Quantitative volumetric analysis of cross-linked gutta-percha obturators

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Summary

***Aim*. The purpose of this study was to evaluate the effects of technique on the filling quality of 2 recently introduced obturation systems comparatively with warm vertical compaction using micro-computed tomography.**
***Methods.* 36 single-rooted teeth were selected, root canals prepared, and assigned to 3 groups (n=12), according to the filling technique: warm vertical compaction technique WVC, GuttaCore (Dentsply Tulsa Dental Specialties, Tulsa, OK) and Gutta Fusion (VDW, Germany). Each specimen was scanned using a micro-CT. Percentage of voids was calculated and data statistically analyzed using Kruskal Wallis test with a significance level of 5%.**
***Results.* All obturations showed satisfactory similar results at the apical level. Differences between the three obturation methods were not significant at 1 mm (-p-value >0.05), 3 mm (-p-value >0.05) and 5 mm (-p- value >0.05). No root fillings were void-free. No significant difference was found between the WVC technique, the GuttaCore technique and the Gutta Fusion technique concerning percentage of apical voids regardless of canal level.**
***Conclusion.* This study shows the efficiency of cross-linked obturators in filling root canals hermetically by comparing them to the warm vertical compaction technique. Results show that these obturation techniques were equally sufficient concerning apical adaptation making them appropriate to use in endodontic obturations.**

Key words: guttacore, gutta fusion, micro-ct, obturation, voids.

Introduction

One of the main goals of endodontic treatment is achieving a hermetic seal of root canals (1). In order to increase success of endodontically treated teeth, the seal must be effective coronally and apically preventing bacterial recontamination leading to failure (2, 3) consequently blocking the circulation of tissue fluids that could be diffused from the periapex. Many attempts based on variations in obturation techniques have been made to solve problems, such as lack of surface adaptation, incorporation of apical voids combined with time effect on sealer composition. Simplified methods of thermoplasticizing gutta-percha have become increasingly popular. Schilder introduced the concept of warm vertical compaction WVC of gutta-percha in 1967, using an electrically heated plugger to condense apically (4). In 1978, Johnson proposed a gutta-percha coated metallic obturator oven-heated in order to be plasticized before it is inserted into the root canal (5). This system has undergone numerous improvements: the metal core was replaced by a plastic support (1991) and more recently, with a cross-linked gutta-percha core obturator. The latest on the market are GuttaCore® (Dentsply Tulsa Dental Specialties, Tulsa, OK) and Gutta Fusion® (VDW, Germany). These systems promise to be efficient, safe, biocompatible, and more effective in filling the complexities of the root canal system, compared to other methods currently available (6, 7).To assess the quality of root fillings, various experimental methods have been used, such as fluid filtration, dye penetration, radioisotope, SEM analysis, bacterial leakage evaluation and recently micro-computed tomography (micro-CT). Micro-CT, a three-dimensional imaging tool, has the virtues of being highly accurate and nondestructive, so it overcomes the limitations of the previously used methods (8).The aim of this study was to investigate and to calculate the percentage of volume of voids and gaps in root canals filled with GuttaCore and Gutta Fusion obturators comparatively with WVC using micro-CT. The null hypothesis was that there was no significant difference between the three techniques considering the volume and distribution of voids.

Materials and methods

Sample Selection and Specimen Preparation

36 single-rooted extracted teeth with less than 10 degrees curvature, as determined by Schneider's method (9), were collected. Teeth with root resorptions, fracture or immature apices were excluded from the study. Preliminary radiographs were taken in bucco-lingual and mesio-distal directions using a digital sensor (ERLM Digora® Optime - Soredex, Finland). Teeth with previous root canal treatment, multiple canals and intracanalar irregularities were discarded. After scaling of root surfaces, teeth were rinsed under running water then kept in Formol 10% for 1 week. The crowns were removed with a water-cooled diamond disc (KG Sorensen, Barueri, SP, Brazil) and root length adjusted at 16 mm. A #10 K-flexofile (Dentsply, Maillefer, Switzerland) was introduced, when it reached the apical foramen, working length (WL) was determined and a radiograph taken.

Root canal instrumentation

After introduction of hand files and establishment of a glide path, WaveOne Primary® (25/08) (Dentsply Tulsa Dental Specialties, Tulsa, OK) was used in a reciprocating movement with light pressure. Afterwards, a size #10 K-file was taken to the WL to check patency and irrigation followed with 1ml of 5.25% NaOCl. The previous sequence was repeated until the instrument reached the WL. WaveOne Large® (40/08) (Dentsply Tulsa Dental Specialties, Tulsa, OK) was then used to the WL.A final flush of 2 mL 17% EDTA (pH=7.7) SmearClear (SybronEndo, Orange, CA, USA) was used to eliminate the smear layer. Then, the canals were washed with 5 mL saline solution and dried with paper points (Dentsply Maillefer).

Root canal filling

After preparations, all roots were randomly assigned to 3 experimental groups (n=12) according to the choice of filling technique. The first group was filled with WVC technique. A fine-medium sized gutta-percha cone (Dentsply Tulsa Dental) was selected as the master cone, and trimmed to fit within 0.5 mm of the WL. The prefitted master cone coated with a thin layer of AH Plus® sealer (Dentsply International) was inserted into the canal and down-packed to 5 mm from the WL with a Touch n' Heat source (SybronEndo, Orange, CA). Subsequently, 3-4 mm segments of gutta-percha were backpacked with the Obtura II unit (SybronEndo, Orange, CA) until the canals were completely obturated.The second group was obturated with GuttaCore and AH Plus® and the third with GuttaFusion and AH Plus®. In those two groups, canals were filled with GuttaCore (Dentsply Tulsa Dental Specialties, Tulsa, OK) and Gutta Fusion (VDW Munich, Germany) obturators selected by passively inserting a verifier to WL-0.5 mm and the rubber markers set accordingly on the obturators. The prefitted obturator was heated in the oven [GuttaCore TMOven (Dentsply Tulsa Dental Specialties, Tulsa, OK) and Gutta Fusion®Oven (VDW Munich, Germany)]. A thin layer of the AH Plus® sealer was applied to the canal walls with the verifier. After completion of the heating cycle, the obturator was removed from the oven and slowly inserted (6 to 7 seconds) into the canal to the WL. The handle of the carrier was stabilized with finger pressure and then separated at the orifice of the canal. All roots were stored at 37 °C with 100% humidity for about 72 hours to allow the sealers to set completely until being imaged by a micro-CT scan.

Micro CT

The qualitative analysis of the root-canal fillings was carried out using a micro-CT. A vltomelx 240D (General Electric, MA, USA) high-resolution micro-CT was used to scan the specimens. After adjusting the appropriate parameter, 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 datoslx 2.0 software, images obtained from the scan were reconstructed to show slices of the inner structure of the roots in 2D and velo/CT for the 3D volumetric visualization.
Two different parameters were assessed: on axial sections at 1, 3, and 5 mm from apex, area of voids/gaps in square micrometers and ratio between voids/gaps and the total canal area in the section was calculated. In 3D surface-rendered reconstructions, the volume of voids in cubic micrometers was calculated then the ratio between volume of voids/gaps and the total canal volume (Figure 1). Each section was assessed by the same observer.

Statistical analysis

Statistical analyses were performed using a software program (SPSS for Windows, Version 18.0, Chicago, IL). The level of significance was set at $\alpha=0.05$. Variable was tested for normal distribution using the Kolmogorov Smirnov test. Kruskal Wallis tests were used to explore significant difference among groups.

Results

Mean and standard-deviation of the percentage of voids among groups are presented in Table 1 and Figure 2.
This study showed that the volume of voids was minimal in the three groups and results within the 3 groups were equivalent. None of the root canal filled teeth were void-free, and no significant difference was found within the three obturation methods at 1 mm (-p-value=0.288), 3 mm (-p-value=0.440) and 5 mm (-p-value=0.287).

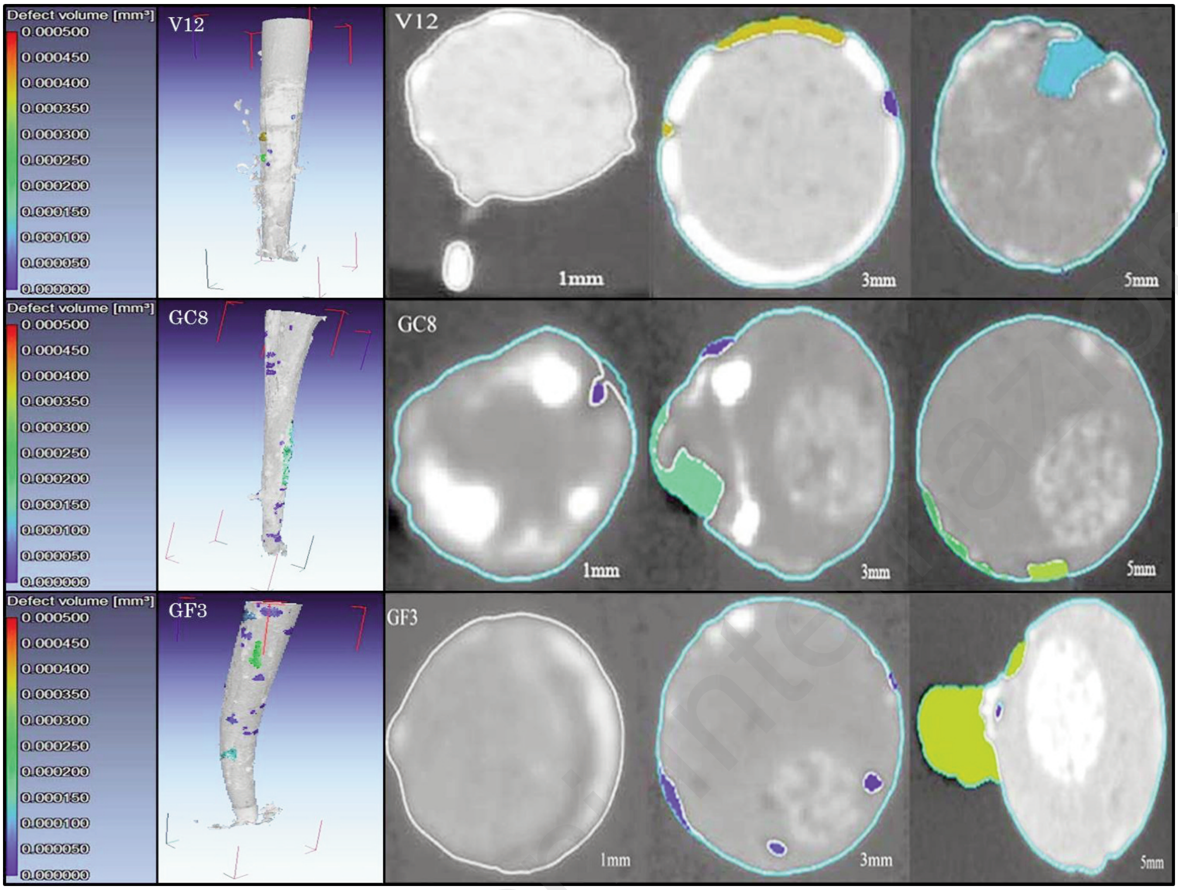

Figure 1. Micro-CT three-dimensional reconstructions and horizontal cross-sections at 1, 3 and 5 mm from the apex of root canal systems obturated with warm vertical compaction techniques (V12), GuttaCore (GC8) and Gutta Fusion (GF3). Voids, when present, are shown in colored spots and calculated at 1, 3 and 5 mm from apex.

Discussion

The role of root canal filling is to avoid leakage of oral fluids containing bacteria and their products from the oral cavity to the apical periodontium through the root canal, and to prevent the exit to the periapex, of microorganisms that persisted in the root canal after cleaning and shaping (10). Voids can be captured during root filling procedures. In fact, internal voids are not in communication with the canal walls, thus they could be considered less clinically significant for the endodontic prognosis. In other words, residual bacteria, if present, are confined in an unfavorable environment (11). But external and combined voids form a gap between the filling materials and the canal walls resulting in a space where bacteria can grow and leakage takes place due to failure of the sealer (12).
Leakage or percolation was defined by the AAE (American Association of Endodontists) as the movement of periradicular tissue fluids, micro-organisms and their toxins along the interface between dentinal walls and the filling materials (13). New methods have been used to evaluate the sealing ability of root-filling techniques and materials because the conventional ones have shown several disadvantages: radiographs provide 2D interpretations only, while the canal system should be analyzed by a three dimensionally imaging technology; with the root sectioning, there could be loss of material which might mimic voids; the time taken for fluid filtration and clearing techniques might affect the results, dye penetration studies do not correlate clinically and dye extraction studies evaluate only the apical third of the tooth. Bacterial microleakage studies need long periods of observation and don't allow quantification of the number of penetrating bacteria. A noninvasive *in vitro* analytical method for imaging has been described. Thus, the analysis using micro-CT can be repeated on the same specimen, results obtained from such analysis were comparable to histological studies (14). Artefacts can be eliminated, hence, the data are objective and quantitative or qualitative evaluations are reliable (15). In endodontics, this technology has been used for the evaluation of root canal anatomy, assessment of root canal morphology after instrumentation, and analysis of obturated root canals. Several comparisons between obturation techniques *in vitro* compared different parameters such as length of fill, de-

Table 1. Mean percentage of voids among groups.

Percentage of voids	Methods	Mean	Standard Deviation
	WVC	1.111	2.350
1 mm	GuttaCore	1.343	1.901
	Gutta Fusion	1.388	1.466
	WVC	0.613	1.225
3 mm	GuttaCore	0.728	0.712
	Gutta Fusion	1.377	1.551
	WVC	0.805	1.712
5 mm	GuttaCore	1.007	1.285
	Gutta Fusion	0.827	0.832

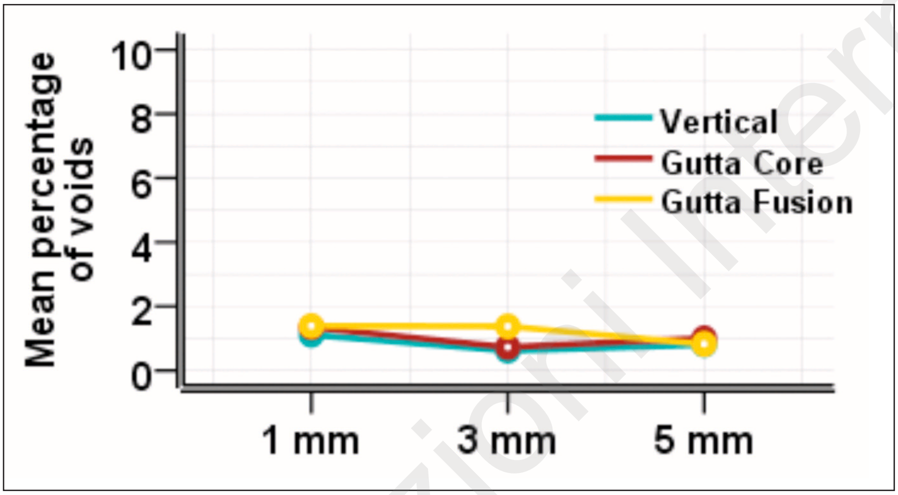

Figure 2. Mean percentage of voids among groups.

fect replication and gutta-percha density. In this study, a volume analysis was performed with micro-CT in which the focus was on the volume of voids created in the fillings. Micro-CT can differentiate the volume percentage of gutta-percha and sealer in the obturating material by different colors. But, like in previous micro-CT studies (8, 16), sealer and gutta-percha were segmented together and analyzed as a single root-filling entity because the majority of obturators fillings sealer was indistinguishable from gutta-percha. Since, micro-CT offers the possibility of repeated scanning; it will be possible to evaluate changes of filling over time (15). On the other hand, the micro-CT has limitations with *in vivo* applications, and the use of this technique is restrained to the examination of specimens of limited size (15).In this study, the use of WaveOne Large® 40/8 till the WL has been supported by severalprevious studies because the increase in the final preparation taper improves irrigant replacement and wall shear stress. Moreover, enlarging the apical third (especially the last 3 mm) of root canals to an 8% taper is necessary to achieve a better sealing ability and thus long-term success for root canal obturations (17, 18). Endodontic sealers differ in physical properties which might determine the sealing ability of the root filling (11). The AH 26® and AH Plus® (Dentsply International) used in association with gutta percha, have been known for their quality and advantages; this is why most of the studies including ours that compared the microleakage of gutta-percha with any other filling material use this sealer. Besides, the good dimensional stability of AH Plus® sealer has been demonstrated (19, 20) and its application can be suggested.

It is important to obturate the whole length of root canal. However, since the apical third is especially important, all the measurements were done for the apical third. One of the reasons for the inadequately filled canals could be that the canal anatomy prevents adequate cleaning of the narrow fissured areas with circular root files since the canal lumen is irregular and the risk of subsequently creating voids is high (21, 22). Moreover, inadequately filled canals could be the consequence of root filling technique.

Based on the results of the present study, none of the tested techniques provided a void-free filling at the

apical third. This finding is similar with the study of Somma et al. in 2011 who compared the quality of root fillings completed by two thermoplasticized gutta-percha techniques (Thermafil and System B) and a cold gutta-percha technique (single point) by micro-CT analysis.
All techniques produced comparable results in terms of percentage of filling and void distribution (11). In particular, most of filling techniques do not completely fill the root canal system (8, 11, 16). However, when ultrasonic (UL) was used to lower gap volumes between gutta-percha cones and sealer (23), the filled volume obtained by WV compaction was similar to that obtained using UL compaction. Micro-CT images revealed the presence of gaps between the canal wall and the master cone in some sections.
No statistically significant difference was found in percentage of voids and gaps between the 3 root filling techniques. Our findings are similar to those published in a recent study by Li et al. (24), where micro-CT and SEM data identified no significant difference in the percentage of interfacial gaps and voids in canals obturated by WVC or GuttaCore core-carriers. These results obtained from the obturators with gutta-percha core are consistent with those reported for the TheramFil (25). The advantage of carrier-based systems and WVC technique is the possibility of filling the canal's apical portion with thermoplasticized gutta-percha (26, 27). When the material is heated it expands, and during cooling it contracts (1-2%), leading to voids along the root filling. A lower percentage of gaps was found in the WVC. The largest percentage of voids was found in the apical last millimeters. Better results were found at 3 and 5 mm sections from apex. This is in concordance with the findings of Gambarini et al. (2016) who compared two Carrier-based obturation systems Thermafil and Soft Core using CBCT where no difference in the percentage of canals with voids between the two groups was noted (28).
As described in the current study, in the WVC technique, gutta-percha is thermomechanically condensed with pluggers in multiple steps and voids could be entrapped. The 2 techniques using obturators consist of a one-step filling procedure in which thermoplasticized gutta-percha is inserted into the canal through a gutta carrier; insertion may create voids because of imperfect gutta-percha adaptation to canal walls or stripping from the carrier. Moreover, friction against the walls can cause loss of gutta-percha from the carrier especially in the apical third of the narrow and curved canals (29).
The present *in vitro* study showed that all obturation techniques were equally sufficient concerning apical adaptation. But none of the root canal filled teeth was void-free especially at 1 mm. Obturator techniques and the WVC technique acted the same at 1, 3 and 5 mm. There was no significant difference concerning percentage of apical voids regardless of canal level. In addition to the *in vitro* studies, clinical studies evaluating the different endodontic obturation systems would be beneficial.

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Conflict of interest statement
All Authors declare that there is no conflict of interest of any kind regarding the publication of this paper.

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