The effect of root canal sealers and timing of cementation on the microleakage of the parapost luted with resin cement

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Received 13 September 2009; revised 12 October 2009; accepted 9 December 2009
Available online 6 February 2010

Abstract  Objectives: The objectives of the study were to study the effect of root canal sealers either eugenol or non-eugenol and timing of cementation on microleakage of the parapost luted with resin cement.

Materials and methods: Seventy extracted human, single-rooted teeth were instrumented using a crown-down technique. All teeth were instrumented up to a size 50.04 taper ProFile followed by the use of Gates Glidden drills from size 2 up to 5. Following instrumentation, the teeth were randomly divided into four experimental groups of fifteen teeth each, based on type of root canal sealer (eugenol or non-eugenol sealer) and timing of post cementation (immediate or delayed). The remaining ten teeth were divided into two control groups with five teeth per group. All teeth were tested for microleakage using a fluid filtration method.

Results: The microleakage of the paraposts luted with resin cement increased over time, irrespective of sealer type or timing of post cementation. Immediate post cementation following obturation with AH26 (non-eugenol sealer) produced the least microleakage at all three time periods at 24 h, 2 months and 3 months.

Conclusions: The microleakage paraposts luted with resin cement was not influenced by either sealer type or timing of post placement. All experimental groups demonstrated a significant increase in microleakage over time as well as the presence of voids at the resin–dentin interface.

1. Introduction

Posts are often used to restore endodontically treated teeth (Robbins, 1990). In addition to providing retention for coronal restorations, they also provide a hermetic coronal seal. Coronal microleakage of endodontically treated teeth may result in recurrent caries and failure of the root canal treatment, therefore, the coronal seal is as important as the apical seal in determining long-term success of root canal treatment (Saunders and Saunders, 1994). Many studies (Saunders and
Microleakage is one of the primary causes of endodontic failure. Friedman et al. (1986) showed that leakage of temporary restorations increased over time while Torabinejad et al. (1990) demonstrated that unssealed, obturated root canals were completely re-contaminated within 30 days. Therefore, endodontically treated teeth should be restored as soon as possible. Immediate post cementation at the time of obturation would be ideal provided that any residual effect of eugenol from endodontic sealers does not affect the coronal seal of the post system.

Post cementation using resin cement has been recommended for restoration of endodontically treated teeth (Wood, 1983). They have the advantage of increased retentive properties through micro-mechanical and chemical bonding to both dentin and metal (Burns et al., 1993). Studies by Fogel (1995) and Bachicha et al. (1998) had demonstrated that less microleakage occurred around posts cemented with resin cement when compared with zinc phosphate or glass-ionomer cements. However, the root canals were not obturated prior to post-space preparation in these studies. Any residual effects of the filling materials or sealers on microleakage of the post systems were, therefore, not considered. This is important because many of the endodontic sealers contain eugenol which has been shown to inhibit resin polymerization (Philips, 1982; Rosenstiel and Gegauff, 1988; Al Wazzan et al., 1997; Watanabe et al. 1997; Paul and Scharer, 1997; Mayer et al., 1997; Schwartz et al., 1992; Woody and Davis, 1992; Hansen and Asmussen, 1987). The objectives of this study were: (i) to evaluate the microleakage of paraposts luted with resin cement following obturation with either eugenol or noneugenol sealer, and (ii) to evaluate the effect of immediate versus delayed post cementation on the resin cement.

2. Materials and methods

Seventy extracted human, single-rooted teeth were collected and used for this study within 6 months of extraction. All teeth were stored in saline solution with 0.5% chloramine-T to prevent bacterial growth. Specimens were radiographed from the buccolingual and mesiodistal dimensions in order to evaluate canal morphology and root integrity. Teeth with similar root morphology, size and shape were selected in an attempt to standardize the sample population. Roots that displayed cracks, resorptions or open apices were excluded from the study. An ultrasonic scaler was used to remove external root debris followed by rinsing with 5.25% NaOCl. A low speed diamond saw with water irrigation was used to remove the crowns of the teeth at the cemento-enamel junction. All specimens were stored at room temperature (23 °C) in saline solution with 0.5% chloramine-T until ready for use.

Using a crown-down technique, all teeth were instrumented up to a size 50 .04 taper ProFile (Dentsply, Tulsa, Oklahoma City, OK, USA), followed by use of Gates Glidden drills size 2, 3, 4 and 5 (Miltex Union Brouch, York, PA, USA) to flare the coronal third of the canal. Canal length was determined by visualization of the tip of a #10 K-file (Dentsply, Tulsa, Oklahoma City, OK, USA) at the root apex. A working length of 0.5 mm from the apex was used. All instrumentation was performed using RC-Prep (Premier Product Company, PA, USA) lubrication and irrigation with 5.25% NaOCl in between changes in file sizes. Each rotary file was discarded after use in five canals.

Following instrumentation, the teeth were randomly divided into four experimental groups of 15 teeth each, based on type of root canal sealer (eugenol or non-eugenol sealer) and timing of post cementation (immediate or delayed). The remaining ten teeth were divided into two control groups with five teeth per group.

2.1. Experimental groups

(1) Eugenol sealer + Immediate post cementation with C&B Metabond.
(2) Eugenol sealer + Delayed post cementation with C&B Metabond.
(3) Non-eugenol sealer + Immediate post cementation with C&B Metabond.
(4) Non-eugenol sealer + Delayed post cementation with C&B Metabond.
(5) Positive control: Paraposts placed into the canals without any cement.
(6) Negative control: C&B metabond placed into the canals without any post.

Prior to obturation, canals were treated with 17% EDTA for ten seconds, followed by 5.25% NaOCl in order to remove the smear layer. After a final rinse with sterile water, the canals were dried with paper points and obturated with vertically condensed gutta-percha using one of two sealers: Roth’s 801 Elite Grade eugenol-containing sealer (Roth International, Chicago, IL, USA) or AH26 non-eugenol sealer (Dentsply/Maillefer, Tulsa, OK, USA).

2.1.1. Immediate post cementation

In specimens that received immediate post placement (directly following obturation), apical tooth structure was removed using a low speed diamond saw with water irrigation to achieve a standardized root length of 10 mm. A 7 mm post-space was then prepared for a parallel-sided, stainless steel #4 parapost (Coltene/Whaledent Corp., Mahwah, NJ, USA) by sequential use of a series of parapost drills. All canals were treated with the etchant and dentin conditioner included in the C&B Metabond adhesive system in order to remove the smear layer. Post cementation was performed using C&B Metabond cement (Parkell, Farmingdale, NY, USA). The resin cement was mixed and placed according to the manufacturer’s instructions. Cement was applied to the post surface as well as directly into the post-space. The posts were then placed into the canal to the predetermined depth and held in place with finger pressure until an initial set had occurred. Excess cement was removed flush on the top of the tooth. The remaining gutta-percha in the apical 3 mm was then removed using a System B unit (Analytic Corp., Orange, CA) prior to testing for microleakage.

2.1.2. Delayed post cementation

In specimens that received delayed post cementation (7 days after obturation), 3 mm of coronal gutta-percha was removed
using the System B unit followed by placement of a Cavit temporary restoration. After 1 week storage at 23 °C in 100% humidity, the Cavit was removed by sectioning the tooth below the temporary restoration with a low speed diamond saw under water irrigation. Apical tooth structure was then removed using the low speed diamond saw with water irrigation to achieve a standardized root length of 10 mm. Subsequent post-space preparations, smear layer removal, post cementation, and gutta-percha removal were then performed as previously described for the specimens that received immediate post placement and cementation.

To ensure complete setting of the cement, all teeth were placed at room temperature in 100% humidity for 1 h. All specimens were then stored at room temperature (23 °C) in saline solution with 0.5% chloramine-T prior to testing for microleakage at 24 h, 2 months and 3 months.

2.1.3. Microleakage evaluation

Microleakage of the cemented posts were evaluated using a modification of the fluid filtration apparatus described by Bachicha et al. (1998). The specimens were prepared by enlarging the diameter of the apical opening to a size 120 k-file in order to accommodate the snug placement of an 18½ gauge stainless-steel tube through the apical end of each specimen. The stainless-steel tubing was then cemented in place using C&B Metabond. The opposite end of the stainless-steel tube was attached to the polyethylene tubing of the fluid filtration apparatus in order to allow for direct communication between the root canal and the fluid filtration apparatus.

The fluid filtration apparatus was comprised of a pressurized tank of argon gas, a pressurized fluid reservoir within a pressure container, polyethylene tubing containing a 20 μl micropipette, a microsyringe that introduced an air bubble into the system, and the specimen attached to the 18½ gauge stainless-steel tube. Microleakage measurements were performed by applying argon gas at a pressure of 15 psi to the pressure reservoir (14.7 psi = 1 atm at 23 °C) which held a plastic beaker of isotonic saline solution. The fluid within the reservoir was carried into the system by a canula extending through the top of the pressure reservoir. Polyethylene tubing, with an internal diameter of 1.14 mm and outer diameter of 1.57 mm, was connected to the canula of the pressure reservoir and to a 20 μl micropipette that contained an air bubble introduced by the microsyringe. Movement of the air bubble in the micropipette toward the apical end of the root per unit time provided a measure of the microleakage as fluid moved from the internal root surface toward the external surface. Measurements were made at two minute intervals and were repeated with a total of four times for each specimen. Since the volume and length of the micropipette are known, the measurements in mm/min were then converted to nl/min. That fluid rate was then divided by the applied pressure (in cm H2O) to calculate the fluid flow in nl/min/cmH2O. All specimens were stored at room temperature (23 °C) in saline solution with 0.5% chloramine-T in between measurements of microleakage made after 24 h, 2 months and 3 months.

2.2. Statistical analysis

A power analysis was performed and it was determined that a sample size of 15 teeth per group would provide a power of 0.90 (β = 0.10) for detecting a mean difference that is 0.6 standard deviation in magnitude (σ = 0.05). All microleakage measurements were performed by one investigator in order to minimize operator bias. Specimens were evaluated on a rotating basis from each of the four experimental groups in an attempt to reduce variability between groups. Data was analyzed using a 3-way repeated measures analysis of variance (ANOVA). Significance was determined at the 0.05 level.

3. Results

3.1. Microleakage evaluation

Microleakage results for the experimental groups at 24 h, 2 months and 3 months are summarized in Table 1. Microleakage of the paraposts luted with resin cement increased over time, irrespective of sealer type or timing of post cementation. Immediate post cementation following obturation with AH26 sealer produced the least microleakage at all three time periods. This group showed a mean fluid flow of 0.0142 nl/min·1 cm H2O·1 at 24 h which increased to 0.0332 nl/min·1 cm H2O·1 at 3 months. Delayed post cementation following obturation with Roth’s eugenol sealer produced the most microleakage at all tested time periods. This group showed a mean fluid flow of 0.0283 nl/min·1 cm H2O·1 at 24 hours which increased to 0.0476 nl/min·1 cm H2O·1 at 3 months. It was noted that 7/15 teeth in group 1, 6/15 teeth in group 2, 6/15 teeth in group 3, and 7/15 teeth in group 4 demonstrated no measurable microleakage at 24 h. However, at 2 months and 3 months, all specimens showed some evidence of microleakage. Results for the control groups are summarized in Table 1. The negative controls showed no evidence of microleakage. The positive controls demonstrated significantly greater microleakage than the experimental groups with a mean fluid flow of 3.77 × 10⁻⁴ nl/min·1 cm H2O·1.

<table>
<thead>
<tr>
<th>Time</th>
<th>Roth’s 801 sealer Immediate post cementation</th>
<th>Roth’s 801 sealer Delayed post cementation</th>
<th>AH26 sealer Immediate post cementation</th>
<th>AH26 sealer Delayed post cementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>24 h</td>
<td>0.0260 (±0.037)</td>
<td>0.0283 (±0.0469)</td>
<td>0.0142 (±0.0168)</td>
<td>0.0167 (±0.0183)</td>
</tr>
<tr>
<td>2 months</td>
<td>0.0408 (±0.0338)</td>
<td>0.0426 (±0.0492)</td>
<td>0.0276 (±0.0206)</td>
<td>0.0319 (±0.0220)</td>
</tr>
<tr>
<td>3 months</td>
<td>0.0457 (±0.0348)</td>
<td>0.0476 (±0.0477)</td>
<td>0.0332 (±0.0213)</td>
<td>0.0372 (±0.0225)</td>
</tr>
</tbody>
</table>

Table 1 Mean microleakage of experimental groups in nl/min·1 cm H2O·1.

<table>
<thead>
<tr>
<th>Controls</th>
<th>Microleakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Negative controls</td>
<td>0.00 (±0.00)</td>
</tr>
<tr>
<td>Positive controls</td>
<td>3.77 × 10⁴ (±2.74 × 10⁴)</td>
</tr>
</tbody>
</table>
The 3-way ANOVA test revealed a statistical significant difference for time on microleakage ($P < 0.05$). Multiple comparisons using the Bonferroni procedure showed a significant difference in microleakage between 24 h and 2 months but no significant difference between 2 months and 3 months. No other statistical significant difference or interactions within groups were found. Univariate analysis showed no significant effect of either the type of root canal sealer or the timing of post cementation on microleakage at 24 h, 2 months, and 3 months.

At each time period, groups obturated with AH26 sealer demonstrated less microleakage than those obturated with Roth’s eugenol sealer although the difference was not statistically significant ($P < 0.05$).

Due to the lack of microleakage at 24 h demonstrated by some of the specimens in each of the experimental groups, the data did not follow a normal distribution. Therefore, the Friedman non-parametric test was also used to evaluate for differences in leakage over time. This test revealed significant overall change ($F_{2,118} = 145.21$). Follow-up multiple comparison procedures indicated significant differences in microleakage between all time groups. Since these results are very similar to those obtained from the parametric tests, univariate testing was included in the analysis in order to allow for evaluation of any interactions within groups.

4. Discussion

An in vitro study on the coronal leakage of endodontic posts has shown that dentin-bonding cements have less microleakage than the traditional, nondentin-bonding cements (Bachicha et al., 1998). However, the posts were cemented into canals that were not previously obturated. Therefore, the residual effect that eugenol sealers could have on the microleakage of posts cemented with resin was not considered. Another study has shown that eugenol-based sealers do not have a negative effect on the coronal seal of resin-cemented posts (Mannocci et al., 2001). However, there was no quantitative measurement of microleakage. A dye penetration model was used to provide only a qualitative evaluation of coronal leakage. In addition, post cementation was performed one week after obturation, following complete setting of the eugenol sealer. No published reports have quantitatively evaluated the effect of eugenol sealers and immediate versus delayed post cementation on the microleakage of resin-cemented posts.

C&B Metabond has shown to have the greatest post retention (Gaston et al., 2001) and the least amount of post microleakage (Bachicha et al., 1998) among the various dentin-bonding cements. The C&B Metabond adhesive system has its own etchant and dentin conditioner (an aqueous solution of 10% citric acid and 3% ferric chloride) that exposes collagen by removing the smear layer and demineralizing dentin. C&B Metabond consists of a methylmethacrylate monomer system that is hydrophilic by the function of a 4-META molecule in methyl methacrylate (initiated by the catalyst tri-n-butyl borane). Bonding of the resin cement to dentin occurs by infiltration of the monomer into the dentinal tubules and impregnation with the exposed collagen to form a hybrid layer (Nakabayashi et al., 1992).

Incomplete removal of root canal sealer from the post space reduces the bond strength of resin to dentin (Macchi et al., 1992) and may therefore have an adverse effect on post microleakage. The results of this study indicated that sealer type and timing of post placement do not affect the microleakage of resin-cemented posts. Any residual eugenol in the canal from the Roth’s sealer was likely removed by the mechanical preparation of the post-space as well as conditioning of the dentin prior to post cementation. These results suggest that resin-cemented posts can be placed immediately following obturation with an eugenol-based sealer.

This is in agreement with the study by Boone et al. (2001) which found that sealer type and timing of post cementation had no effect on the retention of resin-cemented posts provided that the post-spaces were prepared following obturation of the canal. It is likely that post-space preparation after obturation produces a clean dentinal surface that is essential for enhancing post retention and for achieving an effective coronal seal.

Although there was no significant difference in microleakage between the experimental groups, there were large variations in the microleakage observed within the groups. Despite measures taken to standardize the sample population, certain clinical factors were difficult to control. Variations in root canal anatomy, volume of the prepared spaces, thickness of the smear layer, and patency of the dentinal tubules may have contributed to the wide variations in microleakage. Other potential confounding factors include variations in the volume of sealer and cement placed into the post space, distribution of the cement within the post space, and adaptation of the cement to the surfaces of the post and canal wall. In addition, dentin permeability may be influenced by the remaining dentin thickness and the surface area of the prepared canal walls (Fogel, 1995). As a result, the fluid flow measured may have been partially due to fluid movement into dentinal tubules or root canal ramifications and may not be solely attributed to microleakage of the cemented post.

Fluid conductance through the described apparatus could have been caused by movement of fluid through (i) the resin-dentin interface; (ii) the resin-post interface; or (iii) the dentinal tubules. The various connections within the system could have served as a potential pathway for fluid movement. However, the zero microleakage observed in the negative controls indicated that this was not a factor. This in vitro method of measuring microleakage obviously cannot duplicate the biologic environment that exists in vivo. The fluid filtration method used in this study applied a constant hydrostatic pressure of 15 psi (1051 cm H₂O) to measure microleakage (approximately 75 times the physiologic pulpal tissue pressure). This is the same hydrostatic pressure used by Derksen et al. (1986) to measure microleakage of restorative materials and by Bachicha et al. (1998) to measure microleakage of teeth restored with posts. This high pressure allows acceleration of microleakage measurement in vitro. A restorative post cemented within the root canal demonstrates a large interface of the luting agent with both the dentinal wall and the post surface. This requires a force greater than the physiologic pulpal tissue pressure in order to facilitate measurement of microleakage over a practical time period and in a manner that is reproducible.

Pommel and Camps (2001) investigated the effects of pressure and measurement time on the fluid filtration method. Fluid flow decreased as measurement time increased while greater fluid movement was observed when higher pressures were applied. The compliance of the system and the initial fill-
ing of microscopic voids may explain the decrease in fluid movement observed over time. The pressure and measurement time used in this study are not clinically relevant, however, this is not of great concern since the purpose of this type of investigation is to compare different materials and techniques. In addition, this method measures fluid movement from inside the tooth towards the external surface. While it may be more clinically relevant to filter fluid from the external tooth surface towards the inside of the tooth, Derksen et al. (1986) found no statistically significant differences between the fluid filtration rates measured in either direction.

Movement of fluid follows the laws that govern the phenomenon of filtration, such as the Poiseuille equation:

\[ V = \frac{\pi \cdot \Delta P \cdot r^4}{8 \cdot L \cdot \eta} \]

where \( V \) = volume of flow (m³/s), \( \Delta P \) = hydrostatic pressure difference at the ends (Pa), \( L \) = length of the void (m), \( r \) = radius of the void (m), and \( \eta \) = viscosity of the fluid (Pa s). The pressure used in this study was 15 psi (1.03 \( \times \) 10⁵ Pa), the length of the void is the entire 7 mm (7 \( \times \) 10⁻³ m) length of the post space, and the viscosity of saline is 10⁻³ Pa s at 20°C. The void diameter that would be large enough to allow bacterial penetration is 2 μm (\( r \) = 10⁻⁶ m). Using the above calculation, the limiting fluid movement should be:

\[ V = \frac{\pi \times (1.03 \times 10^5)(10^{-6})^4}{8 \times (7 \times 10^{-3})(10^{-3})} \text{ m}^3/\text{s} \]
\[ = 5.78 \times 10^{-12} \text{ m}^3/\text{s} \]
\[ = 0.347 \text{ nl/min} \]

Therefore, at 15 psi, a fluid flow of less than 0.347 nl/min would be the criterion for a ‘bacteria-tight’ seal. The measured microleakage of all of the experimental groups in this study was lower than the limiting value. The lowest recorded microleakage of 0.0142 nl/min \( \times \) cm H₂O⁻¹ (Group 3 at 24 h) was 24 times lower than this limiting value while the highest recorded microleakage of 0.0476 nl/min⁻¹ \( \times \) cm H₂O⁻¹ (Group 2 at 3 months) was seven times lower than this value. This suggests that although all teeth demonstrated some evidence of microleakage by 3 months, the size of the voids was not large enough to allow bacterial penetration into the restored post-space. Therefore, all of the tested specimens in this investigation had a “bacteria-tight” coronal seal according to the criteria of Wu et al. (1993).

Wu and Wesselink (1993) have also postulated that leakage of smaller molecules, such as nutrients and bacterial toxins, may serve as a potential problem in obturated root canals that appear to be unsusceptible to bacterial penetration. It is not possible to completely sterilize the root canal following endodontic treatment (Bystrom and Sundqvist, 1981). Therefore, leakage of nutrients into the restored post space could allow for proliferation of any bacteria remaining within the canal following instrumentation. This would increase the potential for spread of bacteria and their metabolic by-products into the periradicular tissues via lateral canals and/or the apical foramina.

5. Conclusion

The significance of this research was to evaluate the effect of sealer type and timing of post placement on the coronal leakage of paraposts luted with resin cement. Microleakage is one of the primary causes of endodontic failure. A more effective coronal seal will not only improve the restoration of endodontically treated teeth, but will also improve the prognosis of endodontic therapy. Based on the results of this study, it appears that microleakage of resin-cemented posts is not influenced by either sealer type or timing of post placement. All experimental groups demonstrated a significant increase in microleakage over time as well as the presence of voids at the resin–dentin interface. Since materials can show

![Figure 1](image_url)
dimensional changes over time, future studies should evaluate post microleakage over an extended time period in order to evaluate the long-term effectiveness of the coronal seal.

Acknowledgement

Fig. 1 was adapted from Bachicha et al., 1998. J. Endodon. 24, 703–708.

References


