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ORIGINAL RESEARCH

The Quality of Thermafil Obturations with Different Final Apical Tapers: A Three-dimensional Microcomputed Tomographic Comparative Study

Carla Zogheib, Alfred Naaman, Etienne Medioni, Gaël Bourbouze, Reza Arbab-Chirani

ABSTRACT

Aim: The aim of this study is to evaluate the influence of final canal taper on the sealing ability of Thermafil by using micro-computed tomography (micro-CT).

Materials and methods: Fifty-four single-rooted teeth were instrumented to apical size 40 taper 4, 6 and 8%. Teeth were divided into three groups. All teeth were filled with Thermafil (Dentsply,Tulsa Dental Products). Using micro-CT, roots were scanned and volume measurements of voids at 1, 3 and 5 mm from the apex were calculated using specialized CT software. Measurements were analyzed statistically with ANOVA followed by Bonferroni multiple comparison correction.

Results: Data analysis showed that 0.08 preparations provided better results than 0.06 and 0.04% tapered samples especially at 1 mm from the apex. Mean percentage of voids were significantly higher with Thermafil taper 0.06% ($p = 0.05$). None of the root canals filled teeth were gap free. Root canal preparations with bigger taper exhibited less voids than smaller tapered preparations.

Clinical significance: In our daily practice, enlarging the apical third (last 3 mm) of root canals to an 8% taper gives a better sealing ability and thus long-term success for our root canal obturations.

Keywords: Micro-CT, Taper, Thermafil, Voids.

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INTRODUCTION

The main goal of root canal therapy is two-fold: To eliminate microorganisms and their by-products from the root canal system in addition to the prevention of reinfection.

However, it is difficult or even impossible to eliminate completely all organisms from the canal space.[1] The purpose of obturation is to eliminate leakage pathways from the coronal and apical directions and entomb remaining bacteria in the root canal system.[2] The most commonly used material for root canal obturation is gutta-percha combined with a sealer. However, this approach does not provide a complete bacteria-tight seal of the root canal system.[3,4] However, because the sealer can dissolve or shrink, it is thought that the thinner the sealer layer, the less the potential for gaps developing and thus presumably the better the seal.[5,6] Thus, the use of a heat source can enhance the thermoplastic properties of both core materials to allow for a thinner sealer layer and a more complete obturation.[7]

The Thermafil technique involves the obturation of the root canal with heated gutta-percha on a plastic carrier. Gençoglu[8] stated that carrier-guided gutta-percha techniques are easier to use than most of the thermoplastic techniques and are able to reduce the sealer component, showing less leakage *in vitro* compared with the lateral compaction technique. Dummer[9] reported that the Thermafil technique is superior regarding its adaptation abilities when compared with lateral condensation.

Throughout the endodontic literature, these techniques have been compared based on their leakage patterns. Recently, micro-CT technology is frequently used for the evaluation of root canal obturation.[10,11] Among these studies, only few compared micro-CT results with conventional histological sections calculating voids qualitatively and quantitatively.[11,12]

In order to evaluate the sealing ability of Thermafill, the volume of voids in root canals prepared with three different taper sizes (4, 6 and 8%) was measured by using micro-CT at 1, 3 and 5 mm from the apex. The null

hypothesis entails that there would be no voids between canals obturated with different tapers.

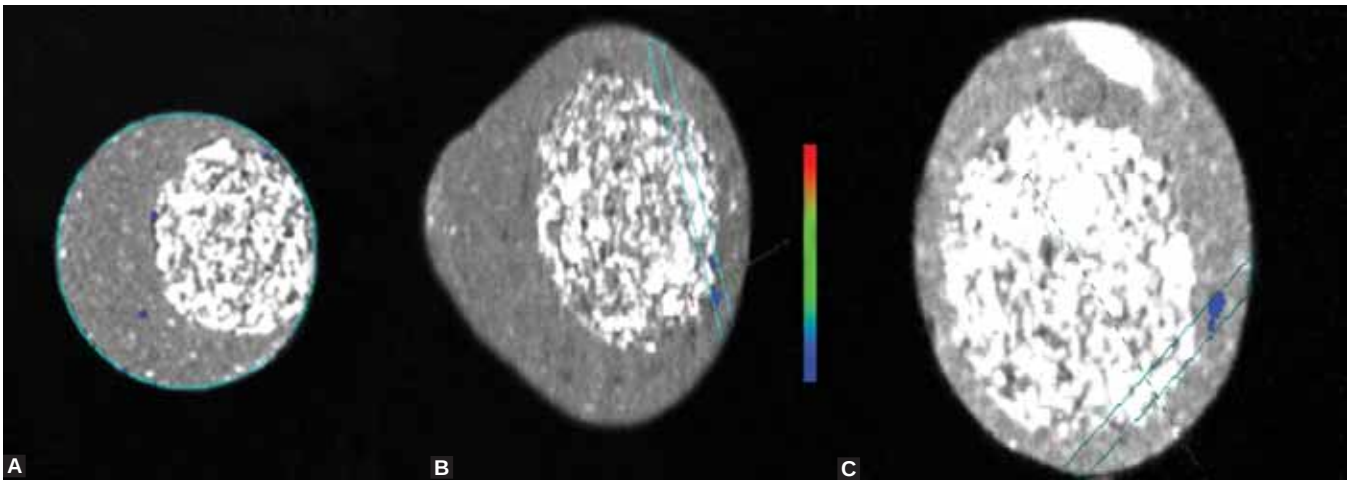
MATERIALS AND METHODS

Selection and preparation of teeth Fifty-four single-canal freshly extracted teeth, with a curvature less than 10° determined by Schneider's technique,[13,14] were collected and kept in 10% buffered formalin. The teeth were marked then decoronated to achieve a length of 16 mm perpendicularly to the long axis using a cylindrical diamond bur. Once access to the pulp chamber had been gained, the patency of the apical foramen was checked using a stainless steel no. 10K-file (Dentsply Tulsa Dental, Tulsa, OK, USA). The working length was measured by inserting the instrument into the root canal until it was visible at the apex and subtracting 0.5 mm. After hand files introduction and establishment of a glide path, TF files # 25 taper 4 prepared group 1, # 25 taper 6 group 2, and # 25 taper 8 group 3. In order to have all apical preparations to 40/100, the use of TF was followed by the use of GT (Dentsply Tulsa Dental) rotary files. In this way all groups were prepared to the same apical size of 40/100 but with different tapers of 4, 6 and 8% with respectively GT # 40.04, 40.06 and 40.08.

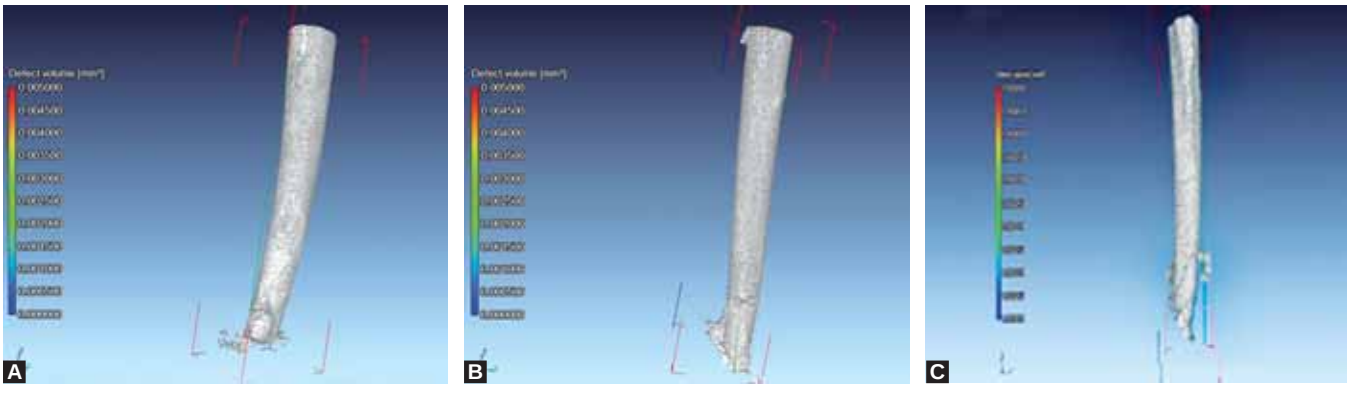
After preparation, the smear layer was removed with a 2 minutes rinse of a liquid EDTA solution, such as SmearClear (SybronEndo, Orange, CA, USA). During preparation and between each file, 1 ml of 5.25% sodium hypochlorite was used as irrigant. After drying all canals with paper points. Obturations were performed by using 40.04 Thermafil carrier points. Thermaprep (Dentsply-Tulsa) oven was used respectively, according to manufacturer instructions.

Micro-CT Acquisitions

All roots were stored at 37° with 100% humidity to allow the sealer to set completely until being imaged by micro-CT scan. A high-resolution computed tomography scanner, v|tome|x 240D (General Electric, Wunstorf, Germany) was used to scan the teeth. After adjusting the appropriate parameters for scanning, each tooth was positioned on the specimen stage and scanned with an isotropic resolution of 4 µm, rotational step of 0.60°, and rotational angle of 360°. With the measure/CT with datos/x 2.0 software, images obtained from the scan were reconstructed to show two dimensional slices of the inner structure of the roots (Figs 1A to C) and velo/CT for the 3-D volumetric visualization (Figs 2A to C).



Figs 1A to C: Images reconstructed to show 2-D slices at different sections of the inner structure of the roots filled with Thermafil respectively (A) taper 4% (B) taper 6% and (C) taper 8%. Voids, when present, are shown in colored spots and calculated at 1, 3 and 5 mm from apex



Figs 2A to C: Three-dimensional µ-CT scans of root canal systems of samples filled with Thermafil with a final apical taper of 4% (A), final apical taper of 6% (B) and (C)final apical taper of 8%

Statistical Analysis

Repeated measure analysis of variance (ANOVA) with one between subject factor (Taper) and one within subject factor (distance from foramen) was conducted followed by Bonferroni multiple comparisons. The following outcome measures were assessed: (1) Volume of voids within the apical third of the canals and (2) percentage of voids measured on sections at 1, 3 and 5 mm from the apex coronally.

Relationship between taper and percentage voids was investigated using Pearson product moment correlation coefficient.

RESULTS

Mean volumes of voids and percentage of voids at 1, 3 and 5 mm from the apex for different taper preparation are shown in Tables 1 and 2. At 1 mm, mean percentage of voids was significantly different among tapers (p = 0.029).

Mean percentage of voids was lower with taper 0.08, followed by 0.04 and 0.06. No significant difference between tapers was found at 3 mm (p = 0.134) and at 5 mm (p = 0.731).

Among 0.06 tapered preparations, mean percentage of voids was significantly higher in 1 mm sections (p = 0.002), and no significant difference was found among sections at 3 and 5 mm (p = 1.000) of the same group. For 0.04 taper preparations, mean percentage voids was near significance (p-value = 0.054). No significant difference between sections was found with 0.08 (p-value = 0.988) (Table 1). Overall, canals with taper 8% showed the lowest percentage of voids whereas those prepared to taper 4 and 6% showed a higher percentage (Fig. 3). The correlation between the two variables was near significance (p-value = 0.058) with high percentage voids associated with low taper (Table 2).

Table 1: Measures of voids at 1, 3 and 5 mm from apex and Standard Deviations of each group

	Taper	*Mean*	*Std. Deviation*	*N*
1 mm	0.04	8.5156	13.07033	9
	0.06	22.3738	24.73499	9
	0.08	0.8103	1.21940	9
3 mm	0.04	1.7626	2.73585	9
	0.06	0.5038	0.53097	9
	0.08	0.2815	0.30970	9
5 mm	0.04	0.4928	0.70309	9
	0.06	0.5868	0.71254	9
	0.08	0.3555	0.38365	9

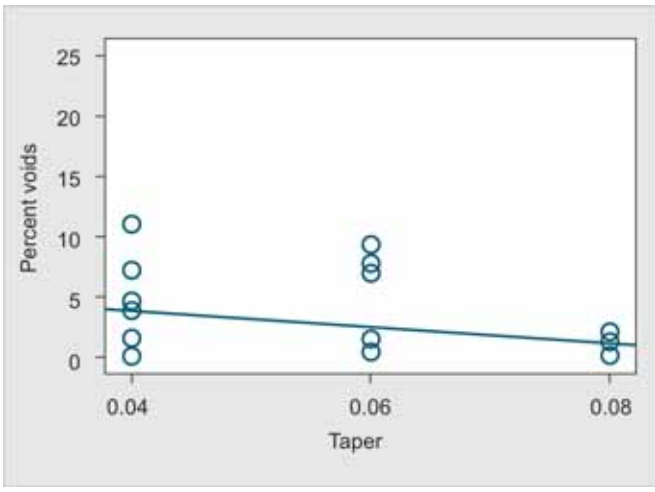


Fig. 3: Representative patterns of void presence in the apical third with Thermafil at 1, 3 and 5 mm for different taper using repeated measure analysis of variance (ANOVA) within subject factor (distance from foramen) and, was conducted followed by Bonferroni multiple comparison correction

DISCUSSION

The integrity of the root canal filling in the apical few millimeters is believed to be one of the criteria necessary to ensure successful endodontic treatment.[2] Voids in root fillings can, theoretically, compromise the outcome of root canal treatment. Voids along the canal walls are caused by the presence of a gap between the filling material and the dentinal walls and may jeopardize the outcome, because they are in contact with potentially infected canal walls; furthermore, they represent a gap that may promote the failure of the sealer and lead to leakage.[15]

Clinically, voids in root fillings are difficult to detect.[16] Many methods (dye penetration, fluid transport and cross-section analyses, etc.) have been used to investigate the sealing ability of root-filling techniques and materials.[17,18] However, all had the limitation of measuring voids by analysis of sectioned roots and digital imaging software. This might not be accurate because some filling material might be lost in the process.[19] It is difficult to compare results with other studies as there is considerable variation in methodologies employed and a lack of standardized parameters evaluated.[20] Dye penetration method for evaluating root canal obturations is affected negatively by air entrapped in the gaps between the root-filling materials and the canal wall, resulting in failure to reveal the full extent of the void.[20] Micro-CT scanning has been used

Table 2: Mean volume measures of voids in the apical third and Standard Deviations of final taper

Techniques	*Taper*		*N*	*Minimum*	*Maximum*	*Mean*	*Std. Deviation*
Thermafil	0.04	%vide	9	0.04	11.01	3.4425	3.68139
	0.06	%vide	9	0.27	9.32	3.1592	3.71771
	0.08	%vide	9	0.08	2.10	0.5946	0.69273

previously to evaluate the quality of root canal fillings. Micro-CT represents a noninvasive analytical method, which provides objective data because of the elimination of artifacts.[15] Jung, Lommel and Klimeck[12] have shown that the root canal filling may be differentiated from the canal wall in a micro-CT scan using digital root slices. Former studies of root canal obturation quality commonly used two-dimensional analysis of either root slices or digital cross-sections generated from micro-CT scans.[6-8] These could serve as a semi-quantitative representation of the root canal filling. A three-dimensional analysis of micro-CT images, similar to the one used in the present study, was applied by Hammad[21] and Metzger[22] for the analysis of voids and gaps present in root canal fillings. Huybrechts[23] validated the use of micro-CT in endodontics. Micro-CT was therefore compared with optical microscopy using custom-made software for quantitative registration-based validation. They demonstrated that micro-CT can be used for quantitative analysis of root dentine removal. The outcome of endodontic shaping procedures can be examined nondestructively in three-dimensions (3D) and with a spatial resolution of at least 30 µm. For the validation they concluded that micro-CT will provide reliable and accurate cross-sectional views of the morphologic features associated with root canal shaping procedures, if proper settings and software used. On the other hand, they found that obturated canals should be analyzed with caution using this type of device because the presence of filling components and the limited resolution of micro-CT will complicate imaging and analysis procedures.[23] In recent years, the resolution of micro-CT has improved considerably from 81 µm and values between 34 and 68 to 25 and recently to 14 µm.[21,22] This study is considered to be among the very few to use micro-CT to measure percentage of volume of voids and gaps in the root canal with a resolution <4 µm and with a relatively numerous samples (27/method, n = 54).

Removal of the smear layer is considered to be essential for root canal sealers to penetrate into dentinal tubules irrespective of the sealer used.[24] Alternating the use of 5.25% NaOCl and 17% EDTA had been previously recommended for the effective removal of both the organic and inorganic components of the smear layer.[25] The relevant literature shows a wide variety of irrigation times in removing the smear layer. The effectiveness of 1 minute irrigation with 17% EDTA on smear layer removal has been shown.[26] Therefore, in this study, EDTA was used for a short time (1 minute) to minimize destructive effects on dentin.[26]

Studies have shown that plasticized gutta-percha can easily be moved into the canal irregularities, thus replicating the intricacies of the root canal system. There are a number of methods that make use of plasticized gutta-percha. These include warm lateral condensation, warm vertical condensation, coated carrier systems, injection systems and thermomechanical compaction.

Because all new gutta-percha condensing techniques have been developed to minimize the sealer and maximize the gutta-percha content, there have been few studies reporting the absolute gutta-percha content achievable with these techniques.

This study was undertaken to assess the sealing ability of this carrier-based obturation system in root canals prepared with different tapers. Overall none of the three groups were void free. The presence of voids can be attributed to the fact that heated gutta-percha undergoes a shrinkage which might lead to gap and void formation in the canal.[27]

When comparing group 3 (taper 0.08%) to group 2 (taper 0.06%) and group 1 (taper 0.04%), the percentage of voids was significantly higher in smaller tapers especially at 1 mm. No significant difference was found between tapers at 3 and 5 mm. Partial or total exposure of the carriers can explain the presence of voids especially at 1 mm of the apex.[24]

CONCLUSION

The present study, revealed that Thermafil was not able to provide a void-free root canal filling for most preparations and that root canal preparations with bigger taper exhibited less voids than smaller tapered preparations. In addition to the *in vitro* studies, clinical studies evaluating the different endodontic obturation systems and comparing them with Thermafil would be beneficial.

CLINICAL SIGNIFICANCE

In our daily practice, enlarging the apical third (last 3 mm) of root canals to an 8% taper is necessary to achieve a better sealing ability and thus long-term success for our root canal obturations.

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