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Sealer area associated with cold lateral condensation of gutta-percha and warm coated carrier filling systems in canals prepared with various rotary NiTi systems

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Abstract

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Aim To compare the area of sealer surrounding root fillings completed by two coated carrier systems (Thermafil Obturator and System GT Obturator) and the cold lateral compaction technique, following root canal preparation with two different NiTi rotary systems (Profile ISO and System GT).

Methodology Sixty extracted human mandibular premolars were instrumented with ProFile ISO 0.06 taper and System GT instruments ($n = 30$ each). The teeth were divided into four subgroups ($n = 15$) for filling as following: group 1: ProFile + Thermafil Obturator, group 2: ProFile + Cold Lateral Compaction, group 3: System GT + GT Obturator, and group 4: System GT + Cold Lateral Compaction. In all groups the canals were prepared to a final size of 40, 0.06 taper in accordance with the manufacturer's instructions and Topseal was used as a sealer. Horizontal sections were obtained every 1 mm up to 12 mm from the apical foramen. Sections were digitally photographed under a stereomicroscope and the images were transferred to an IBM-compatible PC for image analysis. The cross-sectional area of the root canal and the area filled by sealer were calculated for each section and compared statistically both at all levels and by grouping the data as apical, middle and coronal segments; using the Kruskal–Wallis test with Bonferroni correction and chi-square tests ($P = 0.05$).

Results In the apical third (1–4 mm), the GT Obturator (group 3) had significantly less area of sealer ($P < 0.05$), while the difference between groups 1 and 2 was not significant ($P > 0.05$). For the middle and coronal thirds, both coated-carrier systems had significantly less area of sealer compared with their laterally compacted counterparts ($P < 0.05$).

Conclusions With the combined use of ProFile + Thermafil Obturator and System GT + GT Obturator, significantly less area of sealer occurred than that achieved with both NiTi preparation systems followed by cold lateral compaction.

Keywords: filling techniques, gutta-percha-filled area, image analysis, NiTi instruments, obturation, sealer cements.

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Introduction

To complement proper cleaning and shaping of the root canal system, complete filling with a biologically inert and dimensionally stable material is a major objective of root canal treatment (Hülsmann *et al.* 2005). Today,

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most canal filling methods utilize different formulations of gutta-percha, cemented into the root canal with a sealer. Endodontic sealers are capable of filling imperfections, patent accessory canals and multiple foramina (Wu *et al.* 2000). On the other hand, previous studies have shown that the sealer component should be kept to a minimum due to their dimensional instability (shrinkage) and solubility over time (Ørstavik 1983, Peters 1986, Georgopolou *et al.* 1995).

Many techniques have been developed for placing gutta-percha in the root canal but cold lateral compaction continues to be used with great frequency (Leung & Gulabivala 1994, Schäfer & Olthoff 2002). One major advantage of this technique is the ability to control the length of fill (Schäfer & Olthoff 2002). On the other hand, the shape of many root canal systems can complicate its application (Leung & Gulabivala 1994), and a homogeneous mass of gutta-percha is never produced (Gilbert *et al.* 2001). The use of techniques utilizing thermoplasticized gutta-percha has, therefore, gained popularity over time (Schilder 1967, Johnson 1978, Silver *et al.* 1999). Among these, coated carrier systems consisting of a plastic central carrier coated with a layer of so-called α-phase gutta-percha (Johnson 1978, Schäfer & Olthoff 2002), which is softened by heat before insertion into the prepared root canal, have become popular. Previous reports suggest that this technique is capable of producing a homogenous mass in the root canal with a better core/sealer ratio than that achieved with cold lateral compaction (Gençoğlu *et al.* 2002). However, leakage studies have reported conflicting results, showing that coated carrier systems may (Beatty *et al.* 1989, Gençoğlu *et al.* 2002) or may not (Lares & El Deeb 1990, Haddix *et al.* 1991) provide a better seal than cold lateral compaction. Furthermore, little published data exists with regard to adaptation of coated carrier systems in root canals prepared with nickel–titanium (NiTi) rotary systems (Gulabivala *et al.* 1998, Kytridou *et al.* 1999), although manufacturers are continuously developing new 'instrumentation-obturation' systems that can be matched and adapted more closely to a uniformly and centrically prepared root canal (Bal *et al.* 2001).

Because the optimal outcome in canal filling is to maximize the volume of the core material and minimize the amount of sealer (Ørstavik 1983, Peters 1986, Georgopolou *et al.* 1995, Veis *et al.* 2004, De-Deus *et al.* 2006), the aim of this study was to compare the cross-sectional area of sealer in the apical, middle and coronal regions of root canal fillings completed by two coated carrier systems (Thermafil Obturator and System GT Obturator) and the cold lateral compaction technique, following root canal preparation with two different NiTi rotary systems (ProFile ISO and System GT).

Materials and methods

Specimen preparation

Sixty periodontally involved single-rooted mandibular human premolars with radiographically confirmed straight root canals were used. The teeth were stored in 0.2% thymol in normal saline solution before use (a maximum of 1 month). Soft tissue remnants were removed from the root surfaces and the crowns were sectioned below the cemento-enamel junction using a low-speed water-cooled diamond saw (Isomet 4000, Buehler, Lake Bluff, IL, USA), so that the length of all roots was adjusted to approximately 18 mm from the coronal reference point to the apex. This length was determined in a pilot study and provided the opportunity to obtain 12 slices 1 mm-thick with an additional loss of approximately 6 mm sound tissue due to the thickness of the blade. The roots were, thereafter, randomly assigned into four groups using envelopes ($n = 15$/each):

Group 1: Roots were instrumented with the ProFile ISO 06 NiTi rotary system (Dentsply Maillefer, Ballaigues, Switzerland) in a crown-down manner. Between each instrument size, the canals were irrigated with 2 mL 5.25% sodium hypochlorite (NaOCl) using a 27-gauge needle. All canals were enlarged to size 40, 0.06 taper to the working length (1 mm from the apical foramen). Each instrument was used to enlarge five root canals. Following preparation, the canals were irrigated with 5 mL 17% EDTA for 60 s, followed by 5 mL 5.25% NaOCl for 60 s. The canals were subsequently dried with paper points.

Prepared roots were filled using the Thermafil System (Dentsply Maillefer) in conjunction with an endodontic sealer (Topseal, Dentsply). For the purpose of standardization, 0.05 mL of mixed sealer was injected into the canal orifice with a 0.5 mL insulin syringe, while the Thermafil Obturator (size 40, as determined with a Thermafil verifier) was heated in a Thermaprep oven for 30 s according to the manufacturer's recommendations. The Thermafil Obturator was slowly inserted into the canal to the working length with firm pressure. Excess coronal gutta-percha and the plastic handle were removed with a round bur (Thermocut, Dentsply Maillefer).

Group 2: The root canals were prepared as with group 1 (ProFile System) and filled using cold lateral compaction. A size 40, 0.06 taper gutta-percha cone (Dentsply Maillefer) was inserted to the working length and a tight fit was assured by obtaining a small degree of resistance or 'tug-back' on removal. Topseal was applied into the canal as with group 1. Then, the master cone was gently seated in the canal and condensed with spreaders. Accessory gutta-percha cones (size 20) were inserted until they could not be introduced >3 mm into the root canal. Excess gutta-percha was removed using a warm excavator and final vertical compaction was completed with a plugger to a depth of approximately 1 mm.

Group 3: Roots were instrumented with the System GT NiTi rotary system (Dentsply Maillefer) in a crown-down manner. All canals were enlarged to size 40, 0.06 taper to the working length (1 mm from the apical foramen). Irrigation and drying of the root canals was performed as with group 1. The roots were filled using System GT Obturators (size 40, 0.06 Taper) in conjunction with 0.05 mL of Topseal. Application of the sealer and System GT Obturator and removal of excess material was accomplished as with group 1.

Group 4. The root canals were prepared as with group 3 (System GT) and filled using a cold lateral compaction technique, in conjunction with the experimental protocol followed in group 2.

The coronal access of all specimens were restored using a microfill hybrid resin composite material (Spectrum TPH, Dentsply) bonded with a total-etch single-bottle adhesive system (Prime & Bond NT, Dentsply). To avoid discrepancies owing to operator variations, all clinical procedures were performed by the same investigator.

Sectioning and image analysis

Filled roots were stored in 100% humidity at 37 °C for 1 week. Specimens were then embedded in epoxy resin (Araldite M, Agar Scientific Limited, Essex, UK). For each specimen, horizontal sections were obtained every 1 mm up to 12 mm from the apical foramen, using the Isomet saw at the lowest speed setting (200 rpm) and continuous water cooling to prevent frictional heat, and thus, smearing of gutta-percha that may tend to hide areas of sealer. A digital photograph of the coronal surface of each section was obtained at 40 × magnification under a stereomicroscope (Microflex, Nikon, Tokyo, Japan) and transferred to an IBM-compatible PC as an uncompressed TIFF file. AutoCAD 2000 software (Autodesk Inc., San Rafael, CA, USA) was used to calculate the cross-sectional area of the root canal and the area filled by the sealer (and voids, if present). The non-parametric data (ratios of sealer to root canal area, as calculated by dividing sealer area by root canal area) was analyzed statistically by the Kruskal–Wallis test with Bonferroni correction and chi-square tests with the level of significance set at $P < 0.05$. Comparisons were made at each level and by grouping the data as apical, middle and coronal.

Results

For every section (1–12 mm), the ratio of the cross-sectional area of sealer + voids to that of the root canal is presented in Table 1 as means, medians and standard

Table 1 The ratio of the cross-sectional area of sealer + voids to the area root canal

Section (mm)	Group I (ProFile/Thermafil)			Group II (ProFile/Cold Lateral Compaction)			Group III (System GT/GT Obturator)			Group IV (System GT/Cold Lateral Compaction)		
	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD	Mean	Median	SD
1	0.162	0.126	0.116	0.144	0.119	0.132	0.039	0.015	0.051	0.162	0.129	0.137
2	0.143	0.101	0.114	0.150	0.180	0.103	0.053	0.00	0.077	0.174	0.188	0.078
3	0.124	0.051	0.119	0.136	0.110	0.102	0.017	0.00	0.034	0.156	0.149	0.124
4	0.034	0.017	0.049	0.083	0.069	0.063	0.004	0.00	0.011	0.140	0.100	0.129
5	0.015	0.010	0.017	0.048	0.033	0.046	0.001	0.00	0.006	0.087	0.063	0.096
6	0.011	0.00	0.017	0.055	0.056	0.060	0.004	0.00	0.014	0.092	0.063	0.095
7	0.006	0.00	0.010	0.043	0.019	0.056	0.009	0.00	0.026	0.046	0.045	0.043
8	0.007	0.00	0.013	0.029	0.011	0.053	0.006	0.00	0.021	0.025	0.017	0.034
9	0.008	0.00	0.013	0.034	0.019	0.044	0.007	0.00	0.020	0.017	0.007	0.023
10	0.016	0.011	0.020	0.039	0.028	0.044	0.010	0.00	0.029	0.036	0.024	0.043
11	0.024	0.027	0.024	0.060	0.041	0.058	0.013	0.00	0.036	0.060	0.031	0.063
12	0.019	0.019	0.017	0.087	0.052	0.078	0.016	0.00	0.038	0.056	0.046	0.046

deviations. When group 1 (ProFile + Thermafil) and group 2 (ProFile + CLC) were compared statistically, there were no significant differences at the 1–5, 8, 10 and 11 mm levels ($P > 0.05$). For the 6, 7, 9 and 12 mm sections, group 1 had a significantly lower sealer area ($P < 0.05$). A comparison of group 3 (System GT + GT Obturator) and group 4 (System GT + CLC) showed that except for the 9 mm sections, group 3 had significantly lower sealer area than group 4 ($P < 0.05$). When both coated-carrier systems were compared statistically, group 3 (System GT + GT Obturator) had significantly lower sealer area at 1–5 and 11 mm ($P < 0.05$). Finally, a comparison of both CLC groups showed that there were no significant differences between group 2 (ProFile + CLC) and group 4 (System GT + CLC) at any level ($P > 0.05$).

When the data was pooled as apical (1–4 mm), mid-root (5–8 mm) and coronal (9–12 mm) thirds (Fig. 1), there were no differences between the sealer area of group 1 (ProFile + Thermafil) and group 2 (ProFile + CLC) in the apical third ($P > 0.05$), while group 1 had significantly lower sealer area at the middle and coronal thirds. For all levels, group 3 (System GT + GT Obturator) had significantly lower sealer area than group 4 (System GT + CLC), ($P < 0.05$). For the coated-carrier systems, group 3 (System GT + GT Obturator) had significantly lower sealer area than group 1 (ProFile + Thermafil) in the apical third ($P < 0.05$), but there was no significant difference between the two groups in the middle and coronal thirds ($P > 0.05$). When both CLC groups were compared, there was no significant difference between group 2 (ProFile + CLC) and group 4 (System GT + CLC) at any level ($P > 0.05$).

Discussion

Currently, cold lateral compaction of gutta-percha in combination with an insoluble endodontic sealer remains the most widely accepted and used obturation

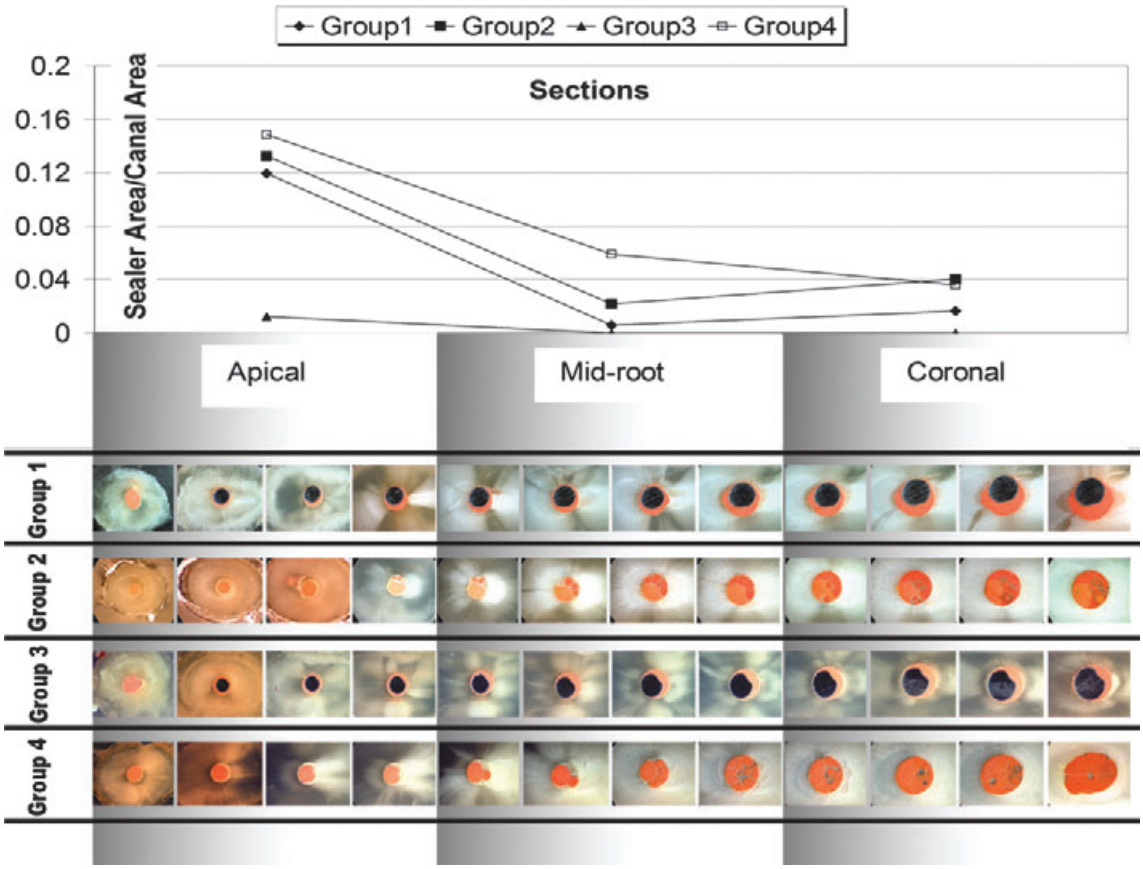

Figure 1 The ratio of the cross-sectional area of sealer + voids to the area of root canal at apical (1–4 mm), middle (5–8 mm) and coronal (9–12 mm) thirds (graph), and corresponding representative sections for each obturation method tested.

technique (Dummer 1991, Peak *et al.* 2001). In many studies, this method has served as a standard against which new techniques are often tested (Schäfer & Olthoff 2002, Veis *et al.* 2004, De-Deus *et al.* 2006). One of the main disadvantages of this technique is its inability to replicate the inner surface of the prepared root canal (Chu *et al.* 2005). Consequently, there will be spaces between the gutta-percha and root canal wall as well as the gutta-percha cones, which is probably filled with sealer (Chu *et al.* 2005). The use of rotary NiTi instruments have given rise to thermoplasticized coated carrier obturation techniques designed to optimally adapt to such root canal preparations and reduce the amount of sealer (Bal *et al.* 2001, Wu *et al.* 2002). The manufacturer of the tested systems (ProFile ISO and System GT) also recommends obturation of prepared root canals with their respective coated carrier systems (Thermafil Obturator and System GT Obturator, respectively). It is important to compare these relatively new filling systems with cold lateral compaction to determine the best outcome with reference to the sealer component (Ørstavik 1983, Peters 1986, Georgopolou *et al.* 1995, Veis *et al.* 2004, De-Deus *et al.* 2006).

The apical root filling should provide a good seal, especially after post-space preparation where only 3–4 mm of the apical root filling is left (Wu *et al.* 2002). In the present study, the use of GT Obturators after root canal preparation with System GT instruments produced a significantly lower sealer component than that of group 1 (ProFile ISO + Thermafil) and the other test groups in all apical sections (1–4 mm). The difference between the two coated-carrier systems can be explained by the design of the obturators. Because the final GT instruments and GT Obturators have both the same file size and taper size (0.06), they can be expected to conform optimally to the natural shape of the prepared canal provided that the canals are round in shape and straight. In the Thermafil system, however, the size of obturator is determined according to the 'best fitting' verifier (Veis *et al.* 2004). Thus, when the canal is enlarged to size 40 with a 0.06 taper instrument as in the present study, the Thermafil Obturator may have an adaptation less than optimal, compared with that achieved with the GT Obturator. This may also explain the similarity in the amount of sealer between Thermafil and cold lateral compaction groups (1 and 2) in the apical third. These results may have some clinical implications. For instance, if a post-space preparation is planned after root canal filling, a combination of root canal preparation with System GT instruments, followed by GT Obturator may provide the least sealer component. It should be cautioned that, although size 40, 0.06 taper instruments were used in all groups, the canal area might differ considering the canal morphology as a factor. The possible effect of this parameter was not investigated in the present study due to the destructive nature of sectioning. Further research using high-resolution non-destructive diagnostic techniques such as micro-computed tomography is, therefore, necessary to clarify this issue.

Coronal microleakage has also been cited as a significant cause of post-treatment disease (Saunders & Saunders 1994, Trope *et al.* 1995, Cheung 1996). While gutta-percha and sealers may fail to prevent bacterial leakage (Magure *et al.* 1991, Trope *et al.* 1995), an optimal root filling may help resist coronal microleakage in conjunction with a sound coronal restoration (Ray & Trope 1995). In the present study, the GT Obturators and Thermafil obturation in the middle and coronal levels were not significantly different. Both methods provided significantly less sealer component than laterally compacted gutta-percha, implying that the coated-carrier systems, in conjunction with their relevant NiTi rotary preparation systems adapted better to the root canal and minimized the amount of sealer. As for the cold lateral compaction groups, there were no significant differences for the sealer component at any level.

In order to adhere to the manufacturer's recommendations, a sealer was used in all groups in the present study. Although not generally recommended, previous laboratory studies (Smith *et al.* 2000, Wu *et al.* 2002, De-Deus *et al.* 2006) have not used a sealer to prevent methodological problems such as standardizing the volume of sealer. Indeed, despite a standardized amount of sealer being used in the present study (0.05 mL), it may be difficult to standardize the amount of sealer reaching the apical region (Wu *et al.* 2002). However, including a sealer may facilitate gutta-percha movement (Wu *et al.* 2002) and more notably simulate clinical conditions. Moreover, similar laboratory results have been obtained with (Gençoğlu 2003, Veis *et al.* 2004) and without (Wu *et al.* 2002, De-Deus *et al.* 2006) the use of sealer for the outcome of sealer component when Thermafil was compared with lateral compaction, regardless of the root canal preparation technique used. Due to the lack of published data, however, a similar comparison with the GT Obturator cannot be made. It should be noted that the amount of sealer considered adequate for cold lateral compaction

is considerably more than that inserted when using coated-carrier systems to avoid sealer extrusion. Thus, apical extrusion would be a significant issue with this form of root filling if such an excess of sealer was used.

Conclusion

With the exception of Thermafil and cold lateral compaction at the apical third, the present study has shown that the combined use of ProFile + Thermafil Obturator and System GT + GT Obturator results in significantly less sealer component, compared with that achieved with both NiTi preparation systems with cold lateral compaction. If a post-space preparation is planned, the use of GT Obturator may result in the least amount of sealer in the apical region.

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