In vitro evaluation of root canals obturated with four different techniques Part 2: Apical leakage

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INTRODUCTION

It is well known that bacteria are the primary source of persistent peri-radicular inflammation and endodontic failure. Once the root canal has been adequately debrided, shaped and disinfected, the final objective of the endodontic procedure is to obtain a three dimensional obturation of the root canal space with a fluid-tight seal of the apical foramen.[1] This is to achieve an hermetic apical seal in order to prevent the infiltration of exudate and microorganisms between the dentine wall and the obturation material.[2] Failures of endodontic treatment can result from inadequate filling of the root canal system.[2,3]

The cold lateral-condensation technique of gutta-percha is still the standard, despite all the new obturation techniques.[4] Most of the new obturation techniques are based on heating or preheating gutta-percha and are designed to obturate root canals three dimensionally.

Root canal sealers have become indispensable in the obturation procedure. They seal the space between the dentinal wall and the obturating core interface, fill voids and irregularities, lateral and accessory canals and also fill spaces between gutta-percha points when the lateral condensation technique is used. The properties of an ideal sealer are outlined by Grossman,[5] but no sealer currently available satisfies all the criteria. When freshly mixed, all sealers exhibit toxicity and, although this is reduced upon setting,[6] extrusion of sealers into the peri-radicular tissues should be avoided if at all possible.

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Figure 1: Sectioned specimen in 1mm increments.

The most commonly-used endodontic sealers are zinc oxide-eugenol formulations, calcium hydroxides, resin-based and silicone-based sealers. Zinc oxide-eugenol sealers have been used successfully over an extended period of time. The main advantages include their excellent antimicrobial properties[7] and the fact that the sealers will resorb if extruded into the periapical tissues.[8] They have the disadvantage of a slow setting time,[9] exhibit shrinkage on setting[10] and can stain tooth structure.[11]

Common brand names of zinc oxide-eugenol-based sealers are Roth's (Roth Inc., Chicago, IL, USA) and Pulp Canal Sealer/Rickert's (Kerr, Romulus, MI, USA).

Resin-based sealers have a long history of use and provide adhesion to gutta-percha and dentine.[12] They do not contain eugenol and cause a dose-dependent increase in genotoxicity.[13] Resin-based sealers display deeper and more consistent penetration into the dentinal tubules compared with all the other types of sealers.[14]

AH26 (Dentsply Maillefer, Ballaigues, Switzerland) was a sealer dependant upon methenamine polymerisation which released formaldehyde during setting. This resulted in the development of AH Plus. AH Plus/Topseal (Dentsply Maillefer), is a bis-phenol resin using adamantine for polymerization.[15]

EndoREZ (Ultradent, South Jordan, UT, USA) is based on urethane dimethacrylate (UDMA) resin[16] and has some hydrophilic properties assumed to improve performance even in the presence of moisture. Resin-coated gutta-percha points are used and this bonding to the sealer supposedly provides better adhesion and seal throughout the filling mass.[17]

Epiphany/Resilon (Pentron, Wallingford, CT, USA) improved the EndoREZ concept.[18] Following the removal of the smear layer with a chelator, a self-etching primer is applied to the dentine surface. A dual-curing sealer based on Bisphenol-A-glycidyldimethacrylate (BisGMA), UDMA and hydrophilic

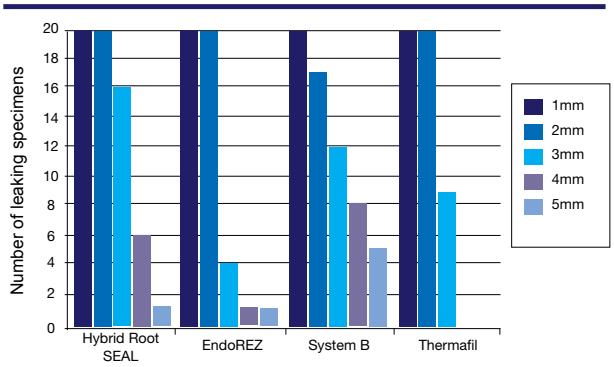

Figure 2: Apical leakage of Hybrid Root SEAL, EndoREZ, System B/Obtura and Thermafil techniques in the apical aspects of the root canals.

methacrylates with radiopaque fillers, is used to coat the primed dentine. Insertion of resin cones or thermally plasticised resin core material completes the obturation of the root canal space. This gives rise to the concept of a homogeneous 'monoblock' root filling with little or no voids and achieving adhesion to dentine.[19]

Hybrid Root SEAL (J Morita, Dietzenbach, Germany) is a dual-cure, self-etching resin cement for root canal obturation. It contains 4-methacryloyloxyethy trimellitate anhydride (4-META), a high performance adhesive monomer that decalcifies tooth substrate and penetrates through the smear layer to form a hybrid layer, creating high polymerisation, especially in the interface between root canal walls and cement. Hybrid Root SEAL shows high bond strength to dentine, biocompatibility and good sealability. In a comparative evaluation it showed similar sealing performance to the resin-based sealer, AH Plus.[20]

Table 1: Apical leakage of Group A (Hybrid Root SEAL).

Tooth	Canal	1mm	2mm	3mm	4mm	5mm
Molar Upper	MB 1	*	*			
	MB 2	*	*			
	BD	*	*			
	P	*	*	*	*	
Molar Lower	MB	*	*	*		
	ML	*	*	*		
	D	*	*	*	*	
Premolar Upper	B	*	*	*	*	
	P	*	*	*	*	
Premolar Upper	B	*	*	*		
	P	*	*	*		
Premolar Upper	B	*	*	*		
	P	*	*	*	*	
Premolar Lower		*	*	*		
Premolar Lower		*	*	*		
Premolar Lower		*	*	*		
Canine Upper		*	*	*	*	*
Canine Lower		*	*	*		
Central Upper		*	*			

The objective of this *in vitro* study were to evaluate four different root canal obturation techniques in respect of apical leakage.

MATERIALS AND METHODS

Ninety-six non-carious, recently-extracted human teeth were collected from various dental clinics. The teeth were prepared according to the techniques outlined in Part 1 of this series[21] and were then divided into four groups (n = 40 canals). The prepared root canals of the teeth were obturated by different techniques in each of the four groups, thus:

- **Group A:** Single Cone Technique with Gutta-percha and Hybrid Root SEAL cement (Hybrid Root SEAL technique).
- **Group B:** Single Cone Technique with Gutta-percha and EndoREZ Cement (EndoREZ technique).
- **Group C:** Continuous Wave of Obturation with Gutta-percha and Pulp Canal Sealer (System B/Obtura technique).
- **Group D:** Thermafil Obturators with Pulp Canal Sealer (Thermafil technique).

The specimens of each obturation group were subdivided into two equal groups (n=20 canals). One group was used to determine apical leakage of the root canal obturation materials and the second group used to assess the ability of the root canal obturation techniques to obturate lateral canals (Part 3 of this series). Each group represented canals from the following teeth (n=20 canals):

- one maxillary first molar (four canals);
- three maxillary premolars (two canals each);
- one maxillary canine (one canal);
- one maxillary central incisor (one canal);

Table 2: Apical leakage of Group B (EndoREZ).

Tooth	Canal	1mm	2mm	3mm	4mm	5mm
Molar Upper	MB 1	*	*			
	MB 2	*	*			
	BD	*	*			
	P	*	*			
Molar Lower	MB	*	*			
	ML	*	*			
	D	*	*			
Premolar Upper	B	*	*			
	P	*	*			
Premolar Upper	B	*	*			
	P	*	*			
Premolar Upper	B	*	*	*		
	P	*	*			
Premolar Lower		*	*			
Premolar Lower		*	*			
Premolar Lower		*	*	*		
Canine Upper		*	*	*		
Canine Lower		*	*	*	*	*
Central Upper		*	*			
Central Lower		*	*			

- one mandibular molar (three canals);
- three mandibular premolars (one canal each);
- one mandibular canine (one canal);
- one mandibular central incisor (one canal).

For evaluation of apical leakage, the root surface of each tooth was coated with three layers of nail varnish and a final layer of sticky wax, but leaving 4mm around the apical foramen exposed. The specimens were then immersed in two percent methylene blue dye (pH 7.0) for 48 hours. After removal from the dye the specimens were rinsed in distilled water and embedded in clear acrylic resin.

All the specimens were then processed according to the sequence prescribed by Wu *et al.*[22]:

- Specimens were sectioned horizontally in 1mm increments (Figure 1) with a wafering blade set in an Isomet 11-1180 low speed saw (Buehler Ltd., LakeBluff, Illinois, USA) under permanent water irrigation. Teeth were orientated so that the sections were perpendicular to their long axes.
- Each succeeding section was advanced 1mm so that the new section would represent the next 1mm level.
- Specimens were sectioned to their midroot area unless dye penetration was still visible.
- The resulting sections of each specimen were mounted on microscopic slides and examined in a stereomicroscope (Leica, Microsystems, Heerbrugg, Switzerland) by two independent evaluators who were unaware of the material used.
- The extent of dye penetration was measured, to the nearest demonstrable millimeter, to the level where the presence of dye was still visible on the filling material or dentine walls.
- Apical leakage was measured at the point where gutta-percha was first observed. In teeth where the foramen exited short of the anatomical apex, the most apical segment was removed until gutta-percha was exposed.

All the data was collected, tabulated and statistically analysed using the Mann-Whitney U test.

RESULTS

The apical leakage scores of the four different obturation groups are presented in Tables 1-4 and summarised in Figure 2.

The means, standard deviations and coefficients of variance for the apical leakage are presented in Table 5 and the significance of differences is presented in Table 6.

Group A: Hybrid Root SEAL technique

Sixteen canals of the specimens in the Hybrid Root SEAL technique group showed apical leakage up to 3mm from the apical foramina and six canals demonstrated apical leakage up to 4mm from the apical foramina.

Only one root canal (upper canine) illustrated leakage (arrows) up to 5mm from the apical foramina (Figure 3).

Group B: EndoREZ technique

In this group, four root canals demonstrated apical leakage up to 3mm from the apical foramina and one root canal (upper canine) showed apical leakage up to 5mm from the apical foramina.

Table 3: Apical leakage of Group C (System B).

Tooth	Canal	1mm	2mm	3mm	4mm	5mm
Molar Upper	MB 1	*	*	*		
	MB 2	*	*	*	*	*
	BD	*	*	*		
	P	*	*			
Molar Lower	MB	*	*	*	*	*
	ML	*	*	*		
	D	*	*			
Premolar Upper	B	*	*	*	*	*
	P	*	*	*	*	
Premolar Upper	B	*	*	*	*	
	P	*	*	*	*	*
Premolar Upper	B	*	*	*		
	P	*	*	*	*	
Premolar Lower		*	*	*	*	*
Premolar Lower		*	*	*		
Premolar Lower		*	*			
Canine Upper		*	*			
Canine Lower		*				
Central Upper		*				
Central Lower		*				

Table 4: Apical leakage of Group D (Thermafil).

Tooth	Canal	1mm	2mm	3mm	4mm	5mm
Molar Upper	MB 1	*	*	*		
	MB 2	*	*	*		
	BD	*	*	*		
	P	*	*	*		
Molar Lower	MB	*	*	*		
	ML	*	*	*		
	D	*	*	*		
Premolar Upper	B	*	*			
	P	*	*			
Premolar Upper	B	*	*			
	P	*	*			
Premolar Upper	B	*	*			
	P	*	*			
Premolar Lower		*	*			
Premolar Lower		*	*	*		
Premolar Lower		*	*			
Canine Upper		*	*	*		
Canine Lower		*	*			
Central Upper		*	*			
Central Lower		*	*			

The specimens that were obturated with EndoREZ technique demonstrated the least apical leakage compared with all the other groups. Figure 4 depicts an example of one of the specimens in this group that demonstrated apical leakage only up to a level of 2mm. However, there was a statistically significant ($p<0.05$) difference in apical leakage only when EndoREZ technique was compared with Hybrid Root SEAL and with System B/Obtura techniques. There was no significant difference between the data from the EndoREZ and Thermafil techniques ($p>0.05$).

Group C: System B/Obtura techniques

Thirteen canals of the System B/Obtura technique group showed apical leakage of up to 3mm from the apical foramina; eight canals demonstrated apical leakage up to 4mm from the apical foramina and five canals demonstrated apical leakage (arrows) up to 5mm from the apical foramina (Figure 5).

The specimens that were obturated with System B/Obtura technique demonstrated the most apical leakage compared with all the other techniques. However, there was a statistically significant ($p<0.05$) difference in apical leakage only when the data from System B/Obtura technique was compared with that from the EndoREZ and Thermafil techniques. There was no significant difference between the means from System B/Obtura and from Hybrid Root SEAL techniques ($p>0.05$).

Group D: Thermafil technique

In this group, nine of the canals showed apical leakage extending up to 3 mm from the apical foramina. There was no evidence of apical leakage past the 3mm level in any of the specimens (Figure 6).

DISCUSSION

It is not possible by means of a radiograph to fully assess the seal established during obturation, and it is important to remember that no material or technique will prevent leakage or maintain a long-term apical seal.[23,24,25]

Obturation can only be complete by using a sealer in conjunction with a core material such as gutta-percha.[26] Clinical studies addressing the causes of endodontic failure established that incomplete obturation accounted for many of these, and an *in vitro* study also indicated that incomplete obturation allowed microleakage.[27]

In the present study the System B group displayed the most apical leakage compared with all the other groups. However, there was a statistically significant ($p<0.05$) difference in the data recording apical leakage only when System B was compared with EndoREZ and Thermafil. There was no significant difference between System B and Hybrid Root SEAL ($p>0.05$).

Pommel and Camps[28] examined the *in vitro* apical leakage of System B compared with other filling techniques. In their study System B was found to be as effective as either vertical condensation or the Thermafil technique. Inan *et al.*,[29] compared the leakage of lateral condensation in System B and Thermafil techniques by using electro-chemical and dye penetration methods. In this study the lowest mean leakage values were observed with Thermafil and the highest were observed for the cold lateral condensation technique. System B obturations showed a moderate amount of apical leakage in their study.

Table 5: Mean, Standard Deviation and Coefficient of Variance of the apical leakage of Hybrid Root SEAL, EndoREZ, System B/Obtura and Thermafil techniques.

	Hybrid Root SEAL	EndoREZ	System B	Thermafil
Mean mms	3.1500	2.3000	3.4500	2.4500
Standard Deviation	0.8127	07327	1.1459	0.5104
Coefficient of Variance	25.801	31.856	33.215	20.833

Table 6: Significance of the differences between the mean values (Table 5) of the apical leakage measurements of Hybrid Root SEAL, EndoREZ, System B/Obtura and Thermafil techniques.

	EndoREZ	System B	Thermafil
Hybrid Root SEAL	p<0,05	p>0,05	p<0,05
EndoREZ		p<0,05	p>0,05
System B			p<0,05

It is important to note that in the present study a selection of different teeth was used for each obturation group. This variation may have influenced the results of this *in vitro* study. If one looks at the apical leakage results of the System B group (Table 3), it is evident that teeth with single, round canals and straight root canals demonstrated less apical leakage compared with teeth presenting with more complex root canal systems. However, this observation was not as significant in the apical leakage results for the other groups tested in this study (Tables 1, 2 and 4). De-Deus *et al.*,[30] demonstrated that the System B technique resulted in fewer gutta-percha-filled areas in the apical aspects of root canals compared with the Thermafil technique. In their study, samples with oval or flattened canals demonstrated poor filling when System B was used. Only the Thermafil technique was efficient in filling irregular root canal forms.

The Hybrid Root SEAL group illustrated the second-most apical leakage in the present study. Results for this new dual-cure self-etching resin cement were very disappointing. Hybrid Root SEAL contains 4-META, well known for its ability to promote monomer diffusion into the acid-conditioned and intact underlying dentine, leading to the formation of a hybrid layer.[31] As far as the authors could determine, only one other research paper has been published on the efficacy of this root canal cement where the long-term sealing ability of Hybrid Root SEAL was compared with RealSeal and AH Plus sealers.[20] It was concluded that Hybrid Root SEAL showed similar sealing properties to those of RealSeal or AH Plus when used with either gutta-percha or Resilon cones after 24 weeks.

The best apical seal in the present study was obtained by the EndoREZ group. However, there was no statistically significant difference between the mean apical leakage scores of EndoREZ and Thermafil ($p>0.05$).

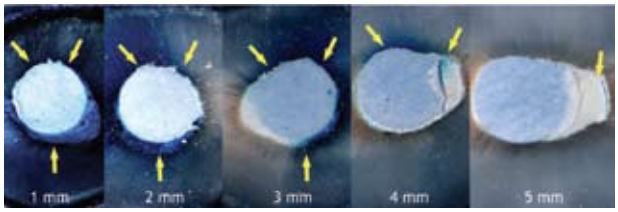

Figure 3: An example of one of the root canals (upper canine) obturated with Hybrid Root SEAL technique illustrating apical leakage (arrows) up to 5mm from the apical foramina (5X magnification).

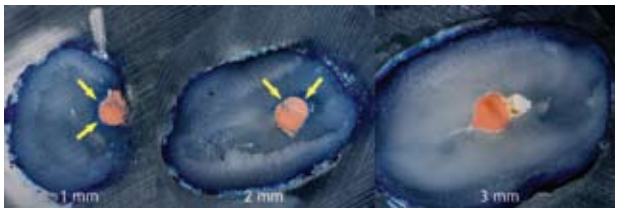

Figure 4: Specimen obturated with EndoREZ technique. Apical leakage (arrows) was visible only up to 2mm from the apical foramina (5X magnification).

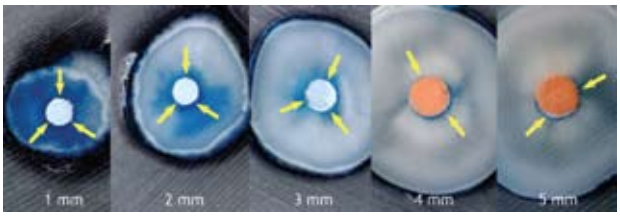

Figure 5: An example of a specimen obturated with System B/Obtura technique that demonstrated apical leakage (arrows) up to 5mm from the apical foramina (5X magnification).

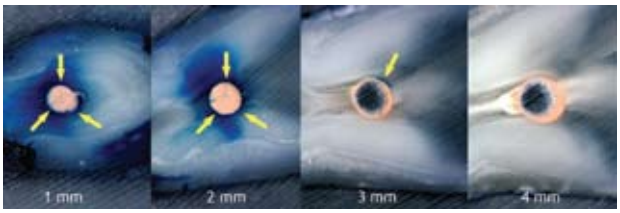

Figure 6: An example of a specimen obturated with Thermafil technique that showed apical leakage (arrows) up to 3mm from the apical foramina (5X magnification).

In a study done by Zmener and Pameijer[16] where EndoREZ was compared with Grossman's sealer, EndoREZ also presented with the least amount of apical leakage. In a more recent study by Gernhardt *et al.*,[4] EndoREZ was compared with another epoxy resin-based sealer (AH Plus) using the lateral condensation, warm vertical and Thermafil techniques. The results indicated that the sealing ability of EndoREZ was not as effective as that of AH Plus. However, the authors suggested that when EndoREZ is used with the warm vertical condensation or Thermafil technique it might decrease the risk of apical leakage.

In the present study the Thermafil technique also obtained very low apical leakage values. Despite the fact that there were no statistically significant differences between the mean apical leakage scores of Thermafil and EndoREZ, it must be noted that there was apical leakage only up to the three mm level from the apical foramina in all the specimens of this group. EndoREZ specimens demonstrated a slightly lower mean apical leakage value but some of the specimens illustrated leakage up to the 5mm level from the apical foramina.

As previously mentioned, the study by De-Deus *et al.*[30] demonstrated that the Thermafil technique can produce higher gutta-percha filled areas in the apical aspects of root canal compared with the lateral condensation or System B techniques. This phenomenon is very evident if one considers the apical cross-sections of the Thermafil specimens in the present study (Figure 6). There was a more homogenous mass which included only gutta-percha or gutta-percha and plastic carrier, surrounded by a very thin uniform layer of root canal cement around the perimeter of the canal. All specimens of the other obturation techniques in this study demonstrated a central mass of gutta-percha surrounded by a thicker layer of root canal cement. Restricting the sealer to a thin layer, uniformly distributed around a solid mass of gutta-percha, has been the aim of recent investigations.[31] It can be speculated that the thicker the layer of root canal cement between the gutta-percha and the canal wall, the higher the amount of apical leakage.[31]

CONCLUSIONS

- The specimens that were obturated with the EndoREZ technique demonstrated the least apical leakage compared with the performance of all the other obturation techniques tested in this study. However, there was a statistically significant difference only when the mean data of the EndoREZ technique was compared with that of the Hybrid Root SEAL and System B/Obtura techniques ($p<0.05$).
- The specimens that were obturated with the System B/Obtura technique demonstrated the most apical leakage compared with all the other obturation techniques tested in this study. However, there was a statistically significant difference only when the data from the System B/Obtura technique was compared with that from the EndoREZ and Thermafil techniques ($p<0.05$).

Declaration: No conflict of interest declared

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