The Effect of Different Access Cavity Designs in Combination with WaveOne Gold and TruNatomy Instrumentation on Remaining Dentin Thickness and Volume

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Abstract

Introduction: The purpose of this study was to evaluate and compare 2 different access cavity designs in combination with 2 popular single-file preparation systems to see which combination preserves dentin, more specifically pericervical dentin, best. The minimum remaining dentin thickness and dentin volumes were evaluated pre- and postinstrumentation.

Methods: Sixty extracted human mandibular molars were selected and randomly divided into 2 different access cavity design preparation groups: traditional access cavities ($n = 30$) and conservative access cavities ($n = 30$). Within each cavity preparation design group, the 30 teeth were divided into 2 instrumentation groups (WaveOne Gold Primary; Dentsply Sirona, Ballaigues, Switzerland [$n = 15$] and TruNatomy Prime, Dentsply Sirona [$n = 15$]). Samples were scanned using micro–computed tomographic imaging before and after access cavity preparation as well as after final endodontic instrumentation. The pericervical remaining dentin thickness and dentin volume changes were evaluated and compared.

Results: Conservative access cavity designs resulted in more favorable remaining dentin thickness. The least amount of mean dentin volume loss was also recorded in the conservative access cavity preparation groups regardless of the preparation instrumentation.

Conclusions: In terms of the remaining pericervical dentin thickness and dentin volume reductions, the authors conclude that conservative access cavity designs preserve dentin best.

Key Words: Endodontic access cavity; micro–computed tomography; pericervical dentin; TruNatomy, WaveOne Gold

Significance: In this article, the authors report on the effect different molar access cavities in combination with 2 popular single-file reciprocating and rotating endodontic shaping instrumentation systems have on the remaining pericervical dentin volume and thickness.

Structural integrity and the associated fracture resistance after endodontic treatment of human teeth remain crucial when evaluating the long-term success of these teeth[1]. Although access cavities and canal preparations should aid in direct access to the root canal system, the conservation of dentin to maintain as much tooth structure as possible remains important[2].

A minimally invasive approach to endodontics and the preservation of dentin during access cavities have been much debated in recent years. The preservation of pericervical dentin (PCD) is described in the international literature as a key factor in increasing the fracture resistance of endodontically treated teeth[3]. A traditional endodontic access cavity (TAC) refers to the exposure of all pulp horns and straight-line access to the root canal system with slightly diverging walls. The aim is direct visualization of canal orifices without changing the angle of view and without any dentin undercuts[4]. On the other hand, conservative or contracted endodontic access cavities (CACs) are based on the principle of dentin preservation with only partial deroofing of the pulpal roof with preservation of the pulpal horns and slight convergence or divergence of the cavity walls. The visualization of orifices is possible only from different visual angles. Pulpal chambers are accessed from the central fossa and extended only enough to locate canal orifices. During ultraconservative preparation, molars are accessed through the central fossa with no further extensions into the dentin, preserving as much PCD and pulp chamber roof as possible[5,6].

The preservation of dental hard tissue in this region has also been shown to significantly reduce stress concentrations in the cervical region[7]. Clark and Khademi[5] described PCD as roughly 4 mm coronal to the crestal bone and 4 mm apical of the crestal bone. Dentin reduction, contributing to the susceptibility to fracture, mainly happens in the access cavity preparation phase and during cleaning and shaping in order to disinfect7, 8, 9, 10. Therefore, the amount of remaining dentin after access cavity preparation and root canal shaping appears to be the major contributing factor in determining the fracture resistance and long-term prognosis in teeth after endodontic treatment[11]. Özyürek et al[12] found that the CAC design did not increase the fracture resistance in comparison to TAC preparations. Zhang et al[7] reported the opposite, stating that CAC preparations increased the fracture resistance of endodontically treated teeth compared with the CAC preparation groups.

Two single-file instruments (WaveOne Gold Primary [Dentsply Sirona, Ballaigues, Switzerland] and TruNatomy Prime [Dentsply Sirona]) in combination with TACs and CACs were investigated in this study to evaluate the effect on the minimum remaining dentin and dentin volume, especially the pericervical region in mandibular first molars. The WaveOne Gold system operates in a counterclockwise reciprocation motion, offering the clinician greater simplicity and safety and improved cutting efficiency and mechanical properties than the previous generation of reciprocating instruments[13]. The WaveOne Gold Primary final preparation instrument is 50% more resistant to cyclic fatigue, 80% more flexible, and 23% more efficient than the conventional Primary WaveOne (Dentsply Sirona) instrument[13,14].

TruNatomy is a new popular instrumentation system operating in rotary motion and designed with minimally invasive endodontic preparations and the preservation of PCD in mind. TruNatomy instruments are manufactured using a smaller initial wire (0.8-mm diameter) than the 1.1-mm diameter of other instruments.

The instruments are designed with a regressive taper as it progresses coronally, allowing each instrument to maintain a maximum flute diameter of 0.8 mm.

In this study, TACs and CACs in combination with WaveOne Gold Primary and TruNatomy Prime instruments were evaluated for their effect on the minimum remaining PCD and dentin volume reduction after access preparation and root canal shaping, respectively.

Materials and Methods

Ethics approval (reference 484/2020) was obtained from the Research Ethics Committee, Faculty of Health Sciences, University of Pretoria, Pretoria, South Africa, before commencement. Sixty extracted, previously untreated, mandibular first molars with visible canals on the preoperative radiographic investigation were selected. In order to standardize samples, only mandibular molars with mesiobuccal root canals with curvatures between 25° and 35° and radii <10 mm were selected for this study[15]. The Schneider method was used to evaluate each canal curvature using a size 0.8 Kerr K-Flex file (SybronEndo, Orange, CA)[16]. Access cavity preparation and length determination were performed under 10× magnification (dental operating microscope; Zumax OMS2350, Zumax Medical Co Ltd, Jiangsu, China) according to the guidelines discussed previously and illustrated in Figures 1 and 2. The Endo Access Bur (Dentsply Sirona) was used for preparation and refined in the TAC groups with the Endo-Z Bur (Dentsply Sirona). The working length was determined by subtracting 0.5 mm from the length measured to the major apical terminus, and canals were explored with a size 0.8 K-file and negotiated to patency. The specimens were coded and randomly divided into 4 equal experimental groups (n = 15).

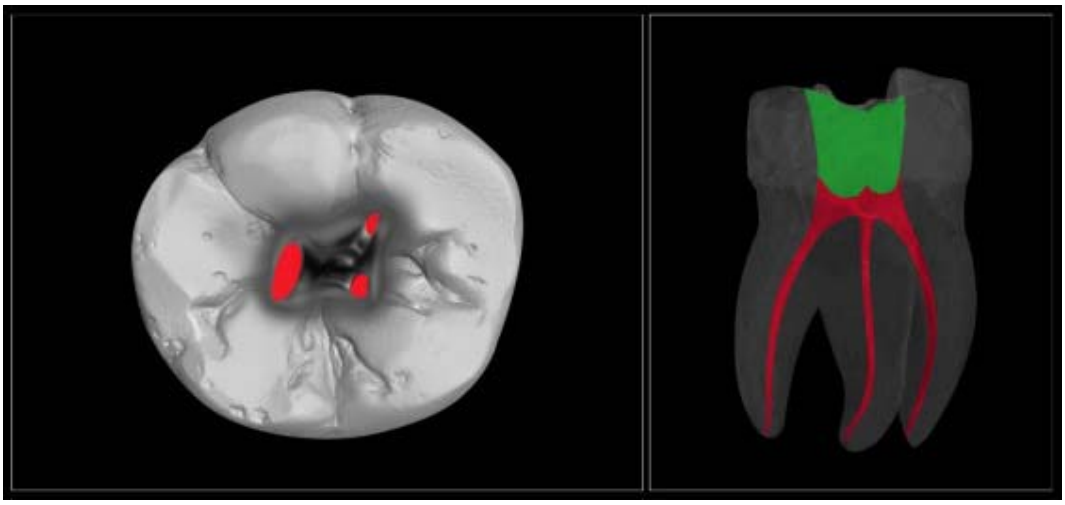

Figure 1. Occlusal and buccal views of a micro–computed tomographic illustration of TAC preparation.

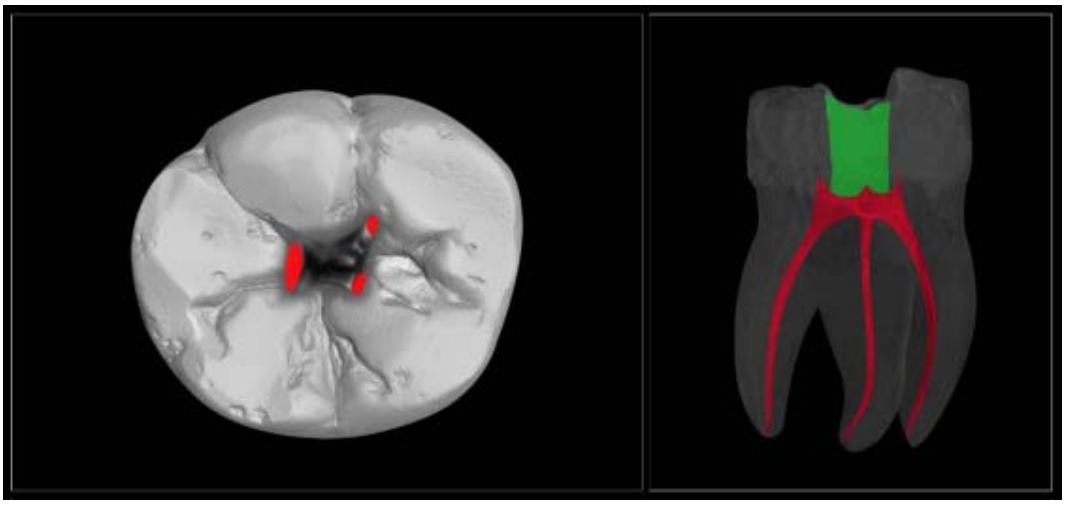

Figure 2. Occlusal and buccal views of a micro–computed tomographic illustration of CAC preparation.

Glide Path and Final Preparation

Preparation was performed by a single operator in strict accordance with the manufacturer's recommendations for each system. Preparation files were operated by a 16:1 gear reduction handpiece powered by the X-Smart IQ (Dentsply Sirona) cordless motor. RC Prep (Premier, Plymouth Meeting, PA) was used as a lubricating agent, and 3% sodium hypochlorite was used for canal irrigation. Specimens were mounted in an FKG vice (FKG Dentaire, La Chaux-de-Fonds, Switzerland) in order to simulate clinical scenarios and standardize the preparation conditions. The initial canal instrumentation was performed using a precurved stainless steel size 0.10 K-file. Files were negotiated to the working length with increasing amplitudes of 1–3 mm to ensure an initial manually reproducible glide path. The WaveOne Gold Glider (Dentsply Sirona) and WaveOne Gold Primary instruments were used in reciprocating motion at a speed of 350 rpm. The TruNatomy Orifice Modifier (Dentsply Sirona), TruNatomy Glider (Dentsply Sirona), and TruNatomy Prime were used in rotation motion at 500 rpm and 1.5 Ncm.

TAC/WaveOne Gold and CAC/WaveOne Gold Group

The WaveOne Gold Glider (15/02) was used to further enlarge each canal in these groups. The final preparation with the Primary WaveOne Gold (25/07) instrument was performed according to the manufacturer's instructions.

TAC/TruNatomy and CAC/TruNatomy Group

The TruNatomy Orifice Modifier (20/08) and TruNatomy Glider (17/02) were used to further enlarge each canal in these groups. The final preparation with the TruNatomy Prime (26/04) instrument was performed according to the manufacturer's instructions. Each glide path and final preparation file were only used for 1 sample preparation and were discarded after preparation.

The selected teeth were scanned using the XTH 225 ST (Nikon Metrology, Leuven, Belgium) microfocus X-ray computed tomographic system at the Micro-focus X-ray Radiography and

Tomography facility at the South African Nuclear Energy Corporation SOC Limited. This system has a spatial resolution capability of 0.001–0.006 mm. The voltage setting ranges between 30 and 225 kV and the beam current between 0 and 1 mA. Samples were scanned preoperatively, again after access cavity preparation, and finally after the final shaping with endodontic preparation instruments. Samples were placed on a stable support, and a series of sequential 2-dimensional X-ray images were captured as the samples rotated 360°. These images were then reconstructed to generate 3-dimensional volumetric representations of each tooth. Reconstruction of the micro–computed tomographic images was performed with the use of VG Studio-Max (Volume Graphics GmbH, Heidelberg, Germany) visualization software, whereas investigations were performed using Avizo edition 2019.1 (Thermo Fisher Scientific, Waltham, MA) imagining software. The remaining dentin thickness on levels 4 mm above the cementoenamel junction (CEJ) to 6 mm below the CEJ was measured in millimeters to include the PCD, and the location was recorded. The CEJ was used as reference because the crestal bone on extracted teeth is not identifiable or reproducible during measurement. The remaining dentin thickness was measured before access, after access, and after the final canal preparation. This was performed by measuring the shortest distance from the margin of the canal to the closest margin of the tooth. The dentin volume was also calculated using volume extraction modules and Avizo software and compared before access, after access, and after the final preparation. The same was done in terms of the dentin volume (measured in mm^3) in this region before access, after access, and after the final canal preparation. The reduction of dentin was recorded after access cavity preparation as was dentin volume loss as a result of canal preparation. The combined dentin volume loss was also recorded and compared over the pericervical region. Only 3 canals (ie, the mesiobuccal, mesiolingual, and distobuccal canals) were prepared in samples with more than 3 canals in order to standardize the amount of dentin loss between these samples.

Statistical Analysis

To test significant differences of means across groups, the analysis of variance and Kruskal-Wallis tests were used. The former was used in instances in which the normality assumption was upheld or variables transformed and the latter when the normality assumption was violated. The Stata Statistical Software: Release 17 (StataCorp LLC, College Station, TX) package was used throughout the analysis. The significance level was set at $P < .05$.

Results

Minimum Remaining Dentin Thickness

The first parameter that was investigated was the remaining dentin thickness. The thinnest wall of dentin was measured on each millimeter over the pericervical region. To standardize measurements, the CEJ was used as reference instead of the crestal bone level. The crestal bone level is difficult to determine on extracted teeth and not reproducible. The remaining dentin thickness was measured as the thinnest amount of remaining dentin. The location for this measurement was also recorded. All teeth were aligned according to the CEJ during all 3 reconstructions of micro-CT scans in order to compare measurements after each scan. The remaining dentin thickness before access cavity preparation was determined to evaluate if all samples had comparable average remaining dentin thickness before access cavity preparation, which was found to be the case.

Remaining Dentin Thickness after Access Cavity Preparation

Table 1 indicates the average minimum remaining dentin thickness (in mm) measured after access cavity preparation in the 4 groups on the level of the CEJ to 4 mm above the CEJ.

Table 1. The Mean (and Standard Error) of Remaining Dentin Thickness (RDT) after Access and Final Canal Preparation across Groups (mm)

Level	Group			
	TAC/WOG	**CAC/WOG**	**TAC/TN**	**CAC/TN**
Mean RDT after access cavity preparation				
4 mm above CEJ	$2.76^{a} \pm 0.06$	$3.64^{b} \pm 0.08$	$2.41^{a} \pm 0.11$	$3.27^{b} \pm 0.09$
3 mm above CEJ	$3.10^{a} \pm 0.07$	$3.70^{b} \pm 0.06$	$2.82^{a} \pm 0.06$	$3.57^{b} \pm 0.07$
2 mm above CEJ	$3.04^{a} \pm 0.09$	$3.65^{b} \pm 0.11$	$2.80^{a} \pm 0.07$	$3.56^{b} \pm 0.06$
1 mm above CEJ	$2.56^{a} \pm 0.09$	$2.71^{a} \pm 0.11$	$2.54^{a} \pm 0.10$	$2.60^{a} \pm 0.09$
CEJ	$2.27^{a} \pm 0.08$	$2.44^{a} \pm 0.09$	$2.26^{a} \pm 0.09$	$2.47^{a} \pm 0.08$
Mean RDT after final preparation				
1 mm above CEJ	$2.50^{a} \pm 0.21$	$2.71^{a} \pm 0.15$	$2.54^{a} \pm 0.09$	$2.60^{a} \pm 0.06$
CEJ	$2.21^{a} \pm 0.05$	$2.40^{b} \pm 0.06$	$2.25^{a} \pm 0.09$	$2.45^{b} \pm 0.07$
1 mm below CEJ	$2.15^{a} \pm 0.06$	$2.34^{b} \pm 0.09$	$2.20^{a} \pm 0.09$	$2.42^{b} \pm 0.07$
2 mm below CEJ	$2.07^{a} \pm 0.07$	$2.10^{a} \pm 0.08$	$2.17^{a} \pm 0.11$	$2.18^{a} \pm 0.06$
3 mm below CEJ	$1.75^{a} \pm 0.09$	$1.64^{a} \pm 0.14$	$1.96^{b} \pm 0.09$	$1.92^{b} \pm 0.06$
4 mm below CEJ	$1.46^{a} \pm 0.09$	$1.31^{a} \pm 0.13$	$1.56^{a} \pm 0.11$	$1.48^{a} \pm 0.10$
5 mm below CEJ	$1.04^{a} \pm 0.09$	$0.99^{a} \pm 0.10$	$1.05^{a} \pm 0.11$	$0.97^{a} \pm 0.09$
6 mm below CEJ	$0.81^{a} \pm 0.06$	$0.79^{a} \pm 0.09$	$0.89^{a} \pm 0.08$	$0.80^{a} \pm 0.06$

CEJ, cementoenamel junction.

Mean values with different superscript letters within a level were statistically different at $P < .0.5$.

Access cavity preparation had no effect on levels 1 mm below the CEJ up to 6 mm below the CEJ. This region was used as a control to verify that no changes in the mean remaining dentin thickness were observed when comparing the remaining dentin thickness before and after access cavity preparation. However, these levels were investigated to evaluate and compare the effect of the final canal shaping on the remaining dentin thickness in combination with the different access cavity preparation groups.

When evaluating the remaining dentin thickness after cavity preparation in the CEJ to 1 mm above CEJ levels, no statistically significant difference was observed between groups (CEJ 1 mm above: $P = .067$ and CEJ: $P = .703$, respectively). In the region 2–4 mm above the CEJ, the TAC group had significantly lower values of remaining dentin thickness than the CAC groups.

Remaining Dentin Thickness after Final Canal Preparation

Table 1 indicates the remaining dentin thickness after the final preparation. Only level 1 mm above the CEJ up to 6 mm below the CEJ were investigated because levels 2–4 mm above the CEJ were not affected by canal preparations. These levels were again used as a control when comparing the remaining dentin thickness pre- and postcanal preparation. The location where the minimum remaining dentin thickness was observed was also recorded.

After the final canal preparation, no statistically significant difference in the remaining dentin thickness at level 1 mm above the CEJ was recorded between groups. On the CEJ level, CAC/WaveOne Gold and CAC/TruNatomy showed more favorable remaining dentin thickness than the TAC/WaveOne Gold and TAC/TruNatomy groups. No difference was observed between the TAC/WaveOne Gold and TAC/TruNatomy preparation groups. The Bonferroni tests suggested that the TAC groups and the CAC combination groups were not equal.

The same was observed on the level 1 mm below the CEJ; CAC/WaveOne Gold and CAC/TruNatomy preserved PCD better than the TAC combination groups ($P = .019$). With the exception of 3 mm below the CEJ where TruNatomy in combination with both CAC and TAC preserved dentin better than WaveOne Gold, no statistically significant difference in the remaining dentin thickness was observed when evaluating levels 2–6 mm below the CEJ in terms of the remaining dentin thickness after canal preparation.

Overall Dentin Volume and Dentin Volume Reduction

The volume of PCD was measured before access cavity preparation, after access cavity preparation, and after the final canal preparation (in mm^3). The reduction after access and the reduction after the final preparation as well as the total combined reduction in dentin volume were also recorded.

No statistically significant difference was observed when comparing the volume of dentin before access across the groups. This was done as a control before access cavity preparation to ensure equal volumes of dentin across groups were investigated.

Table 2. The Mean and Standard Error Values of Pericervical Dentin (PCD) Volume Reduction Across Groups (mm^3)

Group	Mean PCD before access	Mean PCD after access	Mean PCD reduction after access	Mean PCD after final canal preparation	Mean PCD reduction after final canal preparation	Mean total combined PCD reduction
TAC/WOG	$664.78^{a} \pm 25.03$	$607.78^{a} \pm 24.95$	$56.99^{a} \pm 5.60$	$594.57^{a} \pm 22.93$	$13.21^{a} \pm 5.60$	$70.22^{a} \pm 4.49$
CAC/WOG	$642.56^{a} \pm 23.82$	$618.01^{a} \pm 22.76$	$24.54^{b} \pm 8.43$	$608.00^{a} \pm 22.85$	$10.01^{a} \pm 1.99$	$34.56^{b} \pm 9.39$
TAC/TN	$611.72^{a} \pm 32.55$	$547.10^{a} \pm 27.99$	$64.61^{a} \pm 7.12$	$544.79^{a} \pm 28.07$	$2.32^{b} \pm 0.76$	$66.93^{a} \pm 7.07$
CAC/TN	$604.62^{a} \pm 21.03$	$583.44^{a} \pm 20.23$	$21.17^{b} \pm 2.39$	$578.06^{a} \pm 20.84$	$5.39^{ab} \pm 1.44$	$26.57^{b} \pm 2.29$

Mean values with different superscript letters were statistically different at $P < .05$.

Table 2 illustrates the amount of PCD after each preparation phase and dentin volume reduction after access cavity preparation and the final canal preparation. When evaluating the dentin volume reduction, TAC showed significantly more dentin volume loss than CAC. More dentin loss was observed in the CAC/TruNatomy group than in the TAC/TruNatomy group when evaluating dentin reduction after canal preparation. In terms of the reduction of dentin volume in the pericervical area after the final canal preparation, TruNatomy in combination with both

TAC and CAC design groups removed significantly less dentin than WaveOne Gold in combination with both TAC and CAC design groups.

Discussion

The current endodontic preparation protocols and the development of instrumentation systems are focused around the concept of minimally invasive endodontics and the preservation of PCD. The present study compared TACs and CACs in combination with TruNatomy and WaveOne Gold for their effect on the remaining PCD thickness and volume in mandibular first molars.

The location on the tooth/canal where the thinnest remaining dentin thickness value was measured was also recorded pre- and postpreparation. The thinnest remaining dentin thickness values after access cavity preparation were observed in the lingual aspect of the first mandibular molars when evaluating levels 2–4 mm above the CEJ. On levels 1 mm above and 1 mm below the CEJ, the minimum remaining dentin thickness was observed mostly in the mesiobuccal roots of samples, with only 2 showing the minimum remaining dentin thickness in the distal roots. After the final canal preparation, it was noted that on levels 1–4 mm below the CEJ, the thinnest remaining dentin thickness was still recorded in the mesiobuccal roots in a mesial direction. On levels 5 mm and 6 mm below the CEJ, the minimum remaining dentin thickness was again observed in the mesiobuccal roots, but on these levels it was seen in a distal direction in the mesiobuccal roots. This can be explained by the anatomic curve of the mesiobuccal roots in mandibular first molars in a distal dimension. Clinicians should proceed with care because this area has an increased risk of procedural errors, such as stripping or root perforation. The mean remaining dentin thickness 6 mm below the CEJ was recorded to be <1 mm in all preparation groups. This corresponds with a study evaluating the remaining dentin thickness after the final preparation with WaveOne Gold Primary instruments on mandibular first molars[17].

No statistically significant difference in the remaining dentin thickness on level 1 mm above the CEJ was recorded between groups after the final canal preparation. On CEJ and 1 mm below the level, CAC in combination with both WaveOne Gold and TruNatomy showed more favorable remaining dentin thickness compared with the TAC groups. No significant difference in the remaining dentin thickness was observed when levels 2–6 mm below the CEJ were evaluated after canal preparation. These findings are similar to results found in a recent study comparing the minimum remaining periradicular dentin thickness after instrumentation using TruNatomy and ProTaper Gold (Dentsply Sirona) in mandibular molars. The authors found no significant difference in periradicular dentin thickness between these preparation groups[18].

In this present study, although not always statistically significant, on levels 2–4 mm below the CEJ, it was observed that the thickest amount of remaining dentin was observed in the TAC/TruNatomy and CAC/TruNatomy groups. It seems that the design of the TruNatomy system, with the reduced maximum diameter of the instrument, does preserve dentin in the region 2–4 mm below the CEJ slightly better. Interestingly, the authors observed that WaveOne Gold and TruNatomy in combination with TACs preserved dentin better on levels 3–6 mm below the CEJ compared with WaveOne Gold and TruNatomy in combination with CACs. Further research is required to see if centering ability and transportation values differ on levels 3–6 mm below the CEJ between these 4 preparation groups. Some studies suggest that CAC results in less centred preparation than TAC designs[19,20]. However, Barbosa et al[21] reported no difference between TAC and minimally invasive designs when evaluating canal transportation.

TAC showed significantly more dentin volume loss compared with CAC during access cavity preparation. TruNatomy removed significantly less dentin compared with WaveOne Gold regardless of the access cavity design. The type of access cavity had no significant effect on the volume of dentin removed during the final preparation over the region investigated. This is in agreement with all previous studies on remaining dentin thickness and volume reduction according to a literature review by Shabbir et al[22]. TruNatomy removed less dentin volume during the final instrumentation compared with WaveOne Gold. Combined values for the evaluation of dentin reduction in the pericervical area indicated that both WaveOne Gold and TruNatomy in combination with CAC designs preserved dentin better than TAC design groups. Although not statistically significant, the smallest amount of dentin loss after the final preparation and combined values was observed in the CAC/TruNatomy group.

This study is the first to evaluate and compare the effect of TruNatomy and WaveOne Gold in combination with different endodontic access cavities on the minimum remaining dentin thickness and volume, specifically in the pericervical area.

Conclusion

The least amount of PCD loss and the highest minimum remaining dentin thickness values were found in the CAC design groups in combination with both WaveOne Gold and TruNatomy overall. Although not statistically significant, the most conservative in terms of overall PCD volume reduction and the highest remaining dentin thickness values was observed in the CAC in combination with TruNatomy preparation group. Further investigation is needed to investigate any possible correlation between these findings and fracture resistance in mandibular molars after endodontic treatment. The authors stress that the remaining dentin thickness and PCD volume reduction were the only parameters investigated in this study and that many other factors should be considered when deciding on the appropriate access cavity design.

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

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