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ORIGINAL ARTICLE

Comparative micro-computed tomographic evaluation of two carrier-based obturation systems

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Abstract
Objectives The aim of the study was to measure the percentage of volume of voids and gaps in the apical third of root canals obturated with two techniques using micro-computed tomography.
Materials and methods Fifty-four single-rooted teeth were collected and root canal-prepared. The roots were randomly allocated into two groups; each group was obturated by using thermoplasticized technique with a different material (gutta-percha and Topseal for Thermafil, Resilon and RealSeal for RealSeal 1). Roots were then scanned, and volume measurements for voids and gaps in the obturated roots were carried out using specialized CT software. Percentage of gaps and voids was calculated.
Results The present study showed that none of the root canal-filled teeth was gap free. Student *t* test was conducted. No significant difference was found between Thermafil and RealSeal 1 concerning percentage of voids in the apical third ($P>0.05$). Both materials showed statistically significant difference between the levels where 1 mm showed the highest volume of voids ($P<0.05$).
Conclusions Both carrier-based techniques allowed a good sealing ability in root canals but none of the materials was gap free. Statistically significant difference between the levels was found and 1 mm showed the highest volume of voids.
Clinical relevance This study shows the efficiency of carrier-based obturation systems in filling root canals hermetically. It compares new adhesive endodontic materials with the traditional gold standard gutta-percha. Results show the good sealing ability of both techniques making them appropriate to use in daily endodontic obturations.

Keywords Micro-CT · Obturation · RealSeal 1 · Sealing ability · Thermafil · Voids

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Introduction

The ultimate aim of a root filling is to fill the entire prepared and cleaned root canal [1, 2]. In order to prevent re-infection, as many microorganisms as possible should be eradicated and no space should be left for bacteria to populate and proliferate [2, 3]. Currently, the best filling material universally considered is gutta-percha associated with a thin layer of cement used in many techniques and procedures [3–5]. Warm vertical condensation, lateral condensation, and System B techniques

improved the sealing of the filling material; however, these require a long learning period, a long operative time, and a relatively invasive endodontic preparation. The introduction of the Thermafil system on the market marked an important stage in the development of endodontic filling techniques [6]. According to this method, the alpha-type gutta-percha is deposited perimetrically on special carriers. The alpha-form gutta-percha, hard at room temperature, becomes viscous, sticky [7–9] at higher temperatures, and more adaptable to the carrier and to the dentinal walls. Even when associated with a sealer, gutta-percha is not capable of preventing leakage [10]. It would thus be advantageous to use sealers and core materials that have better adhesive properties.

Improvements in adhesive technology (Resilon Research, Wallingford, CT, USA) introduced Resilon obturation points and resin sealer. This polymer-based thermoplastic resin material [10] is used in conjunction with the Epiphany Root canal Sealer (Pentron Clinical Technologies, Wallingford, CT, USA) or RealSeal (Sybron Endo, Orange, CA, USA) which is a dual-curable resin material containing dimethacrylates to create a solid monoblock [11, 12]. Recently, a new adhesive system from Sybron Endo was introduced to the market: RealSeal 1 associating the advantages of Thermafil and the adhesive properties of Resilon [11, 13]. Micro-computed tomography scans (micro-CT) have been used to scan filled roots and three-dimensionally reconstruct them to accurately measure the adaptation of the root filling to the canal walls [2, 14]. This nondestructive imaging tool overcomes the limitations of the previously used models [14, 15]: Dye penetration, fluid transport, and cross-section analyses are valuable techniques but do not always corroborate each other [16, 17].

The aim of this study was to investigate and measure the percentage of volume of voids in root canals obturated with two different obturator methods by using micro-computed tomography. The null hypothesis stated that there were no differences in the percentage of volume of voids and gaps between the two techniques.

Materials and methods

Tooth preparation, shaping, and cleaning

Single-canal freshly extracted human teeth (n=54) with a curvature less than 10° were collected and kept in 10 % buffered formalin. Teeth with immature apices, those that had undergone root canal treatment, or those that had root decays or restorations were excluded from the study.

The roots were cut coronally in order to achieve a length of 16 mm. Access into the canals was carried out, and working length was determined by introducing a size 10 file until it exited from the apex and working length established until apex. After hand files introduction and establishment of a glide path, TF Files (Sybron Endo, Orange, CA) were used to clean and shape the root canal.

During preparation and between each file, 1 ml of 5.25 % sodium hypochlorite was used as an irrigant. All teeth had a final taper of 8 % and an apical diameter of 40 finished with a size 40 GT 0.08.

Filling of the root canals

The teeth were subdivided in two groups A and B, with 27 each. Canals were dried and obturated as follows—A: final flush of 10 mL of 17 % ethylene diamine tetraacetic acid (pH7.7) for 3 min, followed by 10 mL of 5.25 % sodium hypochlorite to remove the smear layer 12 RealSeal 1 obturators #40 4 % and real seal sealer (Sybron Endo, Orange, CA); B: Thermafil obturators no. 40, 4 %, and AHplus sealer. K file no. 40 was used to place sealer into the canal whilst rotating it counterclockwise.

With Thermafil, the prefitted obturator was heated in the ThermaPrep Plus Oven (Dentsply Tulsa Dental Specialties). Once heated, the obturator was removed from the oven and inserted slowly into the canal to the working length. With RealSeal 1 technique, obturator no. 40–0.04 was heated in the real seal oven. At the end, light cure was applied for 40 s.

All roots were stored at 37 °C with 100 % humidity allowing sealers to set completely until being imaged by a micro-CT scan.

Micro-CT imaging

A v|tome|x 240D (General Electric, MA, USA) high-resolution micro-CT scanner was used to scan the teeth. After adjusting the appropriate parameters for scanning, each tooth was positioned on the specimen stage and scanned with a very high isotropic resolution of 4 μm, rotational step of 0.60°, rotational angle of 360°. With a fully automated CT scan reconstruction and analysis process (datos|x 2.0 software) with high precision and reproducible 3D metrology, images obtained from the scan were reconstructed to show two-dimensional slices (Fig. 1b) of the inner structure of the roots and accelerated 3D CT reconstruction technique (depending of the volume size) by velo|CT software was used for volume visualization in 3D-rendered mode (Fig. 1a), analysis, and measurement (Fig. 1c) of the volume of the root canal filling material and percentage of gaps and voids present in the canals.

We assessed two different parameters: on axial sections at 1, 3, and 5 mm from apex, we measured the area of voids/gaps in square micrometers then the ratio between voids/

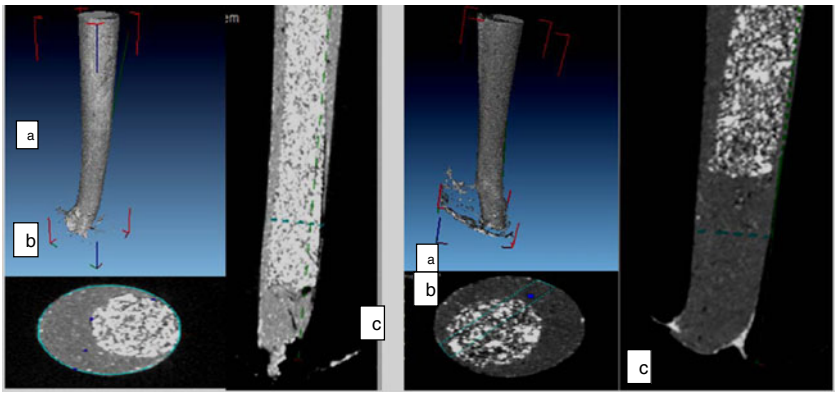

Fig. 1 Three-dimensional μCT scans of root canal systems of two different samples filled with thermafil: **a** three-dimensional 3D surface rendered reconstruction of root canal material; **b** cross-section of the root canal at 1 mm from apex; **c** longitudinal scan in the apical third. 232×109 mm (96×96 DPI)

gaps and the total canal area in the section was calculated. In 3D surface-rendered reconstructions, we calculated the volume of voids in cubic micrometers then the ratio between volume of voids/gaps and the total canal volume was calculated.

A total micro-CT 3D reconstruction of the filling material in the root with different colors depending on the volume of voids was also possible as shown in the supplementary material (video RS1).

Statistical analysis

Student *t* test, at 5 % significance level, was conducted to explore significant difference between Thermafil and RealSeal 1. The following outcome measures were assessed: (1) percentage of volume of voids on 3D surface rendered reconstruction (Fig. 1c) within the apical third of the canals and (2) percentage of area of voids measured on sections (Fig. 1b) at 1, 3, and 5 mm from the apex coronally.

Results

The mean volume measures of voids in the apical third (in percentage: ratio volume of voids/total volume) are listed in Table 1 and mean percentage of voids in sections at 1, 3, and 5 mm from apex are listed in Table 2. Both filling techniques showed ability to fill the root canals. From the 27 teeth analyzed for each filling technique, Student *t* tests indicated no significant difference in the percentage of voids in the apical third between both materials and at the 3- or the 5-mm level ($P>0.05$; Table 2). Figure 2 shows representative patterns of void presence in root canal and in cross-sectional sections of the filled area respectively. Both obturators displayed different amounts of voids in obturations. Overall, no significant difference was found between Thermafil and RealSeal 1 concerning percentage of apical voids ($P=0.166$).

At 1 mm, root canals obturated with Thermafil showed the lowest percentage of volume of voids and gaps (1.1 %) whereas canals obturated with RealSeal 1 showed a higher percentage (4.8 %). At 3 and 5 mm, there was no statistical significant difference between the root canals filled with Thermafil and RealSeal 1. No significant difference was found between Thermafil and RealSeal 1 concerning percentage of voids at 1 mm ($P=0.929$), 3 mm ($P=0.629$), and 5 mm ($P=0.351$). Both materials showed statistically significantly difference between the levels where 1 mm showed the highest volume of voids. ($P=0.001$)

Table 1 Mean volume measures (in cubic micrometer) of voids in the apical third and standard deviations of each group

	Technique	Number	Mean
Voids percentage	Thermafil	27	2.3988±3.20538
	RealSeal 1	27	4.1376±5.57424

Discussion

Success of endodontic therapy depends on an effective microbial-control phase and an adequately prepared and filled canal. Gutta-percha has for many years been used in root fillings associated with different types of sealers [11]. Unfortunately, it does not provide chemical bonding to the root canal wall. Many obturation methods are used today ranging from lateral compaction to a variety of heat-softened gutta-percha techniques [18]. All aim to provide a good adaptation of the filling material to the canal walls,

Table 2 Measures of voids in sections at 1, 3, and 5 mm (in square micrometer) from apex and standard deviations of each group

Apical level	Technique	Number	Mean
1 mm	Thermafil	27	10.5666±17.99822
	RealSeal 1	27	10.1313±17.74115
3 mm	Thermafil	27	0.8493±1.69143
	RealSeal 1	27	0.6362±1.52679
5 mm	Thermafil	27	0.4784±0.60247
	RealSeal 1	27	1.4230±5.13292

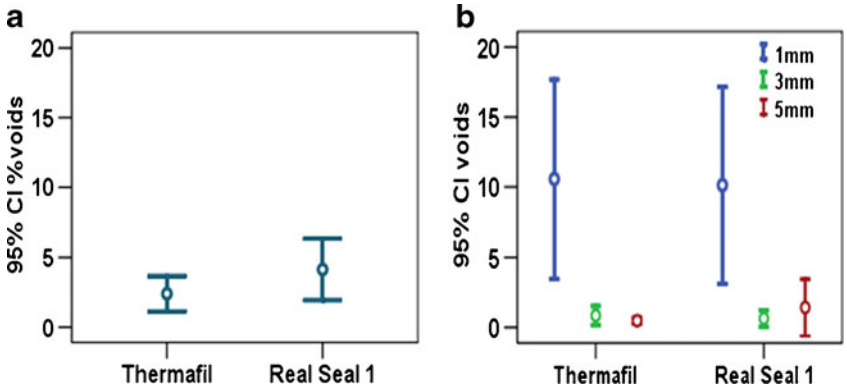

Fig. 2 Representative patterns of (**a**) void presence in the apical third of the root canal and (**b**) in cross-sectional sections of the filled area

thus ensuring an adequate seal preventing bacterial contamination/re-contamination of the root canal system. The introduction of the Thermafil system marked an important stage in the development of endodontic filling techniques [19]. Gutta-percha deposited perimetrically on special plastic carriers has been widely used. Recent advances in obturation materials introduced resins into the filling material in cones [12, 20]. Resin-bonded obturators were recently introduced to outcome thermafil in many aspects especially in apical sealing ability. RealSeal 1-bonded obturation system was designed to eliminate the potential of poor fills due to gaps in root canal fillings. It uses Resilon as the filling material coating the outside of the core and heated by a proprietary oven in conjunction with self-etching, resin-based sealer which eliminates the priming step of the original system. This study was undertaken to assess a comparative sealing ability analysis of two carrier-based filling methods.

Many laboratory testing techniques were developed to evaluate the sealing ability of root fillings: dye penetration, fluid transport, and cross-section analyses, etc [21, 22]. All had the limitation of measuring voids by analysis of sectioned roots and digital imaging software [23–26]. This might not be accurate because some filling material might be lost in the process [12] and they all give only bidimensional picture of the material adaptation at the dentinal walls.

High-resolution micro-CT is an emerging technology with several promising applications in many different fields of dentistry [27] and endodontics [28, 29]. Its use has increased dramatically during the past two decades [30]. 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 [30]. This study is considered to be among the firsts very few to use micro-CT to measure percentage of volume of voids or gaps in the root canal with a resolution <4 μm and with a relatively numerous samples (27 teeth per group, total number of teeth=54) comparatively with other micro-Ct scan studies [2, 14, 30]. A previous study [19] showed that 3D reconstruction of the root canal filling is possible. In addition, high-resolution scanner was used for volumetric measurements of root canal fillings [30]. Using a micro-CT is a precise, highly accurate, and nondestructive method for in vitro evaluation of root canal fillings [2, 14, 27]. It was previously validated by a high correlation between micro-CT images and histological cross-sections of filled roots [14]. Carrier-based root fillings, in particular, have a mean sealer thickness of 2 μm, considerably less than the 7-μm resolution capability of the micro-CT scanner. This may explain why in the majority of Thermafil obturators fillings sealer was indistinguishable from gutta-percha. This is similar to previous micro-CT studies [2, 14, 31], sealer and core material, gutta-percha [2, 14], or RealSeal 1 [31] were analyzed as a single root-filling entity. In this study, interfaces were not subject to analysis because of the possible risk of artifacts due to dehydration with the hours-long scan times. This is in agreement with the finding of previous studies [2, 32] on micro-CT for visualization of root canal obturation materials.

Student *t* test was performed to explore significant difference between groups at a 5 % significance level. None of the tested materials provided a gap-free or void-free root canal filling.

This finding was consistent with previous studies [23, 30]. The null hypothesis was confirmed. Thermafil exhibited the same percentage of voids and gaps in the root sections as RealSeal 1. The biggest amount of voids and gaps was found in the apical last millimeters. Better results with both techniques were found at 3- and 5-mm sections from apex. The good adaptation of Thermafil fillings at all canal levels was in agreement with the results of previously reported comparisons of carrier-based and condensed gutta-percha fillings [19]. Other studies found no significant difference in the percentage of sealer penetration in the root canal walls with both thermoplastic carriers based systems. Because the assessment in those studies was not performed by micro-CT scans, a direct comparison of their results with those of the present study was not possible. A more recent study compared Thermafil to System B [33], where assessment of the root filling was carried out by μCT, using a desktop X-ray micro focus CT scanner and no statistically significant difference was found among the groups. This finding is comparable to our results

since all techniques produced comparable results in terms of percentage of filling and void distribution.

Overall, no significant difference was found between Thermafil and RealSeal 1 concerning percentage of apical voids (P=0.166) regardless of canal level. Although more voids or gaps were obtained at 1 mm, this does not necessarily indicate it provides a better seal [28].

Within the limitations of the present study, both core-carrier-based techniques allowed a good sealing ability in root canals but none of the materials was gap free especially at 1 mm.

Results suggested that carrier-obturators filling method would merit consideration and in addition to the in vitro studies, clinical studies evaluating the different endodontic obturation systems would be beneficial.

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Conflicts of interest The authors declare that they have no conflict of interest or any financial relationship with the organizations that sponsored the research.

References

1. Huybrechts B, Bud M, Bergmans L, Lambrechts P, Jacobs R (2009) Void detection in root fillings using intraoral analogue, intraoral digital and cone beam CT images. Int Endod J 42:675–685
2. Hammad M, Qualtrough A, Silikas N (2009) Evaluation of root canal obturation: a three dimensional in vitro study. J Endod 35:541–544
3. Schilder H (1967) Filling root canals in three dimensions. Dent Clin N Am 11:723–744
4. DuLac K, Nielsen C, Tomazic T, Ferrillo P, Hatton J (1999) Comparison of the obturation of lateral canals by six techniques. J Endod 5:376–380
5. Weller RN et al (1997) A comparison of thermoplastic obturation techniques: adaptation to the canal walls. J Endod 23:703–706
6. Becker TA et al (1997) Thermafil obturation: a literature review. Gen Dent 45:46–55
7. Sutow E, Foong W, Zakariasen K, Hall G, Jones D (1999) Corrosion and cytotoxicity evaluation of Thermafil endodontic obturator carriers. J Endod 8:562–566
8. Marlin J, Schilder H (1973) Physical properties of gutta-percha when subjected to heat and condensation. Oral Surg Oral Med Oral Pathol 36:872
9. Marciano J, Michailesco PM (1989) Dental gutta-percha chemical composition, X-ray identification, enthalpic studies and clinical applications. J Endod 11:149–153
10. Shipper G, Teixeira FB, Trope M (2004) An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 30:342–347
11. Teixeira FB, Arnold R, Trope M (2005) Periapical inflammation after coronal microbial inoculation of dog roots filled with gutta-percha or Resilon. J Endod 31:91–96
12. Tay FR, Hiraishi N, Pashley DH, Loushine RJ, Weller N, Gillespie WT, Doyle MD (2006) Bondability of resilon to a methacrylate-based root canal sealer. J Endod 32:133–137
13. Kqiku L, Stadtler P, Gruber HJ, Baraba A, Anic I, Miletic I (2011) Active versus passive microleakage of Resilon/Epiphany and gutta-percha/AH Plus. Aust Endod J 37(3):141–146
14. Jung M, Lommel D, Klimek J (2005) The imaging of root canal obturation using micro-CT. Int Endod J 38:617–626
15. Dowker SE, Davis GR, Elliott JC (1997) X-ray microtomography: nondestructive threedimensional imaging for in vitro endodontic studies. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 83:510–516
16. Swain MV, Xue J (2009) State of the art of micro-CT applications in dental research. Int J Oral Sc 1:177–188
17. Farea M, Masudi S, Wan Bakar WZ (2010) Apical microleakage evaluation of system B compared with cold lateral technique: in vitro study. Aust Endod J 36:48–53
18. Whitworth J (2005) Methods of filling root canals: principles and practice. Endod Top 12:2–24
19. Lares C, Eldeeb M (1990) The sealing ability of the Thermafil obturation technique. J Endod 16:474–479
20. De-Deus G, Brandao MC, Fidel RA, Fidel SR (2007) The sealing ability of GuttaFlow in ovalshaped canals: an ex vivo study using a polymicrobial leakage model. Int Endod J 40:794–799
21. Wu M-K, van der Sluis LWM, Wesselink PR (2002) A preliminary study of the percentage of the gutta-percha-filled area in the apical canal filled with vertically compacted warm gutta-percha. Int Endod J 35:527–535
22. Goldberg F, Artaza LP, De Silvio A (2001) Effectiveness of different obturation techniques in the filling of simulated lateral canals. J Endod 27:362–364
23. Epley S, Fleischman J, Hartwell G, Cicalese C (2006) Completeness of root canal obturations: epiphany techniques versus gutta-percha techniques. J Endod 32:541–555
24. Gulsahi K, Cehreli ZC, Onay EO, Tasman-Dagli F, Ungor M (2007) Comparison of the area of resin-based sealer and voids in roots obturated with Resilon and gutta-percha. J Endod 33:1338–1341
25. Elayouti A, Achleithner C, Lost C, Weiger R (2005) Homogeneity and adaptation of a new gutta-percha paste to root canal walls. J Endod 31:687–690
26. James BL, Brown CE, Legan JJ, Moore BK, Vail MM (2007) An in vitro evaluation of the contents of root canals obturated with gutta percha and AH-26 sealer or Resilon and Epiphany sealer. J Endod 33:1359–1363
27. Nielsen RB, Alyassin AM, Peters DD et al (1995) Microcomputed tomography: an advanced system for detailed endodontic research. J Endod 21:561–568
28. Hammad M, Qualtrough A, Silikas N (2008) Three-dimensional evaluation of effectiveness of hand and rotary instrumentation for retreatment of canals filled with different materials. J Endod 34:1370–1373
29. Barletta FB, Rahde Nde M, Limongi O, Moura AA, Zanesco C, Mazocatto G (2007) In vitro comparative analysis of 2 mechanical techniques for removing gutta-percha during retreatment. J Can Dent Assoc 73:65
30. Endal U, Shen Y, Knut A, Gao Y, Haapasalo M (2011) A high-resolution computed tomographic study of changes in root canal isthmus area by instrumentation and root filling. J Endod 37:223–227
31. Zogheib C, Naaman A, Medioni E, Arbab-Chirani R (2012) Influence of apical taper on the quality of thermoplasticized root fillings assessed by micro-computed tomography. Clin Oral Investig 16 (5):1493–1498
32. Zaslansky P, Fratzl P, Rack A, Wu MK, Wesselink PR, Shemesh H (2011) Identification of root filling interfaces by microscopy and tomography methods. Int Endod J 44(5):395–401
33. Somma F, Cretella G, Carotenuto M et al (2011) Quality of thermoplasticized and single point root fillings assessed by micro-computed tomography. Int Endod J 44(4):362–369