

Analysis of single point and continuous wave of condensation root filling techniques by micro-computed tomography

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Summary. The aim of the present microtomographic study was to investigate the quality of root canal filling and the voids formation in canals of extracted teeth instrumented with a simultaneous technique and filled with two different methods. Twenty-four single-rooted teeth were assigned to two experimental groups (no. = 12); canals were shaped with NiTi rotary files, irrigated with NaOCl and filled either with the single point (group 1) or the continuous wave of condensation technique (group 2). Specimens underwent microtomographic scanning. Collected data were statistically analyzed by nonparametric methods. Void mean percentages were found to be limited and similar between the two groups; the single point technique led to greater sealer thickness in partially oval canals.

Key words: endodontics, root canal therapy, X-ray microtomography, root canal filling materials, gutta-percha.

Riassunto (*Analisi delle tecniche di otturazione a cono singolo e dell'onda continua di condensazione tramite microtomografia computerizzata*). Lo scopo del presente studio microtomografico è analizzare la qualità dell'otturazione canalare e la formazione di vuoti in canali di denti estratti strumentati con tecnica simultanea e otturati con due diverse metodiche. Ventiquattro denti monoradicolarati sono stati assegnati a due gruppi sperimentali (n. = 12); i canali sono stati sagomati con file rotanti al NiTi, irrigati con NaOCl e otturati con tecnica del cono singolo (gruppo 1) o dell'onda continua di condensazione (gruppo 2). I campioni sono stati sottoposti a scansione microtomografica. I dati ottenuti sono stati analizzati statisticamente con metodi non parametrici. Le percentuali medie di vuoti all'interno dei canali sono risultate contenute e paragonabili tra i due gruppi; il cono singolo genera spessori maggiori di sealer in canali parzialmente ovalari.

Parole chiave: endodonzia, terapia canalare, microtomografia a raggi X, materiali di otturazione del canale radicolare, gutta-perca.

INTRODUCTION

The quality of root fillings in extracted teeth has been assessed through different experimental approaches, such as acidic dissolution of roots [1], longitudinal [2] or cross [3] sections of the sample and SEM analysis of the interface between the filling material and the canal walls [4]. Notwithstanding, only limited aspects of the filling quality can be investigated with these techniques, and many of them involve destructive processes. In addition, the results on sealing ability of various root-filling techniques reported in clinical and laboratory studies with different methodological design are inconsistent [5-12].

Ideally, the sample integrity should be respected by the experimental procedures in order to avoid structural alterations or damage. The X-ray computed transaxial microtomography, or micro-CT, represents a modern instrument for hard tissues *in vitro* investi-

gations [13-16], which is gaining popularity and might compensate for the abovementioned inconveniences. Microtomographic analysis has been employed in anatomic studies, such as the enamel thickness measurement [17], and also in endodontic science to determine the area and volume of root canals in extracted teeth [18-23] or to assess the efficiency of root canal preparation techniques [24-32]. Relatively few articles [33-38] on the quality of root canal filling assessed by micro computed tomography are available.

It has been widely debated whether warm gutta-percha compaction techniques can be considered superior to cold compaction techniques. The continuous wave of condensation is commonly considered one of the most effective root filling techniques [5, 39, 40]. However, it has been described as challenging and presenting a relatively high learning curve [35]. Moreover, it requires the plugger to be inserted

within 2-3 mm of the working length to plasticize the apical gutta-percha [41]; thus resulting in considerable vertical and lateral stress [42], which might increase the fracture risk [43]. Some Authors [44] pointed out that employing this technique in narrow canals leads to cold condensation of the apical portion of the point. The single point technique does not require compaction and is attractive because of its ease and speed of application. A recent micro-CT study [41] compared the single point technique to two warm gutta-percha techniques in canals instrumented by a crown down technique; no differences in filling ability were found amongst the three techniques. It is still unknown if similar results can be achieved with other root canal instrumentation systems.

The aim of the present microtomographic study was to evaluate the root filling quality and voids formation in extracted teeth shaped with a simultaneous technique and filled either with single point or continuous wave of condensation techniques. The null hypothesis was that there is no significant difference between the techniques considering the volume and distribution of voids.

MATERIALS AND METHODS

Twenty-four freshly-extracted single-rooted permanent teeth were collected. The patients (average age 55.5 ± 6.9 years) underwent tooth extraction for periodontal reasons. Each tooth was examined with the aid of a microscope (Stemi SV6; Carl Zeiss, Oberkochen, Germany) at $12\times$ magnifications. The presence of root resorption, fracture or any visible defect caused the tooth exclusion from the study. Preliminary direct radiographs were taken in bucco-lingual and mesio-distal direction using a digital sensor with dedicated software (CDR-Schick Technologies Inc., Long Island City, NY, USA; version 2.6) in order to verify the absence of endodontic irregularities, multiple or excessively wide canals. Root surfaces were manually scaled. Teeth were placed in a 5.25% NaClO solution for two hours to dissolve the periodontal ligament, then were copiously rinsed with tap water and finally stored in 0.2% thymol solution.

Root canal treatment

The crown of each tooth was cross-sectioned with a diamond bur and the access to the pulp chamber obtained; the patency of the apex was verified with a stainless steel size 10 K-file (Dentsply Tulsa Dental, Tulsa, OK, USA). Working length determination was performed by inserting the file until the tip of the instrument was visible at the foramen under microscope magnification and then shortening this length by 0.5 mm.

Canals were mechanically instrumented with Mtwo rotary files (Sweden & Martina, Padua, Italy) in the simultaneous technique described by Plotino *et al.* [45]. No early coronal enlargement was performed. Each

rotary file was inserted to the working length without apical pressure. Every time the operator felt a binding sensation, the file was withdrawn 1-2 mm in order to gradually and passively reach the apex in a brushing action. While rotating, the files were maintained at the working length for only 2-3 seconds. Sequence of files was: 10/.04, 15/.05, 20/.06, 25/.06, 30/.06. Apical gauging was performed by means of NiTi manual files (Dentsply Maillefer, Ballaigues, Switzerland). Canals with apical diameter greater than 0.30 mm were excluded from the experimentation.

Root canal irrigation was performed with 2.5 mL 5.25% NaClO after each instrument, with 5 mL 17% EDTA (Pulpdent, Watertown, MA, USA) for 120s after instrumentation, and finally with 5 mL 5.25% NaOCl and physiologic solution. Canals were dried with sterile paper points inserting them to working length. The instrumented canals were randomly assigned to two experimental groups (no. = 12): single point (group 1, G1) or continuous wave of condensation (group 2, G2) filling techniques.

Group 1: a paper point was used to smear the canal walls with AH Plus Sealer (Dentsply DeTrey GmbH, Konstanz, Germany). The apical portion of a Mtwo gutta-percha master point corresponding to the final rotary file was coated with the sealer; the point was inserted into the canal to the working length. A radiograph was taken to check the proper canal filling; the coronal excess of gutta-percha and sealer was removed by cutting the point at orifice level with a hot instrument.

Group 2: a System B (SybronEndo Corp., Orange CA, USA) heating unit was set at 200 °C and full power; the switch was placed on touch mode. A X-Fine or Fine System B Buchanan plugger (SybronEndo Corp.) was mounted on the device's handle and inserted to 3-4 mm from the working length without binding on the canal walls; at this level a rubber stopper was positioned to mark the coronal reference point. The tip of a Mtwo gutta-percha master point having the same taper of the final instrument was trimmed with a scalpel in order to obtain a proper tug-back at 0.5 mm from the working length. The apical portion of the master point was coated with AH Plus sealer and the point was inserted with a pumping motion to reach the established length. The plugger was activated, inserted into the canal filled with the gutta-percha point, and slowly lead to 1 mm before the rubber stopper reached the coronal reference point. The heat source was deactivated and the plugger was pushed in apical direction for 10 s. The power of the heat source was activated again for 1 s to separate the plugger from the compacted gutta-percha; then the plugger was extracted. If present, gutta-percha remnants were removed from the canal walls. In order to perform the backfill a gutta-percha point was shortened until tug-back was achieved at the depth reached by the plugger, which was reinserted to half the previous length with a 1 s activation at a lower temperature (100 °C) to achieve the backfilling point stabilization. The heat source was set again to 200 °C

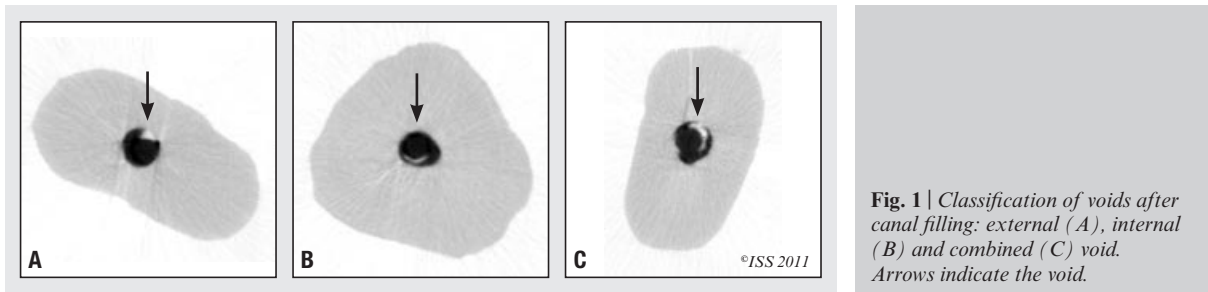


Fig. 1 | Classification of voids after canal filling: external (A), internal (B) and combined (C) void. Arrows indicate the void.

and the point compacted. The backfilling procedure was repeated until the whole canal was filled.

Micro-CT analysis of the samples

The qualitative analysis of the root-canal fillings was carried out with the aid of the micro-computerized tomography (micro-CT). A custom-designed sample holder was made ad hoc to optimize the scanning procedure to obtain valid data for the subsequent reconstruction procedure.

The samples were scanned using a SkyScan 1072 (SkyScan, Kartuizersweg 3B, 2550 Kontich, Belgium) instrument; and the scanning procedure was carried out using 10 W, 100 kV, 98 μ A, a 1-mm-thick aluminium plate, with a magnification 15 \times , 5.9 s exposure time and 0.45 $^\circ$ rotation step, resulting in a pixel size of 19.1 \times 19.1 μ m. The obtained data were processed by NRecon V1.4.0 reconstruction software (SkyScan, Kartuizersweg 3B, 2550 Kontich, Belgium). Using CT-Analyser V1.9 software (SkyScan, Kartuizersweg 3B, 2550 Kontich, Belgium), each sample were processed again according to stepwise using a slice spacing factor of 2 in vertical cross-section.

By means of micro-CT analysis has been possible to obtain the canal volume, considering a standard range of analysis of 10 mm from the end point of the root filling for all the samples. By the same analysis has been possible to obtain the root filling volume, defined as the volume sum of the gutta-percha, the endodontic sealer and the Thermafil carrier in group 2. At last by micro-CT analysis has been obtained the volume of the internal voids distributed inside the filling material, the external voids along the canal walls and the combined voids into the materials communicating with the canal walls (Figure 1). The percentages of root canal filling materials and voids were also obtained.

Histomorphometric parameters were obtained after the binarization or thresholding process, that is widely used and needs only one parameter (*i.e.* the grey level value) to be set by the user.

For each slice, regions of interest (ROI) were chosen to each contain one single object entirely to allow the calculation of the respective volumes (canal volume, filling material volume, void volume).

After scanning procedure, the samples were replaced in the saline solution.

Data analysis

Data were analyzed using the Statistical Package for Social Sciences Software 15.0 for Windows (SPSS Inc., Chicago, IL, USA). All datasets were tested for the normality of the data by the Shapiro-Wilk test and Q-Q normality plots and for the equality of variance among the datasets using the Levene test. As a result, non-parametric tests were chosen. The Mann-Whitney U test was employed to assess the significance of the differences between groups in terms of percentage of canal filling and voids. A P value less than 0.05 was regarded as statistically significant.

RESULTS

Table 1 summarizes average percentage values \pm SD of filling materials and voids. Both considered techniques demonstrated good filling ability. No statistically significant difference between the two groups was found in percentage of filling material volume and void distribution. Regarding the single-point group, analysis of the three-dimensional micro-CT reconstruction evidenced a greater amount of sealer in partially oval shaped canals than in the mostly round ones (Figures 2 and 3). Contrariwise, the continuous wave of condensation technique produced a thin sealer layer independently of the canal shape (Figure 4).

DISCUSSION

The endodontic space represents a complex structure and the access to its irregularities is often precluded; consequently, instruments and irrigants cannot always

Table 1 | Mean values \pm SD of the filling and voids volume

Group	Root filling (%)	Internal voids (%)	External voids (%)	Combined voids (%)
Single point	98.428 \pm 1.103	0.331 \pm 0.582	0.718 \pm 0.931	0.522 \pm 0.896
System B	98.393 \pm 3.151	0.094 \pm 0.167	0.807 \pm 2.457	0.706 \pm 2.311

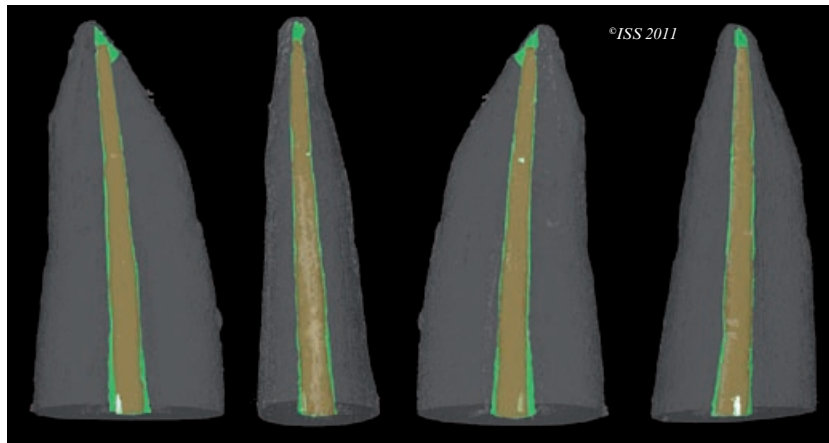


Fig. 2 | Four projections of the three-dimensional reconstruction of a representative specimen filled with single point technique presenting a mostly round canal shape. Colors legend: gutta-percha (orange), sealer (green) and voids (white).

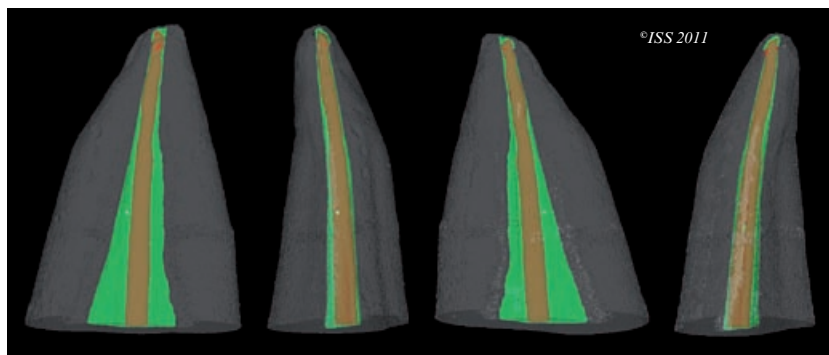


Fig. 3 | Four projections of the three-dimensional reconstruction of a representative specimen filled with single point technique presenting a partially oval canal shape. Colors legend: gutta-percha (orange), sealer (green) and voids (white).

remove bacteria from the canal walls [46]. It is well established that the outcome of the endodontic therapy may be jeopardized by bacteria colonies that remain in the canal after the treatment. The role of root canal filling is: i) to prevent leakage of oral fluids containing bacteria and their products from the oral environment to the apical periodontium through the root canal; and ii) to hinder the exit to the periapex of microorganisms that resisted to root canal disinfection and instrumentation [47].

Voids can be entrapped during root filling procedures, especially if they involve multiple steps. Voids that are not in communication with the canal walls

(internal voids) can be regarded as less dangerous for the endodontic prognosis because the bacteria they might contain are imprisoned in an unfavourable environment. Both external or combined voids constitute a gap between the filling materials and the canal walls and represent a space where bacteria can grow and leakage occur due to failure of the sealer.

Endodontic leakage studies are extremely frequent in literature and several methods have been employed to assess the sealing ability of different filling techniques. Unfortunately, a lack of standardization and substantial differences in methodological approaches have been reported and this compromises the reli-

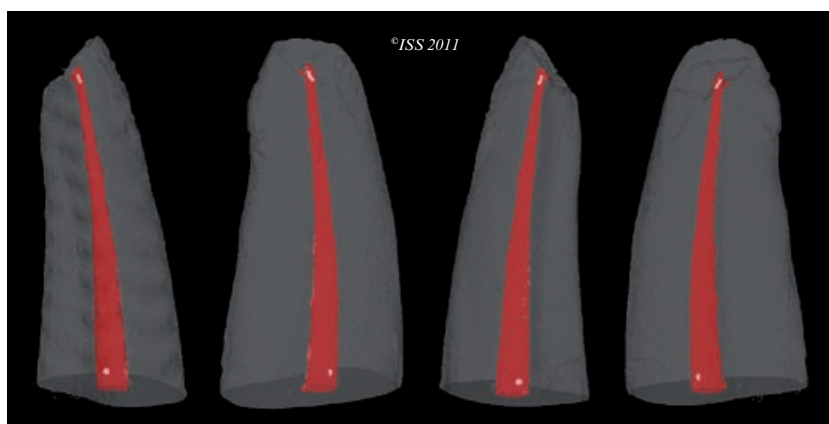


Fig. 4 | Four projections of the three-dimensional reconstruction of a representative specimen filled with System B technique. Colors legend: gutta-percha and sealer (red); voids (white).

ability of the studies and the possibility to compare their findings [48, 49]. Measurement of tracer (dye, radioisotope or other substances) penetration along root filling can be negatively influenced by several factors; as an example, the presence of entrapped air between filling material and canal walls can prevent the entrance of the tracer and lead to leakage underestimation [49, 50].

Micro-CT has the advantage of being a nondestructive method, thus the analysis can be repeated on the same specimen. Artefacts can be eliminated, hence, the data are objective and quantitative or qualitative evaluations are reliable. This technology allows the three-dimensional analysis of filling materials, voids and tooth structures with high accuracy and spatial resolution [33].

The continuous wave of condensation is a technique that theoretically allows gutta-percha thermoplasticization along the entire canal length, but it is performed in multiple steps and voids could be entrapped, especially between the down-packing and back-filling phases [35]. Single-step filling techniques, e.g. single point or carrier based systems, might obviate this problem because gutta-percha mass remains compact. As a consequence, voids can be generated mainly in the sealer and at the interface between filling materials and the canal walls. With this in mind, variations in the volume and distribution of voids were expectable. Nonetheless, the present study showed similar filling ability of the two considered techniques.

In the single point technique the major part of the endodontic space is filled with a cold gutta-percha point, while its irregularities are permeated by the sealer. The amount of sealer this technique requires was referred to be greater than in other compaction techniques [51]; this is more likely to happen in oval-shaped wide canals. This fact was observed also in our study; in fact we registered a greater volume of endodontic sealer in partially oval shaped canals than in round ones. Endodontic sealers differ in physical properties and this might be relevant in determining the sealing ability of the root filling. The dimensional stability of AH Plus sealer has been already demonstrated [52] and its application can be suggested. Similar filling ability amongst single

point, Thermafil and continuous wave of condensation techniques has been reported in a previous microtomographic study [41]: the Authors adopted a crown-down root canal shaping procedure. The results of the present study demonstrate the efficacy of the single point technique after canal instrumentation also with the simultaneous technique, which is simpler and characterized by a lower number of steps. It seems reasonable to affirm that the single point technique can be performed after different canal shaping protocols. The Authors agree with Gordon *et al.* (2005) [53], who stated that the single point technique is simple, but its application must be limited to round canals that have assumed a precise shape given by the instrumentation procedure, provided that a matched-taper gutta-percha point is available. Single point technique resembles carrier-based systems, in which an obturator is inserted into the canal to working length. The advantage of carrier-based systems is the possibility of filling the canal's apical portion with thermoplasticized gutta-percha [54, 55]. However, extrusion through the apex is possible [56, 57]; moreover, friction against the canal walls can lead to loss of gutta-percha from the carrier especially in the apical third of the narrow and curved canals [58]. On the contrary, these disadvantages are not present in the single point technique, which is extremely cheap and fast, and does not require additional devices.

CONCLUSION

Within the limitation of this study, no difference in terms of root canal filling ability and void distribution were found between the two filling techniques. The single-point technique was more effective in narrow round canals. Clinical relevance of these results has to be proved by other *in vivo* studies.

Conflict of interest statement

There are no potential conflicts of interest or any financial or personal relationships with other people or organizations that could inappropriately bias conduct and findings of this study.

Submitted on invitation.

Accepted on 19 December 2011.

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