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Research Article

Impact of Instrumentation of Curved Mesial Canals in Mandibular Molars with the XP-Endo Shaper and Hyflex

Kelly Fonseca Barbosa Aquino[1], Carlos Eduardo da Silveira Bueno[1], Ana Grasiela Limoeiro[2]*, Rina Andrea Pelegrine[1], Wania Christine Figueiredo Dantas[1], Pamela Freitas Aguiar[1], and Carlos Eduardo Fontana[3]

[1]Faculdade São Leopoldo Mandic, Instituto de Pesquisa São Leopoldo Mandic, Campinas, Brasil

[2]Faculdade de Odontologia de Bauru, Departamento de Dentística, Endodontia e Materiais Dentários, Universidade de São Paulo, Bauru, Brasil

[3]Pontifical Catholic University of Campinas, Programa de Pós-graduação em Ciências da Saúde, São Paulo, Brazil

***Corresponding Author:** Ana Grasiela Limoeiro, Faculdade de Odontologia de Bauru, Departamento de Dentística, Endodontia e Materiais Dentários, Universidade de São Paulo, Bauru, Brasil.

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Abstract

Introduction: This study compared the shaping ability of mesial canals in lower molars using the Hyflex CM and XP-endo Shaper rotary instrumentation systems, utilizing high-resolution computed tomography.

Materials and Methods: Thirty-four mesial canals were instrumented and divided into two groups (n = 17): Hyflex CM (HCM) and XP-endo Shaper (XP). A high-resolution computed tomography scan was performed before and after the root canal preparation. The data were analyzed by two trained evaluators. The parameters analyzed included the canal centralization in the cervical, middle, and apical segments, as well as in the entire canal, and the increase in the area at segments 0-3 mm, 0-6 mm, and 0-9 mm from the apex, using the EVOL software. For intragroup and intergroup assessment of the surface area at the three levels, the T-test or Wilcoxon test was used. The ANOVA test was employed for intragroup evaluation of preparation centralization among the three levels.

Results: In the flattening region across all segments, both systems showed statistically significant differences intragroup ($p < 0.05$). Regarding surface area, a statistically significant difference was observed only in the apical segment, where the XP-endo Shaper system resulted in a greater area of wear compared to the preparation provided by the Hyflex system ($p = 0.0025$).

Conclusion: It was concluded that both systems, despite having different instrumentation methodologies and thermal treatments, showed similar outcomes in the instrumentation of curved mesial canals.

Keywords: Endodontic Treatment; High-resolution Computed Tomography; Preparation Centralization; Shaping Ability

Introduction

With the introduction of nickel-titanium rotary systems, instrumentation has become faster and safer than manual instrumentation, favoring the preservation of the original canal anatomy [1]. Due to superelasticity, NiTi instruments offer advantages over stainless steel files, such as greater flexibility and a lower number of ledges formed during instrumentation. The characteristics of the instruments and the manufacturing method can significantly affect the clinical performance of NiTi rotary instruments [2].

Despite improvements in the characteristics of rotary instruments, a portion of the dentin wall area still remains untouched after preparation, which can lead to failures in endodontic treatment [3]. In curved canals, incomplete removal of dentin in one portion of the canal and excessive removal in another can increase the risks of apical transportation, fracture, and root weakening [4].

The first rotary system with controlled memory was launched in 2010 and is called Hyflex CM (Coltène/Whaledent, Allstätten, Switzerland). This controlled memory effect is achieved through a special thermomechanical treatment. The system features multiple instruments with triangular cross-sections (in sizes 25/.08 and 20/.06) and quadrangular cross-sections (in sizes 20/.04, 25/.04, 30/.04, and 40/.04). The flexural resistance of its instruments is up to 300% greater than that of instruments made from conventional NiTi alloys (Tanomaru-Filho., *et al*. 2018) due to the predominance of the martensitic phase in its alloy [5].

The XP-endo Shaper instrument (FKG, La Chaux-de-Fonds, Switzerland) was introduced to the market in 2016, following the concept of single-file preparation, and is made from the MaxWire alloy (Martensite-Austenite Electropolishing-Flex, FKG). This alloy undergoes a transformation from the martensitic phase to the austenitic phase with an increase in temperature (35°C), promoting the expansion of the instrument, originally size 30/.01, to size 30/.04. This expansion occurs, therefore, in a single step, without the need to introduce progressively larger files [6].

Cone beam computed tomography (CBCT) has become available for dental offices due to reductions in cost and size. Unlike conventional tomography, it has a shorter acquisition time and uses lower radiation doses. Furthermore, CBCT images meet the American Association of Endodontics recommendations for effectively resolving complex clinical cases [7].

Therefore, the objective of this study was to evaluate the shaping ability of mesial canals in lower molars using the Hyflex CM and XP-endo Shaper rotary instrumentation systems through high-resolution computed tomography. The null hypothesis tested was that the instruments would provide equivalent canal shaping concerning the analyzed parameters.

Materials and Methods

Selection of teeth

This study was approved by the research ethics committee under no. 3,575,335. A total of 102 freshly extracted lower molars, removed for periodontal reasons and donated by patients, were selected for evaluation. Based on the inclusion criteria, 17 teeth were chosen for the research. The inclusion criteria were lower molars exhibiting intact roots with a Vertucci [8] class IV configuration, with curvature ranging from 20º to 30º [9], and with two independent canals in the mesial root, without prior endodontic treatment. Teeth with cracks, fractures, or internal and/or external resorption, and those that did not allow for patency with a No. 10 file were excluded from the study. The teeth were disinfected in a sodium hypochlorite (NaOCl) solution for 24 hours post-extraction and stored in 0.1% thymol until use.

Image acquisition

A cone beam computed tomography (CBCT) scan (Prexion 3D Elite) was performed before and after instrumentation of all teeth. The apical region of the teeth was sealed with a Gingival Barrier (Top Dam - FGM) to simulate the periodontal ligament, creating a barrier for instrumentation. For the tomographic examination, the teeth were embedded in a base made of addition silicone (Nova DFL), and markings were made on the base to ensure that during both moments of imaging, they remained in the same position to facilitate subsequent analysis. A cone beam tomography system (Prexion 3D Elite CBCT, Prexion 3D XP68, The Yoshida Dental) was used. The tomographic images were taken with FOV: 56.00/81.00 mm; KV: 90.00; mA: 4.00; time: 37.0/19 sec. The acquisition software used was Prexion 3D Scanner, version 6.3.2.3, developed by Prexion - The Yoshida Dental. The analysis software used was EVOL-DX, version 4.5.0.24, developed by CDT Software. Data on the measurements of the teeth were recorded before and after instrumentation.

Preparation of the teeth

All experimental procedures were performed by a single experienced endodontist in an environment with a temperature of 37ºC. For both groups, the endodontic accesses were made with a 1014 HL drill, followed by the Endo Z. The working length was determined using Kerr No. 10 files, to the apical limit, subtracting 1 mm from where the file was visible in the foramen, with the aid of an operating microscope. The glide path was created using manual Kerr #10 and #15 files. Canal patency was maintained during the procedure up to a length of 19 mm, and the final apical preparation was determined up to size 35. Between each stage of preparation, the instrument was cleaned with gauze, and irrigation was performed using a disposable syringe and a 30-G NaviTip hypodermic needle positioned 2 mm from the working length, totaling 20 mL of 2.5% NaOCl, with 10 mL for each root. The motor used was the Reciproc Silver (VDW), following the manufacturer's recommendations for each system. The canals were dried with absorbent paper and repositioned for final scanning. Each mesial root was instrumented with both systems, with the selection of which canal would be instrumented by each system chosen randomly through a drawing, according to the following groups:

- Hyflex CM Group (HCM) - The instruments were used with a torque of 2.5 Ncm and a speed of 500 rpm. The instrumentation sequence using the crown-to-apex technique followed the order: 25/08, 20/04, 25/04, 20/06, 30/04.
- XP-endo Shaper Group (XPS) - The instruments were used with a torque of 1.0 Ncm and a speed of 800 rpm. After five movements of the instrument, a 30/0.4 gutta-percha cone was tested, and once it fit properly, the instrumentation was ceased.

Assessment methodology

The first analysis performed was a millimetric measurement using the EVOL-DX software, version 4.5.0.24, developed by CDT Software. The volume analyzed was from the external walls of the teeth in the mesial roots to the internal wall of the canal (Figure 1 and Table 1). For this, the surface area of the roots was obtained in mm^2 before and after preparation.

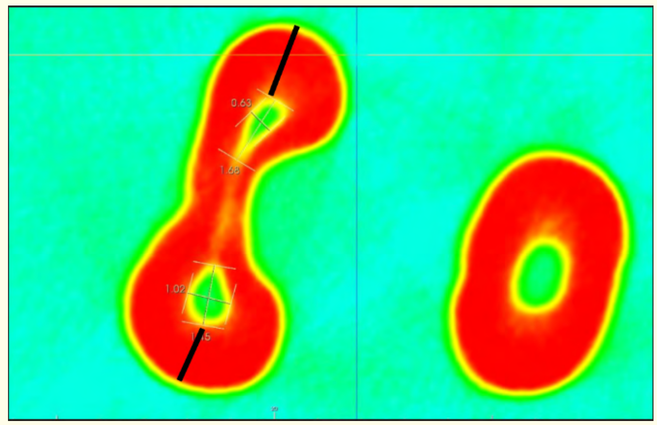

Figure 1: Blue lines demonstrating measurement 01. Where the dentin thickness between the external wall and the internal wall of the root canal was measured in mm, before and after instrumentation with both tested systems.

Groups	Level	Surface area before		Surface area after	
		Mean (SD)	Median (IQ)	Mean (SD)	Median (IQ)
HyFlex	3 mm	1.26 ± 0.49	1.29 (0.91/1.56)	1.34 ± 0.43	1.29 (1.1/1.49)
	6 mm	1.54 ± 0.39	1.51 (1.44/1.64)	1.52 ± 0.34	1.42 (1.35/1.61)
	9 mm	1.96 ± 0.37	1.85 (1.72/2.27)	1.97 ± 0.35	1.84 (1.74/2.00)
XP-Endo Shaper	3 mm	1.27 ± 0.46	1.28 (1.04/1.55)	1.3 ± 0.47	1.29 (0.93/1.44)
	6 mm	1.47 ± 0.31	1.41 (1.32/1.57)	1.44 ± 0.26	1.41 (1.26/1.61)
	9 mm	1.90 ± 0.43	1.91 (1.69/2.06)	1.91 ± 0.26	1.97 (1.73/2.07)

Table 1: Surface area (mm^2) of the root canals, before and after preparation, considering the three evaluated segments (3, 6, and 9mm).

The second analysis was performed on the internal walls of the mesial canals, where the size of their internal walls was measured in millimeters in the bucco-lingual direction (Figure 2 and Table 2).

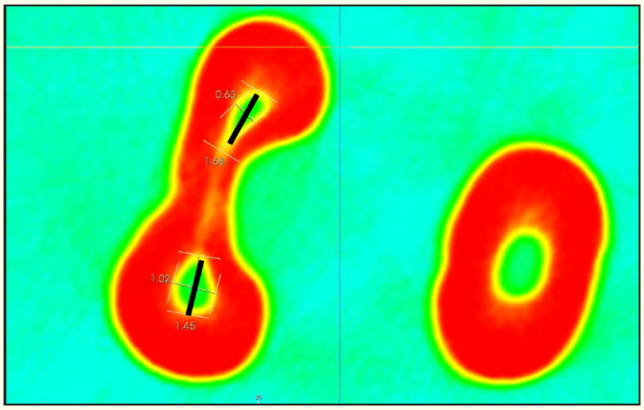

Figure 2: Blue lines demonstrating measurement 02. Where the vestibulo-lingual distance of the internal walls in the root canal was measured in mm, and measured before and after with both tested systems.

Groups	Level	Surface area before		Surface area after	
		Mean (SD)	Median (IQ)	Mean (SD)	Median (IQ)
HyFlex	3 mm	0.50 ± 0.21	0.46 (0.43/0.68)	0.61 ± 0.09	0.63 (0.59/0.65)
	6 mm	0.87 ± 0.36	0.81 (0.62/0.89)	0.99 ± 0.30	0.95 (0.77/1.05)
	9 mm	1.71 ± 1.60	0.87 (0.78/1.65)	2.43 ± 1.79	1.3 (1.07/4.17)
XP-Endo Shaper	3 mm	0.40 ± 0.19^{A}	0.38 (0.23/0.50)	0.66 ± 0.12^{B}	0.62 (0.61/0.67)
	6 mm	0.78 ± 0.39	0.79 (0.41/1.07)	0.93 ± 0.21	0.94 (0.83/1.08)
	9 mm	1.7 ± 1.59	1.11 (0.71/1.37)	2.51 ± 1.72	1.37 (1.15/4.17)

Table 2: Surface area (mm^2) of the root canals, before and after preparation, considering the three evaluated segments (3, 6, and 9mm) in the bucco-lingual direction.

The third analysis was also performed on the internal walls of the mesial canals, where the size of their internal walls was measured in millimeters in the mesio-distal direction (Figure 3 and Table 3).

Groups	Level	Surface area before		Surface area after	
		Mean (SD)	Median (IQ)	Mean (SD)	Median (IQ)
HyFlex	3 mm	0.33 ± 0.16^{A}	0.31 (0.26/0.44)	0.51 ± 0.10^{B}	0.51 (0.47/0.56)
	6 mm	0.48 ± 0.08^{B}	0.45 (0.41/0.50)	0.75 ± 0.08^{C}	0.74 (0.71/0.79)
	9 mm	0.65 ± 0.15^{C}	0.61 (0.60/0.66)	1.06 ± 0.17^{D}	1.05 (1.00/1.11)
XP-Endo Shaper	3 mm	0.36 ± 0.25^{D}	0.34 (0.14/0.54)	0.60 ± 0.17^{E}	0.55 (0.53/0.64)
	6 mm	0.52 ± 0.23^{E}	0.54 (0.33/0.61)	0.82 ± 0.13^{F}	0.80 (0.78/0.86)
	9 mm	0.71 ± 0.22^{F}	0.64 (0.59/0.73)	1.11 ± 0.24^{G}	1.06 (0.99/1.17)

Table 3: Surface area (mm^2) of the root canals, before and after preparation, considering the three evaluated segments (3, 6, and 9mm) in the mesio-distal direction.

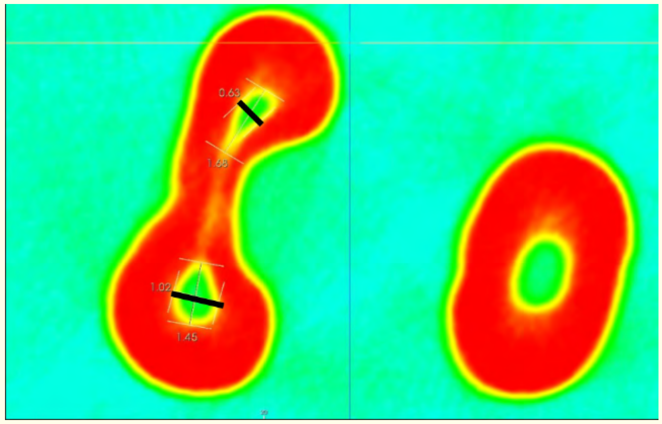

Figure 3: Blue lines demonstrating measurement 03. Where the distance in mm of the internal walls of the root canal was measured in the Mesio-Distal direction (region of greatest flattening), performed before and after instrumentation with both tested systems.

The last analysis aimed to assess canal centralization, verifying whether the systems used could maintain their position at the center of the root canal after instrumentation. Measurements were taken in mm in the central region between the root canals. After these measurements, it was possible to evaluate the centralization and any potential deviations in the preparation of the canals (Table 4).

Group	Segment	Mean (SD)	Median (IQR)
Before	Cervical	2.13 (0.91)	2.12 (1.65/2.60)
	Middle	2.3 (0.62)	2.18 (1.89/2.73)
	Apical	2.01 (0.8)	1.94 (1.52/2.5)
After	Cervical	1.93 (0.9)	2.1 (1.42/2.62)
	Middle	2.28 (0.63)	2.15 (1.88/2.82)
	Apical	1.89 (0.77)	1.91 (1.2/2.37)

Table 4: Change in center of gravity (mm-1), before and after preparation.

The images were analyzed by two independent evaluators using the EVOL-DX software, version 4.5.0.24 (CDT Software), utilizing a color map tool, which clearly demonstrates the thickness of the dentin.

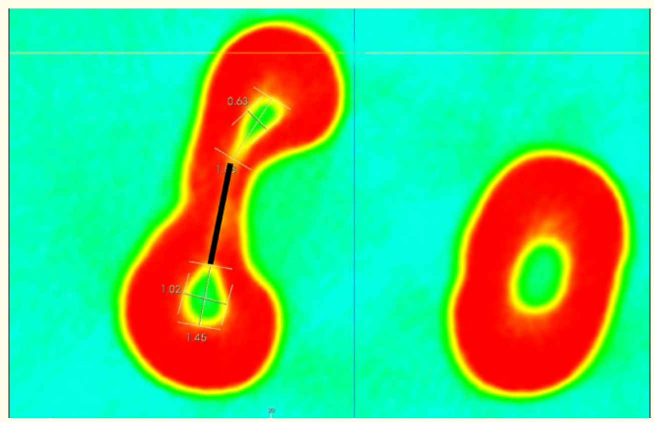

Figure 4: Blue lines demonstrating measurement 04. Where the distance in mm of the internal walls of the root canal was measured in the Mesio-Distal direction (region of greatest flattening), performed before and after instrumentation with both tested systems.

Statistical analysis

The data distribution was assessed using the Shapiro-Wilk normality test. For intragroup evaluation of the surface area at three levels (3 mm, 6 mm, and 9 mm) before and after, the t-test or Wilcoxon test was used when necessary. The evaluation of the surface area between the groups, also at the three levels before and after, utilized the t-test or Wilcoxon test as needed. The ANOVA test was employed for intragroup evaluation of canal transportation. A p value < 0.05 was considered statistically significant. For this analysis, RStudio software (R3.2.2, 2015-08-14; New Zealand) was used, and GraphPad Prism 5 for Windows (GraphPad Software, CA, USA) was used for the graphs.

Results

The values related to the volume of the root canal, wear of the internal walls, and preparation centralization are shown in Tables 1 to 4. All teeth were paired in a manner that ensured their measurements were similar ($p > 0.05$). There was no significant difference between the two systems when comparing "within and between groups" regarding the surface area (mm^3), with both groups considered at levels of 3, 6, and 9 mm ($p > 0.05$).

Similarly, there was no significant difference between the two systems regarding the surface area (mm^3), with both groups considered at levels of 3, 6, and 9 mm ($p > 0.05$).

A significant difference ($p = 0.0025$) was found intragroup, between the performance of XP (3 mm) before and after, where the XP system showed substantial wear in the region. Again, there was no significant difference between the two systems concerning the surface area (mm^3), with both groups considered at levels of 3, 6, and 9 mm ($p > 0.05$). Both systems were able to perform the instrumentation while remaining at the center of the root canal ($p > 0.05$).

Discussion

This study aimed to evaluate the shaping ability of mesial canals in lower molars using the Hyflex CM (HCM) and XP-endo Shaper (XPS) rotary instrumentation systems, employing cone beam computed tomography (CBCT). The study did not reveal significant differences between the systems in the parameters analyzed; therefore, the null hypothesis was accepted.

Using extracted teeth, rather than artificial ones [10], allowed for testing the file systems under natural dentin conditions. Mandibular molars were selected due to their frequent indication for endodontic treatment and their roots' challenging anatomies with curvatures, which can heighten the risk of apical transportation during instrumentation [11].

Various methods have been used to evaluate the efficiency of root canal instrumentation, including radiographic comparisons, histological sections, scanning electron microscopy, CBCT [12], and micro-CT [13]. CBCT was chosen for evaluation due to significant advancements in tomography and assessment software, providing good clinical applicability by allowing for in vivo results reproduction, as well as evaluation of dentin volume removed, surface area, constriction, and canal cross-section shape without damaging the dental structure [14].

Measurements taken before and after instrumentation indicated no statistical differences between the groups. However, an intragroup statistical difference was found in the apical region (3 mm) for the XPS system, likely due to its capacity to expand within the canal, resulting in a larger canal size in the apical portion where dentin walls are thinner. Apical canal transportation measuring less than 0.3 mm, as found in our results, suggests minimal impact on the prognosis of endodontic treatment [15]. The results with XPS can be linked to its Adaptive Core technology, which helps preserve the original anatomy of the root canal. Previous evaluations of canal transportation and centralization capabilities of XPS and Wave One Gold have shown that XPS consistently displays transport values below 0.3 mm [12].

In our study, no significant differences were observed between the systems regarding centralization, aligning with findings from other studies [13,16] that demonstrated success in maintaining canal centralization during instrumentation. This can be attributed to the high flexibility of both systems, and the type of alloy may also contribute to their performance in curved canals [17]. Additional evidence from studies involving mandibular canines and mesiobuccal canals of mandibular molars indicates favorable centralization with XPS compared to other systems [16,18].

Despite the Hyflex system utilizing multiple instruments, our study found no greater effectiveness than the single-file approach of XPS, as both systems achieved similar levels of wear among canal walls, including in the flattening region. This observation corroborates another study [17] while contradicting claims from Vinodhini., *et al.* [14] that suggested HCM maintained better centrality.

Both groups exhibited wear in the flattening region, which is considered a risk zone [4]; however, this difference was not statistically significant. The intragroup difference in wear was not deemed harmful to endodontic treatment, as there was no weakening of the mesial root structures. This study also found no significant differences in canal transportation between HCM and XPS, which aligns with observations in mandibular premolars [19], contrasting with findings from Khandeparkar., *et al*. [20], where XPS demonstrated higher transportation than HCM and Trunatomy in the apical region of mesio-buccal canals, although all three systems maintained the canal center similarly.

Regarding the increased perimeter of the inner canal walls, both systems showed conservative treatments, particularly in the cervical region, which differs from another study comparing XPS with Reciproc, where Reciproc made more contacts with walls and promoted greater dentin preservation in the apical zone [21]. The increase in perimeter across all segments indicates instrumental contact with the walls, resulting in structural wear. This suggests that superelasticity did not compromise the cutting ability of the instruments, as wall wear occurred consistently across all segments. However, this wear did not detrimentally affect the root structures, and when combined with chemical cleaning, it may contribute to the success of endodontic treatments.

Considering the methodological differences between the Hyflex system, which employs five instruments and therefore requires a longer clinical time, and the XPS system, which utilizes only one instrument, the impact of this difference was not significant in our study. Additionally, the final preparation achieved in the canals was very similar for both systems. As a result, clinicians can select the instrumentation systems for clinical treatments based on their personal preferences, provided that these instruments feature treated alloys that ensure the necessary superelasticity for effectively managing curved canals.

In conclusion, under the conditions of this ex vivo study, the instrumentation of moderately curved mesial roots with two independent root canals and foramina using the HCM and XPS rotary systems resulted in minimal apical transportation. Both instruments demonstrated minimal procedural errors during the shaping of the root canals.

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