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Quality of thermoplasticized and single point root fillings assessed by micro-computed tomography

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Abstract

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Aim To evaluate *ex vivo* 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 μCT analysis.

Methodology A total of 30 freshly extracted human single-rooted permanent teeth were selected. Root canals were prepared with ProTaper Universal instruments and then randomly divided into three groups ($n = 10$) depending on the filling technique. In group 1, canals were filled with a single-point technique; group 2 was filled with Thermafil; in group 3 System B was used. In group 1 and group 3, the root filling was performed using ProTaper Universal gutta-percha points, in group 2 Thermafil obturators were used; AH-Plus sealer was used in all groups. Assessment of the root filling was carried out by μCT, using a desktop X-ray micro focus CT scanner. Percentage of root canal filling materials and voids was calculated for each specimen. Data were statistically analysed using Kruskal–Wallis test ($P < 0.05$).

Results Mean percentages of filling materials were 98.379 ± 1.204 in the single-point group, 99.023 ± 1.457 in Thermafil group, and 98.167 ± 3.432 in System B group. No statistically significant difference was found amongst the groups.

Conclusion All techniques produced comparable results in terms of percentage of filling and void distribution.

Keywords: endodontics, micro-computed tomography, root canal treatment.

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Introduction

Several methods of evaluating root fillings have been described using extracted teeth, including complete dissolution of teeth in acid (Bryton *et al.* 1973), longitudinal (ElDeeb 1985) or cross (Limkangwalmongkol *et al.* 1991) sections of the root surface, SEM observation of the interface between the gutta-percha and the dentinal walls (Mannocci *et al.* 1998). However, many of these procedures allow only partial evaluation of root fillings and some may create irreversible damage. Moreover, many laboratory and clinical studies comparing several filling techniques using different methodological approaches have produced contrasting results (Al-Dewani *et al.* 2000, Abarca *et al.* 2001, Goldberg *et al.* 2001, Pommel & Camps 2001, Gençoglu *et al.* 2002, Hoskinson *et al.* 2002, Jacobson *et al.* 2002, Maden *et al.* 2002, Friedman *et al.* 2003, Chu *et al.* 2005, Yucel & Ciftci 2006, Perez Heredia *et al.* 2007).

An ideal experimental model should allow the preservation of sample integrity to avoid irreversible structural damage. A noninvasive technique has been introduced and has gained increasing popularity in the study of hard tissues, namely, X-ray computed transaxial microtomography, or μCT (Elliott & Dover 1984,

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Huiskes *et al.* 1987, Kuhn *et al.* 1990, Fyhrie *et al.* 1995, Davis & Wong 1996, Ruegsegger *et al.* 1996, Muller & Ruegsegger 1997, Van Rietbergen *et al.* 1998, Hara *et al.* 2002). The feasibility of clinical μCT studies of human teeth was suggested initially by Tachibana & Matsumoto (1990) and has been used to measure enamel thickness (Spoor *et al.* 1993), area and volume of root canals in teeth (Nielsen *et al.* 1995, Dowker *et al.* 1997, Bjorndal *et al.* 1999, Peters *et al.* 2000, Suto *et al.* 2002, Oi *et al.* 2004), root canal instrumentation techniques (Gambill *et al.* 1996, Rhodes *et al.* 1999, Bergmans *et al.* 2001, 2002, 2003, Peters *et al.* 2001a,b, 2003, Hubscher *et al.* 2003).

The aim of this study was to evaluate and compare the voids in root fillings in extracted teeth with μCT using two thermoplasticized gutta-percha techniques (Thermafil and System B) versus cold gutta-percha (single point) technique. The null hypothesis was that there is no significant difference amongst the three techniques regarding the volume and distribution of voids.

Materials and methods

Thirty straight single-rooted permanent teeth were selected from a pool of freshly extracted teeth. The patients were 51–63 years old and needed tooth extraction for periodontal reasons. After an examination under a stereomicroscope at 12× magnification (Stemi SV6; Carl Zeiss, Oberkochen, Germany), only those teeth with a fully formed apex were selected; roots with resorption, defects, fractures or open apices were excluded. The teeth were then initially placed in a 5.25% sodium hypochlorite solution for 2 h to remove the periodontal ligament. Later, all the remaining soft and hard aggregations were removed with a scaler. The teeth were then washed under running water and stored in 0.2% solution of sodium chloride and thymol.

Radiographs were taken using a digital sensor (version 2.6; CDR-Schick Technologies Inc., Long Island City, NY, USA) in bucco-lingual (BL) and mesio-distal (MD) directions to evaluate the root canal anatomy and to identify the radiographic apex. Teeth with anomalies of endodontic anatomy and/or an excessively wide canal were excluded.

The crown of each tooth was sectioned 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 size 10 K-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 with a stereomicroscope and subtracting 0.5 mm. Canal shaping was performed with a crown-down technique using ProTaper Universal and Pathfiles Nickel-Titanium rotary instruments (Dentsply Maillefer, Ballaigues, Switzerland) (Table 1).

During instrumentation, constant irrigation of the root canals was performed with 2.5 mL 5.25% sodium hypochlorite (NaOCl). All samples were finally irrigated with 5 mL 17% EDTA (Pulpdent, Watertown, MA, USA) for 120 s, followed by 5 mL 5.25% NaOCl and copious rinsing with physiological solution. The canals were dried with sterile ProTaper paper points. Before root canal filling, the samples were randomly assigned to three groups (n = 10) according to the filling technique used.

Group1: Single-point technique. A ProTaper gutta-percha master point corresponding to the final instrument was chosen. Canal walls were covered with AH-Plus sealer (Dentsply DeTrey GmbH, Konstanz, Germany) using a paper point; the apical portion of the gutta-percha master cone was coated with sealer before insertion into the canal. After radiographic control, the excess of gutta-percha and sealer was removed with a hot instrument.

Table 1 Canal shaping procedure

Step	Description
1	Manual root canal scouting with size 10 and size 15 K-files
2	Shaping file SX used in a brushing back motion to create straight-line access to coronal orifice
3	Check the working length using size10 K-file
4	Shaping files S1 and S2 with brushing action designed for coronal and middle third enlargement with recapitulations with size 10 K-file
5	Preflaring the apical third with Pathfiles with size 13, size 16 and size 19
6	Apical foramen gauging using the largest K-file reaching the apical constriction
7	Use Finishing File F1, F2 and F3 to working length in an ‘in and out’ action

Group2: Thermafil obturation system. According to the manufacturers (Dentsply Tulsa Dental Specialities, Tulsa, OK, USA) instructions, a ProTaper Obturator corresponding to the final Finishing instrument used was selected. After checking the adaptation of the selected carrier with the correspondent Verifier file (Dentsply Tulsa), at 0.5 mm from the working length, a paper point was coated with AH-Plus sealer to smear the root canal. The Obturator was placed into Therma-prep Plus oven (Dentsply Tulsa Dental Specialities) and inserted to working length with light steady pressure and with a 1/4 clockwise turn rotating motion. After radiographic control, the handle of the Obturator was removed with a round diamond bur.

Group3: Continuous Wave of Condensation technique (System B; SybronEndo Corp., Orange CA, USA). A System B heating tip (XF or F Buchanan pluggers; SybronEndo Corp.) was selected to fit 3–4 mm short of the working length without binding on the canal walls. This depth was marked using a rubber stopper at the reference point. A ProTaper gutta-percha master point corresponding to the final instrument was inserted 0.5 mm short of working length and adjusted with a scalpel until tug-back was achieved. The point was extracted, its tip was covered with AH Plus sealer and then it was reinserted in a pumping motion. The System B heat source was set at 200 °C and full power mode; the switch was placed on touch mode. The activated plugger was driven through the gutta-percha master point with a slow motion to 1 mm before the rubber stopper reached the reference point. The power was then deactivated and the plugger pushed apically for 10 s. A further 1-s touch of heat was applied and the plugger extracted. Once the excess gutta-percha was removed from the canal walls, backfill of the middle and coronal thirds was performed. A backfilling gutta-percha point was trimmed to achieve tug-back at the level reached by the plugger, which was reinserted with a 1-s activation at a lower temperature (100 °C) to half the previous length in order to stabilize the backfilling point. The temperature was set again to 200 °C, and the coronal portion of the point was heated and condensed with the plugger. The backfilling procedure was repeated to fill the entire canal.

μCT analysis of the samples

The qualitative analysis of the root canal fillings was carried out with the aid of μCT. A custom-designed specimen holder for the micro-computerized tomography (μCT) was made to fit the specimen with the crown positioned downwards and its long axis perpendicular to the floor of the specimen holder of the MCT and the X-ray source. The analysis of each sample consisted of two stages and required approximately 4 h to complete one scan: 2 h for scanning procedure, and 2 h for the reconstruction procedure.

The samples were scanned using a desktop X-ray microfocus CT scanner (SkyScan 1072; SkyScan, Kartuizersweg, Belgium), and the scanning procedure was completed using 10 W, 100 kV, 98 μA, a 1-mm-thick aluminium plate, and ×15 magnification with 5.9 s exposure time and 0.45° rotation step, resulting in a pixel size of 19.1×19.1 μm. The acquisition procedures consisted in the attainment of several 2-dimensional lateral projections of the specimens during a 180° rotation around the vertical axis. The digital data were further elaborated by reconstruction software (NRecon V1.4.0; SkyScan) providing new axial cross sections with a pixel size of 19.1 μ× 19.1 μm. The distance between each cross section was 38.0 μm. The cross sections were collected by sample, and after cone-beam reconstruction the raw data were converted to 16-bit-greyscale picture files with a resolution of 512×512 pixels. Using a computer software analysis system (μCT-Analyser V1.9; SkyScan), all the files of each sample were resliced stepwise using a slice spacing factor of 2 in vertical cross section. These data were then stored for later use. After completion of the scanning procedure, the samples were replaced in the saline solution.

The μCT has been used to quantify (mm^3):

- the canal volume, considering a standard range of analysis of 10 mm from the end point of the root filling for all the samples;
- the root-filling volume, defined as the volume sum of the gutta-percha, the endodontic sealer and the Thermafil carrier in group 2;
- the volume of the voids distributed (i) inside the filling material (internal voids), (ii) along the canal walls (external voids) and (iii) into the materials communicating with the canal walls (combined voids) (Fig. 1).

The percentage of root canal filling and of voids was calculated. For the calculation of the histomorphometric parameters (including those listed above), the greylevel image was segmented into a material and nonmaterial (void). This process, also called 'binarization' or 'thresholding', entails choosing the range of grey levels necessary to obtain an image composed only of black and white pixels. The global threshold method

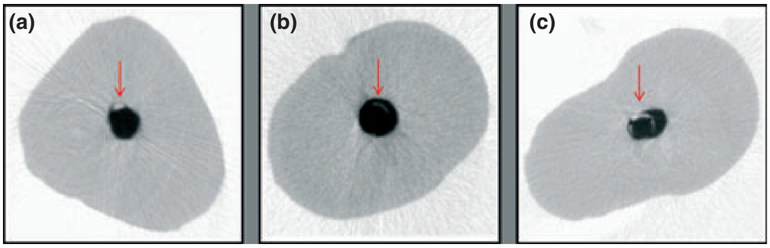

Figure 1 Classification of voids after canal filling: external (a), internal (b) and combined (c) void, indicated by arrow.

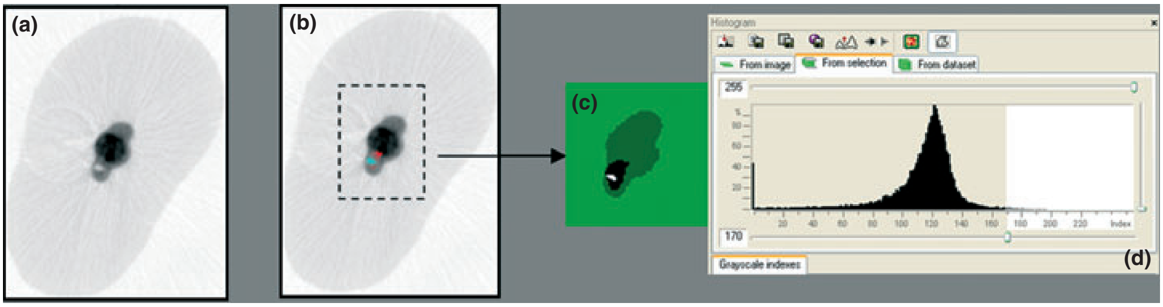

Figure 2 Example of internal void (a); selection of region of interest that is in this case a void (b); image binarized (c) by a greylevel histogram (d).

Table 2 Mean values ± SD of the filling and voids volume

Group	Root filling (%)	Internal voids (%)	External voids (%)	Combined voids (%)
Single cone	98.379 ± 1.204	0.322 ± 0.627	0.748 ± 1.025	0.550 ± 0.987
Thermafil	99.023 ± 1.457	0.218 ± 0.651	0.485 ± 0.636	0.273 ± 0.864
System B	98.167 ± 3.432	0.059 ± 0.141	0.945 ± 2.693	0.828 ± 2.534

is widely used and needs only one parameter (i.e. the greylevel value) to be set by the user; this method was used for the binarization of the reconstructed images (software 'CT-Analyser' ver. 1.9; Skyscan). In the example represented in Fig. 2, the grey level image has been segmented, with the binarized image composed of only black pixels (material) and white pixels (void). Separately and for each slice, regions of interest were chosen to each contain one single object entirely to allow the calculation of the respective volumes (canal volume, filling volume and voids volume).

Data analysis

The Statistical Package for Social Sciences Software 13.0 for Windows (SPSS Inc., Chicago, IL, USA) was used for data analysis. After testing for the normality of the data, by a Shapiro–Wilk test and Q-Q normality plots, and the equality of variance amongst the data sets using a Levene test, nonparametric methods were chosen. The significance of the differences amongst the groups in percentage of canal filling and voids was assessed by Kruskal–Wallis test and Mann–Whitney *U* test with Bonferroni adjustment. A *P* value <0.05 was used in the rejection of the null hypothesis.

Results

Mean percentage values ± SD of filling materials and voids are summarized in Table 2. All filling techniques demonstrated good filling ability. No statistically significant difference was found in percentage of filling material volume and void distribution.

From the visual analysis of the three-dimensional μCT reconstruction, a difference in the amount of sealer amongst the partially oval shaped and mostly round canals was detected in single-point group: a greater amount of sealer was observed in the former (Figs 3 and 4). Both Thermafil and System B techniques produced a thin sealer layer (Figs 5 and 6). Gutta-percha was always observed at the apex in the Thermafil group: the plastic carrier stopped short of the end-point (Fig. 5).

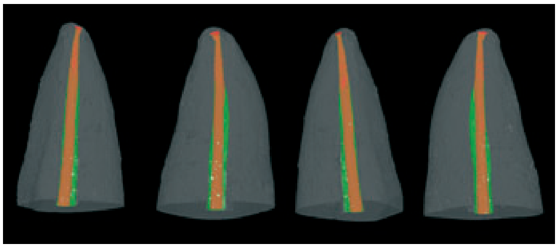

Figure 3 3D model of a sample filling using single-point technique in partially oval shaped canal observed in four projections: gutta-percha (red), cement (green) and voids (white).

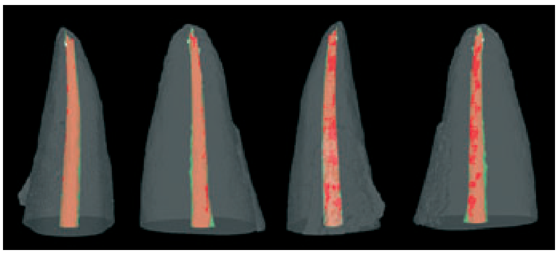

Figure 4 3D model of a sample filling using single-point technique in mostly round shaped canal observed in four projections: gutta-percha (red), cement (green) and voids (white).

Discussion

Removal of bacteria from the root canal system is not always achieved by instruments and irrigants alone, because of anatomical complexity and limitations in accessing the entire endodontic space (Kandaswamy *et al.* 2010). Remaining bacteria may continue growing in unfilled areas and possibly compromise the treatment outcome. A root filling should prevent the penetration of micro-organisms and toxins from the oral cavity via the root canal into the periradicular tissues and block the portal of exit to the periapex for organisms that, even after instrumentation and disinfection, have survived (Saunders & Saunders 1994).

Occasionally there are voids in the root filling. Voids inside filling materials (internal voids) could be considered less clinically relevant because bacteria, if present, are confined in an unfavourable environment. Voids along the canal walls (external and combined voids) 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.

Many methods have been used to investigate the sealing ability of root-filling techniques and materials. However, it has been reported. It is difficult to compare results as there is considerable variation in methodologies employed and a lack of standardized parameters evaluated (Branstetter & von Fraunhofer 1982, Wu & Wesselink 1993). Dye penetration 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 (Spradling & Senia 1982, Spangberg *et al.* 1989, Wu & Wesselink 1993).

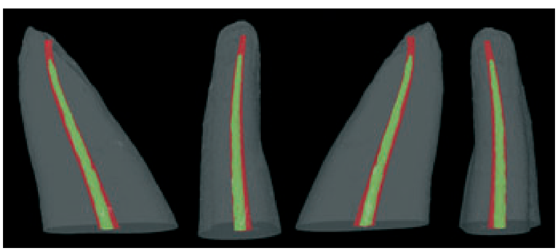

Figure 5 3D model of a sample filling using the Thermafil technique observed in four projections: gutta-percha (red), carrier (green) and voids (white).

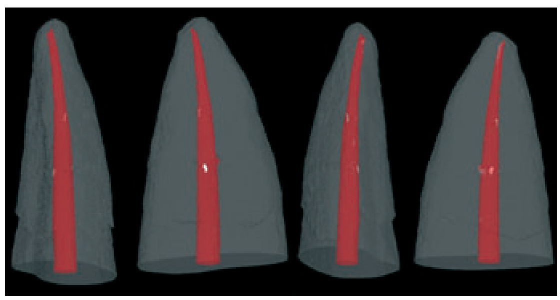

Figure 6 3D model of a sample filling using System B technique observed in four projections: gutta-percha (red), cement (green) and voids (white).

Micro CT represents a nondestructive analytical method, which provides objective data because of the elimination of artefacts. Specimens can be both quantitatively and qualitatively examined, i.e. volumes are calculated by dedicated software, whilst it is possible to localize specific details with visual image analysis. This technology is capable of distinguishing filling materials, voids and tooth structures with high accuracy and spatial resolution (Jung *et al.* 2005).

As described in the present study, in the continuous wave of condensation technique gutta-percha is thermomechanically condensed with pluggers in multiple steps and voids could be entrapped. The Thermafil technique consists of a one-step filling procedure in which thermoplasticized gutta-percha is inserted into the canal by means of a plastic carrier; insertion may create voids because of imperfect gutta-percha adaptation to canal walls or stripping from the carrier. In the single-point technique, a cold gutta-percha point is inserted into the canal and the sealer fills the irregularities. Therefore, the three techniques are inherently different and variations in the volume of voids and distribution were expected. Nevertheless, the present study showed comparable μCT results amongst the groups.

Wu *et al.* (2009) asserted that the single-point technique required a larger volume of sealer than most other compaction techniques. This is evident in irregular or oval shaped canals; in fact, in this study partially oval shaped canals filled with the single-point technique had a greater volume of endodontic sealer than round ones. Moreover, McMichen *et al.* (2003) and Garrido *et al.* (2010) demonstrated a good dimensional stability of the AH Plus sealer. The use of matched-taper gutta-percha points relies on the original canal shape and the ability to create a tapered circular preparation (Gordon *et al.* 2005). Thus, the single-point technique is simple and may be indicated in round canals teeth that have been prepared to the shape of the instruments used, (Gordon *et al.* 2005).

The Thermafil technique can carry thermoplasticized gutta-percha towards the apical portion of the canal with the filling of irregularities being enhanced (Clinton & Himel Van 2001, Gencoglu 2003, De-Deus *et al.* 2007, Ozawa *et al.* 2009). As with the single-point technique, carrier-based filling techniques are simple *(*Mirfendereski *et al. 2009)* and their application is less operator-dependent in comparison with other techniques. It is appropriate for long, curved or S-shaped canals and respects the principles of warm gutta-percha condensation with the carrier acting as a plugger, pushing the material towards the apical region. The three-dimensional observation revealed that in the Thermafil group all the samples were filled in the apical third by gutta-percha and sealer but not the carrier, thus demonstrating the efficacy of this filling technique.

Finally, the continuous wave of condensation technique produced comparable results to the Thermafil technique. However, it is a more challenging technique and requires the plugger to be inserted within 2–3 mm of the working length.

Conclusion

In the limits of the present study, no difference in terms of root canal filling ability and void distribution were found amongst the three different filling techniques. The single-point technique was more effective in narrow round canals. Further studies are needed to understand the clinical relevance of these results.

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