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SEM Study of Thermafil Obturation Technique with 5 Endodontic Sealers

SUMMARY

Aim: *To measure layer thickness of 5 endodontic sealers and evaluate sealer distribution and adaptation of thermafil and sealer within root canals.*

Material and Methods: *20 single-rooted teeth divided into 5 groups were prepared in the crown-down technique. Smear layer was removed and root canals were obturated with Thermafil and 1 of 5 different endodontic sealers: AH Plus, Tubliseal, Acroseal, Apexit and Sealapex. Roots were cross-sectioned in 3 levels resulting in 4 sections for scanning electron microscopy (SEM).*

Results: *Acroseal exhibited the greatest mean layer thickness, followed by AH Plus, while Tubliseal showed the thinnest mean layer. Sealers were unevenly distributed with incomplete layer along root canal perimeter. No sealer formed a continuous layer between the dentinal wall and gutta-percha. Gaps of up to 10 μm were observed between core plastic carrier and gutta-percha. Microscopically visible voids were present in different levels of root canals, usually between dentinal wall and sealer/gutta-percha.*

Conclusions: *The layer thickness in decreasing order were: Acroseal > AH Plus > Sealapex > Apexit > Tubliseal. Microgaps between dentinal wall and the obturating material and gutta-percha / carrier could contribute to inadequate adhesion within the root canal and increased microleakage of Thermafil compared to other obturation techniques.*

Keywords: Endodontic Sealers; Marginal Adaptation; Thermafil

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Introduction

In an attempt to achieve hermetical 3-dimensional seal of canal orifices, dentinal tubules and portals of exit, many materials and obturation techniques have been developed. The contemporary standard of care should consist of minimal amounts of root canal sealer with core obturating material used to gain an adequate seal. The idea is to fill the irregularities of dentinal walls for a hermetical seal and to minimize the contraction of sealers during setting. A core obturating material can either be gutta-percha alone or combined with a carrier, as in the Thermafil obturation technique.

The essence of Thermafil technique is to insert thermoplastized gutta-percha and push it along the root canal with a rigid core carrier in order to enhance adherence and fill all portals of exit. Many studies have been carried out to compare Thermafil with other obturation techniques[1-3,11,14,15]. The most commonly used evaluation method is the dye penetration test. Most studies have suggested that Thermafil obturation technique does not achieve a seal as good as lateral condensation technique since it exhibits significantly greater scores of dye penetration[2,3,14]. However, some authors have found that Thermafil demonstrates a comparable seal to lateral condensation as long as a sealer is used[15]. Only a few scanning electron microscopy (SEM) studies have investigated the adaptation of different sealers[16] or Thermafil components[7]. Film thickness of different sealers was investigated *in vitro* by Lacey et al[12] and McMichen et al[13] using a 2-plates method. Microscopic studies by Da Silva et al[1] and Weis et al[17] have investigated the thickness of AH 26 and AH Plus with various obturation techniques.

The **aim** of the present study was to measure the thickness of 5 endodontic sealers: AH Plus (resin based), Tubliseal (zinc oxide eugenol based), Apexit, Sealapex and Acroseal (calcium hydroxide based) with Thermafil obturation technique and to analyze distribution and adaptation of sealers and Thermafil components within root canals.

Materials and Methods

20 freshly extracted single-rooted teeth were randomly divided into 5 groups. All teeth were cleaned from debris immediately after extraction, and kept in 0.2% thymol solution until the beginning of the experiment. After rinsing under tap water, crowns and roots were separated with a diamond cylindrical bur in a high-speed handpiece under constant water cooling.

All canals were prepared using the crown-down technique and rotary Protaper files of 0.06 taper (Dentsply-Maillefer, Ballaigues, Switzerland) in a torque control handpiece (Dentsply-Maillefer, Ballaigues, Switzerland). After initial canal negotiating with #10 and #15 hand files up to ⅔ of the canal, canals were prepared with S1, S2 and Sx Protaper files in a brushing motion and with copious irrigation with 3% sodium hypochlorite (Parcan®, Septodont, Saint-Maur Cedex, France). Working length was determined by placing a #15 file up to the anatomical foramen and reducing this length for 0.5 mm. All canals were prepared to working length using S1, S2, F1 Protaper files and finished with a F2 Protaper file. The canals were rinsed with 17% EDTA in order to remove the smear layer and finally with 3% sodium hypochlorite.

Roots were embedded in small plastic moulds filled with slightly wet pieces of sponge prior to obturation and fixed with wax. Paper points (#25 and 0.06 taper) were used to dry the canals. Each group of 4 teeth was obturated with Thermafil® (Dentsply-Maillefer, Ballaigues, Switzerland) and the following sealers: Group 1 - AH Plus (Dentsply DeTrey GmbH, Konstanz, Germany), Group 2 - Tubliseal (Kerr Corp, Orange CA, USA), Group 3 - Acroseal (Septodont, Saint-Maur Cedex, France), Group 4 - Apexit (Ivoclar Vivadent AG, Schaan, Liechtenstein), and Group 5 - Sealapex (Kerr Corp., Orange CA, USA). Each sealer was mixed according to the manufacturer's instructions and inserted into the canal with a #30 lentulo spiral. The amount of sealer enough to cover the spirals of the lentulo spiral was taken and inserted into the canal to ½ of the working length only once for each canal. A #30 Thermafil® was used for obturating each canal according to the manufacturers' instructions. After heating in the ThermaPrep® oven, a Thermafil obturator was inserted into the canal to working length, applying a gentle pressure apically. All canals were obturated by one operator. Radiographs were taken in mesio-distal and bucco-oral directions to verify the quality of obturation. After removing the excess plastic carrier and guttapercha, coronal parts of the canals were sealed with FujiIX glass ionomer cement (GC Corp, Tokyo, Japan) and roots were kept in saline at 37ºC for 5 days prior to proceeding to SEM.

Roots were sectioned transversely with a diamond saw and under constant water cooling into 4 sections each: at 2 mm below cemento-enamel junction (coronal section); 2 mm above the root apex (apical section); and in the middle of the remaining part of the root (middle I and middle II section, labeled from coronally). All sections were labeled. Sections were mounted on aluminium stubs, vacuum-dried, coated with 8 nm of gold and then examined under SEM (JEOL JSM-6460LV, JEOL Ltd, Tokyo, Japan). All sections were analyzed under x100, x500, x1000 and x2000 magnification. Samples were analyzed in respect to sealer thickness and sealer and gutta-percha adaptation.

Results were statistically analyzed using Kruskal-Wallis Test (nonparametric ANOVA) with Dunn's Multiple Comparisons post-test (GraphPad Instat v. 3.00, GraphPad Software Inc, San Diego CA, USA).

Results

Control X-rays revealed the extrusion of gutta-percha and sealer in 12 out of 20 teeth (60%). Neither gutta-percha nor the sealer was overfilled in the Acroseal group. Besides, 2 specimens from the Tubliseal and 2 from the Sealapex group did not exhibit overfilling. SEM revealed different layer thickness for different sealers. Mean sealer thickness and standard deviations (SD) for each group of sealers are presented in table 1.

Table 1. Mean layer thickness with standard deviation (SD) for each sealer

Sealer	Number of sections (N)	Number of measured points (n)	Mean ± SD (μm)
AH Plus	16	46	21.6 ± 10.6
Tubliseal	16	38	10.9 ± 7.3
Acroseal	16	42	33.4 ± 16.8
Apexit	16	36	11.5 ± 8.2
Sealapex	16	36	12.6 ± 6.0

Number of measuring points varied for different sealers as various amounts of sealers were present in SEM figures. Acroseal formed the thickest mean layer of 33.4 μm, followed by AH Plus (21.6 μm); the other 2 calcium-hydroxide-based sealers, Apexit and Sealapex, formed much thinner layers compared to Acroseal - 11.5 μm and 12.6 μm, respectively (Figs. 1 and 2). The thinnest mean layer was formed by Tubliseal, 10.9 μm.

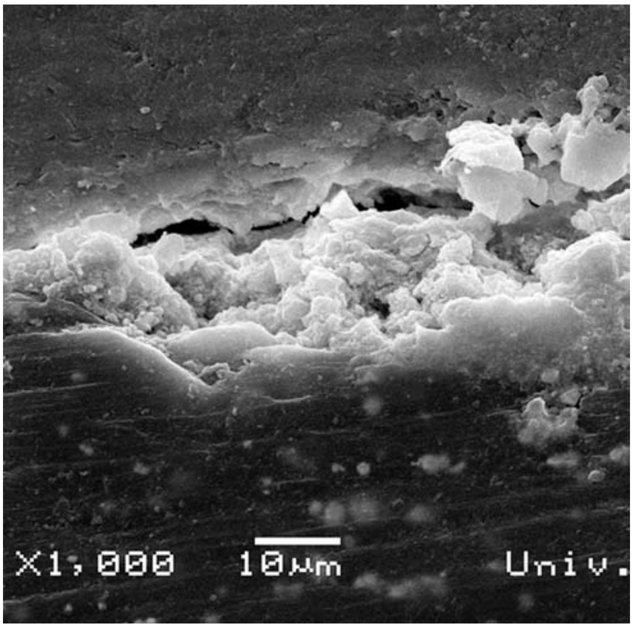

Figure 1. A specimen from the Acroseal group (x1000)

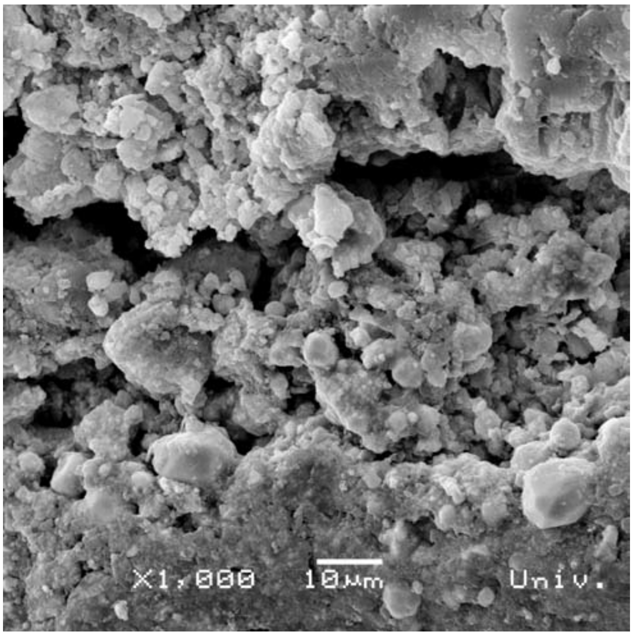

Figure 2. A specimen from the AH Plus group (x1000)

Table 2 presents statistical differences between each pair of sealers. Acroseal exhibited significantly greater mean layer thickness compared to Tubliseal ($p<0.001$), Apexit ($p<0.001$) and Sealapex ($p<0.01$). The difference between AH Plus and Acroseal was not statistically significant ($p>0.05$). Among other pairs of sealers there were no statistically significant difference in sealer thickness except for AH Plus - Tubliseal ($p<0.01$) and AH Plus - Apexit groups ($p<0.05$).

In all investigated groups, the sealer appeared as a discontinuous layer covering various percentage of root canal perimeter (Fig. 2). Furthermore, all sealers exhibited tendency to form unevenly thick layers. Standard deviation values presented in table 1 show that the greatest variation in layer thickness occurred in the Acroseal group, while Sealapex appeared to have the least variable layers.

Table 2. Statistical difference between 5 groups of sealers (Kruskal-Wallis Test with Dunn's Multiple Comparisons post-test)

Sealers	Sealapex	Apexit	Acroseal	Tubliseal
AH Plus	NS $p>0.05$	* $p<0.05$	NS $p>0.05$	** $p<0.01$
Tubliseal	NS $p>0.05$	NS $p>0.05$	*** $p<0.001$	
Acroseal	** $p<0.01$	*** $p<0.001$		
Apexit	NS $p>0.05$			

In all sealer groups, it was observed that sealers had good adaptability potential to fill the irregularities of dentinal wall but also canal isthmuses, diverticuli and accessory canals. However, micro-gaps of up to 10 μm appeared between dentinal wall and sealer/Thermafil, mostly in coronal and middle segments in AH Plus, Acroseal, Apexit and Tubliseal groups (Fig. 3). Furthermore, in some cases, microscopic voids, undetectable on control X-rays, were noticed in AH Plus (middle I section), Acroseal (coronal section), Sealapex (middle II section) and Apexit (middle II section). Round to oval shaped and 200-250 μm in greatest diameter, these voids were positioned within gutta-percha (Acroseal, Apexit), or between dentinal wall and sealer/gutta-percha (AH Plus, Sealapex) - figure 4.

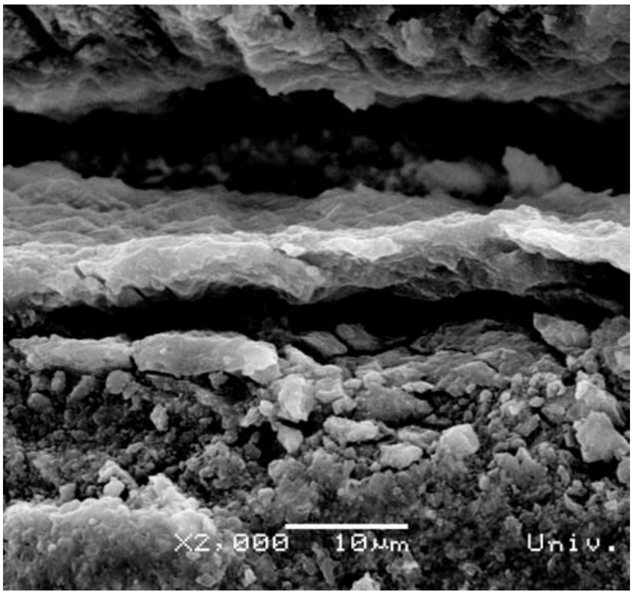

Figure 3. A specimen from the Apexit group, noticeably thinner than previous sealers (x1000)

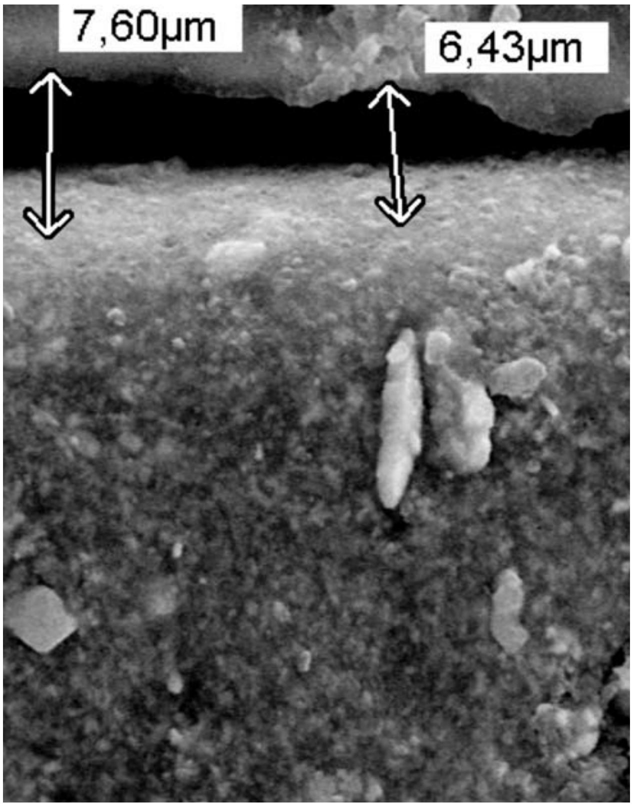

Figure 4. Micro-gaps of up to 10 µm present between dentinal wall and gutta-percha (x1000)

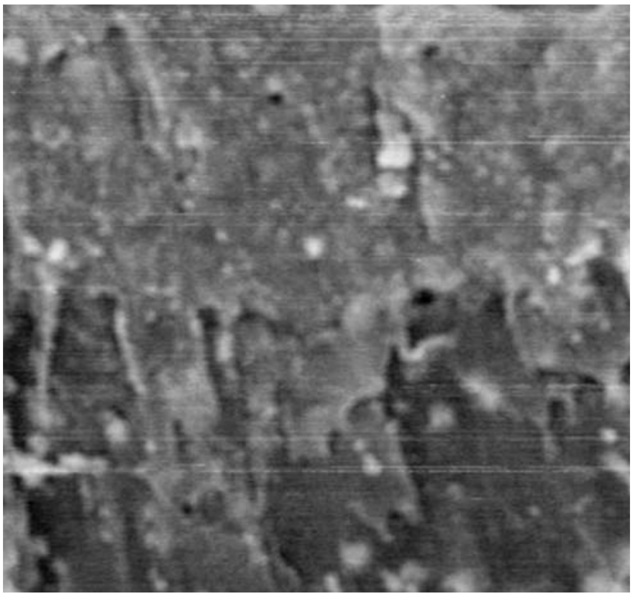

Figure 5. Oval void of about 250 µm in diameter between dentinal wall and gutta-percha (x500)

Thermafil core plastic carrier maintained its original round cross-section in all studied groups, but was not always centrally positioned in the root canal. This was seen in middle II and apical segments in AH Plus, Acroseal and Apexit, and apical segments in Sealapex and Tubliseal groups (Fig. 5).

Discussion

Layer thickness of 5 endodontic sealers, their distribution and adaptation of Thermafil components after root canal obturation were analyzed in the present study. Although Acroseal is not a brand new Ca-hydroxide based material, it has not been thoroughly investigated. One pilot study showed that Acroseal had significantly less microleakage, compared to Apexit and Apexit Plus, immediately after obturation and material setting[6]. Therefore, within the scope of the present study, Acroseal was compared to sealers from the same, as well as from different groups.

While designing methodology, it was decided that smear layer would be removed prior to obturation using 17% EDTA, because previous studies have reported that it increases material retention and adhesion to dentinal walls and penetration into the dentinal tubules[4,9-11].

Several *in vitro* studies have reported the extrusion of obturation material beyond root apex during Thermafil obturation technique in almost 100% of cases regardless whether plastic blocks or extracted teeth were used[1,11,14]. In these studies, the fact that periodontal ligament and periradicular tissue pose certain resistance in clinical conditions was not taken into account. Therefore, certain innovations were introduced into the design of the present study. Prior to obturation, each root was embedded in a slightly wet (saline) piece of sponge, fixed with wax in the cervical segment and put in a plastic mould. This accounted for a closer simulation of clinical conditions compared to the situation in which root canal obturation is done in teeth or plastic blocks surrounded by air. This was confirmed by 40% less frequency of material extrusion in the present study. However, the resistance of surrounding tissues was not the only reason for material extrusion. It was also influenced by sealer's ability to flow along canal walls. In the Acroseal group, material extrusion was not recorded in either case and this could be explained by higher viscosity of this sealer compared to others.

This result was in correlation with SEM findings in this study, showing that Acroseal exhibited the greatest mean layer thickness, significantly greater than Apexit, Sealapex and Tubliseal. AH Plus layer thickness was smaller than Acroseal, but not significantly. This result could also be explained with more viscous consistency of Acroseal and AH Plus, and higher surface energy compared to other sealers. The thickness values in the present study were significantly lower than in 2 *in vitro* 2-plate tests[12,13]. However, although the absolute values were different, a similar pattern was observed. Tubliseal exhibited smaller thickness than Apexit, and both of them showed smaller layer thickness than AH Plus. Lacey et al[12] reported the lower viscosity of Tubliseal than other sealers, and higher viscosity flow rate of Tubliseal and Apexit. These findings could be the reason for lower thickness values of these sealers compared to Acroseal and AH Plus, as recorded in the present SEM study. Beside the mean thickness value, one must take into consideration standard deviation which showed relatively high values in all sealer groups. This result implied prominent tendency of all sealers to form layers of variable thickness in all segments from coronal to apical.

Beside variable sealer thickness, it was also observed that all sealers formed discontinuous layers covering variable percentage of root canal perimeter. This finding is in accordance with two previous results[5,7] while Weis et al[17] reported the complete encasement of Thermafil core. The discontinuous sealer film could be the result of the pressure of thermoplastized gutta-percha and rigid carrier and the initial minimal amount of inserted sealer. This thesis was also confirmed by Wu et al[18], who reported that the percentage of sealer coated root canal perimeter was less than 50% in compaction techniques and 97% in the monocone obturation technique.

The findings of this SEM study are in accordance with previous results that Thermafil technique exhibited greater microleakage, both coronal and apical, compared to lateral and vertical compaction techniques[2,3,11,14]. Complete, hermetical, 3-dimensional seal remains an ideal in the Thermafil technique. The present SEM study revealed that, in spite of sealer penetration into dentinal tubules, there were also micro-gaps between dentinal wall and gutta-percha/sealer, observed in various coronal-to-apical segments. The diameter of these micro-gaps was up to 10 μm. In addition to this, minute air bubbles, unidentifiable in control X rays, were also observed in several sections contributing to less than ideal root canal obturation. The third *locus minoris* for greater microleakage was the gutta-percha/carrier interface. While in compaction techniques, the core material is gutta-percha alone, the core in Thermafil technique is made up of 2 very different materials. The core carrier and gutta-percha do not interact chemically, but form only intimate physical contact instead. The carrier design is not in favour of micromechanical retention which is present between the obturating material and open dentine tubules on the opposite side. Such smooth surface of the carrier, along with the possible contraction of gutta-percha during cooling, could be the cause of the imperfect interface, as observed in the present study.

Conclusion

The layer thickness in decreasing order were: Acroseal > AH Plus > Sealapex > Apexit > Tubliseal. In Thermafil technique, no sealer formed a continuous layer between the dentinal wall and gutta-percha. The imperfect marginal adaptation at the gutta-percha/core carrier interface and micro-gaps between dentinal wall and the obturating material could contribute to inadequate adhesion within the root canal and increased microleakage of Thermafil compared to other obturation techniques.

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