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Sealing properties of a new root canal sealer

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Abstract

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Aim To evaluate bacterial leakage of Apexit Plus, a new root canal sealer, in comparison with AH Plus.

Methodology A total of 56 single-rooted human teeth were randomly divided into two experimental groups of 16 roots and two control groups. Roots were filled by lateral condensation with Gutta-percha and AH Plus or with Gutta-percha and Apexit Plus. A split chamber microbial leakage model was used in which *Streptococcus mutans* placed in the upper chamber could reach the lower chamber only through the filled canal. Positive controls were filled only with Gutta-percha and tested with bacteria, whereas negative controls were sealed with wax to test the seal between chambers. Additionally, film thickness, solubility and dimensional change were determined.

Results All positive controls leaked within 24 h, whereas none of the negative controls leaked after 30 days. Apexit Plus had significant less bacterial leakage (log-rank test, $P < 0.0001$) than AH Plus. AH Plus (0.3% solubility) showed a slightly lower solubility than Apexit Plus (0.5% solubility) but a larger film thickness (28 vs. 11 μm) according to ISO 6876:2001.

Conclusion Apexit Plus had a better sealing ability in comparison with AH Plus.

Keywords: AH Plus, Apexit Plus, bacterial leakage, root canal sealer.

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Introduction

In general, a root filling is composed of two materials: a solid core material and a sealer. The most commonly used core material is Gutta-percha, which can be placed into the root canal in a cold or a warm state. The main purpose of the root canal sealer is to fill the interface between the core material and the dentine wall, the voids inside the core material and the accessory canals, to serve as a lubricant and to obtain a hermetic apical seal (Skinner & Himel 1987). Although the most important property of a root canal sealer is its sealing ability, there is no standardized sealing test that is part of the ISO 6876:2001 ('Dental root canal sealing materials'). However, limits of water solubility, film thickness and dimensional change following setting are components of the standard providing an indirect indication of sealing ability.

Dye penetration experiments have been performed for the assessment of the sealing behaviour of endodontic materials. However, the frequent approach of sectioning teeth vertically or horizontally to determine tracer depth is not reproducible, and rarely yields statistically significant differences between materials (Schuurs *et al.* 1993, Wu & Wesselink 1993, Camps & Pashley 2003). A quantitative measurement of penetrated dye should be possible by dissolving roots in nitric acid and spectrophotometric determination of extracted dye (Mandras *et al.* 1993, Camps & Pashley 2003). Unfortunately, methylene blue and other dyes are not stable against nitric and hydrochloric acid (Mandras *et al.* 1993). Hence, dyes are unsuitable for such studies. Further applied test methods include, amongst others (Al-Ghamdi & Wennberg 1994), fluid filtration measurements (Wu *et al.* 1993, Pommel *et al.* 2003) and movement of glucose solution under low hydrostatic pressure (Xu *et al.* 2005).

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Kersten & Moorer (1989) suggested that penetration experiments with particles the size of bacteria may be more relevant than using small molecules. If bacteria are used as a leakage tracer the experiment will be more closely related to the clinical situation (Wolanek *et al.* 2001). For this purpose, different types of bacteria have been used, e.g. *Enterococcus faecalis* (Saleh *et al.* 2008, Fransen *et al.* 2008) as well as *Streptococcus mutans* (Monticelli *et al.* 2007).

Therefore, the main purpose of this laboratory study was to assess the penetration of *S. mutans* through coronally unsealed root canals to compare the effectiveness of AH Plus and Apexit Plus to resist bacterial leakage.

Materials and methods

Tests according to ISO 6876

Sample preparation and measurement of solubility, film thickness and dimensional change following setting were performed in accordance with ISO 6876:2001. Solubility means the amount of material dissolved by water out of a test specimen of 20 mm diameter and 1.5 mm height after 24 h at 37 °C. Film thickness was determined by displacement of mixed sealer under a load of 150 N for 7 min. Dimensional change is the longitudinal change of a test specimen having a diameter of 6 mm and a height of 12 mm after 30 days storage in water at 37 °C. The dimensional change was determined by an independent institute (NIOM; test-report T051/03). Following sealers were used: Apexit Plus (Ivoclar Vivadent AG, Schaan, Liechtenstein) and AH Plus (Dentsply de Trey GmbH, Konstanz, Germany).

Bacterial leakage test

A total of 56 extracted, single-rooted human teeth were divided into two experimental (n = 16) and two control groups (n = 12). To standardize the length of root canals involved in each experimental group, the length of all roots was measured and root segments ranging 11–16 mm were equally distributed to the groups. Each root canal was coronally enlarged with Largo Peeso Reamers (Dentsply Maillefer, Ballaigues, Switzerland)) to size 90 or 110 to obtain standardized round root canal shapes. Hand K-files were also used to finish the enlargement and achieve better adaptation of core materials to the root segments. In both experimental groups the canals were enlarged to the same size.

The root canals were irrigated with 1.25% NaOCl during instrumentation and then sterilized by autoclaving for 20 min at 121 ± 2 °C. The smear layer was removed with 17% EDTA and the canals rinsed with sterile water.

The canals were filled with Gutta-percha and sealer (except positive control) using cold lateral condensation technique as follows: a size 50 master Gutta-percha cone (Kerr, Orange, CA, USA) was coated with the sealer and placed into the root canal to working length. A size 30 finger spreader (Dentsply Maillefer) was then inserted into the canal to a level about 1 mm short of working length. Lateral condensation with fine accessory Gutta-percha cones (Kerr) was performed.

Group 1

Cold lateral condensation of Gutta-percha with AH Plus (Dentsply) according to the instructions for use.

Group 2

Cold lateral condensation of Gutta-percha with Apexit Plus (Ivoclar Vivadent) according to the instructions for use.

Positive control

Cold lateral condensation of Gutta-percha without sealer.

Negative control

Cold lateral condensation of Gutta-percha with AH Plus, sticky wax was applied to completely cover the root and coronal orifice of canal.

All root canal treatment and filling procedures were completed by one endodontist at the Scandinavian Institute of Dental Materials (NIOM; test-report T074/04). Teeth were then placed in an incubator at 37 °C for 14 days to allow the sealer to set.

The microbial leakage test was performed in a two-chamber set-up as described by Shipper *et al.* (2004). The upper chamber consisted of a 15-mL polycarbonate centrifuge tube (Corning Inc, Corning, NY, USA) with a small hole prepared at the bottom to receive the root-end (see Fig. 1). The tooth was inserted into the tube and gently pushed through the opening until approximately one-half of it protruded through the tube. The space between the tube and the tooth was then sealed with sticky wax (Kerr Cooperation). The tube was introduced into and sealed to the neck of a flat-bottomed scintillation vial. The tip of the root was mounted to reach approximately 3 mm into the sterile TSB (Trypticase Soy Broth) with streptomycin in the

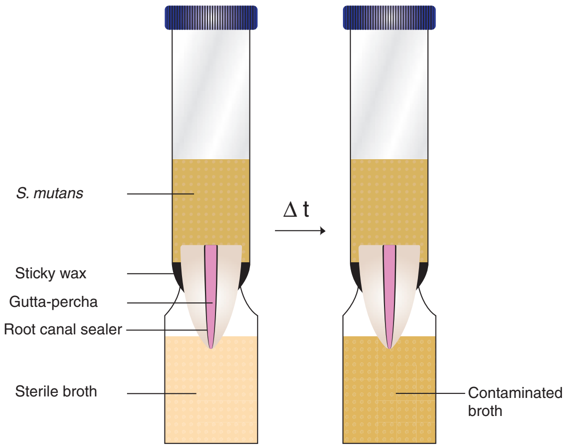

Figure 1 Experimental setup of the bacterial leakage model used: A culture of *Streptococcus mutans* was placed in the upper chamber of the setup and sterile broth in the lower chamber. Growth of bacteria in the lower chamber as indicator of leakage was observed visually by appearance of turbidity.

lower chamber. The upper chamber was filled with medium without bacteria on day −1, and checked for leakage until day 0. *Streptococcus mutans* (VA 159) was added to the upper chamber and the time for *S. mutans* to eventually penetrate into the lower chamber was noted. Bacteria penetrating along the root filling were detected by turbidity observed in the lower chamber. Maximum observation time was 30 days. Bacterial growth in teeth with turbidity was checked by seeding the liquid on agar plates, followed by incubation and microscopy.

Statistical analysis

The Kaplan–Meier method was used to estimate the survival curves. Specimens that did not leak until the end of the observation time were computed with an event time of 30 days as censored variables. The non-parametric log-rank test was used to compare the survival curves using a significance level of 0.05. The results at the end of the observation time (30 days) was further analysed by chi-square testing.

Results

Results of measurements of solubility, film thickness and dimensional change following setting are summarized in Table 1. AH Plus had a slightly lower solubility (0.3% solubility) than Apexit Plus (0.5% solubility). The film thickness of AH Plus was higher (28 μm) than Apexit Plus (11 μm).

In the bacterial leakage test, all positive controls leaked within 24 h and no penetration of bacteria was observed in the negative controls during the observation time of 30 days. The Kaplan–Meier survival probabilities for the experimental groups are shown in Fig. 2. Significant differences were observed amongst the experimental groups ($P < 0.0001$, log-rank test) and also at the end of the observation time after 30 day a significant difference was observed ($P < 0.0005$, chi-squared test). The mean time for the bacteria to penetrate the root canal in the AH Plus group was 5.3 days (CI: 3.7–7.0 days). For the Apexit Plus group, the mean penetration time was not calculated because at the end of the observation time more than 63% (10 of 16) of the specimens had not allowed passage of bacteria.

Discussion

To ensure a permanent seal of the root canal and prevent the penetration of bacteria into the apical periodontium, the root canal sealer must be insoluble. A low solubility of endodontic sealers is a requirement of the ISO 6876 standard. To comply with this standard, the solubility of the sealer after 24-h immersion in water must not exceed 3% (w/w). For Apexit Plus and AH Plus, low solubility values were observed (0.5% solubility and 0.3% solubility respectively). These values are comparable with AH 26 (Dentsply DeTrey, 0.4%) (Schafer & Zandbiglari 2003) and RoekoSeal (Coltène/Whaledent, 0.5%) (Schafer & Zandbiglari 2003). According to the literature, Ketac Endo (3 M Espe AG, 6.1%) (Schafer & Zandbiglari 2003), Epiphany (Pentron, 3.4%) (Versiani *et al.* 2006) and both Sybron Endo sealers Sealapex (4.2%) (Schafer & Zandbiglari 2003) and Pulp Canal Sealer (3.6%)

Table 1 Solubility after 24 h, film thickness and dimensional change following setting of Apexit Plus and AH Plus according to ISO 6876:2001

	ISO 6876 limits	AH Plus	Apexit Plus
Solubility/%	≤3.0	0.3	0.5
Film thickness/μm	≤50	28	11
Dimensional change following setting[a]/%	≤0.1 (expansion) ≤1 (shrinkage)	0.2 (expansion)	0.4 (expansion)

[a]NIOM; test-report T051/03.

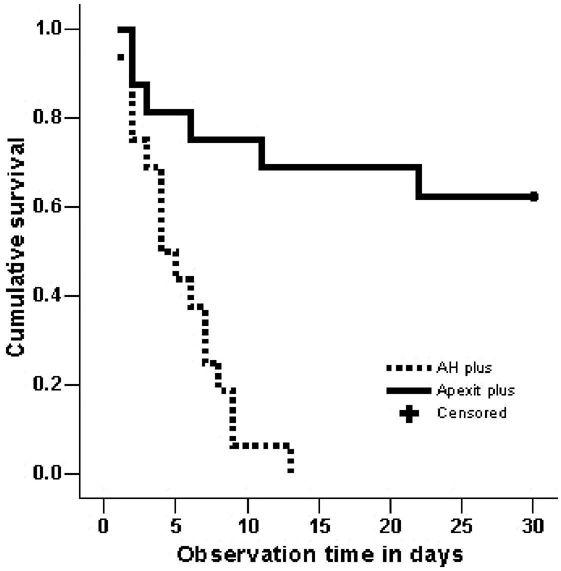

Figure 2 Kaplan–Meier survival curves of the sealed root canals for the two different sealers in the bacterial leakage test (NIOM; test-report T074/04).

(Ørstavik 1983) fail to fulfil the requirements of ISO 6876. The high solubility of Epiphany may explain why the apical sealing ability of Resilon/Epiphany is reduced after 16 months of water storage (Paqué & Sirtes 2007). A matter of particular interest is the significant difference in solubility between Apexit Plus and Sealapex, because both materials are calcium salicylate based sealers. This may indicate that the setting reaction of Apexit Plus is more consistent than that of Sealapex.

The film thickness describes the ability of the material to adapt to the geometry of the canal wall. The lower the film thickness, the better is the adaptation of the material. ISO 6876 requires a maximum of 50 μm. The film thickness of Apexit Plus was 11 μm and of AH Plus 28 μm. AH 26 (36 μm) and Sealapex (36 μm) exhibit a higher film thickness; however, they do fulfil the ISO requisite (Oguntebi & Shen 1992).

Dimensional change following setting may lead to gap and channel formation along the interface between sealer and dentine or Gutta-percha. These gaps and channels may be large enough for microorganisms to pass (Ørstavik *et al.* 2001). Therefore, the ISO requirement of linear shrinkage was set to not more than 1%. An expansion after setting has a two-edged effect: On the one hand, a slight expansion favours a better seal. On the other hand, expansion of root canal sealers increases the risk of root fracture caused by radial pressure on the pulpal aspect of dentine. This risk is highly material dependent, the higher the bulk modulus of the sealer the higher the pressure. The limit within ISO 6876 is expansion of 0.1%. Therefore, neither Apexit Plus nor AH Plus complied with this requirement. However, because of its low bulk modulus, at least for Apexit Plus a risk of root fracture caused by expansion can be neglected. Ørstavik *et al.* (2001) observed for RoekoSeal a slight (0.2%) and for AH 26 a distinct expansion (4%), whilst both Pulp Canal Sealer and Ketac Endo shrank around 1%. For Sealapex, determination of dimensional change was not possible because the test specimens expanded and disintegrated during the experiment. Versiani *et al.* (2006) reported a pronounced expansion of 8% for the resin-based sealer Epiphany.

All three tested parameters imply a good sealing ability of Apexit Plus. However, these parameters are only indirect indicators for sealing performance. Therefore, a laboratory bacterial leakage test was conducted.

For the bacterial leakage model, *S. mutans* was used as bacterial marker. It is a nonmotile facultative aerobic bacteria that often is found in endodontic infections (Baumgartner & Falkler 1991). It penetrates easily along root fillings (Saleh *et al.* 2008) and is easy to handle in the laboratory setting (Weinberger & Wright 1989). The number of bacteria penetrating through the root canal filling was not determined because the purpose of the experiment was only to test if the root filling can prevent penetration of bacteria into the lower chamber.

The comparator product AH Plus had a mean leakage time of 5.3 days. This result is consistent with the findings in other studies investigating coronal bacterial leakage in teeth obturated employing cold lateral condensation techniques (Yucel *et al.* 2006, Eldeniz & Ørstavik 2007). However, in studies with alternative microbial markers, different mean break-through-times were observed (Timpawat *et al.* 2001, Miletic *et al.* 2002, De-Deus *et al.* 2006). For Apexit Plus, more than 50% of the specimens did not leak at the end of the experiment. One explanation for the observed difference between the two products could be the more optimal film thickness of Apexit Plus. Another explanation could be that Apexit Plus exhibits some antimicrobial activity. Calcium hydroxide-based root canal sealers are often suspected to have a high pH value that kills the bacteria (Heling & Chandler 1996, Fuss *et al.* 1997). At least for Apexit Plus, this is a misunderstanding, as during the setting reaction the calcium hydroxide forms a stable complex with the salicylat derivative resulting in a product with a pH<8. To insure complete setting of the sealer, the bacterial penetration experiment commenced after a pre-incubation period of 14 days. At this time-point no antimicrobial activity could be detected for Apexit Plus (Slutzky-Goldberg *et al.* 2008). This is in agreement with the results for Apexit, were no antibacterial activity was detected (Evcil & Colak 2004, Kayaoglu *et al.* 2005, Eldeniz *et al.* 2006).

Conclusion

The better sealing ability of Apexit Plus compared with AH Plus may be explained by the physical-chemical properties and not by a potential antimicrobial effect of the material.

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