07±0.36) and glass ionomer sealer (1.5± 0.269).
DEDICATION

I dedicate this thesis to my parents for all their support and love, without their support this would not have been possible, and to my sisters Hamsa and Deema for always being there for me.
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INTRODUCTION

Endodontic treatment cleans, shapes and seals the root canal and effectively eliminates all organic materials and seals the pulp chamber as well as the canal. A successful root canal treatment depends on establishing and maintaining a good seal between the endodontic sealer and the gutta-percha. Because gutta-percha does not seal the root canal effectively, sealers are added to fill and seal the space between the gutta-percha and the dentinal wall. Prepared root canals are commonly obturated with solid cones and sealers to obtain a durable hermetic seal for long-term success. Endodontic sealers fill the space between the plastic gutta percha cones and the prepared canal to improve the sealing ability of endodontic filling\(^1\).

An ideal sealer is a material with no shrinkage, no solubility in tissue fluids, no water absorption, no tooth discoloration, in addition, such a sealer hardens in the presence of moisture, adhesive to dentin and the composite resin core material (e.g. gutta-percha cones), establishes a hermetic seal, biocompatible and antimicrobial, stimulates periapical healing, radiopaque. Sealers should also aid the placement of gutta percha materials by acting as a lubricant\(^2-3-4\).

The most important of these characteristics are providing a hermetic seal and producing minimal toxicity\(^5\). Minimal toxicity is particularly important if the sealer is extruded past the tooth apex since and inflammatory reaction in the periapical tissue by the extruded material interrupts healing. Although all sealers demonstrate toxicity to some degree to periradicular tissues this toxicity decreases with time \(^6-9\).
Classification of Dental Sealers

Two main groups of root canal sealers have been used in dentistry: eugenol (e.g. zinc oxide eugenol) and non- eugenol sealers (e.g. calcium hydroxide, resin, glass ionomer) 1.

1) Eugenol sealers:

Zinc oxide- eugenol sealers have been used often in clinical dentistry due to their low toxicity and the reliable of their formulations 10. Reckert and Dixon’s formula was developed in 1931 as an alternative to (chloropercha) sealers and has undergone significant development because of the rapid setting time of this sealer. Grossman’s formula, developed in 1936, has the following composition: a powder consisting of silver, hydrogenated resin and zinc oxide; and a liquid composed of eugenol and zinc chloride solution.

In 1958, it was reported that silver produced sulfides that darken the teeth, and Grossman eliminated silver from the powder composition and replaced zinc chloride in the formulation with almond oil to delay the setting time and increase working time. In 1962, Grossman added anhydrous sodium tetraborate to the powder to retard the setting time. Further modification occurred in 1974 when he concluded that the addition of almond oil was not necessary because the anhydrous sodium tetraborate provided a satisfactory working time 11.

Zinc oxide eugenol sealer sets as a result of combination of chemical and physical properties, into a hardened mass of zinc oxide embedded in a matrix of zinc eugenolate [C_{10} H_{n}O_{2}JZn] crystals. Excess eugenol is released and absorbed by both the zinc oxide
and the eugenolate. The presence of water, the particle size of the zinc oxide and the pH are all-important factors in the setting reaction. Hardening of the mixture is caused by the zinc oxide eugenolate formation. Unreacted eugenol remains trapped in the mix and tends to weaken the mass in comparison with hardness of fresh dentin to that exposed to zinc oxide eugenol sealers. The hardness is increased in direct proportion to the amount of free eugenol available; the free eugenol mostly increases the cytotoxicity than altering the physical properties of dentin¹.

Zinc oxide has a clinically acceptable e working and setting time that allows adequate manipulation by endodontists. However, the setting time of zinc oxide eugenol can vary according to the ambient temperature and humidity, as well as according to the individual components of the sealer, the resin type and the size of the zinc oxide particles. The working time as well as the setting time of zinc oxide eugenol varies according to the powder/liquid ratio; therefore, zinc oxide eugenol sealers can be prepared in differing consistencies according to the filling technique that has been used¹²-¹³. However, this is not a good method of controlling working time; excess eugenol is trapped, and the sealer is therefore weakened. In addition, viscosity – shear rate of such sealers decreases with stress, this property called is thixotropic. This property is an advantage in endodontics because a thick layer of root canal sealer prevents the adequate insertion of the gutta-percha master cone; as a result the zinc oxide eugenol based sealers have a good flow property than other root canal sealers ¹⁴. Zinc oxide eugenol with higher powder/liquid ratios show increased dimensional stability and decreased solubility¹².
**Biocompatibility of Zinc Oxide Eugenol**

Eliminating microorganisms from the root canal and preventing reinfection are the main purposes of root canal therapy. Although chemo-mechanical preparation and obturation of canal may achieve these purposes, some microorganisms can still be present after preparation and biochemical irrigation and may re-infect the treated endodontic tooth.\textsuperscript{15} for this reason, antimicrobial root canal sealers may prove beneficial by preventing growth of residual microorganisms.

Eugenol remaining in the mixed of the sealer has antimicrobial properties and even low concentrations of eugenol exert anti-inflammatory and local anesthetic effects on the dental pulp. However, a greater amount of free eugenol results in increased cytotoxicity\textsuperscript{16}.

Gulati et al showed that toxicity was greater for zinc oxide eugenol sealer than for the zinc oxide glycerine sealer; as a result the zinc oxide glycerine sealer showed milder tissue response during different time intervals\textsuperscript{17}.

**2- Non-Eugenol Sealers:**

Glass ionomer cements (GIC) were introduced in 1979 as root canal sealers in an \textit{in vitro} study by Pitt Ford \textsuperscript{18}. these cements seemed to be successful when used with a single cone technique, but the working time was too short for them to be used with a lateral condensation filling technique. Stewart et al \textsuperscript{19} proposed two other formulations that increased working time and radiopacity by adding barium sulphate to the formulations. In 1991, Ray & Seltzer et al \textsuperscript{20} introduced a usable experimental formulation with adequate working time, radiopacity and adhesion to the root canal wall; this formulation led to Ketac-Endo in 1990.
Composition of Glass Ionomer Sealer

Wilson & Kent et al (1972) \(^{21}\) used a reactive aluminosilicate glass to combine the strength, rigidity and fluoride release properties of the glass powder with the biocompatibility and adhesive properties of an acrylic liquid. The composition of the silicate glass powder in GIC was based on the formulation $\text{SiO}_2$-$\text{Al}_2\text{O}_3$-$\text{CaF}_2$-$\text{AlPO}_4$-$\text{Na}_3\text{AlF}_6$. Some present GIC contain fluorite, strontium or barium to enhance opacity. Several GIC contain a copolymer of acrylic acid with dicarboxylic acid to control the viscosity of polycarboxylic acid\(^{23}\).

Biocompatibility of Glass Ionomer Sealer

Conventional GIC have excellent biocompatibility for three reasons: They set with minimal exotherm, neutralization is sufficiently rapid that any irritation from free acid is minimal and the substances leached from the set cement are benign to the tissue. Although specific research on GIC root canal sealers is limited, GIC in general are biocompatible. Subcutaneous implantation in rats caused a mild inflammatory reaction on the fifth day, and this reaction decreased progressively, in comparison, zinc oxide eugenol based sealers produced severe irritation. In addition, GIC was nontoxic in baboons and in human in bulk and showed normal haemopoietic and osteoplastic activities on the cement surface\(^{25}\).

Commercial GIC consist of an aluminosilicate glass powder in an aqueous solution of a copolymer of acrylic acid and tartaric acid. When the liquid is mixed with the powder, hardening takes place when an acid attack of the glass surface causes release of calcium and aluminum ions. The ions form a salt bridge between the carboxyl groups of the polyacid, and the result is a matrix surrounding the intact glass particles. The
matrix is adhesive to the tooth because calcium ions bind to the carboxylate groups of polyacid chains\textsuperscript{26}.

The success of the restored endodontically treated teeth depends upon the success of each step in the endodontic filling and restoration procedure. The root canal filling must produce an excellent seal to prevent apical failure. The sealing ability of GIC has mostly have examined \textit{in vitro}. Although somewhat controversial, GIC have shown similar sealing ability when compared to those conventional sealers based on zinc oxide eugenol or resin\textsuperscript{27-28-29-30}.

GIC is often used in combination with a single cone technique because of the short working time of glass ionomer sealers. This rapid set leads to a poor seal because of the increased viscosity of the GI sealer\textsuperscript{31-32}.

Leakage mainly occurs between the root canal wall and the sealer, where the smear layer influences the seal; removal of smear layers opens the dentinal tubules and enhances the bond strength\textsuperscript{33}. In a comparative study by Saunders & Saunders et al\textsuperscript{34} the group treated with Ketac-Endo and Thermafil pretreated with a conditioner to remove the smear layer showed less leakage after 7 days than the other groups.

Sauders et al\textsuperscript{35} demonstrated that leakage may be produced by irrigating solutions and intracanal medicaments used during root canal treatment. Using 40\% citric acid to remove the smear layer then filling the teeth by lateral condensation of gutta-percha with Tubliseal, a resin based glass ionomer, or Vitrabond. With both sealers, those teeth in which the smear layer had been removed had significantly less leakage than the specimens in which the smear layer was left intact (P < 0.001).
After endodontic treatment, the tooth must return to normal function. However, when a great amount of dental structure is lost, a post must be placed in the prepared canal space to retain the crown. In addition crown retention is increased and the leakage of microorganisms from the oral cavity into the root canal system is decreased\textsuperscript{36-38}. Recently, the choice of post materials available for restoring endodontically treated teeth has increased. In addition to custom cast posts carbon fiber, ceramic and glass fiber posts are available. Either cast or prefabricated metal posts may be more rigid than dentin; with rigid posts, during function, load is transferred to the canal walls and the result may be root fracture. Fiber posts with a modulus of elasticity similar to dentin produce better distribution of forces; during function. King et al \textsuperscript{39} reported that the mode of failure of carbon fiber reinforced epoxy posts was more favorable to the tooth compared to metallic posts.

Carbon fiber posts were introduced in the 1990s, made of stretched and aligned carbon fibers embedded in an epoxy resin matrix, these posts showed high fatigue resistance and high tensile strength with a modulus of elasticity similar to that of dentin\textsuperscript{40}. However, carbon fiber posts are dark, which produces a problem when an esthetic restoration is required. More recently other types of fiber posts have become available; including quartz fiber, glass fiber and silicone fiber posts\textsuperscript{41}. In vitro studies have demonstrated that adhesive resin luting agents improve post retention. Bonding within the root canal is difficult for the practitioners with current dentin-enamel bonding systems. Many factors play a role in this procedure, such as the time elapsed from the endodontics treatment to the restorative phase, strict moisture control, inadequate placement and coverage of the adhesive components into the prepared
canal space, variability in root structure, short working time and type of endodontic sealer used in the root canal treatment. Because eugenol has deleterious effect on resin components, significant loss of retention has been shown when eugenol was used with resin–based cement. Hagge et al found that a long interval between root canal obturation with zinc oxide eugenol sealers and post placement has a negative effect on retention and that this effect probably results from the greater penetration of eugenol into the dentinal tubules.

Bonding to dentin is usually starts with etching the dentin, removing the smear layer, and followed by placing a layer of hydrophilic primers that diffuse into the demineralized dentin. A final application of bonding resin and its polymerization completes the bonding process. The diffusion area forms a hybrid layer by diffusing around the exposed collagen fibers and by penetrating into the opened dentin tubules.

The etching time, acid concentration and penetration of the etchant into the canal can affect the demineralization of the dentin and subsequently the bond strength of the adhesive. The hybrid’s layer and resulting bond strength is affected by several factors such as, variability in the dentin substrate, inadequate primer coverage, solvent removal, curing and the adhesive resin luting system. Metal posts have been standard for many years in restorative dentistry; however, recently, there has been a movement toward non-metal posts due to their ability to bond to resin cements and dentin.

**Types of Endodontic Posts**

Numerous factors contribute to post retention. These factors include post design, post length, post diameter, surface roughness, canal preparation, method of cementation
and the luting cement. Posts can be divided into active and passive. Active posts are threaded into dentin and are more retentive than passive posts introduce more stress into the dentin\textsuperscript{54}.

Passive posts can be divided further into parallel–sided or tapered. Parallel posts provide greater retention than tapered posts. In addition, even if passive posts do not engage the dentin, they introduce stress to the remaining root canal; however, the amount of stress produced is less than that with active posts.

**Metal cast post and core**

The custom cast post and core technique has a history of success in restorative dentistry. Traditional cast posts either are made from a direct pattern that consists of resin and are fabricated in the patient’s mouth or are made from an indirect pattern that consists of resin and wax and is fabricated in the dental laboratory on a cast. Both patterns are usually cast in metal at the laboratory which makes cast and core posts a two visit procedure and, more expensive and time consuming technique than a prefabricated post and core. In this system post retention is based on the intimate fitting (friction) of the post to the walls of the prepared post; these posts are cemented with zinc phosphate, glass-ionomer, resin or polycarboxylate cements. Cast posts are rigid and stiff, with an elastic modulus higher than dentin\textsuperscript{54}.

The more rigid metal transfers lateral forces to the dentin and increases the incidence of root fracture. *In vitro* studies\textsuperscript{56-57} and retrospective clinical studies\textsuperscript{58-59} have consistently shown that the fracture resistance of teeth restored with custom cast posts is lower than prefabricated posts.
Sorensen and Martinoff\textsuperscript{60} reported the results of a retrospective clinical study on restored endodontically treated teeth in which 600 patient records from nine dentists in general practice were examined. They found that 12.6% failed in different modes that 10 teeth had non-restorable fractures, and that in 11 teeth post dislodgement occurred. The results of this and previous studies demonstrated that failure was primarily caused by post movements and root fracture.

Root fracture is caused by stress distribution of the post inside the canal wall, the modulus of elasticity of the post, the luting agent and the remaining tooth structure. The modulus of elasticity of the post is higher than dentin which is more elastic. This difference may lead to stress concentration on the root and then to fracture\textsuperscript{59}. Pontius et al\textsuperscript{61} performed an \textit{in vitro} fatigue study of endodontically treated teeth with different post systems and demonstrated that the survival rate after 1,200,000 cycles in the artificial mouth were: 90% in the group restored a with a zirconia post and prefabricated bonded ceramic core, 80% in the group restored with a ceramic post, and with prefabricated ceramic core 60% and 100% in the group restored with a light-cured composite and dentin bonding agent. Samples restored with a cast post and core demonstrated more vertical root fractures.

The importance of the crown ferrule was demonstrated in an \textit{in vitro} study by Pereira et al\textsuperscript{62} who reported an increase in the amount of prepared coronal dentin (ferrule) significantly increased the fracture resistance of teeth treated endodontically with prefabricated posts and core. They showed that the fracture resistance of the 3mm ferrule group was significantly higher than the 0-mm and 1-mm group. Clarisse and
Herman et al.\textsuperscript{63} reported that the remaining coronal tooth structure may be affecting the fracture resistance of the restoration.

**Prefabricated Metal Posts**

Prefabricated posts are made of stainless steel, nickel chromium alloy or titanium alloy. Ideally, post and core material should have a modulus of elasticity, compressive strength and coefficient thermal expansion similar to those of dentin and should be non-corrosive and luted easily into dentin. Stainless steel has been used as a prefabricated post; however, it contains nickel, and nickel sensitivity is a problem in some patients. Pure titanium has slightly lower physical properties like compressive and flexural strength than alloys do, but it is the least corrosive and the most biocompatible. A study by Akkayan et al.\textsuperscript{64} showed that in comparison with teeth restored with glass fiber posts, those restored with quartz fiber posts have higher resistance to fracture; Teeth restored with glass fiber and zirconia posts were similar ($p>.05$).

**Prefabricated Fiber Posts**

In the 1990s, a non-metallic material was popular for posts based on carbon fiber reinforcement\textsuperscript{65}. the main proposed advantage with this post was that it could be bonded to the tooth with resin cement, however epoxy posts can not bond to composite resin\textsuperscript{1}. However, with modern adhesives and resin cements and composite fiber posts have come significant improvements in post retention. Adhesive resin cements have been advocated for post cementation because they bond the post to the tooth structure (Mendoza and Eakle\textsuperscript{66} and may reduce leakage between the cement and the dentin; therefore, the
potential for recurrent caries or endodontic complications is decreased (Hill et al., 1986)\textsuperscript{67} If cement could improve post retention, then shorter posts would provide adequate retention. Shorter posts would be easier to prepare, would conserve tooth structure, increase apical seal and would reduce the risk of lateral root perforation during preparation\textsuperscript{67-68}.

However, some studies have not shown improved post retention with resin cements and eugenol containing sealers \textsuperscript{69-70}. One possible explanation for this finding is the polymerization inhibiting effects of eugenol on composite resins\textsuperscript{71-72}. A second factor could be that the irrigating solutions used during the endodontic filling procedure could inhibit polymerization of the resin cement\textsuperscript{73}. In that study, Boone et al discovered that removing additional tooth structure during post space preparation after using an eugenol sealer eliminated the retention decreasing effects of the eugenol. Another factor limiting the effectiveness of adhesive is the difficulty of applying bonding agents in a canal space, rinsing the etchant, drying the primer completely and applying the unfilled resin adhesive. Montes et al \textsuperscript{74} reported that the delivery system is critical in applying the adhesive properly. Using a syringe delivery system and adapters for air drying the canal resulted in post retention that was greater than the post retention obtained with self-adhesive cement (Unicem). A final factor limiting the ability of adhesive to improve post retention is the C factor and lack of compliance of the root. (Bouillaguet et al 2007). Mannocci \textsuperscript{75-76} has reported, that although bonded posts initially increase root strength, this strengthening effect is lost after functional loading and thermocycling. Predictable bonding in prepared post spaces is difficult and may not lead to increased post retention\textsuperscript{77}. 
The proposed advantages of prefabricated fiber posts are that most of these posts can be bonded to the tooth with resin cement, have a modulus of elasticity similar to that of dentin\textsuperscript{78} and can be easily removed for re-treatment. They are made out of carbon, glass or quartz fibers embedded in a resin matrix. The resulting post is strong but has significantly less stiffness than ceramic or metal posts do. These posts are bonded in the prepared post space; therefore, their retention is based on the bond strength achieved by the correct manipulation of the bonding and luting agents by the clinician. The white or translucent posts are esthetically acceptable; that are white or translucent except for the carbon fiber post because of their dark color\textsuperscript{79}.

A study by Cagidiaco et al\textsuperscript{80} evaluated the two year clinical performance of 162 endodontically treated teeth restored with glass-fiber posts. 150 patients were restored. The patient age and gender, tooth type (anterior or posterior), number of residual coronal walls, size of the post placed and type of restoration. Results of two years, recall revealed no root or no post fractures, and no failures of the core buildup were recorded. The failure found was post debonding in 7 (4.3\%) cases; two occurred in anterior teeth, and five occurred in posterior teeth. An endodontic failure was found (3.0\%) in 2 anterior teeth and 3 posterior teeth. In all cases, post debondings were in crown-covered teeth. Adequate fatigue resistance of posts used in the study might explain the low percentage of failures in general and lack of post fracture.

*Properties of the Fiber Post*

Many fiber posts studies focused on their physical properties under load\textsuperscript{81-82-83} it is essential to know the mechanical properties of these post to understand their behavior
Post fracture is a cause of the post failure and will cause loss of the final restoration or even root fracture. Some authors recommend a more rigid system that uses a smaller post diameter gives greater conservation of tooth tissue during preparation. Results of three–point bending tests of fiber based posts and metal posts have shown that fiber posts are more rigid than metal posts.

Flexural strength is defined as the property of a material or a structural member that indicates its ability to resist failure in bending. Galbano et al (2005) measured the flexural strength of 8 fiber posts with a three point bend and test reported that their flexural strength ranged from 677 MPa to 434 MPa and stated that the values obtained depended upon the number of fibers in the post. Mannocci et al found only one failure in each of two fiber post groups (quartz fiber, carbon–quartz fiber posts), and six failures (one crown fracture, 5 root fracture and post fracture) while six failures were reported in zirconia posts; all failures occurred after intermittent loading at an angle of 45 degrees to the long axis of the tooth at a frequency of two cycles per seconds.

Modulus of elasticity is the slope of the linear part of the stress-strain curve in the elastic region. It is a measure of the stiffness of the material and is dependent upon the strength of interatomic bonds and the composition and not upon microstructure. Modulus of elasticity is also called Young’s modulus.

Some factors can change fiber posts physical properties. Flexural strength decreased when fiber posts are immersed in water and after thermocycling and these factors might be cause of clinical failures of fiber based posts.

Fracture resistance testing of fiber posts will give an idea of their clinical performance. Albuquerque et al reported that stainless steel posts have a higher level of
stressed concentration than titanium and carbon/Bis-GMA posts. Pegoretti et al.\textsuperscript{87} evaluated the finite elements of the glass fiber composite post, carbon fiber post, gold alloy post and natural teeth and found that the mechanical behavior of gold cast post and core produced the greatest stress concentration at the post–dentin interface. The glass fiber composite had the lowest peak stresses inside the root because its stiffness is similar to dentin. Also, the fiber composite post induces a stress field quite similar to that of the natural tooth.

\textit{Macrostructure and Microstructure of the post}

These composite fiber posts have a resin matrix surrounding reinforcing glass fibers. The microstructure of each post is based on the diameter of the single fibers, on their density, and on the quality of adhesion between them. For superior mechanical properties, the glass fibers are oriented parallel and are distributed equally over the surface area. Also, during the manufacturing process, the glass fibers are inserted into the resin under tension to improve post stability.

\textbf{Other Prefabricated Tooth-Colored Posts}

Metal posts are rarely used in anterior restorations because they are dark and therefore are not esthetically acceptable. Tooth colored posts include zirconia and composite resin fiber posts. Zirconia posts have a successful clinical history and are biocompatible and radiopaque\textsuperscript{88}. However, they are rigid and brittle and have a higher modulus of elasticity than stainless steel\textsuperscript{89} in addition; unlike feldspathic porcelain posts these posts cannot be etched to improve the bond\textsuperscript{90}. 
Endodontic Procedure

Restoring endodontically treated teeth is a common procedure in the clinical practice of dentistry. Morgano et al.\(^1\) reported that 85\% (909 of 1066) of the dentists surveyed restored more than 30 endodontically treated teeth per year. Techniques used to restore endodontically treated teeth vary by geographic region, age, training and specialty status of the restoring dentist. Endodontic procedures require the cleaning, preparation, and filling of the canal space with gutta-percha. Different solutions such as disinfectants or irrigants are used during endodontic preparation. These materials may have an unfavorable action on the bonding mechanism during the restoration of an endodontically treated tooth with a fiber post. In addition, the surface of the canal also contaminated by the use of eugenol-containing endodontic sealers; there is a concern that such contamination may interfere with the polymerization process. Hagge et al.\(^4\) and Edson et al.\(^2\) reported that eugenol reduced the bond strength of resin-based materials. This finding disagrees with the results shown by Kurtz et al.\(^3\) and Schwartz et al.\(^4\) who reported that the sealer used in the endodontic procedure had no effect on the bond strength. The differences in these studies are related to the experimental protocol used. Ngoh et al.\(^5\) used liquid sealer instead of powder which is not used clinically. EDTA has an adverse effect similar to eugenol on the dentin bonding procedure.\(^6\) Irrigating the canal with sodium hypochlorite removes tissue tags and is bactericidal which is beneficial to the endodontic procedure. However, Ari et al have stated that NAOCL causes strong inhibition of the interfacial polymerization of resin bonding materials.\(^7\)

The push-out test is used to determine the strength of the bond between the resin luting agent and the dentin. This test was used in recent studies evaluating bond strengths
of endodontic posts cemented with different adhesive resin luting systems. Ferrari et al. compared the results from a push-out test with those from a microtensile technique and concluded that the push-out test is more reliable than microtensile test when measuring the bond strength of luted fiber posts.

**Objective of the Study**

Post retention can be increased by increasing post length, by using rough instead of smooth walls and by using active or parallel sided post instead of tapered posts surfaces. Post retention is determined by the cement, surface design of the post, post length and post shape. Active posts have the greatest retention, parallel posts are intermediate and tapered posts are the least retentive. Resin cements, within limits, enhance post retention in endodontically treated teeth. Using eugenol with resin based cement can lead to extensive loss of retention; this loss results from greater penetration of eugenol into the dentinal tubules.

The purposes of this study were to evaluate the bond strength of fiber posts cemented to dentin and sealed with different sealers (zinc oxide eugenol or glass ionomer) and two dual cure resin cements (self–etch and self-adhesive bonding systems). We also measured the effect of different cementing systems on the cervical, middle and apical levels of root canal dentin. Scanning electron micrographs (SEMs) were used to evaluate the fracture mode of the adhesive resin luting system to dentin. The null hypotheses to be tested were as follows (1) There is no statistically significant difference in microleakage and apical seal when (Activ-GP) glass ionomer or (Roth’s) zinc oxide eugenol is used (2) there is no difference in post retention when the posts are cemented with a self-adhesive (Rely X Unicem) or a dual cure (Panavia F2.0) cement and (3) there
is no effect on post retention of either cement with a zinc oxide eugenol sealer or the glass ionomer sealer.

Specific Aims

1) To measure and compare the leakage of glass ionomer and zinc oxide eugenol sealers.

2) To evaluate the effect of available different dual-cure resin luting systems on push out strength of adhesively cemented prefabricated fiber posts from the root canal dentin.

3) To measure the effect of different endodontic sealers on the bond strength of resin cement to root canal dentin.
MATERIAL AND METHODS

Forty extracted caries free human single rooted teeth were selected on the basis of similarities in canal shape, size and location (Fig 1). Radiographs were taken in mesiodistal and buccolingual directions (Fig 2). Teeth with multiple or irregularly shaped canals or visible cracks were excluded from the study. Teeth included in the study had a root length of 16 mm from the cement-enamel junction (CEJ) to the anatomical apex. All crowns were separated from their roots at the level of the CEJ, by using a low speed diamond wheel (Brasseler, Savannah, GA, USA), and the crowns discarded.

Endodontic Procedure

An endodontic filling was completed on all teeth. The root canals were cleaned and shaped with stainless steel K-Flex hand files started from #15 (Kerr Division, Sybron Corporation, Romulus, MI, USA), with copious sodium hypochlorite irrigation. Each tooth was instrumented to a size 45 file. Lateral condensation was used to place the accessory cones after a master cone had been cemented. Roth’s (811) eugenol based cements and glass ionomer (non-eugenol) based cements (Bresseler, Savannah GA, USA) were used to cement a 0.04 tapered size 45 gutta-percha master cone (Henry Schein, Melville, NY, USA) to the working length. Accessory points with finger spreaders were used to complete the obturation with the lateral condensation (Fig 3).
Post Space Preparation

After completing the root canal filling, the teeth were stored in the normal saline. Each post space was prepared to a standard depth of 8 mm to ensure that at least 4 mm of gutta-percha were left at the apical seal area. Peso reamers (Moyco Union Broach, York, PA, USA) were used to remove the 8 mm of gutta-percha; this procedure was begun with size 2 and ended with size 4 reamer. After the reaming was completed a number 2 finishing drill (3M ESPE Dental products, St. Paul, MN, USA) was used to finalize the preparation of the post space (Fig 4). Radiographs were taken to confirm that at least of 4 mm of gutta-percha remained at the apex and to check the fit of the post in the prepared space.

Group Distribution

Ten teeth were randomly assigned to one of four groups as follows: Group 1, Rely X Unicem (3M ESPE Dental products, St. Paul, MN, USA)(Fig 5) + zinc oxide eugenol sealer (Roth’s (811) eugenol based cement; Group 2, Rely X Unicem (3M ESPE Dental products, St. Paul, MN, USA) + glass ionomer sealer (Brasseler, Savannah GA, USA); Group 3, Panavia F 2.0 and ED Primer II (Kuraray America, Inc, NY,USA)(fig 6) + zinc oxide eugenol(Roth’s (811) eugenol based cement; Group 4, Panavia F 2.0 and ED Primer II (Kuraray America, Inc, NY, USA) + glass ionomer sealer (Brasseler, Savannah GA, USA) (table 1).
Table 1 Experimental groups

<table>
<thead>
<tr>
<th>Group</th>
<th>Adhesive Cements</th>
<th>Sealer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Rely X Unicem</em> (3M ESPE Dental products, St. Paul, MN)</td>
<td>Zinc oxide- eugenol(Roth’s (811) eugenol based cement)</td>
</tr>
<tr>
<td>2</td>
<td><em>Rely X Unicem</em> (3M ESPE Dental products, St. Paul, MN)</td>
<td>Glass ionomer cement(Brasseler, Savannah GA, USA)</td>
</tr>
<tr>
<td>3</td>
<td><em>Panavia F 2.0 and ED Primer II</em> (Kuraray America Inc, NY).</td>
<td>Zinc oxide- eugenol(Roth’s (811) eugenol based cement)</td>
</tr>
<tr>
<td>4</td>
<td><em>Panavia F 2.0 and ED Primer II</em> (Kuraray America Inc, NY).</td>
<td>Glass ionomer cement(Brasseler, Savannah GA, USA)</td>
</tr>
</tbody>
</table>

**Bonding Technique**

Group #1, *Rely X Unicem* (3M ESPE Dental Products, St. Paul, MN, USA) + Zinc oxide eugenol sealer. The canal was rinsed with water and air-dried. *Unicem Aplicap* was activated for 2-4 seconds and mixed in a high frequency mixing unit for 15 seconds, and an elongation tip attached to the end of the capsule. The cement was injected coronally from the apex in no less than 5 seconds. The #2 post was inserted, and the excess cement removed with a brush. The cement was tack cured by placing a curing light at the end of the post and light curing for 20 seconds. The same procedure was used with *Rely X*
Unicem (3M ESPE Dental products, St. Paul, MN. USA) and glass ionomer sealer (Fig 9).

Group #2, Panavia F 2.0 and ED Primer II (Kuraray America, Inc, NY) + Zinc oxide-eugenol. The ED II primers (parts A and B) were mixed and applied to the canal with a Skini syringe fitted with a 20 gauge Endo-Eze tip (Ultradent Products, Inc., South Jordan, UT). The tip was inserted to the full depth of the canal, and the cement was injected as the tip was withdrawn. After 30 seconds had passed the canal was gently dried with an air/water syringe. Equal parts of Panavia paste A&B were mixed and injected into the canal with a Skini syringe fitted with a 20 gauge Endo-Eze tip (Ultradent Products, Inc., South Jordan, UT) and the post was seated into the canal. Excess cement was removed with a brush, the post was tack cured and a one kilogram weight was applied to the post, and which was then cured by placing a curing light at the end of the post for 20 seconds. This procedure was repeated for the Panavia F 2.0 and ED Primer II (Kuraray America, Inc, NY, USA) and glass ionomer sealer (Fig 7-8).

**Push –Out Test Sample Preparation**

Seventy–two hours after cementation, the root was cut into three sections starting at the cervical root end using a low speed diamond wheel (Brasseler, Savannah GA, USA). The four resulting 2 mm root sections were used to determine the bond strength of the cemented posts to dentin at standardized levels within the root. The apical area of each section was marked with a black Sharpie permanent marker (AP.USA) to differentiate the cervical and apical sides of each radicular section (Fig 10) A digital caliper (Mitutoyo, Absolute Digimatic Series 500, Japan) was used to determine and record the diameter of
the cemented post canal on the cervical and apical sides of each root section, the caliper was also used to measure and record the length of each root section (Fig 11).

The push-out test was performed on all of the different section levels of the root in all groups with the use of a Universal Testing Machine (Instron Model # 5565, MA, USA) (Fig 12) and a custom made fixture (Fig 13). This fixture aligned the post with the stainless steel rod on the upper crosshead of the Instron. When the rod contacted the post, the cemented posts were pushed out of their corresponding root sections at a rate of 1.0 mm/min by using a 500 Newton load cell. The maximum strength before bonding failure occurred was recorded in Newtons (N).

The maximum push-out values were converted into Megapascals (MPa) by dividing the maximum load by the bonded surface area of each post specimen in mm². The bonded surface area was calculated by using the following equation: $A = \text{surface area of the Trapezoid} = \frac{(a+b)}{2} \times h$, where $a$ = is the upper part of the post section, $b$ = the lower part of the section and $h$ = the height of the post.

The data were analyzed by using a three-way ANOVA for the variables (groups, levels and the interaction between the cements and the sealers). Because this method was specifically designed to compare means among more than two groups, a post-hoc test, the Tukey-Kramer analysis, was used to make air wise comparisons between two specific groups and two specific levels.

**SEM Sample Evaluation**

One specimen from each group was evaluated with scanning electron microscopy (SEM, ISI SX 30, Cambridge, MA, USA) (fig 14) to examine the adaptation of the resin luting agent to the root canal dentin. Each root section was examined. The post sections
with their bonded surface were placed in a Sputter Coater (Hummer X, Anatech, Hayward, CA) coated with gold and palladium. The specimens were used to determine the resin tag formation and the morphology of the root canal dentin. Each specimen was examined, and a representative section chosen and photographed at 2000X power magnification.

Apical leakage Measurements

In both groups, after cutting the specimens for the push-out test the apical third of each tooth were taken (Fig 15), and each part were coated with two layers of nail polish (MAYBELLINE, New York, USA); leaving the apical 1 mm uncoated. The specimens were immersed into a 50% silver nitrate dye for one hour, washed with distilled water for one minute, and inserted into photo developing solution and the exposed to light for 12 h. After the specimens were washed with running water, the nail polish was removed. All specimens were cleared by using a 5% nitric acid, and then washing them for 2 h; the specimens were then dehydrated in ascending concentration of alcohol (80%, 90%, and 100%) of alcohol. The roots were subsequently cleared by using methyl salicylate (Fisher Scientific, Fair Lawn, NJ. USA). The cleared specimens were examined under 3D Digital Microscope (Keyence. USA) 100X magnification (Fig 16 17-18).

Dye Preparations

Preparation of 50%WT of silver nitrate:

The ammonium solution (AgNO₃) was made by dissolving 25 g of AgNO₃ crystals (Fisher Scientific, Fair Lawn. NJ, USA) in 25 ml of 28 wt % aqueous ammonium hydroxide (Fisher Scientific, Fair lawn, NJ, USA) in the presence of ambient laboratory
light. An additional 28% NH₄OH was used to titrate the solution until the solution slowly cleared as ammonium ions complex the silver into diammine silver ions ([Ag (NH₃)₂]⁺). This solution was diluted with 50 ml in distilled water to obtain a 50 wt% solution. Then all each group was immersed in the dye¹⁰⁰-¹⁰².
Fig 1. Forty mandibular premolar teeth were collected for the study.

Fig 2. Radiographs of all specimens were taken in the buccolingual and mesiodistal directions.
Fig 3. Root canal obturation after the extracted teeth was sectioned at the CEJ. All teeth were obturated with lateral condensation technique with Roth’s cements or glass ionomer and with gutta-percha.

Fig 4. Post space preparation. After the peeso reamers were used, a number 2 finishing drill (3M ESPE Dental Products, St. Paul, MN) was used to prepare the post space before post cementation.
**Fig 5.** Rely X Unicem (3M ESPE Dental Products, St. Paul, MN, USA).

**Fig 6.** Panavia F 2.0 and ED Primer II (Kuraray America, Inc, NY, USA). The Panavia F 2.0 system is self-etch-primer system was used according to manufacturers instructions.
Fig 7. Rinsing and drying the canal. An Endo-Eze tip adapted into the conventional air/water syringe was used and the ED primer II A and B were mixed in Group 2, 4 and injected into the canal instead of using the brush with a syringe and a 20 gauge Endo-Eze tip was used.

Fig 8. Cementation technique the self-etch primer system. Equal parts of paste A&B were mixed, loaded in a plastic syringe and injected into the canal; the post was seated into the post space, the excess cement removed and a weight applied to the top of the post. The cement was light cured for 20 seconds.
Fig 9. Cementation technique for the self-adhesive system. After cleaning the canal with water the Unicem Aplicap was activated and mixed in a high frequency mixing unit (Kerr.USA). An elongation tip was attached to the mixed capsule to inject the cement into the canal and the post seated in the post space. A weight was applied and the cement cured for 20 seconds.

Fig 10. Three sections were cut from each root producing 3; each section measured about 2.33 mm. The apical part of each section was marked for identification.
Fig 11. Calculation of surface area. Using digital caliper (Mitutoyo. Absolute Digital Series 500, Japan). The diameter of the cemented post on the coronal and apical side of each root section was measured.

Fig 12. Universal Testing Machine; Instron Machine (Model #5565,MA,USA) A push-out test was performed on all the different root sections in all groups.
Fig 13. A custom made device was created to make the push-out test for the different sizes of samples.

Fig 14. SEM evaluation. One specimen from each group was evaluated using scanning electron microscope (SEM, ISI SX 30, Cambridge, MA, USA) to examine the prepared post space.
Fig 15. Apical parts of each root were used to measure the microleakage. By sealing the occlusal portion of the root with composite resin, soaking the roots in silver nitrate and then clearing them with methyl salysilate solution. This procedure allowing 3-D viewing of the leakage pattern in each specimen.

Fig 16 (Keyence, 3D Microscope, USA) was used to measure the dye penetration into the apical part of the root.
Fig 17. The apical part of the teeth under 3 D Microscope after clearing.

Fig 18. Apical part of the teeth under the Keyence scope, the maximum amount of dye penetration was measured in microns and converted to mm.
RESULTS

Table 2 and Figure 19 illustrate the mean values for the maximum bond strength push-out tests of the two cements (Panavia F 2.0 and Rely X Unicem Aplicap). Panavia F 2.0 and Rely X Unicem had similar bond strengths.

Table 2. Mean values for maximum bond strength of four groups.

<table>
<thead>
<tr>
<th>Sealer</th>
<th>Cement</th>
<th>Means</th>
<th>Std.Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIC</td>
<td>Panavia F 2.0</td>
<td>7.72</td>
<td>3</td>
</tr>
<tr>
<td>GIC</td>
<td>Rely X Unicem</td>
<td>10.34</td>
<td>1.3</td>
</tr>
<tr>
<td>ZOE</td>
<td>Panavia F 2.0</td>
<td>8</td>
<td>1.2</td>
</tr>
<tr>
<td>ZOE</td>
<td>Rely X Unicem</td>
<td>12</td>
<td>2.5</td>
</tr>
</tbody>
</table>

The three-way ANOVA showed no statistically significant difference among the four groups or among the tooth section (Table 3)

Table 3. The three-way ANOVA statistical analysis.

<table>
<thead>
<tr>
<th>Source</th>
<th>Mean square</th>
<th>F- value</th>
<th>P- value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tooth</td>
<td>4.62720054</td>
<td>0.19</td>
<td>0.6605</td>
</tr>
<tr>
<td>Third(tooth section)</td>
<td>24.38568757</td>
<td>0.51</td>
<td>0.6012</td>
</tr>
<tr>
<td>Sealer</td>
<td>1.08062468</td>
<td>0.05</td>
<td>0.8318</td>
</tr>
<tr>
<td>Cement</td>
<td>76.98641397</td>
<td>3.23</td>
<td>0.0752</td>
</tr>
<tr>
<td>Sealer*Cement</td>
<td>11.52973478</td>
<td>0.48</td>
<td>0.4884</td>
</tr>
</tbody>
</table>
As in table 4 indicates, Tukey-Kramer analysis yielded statistically no significant difference between the two adhesive techniques.

**Table 4.** Tukey-Kramer Analysis.

<table>
<thead>
<tr>
<th>Cement</th>
<th>Means</th>
<th>Std .Error</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rely X Unicem</td>
<td>11</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Panavia F 2.0</td>
<td>7.75</td>
<td>1.04</td>
<td>0.0752</td>
</tr>
</tbody>
</table>

A t-test was performed to compare the maximum dye penetration in the microleakage samples. Test results showed that there was a significant difference between the two sealers. As shown in table 5.

**Table 5.** Means and Standard deviation of Microleakage

<table>
<thead>
<tr>
<th>Sealers</th>
<th>Mean</th>
<th>Std Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>GIC</td>
<td>1.4936</td>
<td>0.2696</td>
</tr>
<tr>
<td>ZOE</td>
<td>2.0715</td>
<td>0.3607</td>
</tr>
</tbody>
</table>
SEM Evaluation

Selected SEMs were made to evaluate the interfacial failure mechanism, the resin formation and root canal dentin morphology. Each specimen was examined and sections selected and photographed at 2000X magnification.

The adhesive surface and resin tag formation were analyzed for all groups, as was the morphology of the post surface and tooth section, the tooth surface showed

In the Rely X Unicem group resin tags were present in all levels, and also a rough surface was observed (Fig. 21). In Group cemented with Panavia F 2.0; there was very little evidence of resin cement trying to enter the dentin tubules area (Fig 22). A complete removal of smear layer was observed in all groups. The post surface showed a rough surface and cements remnants (Fig 23).
**Fig 19.** Interaction among post retention, sealer type and cement.

**Fig 20.** Means ± SD for Microleakage
Fig 21. Rely X Unicem- Root canal Dentin. Rough surface, 2000X

Fig 22. Panavia F 2.0 – Root canal dentin. Dentinal tubules openings, some of resin tags trying to enter the tubules. 2000X
Fig 23. Post surface of Rely X Unicem, very rough surface and cement remnants. 400X

Fig 24. Post surface of Panavia F 2.0, cement was observed in all pushed-out posts. 400X
DISCUSSION

When traditional non-adhesive cements are considered the choice of luting agent seems to have little effect on post retention. However, adhesive resin luting agents have the potential to improve retention of post and core restorations and *in vitro* studies have shown improved retention using these cements. At the same time, bonding within the prepared post space is difficult with resin luting systems because these agents are more technique sensitive and require multiple steps compared to traditional luting agents. Using the adhesive system incorrectly can increase restoration failure. Several studies have measured and compared the bond strengths of fiber posts cemented with different resin luting systems on different levels of radicular dentin. Etch-and-rinse, self-etch primer, and self-adhesive systems have all been tested on the different levels of the root canal, however, different results have been reported even with the same types of adhesive luting systems.

In this study, we evaluated the effect of different endodontic sealers and resin cements on the retention of adhesively cemented prefabricated fiber posts. All procedures were done by a single operator were controlled. No statistically significant difference was found in the mean maximum push-out bond strength. Foxton et al also reported no difference in microtensile bond strengths at the coronal and apical thirds of root canal dentin when testing a dual-cure composite resin which supports our findings. Results of
a study by Zicari et al\textsuperscript{108} were also similar to our results since they reported no significant difference among the coronal, middle and apical sections for each luting cement when the bond strength was measured for Panavia 21 (12.6 ± 3) Rely X Unicem (11 ± 4) and Variolink II (11 ± 4). Several studies contradict the results of our study. Those studies reported that the maximum bond strength occurred at the coronal section of the canal space and that the lowest strength occurred at the apical part.\textsuperscript{96, 109-110} One important factor in the differences shown by these groups was the delivery method used in our study. A syringe insertion method more effectively coated the entire dentin root canal surface in the group that was cemented with Panavia F 2.0. A 20 gauge Endo-Eze tip (Ultradent Products, Inc., South Jordan, UT) that reached the most apical area of the root canal space was utilized in this group and improved delivery of the conditioner to the deepest portion of the canal. At the time of rinsing and removal of the etchant from the canal, the conventional water/air syringe with a fitted 20 gauge Endo-Eze tip resulted in the complete removal of the etchant from the root canal.

Bond strengths were calculated for the three sections showing that the self-adhesive Rely X Unicem cement used with a zinc oxide eugenol sealer had no decrease in bonding from the eugenol sealer. These results are similar to those reported by Hagge et al\textsuperscript{44} who examined the effect of five different cements on the retention of prefabricated posts placed into root canals previously obturated with gutta-percha and zinc oxide/eugenol sealer. They concluded that significantly higher mean bond strengths are obtained for retention of adhesively cemented posts when no eugenol is used as part of the sealing material. However, a study by Kurtz et al\textsuperscript{93} showed that the eugenol-containing sealer does not have any effect on the bond strength of adhesively cemented...
fiber posts. Also, Davis et al\textsuperscript{111} reported no difference in post retention with zinc oxide-eugenol or calcium hydroxide when prefabricated posts luted with resin cement were subjected to tensile forces.

When the SEM evaluations of the different root sections were considered results from this study differed from those found by several groups of authors, who noted significant differences between the cervical and coronal sections of the root. In addition, they includes presence and lack of resin tags, as well as difference in their length and pattern\textsuperscript{1, 58} Differences findings for resin tags might be related to a an inability to completely remove the smear layer; this inability could lead to corresponding inability to visualize the flow of etching materials that affect the micromechanical interlocking between the teeth and the adhesive.

The SEM micrographic evaluation showed no differences among the four groups regarding the interface between adhesive and root dentin. The positive replica of the bonded surface was evaluated to determine the effect of resin tag formation and the morphology of the root canal dentin. Each specimen was examined at 2000X power magnification. In all groups, only a few resin tags were only present and little evidence existed of the entry of resin cement into the dentinal tubules.

In a study by Al-Assaf et al\textsuperscript{112}, the interfacial characteristics of five adhesive resin luting systems with dentin were evaluated by SEM to determine mode of failure, extent of demineralization, morphological changes and hybrid layer formation. The cements tested were Bistite II DC (BDC), C&B Super-Bond (CBM), M-Bond (MBD), Panavia-F (PAF) and Rely-X Unicem (RXU). The highest percentage of debonded dentin area covered with resin was reported for each cement- BDC (47.80) and MBD (38.12).
findings were significantly different from those for CBM (17.20), PAF (16.47) and RXU (16.50). The extent of demineralization for CBM was 100%. No statistical differences were found between BDC (60.86%), MBD (60.22%) and PAF (51.99%). RXU (45.03%) showed the lowest value. CBM induced the most pronounced tubule funneling and intertubular dissolution, followed by PAF, BDC and MDB. RXU partially removed the smear layer without opening tubule orifices. The thickest hybrid layer was found in CBM (4.17 µ), followed by MBD (2.39 µ). No statistically significant differences were found between PAF (0.95 µ) and BDC (1.12 µ), whereas RXU showed no detectable hybrid layer. These results are consistent with the findings of Bitter et al who reported that etching root canal dentin with phosphoric acid produced a thicker more uniform interdiffusion zone, which created wide micromechanical interlocking areas between the adhesive and the etched dentin with more resin tags than self-etch adhesives.

Self-adhesive systems do not use an etch and rinse step since they have an increased concentration of acidic resin monomers. However, their relative inefficiency at infiltrating thick smear layers is a major concern.

Proper sealing is one of the most important goals in root canal treatment and different endodontic sealers help achieve this seal. This study was conducted to measure the apical seal of two sealers. In one study there was a significantly difference between two sealers; no material completely sealed and had similar maximum leakage for both zinc oxide eugenol and glass ionomer sealers. These results contradict the study by Fernando et al who reported no significant difference between Tubli Seal (eugenol based sealer) or Ketac-Endo (glass ionomer cements). Pit Ford et al had similar results.
after comparing the sealing ability of zinc oxide eugenol sealers and glass Ionomer cements.
CONCLUSION

The results of this study agreed with the null hypotheses. These hypotheses were as follows: 1) There is no statistically significant difference in post retention when the posts are cemented with self-adhesive cement or with dual-cure (Panavia F 2.0) cement. 2) There is no effect on post retention of either cement by zinc oxide eugenol sealer or glass ionomer. The null hypothesis which was there is no statistically significant difference in microleakage with a glass ionomer sealer or a zinc-oxide eugenol sealer was rejected.

Within the limitations of this study, it can concluded that the use of different resin luting systems did not influence the bond strength of cemented prefabricated fiber posts that the adhesive monomers responsible for substrate conditioning of the adhesive agents appeared to be unable to effectively remove the thick smear layer formed in the root canal dentinal tubules during post preparation. The removal of the smear layer reduces the formation of micro-mechanical interlocking areas between the adhesive material and the root canal dentin. The push–out test is similar to clinical forces placed on the post and somewhat reproduces vertical forces of occlusion. The failure occurs parallel to the post-cement-dentin interface.

The choice of resin luting cement and cement with prefabricated fiber posts are very important but are not the key factor in the longevity of a post-restored tooth.
The selection of the final restoration, the occlusion and the presence of a ferrule (1.5-2 mm) around the tooth are important for protecting the tooth from fracture. No cement can overcome the insufficiency of a poorly designed post and core restoration.

As a specific conclusion for this study, the statements can be made that injecting the etchant instead of using the conventional method helps in achieving higher bond strength on the different sections of dentin. When the conventional technique is used the etchant does not adequately coat the canal space producing different bond strengths in different root canal sections.

Further research on other similar resin materials and cementation techniques with a self-adhesive (RelyX Unicem should focus on improving bond strength in root canal dentin. Improving bond strength could increase the long term clinical success of restored endodontically treated teeth.
The selection of materials for the restoration of an endodontically filled tooth has changed. The use of adhesive systems to cement a prefabricated post is a desirable clinical concept because these bonding agents have the potential to improve the performance of post and core restorations. Because these systems have mechanical properties resembling those of dentin and because the procedure involved can done in a single appointment, adhesive systems have become the option of choice in the restoration of endodontically treated teeth. In addition, bonding to root canal dentin presents difficult clinical situations because they can be affected by root canal sealers. More useful systems are now available that require fewer bonding steps to achieve a successful restoration than the conventional etch-and-rinse systems require. However, concern with the use of the new systems is their relative lack of efficiency removing the thick smear layer.

The results of this study verify the efficiency of the cementation of prefabricated fiber posts with self-etch primer and self-adhesive agents. The push-out test reproduces the clinical forces exerted on the post that are similar to the vertical force of occlusion. This test has been shown to be dependable and reliable for determining the bond strength of a resin luting agent to the dentinal tubule.
REFERENCES


27. Wu MK. Wesselinck PR. Endodontic leakage studies reconsidered. Part I.
Methodology, application and relevance. Int Endo J 1993; 26:37-43.


DATE: 2/27/03

MEMORANDUM

TO: Dr. John O Burgess
   Principal Investigator

FROM: Sheila Moore, CIP
   Director, IRB

RE: Request for Determination—Human Subjects Research
   IRB Protocol #N00215007—Endodontic sealers: their properties and effect on fiber post retention

An IRB Member has reviewed your application for Designation of Not Human Subjects Research for above reference proposal.

The reviewer has determined that this proposal is not subject to FDA regulations and is not Human Subjects Research. Note that any changes to the project should be resubmitted to the Office of the IRB for determination.

SM/Al