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Original

Effect of the smear layer on apical seals produced by two calcium silicate-based endodontic sealers

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Abstract: We compared the apical seals of two new calcium silicate-based sealers (iRoot SP and MTA Fillapex) in the presence and absence of a smear layer. Eighty-two human premolars were prepared and randomly divided into four groups. In groups 1 and 3, the smear layer was retained. In groups 2 and 4, the root canals were irrigated with EDTA to remove the smear layer. Canals were filled using gutta-percha/iRoot SP (in groups 1 and 2) or obturated with gutta-percha/MTA Fillapex (in groups 3 and 4). Fluid filtration was used to evaluate apical microleakage. The presence of the smear layer had no significant effect on the sealing properties of the filling materials, except for iRoot SP at 2 weeks ($P = 0.007$). There was significantly less microleakage with iRoot SP than with MTA Fillapex ($P = 0.025$ at 2 weeks; $P < 0.001$ at 3 months). Leakage decreased significantly over time in all specimens, except in group 2 ($P = 0.473$). In conclusion, removal of the smear layer had no adverse effect on the sealing properties of calcium silicate-based sealers. In addition, the sealing ability of iRoot SP was superior to that of MTA Fillapex.
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Introduction

The main objective of root canal obturation is to attain and maintain a hermetic seal in the entire root canal space (1). Gutta-percha is typically used with a root canal sealer to obtain a fluid-tight seal. Root canal sealers fill the voids between gutta-percha points and between gutta-percha and root canal walls (2).

Incomplete obturation of the root canal is a common reason for clinical failure of endodontic therapy (3). Microleakage along the root canal obturation may occur between gutta-percha and sealer, through voids within the sealer, or between the sealer and dentin (4). Therefore, the seal quality of a root canal filling and the success rate of endodontic treatment depend greatly on the sealing ability of a root canal sealer (5).

A variety of sealers are available for use. Sealants based on calcium silicate have been introduced for obturation of endodontically treated teeth. iRoot SP (Innovative BioCeramix, Vancouver, Canada) is a premixed, ready-to-use, injectable white cement paste that is described by its manufacturer as an insoluble, radiopaque, aluminum-free material composed of calcium, calcium phosphate, calcium hydroxide, and zirconium oxide similar to that of white mineral trioxide aggregate (MTA). iRoot SP exhibits cytocompatibility and antibacterial activity (6,7), with satisfactory sealing ability (6) and bonding to

Table 1 Chemical composition of endodontic sealers used in this study

Material (Manufacturer)	Chemical composition
MTA Fillapex (Angelus, Soluções Odontológicas, Londrina, Brazil)	Paste A: salicylate resin, bismuth trioxide, fumed silica
	Paste B: fumed silica, titanium dioxide, mineral trioxide, aggregate (40%), base resin
iRoot SP (Innovative BioCeramix, Vancouver, Canada)	zirconium oxide, calcium silicates, calcium phosphate monobasic, calcium hydroxide, filler, thickening agents

root canal dentin (8).

Another calcium silicate-based sealer, MTA Fillapex (Angelus, Soluções Odontológicas, Londrina, Brazil), contains salicylate resin, diluting resins, natural resin, silica nanoparticles, bismuth trioxide, and MTA. MTA Fillapex is also biocompatible (9) and has antibacterial activity (10). However, the sealing ability of MTA Fillapex is variable (11,12).

There has been much interest in the possible effects of the smear layer, which is formed during root canal preparation, on leakage of obturated root canals. Numerous leakage studies have evaluated apical and coronal leakage in the presence or absence of the smear layer; however, there is no consensus among researchers as to whether the smear layer is associated with more leakage in obturated canals (13-15). Smear layer removal resulted in mechanical interlocking of sealer plugs inside tubules (16), which might improve the sealing ability of the material (17). However, bond strength between some sealers and dentin was reported to be better when the smear layer was left intact (18). In addition, previous studies (19,20) found that removal of the smear layer can compromise the sealing properties of MTA. To our knowledge, there is no information on the effect of smear layer removal on the apical microleakage of silicate-based endodontic sealers. Therefore, we evaluated microleakage of iRoot SP and MTA Fillapex sealers in the presence and absence of the smear layer.

Materials and Methods

We selected 82 extracted single-rooted human premolar teeth with closed apices for this study. All teeth had normal root development, with relatively straight roots and no cracks or resorptive defects. The research protocol was approved by the Vice Chancellor for Research at Mashhad University of Medical Sciences (#910211, 2011). The teeth were cleaned of debris, soaked for 10 min in a 5.25% NaOCl solution, and then rinsed and stored in saline solution until use in this study.

The teeth were decoronated to a standard length of 15 mm, using a water-cooled diamond disc. The working length was established as 1 mm short of the apex. A crown-down root canal preparation was performed using Gates-Glidden drills #5, #4, #3, and #2 (Dentsply, Maillefer, Ballaigues, Switzerland) in the coronal and middle thirds of the root canals. This was followed by step-back instrumentation of the apical third to a master apical file #35. The root canals were irrigated with 5 mL of 5.25% NaOCl during instrumentation. Then, the specimens were randomly divided into 4 groups (n = 20 each). In group 1 no attempt was made to remove the smear layer. After completion of instrumentation, the canals were irrigated with 10 mL of distilled water and dried with paper points (Ariadent, Tehran, Iran). The canals were obturated with lateral compaction of gutta-percha in combination with iRoot SP sealer, according to the manufacturer's instructions. In group 2 the root canals were irrigated with 3 mL of 17% EDTA for 5 min to remove the smear layer. A final flush with 10 mL of distilled water was then used to wash out EDTA and NaOCl, after which the root canals were dried with paper points and obturated with gutta-percha/iRoot SP sealer, as in group 1. In group 3 the smear layer was left intact and the canals were obturated with gutta-percha and MTA Fillapex sealer, according to the manufacturer's instructions. In group 4 the smear layer was removed, as in group 2, and the canals were obturated in the same way as in group 3.

To evaluate the fluid filtration system, two teeth were used as positive and negative controls. In the positive control, the root canal was not filled; in the negative control, the root canal was filled in a manner similar to that in the experimental groups. Table 1 shows the names, composition, and manufacturers of the endodontic sealers used in this study.

All specimens were stored at 37°C and 100% humidity until microleakage evaluation. Two layers of nail varnish (Arcancil, Paris, France) were applied to the external root surfaces of the specimens in the experimental and the positive control groups, except for a 2.0-mm area

Table 2 Mean apical microleakage (μL/min/cm H_2O) of experimental sealers at 2 weeks and 3 months after obturation

		2 weeks		3 months		
Groups	Sample size	Mean	SD	Mean	SD	*P* value
1	20	0.00320	0.00277	0.00086	0.00066	0.042
2	20	0.00115	0.00160	0.00084	0.00104	0.473
P value		0.007		0.927		
3	20	0.00343	0.00175	0.00256	0.00204	0.001
4	20	0.00396	0.00468	0.00209	0.00192	0.038
P value		0.962		0.639		

around the apical foramen. All specimen surfaces in the negative control group were completely covered. The first fluid transport measurement was made after 2 weeks and repeated after 3 months.

Leakage was evaluated by a fluid filtration technique, according to the procedure used by Moradi et al. (21). The roots were connected to the fluid filtration system. Water movement through obturated canals was measured under a pressure of 3 psi (0.2 atm) by monitoring the movement of an in-line bubble at 2-min intervals for 8 min. All procedures were performed by the same operator.

Data were analyzed using SPSS 11 with two-way ANOVA and the paired-sample *t*-test. The significance level was set as $P < 0.05$.

Results

Quantitative leakage values for all experimental groups at 2 weeks and 3 months are shown in Table 2.

ANOVA showed no significant difference between the smear-positive and -negative groups for root canals obturated with MTA Fillapex ($P = 0.962$ at 2 weeks; $P = 0.639$ at 3 months). For root canals filled with iRoot SP, leakage was greater in the smear-positive group than in the smear-negative group after 2 weeks ($P = 0.007$). However, after 3 months, microleakage did not significantly differ between groups ($P = 0.927$).

Regarding sealer type, there was significantly less microleakage for iRoot SP than for MTA Fillapex, regardless of the presence of the smear layer or time since obturation ($P = 0.025$ at 2 weeks; $P < 0.001$ at 3 months).

Leakage decreased over time in all specimens ($P < 0.05$); however, the decrease was not significant in group 2 ($P = 0.473$).

Discussion

Many variables can influence leakage, including root obturation techniques, the properties of endodontic sealers, and the presence of a smear layer. Therefore, when evaluating a new sealer, its sealing ability must be examined under different conditions. The smear layer modifies the sealing properties of root canal sealers (22). The composition of the iRoot SP and MTA Fillapex sealers is similar to that of MTA (6). Some previous studies found that removal of the smear layer increased microleakage in root-end cavities and root canals filled with MTA (19,20). However, in the present study, smear layer removal had no adverse effects on the sealing properties of iRoot SP or MTA Fillapex. Yildirim et al. (20) reported that the hydrophilic properties of MTA and its particle size (which is not suitable for full penetration of dentinal tubules) might decrease leakage in smeared groups. However, iRoot SP and MTA Fillapex, which have a small particle size, have favorable viscosity and can flow readily into dentinal tubules (23). Shokouhinejad et al. (24) reported that the presence of a smear layer had no effect on bond strength between Endosequence BC sealer (which has the same composition as iRoot SP) and root dentin.

In this study, 5.25% NaOCl and 17% EDTA were used to remove the smear layer. Alternating use of NaOCl and EDTA is the method of choice for smear layer removal (25).

In the present study, leakage was measured with fluid filtration, which is recommended because it yields reproducible quantitative results, thereby enhancing reliability. This method is nondestructive and can be used in longitudinal studies (26,27).

This pioneering study compared the sealing ability of iRoot SP and MTA Fillapex and evaluated the effect of smear layer removal on their sealing properties. It was therefore difficult to compare our results with those of previous studies. The adhesion of sealers to radicular dentin seems necessary for maintaining the integrity of the sealer-dentin interface and preventing microleakage. Sagsen et al. (28) assessed the push-out bond strength of MTA Fillapex and iRoot SP sealer and found no significant differences between iRoot SP and AH-plus (an epoxy resin-based root canal sealer regarded as the

gold standard in endodontics); MTA Fillapex had the lowest push-out bond values. These results are consistent with those reported by Nagas et al. (29). The resin components of MTA Fillapex might adversely affect its bonding to dentin and sealing properties (30). Using scanning electron microscopy, Barges et al. (31) found that exposing MTA Fillapex specimens to deionized water results in porosities and cracks in the resin matrix. Energy-dispersive spectroscopy confirmed this polymer degradation and a decrease in the carbon element.

iRoot SP hardens in the presence of water and does not shrink during setting (6). The manufacturer claims that iRoot SP has both hydrophilicity and adhesiveness and chemically bonds to root canal walls (8). Thus, microleakage might be less for iRoot SP than for MTA Fillapex.

Previous studies found that leakage of obturated canals may increase or decrease with time (21,32,33). In the present study, the sealing ability of iRoot SP and MTA Fillapex was lower after 3 months. Gandolfi and Prati (34) and Camilleri et al. (35) also evaluated the sealing properties of MTA root canal sealers and reported that the sealing abilities of these sealers decreased with time. The hydrophilicity and setting expansion of calcium silicate-based sealers might responsible for long-term sealing ability.

The findings of this *in vitro* study indicate that the sealing ability of iRoot SP was better than that of MTA Fillapex. The presence of a smear layer did not affect microleakage of calcium silicate-based sealers, and the sealing ability of these sealers was stable over time. However, additional studies are needed in order to confirm these results.

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