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Shaping ability of BlueShaper, TruNatomy, DC Taper and HyFlex EDM in long oval canals: An ex vivo study

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Abstract

Aim: This study evaluated and compared the shaping ability of four rotary instrument systems in long–oval root canals using microcomputed tomographic (micro-CT) evaluation. Currently, there is no data available on the canal shaping abilities of BlueShaper and DC Taper instruments.

Methodology: Sixty-four single-rooted mandibular premolars were matched based on similar root canal morphologic features as determined by (micro-CT) and randomly assigned to 1 of 4 experimental groups ($n = 16$) according to the instrument system used: BlueShaper, TruNatomy, DC Taper and HyFlex EDM One File. Changes in the root canal surface and volume, remaining dentine thickness, and number of prepared areas were assessed.

Results: No significant differences were found amongst the four instrument systems for the parameters evaluated ($p > .05$). There was a significant reduction in the number of unprepared areas and the remaining dentine thickness after each increase in size of the instruments tested ($p < .05$).

Conclusions: The four instrument systems perform similarly in long oval root canals. Although none could prepare all canal walls, larger preparations incorporated significantly more surfaces in the final shape.

KEYWORDS
micro-computed tomography, oval root canals, root canal preparation, shaping ability

INTRODUCTION

The main purpose of chemomechanical preparation is to remove pulp tissue and bacteria from the root canal and give it a shape that permits adequate irrigation and obturation (European Society of Endodontology, 2006). Oval, long oval and flattened canals are of particular concern because rotary instrumentation usually creates a round cross-sectional shape that leaves behind unaffected areas in the extremities of the largest diameter of the canal (Lacerda et al., 2017). These areas can harbour residual bacteria or necrotic pulp remnants that may serve as a potential source of persistent infection (Lacerda et al., 2017; Pérez et al., 2020; Siqueira et al., 2010, 2018).

Different engine-driven nickel–titanium (NiTi) instruments have been introduced to improve cleaning and shaping ability, particularly, in canals with complex anatomies.

For instance, the TruNatomy rotary system (Dentsply Sirona) is a set of instruments made of a maximum fluted diameter of 0.8-mm NiTi wire, with post-manufacturing thermal treatment, regressive taper and off-centered parallelogram cross-section (Peters et al., 2020). Previous studies have reported on their shaping performance and the ability to preserve the original canal anatomy (Morales et al., 2021; Silva et al., 2022).

The HyFlex EDM One File (Coltene/Whaldent) is a rotary instrument with controlled memory properties and is manufactured by electrical discharge machining. It has a variable cross-section, which is approximately triangular near the shaft, trapezoidal in the middle part and rectangular at the tip. The tip size of the HyFlex EDM OneFile is 0.25 mm and the taper is 0.08 mm/mm along the initial 4 mm, decreasing to 0.04 mm/mm towards the middle and coronal portions of the instrument. As for shaping, it has been reported to perform similarly to or even better than ProTaper Next instrument, but it was less effective in terms of centring ability and cleanliness than the GentleFile (Htun et al., 2020; Venino et al., 2017).

The newly introduced BlueShaper (Zarc4Endo) rotary system is claimed by the manufacturer to be the first 6th generation NiTi system to incorporate the pink alloy present in the Z1 file, which gives it enough torsional resistance to advance in any canal, even when narrow or calcified ones. The blue alloy, present in the other files of this system, increases cyclic fatigue resistance. These instruments have a variable taper, constant helical angle, and a convex triangular cross-section.

The recently renamed DC Taper files (Original V-Taper 2H) (SS White) are CM-wire rotary instruments with variable taper, helical angle and flute pitch. The manufacturer reports that these instruments effectively preserve the dentinal tissue throughout the pericervical area.

Currently, no data are available on the canal shaping abilities of BlueShaper and DC Taper instruments. In addition, the available literature regarding the shaping ability of TruNatomy and HyFlex EDM instruments is still scarce. Therefore, the purpose of this study was to evaluate and compare the shaping ability of these four instrument systems in long oval root canals from mandibular premolars using microcomputed tomography (micro-CT) analysis. The parameters evaluated included changes in the canal surface area and volume, amount of unprepared canal area surfaces, and remaining dentine thickness. For three of these systems, the effects of larger apical preparation sizes were also assessed. The null hypothesis was that no difference in the shaping ability would be demonstrated amongst the tested instruments.

MATERIALS AND METHODS

Tooth selection and distribution

The study protocol was approved by the institutional ethics committee for human research at Nuevo León University (Monterrey) (SPSI-010613. Form No. 00275). The manuscript of this laboratory study was prepared according to Preferred Reporting Items for Laboratory studies in Endodontology (PRILE) guidelines (Nagendrababu et al., 2021). The steps of this study are depicted in the PRILE flowchart (Figure 1).

Calculation of the sample size was done using the G*Power 3.1 software (Heinrich Heine Universität) using an alpha-type error of 0.05 and 95% power, which demonstrated that at least 12 canals per group were necessary (Guedes et al., 2022). Seventy specimens were selected from a pool of 170 mandibular first premolars extracted for orthodontic reasons. For selection, the teeth were radiographed in buccolingual and mesiodistal projections, and the inclusion criteria involved teeth with a single and long oval canal (with a >2:1 ratio between the buccolingual and mesiodistal dimensions along its coronal two-thirds), intact crowns, straight and completely formed roots and no evidence of root resorption or fracture. The tooth crown was sectioned at 4 mm from the cementoenamel junction to establish a plateau, and an initial morphometric evaluation of the root canal was performed using micro-CT imaging with the parameters described below.

From the initial sample, 64 teeth were further selected and matched in quartets according to the similarities in canal volume, canal surface area and tooth length, as determined by micro-CT evaluation. One specimen from each quartet was then randomly assigned (www.random.org) to each of the four experimental groups ($n = 16$): BlueShaper, DC Taper, HyFlex EDM and TruNatomy.

After the access cavity was prepared, the working length (WL) was established by inserting a size 15 K-file (Dentsply Maillefer) until the tip of the file was visible at the major apical foramen under 20× magnification with an operating microscope. At this point, the silicone stop was adjusted at the reference point, the file was removed from the canal and the distance between the silicone stop and the file tip was measured with a 0.01-mm precision digital calliper. The WL was set 1.0 mm short of this measurement. Canal shaping procedures in all cases with all instruments were always performed by a single operator.

Root canal preparation

The root canals were instrumented according to the manufacturers' instructions, as follows.

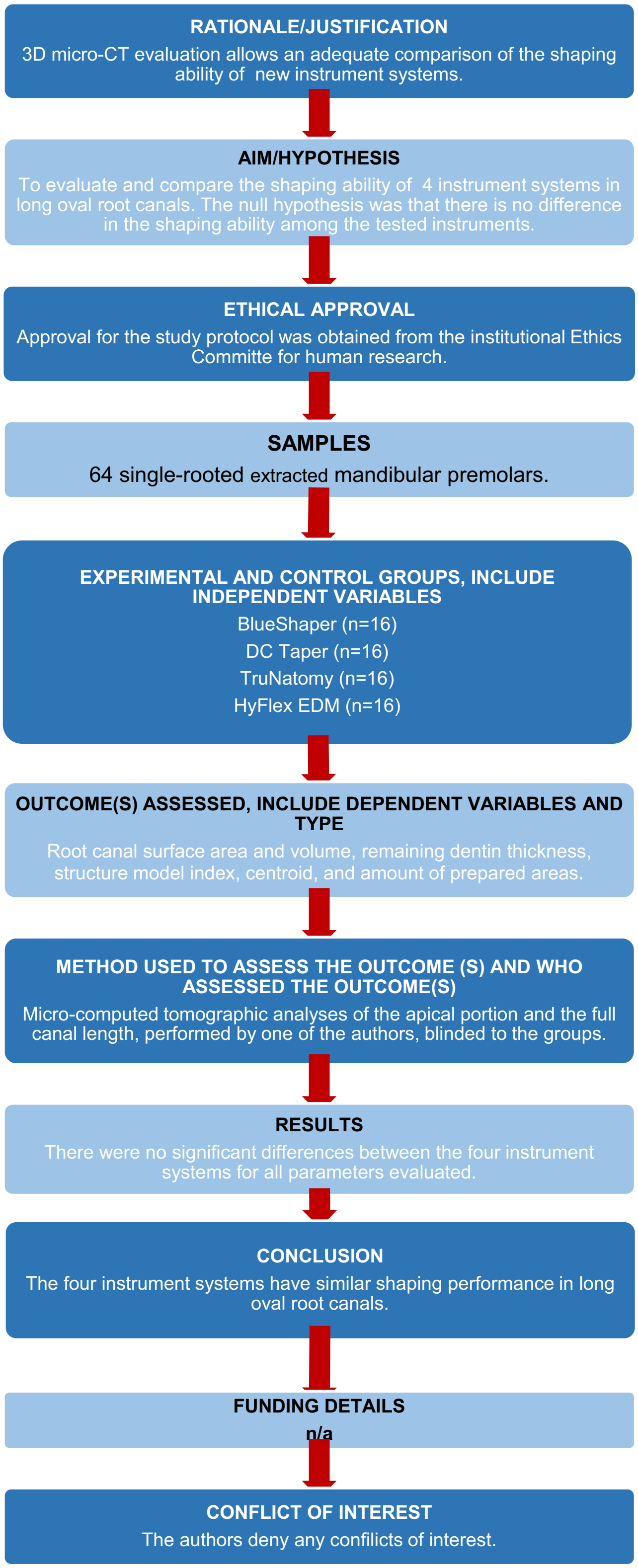

FIGURE 1 Flowchart according to the preferred reporting items for laboratory studies in Endodontology (PRILE) 2021 guidelines.

BlueShaper group

The root canals were enlarged up to the WL by sequentially using the instruments Z1 (14/.02), Z2 (17/.02), Z3 (19/.05) and Z4 (25/.05) at 500 rpm and 4 Ncm. Micro-CT scanning was conducted at this point, and the canal was further prepared to one size larger than the master apical file (Z5 30/.05). A final micro-CT scan was performed.

DC Taper. After the orifice opener instrument (25/0.09) was used, the canals were prepared to the WL with a 14/0.03 glide path file, followed by a sequence of conforming files 17/0.04, 20/0.06, 22/0.07 and 25/0.06. All the instruments were worked at 300 rpm and 4.4 Ncm. Micro-CT scanning was performed, and the canal was then enlarged to 30/0.06. Another micro-CT scan was taken.

TruNatomy system

After enlargement of the coronal third with the TN orifice modifier instrument (20/0.08), the canal was instrumented to the WL using the TN glider instrument (17/0.02), followed by the TN small (20/0.04) and TN prime (26/0.04) instruments. All the instruments were driven at 500 rpm and 1.5 Ncm. A micro-CT scan was taken after the last instrument size, and the canal was further enlarged with the TN medium file (36/0.03). Another micro-CT scan was performed.

HyFlex EDM

The coronal third of the canal was flared using the orifice opener instrument (25/0.12), and the canal enlarged to the WL by using an HEDM glidepath file (10/0.05) at 300 rpm/1.8 Ncm, followed by OneFile (25/0.08), at 400 rpm/2.5 Ncm. Micro-CT scanning was conducted after the last file used. In the case of this system, the manufacturer suggestion for straight canals was followed, using the One file as the master apical file.

All instruments were driven by an electric motor (X-Smart Plus Dentsply Sirona). In all cases, the patency of the apical foramen was checked and maintained with a manual K-type file size #15 (Dentsply Sirona) initially and after each instrument change. The root canal was irrigated with 1 mL 2.5% NaOCl after each instrument size using a 30-G NaviTip (Ultradent Products Inc.) taken up to 3 mm short of the WL.

Micro-CT analyses

Micro-CT tomographic analyses of the apical portion and the full canal length were performed by one of the authors, blinded to the groups. The specimens were mounted on a custom attachment, and morphometric evaluation of the root canal system was accomplished using a micro-CT device (SkyScan 1174v2; Bruker micro-CT) with an isotropic resolution of 16.29 μm, 50 Kv and 800 μA. Scanning was performed by 180° rotation around the vertical axis with a rotation step of 1° using a 0.5-mm-thick aluminium filter. Images of each specimen were reconstructed with NRecon 1.6.9 software (Bruker micro-CT) providing axial cross sections of the sample. Reconstructed images captured after preparation were co-registered with the pre-operative datasets by using the 3D Slicer 4.4.0 software (http://www.slicer.org), with a custom combination of a rigid registration module based on similarities of image intensity with accuracy >1 voxel (Guedes et al., 2022). The surface area (mm^2) and volume (mm^3) of the apical canal segment (from the WL to 4 mm short of this length) and the full canal length (from the WL to 10 mm short) were calculated before and after preparation using the ImageJ 1.50d software (National Institutes of Health). This software was also used to calculate the area of unprepared canal surface by evaluating the number of static voxels, which was expressed as a percentage of the total number of voxels on the canal surface. Moreover, the CTAN v1.12 was used to evaluate the dentine thickness on the mesial and distal walls at the coronal canal opening level and 3 mm apical to this point (pericervical dentine) before and after preparation. CTVol v.2.2.1 software was used to define a colour-coded standard for root canal models as follows: green was used for the preoperative canal surface, red for the penultimate apical master file and blue for the master apical file.

Statistical analyses

Normal distribution of the data was demonstrated by the Shapiro–Wilk test. The paired sample t-*test* was used within groups and one-way analysis of variance between groups using IB; SPSS Statistic 26 (SPSS Inc). Intergroup analyses for postoperative data involved the four groups for the first master apical file and then three groups for one instrument size larger. Significance was set at $\alpha = 5\%$.

RESULTS

The overall results of the shaping performance of the four instrument systems are detailed in Table 1.

BlueShaper group

After enlargement, the volume and surface area, evaluated for both the full canal length and apical canal segment, were significantly increased ($p < .05$). For the full canal length, the mean numbers of unprepared areas, after preparation with files 25/0.05 and 30/0.05 were 38.2% and 32.7%, respectively; and for the apical canal were 40.5% and 29.4% (Figure 2). For the full canal length and apical canal, a significant increase in area and volume as well as a significant decrease in unprepared areas occurred after the increase in the final instrument size. ($p < .05$). At the CEJ level, and 3 mm apical to this point, a significance decrease in the remaining dentine thickness was observed in the mesial and distal walls ($p < .05$).

DC taper group

The canal volume and surface area were significantly increased after preparation ($p < .05$). The mean numbers of unprepared areas with files 25/0.06 and 30/0.06 were 56% and 42% for the full canal length, and 50.5% and 32.8% for the apical segment, respectively (Figure 2). Whilest the increase in apical preparation from 25/0.06 to 30/0.06 caused no increase in volume and area ($p > .05$), there was a significant reduction in the unprepared areas in both the full and apical canal ($p < .05$). After instrumentation, a significance decrease in the remaining dentine thickness, in both the mesial and distal walls, was observed ($p < .05$).

HyFlex EDM group

The canal volume and surface area increased significantly after instrumentation ($p < .05$). The mean numbers of unprepared areas for the full canal length and the apical segment after preparation with instrument 25/0.08 were 44.6% and 39%, respectively (Figure 2). The remaining dentine thickness significantly decreased in both the mesial and distal walls following preparation ($p < .05$).

TruNatomy group

As with all the other groups, the volume and surface area of the canal were significantly increased after preparation ($p < .05$). A significant difference was also observed after an increase in the apical instrument size from 26/0.04 to 36/0.03 ($p < .05$). The mean numbers of unprepared canal areas after preparation with instruments 26/0.04 and 36/0.03 were, respectively, 52.1% and 28.2% in the full canal length and 47.2% and 21.8% in the apical 4 mm segment (Figure 2). The increase in apical instrument size

TABLE 1 Microcomputed tomographic analyses after preparation of oval root canals using four instrument systems.

	DC taper		Blue shaper		TruNatomy		Hyflex EDM
Data	**25/06**	**30/06**	**25/05**	**30/05**	**26/04**	**36/03**	**25/08**
Total length (10 mm)							
Volume (mm^3)							
Initial	9.14 ± 3.75	9.14 ± 3.75	7.08 ± 3.66	7.08 ± 3.66	8.45 ± 4.62	8.45 ± 4.62	11.11 ± 4.88
After	9.47 ± 3.73	9.68 ± 3.65	7.85 ± 3.22	8.27 ± 3.20	8.77 ± 4.56	9.16 ± 4.45	11.37 ± 4.94
Surface area (mm^2)							
Initial	53.54 ± 13.17	53.54 ± 13.17	48.50 ± 10.79	48.50 ± 10.79	50.80 ± 15.48	50.80 ± 15.48	60.00 ± 16.76
After	55.23 ± 12.60	55.89 ± 12.41	51.38 ± 10.69	52.09 ± 10.53	51.27 ± 15.41	52.77 ± 14.16	60.62 ± 16.69
Unprepared area (%)	56.08	42.02	38.23	32.79	52.14	28.28	44.6
Apical portion (4 mm)							
Volume (mm^3)							
Initial	1.49 ± 1.14	1.49 ± 1.14	1.17 ± 0.88	1.17 ± 0.88	1.33 ± 0.94	1.33 ± 0.94	1.66 ± 1.24
After	1.58 ± 1.11	1.67 ± 1.21	1.31 ± 0.83	1.41 ± 0.82	1.41 ± 0.95	1.53 ± 0.92	1.76 ± 1.18
Surface area (mm^2)							
Initial	13.39 ± 5.41	13.39 ± 5.41	11.70 ± 4.35	11.70 ± 4.35	12.41 ± 4.99	12.41 ± 4.99	14.66 ± 6.70
After	14.00 ± 5.13	14.15 ± 5.06	12.55 ± 4.08	12.93 ± 3.99	12.75 ± 5.04	13.34 ± 4.60	15.16 ± 6.45
Unprepared area (%)	50.56	32.83	40.55	29.48	47.24	21.80	39.07
Dentin thickness (mm)							
At the CEJ							
Mesial canal wall							
Initial	1.45 ± 0.24	1.45 ± 0.24	1.42 ± 0.10	1.42 ± 0.10	1.39 ± 0.17	1.39 ± 0.17	1.53 ± 0.26
Final	1.44 ± 0.24	1.41 ± 0.25	1.33 ± 0.12	1.28 ± 0.14	1.35 ± 0.18	1.30 ± 0.18	1.50 ± 0.25
Distal canal wall							
Initial	1.45 ± 0.15	1.45 ± 0.15	1.41 ± 0.15	1.41 ± 0.15	1.41 ± 0.16	1.41 ± 0.16	1.49 ± 0.24
Final	1.44 ± 0.15	1.42 ± 0.16	1.33 ± 0.15	1.30 ± 0.16	1.37 ± 0.15	1.34 ± 0.15	1.45 ± 0.25
3 mm below the CEJ							
Mesial canal wall							
Initial	1.12 ± 0.17	1.12 ± 0.17	1.16 ± 0.12	1.16 ± 0.12	1.15 ± 0.14	1.15 ± 0.14	1.20 ± 0.21
Final	1.09 ± 0.18	1.06 ± 0.20	1.08 ± 0.11	1.03 ± 0.13	1.12 ± 0.15	1.08 ± 0.14	1.18 ± 0.21
Distal canal wall							
Initial	1.19 ± 0.21	1.19 ± 0.21	1.15 ± 0.14	1.15 ± 0.14	1.18 ± 0.12	1.18 ± 0.12	1.20 ± 0.25
Final	1.13 ± 0.22	1.10 ± 0.22	1.04 ± 0.14	1.01 ± 0.17	1.13 ± 0.14	1.10 ± 0.15	1.14 ± 0.26

Note: Data for the total root canal length (10 mm) and the apical segment (4 mm); expressed as mean ± SD.

Abbreviation: CEJ, cementoenamel junction.

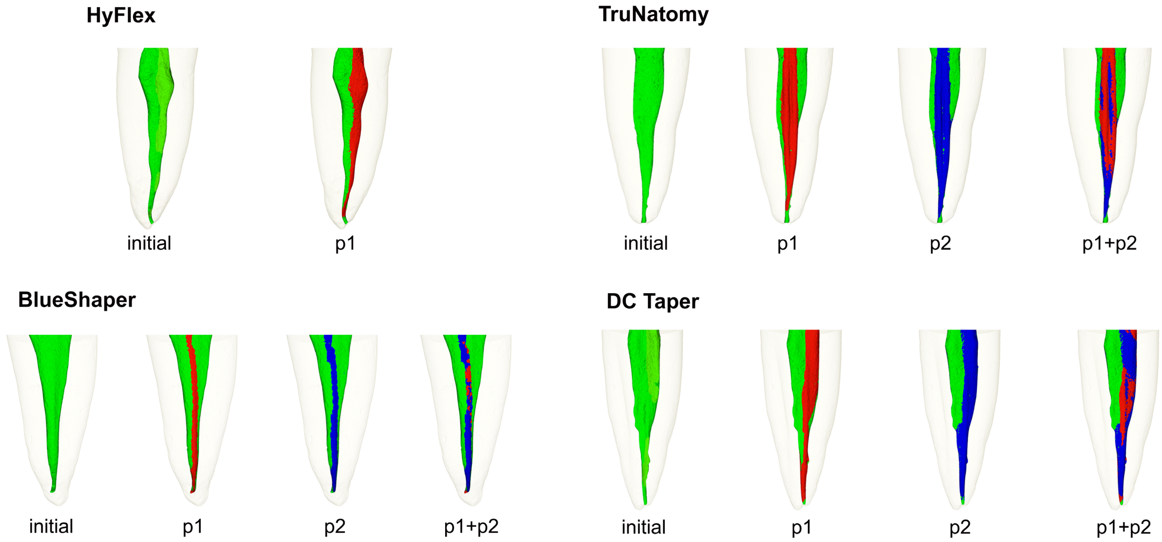

FIGURE 2 Representative 3D reconstructions of micro-CT scans taken before and after root canal preparation using the different instrument systems. Superimposed views depict unprepared surface areas in green, prepared areas after the first master apical file in red (p1) and prepared areas after additional apical enlargement (except for HyFlex) in blue (p2).

promoted a significant additional reduction in the number of unprepared areas ($p < .05$). A significant decrease in the remaining dentine thickness occurred in both the mesial and distal walls ($p < .05$).

Intergroup comparison

No significant differences were found between groups when comparing all the shaping parameters evaluated preoperatively (canal volume and area, unprepared area and dentine thickness) in both the full and apical canal ($p > .05$). The same was observed when comparing groups for postoperative evaluations after the first master apical files (four groups) and the second larger ones (three groups: BlueShaper, TruNatomy and Hyflex EDM) ($p > .05$).

DISCUSSION

The present study compared the shaping ability of four recent rotary NiTi file systems using micro-CT in long oval-shaped canals because this anatomic condition usually represents a challenge for virtually all preparation systems (De-Deus et al., 2011; Siqueira et al., 2010; Versiani et al., 2011). Micro-CT technology allows the root canal morphology to be non-invasively evaluated before and after instrumentation, providing information on changes in several shaping parameters, including the canal volume, area, unprepared surfaces and dentine thickness (Swain & Xue, 2009). In this study, the tooth specimens were matched based on internal morphologic similarities as assessed by micro-CT and then distributed amongst the groups, minimizing biases introduced by anatomic variations. The effectiveness of this approach was confirmed by the findings of no significant intergroup differences in these parameters for pre-operative evaluations.

To reduce the main influence of the instrument size on shaping performance, an attempt was made to select the master apical file within similar sizes: 25/0.05 for BlueShaper, 25/0.06 for DC Taper, 26/0.04 for TruNatomy, and 25/0.08 for Hyflex EDM. Indeed, the present findings demonstrated no significant differences in the post-operative parameters when comparing the four systems. Similar results were observed in the comparisons of the three groups (BlueShaper, DC taper and TruNatomy) in which an additional larger instrumentation was carried out. Therefore, the null hypothesis was accepted.

The number of unprepared canal surface areas is one of the most important parameters evaluated in micro-CT studies (de Sousa-Neto et al., 2018). This is because correlative micro-CT/microscopy studies have demonstrated that residual biofilms or pulp tissue remnants are frequently observed in most unprepared walls (Pérez et al., 2020; Siqueira et al., 2018). None of the examined instrument systems used in this study could prepare the whole root canal surfaces; this agrees with previous studies also using oval-shaped canals (Busquim et al., 2015; ElAyouti et al., 2008; Lacerda et al., 2017; Paqué & Peters, 2011; Paqué et al., 2010; de Sousa-Neto et al., 2018; Thomas et al., 2020; Versiani et al., 2011). However, a decrease in the number of unprepared areas, for both the full and apical canal, following an increase in the apical preparation size, was shown. This was particularly evident for the three systems that had an additional instrumentation to a file size larger and is consistent with the findings from previous studies (De-Deus et al., 2015; Pérez et al., 2018, 2020; Peters et al., 2015). Moreover, studies have shown that larger preparations can promote better canal cleaning and disinfection (Albrecht et al., 2004; Rodrigues et al., 2017); this can be partially explained by the present findings.

TruNatomy was the instrument that prepared the highest amount of canal surface, 71.8% for the full canal and 78.2% for the apical segment, after preparation with 36/03 file. These results are in line with a previous study that reported good-shaping results (88%–94% of the canal surface prepared) when using TruNatomy 36/03 instrument (Silva et al., 2022).

Excessive dentine removal is not desirable because the risk of root fracture increases proportionally to the loss of dentine, especially in the pericervical area (Hulsmann et al., 2005). Consequently, coronal root dentine should be preserved as much as possible; and at least 1 mm of coronal dentine thickness should be conserved around the prepared canal (Katz et al., 2006; Kishen, 2006). In the present study, dentine thickness was significantly reduced at the canal opening and 3 mm apical to this point after instrumentation with all systems; a significant decrease was demonstrated after the additional enlargement. These findings agree with those of previous studies (Pérez et al., 2018, 2021; Silva et al., 2022). However, in most specimens, the thickness of the remaining dentine was above 1 mm, which is consistent with the findings from Pérez et al. (2018) using HyFlex CM preparation in other tooth types.

Considering the lack of research on BlueShaper and DC Taper instruments, further research should focus on evaluating the shaping ability of these systems, as well as that of TruNatomy and HyFlex EDM in curved canals.

CONCLUSION

The four instrument systems had similar shaping ability during the preparation of long oval canals. None of them could completely prepare all the root canal surfaces. A significant reduction in the number of unprepared areas was noted after enlarging the root canal to one file size greater.

AUTHOR CONTRIBUTION

Zenaida García Castañeda: investigation, resources. Susana Gomes Azevedo: conceptualization, methodology, writing - original draft. Jorge Flores Treviño: project administration. Gustavo Marínez: formal analysis. Sabrina C. Brasil: methodology, formal Analysis, investigation. Thaís M. Souza: formal analysis. Isabela N. Rôças: validation, writing - review & editing. José F. Siqueira Jr.: conceptualization, methodology, validation, formal analysis, writing - review & editing, supervision, project administration.

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CONFLICT OF INTEREST STATEMENT

The authors deny any conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the finding of this study are available from the corresponding author upon reasonable request.

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