New Ultrasonic Tip for Root Canal Filling of the Mesial Canals of Mandibular Molars with Isthmus: A Laboratory Evaluation Using Computed Microtomography

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SIGNIFICANCE

A new ultrasonic tip was evaluated for thermoplastic root canal obturation using ultrasonic vertical condensation compared to the Continuous Wave of Condensation technique. None of the techniques completely filled the canal/isthmus of mandibular molars, however, the latter exhibited better performance.

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https://doi.org/10.1016/j.joen.2023.02.010

ABSTRACT

Introduction: The obturation quality of the mandibular molar mesial canals and isthmuses with two thermoplastic techniques, ultrasonic vertical condensation (UVC) and continuous wave of condensation (CWC), was evaluated using computed microtomography (μCT). **Methods:** Thirty-six human mandibular molars had been previously scanned and analyzed using μCT for mesial roots with morphologically similar isthmuses for this study. Coronal access and confirmation of foraminal patency were performed, and the actual length of the teeth was established using a clinical microscope (40X magnification). The canals were prepared using ProTaper Gold instruments up to #F3, with 2.5% sodium hypochlorite as the irrigant solution, followed by a passive ultrasonic irrigation protocol. The specimens were randomly divided into the UVC and CWC groups based on the obturation technique to be used. Obturation was performed with #F3 gutta-percha cones cemented using AH Plus Jet sealer. The μCT scans were performed after 15 days, and the images were evaluated by a calibrated examiner blinded to the experimental groups to determine the filling rate of the entire canal area, including the main canal and isthmus. Student's *t*-test was used for statistical analysis; *P* values $\leq$0.05 were considered significant. **Results:** Neither of the thermoplastic obturation techniques achieved complete filling of the canals (86.3% for UVC and 91.4% for CWC), with a statistically significant difference between them ($P = .029$). **Conclusions:** Under the conditions of the study, it can be concluded that none of the techniques completely filled the canal/isthmus of the mandibular molars; however, the CWC exhibited better performance. *(J Endod 2023;49:544–548.)*

KEY WORDS

Endodontics; root canal filling; ultrasonic vertical condensation; continuous wave of condensation; micro-computed tomography

The presence of isthmus as well as other anatomical variations in the root canal system (RCS) renders endodontic treatment challenging from access to obturation[1]. If not properly disinfected and filled, these anatomical variations and accessory canals can cause treatment failure[2], especially in mandibular molars, which report an 86% incidence of isthmus[3].

In numerous obturation techniques, both conventional and thermoplastic, a combination of gutta-percha and endodontic sealers is commonly used to seal the RCS[4]. In thermoplastic techniques, compaction of heated gutta-percha favors better filling rates and reduces sealer thickness[5,6]. Among these, the continuous wave of condensation (CWC) technique stands out for promoting vertical compaction of gutta-percha in the apical third of the root canals, followed by injection of heated gutta-percha and its compaction for the obturation of the remaining thirds of the root canal[7].

As in other stages of endodontic treatment, the use of ultrasonic vibration for obturation has been revisited because of the emergence of new ultrasonic tips that provide better distribution of the ultrasonic

vibrations through the filling material[8,9]. During the filling process, the heat generated by the ultrasonic tip allows controlled plasticization of the gutta-percha, yielding vertical condensation for more uniform and adapted filling, which results in efficient sealing of the RCS spaces[9-12].

The new thermosonic tip (Helse Ultrasonic, Santa Rosa do Viterbo, SP, Brazil) is used for cutting and condensing the gutta-percha and may be used with another tip to remove the excess material from the cervical third (CutCondenser; Helse Ultrasonic). These stainless steel rod-shaped instruments are 14 mm in length, 0.33 mm in diameter, with a 1.5 mm inverted taper tip of diameter 0.73 mm. These new tips can be used to fill the root canals in the thermoplasticized gutta-percha technique.

Considering the wide use of ultrasonic agitation in endodontics and the lack of studies evaluating its influence on obturation procedures, this study aimed to evaluate and compare the filling of the mesial canals of human mandibular molars with isthmus between the ultrasonic vertical condensation (UVC) and CWC thermoplastic obturation techniques using computed microtomography (μCT). The null hypothesis tested was that the UVC technique has the same filling quality as that of CWC.

MATERIALS AND METHODS

Sample Size Calculation, Tooth Selection, and Canal Preparation

The sample size was calculated based on a previous study[13] by applying an alpha error of 5%, beta power of 80%, and N2/N1 ratio of 1, which estimated that 18 specimens per group were necessary. The final number of specimens included per group was 20, considering the possible losses during the procedures. Thus, 40 mandibular molars were collected according to the protocol approved by the local research and ethics committee (approval no.: 4.538.563). The teeth were immersed in 2.5% sodium hypochlorite (NaOCl) solution for 4 hours, and the tissue remnants, calculus, and other debris were then removed using curettes. After cleaning, the teeth were washed under running water and stored in 0.01% thymol solution until further procedures.

The specimens had been previously subjected to μCT (SkySan #1174; Bruker-microCT, Kontich, Belgium) to confirm the presence of isthmuses in their mesial roots, thereby allowing categorization before randomization. The inclusion criterion was the presence of mesial roots with isthmus type VI (two different canals exiting the pulp chamber[14], merging at the cervical/middle third of the root, and dividing near the apex to end as two separate canals) or type VII (single canal leaving the pulp chamber, dividing, and then joining in the cervical/middle third of the root near the apex and dividing again into two canals). The exclusion criteria were root canals measuring <19 and >21 mm, curvature angles $<20°$ and $>30°$, or apical foramina >200 μm in diameter.

A single operator, who was previously calibrated, performed the coronal access, chemomechanical preparation (CMP), and obturation procedures under a clinical microscope (MC-M12; DF Vasconcellos, Valença, RJ, Brazil).

After coronal access, the canals were irrigated using 2.5% NaOCl (Asfer, São Caetano do Sul, SP, Brazil), and initial pulpal and debris removal was performed using K-type #08 and #10 hand files (Dentsply Sirona, Ballaigues, Switzerland). This was gradually advanced to the apical foramen using #15 and #20 K-type hand files, and the real canal length (RCL) was determined by direct visualization of the file tips through the apical foramen. The working length (WL) was obtained by subtracting 1.0 mm from the RCL.

CMP was performed using a VDW Silver motor (VDW GmbH, Munich, Germany) attached to a 6:1 contra-angle handpiece (Sirona, Bensheim, Germany) and ProTaper Gold instruments (Dentsply Sirona). After each file instrument change, recapitulation was performed to maintain the canal patency with the RCL as the apical limit using a #15 K-file and irrigation with 2.5 mL NaOCl via a disposable syringe and an open-ended 30-G irrigation needle (Endo-Eze NaviTip; Ultradent, Indaiatuba, SP, Brazil). A volume of 10 mL of NaOCl was employed for the CMP of each canal for approximately 5 min. The apical extent of irrigation needle insertion was 2.0 mm short of the WL.

The mechanical preparations were performed under continuous clockwise rotation at 300 rpm and 520 g-cm torque in the cervical and middle thirds. A 150 g-cm torque was used for the apical preparation that was extended to the WL, following the sequence recommended by the manufacturer up to the #F3 instrument.

At the end of the CMP, passive ultrasonic irrigation was performed. The irrigation protocol used 2.5 mL NaOCl for three cycles of agitation for 20 s, followed by 3.0 mL of 17% ethylenediamine tetraacetic acid for three cycles of agitation for 20 s, and final irrigation with 5.0 mL saline. Considering this additional 7.5 mL of NaOCl, a total volume of 20 mL was employed throughout the CMP. Agitations were performed both mesiodistally and buccolingually using a piezoelectric ultrasonic device (UltraWave XS; Ultradent Products Inc., Salt Lake City, USA) at 20% power equipped with an irrisonic tip (Helse Ultrasonic).

Group Allocation and Root Canal Filling

After CMP and passive ultrasonic irrigation, the specimens were scanned again to enable group allocation and ensure that the isthmuses were free of debris. Of the 40 initial specimens, 36 were randomly divided into two groups according to the obturation technique to be applied ($n = 18$/group).

Regardless of the group allocation, a single experienced operator blinded to the experimental group performed the adjustments of the gutta-percha master cones (Dentsply Sirona) by selecting them according to the diameter of the last instrument (#F3) until they were fitted at the WL. The canals were then dried using absorbent paper points (Dentsply Sirona), and AH Plus Jet sealer (Dentsply Sirona) was prepared as recommended by the manufacturer. The master cone was then coated with the sealer and inserted into the root canal.

Ultrasonic Technique

In this technique, the CutCondenser and thermosonic ultrasonic tips were used as per the manufacturer's instructions, which were activated in the UltraWave XS at 30% power without irrigation. When the gutta-percha cone was cemented, it was cut at the root canal orifice using CutCondenser. The middle and apical thirds of the cone were then plasticized by inserting the activated thermosonic in the apical direction up to 2.0 mm from the WL, with a mean activation time of 30 s; the vibration was always targeted in the buccolingual direction. Immediately after removing the tip, which was still activated, vertical condensation of the heated gutta-percha was performed using cold Schilder pluggers (Odous de Deus, Belo Horizonte, MG, Brazil) for 10 s; additional gutta-percha increments were not necessary.

CWC Technique

With the master cone properly cemented, a thermal plugger device (Fast Pack; MK Life Medical and Dental Products, Porto Alegre, RS, Brazil) set at 180°C was used to perform the downpack procedure by activating and inserting the heated plugger (#40/0.025) up to 5 mm from the WL. The heat was maintained until the desired extension was achieved.

Apical compression using the inactivated plugger was performed for 10 s to allow the plasticized gutta-percha to cool. The plugger was then reactivated and removed from the canal to remove any excess filling material. At this stage, further apical compression was performed using cold Schilder pluggers.

A backfill device (Fast-Fill; MK Life Medical and Dental Products) was used to fill the middle and cervical thirds of the root canal, enabling the insertion of thermoplasticized gutta-percha into the empty anatomical spaces left after the first phase of the technique. After the insertion of heated gutta-percha, condensation movements were performed using a cold Schilder plugger while the gutta-percha was still hot.

The pulp chambers of the specimens were cleaned and restored with glass ionomer cement, regardless of the experimental group. The specimens were then stored in an oven at 37°C and 100% humidity for 14 days.

Image Analysis

After the storage period, the teeth were scanned using μCT to acquire postobturation images by following the same parameters used in the preoperative and preobturation phases. After reconstruction of these images, the specimens were evaluated for the volume of void spaces from the canal orifice up to the WL as well as the filling of the existing isthmus.

The void volume was calculated by subtracting the volume of the filling material from that of the postinstrumentation canal, including the area of the isthmus, using the following formula: void spaces = postinstrumentation canal volume–volume of the obturation material[13].

Statistical Analysis

The images were reconstructed with the modified Feldkamp cone-beam algorithm using the NRecon software (Bruker microCT) for data acquisition. The tabulated data were subjected to normality analysis using the Shapiro-Wilk test, which revealed their parametric nature; thus, they were analyzed using the unpaired Student's *t*-test. The level of significance was set at 5%.

RESULTS

Previous statistical analyses showed no differences in the initial isthmus volumes of the teeth allocated to the experimental groups. Figure 1 displays the 3-dimensional (3D) reconstruction and cross-sections of the representative specimens from the evaluated groups. A satisfactory level of filling of the main root canals and isthmuses was observed in both groups. However, none of the evaluated techniques was able to fill the spaces between the main canals and the isthmus area completely.

Data related to descriptive and analytical statistics are presented in Table 1. The filling values were higher in the CWC group than in the UVC group (91.4% vs. 86.3%), with a significant difference between them ($P = .029$).

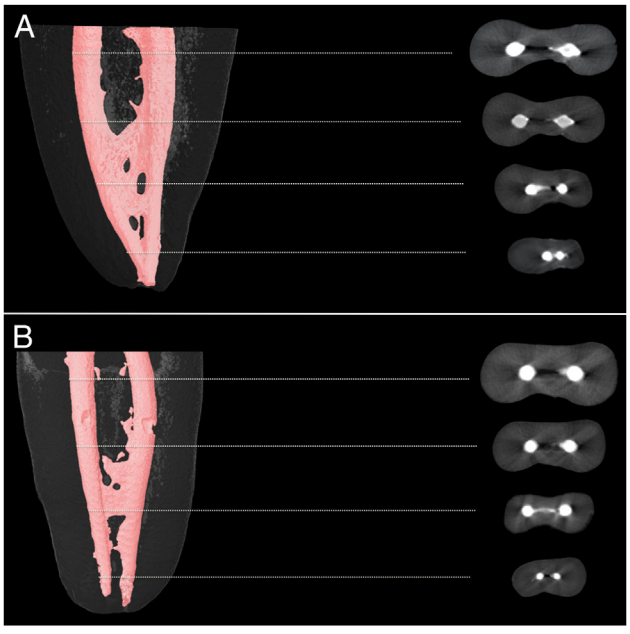

FIGURE 1 – Illustrative 3D and cross-sectional reconstructions of mesial roots filled with the two obturation techniques tested; (*A*) ultrasonic vertical condensation; (*B*) continuous wave of condensation. 3D, 3-dimensional.

DISCUSSION

In the literature, inadequate endodontic fillings have been associated with the presence of voids within the filling material and at the interface between the filling and dentin[1,15]. This could promote bacterial invasion, which could potentially lead to reinfection or persistent apical periodontitis[15]. Given the importance of adequate filling of the root space, this study aimed to compare the obturation quality of the mesial canals of the mandibular molars with isthmus between the UVC and CWC techniques. The null hypothesis was rejected because there was a significant difference between these two filling techniques.

Several studies have used mandibular molars because of their complex anatomy, underlined by the presence of an isthmus in the mesial roots, and the challenges involved in their disinfection and filling[13,16-19]. Debridement of the isthmus is one of the biggest obstacles during root canal treatment, as it often accumulates hard and/or soft tissue debris that may contain biofilms and microorganisms, which could potentially lead to treatment failure[5,18,20,21]. Moreover, their tunneled anatomy hinders the diffusion of solutions and filling material[12,22].

We chose μCT to analyze the obturation quality of the canals and isthmuses because it is a widely accepted method in the literature[1,13,23-27]. In this evaluation, the root canals were considered as a single unit, that is, not divided into thirds, an approach similar to that in previous studies[23,28,29]. The findings of this study highlight that neither technique achieved complete filling of the canals and isthmus, as was shown in previous studies[1,13,21,23,28,30].

Two thermoplasticization techniques were assessed in this study, with one based on the use of ultrasonic agitation as a source of

TABLE 1 - Mean and Standard Deviation Values Observed in the Experimental Groups Regarding Root Canal Filling After Obturation (%)

Group	*N*	Mean	*SD*
UVC	18	86.63[b]	6.39
CWC	18	91.35[a]	5.65

CWC, continuous wave of condensation; SD, standard deviation; UVC, ultrasonic vertical condensation.
Caption: [a,b] Similar superscript letters represent no statistical difference according to the Student's t-test ($P < .05$).

heat and direction for the flow of plasticized gutta-percha and the other using CWC. The first technique has been suggested as an alternative because of its low cost, elimination of the need to purchase a specific device, and simplicity, and it has been proven to be effective even in anatomically complex root canals[9,11,28]. In this technique, heating of the gutta-percha associated with the hydraulic pressure generated by vibration and subsequent condensation produces a compact obturation along the entire RCS[8,10,11]. The second technique is based on the vertical compaction of the heated gutta-percha, where the plasticization of the gutta-percha is achieved by heating a plugger and inserting it up to 4–5 mm from the WL, which guarantees homogeneous melting, followed by laterally heated gutta-percha compaction depending on the volume of the plugger. Due to the quality of the filling in terms of sealing and 3D filling and control of the apical extension with this technique, it is considered an advantageous technique[1,13,20,23,24]. However, it requires professional training and skill in addition to the acquisition of specific equipment.

As for the location of voids, it is not surprising that they were more prevalent in the areas with an isthmus, regardless of the technique employed. It is suggested that a considerable amount of dentin debris is packed into the isthmus area even after continuous irrigation during and after instrumentation[16]. The filling rates observed in this study were 86.63% with UVC and 91.35% with CWC, which were consistent with those reported in the literature, albeit slightly higher[1,23,28]. The superior results with CWC could be attributed to the higher temperature produced by the system and plugger volume, which favored greater flow of the material.

The daily challenges faced by endodontists are not restricted to the RCS anatomy; nonetheless, it arguably represents a major complicating factor in endodontic treatment. Notably, the 3D and complete obturation of the RCS, especially with an isthmus, is challenging for any obturation technique, even when thermoplastic procedures are adopted. The fact that none of the obturation techniques evaluated in this study provided void-free canal fillings further corroborates this observation. Although this was a laboratory study, even when trying to reproduce some clinical conditions, several complicating factors present in clinical practice were minimized.

Until now, information related to this UVC technique and the ultrasonic tips employed here has not been elucidated. Variables such as apical enlargement and gutta-percha volume and their relationship with gutta-percha thermoplasticization must be considered in the future. Furthermore, there is a need for further studies to determine whether changes in the protocol used in this investigation could yield better fillings as well as to assess its efficacy for different anatomies.

CONCLUSION

Under the experimental conditions in this study, we can conclude that despite being unable to fill the canals and isthmuses of the mesial roots of the mandibular molars completely, both the UVC and CWC techniques offer satisfactory fillings, with the latter exhibiting a superior performance than the former.

ACKNOWLEDGMENTS

This study was partially financed by CAPES–Brazilian Federal Agency for Support and Evaluation of Graduate Education within the Ministry of Education of Brazil.

The authors deny any conflicts of interest related to this study.

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