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Evaluation of the Quality of Canal Obturation Using the Continuous Wave Method after Shaping with Different NiTi Rotary Instruments by Micro-CT

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Abstract

Objective The aim of this article was to evaluate the influence of mesial root canal preparation of mandibular molars with the reciprocal systems (RCP) and self-adjusting file (SAF) in the incidence of voids spaces in endodontic obturation performed by modified continuous wave compaction (MCWC) technique, through images obtained in micro-computed tomography (micro-CT).

Materials and Methods Mesial roots of 15 mandibular molars, with two independent root canals, were divided into three groups ($n = 5$/roots), according to the endodontic instrumentation strategy (RCP, SAF, and twisted file [TWF]). After the root canals ($n = 10$, for each instrumentation system) were filled with MCWC, images of each specimen were obtained by micro-CT followed by three-dimensional reconstruction. The percentage of voids was obtained (in mm^3) in relation of the total volume, cervical–middle, and apical thirds.

Statistical Analysis The data obtained were submitted to statistical analysis by Kruskal–Wallis and Dunn tests ($p < 0.05$).

Results With respect to the total volume of root canal, TWF demonstrated a lower percentage in comparison to SAF ($p < 0.05$). No significant difference was obtained between TWF and RCP or RCP and SAF ($p > 0.05$). In the apical third, RCP showed a smaller percentage of voids when compared with SAF ($p < 0.05$); however, TWF demonstrated similarity with RCP and SAF ($p > 0.05$). The middle–cervical third exhibited no statistically difference between TWF and RCP or RCP and SAF ($p > 0.05$), whereas TWF was lower than SAF ($p < 0.05$).

Conclusion Root canal preparation of mesial root of mandibular molars with TWF provides a lower incidence of voids in the endodontic filling performed by MCWC.

Keywords
- endodontic
- X-ray Micro-CT
- root canal filling
- root canal preparation

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Introduction

The success of endodontic treatment is based on obtaining adequate antisepsis and root canal filling, followed by dentistry rehabilitation and functional recovery of the involved tooth.[1,2] Infection control is obtained by chemical strategies using endodontic irrigation systems as solutions with antimicrobial activity and solvent of organic matter in association with mechanical endodontic instruments.[3]

However, the chemical-mechanical preparation of the root canals can be impaired by local anatomic complexity since in isthmus area the endodontic instruments do not act effectively, as well as the action of irrigation solutions, such as sodium hypochlorite, is drastically minimized.[4,5] Also, stainless steel instruments showed restriction of use, as reduced flexibility and low torsional strength, providing inadequate cleaning of the pulp cavity, especially in root canals of mandibular molars.[3–5]

Through the introduction of the endodontic nickel-titanium (NiTi) alloy, new endodontic instruments have been designed and manufactured, allowing its use in mechanically automated systems, with different types of kinematics, such as continuous or reciprocating rotation motion, in root channels with different anatomical characteristics.[2,6,7] This technology allowed to optimize the chemical-mechanical preparation phase.[8–10]

Because of the good acceptance and clinical performance of this metal alloy, endodontic instruments and/or clinical strategies have been refined leading to several mechanized instrumentation systems, such as the twisted file (TWF), Reciproc R25 (RCP), and self-adjusting file (SAF).[3,11] Different of traditional continuous mechanized rotation systems using NiTi instruments, the TWF consists of rotatory instruments subjected to torsion and a specific heat treatment, which provide satisfactory flexural strength and separation during root canal instrumentation.[1,7,8]

On the other side, the minimally invasive concept with greater preservation of the dental structure has gained attraction. Therewith, it has arisen the alternate rotatory instrumentation systems (Reciproc), with the use of an instrument that is virtually unique in the extension of instrumentation.[3,10–12] However, preparation of the root canal, mainly those of oval section and/or in areas of root isthmus can be insecure, due to the kinematics proposed for its use.[12,13]

The SAF system has been proposed to minimize this deficiency, since it consists of a single instrument associated with expandable devices, that friction with the dentin surface of the root canal, under continuous irrigation.[3,12,14] However, there is still a lack of studies evaluating its effectiveness and productivity during endodontic treatment.

Though we have observed a great technological advance in relation to instruments and techniques of endodontic instrumentation, proper modeling of the pulp cavity is crucial for endodontic filling in a more practical, reliable, and compact manner.[15,16] The modified continuous wave compaction (MCWC) technique of endodontic obturation provides a vigorous cervical-apical condensation of the gutta-percha and endodontic cement, promoting the filling of voids spaces in the root canal.[16–18] However, the quality of root canal modeling offered by instrumentation systems may have effects on the final result expected to be obtained by endodontic filling.[16]

The interaction among the type of final preparation provided by the instrumentation systems described previously and the final result proportionated by CWC can be evaluated through the incidence of voids in the root canal, after endodontic obturation, by means of micro-computed tomography (micro-CT) analysis, since it is a three-dimensional and noninvasive evaluation technique.[13,14]

Therefore, the aim of this study was to evaluate the influence of mesiobuccal root canal preparation of mandibular molars with the RCP, the SAF, and the TWF, on the incidence of voids in endodontic obturation by the MCWC technique, by analysis of images produced by micro-CT, in the cervical–middle and apical thirds or in the entire extension of the root canal. The inexistence of differences in the incidence of voids in each third or in all extension of the root canal was considered as the null hypothesis (H0).

Materials and Methods

This research study was submitted to the Ethics Committee on Human Research of Estácio de Sá University, registered and approved by this committee under protocol number CAAE 0182.0.308.000–08.

Preparation of Samples

Fifteen human mandibular molars were extracted for orthodontic or periodontal purposes, containing fully formed roots with similar internal and external root morphology, and similar crown-apical dimension. The teeth were preserved in a 10% formalin solution until the moment of use.

Coronary access has been performed with diamond burs (FG 1012; KG Sorensen, Cotia, São Paulo, Brazil), at high rotation and under continuous irrigation. Thereafter, both independent mesial canals were explored with files #10K (Maillefer Dentsply, Pirassununga, SP, BR) and after observing the two independent foramen openings, the Glyde path was performed with the file #15K (Maillefer Dentsply, Pirassununga, SP, BR), under irrigation with 5 mL of 2.5% sodium hypochlorite solution (Rioquímica, São José do Rio Preto, SP, BR).

The teeth were buccolingual sectioned using a diamond disk (Vortex, Sao Paulo, SP, BR) in the area of the pulpal chamber, under constant refrigeration. Fifteen mesial roots with two independent root canals were obtained and verified by radiographs in the mesiodistal direction. Subsequently, the total root length was determined from the mesiovestibular cusps until visualization of #15K file penetration guide, in the foraminal opening. The working length (CT) was determined at 1 mm below to the total root length.

Preparation of Experimental Groups

Fifteen mesial roots contained 30 root canals that were randomly divided into three groups ($n = 10$ root canals, in

5 roots/group) and distributed according to the root canal instrumentation protocols:

RCP (VDW, Munich, Germany): After obtaining the glide path described previously, the root canal was prepared with the RCP instrument (VDW, Munich, Germany) adapted to a specific counter-angle, activated by an electric motor (VDW, Munich, Germany) in alternative rotatory motion. The instrumentation progression was performed with discrete movements with amplitude of approximately 3 mm in the cervicoapical and apicocervical directions.

After each progression in the apical direction, the root canal was irrigated with 5 mL of 2.5% sodium hypochlorite solution (Rioquímica, São José do Rio Preto, SP, BR) using 30-gauge irrigation cannula (Navitip; Ultradent, Southern Jordan, Utah, United States) and apical patency properly verified with file #15K in exploratory endodontic movement. The instrumentation procedure was performed again until the working length was reached. The instrument was discarded after each use, and a new instrument was used in each root.

SAF (Redent-Nova; Raánana, IL): The root canal was submitted to a previous modeling until the working length, with the instrument #25/.04 (Bio RaCe BR2; FKG Dentaire; Le Crêt-du-Locle, CH) adapted to a specific low speed hand piece and an electric motor (VDW, Munich, Germany) in continuous rotation, at 600 rpm and torque of 1.5N.

Thereafter, the root canal was irrigated with 5 mL of 2.5% sodium hypochlorite solution and submitted to apical patency with #15K file. A SAF instrument of 1.5 mm diameter and 25 mm length was adapted to a RDT3 contra angle (Redent-Nova Inc; Ra'anana, IL), correctly adapted to a specific handpiece (GENTLEpower; Kavo, Biberach Riss; GE). The instrument was introduced into the root canal, the motor was started with a constant vibratory motion (5.000 vibrations/minute) and an amplitude of 0.4mm to reach the working length, with discrete movements in the cervicoapical and apicocervical directions. During preparation of the root canal, the SAF system was connected of a silicone tube to the VATEA (Redent-Nova Inc; Ráanana, IL) system irrigation that provided continuous irrigation with 2.5% sodium hypochlorite solution.

TWF (SybronEndo, Orange, CA, EUA): The root canal was instrumented, into a gradual crown down technique, by inserting files #25/.08TF, #25/.06TF and #25/.04TF adapted to the specific low speed hand piece and an electric motor (VDW, Munich, Germany), at 500 rpm and 1 N/cm^2 of torque, until the working length under continuous irrigation. After the use of each instrument, the root canal was irrigated with 5 mL of sodium hypochlorite at 2.5% and the apical patency was conferred with to the hand file #15K. The final shaping of the root canal was performed again with instrument #25/.06 at working length.

All root canals were submitted to final irrigation with 5 mL of 2.5% sodium hypochlorite, aspirated, filled with 17% EDTA (Biodinâmica, Ibiporã, PR, BR) and kept for 1 minute. Then, the root canals were irrigated again with 2.5% sodium hypochlorite, followed by suction and drying with absorbent paper points (MKLife, Porto Alegre, RS, BR).

Root Canal Filling

First, it was selected the master gutta-percha cone. In RCP, the cone system was used and for the others systems the MF cone was adapted at the working length. The root canal was filled with zinc oxide and eugenol sealer based endodontic cement (Pulp Canal Sealer; SybronEndo, Orange, CA, EUA) inserted with a Lentulo spiral (Dentsply Maillefer, Pirassununga, SP, BR).

Afterward, the master gutta-percha cone was sliced at approximately 3 mm of the working length extension with the cutting device obturation (E & Q Plus; MetaBiomed, Chungbuk, KOR). Thereafter, it was performed a vertical compaction with a gutta-percha condenser. The obturation of cervical and middle thirds of the root canal was made with thermoplasticized gutta-percha by using a thermoinjection device (E & Q Plus; MetaBiomed, Chungbuk, KOR). A new cold vertical condensation was performed after inserting 3 mm of heated gutta-percha into the root canal, as described by Buchanan[15] and Girelli et al.[16]

Incidence of Voids

The images of the specimens were obtained individually by micro-CT analysis (Skyscan 1176; Skyscan, Kontich, BE) as described by Versiani[3] to evaluate the incidence of spaces voids in the total volume and in the cervical-medial and apical thirds of the root canal obturation. The images were obtained with an isotropic voxel of 19.96 mm. The pictures were individually reconstructed using NRecon v.1.6.6.0 software (SkyScan, Konitich, BE).

Images were processed and analyzed with CTAn v.1.11.8 assistance program. Initially, it was obtained the total volume of the root canal area to be evaluated, and thereafter, the total volume of endodontic filling material present. The difference between root canal volume, and/or the third analyzed, and the volume filled by the endodontic obturation was obtained (in mm^3). The value obtained for this difference was converted into a percentage of voids space, in relation to the total volume or third under review of the root canal. Thus, the volumetric percentage of voids was obtained.

Statistical Analysis

The data were evaluated using the Kruskal–Wallis and Dunn test, with a 5% significance level. The nonparametric distribution of the results allowed the application of the Kruskal–Wallis variance analysis test. Dunn method was used for the comparison between two groups ($p < 0.05$).

Results

Total Volume Evaluation of Root Canal

The hierarchical sequence from lowest to highest incidence of spaces voids was TWF, RCP, and SAF. However, there was only a significant difference in the incidence of spaces voids between TWF and SAF ($p < 0.05$). No differences were observed in the incidence of voids between TWF and RCP or RCP and SAF ($p > 0.05$).

►**Table 1** shows the medians, maximum, and minimum values of the first and third quartile of voids incidence (in

Table 1 Median, maximum, and minimum value of the first and third quartile of the incidence of voids spaces (in percentage) in endodontic obturation, in relation to the total volume of the root canal

Third		RCP	SAF	TWF
Total	Median	7.31[ab]	9.86[b]	5.93[a]
	Vmax–Vmin	11.97–2.82	15.02–5.76	7.97–4.48
	1° e 3 ° Q	5.99–10.89	8.59–10.39	5.24–6.73

Abbreviations: Q, quartile; RCP, Reciproc; SAF, self-adjusting file; TWF, twisted file; Vmax, maximum value; Vmin, minimum value.
[a,b]Different letters on the same median line indicate significant differences in the incidence of voids spaces ($p < 0.05$).

percentage) in endodontic obturation and in relation to the total volume of the root canal, after root canal preparation with different instrumentation protocols.

►**Fig. 1** demonstrates a micro-CT image of the endodontic obturation and spaces voids within the root canal, after MCWC technique, according to the chemical–mechanical protocol used.

Evaluation of the Cervical, Middle, and Apical Third

Regarding the apical segment, RCP provided a lower incidence of voids compared with SAF ($p < 0.05$). There was no difference between TWF and RCP or RCP and SAF ($p > 0.05$). Regarding the cervical–middle third, TWF provided a lower incidence of spaces voids in the endodontic obturation compared with SAF ($p < 0.05$), but there were no differences between TWF and RCP or RCP and SAF ($p > 0.05$).

►**Table 2** shows the medians, maximum and minimum values, and the first and third quartile of the incidence of spaces voids (in percent), in the apical and cervical–middle root thirds, after root canal preparation with different instrumentation protocols.

Discussion

This study analyzed the incidence of voids in endodontic obturation performed by the MCWC technique according to different mechanized instrumentation protocols of the root canal. Based on the results obtained, the null hypothesis was rejected, as there were significant differences in the incidence of voids in endodontic obturation, after different mechanized instrumentation protocols for root canals.

The adequate chemical–mechanical preparation of the root canals is crucial for performing endodontic obturation, to provide local antisepsis and shaping of the pulp cavity.[17] With these well-executed procedures, there will be a optimization of operative procedures, preventing the formation of voids that can compromise the success of endodontic treatment.[18]

In this study, we used the mesial root canal of human extracted mandibular molars containing two independent root canals with anatomical similarity, to perform an evaluation as close as possible to the clinical situations.[8,19,20] With this methodology, it was possible to verify the direct interaction of different instrumentation protocols with the dentin substrate on the final performance of MCWC technique, through the incidence of the voids, preventing external

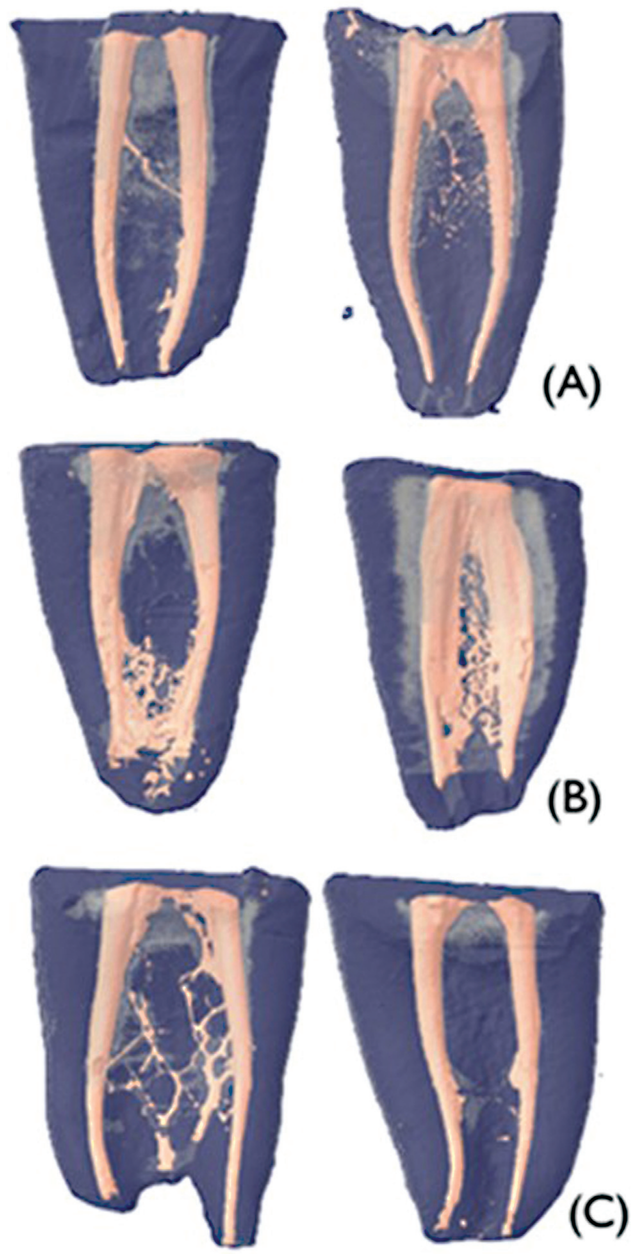

Fig. 1 Representative micro-computed tomography image of the specimens demonstrating endodontic obturation using the continuous wave compaction technique, as a function of root canal instrumentation protocols. (**A**) Reciproc protocol, (**B**), self-adjusting file protocol, and (**C**) twisted file protocol.

Table 2 Median, maximum, and minimum value of the first and third quartile of the incidence of voids spaces (in percentage) in the apical and mid-cervical segments of the radicular

Third		RCP	SAF	TWF
Apical	Median	9.70[a]	16.57[b]	11.17[ab]
	Vmax–Vmin	24.77–4.22	36.66–4.11	14.93–5.23
	1° e 3 ° Q	7.22–11.19	14.20–19.13	9.27-12.59
Cervical Medium	Median	8.36[ab]	9.07[b]	5.86[a]
	Vmax–Vmin	12.09-2.92	13.41–6.93	8.10–3.44
	1° e 3 ° Q	6.36–9.87	7.40–9.17	4.97–6.95

Abbreviations: Q, quartile; RCP, Reciproc; SAF, self-adjusting file; TWF, twisted file; Vmax, maximum value; Vmin, minimum value.
[a,b]Different letters on the same median line indicate significant differences in the incidence of voids spaces ($p < 0.05$).

interferences, such as experiments performed on resin blocks and/or similar.[7,13,21]

The images obtained in micro-CT allowed a quantitative analysis, without destruction of the sample, of the incidence of voids in obturation performed by the modified continuous wave condensation technique after shaping of the root canal by different instrumentation protocols, whereas parameters adopted for the study were obtained by a pilot study.[11,22–26]

The incidence of voids in endodontic obturation performed by CWC was lower after root canal instrumentation with the TWF protocol, when evaluated in the total volume or in the cervical–middle third of the root canal, compared with that provided by the SAF protocol. Interestingly, RCP protocol provided a smaller incidence of voids only in apical third in comparison to the SAF.

The incidence of condensation failure in endodontic obturation, interpreted as voids, is relatively frequent on account of the anatomical complexity of the pulp cavity.[25] The mechanical preparation phase aims to shape the root canal, eliminating and/or minimizing interferences that hinder access to the foraminal opening, therefore facilitating the compaction of the sealing material.[27–30]

Thus, some items may have contributed to the results of this study: 1. final shaping characteristic provided by the instrumentation protocols; 2. adaptation of gutta-percha cone in the entire root canal thirds; 3. type and interaction of the obturation technique of the cervical–middle third with the dilatation provided by the protocols and instrumentation.[3,27–30]

The incidence of voids in the endodontic obturation after preparation with the SAF protocol can be attributed to the smaller dilatation of the root canal, since the first preparation was made with the instrument #25/.04 and the final magnification provided only by abrasion of the SAF instrument on the root dentin that is relatively minimal.[29,30] Therewith, there was a greater difficulty in vertical condensation due to the lack of adaptation of the manual condensers in relation to the root canal diameter.

Conversely, the TWF protocol was finished with instrument #25/.06 and consequently in the cervical–middle third the enlargement and straightening of the root canal was greater factor that optimized the filling material condensation.[3,18,19] However, in this protocol, instruments #25/.08 and #25/.04 were also used, which may have caused similar root canal enlargement, compared with that provided by preparation with the #25/.08 alternating-rotation instrument of the RCP system, parameter that justifies the similarity of results also in the cervical–middle third.[8,9] Interestingly, also in this third, the RCP and SAF protocols provided a similar incidence of void in endodontic filling, possibly due to the lower magnification provided, but not significant compared with TWF, which was close to that of the SAF protocol.

The apical third, the RCP protocol provided the lowest incidence of voids due to the main gutta-percha cone being that of the system itself. Although Metzger et al.[29,30] observed a better adaptation of gutta-percha to the pulp cavity after instrumentation with SAF, but using the active lateral condensation technique.

The final shaping of the root canal provided by the instruments is another factor that may also have contributed to the results obtained, since the instruments were specific to each system itself. The SAF has peculiar geometrical and dynamics characteristics of operation, working mainly by an abrasive action on dentin, maintaining the original morphological characteristics of canal.[28] Contrarily, the RCP and TWF protocols have instrument taper defined, which allowed a constant and standardized enlargement along the entire length of the root canal, resulting in more uniform dilatation than the SAF system, independently of the root canal third.[24,28,30]

The previous expansion of the cervical–middle third of the root canal may have had an effect on the incidence of voids in the endodontic obturation, since when using the SAF protocol alone there is a more uniform dilatation of this third, which will lead to greater homogeneity of endodontic obturation.[5] In this study, the previous preparation with #25/.04 BioRace BR2 was performed, resulting in a larger volume to be filled by the CWC.

Despite proving doubts and opening avenues for a good clinical understanding between mechanized instrumentation protocols and CWC provided by this study, some limitations should be highlighted, such as the need for further study with a larger sample size, evaluation with other cementation and/or root canal filling strategies and with new continuous wave compaction equipment.

Conclusion

Root canal preparation of the mesial root of mandibular molars using the TWF system instrumentation protocol provides a smaller incidence of voids in endodontic obturation performed by the MCWC technique.

Conflict of Interest
None declared.

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