Filling of artificial lateral canals and microleakage and flow of five endodontic sealers

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Abstract


Aim To evaluate the flow characteristics of AH Plus, Epiphany Root Canal Sealant, Endométhasone, Pulp Canal Sealer (EWT) and Sealapex and their ability to fill artificial lateral canals and prevent microleakage.

Methodology Flow of the sealers was analysed using the American Dental Association (ADA) 57 and the International Standards Organization (ISO) 6876 specifications. Two lateral canals were produced in the middle and apical third of 64 roots using 0.1 mm cylindrical drills. Lateral condensation of gutta-percha or Resilon and one or other of the sealers were used to fill the root canals. Buccal-lingual digital radiographs were exposed. After the sealer had set, the roots were immersed in Indian ink and cleared in methyl salicylate. The extent of filling and dye penetration were measured on the buccal and lingual root surfaces under 30× magnification with a stereoscope.

Results AH Plus, Epiphany and Pulp Canal Sealer (EWT) complied with ADA 57 and ISO 6876 specifications. Sealapex complied with the ADA 57 specification but not with ISO 6876. Endométhasone did not comply with either specification. Filling of lateral canals was similar for the five sealers tested. Dye leakage demonstrated that AH Plus, Epiphany and Sealapex permitted less leakage than Pulp Canal Sealer (EWT) (P < 0.05).

Conclusions All the sealers flowed into the 0.1 mm artificial lateral canals. AH Plus, Epiphany and Sealapex allowed less linear leakage than Pulp Canal Sealer (EWT). The flow of Endométhasone did not comply with either ADA 57 or ISO 6876 specifications and Sealapex did not comply with ISO 6876.

Keywords: artificial lateral canal, filling, dye leakage, flow, root canal sealer.

Introduction

An endodontic sealer must have several properties to be considered suitable. Flow is important as it reflects its ability to penetrate into small irregularities and ramifications of the root canal system and dentinal tubules (Grossman 1976, Siqueira et al. 1995, Weis et al. 2004). Moreover, flow along with the sealer’s antimicrobial effectiveness may aid the disinfection of the root canal system (Siqueira et al. 2000, Saleh et al. 2004).

Root canal ramifications, such as lateral, secondary and accessory canals can establish connection between the main root canal and periodontal ligament, as well as the apical foramen (De Deus 1975). Several authors described that localized periodontal problems might be associated with necrotic and infected root canal ramifications (Kirkham 1975, Weine 1984, Barkhordar & Stewart 1990) highlighting the importance of the capacity of the endodontic sealer to flow into these irregularities. Despite the significance of this physical property, the relationship between flow and its ability to penetrate narrow root canal ramifications has not been investigated (Venturi et al. 2003).

Extracted human teeth with confirmed root canal ramifications have been used to evaluate various types of sealers and filling techniques for their ability to fill
the root canal system (Clark & ElDeeb 1993, Karagöz-Kucukay 1994, Venturi et al. 2003). Due to the difficulty of obtaining human teeth with natural ramifications to allow comparisons, several authors have produced artificial canal ramifications in resin blocks (Himmel & Cain 1993, Reader et al. 1993, Dulac et al. 1999, Silver et al. 1999), which resemble those found in natural teeth (Goldberg et al. 2001, 2002, Pecora et al. 2002, Morues et al. 2004). Despite the ease of developing narrow ramifications in resin blocks, their surface texture and condition could influence the flow properties of gutta-percha and sealer (Dulac et al. 1999) and thus, there are limitations of using epoxy blocks instead of natural teeth (Reader et al. 1993).

Gutta-percha thermoplastic techniques were more efficient in filling lateral canals prepared in human teeth than the lateral condensation technique (Goldberg et al. 2001) and the use of calcium hydroxide dressings has been reported to reduce the quality of fillings within root canal ramifications (Goldberg et al. 2002). However, work to date has only illustrated which sealer or filling technique can fill root canal ramifications and doubt remains about the quality of the seal they produce (Weine 1984). Apical and coronal seals and the prevention of microleakage have been studied using several methodologies (Madison & Wilcox 1988, Wu & Wesselink 1993, Lucena-Martin et al. 2002, Zaia et al. 2002). However, the sealing ability of sealers has not been tested exclusively in natural or artificial lateral canals.

The aim of this study was to evaluate the flow characteristics of AH Plus, Epiphany Root Canal Sealant, Endométhasone, Pulp Canal Sealer (EWT) and Sealapex and to determine their ability to fill artificial lateral canals and prevent microleakage.

Materials and methods

Root canal sealers

Five endodontic sealers were used: two resin-based sealers AH Plus (Dentsply DeTrey, Konstanz, Baden-Württemberg, Germany) and Epiphany Root Canal Sealant (Pentron Clinical Technologies, Wallingford, CT, USA); two zinc oxide-eugenol based sealers Endométhasone (Septodont, Saint-Maur-Dés-Fossés, France) and Pulp Canal Sealer EWT (Kerr Corporation, Orange, CA, USA) and one sealer containing calcium hydroxide Sealapex (SybronEndo, Glendora, CA, USA). All materials were prepared according to manufacturers’ instructions.

Flow test

Two international standards were used to conduct the flow test: American Dental Association (ADA) no. 57 (American National Standards/American Dental Association 1983) and International Standards Organization (ISO)-6876 (International Organization for Standardization 2001).

According to the ADA 57 specification, 0.5 mL of the material was mixed and placed on the centre of a glass plate using a graduated syringe (Becton Dickinson, Curitiba, PR, Brazil). At 180 s (±5 s) after initiating mixing, another glass plate was placed centrally on top of the sealer, followed by a weight giving a total mass of 120 g (±2 g). Ten minutes after initiating the mixing, the weight was removed and the maximum and minimum diameters of the compressed discs of sealers were measured. Two conditions were necessary to validate the tests: the difference between the maximum and minimum diameters could not exceed 1.0 mm and the compressed disc should have uniform shape. If these conditions were not met, the test was repeated. Three determinations were carried out and the mean value was calculated to the nearest millimetre. The disc diameter should be at least 25 mm. The only differences between ADA and ISO standards are the volume analysed and the minimum diameter of spread, thus to test the ISO 6876 specification, the volume of sealer was 0.05 mL (±0.005 mL) and each compressed disc should have a diameter not <20 mm.

Filling and microleakage of artificial lateral canals

Sixty-four recently extracted human maxillary anterior teeth were selected with the approval of the Human Ethical Committee of the Piracicaba Dental School, State University of Campinas. The crowns of the teeth were removed using a low-speed diamond disc under running water and a standard length of 15 mm was achieved for every root. A buccal-lingual digital radiograph (Schick Technologies Inc., Long Island, NY, USA) was exposed and teeth with natural lateral canals were discarded. The teeth were randomly divided into five groups according to the sealer employed: G1, AH Plus; G2, Epiphany; G3, Endométhasone; G4, Pulp Canal Sealer (EWT); and G5, Sealapex.

The ramifications produced were called lateral canals, independent of the root canal third in which they appeared. Two artificial lateral canals, one in the middle and the other in the apical third, were prepared perpendicular to the longitudinal axis of the teeth using
0.10 mm cylindrical drills (Union Tool Europe S.A., Marin, Neuchâtel, Switzerland) (Fig. 1) in a machining centre (Discovery-Romi, Santa Bárbara d’Oeste, SP, Brazil), which created the perforations. The penetration of the drill into the root canal was checked by introducing a size 06 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into the perforations and another digital radiograph was exposed. If the file did not penetrate into the main root canal, the tooth was discarded.

The coronal and middle thirds of the root canals were shaped with size 3 and 2 Gates-Glidden burs (Dentsply Maillefer). The working length was established by subtracting 1 mm from the measurement acquired by placing a size 10 K-file (Dentsply Maillefer) into the root canal until the tip could be seen at the foramen. The apical third was prepared up to a size 45 K-file (Dentsply Maillefer); after every change of bur or file the canals were irrigated with 1 mL of 2.5% sodium hypochlorite. Following canal preparation, 3 mL of 17% EDTA was used to remove the smear layer, then 3 mL of 2.5% sodium hypochlorite and 3 mL of saline solution were used as final irrigants. Each canal was dried with paper points.

Before root canal filling, the teeth were mounted in alginate blocks (Dentsply, Petrópolis, RJ, Brazil) to confine the sealer after it had flowed through the artificial lateral canals, in an attempt to simulate the periodontal ligament. In all groups, except G3, the sealer was introduced into the root canals with a size 40 spiral Lentulo (Dentsply Maillefer). For the lateral condensation technique: a size 45 standardized gutta-percha cone (Tanari, Manacapuru, AM, Brazil) coated with sealer was fitted as a master cone. Lateral compaction was performed with 25 and 30 finger spreaders (Dyna, Bourges, France) and B7 and B8 accessory cones (Tanari) were introduced to fill the root canal. Excess gutta-percha was removed with a heated instrument and cold pluggers were used to vertically condense the coronal gutta-percha. In group 2, a paper point coated with Primer was introduced into the canal to its working length. Another paper point was then used to dry the canal and the filling was completed with Resilon cones and Epiphany Root Canal Sealant (Pentron Clinical Technologies), using the lateral condensation technique.

After being filled, all groups of teeth, except G2, were maintained for 48 h at high humidity and 37 °C to allow the sealers to set. Group 2 remained at high humidity and 37 °C for 14 days. The alginate blocks were then removed and digital radiographs were taken. The images were analysed at 100% magnification using the colour inversion facility within the Computed Dental Radiography (CDR) software (Schick Technologies Inc.). The total length of the lateral canal and its filling by sealer were measured with this software and the measurements converted to percentage of canal filled.

The external root surface was sealed with two layers of red nail varnish, except for the area over the lateral canals. Four unfilled teeth were used as positive and negative microleakage controls. The positive control was sealed like the other teeth and the negative control was sealed completely including the lateral canal orifices. All teeth were then immersed in Indian ink (Royal Talens, Apeldoorn, The Netherlands), submitted to vacuum for 30 min and stored in the ink for 24 h. Following exposure to the dye, the teeth were rinsed in tap water and the nail varnish removed completely with a scalpel. The teeth were then decalcified in 5% hydrochloric acid for 72 h and cleared in methyl salicylate according to Zaia et al. (2002).

The extent of filling, dye penetration and the total length of lateral canals were measured on the buccal and lingual root surfaces, under 30× magnification with a stereoscope (Lambda Let 2, ATTO Instruments Co., Hong Kong, China) and ImageLab 2.3 software.
(University of São Paulo, São Paulo, SP, Brazil). These measurements were converted to percentages.

Data were statistically analysed using Kruskal–Wallis, Dunn and Wilcoxon tests using BioEstat 3.0 software (CNPq, Brasília, DF, Brazil). Differences of $P < 0.05$ were considered to be significant. For the microleakage data, all lateral canals were considered together independent of the third they were located in.

**Results**

**Flow test**

The flow of sealers is presented in Table 1. Only Endométhasone did not comply with the ADA 57 specification. The others presented higher flow than the minimum required for this test. Sealapex and Endométhasone did not reach the minimum flow for compliance with ISO 6876. While Sealapex was close to complying with this specification, Endométhasone achieved significantly lower flow than the minimum required.

**Filling and microleakage of artificial lateral canals**

The percentage of canals filled with sealers varied with some lateral canals being full, while others were partially filled or unfilled (Fig. 2). The radiographic analysis failed to identify filled lateral canals in 8% of specimens, that were visible using the clearing technique (Fig. 3). Thus, the parameters for establishing the filling results were based on the clearing technique and dye microleakage, whereas partially filled or unfilled lateral canals were identified radiographically. Unfilled lateral canals were defined as those presenting no radiographic image, no presence of sealer in the clearing technique and with positive dye microleakage. Filled lateral canals were those with positive or negative radiographic images but with sealer present in the clearing technique.

The percentages of filling of lateral canals were consistent for all sealers tested, independent of the root canal third analysed. Unfilled or partially filled lateral canals were detected in few cases. No statistically significant differences were found between the groups for the middle and apical thirds. The results of analysis between the root canal thirds for each tested sealer did not show any differences ($P > 0.05$) (Table 2).

<table>
<thead>
<tr>
<th>Sealers</th>
<th>57 ADA (mm)</th>
<th>6876 ISO (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH Plus</td>
<td>43</td>
<td>22</td>
</tr>
<tr>
<td>Epiphany Root Canal Sealant</td>
<td>36</td>
<td>28</td>
</tr>
<tr>
<td>Endométhasone</td>
<td>20</td>
<td>11</td>
</tr>
<tr>
<td>Pulp Canal Sealer (EWT)</td>
<td>44</td>
<td>23</td>
</tr>
<tr>
<td>Sealapex</td>
<td>31</td>
<td>19</td>
</tr>
</tbody>
</table>

*Table 1 Flow of each endodontic sealer measured against ADA 57 and ISO 6876 specifications*
The clearing technique identified 18 natural root canal ramifications in 13 teeth: two lateral canals, 14 secondary canals, one accessory canal and one recurrent canal. The diameters of these canals ranged between 0.12 and 0.26 mm, except three that had a diameter smaller than 0.10 mm. Ten root canal ramifications were completely filled, five partially filled and three were unfilled (Fig. 4).

All sealers, except Pulp Canal Sealer EWT, were able to seal some artificial lateral canals with no microleakage. All of them allowed partial or total microleakage (Fig. 5). AH Plus, Epiphany and Sealapex had statistically significantly lower percentages of dye microleakage than Pulp Canal Sealer EWT (P < 0.05). Endométhasone did not differ significantly from the other sealers (P > 0.05) (Table 3).

The control teeth demonstrated positive microleakage through the lateral canals that did not receive nail varnish and no microleakage was found in the sealed lateral canals.

**Table 2** Medians of filling percentages for each endodontic sealer and P-comparison values between root canal thirds for each sealer

<table>
<thead>
<tr>
<th>Sealer</th>
<th>Apical third</th>
<th>Middle third</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Medians</td>
<td>Variation interval (%)</td>
</tr>
<tr>
<td>AH Plus</td>
<td>100</td>
<td>100–100</td>
</tr>
<tr>
<td>Epiphany Root Canal Sealant</td>
<td>100</td>
<td>46–100</td>
</tr>
<tr>
<td>Endométhasone</td>
<td>100</td>
<td>0–100</td>
</tr>
<tr>
<td>Pulp Canal Sealer (EWT)</td>
<td>100</td>
<td>0–100</td>
</tr>
<tr>
<td>Sealapex</td>
<td>100</td>
<td>70–100</td>
</tr>
</tbody>
</table>

*Wilcoxon test.

Columns show no statistically significant difference – Kruskal Wallis test (P > 0.05).

![Figure 4](image)

Figure 4 (a) Natural secondary canal (0.23 and 0.26 mm of diameters) filled by AH Plus sealer (amplification 20×), (b) two natural lateral canals (arrows showing 0.13 and 0.12 mm diameters) and an artificial lateral canal (wide arrow showing a 0.10 mm diameter) filled by Epiphany Root Canal Sealant (amplification 25×).

![Figure 5](image)

Figure 5 Cleared teeth images. (a) lateral canals completely filled by AH Plus without any dye microleakage, (b) middle lateral canal filled partially and apical lateral canal completely filled by Endométhasone with different microleakage levels, (c) lateral canals completely filled by Epiphany Root Canal Sealant without any dye microleakage, (d) lateral canals completely filled by Pulp Canal Sealer EWT with extensive dye microleakage, (e) middle lateral canal completely filled with no microleakage and apical lateral canal partially filled by Sealapex with a small amount of microleakage.
Discussion

Flow was different between sealers and when tested using the ADA or ISO specifications (Table 1). The composition of the sealers seems to be the main factor related to its flow characteristics. Thus, the powder particle size in powder/liquid sealers (Weisman 1970), as well as the sealer’s constituents and setting time (Grossman 1976), appears to interfere with flow. Nevertheless, there is little information to relate the composition of paste/paste or resin-based sealers to their flow properties.

The presence of resin in Pulp Canal Sealer EWT’s composition and in the two resin-based sealers could explain their better flow. Conversely, the absence of resin in Endométhasone could explain its poor flow. Endométhasone was the only sealer that did not comply with either of the two specifications. Grossman (1982) reported that a resin additive in zinc oxide–eugenol-based sealers provided plasticity and improved flow.

Endométhasone did not comply with the two international specifications and Sealapex did not comply with the ISO 6876 specification. All sealers demonstrated high percentages of filling when both canal thirds were analysed (Table 2), emphasizing that all sealers tested could fill root canal ramifications. These results illustrate that the flow required by ADA 57 and ISO 6876 specifications did not correlate with the capacity of the sealer to properly fill the artificial ramifications.

The 0.1 mm drills produced regular canals having similar internal and external diameters of the root canal surfaces (Fig. 6). Group 2 remained for 14 days at 37 °C after root canal filling. Epiphany is a dual-curable monomer-based sealer that needs an initiator to promote monomer conversion. The amount of initiator in the sealer is proportional to resin contraction. Epiphany, probably, has a small amount of initiator to avoid contraction and to allow a longer working time. Therefore, small amounts of initiator require more time to set. When a composite is heated, there is an increase in monomer conversion (Daronch et al. 2005). These two facts explain why it was necessary to keep this sealer for 14 days at 37 °C to set under laboratory conditions (Shipper et al. 2004, Oliveira et al. 2006).

The mean percentage of lateral-canal fillings for all sealers was 88% using the lateral condensation technique. The comparison of the results obtained from the radiographic and clearing analyses revealed that approximately 8% of the filled lateral canals did not appear on radiographic images. Thus, radiographs do not only fail to demonstrate the presence of ramifications in the root canal system on preoperative images (Altman et al. 1970, Zillich & Dowson 1973, Scarfe et al. 1995, Omer et al. 2004), but they could not do so predictably after filling. Clark & ElDeeb (1993) reported that filled lateral and accessory canals on cleared teeth, did not always appear on radiographic images.

Linear dye leakage was less than the apical dye leakage for AH Plus, Endométhasone, Sealapex and Pulp Canals Sealer (EWT) (Siqueira et al. 1995, Lucena-Martin et al. 2002, Schäfer & Olthoff 2002, Camps & Pashley 2003). The smaller diameter of the lateral canals when compared with the apical foramen could

Table 3 Medians of dye microleakage percentages for each endodontic sealer

<table>
<thead>
<tr>
<th>Sealers</th>
<th>Median values (%)</th>
<th>Minimum values (%)</th>
<th>Maximum values (%)</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>AH Plus</td>
<td>0  0</td>
<td>100</td>
<td>34.00</td>
<td></td>
</tr>
<tr>
<td>Epiphany Root Canal Sealant</td>
<td>0  0</td>
<td>100</td>
<td>44.92</td>
<td></td>
</tr>
<tr>
<td>Endométhasone</td>
<td>17 0</td>
<td>100</td>
<td>51.29</td>
<td>ab</td>
</tr>
<tr>
<td>Pulp Canal Sealer (EWT)</td>
<td>70 29</td>
<td>100</td>
<td>73.39</td>
<td>a</td>
</tr>
<tr>
<td>Sealapex</td>
<td>21 0</td>
<td>100</td>
<td>43.50</td>
<td>b</td>
</tr>
</tbody>
</table>

Different letters in superscript mean statistically significant difference – Kruskal Wallis and Dunn tests (P < 0.05).

Figure 6 SEM images of lateral canal orifices demonstrating the regularity of 0.1 mm drill perforations, (a) outside surface of dental root (106 μm 140× magnification), (b) inside surface of dental root (108 μm 330× magnification) note the relationship of the artificial lateral canal and the dentinal tubules diameters.
provide better conditions for the sealer to improve their capacity to resist leakage. The new resin filling system (Epiphany/Resilon) resulted in less leakage through artificial lateral canals only when it was compared with Pulp Canal Sealer (EWT). When this system was tested, significantly less microbial leakage was obtained than with all other groups in which AH 26 was used as a sealer (Shipper et al. 2004). Epiphany and Resilon also presented less dye leakage than Tubli-Seal and gutta-percha during apical leakage test (Aptekar & Ginnan 2006). It may be that Epiphany did not demonstrate better results in the present work because the primer did not efficiently reach the dentine inside the lateral root canal, compromising the bond between resin and dentine.

Although a complete apical seal cannot be achieved either with Resilon/Epiphany or sealer and gutta-percha (Tay et al. 2005), the physical presence of the sealer and its antimicrobial property might eliminate or inhibit the growth of microorganisms in the root canal system (Siqueira et al. 2000, Saleh et al. 2004).

Conclusions

Endométhasone did not comply with either ADA 57 or ISO 6876 specifications and Sealapex did not comply with ISO 6876. Lateral canal filling by sealers were not statistically significantly different for the five sealers tested. Dye leakage demonstrated that AH Plus, Epiphany and Sealapex permitted less leakage than Pulp Canal Sealer (EWT) (P < 0.05). Radiographs were not able to show lateral canal filling in approximately 8% of cases. There is no correlation between the flow required by the ADA 57 and ISO 6876 specifications and the sealer’s ability to fill 0.1 mm artificial lateral canals.

Acknowledgements

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