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The sealing ability of GuttaFlow™ in oval-shaped canals: an *ex vivo* study using a polymicrobial leakage model

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Abstract

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Aim To compare systematically the sealing ability provided by four endodontic cements: AH Plus, Pulp Canal Sealer EWT, RoekoSeal and GuttaFlow.

Methodology A sample of 100 human mandibular incisors with oval-shaped canals was selected from an initial sampling of two hundred teeth. The root canals in 80 teeth were prepared and filled by the same operator using the cold lateral compaction technique with one of the following four cements ($n = 20$): G1: AH Plus; G2: Pulp Canal Sealer EWT; G3: RoekoSeal and G4: GuttaFlow. Ten teeth with intact crowns served as negative controls and 10 teeth that were not root filled served as positive controls. All teeth were mounted in a two chamber apparatus and then exposed to human saliva. The number of days over a 9-weeks-period was recorded for the appearance of turbidity in the BHI broth. A Log-rank test was used to analyse the leakage data.

Results Overall, 30% of the samples of the AH Plus group (G1) and 35% of the Pulp Canal Sealer EWT group (G2) were fully contaminated after 9 weeks, whereas 15% of RoekoSeal (G3) and GuttaFlow (G4) groups were fully contaminated. There was a significant difference between (G1/G2) and (G3/G4) ($P < 0.05$). There was no significant difference between G1 and G2 or between G3 and G4 ($P > 0.05$).

Conclusion The silicone-based sealers revealed the best results throughout the experimental period. Leakage patterns of AH plus and Pulp Canal Sealer were statistically similar.

Keywords: bacterial leakage, endodontic sealers, sealing ability.

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Introduction

Re-infection of the root canal system is one of the crucial factors that influence treatment outcomes (Sundqvist *et al.* 1998). For that reason, at the conclusion of root canal treatment, it is advised that the root canal space should be completely and densely filled with a biologically inert material (Schilder 1967). Gutta-percha and root canal sealer are currently the filling materials of choice, but they can be used in a variety of ways to fill the root canal system. Moreover, endodontic cements have been demonstrated to be the essential components in the formation of a seal during canal filling. Laboratory studies have shown that gutta-percha seals significantly better when used in combination with a sealer (Kontakiotis *et al.* 1997, Wu *et al.* 2000). The sealer is capable of filling imperfections and increases adaptation of the root filling (Wu *et al.* 2000), and the quality of apical sealing is influenced by the sealer thickness (De-Deus *et al.* 2006a).

Many types and commercial brands of endodontic sealers are commercially available. To date, they can be divided into: zinc-oxide-eugenol-based cements,

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calcium hydroxide cements, glass–ionomers and plastic resins (Lucena-Martín *et al.* 2002). A new silicone-based sealer (GuttaFlow®, Roeko, Coltene Whaledent, Langenau, Germany) and Resilon (Resilon Research LLC, Madison, CT, USA) have been introduced as alternative root filling materials. GuttaFlow® is a cold, fluid obturation system that combines sealer and gutta-percha in a single material. It consists of a polydimethylsiloxane matrix which is highly filled with very finely ground gutta-percha. Polydimethylsiloxane has been used in dentistry for many years especially in prosthodontics, as silicone-based impression materials with only limited dimensional change in setting (about 0.6–0.15%) and low water sorption.

The finely ground gutta-percha powder and the silicone-based matrix are distributed homogeneously after mixing. GuttaFlow® has very promising properties because of its insolubility, biocompatibility, post-setting expansion, great fluidity, and for providing a thin film of sealer (http://www.guttaflow.com 2007). GuttaFlow® has nano-silver in its composition. Nano-silver is a metallic silver which is distributed uniformly on the surface of the filling. The chemical type and concentration of the nano-silver do not cause corrosion or colour changes in the GuttaFlow®. There is sufficient nano-silver in the material to prevent further spread of bacteria and nano-silver is highly biocompatible (http://www.guttaflow.com 2007).

Roekoseal Automix (RSA, Roeko, Coltene Whaledent, Langenau, Germany) has already been tested in other studies with contradictory results (Economides *et al.* 2005, Wu *et al.* 2006). RSA consists of a new silicone-based sealer that does not belong to any other pre-existing chemical division for filling materials and exhibits post-setting expansion. RoekoSeal is mixed with automix tips similar to those used for impression materials, whilst GuttaFlow® is mixed by trituration before placement into the root canal on either a gutta-percha cone, or by passive injection through a dedicated plastic cannula.

Several methods have been used to assess the quality of root fillings including qualitative (Siqueira *et al.* 1999) and quantitative leakage tests (Wu & Wesselink 1993). However, there is no consensus about the methods used for leakage evaluation (Wu & Wesselink 1993). Conventional dye leakage studies provided only limited information (Wu & Wesselink 1993, Pommel & Camps 2001), and little correlation has been found between the results of apical dye leakage studies and clinical outcome (Oliver & Abbott 2001). Studies using bacterial cultures or saliva have been widely used to test the leakage resistance of endodontic materials and may be considered to have more biological significance than dye leakage tests. The use of human saliva is advantageous because it closely approximates clinical conditions (Siqueira *et al.* 1999, Siqueira *et al.* 2000, De-Deus *et al.* 2006a, De-Deus *et al.* 2006d).

The present paper aims to compare systematically the sealing ability provided by four endodontic cements —AH Plus (Dentsply Maillefer, Ballaigues, Switzerland), Pulp Canal Sealer EWT (Kerr, Sybron Dental Specialties, Romulus, MI, USA), RoekoSeal Automix (Roeko, Langenau, Germany) and GuttaFlow® (Roeko, Langenau, Germany). A polymicrobial leakage model was used for leakage assessment.

Materials and methods

Sample selection

Two hundred left and right mandibular incisors were selected and autoclaved. Periapical radiographs of each tooth were taken in both the buccolingual and mesiodistal planes. Teeth with oval-shaped canals were selected only when the ratio of the long : short diameter was ≥2.5 at 5 mm from the apex (Wu & Wesselink 2001, De-Deus *et al.* 2006c). Teeth presenting with an isthmus, lateral and accessory canals, or more than one canal were excluded from the sample. Therefore, only 107 incisors were classified as single oval-shaped canals. Seven teeth were discarded leaving a total sample of 100 teeth that were stored in 10% neutral formalin.

Instrumentation

Eighty teeth were prepared using the same technique. Conventional access to the root canal system was made using a diamond bur (1099 xl, Dentsply Maillefer), and patency of each canal was confirmed by inserting a size 15 file through the apical foramen before and after the completion of preparation procedures. The working length was determined by subtracting 1 mm from the length of the radiographic apical foramen. The coronal and middle thirds of each canal were prepared using Gates Glidden drills (Dentsply Maillefer, Ballaigues, Switzerland), sizes 110, 090 and 070, sequentially. The apical third was prepared with Flexofiles® (Dentsply Maillefer) sizes 40, 35, 30 and 25 using a balanced-force technique (Roane *et al.* 1985). The canals were irrigated at each change of file with 1 mL of freshly prepared 5.25% NaOCl and received a final flush of

5 mL of 17% EDTA (pH 7.7) for 3 min. The canals were dried with paper points (Dentsply Maillefer).

Thereafter, the prepared teeth were randomly divided in four groups of 20 teeth each.

Obturation of root canals

The eighty teeth were root filled by the same operator using the cold lateral compaction technique with one of the four following cements ($n = 20$ per group): AH Plus (Dentsply Maillefer), Pulp Canal Sealer EWT (Kerr), RoekoSeal (RoekoSeal Automix) and GuttaFlow® (Roeko). The cements were prepared following the manufacturers' instructions. A size 40 file was used to pick up a measured volume of sealer (0.125 mL) from the mixing pad and placed into the canal whilst rotating it counterclockwise (Wu *et al.* 2001). A size 35 master gutta-percha cone (Diadent Group International, Chongchong Buk Do, Korea) was placed in the canal to the full working length. Lateral compaction was undertaken in each canal by inserting 10 accessory gutta-percha cones (MF, Diadent Group International) and endodontic finger spreader size B (Dentsply Maillefer). A heated instrument was used to remove excess coronal gutta-percha.

Ten teeth with intact crowns served as negative controls and 10 teeth with their root not filled served as positive controls. Two coats of nail varnish were applied on the external surface of all teeth, except at the apical and coronal ends. In the negative control group, teeth were completely covered with nail varnish. The obturated teeth were stored at 37 °C and 100% of humidity for 7 days to allow setting of the sealer.

Polymicrobial leakage

The apparatus used to evaluate bacterial leakage was modified from that described previously (Siqueira *et al.* 1999, De-Deus *et al.* 2006c). Briefly, 10-mL glass assay tubes (BD Vacutainer™, Juiz de Fora, Minas Gerais, Brazil) with rubber stoppers were adjusted for use. With a heated instrument, a hole was made through the centre of every rubber stopper in which a cylinder prepared from insulin syringes (BD Vacutainer™) was inserted. The tooth crown was fitted tightly into a rubber tube and sealed using cyanoacrylate. Syringe cylinders were then adapted on the other side of the rubber tube to create a reservoir for saliva. Cyanoacrylate was applied in all junctions of the system.

The testing apparatus was sterilized overnight in ethylene oxide gas (BIOXXI Esterilization Services Ltd., Rio de Janeiro, Brazil). The setup was made in a laminar airflow hood (Bioprotector Plus 09, Veco, Campinas, São Paulo, Brazil), where the glass assay tubes were filled with 3 mL sterile Brain Heart Infusion (BHI, Oxoid Ltd, Basingstoke, UK), so that approximately 2 mm of the resected root was immersed in the broth. The whole apparatus was incubated at 37 °C for 4 days to ensure sterilization (Fig. 1).

The reservoirs were then filled with human saliva (20 mL) mixed in BHI broth in a 1 : 1 (v/v) ratio and replenished every 3 days (Siqueira *et al.* 1999, De-Deus *et al.* 2006c). Human saliva was collected from one individual and the volunteer did not use a tooth brush for at least 12 h before collection (Siqueira *et al.* 1999, De-Deus *et al.* 2006c). The system was incubated at 37 °C and checked daily for the appearance of turbidity in the BHI broth over the following 9 weeks.

Statistical analysis

Data were organized in a contingency table. The Log-rank test was used to analyse the leakage data at intervals of 3, 6 and 9 weeks (Adamo *et al.* 1999). The level of significance in all tests was set at $P < 0.05$.

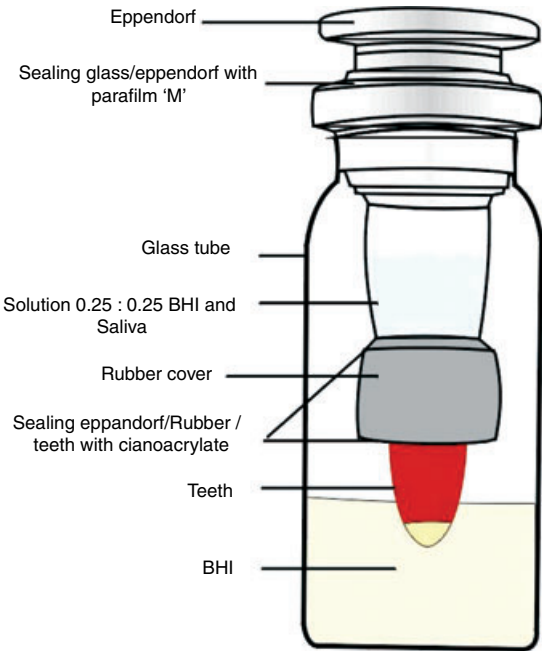

Figure 1 Setup of model design.

SPSS (Statistics 4.0, SPDD, Gorinchem, Netherlands) was also used for the analysis.

Results

No bacterial growth was observed upon checking the sterilization of the whole apparatus. All specimens of the positive control group showed broth turbidity within 2 days of incubation. Leakage in experimental samples was first observed on the 16th day. No evidence of turbidity in the BHI broth occurred in the negative control group throughout the experiment periods. Samples displayed leakage within a range of 16–59 days.

Overall, 30% of the samples of the AH Plus group (G1) and 35% of the Pulp Canal Sealer EWT group (G2) were fully contaminated after 9 weeks, whereas 15% of the RoekoSeal (G3) and GuttaFlow® (G4) groups were fully contaminated. There was a significant difference between (G1/G2) and (G3/G4) ($P < 0.05$). There was no significant difference between G1 and G2 or between G3 and G4 ($P > 0.05$).

The cumulative leakage and the statistical analysis of the experimental groups are shown in Table 1.

Discussion

The introduction of new materials in Endodontics is common because of technological innovations associated with the search for improved clinical success.

Table 1 Summary table of statistical results. Percentage of samples in each group that showed leakage

	Pulp Canal Sealer	AH Plus	RSA	GuttaFlow
3 weeks				
Pulp Canal Sealer	20%		X	X
AH Plus		20%	X	X
RSA	X	X	10%	
GuttaFlow	X	X		10%
6 weeks				
Pulp Canal Sealer	30%		X	X
AH Plus		25%	X	X
RSA	X	X	15%	
GuttaFlow	X	X		15%
9 weeks				
Pulp Canal Sealer	35%		X	X
AH Plus		30%	X	X
RSA	X	X	15%	
GuttaFlow	X	X		15%

X: significant difference ($P < 0.05$) between respective group pairs.

The results of the present study have demonstrated that silicone-based sealers resulted in significantly fewer samples being contaminated at the end of the experimental period when compared with the other sealers tested. In addition, silicone-based sealers appeared to remain stable in terms of bacterial contamination after the third week, whilst both AH Plus and Pulp Canal Sealer EWT allowed more sealers to become contaminated.

The results of the current study are in agreement with the results of a number of *ex vivo* studies. Wu *et al.* (2006) found that RSA was dimensionally stable and prevented leakage for at least 1 year. The authors pointed out that a high gutta-percha/sealer ratio may not be necessary when RSA is used. In addition, laboratory investigations have indicated a 0.2% setting expansion (Orstavik *et al.* 2001), biocompatibility (Miletic *et al.* 2005), and acceptable coverage of the root canal wall (Ardila *et al.* 2003). A clinical trial comparing silicone sealer with zinc-oxide eugenol in lateral condensation revealed comparable healing outcomes (Huumonen *et al.* 2003). Additional favourable properties were its fluidity and capacity to set under both humid and dry conditions (Wu *et al.* 2006). Gençoglu *et al.* (2003) investigating microleakage found the best results in teeth in which RSA was used. In an SEM assessment, RSA showed good adaptation to the root canal wall and penetration into dentinal tubules in the middle third of the canal. Ebert & Petscheldt (1999) investigated the sealing ability of AH26 and RSA and found less leakage with RSA than AH26. Wu *et al.* (2002) reported the reliable long-term sealing ability of RoekoSeal. The initial expansion observed in the silicone-based sealers may explain the better sealing ability provided by these materials. In a study by Schafer and Zandbiglari (2003), solubility of epoxy resins and silicone-based, calcium hydroxide, zinc-oxide-eugenol and glass–ionomer-based sealers were measured. AH plus and RSA were found to be the most dimensionally stable.

In other apical leakage studies, no significant difference was found between RoekoSeal and AH26 (Ebert *et al.* 1999, Schafer & Olthoff 2002, Cobankara *et al.* 2004). Lucena-Martín *et al.* (2002) concluded that no significant differences existed between Endomethasone, TopSeal, and RoekoSeal for apical leakage.

In the present study, the Pulp Canal Sealer group demonstrated a greater number of sealers with bacterial leakage, in disagreement with some other studies (Yared & Bou Dagher 1996, McDougall *et al.* 1999). Such differences in performance may be attributed to

the filling technique and/or method used for leakage evaluation. In the present study, AH Plus allowed more samples to become contaminated over the experimental period, as reported by Timpawat *et al.* (2001). These authors observed, however, that the sealing ability of AH Plus decreased after 14 days. On the contrary, some investigations highlight the good properties of this sealer (Kontakiotis *et al.* 1997, Huang *et al.* 2001, Orstavik *et al.* 2001). However, in the present study both AH Plus and Pulp Canal Sealer allowed more samples to be contaminated than the silicone-based sealers.

Mandibular incisors with single oval-shaped canals were used in the present study with the purpose of evaluating the quality of root canal sealing in canals in which difficulties with the anatomy could complicate the root filling procedure. The studies of Pucci & Reig (1944) and Mauger *et al.* (1988) reported the anatomical variety of those teeth. The problem regarding irregular-shaped canals has been investigated previously. The oval canal shape may make it difficult to clean and fill (Wu *et al.* 2001). De-Deus *et al.* (2006b) reported that the irregular canal shape may influence the filling quality negatively. Kersten *et al.* (1986) pointed out that both cold lateral compaction and warm vertical compaction of gutta-percha had been widely used in root canal treatment, although their quality may vary depending on the root canal shape. Wu *et al.* (2001) postulated that irregularly-shaped canals may be filled more effectively by warm gutta-percha techniques, whilst De-Deus *et al.* (2006b) found that only the Thermafil system was able to fill oval canals in a suitable manner.

Studies using bacterial cultures or saliva have been used widely to test the leakage resistance of endodontic materials because it might be more meaningful and provides more precise and reproducible data (Siqueira *et al.* 1999, Siqueira *et al.* 2000). Such tests may be considered to have more biological significance than dye leakage tests as they reflect more closely the clinical situation, especially, when human saliva is used as a bacterial source. It also allows the evaluation of the samples at specific periods (Siqueira *et al.* 1999, Siqueira *et al.* 2000). Nevertheless, it is a static model that does not simulate clinical conditions fully, needs an extended period of observation and does not allow quantification of the number of penetrating bacteria (Siqueira *et al.* 1999, Siqueira *et al.* 2000).

Under the conditions of this *ex vivo* evaluation, it was concluded that the silicone-based sealers allowed fewer specimens to become contaminated. Patterns of contamination of samples using AH plus and Pulp Canal Sealer were statistically similar.

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