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► To cite this version:

L Pommel, I About, D Pashley, J Camps. Apical Leakage of Four Endodontic Sealers. Journal of Endodontics, 2003, 29 (3), pp.208-210. 10.1097/00004770-200303000-00011 . hal-03552525

HAL Id: hal-03552525

<https://hal.science/hal-03552525>

Submitted on 2 Feb 2022

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Apical Leakage of Four Endodontic Sealers

Ludovic Pommel, Imad About, David Pashley, and Jean Camps

The purpose of this study was to evaluate the sealing properties of four root canal sealers. Forty-eight maxillary central incisors were instrumented with Profile rotary instruments. They were randomly divided into four groups ($n = 12$) and filled using lateral condensation with one of the four sealers: Sealapex, Pulp Canal Sealer, AH 26, and Ketac-Endo. The apical leakage was measured with a fluid filtration method and expressed as $\text{L s}^{-1} \text{KPa}^{-1}$. The teeth filled with Sealapex displayed a higher apical leakage ($8.42 \pm 4.2 \cdot 10^{-11} \text{ L s}^{-1} \text{KPa}^{-1}$) than those filled with AH 26 ($2.10 \pm 1.39 \cdot 10^{-11} \text{ L s}^{-1} \text{KPa}^{-1}$), Pulp Canal Sealer ($0.17 \pm 0.09 \cdot 10^{-11} \text{ L s}^{-1} \text{KPa}^{-1}$) or Ketac-Endo ($0.32 \pm 0.24 \cdot 10^{-11} \text{ L s}^{-1} \text{KPa}^{-1}$) ($p < 0.01$). No statistically significant difference was found among AH 26, Pulp Canal Sealer, and Ketac-Endo. No correlation was found between the sealing efficiency of the four sealers and their adhesive properties recorded in a previous study.

Along with a proper root canal preparation and disinfection, an effective apical sealing guarantees a long-term successful endodontic treatment. A sealer associated with gutta-percha is generally used to achieve an impervious apical sealing. The sealer serves as a lubricant when inserting the gutta-percha point, as a filling material to fill the irregularities of the preparation, and is necessary because gutta-percha does not bond spontaneously to the dentinal walls of the prepared canal (1).

Four types of sealer have been introduced onto the market. The zinc oxide-based sealers (e.g. Pulp Canal Sealer) are by far the most popular and have been used extensively for many decades (2). The resin-based sealers (e.g. AH 26) have also been used for many years despite the insolubility of the set material, making retreatment very difficult (3). The calcium hydroxide-based sealers (e.g. Sealapex) were more recently introduced and aim to induce hard tissue formation at the apex to obtain a natural closure of the endodontic space (4). The glass ionomer-based sealer (e.g. Ketac-Endo), the most recently introduced material, has been proposed as an endodontic sealer because of the natural bonding of the glass ionomer cements to radicular dentin (5).

Adhesion of these four types of sealers to gutta-percha and to dentin has already been reported (6). These materials bonded

differently to gutta-percha and to dentin. For example the adhesion of the zinc oxide-based sealer to gutta-percha was 10 times as high as to dentin. In contrast, the glass ionomer sealer bonded four times more firmly to dentin than to gutta-percha.

Strong adhesion of the sealer to both dentin and gutta-percha may prevent dislodgement of the apical filling when preparing a post, especially in short roots where only few millimeters can be left to increase post length and therefore post retention (7). Adhesion of the sealers to both gutta-percha and to dentin may also improve the sealing properties of the endodontic sealers, even if the correlation between dentin bond strength and microleakage is questioned (8).

Therefore, the purpose of this study was to evaluate, by the fluid filtration method, the efficiency of the four types of sealer at obtaining an impervious apical sealing and to correlate those seals with their adhesive properties. The null hypothesis was that there is no correlation between apical sealing and the adhesive properties of endodontic sealers.

MATERIALS AND METHODS

Root Canal Preparation and Fillings

Forty-eight maxillary central incisors were used for this study. After extraction, the teeth were stored in 0.5% chloramine at 4°C. The crowns were removed at the CEJ with a diamond disk under water coolant. A #10 K file was introduced into the canal to radiographically measure the working length and to verify the apical patency. The root canals were prepared by the same endodontist at the cementodentinal junction with the Profile system (Maillefer, Ballaigues, Switzerland) by using a reduction hand-piece powered by an electric motor following the sequence: Profile.taper 06 #30, #25, and #20, Profile.taper 04 #25 and #20, Profile.taper 06 #20, #25, and #30. A #10 K file was used between each Profile series to verify apical patency. The canals were irrigated with 2.5% NaOCl delivered with a 27-gauge needle, using 2 ml between each file size. The 48 teeth were filled using the lateral condensation technique with one of the four (Table 1) following cements ($n = 12$ per group): Pulp Canal Sealer (Kerr, Romulus, MI), Sealapex (Kerr), AH 26 (DeTrey, Zurich, Switzerland), Ketac-Endo (ESPE, Seefeld, Germany). The cements were prepared according to the instructions of the manufacturer. The canal walls were coated with a paper point dipped into the cement; the apical 2-mm of the gutta-percha cone were also coated with the sealer.

TABLE 1. Endodontic sealers tested

	Weight %
Kerr root canal sealer	
Powder	
Zinc oxide	42
Staybelite resin	27
Bismuth subcarbonate	15
Bismuth sulfate	15
Liquid	
Eugenol	100
Sealapex	
Mixed sealer (polymethylsalicylate)	
Isobutyl salicylate	42.0
Calcium hydroxide	25.0
Barium sulfate	18.6
Zinc oxide	6.5
Titanium dioxide	5.1
Zinc stearate	1.0
AH 26	
Powder	
Bismuth oxide	60
Hexamethylenetetramine	25
Silver powder	10
Titanium oxide	5
Liquid	
Epoxybisphenol-resin	100
Ketac-Endo Aplicaps	
Powder	
Glass fillers	100
Liquid	
Polyalkenoic acid plus modifiers	100

Measurement of Apical Leakage

After filling, the roots were stored for 24 h at 37°C and 100% humidity to allow setting of the sealer. Apical leakage was then evaluated with a fluid filtration method. Briefly, the roots were inserted into a length of soft silicone tubing, 3 mm in internal diameter, and attached with cyanoacrylate cement on the outer surface of the tube. The silicone tube was connected to a thick-walled horizontal capillary, with an internal diameter of 0.7 mm, filled with PBS + penicillin-streptomycin + fungicide. This tube contained a small air bubble and was under a hydrostatic pressure of 15-cm H₂O. This static pressure was created by maintaining a vial, open to the atmosphere, filled with the same liquid, 15-cm above the horizontal tiny tube. Fluid movement was calculated from the bubble movement, which was followed automatically by an infrared light shining through the edge of the bubble to a light-sensitive photodiode. While the bubble moved, due to water displacement along the filling material, the diode energized a step-motor to permit it to always follow the bubble. The step-motor also changed a linear resistance, which provided input to a computer. The displacement of the air bubble could be measured with a linear accuracy 5 μ m, i.e. the smallest measurable volume was 1.9 10^{-9} L. The roots were stored in water during the measurement to prevent water evaporation across dentin caused by uncontrolled dentin dryness. To serve as a negative control, a test was performed with two additional roots, in which the apex was covered with two layers of nail varnish, to ensure that there was no leak or fluid movement anywhere within the device. For each of the 48 teeth the volume of fluid movement was recorded after 24 h of filtration and the results were expressed as L s⁻¹ KPa⁻¹.

TABLE 2. Summary of bond strengths of sealers to dentin and gutta-percha (6)

Material	Dentin (MPa)	Gutta-percha (MPa)
Sealapex	0.24 $\pm$ 0.08	0.22 $\pm$ 0.02
AH 26	2.06 $\pm$ 0.53	2.93 $\pm$ 0.29
Pulp canal sealer	0.07 $\pm$ 0.02	0.99 $\pm$ 0.19
Ketac-Endo	0.74 $\pm$ 0.24	0.14 $\pm$ 0.01

Statistical Analysis

A one-way analysis of variance was used to seek statistically significant differences in apical leakage among the sealer groups. Multiple comparisons were performed using Schilte's test to isolate and compare statistically significant differences.

RESULTS

The analysis of variance showed a statistically significant difference among the apical leakage of the four sealers ($p < 0.001$) demonstrating the influence of the type of sealer on the tightness of the apical filling. The multiple comparison test showed that the teeth filled with Sealapex displayed a higher apical leakage ($8.42 \pm 4.2 \cdot 10^{-11}$ L s⁻¹ KPa⁻¹) than those filled with AH 26 ($2.10 \pm 1.39 \cdot 10^{-11}$ L s⁻¹ KPa⁻¹), Pulp Canal Sealer ($0.17 \pm 0.09 \cdot 10^{-11}$ L s⁻¹ KPa⁻¹), or Ketac-Endo ($0.32 \pm 0.24 \cdot 10^{-11}$ L s⁻¹ KPa⁻¹). No statistically significant difference was found among AH 26, Pulp Canal Sealer, and Ketac-Endo.

DISCUSSION

The comparison of the efficacy of the four types of sealer at preventing apical fluid movement recorded in this study can only be compared to those of other studies with difficulty. For example Özata et al. (9) showed that AH 26 provided a better apical seal than Ketac-Endo, but Dalat and Önal (10) found no difference between the two materials. Such discrepancies probably are due to differences in methodology and sample size. For instance, the apical leakage tested by three different methods, on the same teeth, showed a strong influence of the testing method on the outcome of the test (11).

However, the relationship between this apical leakage study and our recently published bond strength study of the same sealers is interesting (Table 2). At first sight, there seems to be an inverse correlation between bond strength and apical leakage. For example, Sealapex, which had the lowest values of adhesion in the previous study, showed the highest apical leakage. This confirms previous leakage results evaluated using radioisotope tracers (12). However, Pulp Canal Sealer, which had showed a good adhesion to gutta-percha but the lowest adhesion to dentin in the previous study, provided a good apical seal. One may conclude from this that adhesion to gutta-percha is the key factor and is much more important than adhesion to dentin. However, Ketac-Endo with its poor adhesion to gutta-percha showed good results in this study. In line with this idea, adhesion to dentin cannot be considered to be the key factor because AH 26, ranked first for its adhesion to dentin, is ranked third in terms of apical sealing. Thus, the results support the tested null hypothesis. There is no direct correlation between the bond strength of the endodontic sealers, either to dentin or gutta-percha, and their sealing efficiency. This has al-

ready been shown with dentin bonding agents: bond strength to dentin is not directly correlated to marginal microleakage (8). As for restorative materials, the lack of correlation may be related to the micro- and nanoleakage theories already developed to explain the marginal leakage of teeth restored with adhesive resins. Spaces, 10^{-6} to 10^{-9} m in size, may exist between the cement and dentin permitting the filtration of water despite high bond strength values.

The thickness of the endodontic sealer films ranges from 4 to 180 μ m (13). The shear bond strength study (6) was performed with thick layers of sealer for convenience, whereas only thin layers of sealer are necessary to fill a root canal. Differences in sealer thickness, leading to differences in shrinkage of the sealer during setting may explain the lack of correlation (14). The best adhesive results were obtained with Pulp Canal Sealer and Ketac-Endo, which gave the smallest percentage of cohesive failure during adhesion experimentation. In addition, dye penetration within the sealer has already been reported (15). The solubility of some of the sealer components may also play a role. The setting reaction for zinc oxide-eugenol is a chelation reaction allowing an electrostatic double bond to form between one molecule of zinc and two molecules of eugenol (16). Despite low mechanical properties, the set material has a good cohesion. However, AH 26 contains epoxides entrapped in a resinous matrix. The resinous matrix gives to the cement its good mechanical properties but, unlike the silanized glass particles used in composites, the oxides are likely not treated to adhere to the resinous matrix. One may imagine that the epoxy sealer, under filtration pressure may have lost some of the fillers, allowing water to flow within the created microspaces. Evaluation of the shear bond strength of a gutta-percha disk bonded to dentin with clinically relevant thin films of sealer may have given other results.

The rheological properties of the sealer may also be of prime importance in such experiments (17). During the shear bond strength study the sealer was simply placed in bulk onto the dentin. Under these conditions it may have behaved differently than if it was spread onto dentin by the gutta-percha while filling the root canals. The ability of the sealer to fill the irregularities of the canal, all the root long, obviously played an important role in the filtration study but not in the shear bond strength study. The ability of the endodontic cements to spread under pressure should be compared.

The presence of the smear layer on dentin is known to modify the sealing properties of the endodontic cements. The presence of the smear layer increases the apical leakage of teeth filled with AH 26 but not of teeth filled with a zinc oxide-eugenol based sealer (18). Smear layer also modifies the adhesive properties of the glass ionomer cements. Thus, control of canal moisture and removal of the smear layer may be recommended, especially when using AH 26 to take advantage of its excellent adhesive properties.

Besides physical factors, such as film thickness, rheology, and presence of smear layer, chemical factors should also be considered. The carboxylic-based cements bond chemically to the mineral phase of dentin (19). Thus, among the four tested materials,

only Ketac-Endo chemically bonds to dentin. However, the sensitivity of glass ionomer cements to water during setting may explain their low bond strength relative to the higher bond strength of AH 26 to dentin. Thus, good control of canal moisture is a prerequisite for the use of Ketac-Endo. Future research should test the use of a chelating agent, like EDTA, to clean the canal walls, which may also modify the adhesive and sealing properties of Ketac-Endo (20).

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