EGYPTIAN
DENTAL JOURNAL
www.eda-egypt.org

Vol. 70, 3847:3858, October, 2024

Print ISSN 0070-9484 • Online ISSN 2090-2360

Conservative Dentistry and Endodontics

Submit Date : 02-07-2024 • Accept Date : 22-07-2024 • Available online: 05-10-2024 • DOI : 10.21608/EDJ.2024.301189.3101

COMPUTED TOMOGRAPHIC EVALUATION OF SHAPING ABILITY OF ROTATING OR RECIPROCATING FILES THROUGH MODIFIED CONTRACTED ACCESS CAVITY

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ABSTRACT

The Aim of the present study was to compare the effect of reciprocating and rotating enlarging instruments on the shaping geometry of distal canals of mandibular molars when used in a modified contracted access cavity (CECDW).

Materials & Methods: Fifty-four mandibular molars with separate mesial and distal roots were accessed based on the CECDW design. The teeth were randomly divided into three groups (n=18) and were assigned for the preparation of distal canals using continuous rotation with OneShape or Reciprocation with Reciproc and WaveOne. Micro Computed Tomography (MCT) was utilized to compare shaping parameters: canals' volume, surface area, and stracture model index (SMI). The percentage change in volume, surface area, and canal transportation between the two groups was compared using an independent t test. The significance level was set at $P \leq 0.05$.

Results: in all tested instruments, canals' volume and surface areas showed significant increase as compared to the unprepared ones. The highest increase in both parameters was detected in WaveOne P=0.004 and P= 0.043 respectively, followed by Reciproc and OneShape in descending order. All three instruments resulted in a significantly rounder preparation compared to pre-instrumentation SMI <0.001.

Conclusions: CECDW and experimented instruments did not show significant improvement in shaping geometry of distal canals in mandibular molars. WaveOne performed significantly better than Reciproc and OneShape in respect to increasing the canals' volume and surface area. All tested instruments working through CECDW resulted in shift of the SMI towards more round preparation geometry. However, OneShape showed the best maintenance of SMI.

KEYWORDS : OneShape ; Reciproc ;WaveOne, Sructure Model Index

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INTRODUCTION

The latest trend in all dental fields is a conservative approach. Endodontic microscopes and miniature instruments have become essential in treatment protocols[1]. There have been numerous modifications to access cavities with the goal of achieving the smallest and most effective access. This enables three- dimensional cleaning, shaping and obturation of the canal space without unnecessary jeopardizing the peri-cervical dentin [2-4].

There have been numerous ex-vivo studies and clinical trials attempting to establish the feasibility of this relatively new concept but without strong evidences. One of the reported challenges associated with the contracted access certification is the compromised straight line access to the initial canal curvatures and technical incapacity for the instruments to touch canal walls circumferentially[2].This is specially declared and reported in the literature concerning the distal root canal of mandibular molars, which is associated with difficulties in achieving straight-line access through the CEC designs [4,5] and ultraconservative accesses [6] .

Berutti et al [5], suggested that altering the current shape of contracted access (CEC) could potentially improves its currently reported compromised shaping geometry. Recently, Roperto et al[7] introduced and examined a new modified-divergent walled- contracted access (CECDW) on maxillary premolar teeth was proposed and tested by. However, the tested parameter was the effect of CECDW on the biomechanical behavior of premolars. To our knowledge, the new CECDW design was not proposed before or tested on mandibular molars.

However, previous researches has demonstrated that, the design of instruments and the movement kinematics have an impact on the shaping ability of the canals by affecting the amount of untouched canal walls, and altering the original internal canal geometry. Many of these studies were conducted utilizing CBCT[8-13] or MCT [14-17], with MCT studies being considered the gold standard due to its accuracy and precision in this respect [12].

In the literature, several recent studies have focused on testing the shaping geometry of canals using CBCT in restricted, contracted accesses[5,6,19-22]. However, there has been limited number of studies reporting the use of MCT in this respect[2,5]. Many of these studies have been inconclusive, indicating the need for further research to contribute to the body of evidence.

Recently, there is an increasing ergonomic demand to minimize the number of instruments required for canals' preparation. Several recent studies have focused on examining the performance of single files through contracted accesses [14,15, 17,21]. Nonetheless, the behavior of continuous rotation or reciprocation instrumentation movement kinematic of single files through the new modified contracted accesses needs to be investigated.

Null Hypothesis:

1. The CECDW cavity design allows for comparative shaping ability of reciprocation and continuous rotation.
2. No difference between Reciproc and WaveOne reciprocating instruments or between reciprocation and continuous rotation using OneShape in canals' shaping ability.

Methodology:

Sample size calculation:

In a study conducted by Alovisi et al.,2017 (4); the sample size was calculated using G*Power 3.1.4 (Kiel University, Kiel, Germany). It was established that 18 tooth per group would be required to achieve a study power of 80% assuming a large effect size of 1 for the calculated sample size (Faul et al., 2009). Consequently, the study specified a total of fifty-four mandibular molars as a sample size.

Study design was approved by the local ethical committee at Misr University for Science and Technology-Egypt. Committee approval No. FWA00025577.

Teeth selection criteria:

Mandibular first molars were collected from a pool of freshly extracted teeth from the teeth banck at Misr University. Selection was made according to specified inclusion and exclusion criteria as follows: teeth are caries free, with mature apices, with no fused or severely curved roots, no cracks or fractures or external root resorption. Distal roots has 10–30 degrees primary curvature in the clinical mesio-distal view according to the Schneider method[17]. No internal resorption, canal calcifications, or previous RCT as confirmed radiographicaly.

Distal canals of mandibular molars (of 51 teeth) were matched -for balancing the three experimented groups based on similar macro-morphological dimensions and lengths. digital radiography was used. Accordingly, n=18 tooth for each system; namely, WaveOne ((Dentsply Maillefer, Ballaigues, Switzerland), Reciproc (VDW Munich, Germany), and OneShape (OS; Micro Méga, Besançon, France).

Teeth samples were immersed in a 0.01% solution of sodium hypochlorite (NaOCl) for half an hour then rinsed with normal saline. This was followed by gentle air drying and subjecting to pre-instrumentation baseline MCT image acquisition. Teeth were stored in saline solution during the different phases of intervention to prevent specimens' dehydration[4].

Pre-instrumentation micro CT scanning, images acquisition, study parameters calculations, and three-dimensional (3D) re-constructions:

Teeth specimens were scanned pre-instrumentation using SkyScan1172F_11MP_ Hamamatsu High Resolution MCT (Bruker).The specimens and the scanning platform, together with the scanner itself, were all marked to ensure exact repositioning of the samples pre- and post-instrumentation. During the acquisition the specimen rotated 360 degrees with a Rotation Step (deg) =0.400. At each angular position a shadow image or transmission image was acquired and images saved as 16 bit raw data TIFF files. The data set after scanning consisted of a set of normal transmission X-ray images. Scanning parameters were: Camera=Hamamatsu C9300 11Mp camera, Camera Pixel Size (um) = 8.99. Source Voltage (kV) = 100, Source Current (uA) = 100, Image Rotation=0.2800, Image Pixel Size (um) = 13.73, Filter=Al+Cu, Image Format=TIFF, Depth (bits) =16, Exposure (ms) = 2550, Rotation Step (deg) =0.400, Frame Averaging=ON (3), Random Movement=ON (10), Use 360 Rotation=YES

Next, these raw data were reconstructed to bitmap file using the NRecon Software version 1.6.4.8 Skyscan 2011. Reconstruction settings were: Result File Type=BMP, Pixel Size (um) =13.72966.

Reconstruction Angular Range (deg) =360.00, Angular Step (deg) =0.4000, Smoothing=5, Smoothing kernel=2 (Gaussian), Ring Artifact Correction=15, Draw Scales=OFF, Object Bigger than FOV=OFF, Reconstruction from ROI=OFF, and Beam Hardening Correction (%) =40. For each canal, evaluation was done for the full canal length up to the level of the cemento-enamel junction.

Calculation of Canal Volume, Surface Area, and SMI:

The unprocessed images of canals' cross-sections after instrumentation were then restructured using SkyScan's NRecon version 1.6.4 software (Bruker). Images were then saved in a bitmap image (BMP) format. For the 3D reconstruction, CTan v1.11.10.0 software (Bruker) was used to calculate volume and surface area. This was made by subtraction of the pre- and post-instrumentation data (ΔV/mm3) and compared between the three tested shaping techniques. SMI: was calculated following the equation presented in previous similar studies [18].

Access cavity preparations:

CECDW modification was made to the previously described design by Roperto [(7)] for all teeth specimens. Initially, a traditional CEC cavity was created, followed by diverging the mesial and distal cavity walls at an approximate 45° angle towards their respective sides (Figure 1).

Fig. (1) Graphic illustration of CECEC axis cavity

Root canals instrumentation:

The instrumentation of all root canals in the experimented groups was performed by the author. In order to avoid potential bias, the operator made deliberate effort not to examine the virtual models of reconstructed teeth before preparing the root canals. The instrumentation of distal root canals was carried out for each group in accordance with the concerned manufacturer recommendations for each NiTi instrument. The same motor was utilized for all instrument groups (VDWsilver-Dentsply/Sirona).

All samples underwent canal preparation following the specific recommendations of the instrument's manufacturer. A new File set was used for each canal specimen. The irrigation process followed a unified protocol, utilizing 2 ml of 5.25% sodium hypochlorite NaOCl for irrigation prior and during instrumentation. Irrigation was carried out by an intermittent manual flushing with 30 gauge side-vent perforated needles (Hawe irrigation probe, Bioggio, Switzerland).

At the end of instrumentation; each canal was flushed with 5ml of 2.5% NaOCl and then a final flush of 5ml of 17% of ethylene-diamine-tetra-aceatic acid (EDTA) was performed.

Distal root canals' instrumentation per instrument's group:

For OneShape: The OneShape file of tip size 25 and .08% taper was utilized in a continuous rotation crown down technique as per the manufacturer's recommendations. VDW silver motor was used. The instrument was maneuvered using a pecking motion and the canal was intermittently irrigated until reaching the apical contriction and feeling the instrument to rotate freely. Withdrawal was then promptly performed.

For Reciproc: The R40 Reciproc of tip size 40 and .06% taper was used in the VDW silver motor-this was set at the reciprocation mode (RECIPROC ALL) and used during the preparation according to manufacturer's directions. The file was advanced apically in the canal using a pecking motion of 3mm and applying light apical pressure. After three pecks, the instrument was removed from the canal for cleaning and the canals were replenished with the irrigant. This process was repeated until reaching the full working length, and then the instrument was removed at once while still reciprocating.

For WaveOne: Reciprocating WaveOne large file with a tip size 40 and a taper of .08% was used with the same motor. WaveOne file was slowly advanced into the wet canal for three pecking cycles, followed by file withdrawing the file to clean the flutes and irrigate the canals as per the manufacturer's instructions. This process was repeated until the full working length was reached and the file was then while still reciprocating.

Post instrumentation evaluation:

Following instrumentation, the three groups' prepared root canals were re-scanned in the identical position and orientation as the pre-instrumentation ones. The attained images and 3D re-constructions were handled in the same manner as the pre-shaping process. Evaluation of the shaping ability involved calculating the following parameters:

a. Canal's volume:

The volume of canals was re-measured after preparation with each of the tested instruments' design. The difference in volume (D)/$mm^3$was calculated by subtracting the post and pre-canal volumes in order to calculate and compare the volume increase after instrumentation [18,19].

b. Canal's surface area:

Canal's surface area was re-measured after preparation with each of the tested instruments' design. for the same area of interest as before. The difference in surface area (D) /mm^2 was calculated by subtracting the post and pre-canal to compare the surface area increase after instrumentation [15].

c. Structure Model Index: prepared canals SMI change was calculated before and after instrumentation following the previous studies[18, 19] . Figure 2 is an illustration.

This index indicates the difference between flat ribbon-like

Object with SMI=0, similar to the canal in figure 2(a) and a cylindrical shape with SMI=3 which represents the canal after instrumentation in figure 2 (b).

Statistical Analysis

The mean and standard deviation values were computed for every instrument design for each test. Namely, the canals' volume, surface area, and SEM. To assess normality, Kolmogorov-Smirnov and Shapiro-Wilk tests were used, and the data indicated a parametric (normal) distribution. Consequently, data was presented as means ± standard deviations. An independent t test was utilized to compare the percentage change in volume, surface area, and canal transportation between the two groups. For comparison between more than two groups in non-

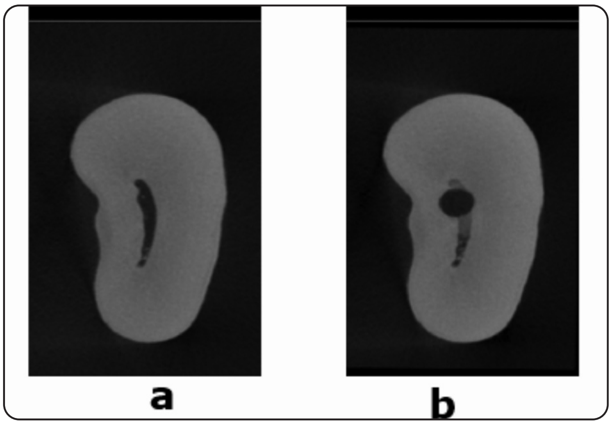

Fig. (2) MCT picture of a canal cross section showing clearly the change in canal geometrical perimeter (SMI) from elongated (a) to round (b) with resulting preparation errors after preparation through CECDW

related samples a one-way ANOVA followed by Tukey post hoc test was employed. The significance level was established at $P \leq 0.05$. The statistical analysis was carried out with IBM® SPSS® Statistics Version 20 for Windows.

RESULTS

The results are shown together in tables 1 and 2 and figures 3 -6 display typical MCT reconstructions of samples of teeth specimens before and after instrumentation *teeth samples*

Volume (mm^3):

Canal volume increased significantly after instrumentation in all tested instruments' groups ($p<0.001$) (table1). The lowest increase in volume was found after preparation with OneShape (fig. 3) Wave One showed the highest increase in volume as compared to Reciproc and OneShape. The difference was statistically significant. However, no statistically significant difference was found between OneShape and Reciproc where ($p=0.894$ (table 2). However, no statistically significant difference was found between OneShape and Reciproc where ($p=0.894$).

TABLE (1) Canals' changes in pre-instrumentation baseline parameters after instrumentation with OneShape, Reciproc, and WaveOne instruments.

Variables	Volume (% change)			Surface area (% change)			SMI (% change)		
	Pre	Post	Δ	Pre	Post	Δ	Pre	Post	Δ
OneShape	4.59±0.5	6.49±0.6	1.9 ±0.16 P<0.001*	35.61±3.6	40.00±3.9	4.39 ±0.3 P<0.001*	2.49 ±0.2	2.73 ±0.2	0.24 ±0.04 P= 0.001*
Reciproc	4.42±0.4	6.23±0.4	1.81 ±02 P <0.001*	29.95±2.2	33.69±2.2	3.74 ±0.02 P <0.001*	2.69 ±0.2	3.01 ±0.1	0.32 ±07 P= 0.038*
WaveOne	5.89±1.2	8.67±1.2	2.78 ±0.04 P <0.001*	36.77±3.4	42.25±3.4	5.48 ±0.03 P <0.001*	2.59 ±0.2	3.03 ±0.2	0.44 ±0.03 P= 0.040*

denotes significance

TABLE (2) Comparison of percent changes in canals' volume, surface area, and structure model index (SMI) for the three tested instruments (presented as means and standard deviations).

Variables	Volume (% change)		Surface area (% change)		SMI (% change)	
	Mean	SD	Mean	SD	Mean	SD
OneShape	27.97 [b]	6.09	11.03 [b]	3.58	10.31 [b]	1.59
Reciproc	28.94 [b]	3.92	11.57 [ab]	1.30	11.51 [b]	1.46
WaveOne	35.07 [a]	5.46	13.80 [a]	2.79	14.18 [a]	3.06
p-value	0.004*		0.043*		<0.001*	

denotes significance ***Different superscripts mark significant difference***

Surface area (mm^2):

Canal surface area increased significantly after instrumentation in all tested instruments' groups (p<0.001) (table1). The largest increase was noted in Wave One. This was followed by Reciproc and OneShape in descending order. The difference was statistically significant between WaveOne and OneShape. The lowest increase in volume was found after preparation with OneShape. However, no significant difference was noted between Reciproc and OneShape (table 2).

SMI:

All the three experimented instruments' designs produced a significantly more round preparation as compared to the pre-instrumentation (SMI 2.73 to 3.3 in One Shape and WaveOne respectively-table 1). Wave One resulted in the largest change to a more round canal. This change was statistically significant as compared to Reciproc and One Shape (p<0.001) and (p=0.013) respectively. No significant difference was noted between One Shape and Reciproc where (p=0.376).

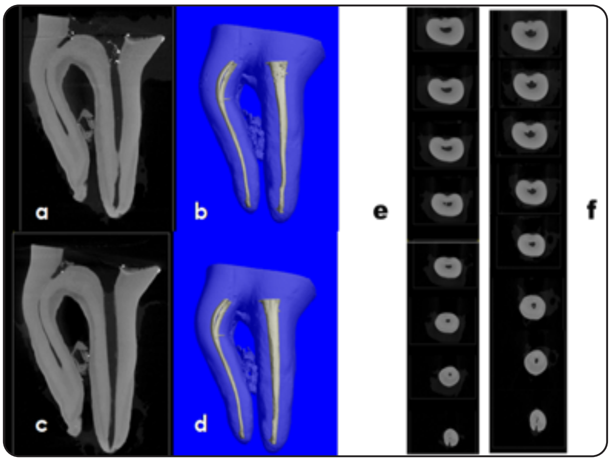

Fig. (3): Left: MCT picture (axial view) of a sample of tooth specimen; where distal canal was prepared with One Shape. a and c are longitudinal sections MCT views of before and after preparation respectively. b and d are 3D reconstruction of the same sample before and after instrumentation. Note Wright pictures, are series 8 MCT cross sections of another sample of instrumented distal canals with OneShape. Pre-instrumentation (e) and post-instrumentation (f) . Note the generally deficit preparation with untouched walls at the 5 coronal sections the deficient preparation especially at the middle/apical canal part. Again, note the zipping of the apical foramen near to the canal terminus (g)

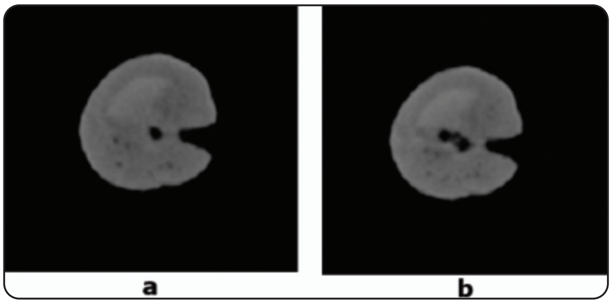

Fig. (4) Zipping of the apical foramen as a result of canal's transportation in a canal prepared by One Shape (a) before and (b) after

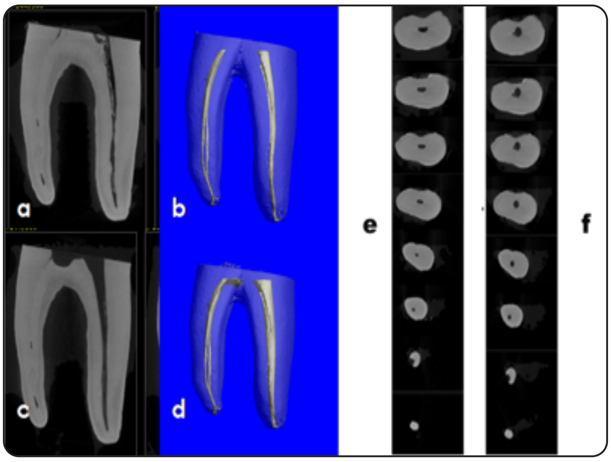

Fig. (5) Left: MCT picture (axial view) of a sample of tooth specimen; where distal canal was prepared with Reciproc. a and c are longitudinal sections MCT views of before and after preparation respectively. b and d are 3D reconstruction of the same sample before and after instrumentation. Note the apparent relatively adequate preparation through the whole canal length, especially at the middle/apical canal part. Wright, are series 8 MCT cross sections of another sample of Reciproc instrumented distal canals. Pre-instrumentation (e) and post-instrumentation (f) .Note the marked canal transportation toward the danger zone in the coronal first three cross sections as well as the change in the SMI from elongated to round cross section.

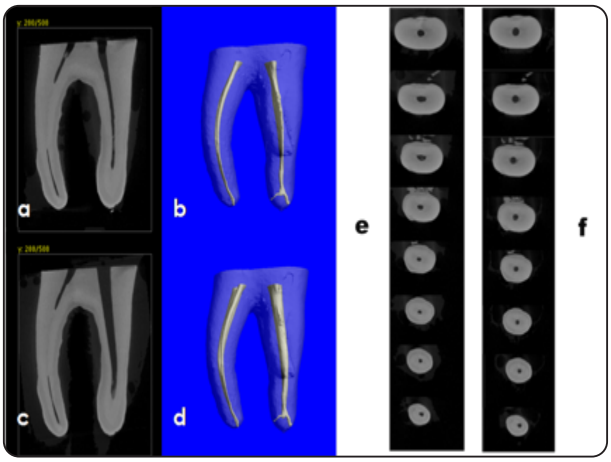

Fig. (6) Figure 6- Left: MCT picture (axial view) of a sample of tooth specimen; where distal canal was prepared with WaveOne. a and c are longitudinal sections MCT views of before and after preparation respectively. b and d are 3D reconstruction of the same sample before and after instrumentation. Note the relatively adequate preparation leaning toward over preparation at the coronal and middle canal thirds. Wright, are series 8 MCT cross sections of another sample of WaveOne instrumented distal canals. Pre-instrumentation (a) and post-instrumentation (f). Note the adequately centralized preparation irrespective of the change in SMI from elliptical to round specially at the coronal 2nd to 4th cross sections.

DISCUSSION

The effective preparation of root canal requires three-dimensional shaping and cleaning to ensure they are ready for obturation. Untouched canal walls can accumulate debris and muds that impeded the use sealer dependent obturation, which is a recent concept [21]. Nowadays, the focus is on single file/single use instrument that can shape the entire canals aiming for simplicity, ergonomics, and to the prevention of cross infections, and potential micro-structural changes during sterilization[22]. In the same time, the recent biological goal is to minimize sacrificing sound tooth tissues [2,3,8].

Mandibular molars Distal canals are categorized as having oval-to long oval shapes with complex anatomy. This particular anatomy is quite prevalent, with a reported incidence rate ranging from 25% to 30% [23,24] that presents challenges in shaping as well as disinfection[25]. A systematic review on mandibular molar by Valencia de Pablo suggested that, access modification and more clinical experience are needed for successful treatment of mandibular molars [26].

The present study aimed to examine the effect of a modified CEC cavity (CECDW) with divergent walls on shaping ability of reciprocation and continuous rotation kinematics. CECDW was recently introduced as a modification for conservative access in premolars [5]. This research focused on the single distal canal of mandibular molars due to the reported challenges in shaping the long oval canals' owing to their anatomy [4,5,26], particularly when using the conservative access designs[28]. To our knowledge the effect of CECDW design for mandibular molars' distal canals' on instrumentation efficiency was not reported before.

The author of the present study [29] and other researchers [30] have previously reported data comparing the impact of unmodified CEC and traditional TEC on the preparation of distal canals of mandibular molars. The results favored TEC in terms of canal transportation; while the access modification did not affect centric ability. Notably, canals prepared with OneShape exhibited significantly better results. These earlier investigations utilized CBCT[29] or simulated canals [30].

The current research utilized MCT to assess the shaping capabilities of three single file systems: rotating and two reciprocating files through CECDW. This approach enabled more precise measurements of shaping effeciency and accurate assessment of SMI variances. Despite MCT being the gold standard for evaluation of shaping ability, there is a limited number of studies in the literature that have employed MCT to assess instrumentation through contracted accesses [2, 4,5].

The study parameters that were selected in the present studt included the canals' volume, surface area, and structure model index, enabled the simulation of changes in the entire canal after instrumentation. These parameters allowed for three-dimensional recognition, measurement and comparison through real time reconstruction [30,31]. From the multi-slices, eight cross sections were chosen to serve as a standard basis for detailed virtual observation and comparison. This approach aligns with the findings of Krishan et al [28] and Dhingra [33] . selecting only the coronal, middle, and apical thirds for measuring canal transportation and centering ability, as seen in most previous studies [2,26]; may not be provide sufficient detailed information about shaping abilities. It is possible that important details depicting gradual or abrupt changes in the root canal system that is many times not anticipated.

The volume and surface area of the canals were assessed before and after instrumentation through CECDW and the data were analyzed using Bruker software. The findings indicated a significantly greater preparation volume following instrumentation with WaveOne in comparison to Reciproc and OneShape, in a descending order. These results align with those of a previous CBCT study [34] and in a classic MCT study [31] focusing on palatal canals.

The design and movement kinematics of all the three instruments used in this study, were found to be inadequate for fully preparing the entire perimeter of the distal root canal. Representative samples of detailed 2D, 3D, and 8 cross sections before and after instrumentation for OneShape, Reciproc, and WaveOne are depicted in figures 3,5, and 6 respectively. This finding is consistent with previous studies regardless of the instrument design or movement kinematic [35]. Given this, the concept introduced by Paque´ [23] in 2010 suggesting the consideration of long oval distal root canals as two canals during instrumentation to ensure more effective shaping of the canal surface area , may warrat further validation.

The findings in figure5 clearly indicate the canal transportation by Reciproc, confirming previous results [34] and highlighting the movement toward the danger zone.

Different trends in the percent change of surface area after preparation through the CECDW were observed for the three instruments tested. Generally, the reciprocating instruments resulted in greater preparation as a function of canals' surface area. This is consistent with the to findings of other research [35]. OneShape showed the smallest increase in surface area compared to the reciprocating instruments studied. This may be attributed to the differences in instruments' tip size and movement kinematic.

The SMI equation was utilized in this study to illustrate how specific instruments behave during when shaping canals' instrumentation and degree of transformation from an oval or elliptical canal to a more round one [31]. In fact this was found to increase the surface area but on the expense of the original canal architectural anatomy without affecting circumferential enlargement and effective filing of most of the canal walls. Actually, it gives a pseudo-signal of an enlarged canal in volume while in reality it is underprepared canal surface in terms of circumferential shaping. There is limited discussion of this concept in the literature [36,37]. Wang et al, attributed it to the inability of energized instruments to confirm to the canal oval and long oval perimeters [32].

For the structure model index, even though results fell within the reported range, in our study the highest Δ change averaged 0.38 (with reciprocating instruments) and 0.24 (with rotating instruments), compared to the 0.54 documented by Peters et al [31]. This variation may be the use of different instruments and techniques for instrumentation.

During this investigation, the three parameters tested- volume, surface area, and SEM- pertain the entire length of the canal; rather than selection of three or four sections at different thirds of the canal. Moreover, 8 cross sections represent the entire length of the canal to simulate real-time observation of sequential changes in the original canal anatomy as well as the untouched areas. These sequential sections have revealed numerous instrumentation errors that could impact the treatment outcome[2, 9,20] (examples can be seen in fig.2and4).

In the current study, all tested instruments regardless of their movement kinematics through the CECDW access, resulted in a change in the pre-instrumentation SMI to a more round preparation with an increase in SMI ranging from 0.24 to 0.44. The greatest change in canal 's SMI was detected after preparation with WaveOne, followed by Reciproc and OneShape in descending order. A recent review by Arias and Peters [22] concluded that, there is currently no instrument design that can ensure three- dimensional shaping of the root canals, regardless of recent designs or materials' used, as supported by several previous studies [2, 20, 38]. In a recent study on long oval canals in mandibular incisors, proposed the use of novel active ultrasonic tips to reduce canals transportation and untouched canal walls. Accordingly, further investigation might be needed.

Based on the presented study results; the two null hypotheses were rejected

Limitation of the present study is that, the modification of CEC involved diverging the mesial and distal walls of the CEC access cavity. However, concerning that, the distal canals are predominantly elongated ovoid in the bucco-lingual direction; suggesting that making the wall divergence bucco-lingually might be more convenient for instrumentation. Another limitation is that calculations of canals' roundness (CR) and aspect ratio (AR) through MCT would provide additional valuable quantitative details.

CONCLUSIONS

CECDW Modified contracted access as well as instrument's movement kinematic did not result in significant enhancement of the shaping geometry in distal canals of mandibular molars. WaveOne showed superior performance compared to Reciproc and OneShape in terms of canals' volume and surface area increase. The difference was statistically significant. All tested instruments working through CECDW shifted the SMI towards more round preparation geometry; however, comparatively, OneShape demonstrated the best maintenance of SMI of the original canal shape.

Conflict of interest:

The author deny any conflict of interest related to this research

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