Evaluation of Root Canal Obturation: A Three-dimensional *In Vitro* Study

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Abstract

The aim of the study was to measure percentage of volume of voids and gaps in root canals obturated with different obturation materials by using micro–computed tomography (micro-CT). Forty-eight single-rooted teeth were collected and decoronated, and root canals were prepared by using rotary files. The roots were randomly allocated into 4 groups, and each group was obturated by using cold lateral compaction with a different material (gutta-percha and TubliSeal sealer, EndoRez points and EndoRez sealer, RealSeal points and RealSeal sealer, and a gutta-percha point and GuttaFlow sealer). Roots were scanned with micro-CT, and volume measurements for voids and gaps in the obturated roots were carried out by using specialized CT software. Percentage of gaps and voids was calculated. Statistical analysis showed that gutta-percha exhibited an overall significantly lower percentage (1.02%) of voids and gaps. The present study showed that none of the root canal filled teeth were gap-free. Roots filled with gutta-percha showed less voids and gaps than roots filled with the remaining filling materials. *(J Endod 2009;■:1–4)*

Key Words

Obturation, Micro-CT, RealSeal, EndoRez, GuttaFlow

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One of the keys to successful root canal therapy is to adequately obturate the prepared root canal space (1–3). Obturation of the canal system has historically been achieved with gutta-percha and a sealer (4). Root canal obturation aims to provide a complete filling of the canal in all dimensions to create a fluid-tight seal to prevent ingress of bacteria and their toxins (4, 5) and their flow into the periapical tissues (6). Development and maintenance of the seal are essential to optimize the outcome of root canal treatment (7).

The success of a clean, well-prepared root canal system will be compromised if the root canal system is not properly obturated (1). Epley et al (1) and Schilder (8) suggested that the ideal root canal obturating material should be well-adapted to the canal walls and its irregularities and that the entire length of the canal be densely compacted with a homogeneous mass of gutta-percha.

Most root canal fillings do not completely fill the root canal system (9). Teeth with inadequate obturation, unfilled root canals, or underextended root fillings might require retreatment before coronal restoration (10). These unfilled areas might create problems because they might contain bacteria that can multiply when in contact with nutrients via the periapical region or lateral canals (11).

The material used for root canal obturations is one of the critical determinants for the success or failure of endodontic treatment (12). Lately, a number of new endodontic materials have been introduced. In 2004, a new obturation system was launched under the name RealSeal, containing Resilon and a resin-based sealer. Resilon (Pentron Clinical Technologies, Wallingford, CT) is a thermoplastic synthetic polymer-based root canal filling material. It performs in a similar manner to gutta-percha, has similar handling properties, and for retreatment purposes might be heat-softened or dissolved with solvents such as chloroform. RealSeal sealer (Pentron Clinical Technologies) is a dual curable dentin resin composite sealer (13) and might be used in conjunction with Resilon points.

EndoRez (Ultradent Inc, South Jordan, UT) is a new hydrophilic, urethane-dimethacrylate–based resin sealer that has been developed for use with a single gutta-percha cone for canal obturation (14). According to the manufacturer, EndoRez has satisfactory sealing properties and an easy delivery system (15).

GuttaFlow (Coltène/Whaledent, Altstätten, Switzerland) is a new root canal filling paste that is a modification of RoekoSeal sealer. GuttaFlow contains gutta-percha particles as filler.

The aim of this study was to investigate and measure the percentage of volume of voids and gaps in root canals obturated with different filling materials by using micro–computed tomography (micro-CT).

The null hypothesis stated that there was no difference in the percentage of volume of voids and gaps between the canals obturated with the different filling materials.

Materials and Methods

Forty-eight single-canal extracted teeth with a curvature less than 10 degrees, as determined by the technique of Schneider (16), were collected and stored in sterile water. The teeth were carefully examined. Teeth with immature apices, those that had undergone root canal treatment, or those that had root caries or restorations were excluded from the study.

Tooth Preparation

The teeth were decoronated with a diamond wheel saw to achieve a length of 12 mm. Access into the canals was carried out, and working length was determined by

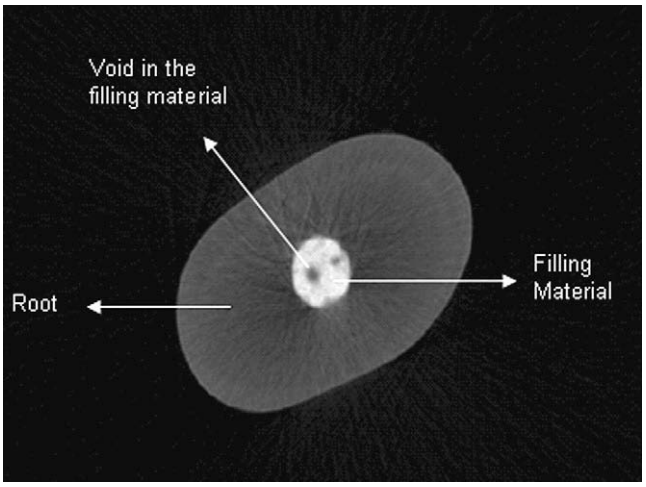

Figure 1. 2D slice showing root filling and void.

introducing a size 10 file into the canal until it exited from the apex; this length was measured, and the working length was set 1 mm short of that length. After introduction of hand files and establishment of a glide path, ProTaper (Dentsply Tulsa Dental, Tulsa, OK) files were used to clean and shape the root canal. During preparation and between each file, 1 milliliter of 0.5% sodium hypochlorite was used as an irrigant. All canals were prepared to a F3 ProTaper file.

After completion of instrumentation, all specimens received a final flush of 5 mL of 17% ethylenediaminetetraacetic acid following the manufacturer's instructions and dried with paper points.

Filling of the Root Canals

Roots were randomly allocated into 4 groups (n = 12). The first group received a root filling by cold lateral condensation technique with gutta-percha and Tubliseal (zinc oxide–eugenol based sealer; SybronEndo, Orange, CA). The second group was root canal filled by using cold lateral condensation with EndoRez points and EndoRez (resin-based sealer). The third group received a root filling by lateral condensation with Resilon points and RealSeal (resin-based sealer). The fourth group received a root canal filling by using a single gutta-percha master cone and GuttaFlow as a sealer.

All roots were stored at 37°C with 100% humidity for about 72 hours to allow the sealers to set completely. A SkyScan 1072 (SkyScan, Kontich, Belgium) 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. Each sample was scanned with a pixel size of 14.6 μm, rotational step of 0.90 degree, rotational angle of 180 degrees, and a 3.1-second exposure time. With the NRecon (Skyscan) software, images obtained from the scan were reconstructed to show 2-dimensional (2D) slices of the inner structure of the roots (Fig. 1). Finally, the CTan and CTVol (Skyscan) software was used for the 3-dimensional (3D) volumetric visualization (Fig. 2), analysis, and measurement of the volume of the root canal filling material and gaps and voids present in the canals. The percentage of voids and gaps was calculated.

One-way analysis of variance with Bonferroni post hoc test was carried out to compare the means by using SPSS software version 15 (SPSS Inc, Chicago, IL), with $P = .05$.

Results

Mean volumes (%) of gaps and voids are shown in Table 1.

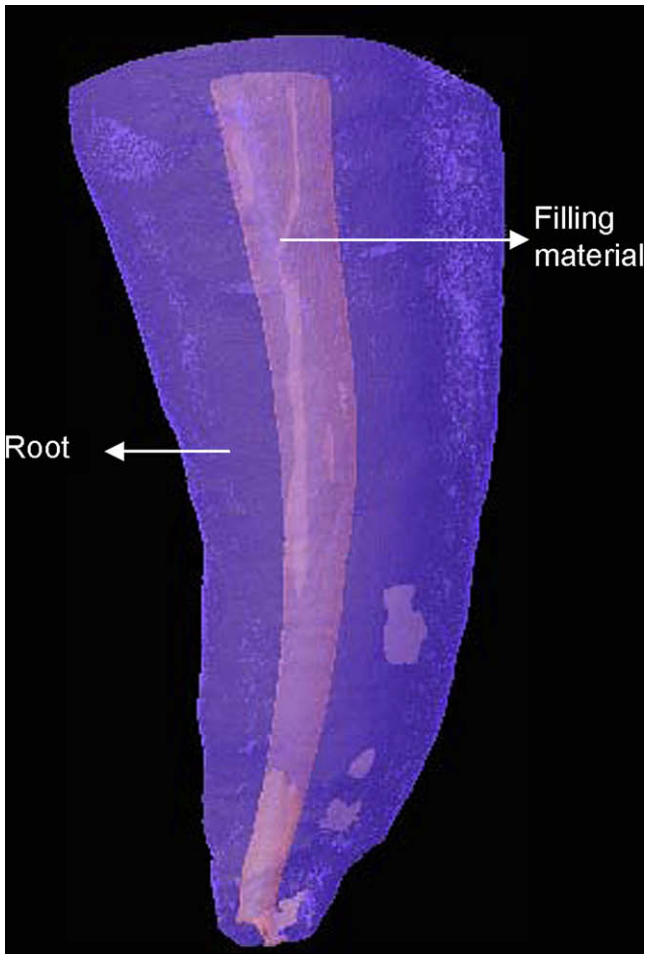

Figure 2. 3D reconstructed model of the obturated root.

Overall, canals obturated with gutta-percha showed the lowest percentage of volume of voids and gaps (1.02%), whereas those obturated with RealSeal showed the highest percentage (4.28%). The mean volume percentage of gaps and voids in root canals filled with gutta-percha was statistically significantly lower than in those filled with the remaining filling materials.

In the coronal third, root canals obturated with gutta-percha showed the lowest percentage of volume of voids and gaps (1.1%), whereas canals obturated with GuttaFlow showed the highest percentage (4.8%). The mean volume percentage of gaps and voids in canals filled with gutta-percha was statistically significantly lower than in those filled with EndoRez and GuttaFlow.

In the middle third, canals obturated with gutta-percha showed the lowest percentage of volume of voids and gaps (0.8 %), whereas canals obturated with RealSeal showed the highest percentage (4.2%). The mean volume percentage of gaps and voids in root canals filled with gutta-percha was statistically significantly lower than in canals filled with EndoRez and RealSeal.

In the apical third, canals obturated with GuttaFlow showed the lowest percentage of volume of voids and gaps (1.5%), whereas those obturated with RealSeal showed the highest percentage (7.5%). The mean volume percentage of gaps and voids in root canals filled with RealSeal was statistically significantly higher than in root canals filled with gutta-percha and GuttaFlow. There was no statistically significant difference in the mean volume of gaps and voids between root canals filled with gutta-percha and GuttaFlow.

TABLE 1. Means and Standard Deviations of Percentage of Voids and Gaps (%) in the Root Canal Filled Teeth

Group	Overall	Coronal third	Middle third	Apical third
Gutta-percha	1.02[a] (0.42)	1.1[a] (0.6)	0.8[a] (0.5)	1.6[a] (1.9)
EndoRez	4.10[b] (2.70)	4.4[b] (3.2)	3.9[b] (2.9)	3.3[a,b] (3.3)
RealSeal	4.28[b] (1.44)	3.1[a,b] (0.9)	4.2[b] (1.9)	7.5[b] (6.9)
GuttaFlow	3.40[b] (1.90)	4.8[b] (3.7)	3.1[a,b] (3.6)	1.5[a] (1.1)

Different superscript letters indicate statistical significance.

Discussion

Several factors contribute to the success of endodontic therapy. After an effective microbial-control phase, an adequately prepared and filled canal should contribute to a high probability of success. Gutta-percha has for many years been widely used as a solid material in root fillings associated with different types of sealers (17). Unfortunately, it does not provide chemical bonding to the root canal wall. Recent advances in obturation materials have centered on the introduction of resins into the filling material in the cones, the sealer, or both. The introduction of new materials in endodontics is facilitated by technological innovations associated with the search for higher clinical success (18). These new materials need to be carefully evaluated (19).

In an attempt to standardize the root canal dimensions, the root lengths were adjusted to 12 mm. Also, any condition that might have an effect on root canal dimensions was excluded from the study such as teeth with immature apices, that had previously undergone root canal treatment, or that had root caries. Only one operator, who had sufficient experience in root canal treatments, carried out the work. This technique was similar to that of a previous study (20). The SkyScan parameters were carefully chosen after conducting many pilot studies.

High-resolution micro-CT is an emerging technology with several promising applications in many different fields of dentistry (21) and in endodontics (20, 22), and its use has increased dramatically during the past 2 decades (23). Micro-CT has been used as a research tool in various applications. In the field of endodontic research, micro-CT technology has been used for the evaluation of root canal anatomy and assessment of root canal morphology after instrumentation (21, 24). A previous study involving the use of SkyScan 1072 (21) showed that 3D reconstruction of the root canal filling and its constituents is possible. In addition, a recent study that also used the SkyScan 1072 showed the possibility of conducting volumetric measurements of root canal fillings (20). Using a micro-CT offers the advantages of being a rapid, highly accurate, and nondestructive method for *in vitro* evaluation of root canal fillings (21, 24).

Previous studies in this field had the limitation of measuring and calculating the percentage of surface areas of filling materials and voids by analysis of sectioned roots and analysis of digital imaging software (1, 6, 25, 26). This might not be accurate because some filling material might be lost in the process (27), and 2D techniques cannot be accurately applied to measure a 3D structure. This study is considered to be one of the first to use micro-CT to measure percentage of volume of voids and gaps in the root canal.

Tests of normality conducted on the results showed normal distribution of data that warranted the use of one-way analysis of variance parametric test. None of the tested materials provided a gap-free or void-free root canal filling. This finding was consistent with previous studies (1, 6, 25, 26, 28). The null hypothesis was rejected. Overall, teeth obturated with gutta-percha and TubliSeal showed the lowest percentage of voids and gaps when compared with the remaining filling materials tested. This might be explained by a recent study that showed that gutta-percha expands in the presence of eugenol in the short term (after 24 hours) and in the long term (4), which might lead to less gap and void formation in the canal. In addition, resin-based sealers showed polymerization shrinkage (29), which might lead to gap and void formation in the canal. Although GuttaFlow is known to expand slightly while setting (29), it showed gaps and voids. That might be explained by the filling technique used. The use of a single-cone filling technique is often considered inferior to the more sophisticated 3D compaction techniques, because the volume of sealer is high relative to the volume of the cone, which promotes void formation and reduces the quality of the seal (9, 30).

Gutta-percha exhibited the lowest percentage of voids and gaps in the root sections except at the apical third where GuttaFlow showed the lowest gaps and voids. This also can be attributed to the filling technique, because the manufacturers of GuttaFlow recommend that it is dispensed first in the apical part of the root canal, and then a master gutta-percha cone is placed. This ensures the least amount of voids and gaps in the apical third.

The legitimate question to be raised here would be whether gutta-percha associated with TubilSeal provides a better seal and resistance to leakage than the remaining tested filling materials. Various studies have reported different leakage results. Some studies showed that GuttaFlow showed better resistance to leakage than gutta-percha (9, 30). Some other studies showed that RealSeal showed better resistance to leakage than gutta-percha (12, 13, 31, 32), whereas others showed RealSeal to be similar or inferior to gutta-percha (7, 33).

Most of the studies that compared the microleakage of gutta-percha with any other filling material used AH 26 or AH Plus (resin-based sealers; Dentsply International, York, PA) as the sealer of choice associated with gutta-percha. Both sealers do not contain eugenol. Although this study showed roots filled with gutta-percha and TubliSeal to have less voids and gaps than the other filling materials, this does not necessarily indicate it provides a better seal. RealSeal and EndoRez provide chemical bonding to the root canal that can be a factor as important in resistance to leakage as percentage of voids and gaps. Also in the long term, TubliSeal is soluble in tissue and oral fluids, which might compromise the seal (2), whereas GuttaFlow is insoluble in tissue and oral fluids (34).

Obturation technique used in this study was the cold lateral compaction technique, because the EndoRez obturation system can only be obturated with this technique. It would be beneficial to carry out tests comparing different obturation techniques.

This present study showed that none of the tested filling materials provided a gap-free or void-free root canal filling, and that gutta-percha used with TubliSeal exhibited less voids and gaps than the other tested materials. In addition to the *in vitro* studies, clinical studies evaluating the different endodontic obturation systems would be beneficial (12).

References

1. Epley SR, Fleischman J, Hartwell G, Cicalese C. Completeness of root canal obturations: Epiphany techniques versus gutta-percha techniques. J Endod 2006;32:541–4.
2. Wu MK, Fan B, Wesselink PR. Diminished leakage along root canals filled with gutta-percha without sealer over time: a laboratory study. Int Endod J 2000;33:121–5.
3. da Silva Neto UX, de Moraes IG, Westphalen VP, Menezes R, Carneiro E, Fariniuk LF. Leakage of 4 resin-based root-canal sealers used with a single-cone technique. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:e53–7.

4. Michaud R, Burgess J, Barfield R, Cakir D, McNeal S, Eleazer P. Volumetric expansion of gutta-percha in contact with eugenol. J Endod 2008;34:1528–32.
5. Ozok AR, van der Sluis LW, Wu MK, Wesselink PR. Sealing ability of a new polydimethylsiloxane-based root canal filling material. J Endod 2008;34:204–7.
6. James BL, Brown CE, Legan JJ, Moore BK, Vail MM. 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 2007;33:1359–63.
7. Paque F, Sirtes G. Apical sealing ability of Resilon/Epiphany versus gutta-percha/AH Plus: immediate and 16-months leakage. Int Endod J 2007;40:722–9.
8. Schilder H. Filling root canals in three dimensions. J Endod 2006;32:281–90.
9. Kontakiotis EG, Tzanetakis GN, Loizides AL. A 12-month longitudinal in vitro leakage study on a new silicon-based root canal filling material (Gutta-Flow). Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:854–9.
10. Lin ZM, Jhugroo A, Ling JQ. An evaluation of the sealing ability of a polycaprolactone-based root canal filling material (Resilon) after retreatment. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;104:846–51.
11. van der Sluis LW, Wu MK, Wesselink PR. An evaluation of the quality of root fillings in mandibular incisors and maxillary and mandibular canines using different methodologies. J Dent 2005;33:683–8.
12. Bodrumlu E, Tunga U. Coronal sealing ability of a new root canal filling material. J Can Dent Assoc 2007;73:623.
13. Shipper G, Orstavik D, Teixeira FB, Trope M. An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon). J Endod 2004;30:342–7.
14. Kardon BP, Kuttler S, Hardigan P, Dorn SO. An in vitro evaluation of the sealing ability of a new root-canal-obturation system. J Endod 2003;29:658–61.
15. Sevimay S, Kalayci A. Evaluation of apical sealing ability and adaptation to dentine of two resin-based sealers. J Oral Rehabil 2005;32:105–10.
16. Schneider S. A comparison of canal preparations in straight and curved root canals. Oral Surg 1971;32:271–5.
17. Teixeira FB, Teixeira EC, Thompson JY, Trope M. Fracture resistance of roots endodontically treated with a new resin filling material. J Am Dent Assoc 2004; 135:646–52.
18. De-Deus G, Brandao MC, Fidel RA, Fidel SR. The sealing ability of GuttaFlow in oval-shaped canals: an ex vivo study using a polymicrobial leakage model. Int Endod J 2007;40:794–9.
19. Pereira Cda C, de Oliveira EP, Gomes MS, et al. Comparative in vivo analysis of the sealing ability of three endodontic sealers in dog teeth after post-space preparation. Aust Endod J 2007;33:101–6.
20. Hammad M, Qualtrough A, Silikas N. Three-dimensional evaluation of effectiveness of hand and rotary instrumentation for retreatment of canals filled with different materials. J Endod 2008;34:1370–3.
21. Jung M, Lommel D, Klimek J. The imaging of root canal obturation using micro-CT. Int Endod J 2005;38:617–26.
22. Barletta FB, Rahde Nde M, Limongi O, Moura AA, Zanesco C, Mazocatto G. In vitro comparative analysis of 2 mechanical techniques for removing gutta-percha during retreatment. J Can Dent Assoc 2007;73:65.
23. Huumonen S, Kvist T, Grondahl K, Molander A. Diagnostic value of computed tomography in re-treatment of root fillings in maxillary molars. Int Endod J 2006;39:827–33.
24. Bartletta F, Reis M, Wagner M, Borges J, Dall'Agnol C. Computed tomography assessment of three techniques for removal of filling material. Aust Endod J 2008;34:102–5.
25. Gulsahi K, Cehreli ZC, Onay EO, Tasman-Dagli F, Ungor M. Comparison of the area of resin-based sealer and voids in roots obturated with Resilon and gutta-percha. J Endod 2007;33:1338–41.
26. Elayouti A, Achleithner C, Lost C, Weiger R. Homogeneity and adaptation of a new gutta-percha paste to root canal walls. J Endod 2005;31:687–90.
27. Barletta F, Reis M, Wagner M, Borges J, Dall'Agnol C. Computed tomography assessment of three techniques for removal of filling materials. Aust Endod J 2008;34: 101–5.
28. Jarrett IS, Marx D, Covey D, Karmazin M, Lavin M, Gound T. Percentage of canals filled in apical cross sections: an in vitro study of seven obturation techniques. Int Endod J 2004;37:392–8.
29. Hammad M, Qualtrough A, Silikas N. Extended setting shrinkage behavior of endodontic sealers. J Endod 2008;34:90–3.
30. Bouillaguet S, Shaw L, Barthelemy J, Krejci I, Wataha JC. Long-term sealing ability of Pulp Canal Sealer, AH-Plus, GuttaFlow and Epiphany. Int Endod J 2008;41: 219–26.
31. Wedding JR, Brown CE, Legan JJ, Moore BK, Vail MM. An in vitro comparison of microleakage between Resilon and gutta-percha with a fluid filtration model. J Endod 2007;33:1447–9.
32. Aptekar A, Ginnan K. Comparative analysis of microleakage and seal for 2 obturation materials: Resilon/Epiphany and gutta-percha. J Can Dent Assoc 2006;72:245.
33. Raina R, Loushine RJ, Weller RN, Tay FR, Pashley DH. Evaluation of the quality of the apical seal in Resilon/Epiphany and Gutta-Percha/AH Plus-filled root canals by using a fluid filtration approach. J Endod 2007;33:944–7.
34. Donnelly A, Sword J, Nishitani Y, et al. Water sorption and solubility of methacrylate resin-based root canal sealers. J Endod 2007;33:990–4.