Comparative Evaluation of Shaping Ability and Cleaning Efficiency of Three Different Nickel-Titanium Rotary Systems

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Abstract:

Objective: This study was conducted to compare the shaping ability and cleaning efficiency of Mtwo, ProTaper Next and HyFlex CM rotary systems. **Materials and Methods:** A total of 45 root canals with curvatures ranging between 20o and 40o were divided into three groups of 15 canals: Mtwo, ProTaper Next and HyFlex CM based on pre-instrumentation radiographs. Canals were prepared to an apical size of 30. Using pre- and post-instrumentation radiographs, canal straightening was determined with a computer image analysis program. Preparation time was also recorded. These data were analysed using one-way analysis of variance (ANOVA) and post hoc Tukey's test, and significance was set at $P < 0.05$. The amounts of debris and smear layer were quantified based on a numerical evaluation scale and were analysed statistically using the Kruskal–Wallis test. **Results:** HyFlex CM and ProTaper Next maintained the canal curvature significantly better than Mtwo ($P < 0.05$). ProTaper Next was significantly faster than the other two systems ($P < 0.05$). For debris removal, Mtwo and ProTaper Next achieved significantly better results ($P < 0.05$) than HyFlex CM in the apical and middle canal thirds. The smear layer results were not significantly different for the different parts of the canals ($P > 0.05$). **Conclusions:** Under the conditions of this study, HyFlex CM and ProTaper Next maintained the original canal curvature better than Mtwo. The use of Mtwo and HyFlex CM required more time to prepare the curved canals. Mtwo and ProTaper Next resulted in better canal cleanliness compared with HyFlex CM.

Introduction:

Successful root canal treatment depends on the reduction of intracanal micro-organisms through a proper chemo-mechanical preparation of the root canal system with the preservation of its geometry and the prevention of recontamination after therapy. The more complex the root canal anatomy, the higher the demands of the endodontic instruments in terms of efficiency and preparation safety.[1, 2]

Since 1970s, the root canal preparation was performed using stainless steel hand instruments, that had a number of limitations mainly in curved canals causing deviations, zip formations and perforations.[3]

Such limitations were behind the continuous researches to find instruments with increased flexibility and cutting efficiency. NiTi rotary systems have proved their ability to closely maintain original canal curvature, create uniformly-tapered canal form and complete instrumentation in reasonable time period.[4]

In spite of the advancements in modern nickel-titanium (NiTi) systems, the symmetrical root canal preparation is still not completely feasible. Curved root canals preparation always remains challenging not only for uniform canal shaping, but also for the proper cleaning of the canal dentin wall.

Shaping of root canals produces debris and an uneven smear layer on the root canal walls[5]. Debris includes dentin chips, remnants of pulp tissue and microorganisms attached to the root canal wall that is considered to be source of infection in most cases.

The smear layer is a thin surface film containing mainly inorganic material that is created when a canal is prepared; therefore, no smear layer is found on areas that are not touched by instruments. The presence of debris and smear layer, especially in the apical region of the canal, is of clinical importance because it may cause endodontic failure. The smear layer closes dentinal tubules and decreases the efficacy of irrigating solutions, affects the quality of obturation and outcome of endodontic treatment.[6]

Mtwo instruments (Sweden Martina, Due Carrare, Padova, Italy) are conventional NiTi rotary instruments that have an S shaped cross-sectional design with two cutting edges and a non-cutting tip. The two cutting edges have a positive rake angle and the pitch length increases from the tip to the shaft. This design is alleged to eliminate the threading and the binding in the continuous rotation and reduce the transportation of the debris toward the apex.[7]

ProTaper Next files (Dentsply Maillefer, Ballaigues, Switzerland) are made of M-Wire NiTi (Sportswire LLC, Langley, OK), which yields a microstructure containing portions of martensite, thus improving the flexibility and cyclic fatigue resistance of the alloy over conventional NiTi. These files present a unique off-centered rectangular cross-section design as well as progressive and regressive percentage tapers on a single file. These design features improve flexibility and debris removal, prevent unnecessary dentin removal and limit taper lock, screwing and torque on any instrument.[8]

HyFlex CM rotary instruments (Coltene-Whaledent AG, Allstetten, Switzerland) are made from CM wire, that is produced by an advanced approach to control the instrument memory. It is claimed that this alloy, together with the design features of the instruments, provide a superior flexibility and up to 300% more cyclic fatigue resistance compared to instruments manufactured from conventional NiTi allowing better maintenance of the original canal curvature as well as increased efficiency and safety.[9]

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The present study is designed to evaluate and compare the shaping ability, via canal straightening, preparation time and incidence of instrument separation, and cleaning efficiency of these three different NiTi rotary systems. The null hypotheses of this study were that there is no significant difference between the three tested rotary NiTi systems regarding canal straightening, preparation time and their cleaning ability in moderately to severely curved root canals.

Materials and Methods:

A total of forty-five freshly extracted mandibular molars for periodontal reasons were included in this study. The teeth were cleaned, disinfected and stored in saline till use. The inclusion criteria are: morphological similarity, moderately or severely curved mesial root canals with single curvature in both buccolingual and mesiodistal radiographic views and root canal width near the apex approximately compatible with size 15 K-file were included. Teeth with extensive restorations, previous root canal treatment, cracked/fractured roots, root resorption, root caries, significant canal calcifications or canals with apical diameters larger than size 15 K- file were excluded.

Sample preparation

A straight-line access cavity was performed using a high-speed hand piece (NSK, Shinagawa, Tokyo, Japan) with a long shank round bur and Ash Tungsten Endo-Z bur (Dentsply Maillefer, Ballaigues, Switzerland). A size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed in the mesiobuccal canal to verify patency.

The crowns of the selected samples were not removed to maintain pulp chamber to act as a reservoir for the irrigant. Before instrumentation, standardized radiographic images were taken with size 15-K file in the mesiobuccal canal. Each sample was placed in a radiographic mount made of silicon-based impression material (Zhermack Via Bovazecchino, Badia Polesine, Italy) to maintain a fixed position. Dental film positioning system (Tpc, Lawson, USA) which held Digora imaging plate (Digora optime, Soredex, Tuusula, Finland) was aligned so that the long axis of the root canal was parallel and as near as possible to the surface of the imaging plate. The X-ray tube (Belmont, chome, Higashishinsaibashi, chuo-Ku, Osaka, Japan) and the central X-ray beam were aligned perpendicular to the root canal. The exposure parameters (0.12 s; 70 kV, 7 mA) were similar for all radiographic images with a fixed source-to-film distance of 15 cm and a sample-to-film distance of 5 mm. The digital radiographs were analyzed using the Digora software to measure the angel of curvature according to Schneider's method[10].

Only teeth with angel of curvature ranged between 20–40 degrees were selected. To ensure similar mean degree of curvature between groups, teeth were divided into four groups according to the degree of canal curvature (20-25) (25-30) (30-35) (35-40) then randomly distributed in three equal groups (N=15) according to the type of instruments used in root canal preparation, (Table 1).

Group A: Mtwo (Sweden Martina, Due Carrare, Padova, Italy).

Group B: ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland).

Group C: HyFlex CM (Coltene Whaledent AG, Altstatten, Switzerland).

Root canal instrumentation

The instruments were used with an x-smart torque limited electric motor (Dentsply Maillefer, Ballaigues, Switzerland) with 16:1 reduction rotary x-smart contra angel hand piece in clockwise rotation respecting manufacturers' recommendations regarding torque and speed. Mtwo protocol required four files sequence (engine settings: 300 rpm and 2.0 N/cm): 15/.05, 20/.06, 25/.06 and 30/.05, with apical diameter of 0.30 mm and 5% taper finishing preparation. ProTaper Next protocol required three files sequence (engine settings: 300 rpm and 2.0 N/cm): X1, X2 and X3, with apical diameter of 0.30 mm 7% taper finishing preparation. HyFlex CM protocol required five files sequence (engine settings: 500 rpm and 2.5 N/cm): .08/25, .04/20, .04/25, .06/20 and .04/30, with apical diameter of 0.30 mm 4% taper finishing preparation.

Each rotary file was used for preparing five root canals. Root canals were irrigated during instrumentation between each file change with 3 mL of 5.25% NaOCl using a plastic syringe with a 30-gauge side vented needle (ENDO-TOP; CERKAMED, Stalowa Wola, Poland). Size 10 k-file was used to check the patency after each file.

After preparation, 4 mL of 17% EDTA (ENDO-SOLution, CERKAMED, Stalowa Wola, Poland) was left in situ for 120 s followed by 1 mL of 5.25% NaOCl for 60 s as final rinse. Finally, all the canals were washed with ethanol for 30 s and dried with size 30 paper points (META BIOMED, Korea).

Shaping ability evaluation

At the end of canal preparation, the canal curvature was redetermined on the basis of a radiograph with the final root canal instrument inserted into the mesiobuccal canal using the same technique. Based on the canal curvatures assessed pre- and post-instrumentation, canal straightening was determined as the difference between canal curvature before and after instrumentation. The preparation time and the number of fractured instruments during instrumentation were recorded. The canal preparation time included total active instrumentation, instrument changes within the sequence, cleaning of the instrument flutes and irrigation.

Cleaning efficiency evaluation

All samples were decoronated and the mesial root was separated from the distal root using a low – speed diamond disc under water. Deep longitudinal grooves were prepared along the buccal and lingual surfaces of the mesial roots without exposing the root canal. Roots were then split longitudinally with a micro-blade and mallet into 2 halves. A stereo microscope was used to view the half with the most visible part of the canal and the other half was discarded.

All specimens were dried in a graded ethanol series and then allowed to dry in a desiccator at room temperature for 24h. The samples were sputter-coated with gold-palladium alloy and mounted on metallic stubs.

Each canal wall was evaluated in the coronal, middle, and apical thirds of the root using a Scanning Electron Microscope (SEM) (JEOL, JSM- 6510LV, JEOL Ltd., Tokyo, Japan). To ensure standardization of the area examined for each sample, the central beam of the SEM was directed to the center of each third of the canal space being analyzed under 30X magnification, which was then increased to 400X for debris and 1000X for smear layer and the selected area of the canal was photographed and used for scoring. One image per third was taken and coded.

The cleanliness of each root canal was evaluated in three areas (apical, middle and coronal third of the root) by means of a numerical evaluation scale (Hulsmann et al.)[11] The following scheme was used:

• Debris scoring:
Score 1: clean root canal wall, only few small debris particles
Score 2: few small agglomerations of debris
Score 3: many agglomerations of debris covering less than 50% of the root canal wall
Score 4: more than 50% of the root canal wall covered by debris
Score 5: complete or nearly complete root canal wall covered by debris.
• Smear layer scoring:
Score 1: no smear layer, orifice of dentinal tubules patent.
Score 2: small amount of smear layer, some open dentinal tubules.
Score 3: homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules.
Score 4: the entire root canal wall covered with a homogenous smear layer, no open dentinal tubules.

Score 5: a thick, homogenous smear layer covering the entire root canal wall.

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences, version 25 (SPSS, Chicago, IL, USA). Canal straightening and preparation time data were analyzed using one way analysis of variance (ANOVA) and Turkey post hoc tests. The significance level was set at $P < 0.05$. The debris and smear layer scores were analyzed statistically using the Kruskal–Wallis test performed for post hoc comparisons among the groups tested and among the thirds of the canals. Statistical significance level was set at $P < 0.05$.

Results:

The mean straightening of the curved canals is shown in, (Table 2). The highest mean value of canal straightening was for the Mtwo group that was 7.31^o with significant difference compared with the other two groups ($P < 0.05$). The lowest mean value was for the HyFlex CM group that was 3.85^o with no significant difference between the HyFlex CM and PTN groups ($P > 0.05$).

During this study, no instrument fracture was recorded in all tested groups. The mean time taken to prepare the canals with the different instruments is shown in, (Table 3). Instrumentation with PTN files was significantly faster than with HyFlex CM and Mtwo files ($P < 0.05$). HyFlex CM was the slowest with no significant difference between Mtwo and Hyflex CM ($P > 0.05$).

The average scores for debris and smear layer in the coronal, middle and apical third of the canals are reported in, (Tables 4 and 5). Completely clean root canals were not found, (Figures 1-4). There was no significant difference in debris scores between Mtwo and PTN groups when comparing coronal, middle and apical thirds ($P > 0.05$). HyFlex CM group showed significantly higher scores than other tested groups in the apical and middle thirds of the canals ($P < 0.05$), while there was no significant difference in debris scores between the three tested groups in the coronal thirds ($P > 0.05$).

Kruskal-Wallis test showed no significant difference in smear layer scores between all tested groups when comparing coronal, middle and apical thirds ($P > 0.05$).

Table 1: Sample distribution in groups according to degree of curvature (n = 15 teeth per group)

Instrument	Curvature [°] Mean ± SD	Min	Max
Mtwo	29.28±5.31	21.43	37.24
ProTaper Next	29.42±5.20	21.89	38.5
HyFlex CM	29.46±5.61	20.22	38.84

SD: Standard Deviation

Table 2: Mean degree of straightening of curved canals (°) and SD after canal preparation with the different instruments (n = 15 canals in each group)

Instrument	Mean	SD	Min	Max
Mtwo	7.31	1.93	4.41	10.33
ProTaper Next	5.43	1.75	2.78	7.93
HyFlex CM	3.85	1.93	0.66	7.29

SD: Standard Deviation

Table 3: Mean preparation time (sec) and SD with the different instrument

Instrument	Mean	SD
Mtwo	296.40	17.42
ProTaper Next	245.40	21.85
HyFlex CM	307.13	24.11

SD: Standard Deviation

Table 4: Average score for debris for the coronal, middle and apical third of the canals (Values with the same superscript letters were not statistically different at * P = 0.05)

Instrument	Coronal	Middle	Apical	Overall
Mtwo	1.13^a	1.2^a	1.8^a	1.38^a
ProTaper Next	1.33^a	1.33^a	1.8^a	1.49^a
HyFlex CM	1.4^a	2.2^b	3^b	2.27^b

Table 5: Average score of the smear layer for the coronal, middle and apical third of the canals (Values with the same superscript letters were not statistically different at *P = 0.05)

Instrument	Coronal	Middle	Apical	Overall
Mtwo	1.2^a	1.4^a	2.07^a	1.56^a
ProTaper Next	1.2^a	1.27^a	1.8^a	1.42^a
HyFlex CM	1.2^a	1.2^a	2.8^a	1.73^a

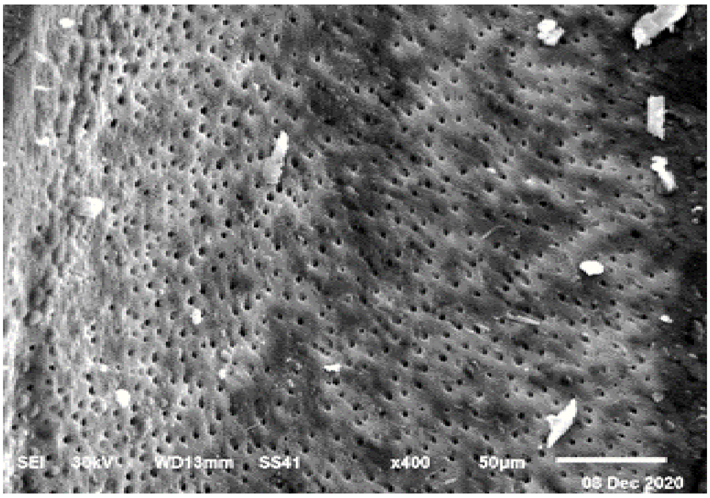

Figure 1: Clean canal wall with only small agglomerations of debris particles in the apical portion of the canal prepared with ProTaper Next (score 1, magnification 400x)

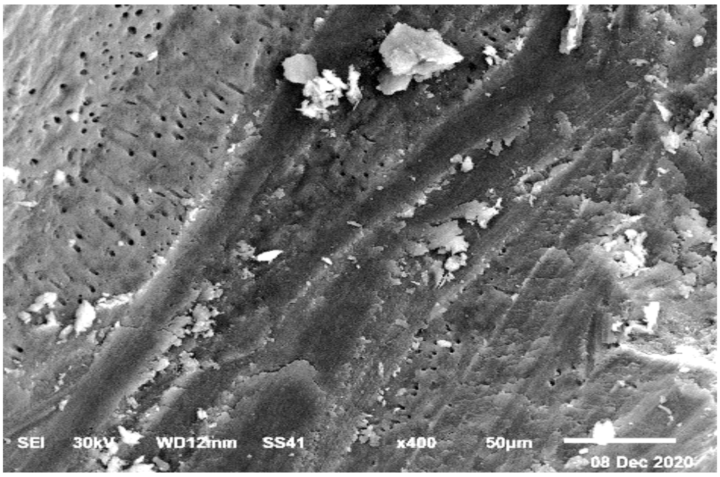

Figure 2: Canal wall with many agglomerations of debris covering more than 50% of the root canal wall in the apical portion of the canal prepared with HyFlex CM (score 4, magnification 400x)

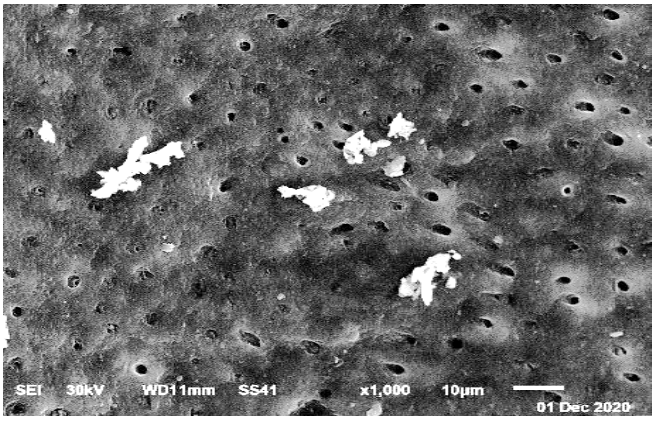

Figure 3: Canal wall with only a small amount of smear layer on the entire canal wall and some open dentinal tubules in the middle portion of the canal prepared with ProTaper Next (score 2, magnification 1000x).

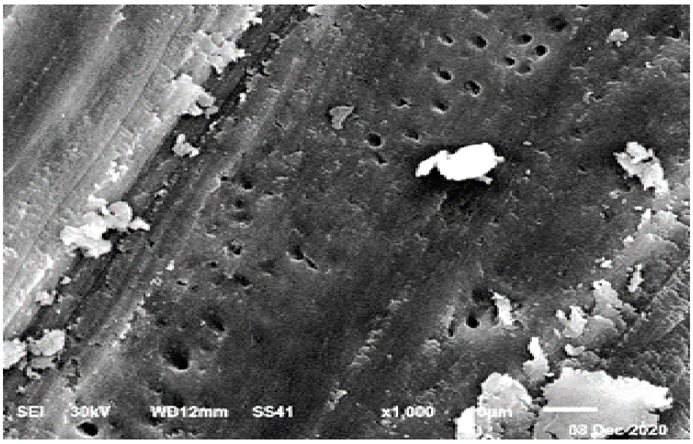

Figure 4: Canal wall with homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules in the apical portion of the canal prepared with HyFlex CM (score 3, magnification 1000x).

Discussion:

This study was designed to evaluate and compare the shaping ability and cleaning efficiency of three rotary file systems in mesiobuccal canals of extracted human mandibular first molars in an experimental setting. These file systems were selected as they represent different endodontic instrument designs as well as different microstructure of NiTi alloys.

In the present study, shaping ability was evaluated using the radiographic method in natural root canals to simulate clinical situations. The radiographic method is a noninvasive method, but it only detects two-dimensional changes in three-dimensional object. However, Katz[12] demonstrated that the greatest changes in the root canal occurs in the mesiodistal dimension.

In the current study, the canal straightening results of HyFlex CM group were comparable to the results obtained by the ProTaper Next group. These findings corroborate those of Huang et al.[13]. These results were in conflict with the results of Saber et al.[14] who revealed that the use of HyFlex CM instruments resulted in significantly less canal straightening than ProTaper Next instruments. This difference may be due to the use of only three instruments from the HyFlex CM system in the latter study rather than the full sequence including the orifice opener as in the current study.

The present study showed that HyFlex CM has superior shaping ability and can prepare curved root canals with minimal canal straightening. These results are supported by Lin et al.[15]. The excellent shaping ability of HyFlex CM can be attributed to the unique manufacturing process of CM wire that controls the material's memory making the files extremely flexible. This also reduces the restoring force magnitude by changing their spiral shape during canal instrumentation, thereby allowing the CM wire to follow the anatomy of the canal very closely and preventing unnecessary iatrogenic errors.

In this study, the eccentric file cross-section, the variable taper, the shorter sequence and the higher cutting efficiency of PTN instruments can justify their good shaping ability similar to HyFlex CM. These results come in accordance with those of Ayyad and Saleh[16].

The current study showed that the use of Mtwo resulted in significantly more pronounced canal straightening. The increased file rigidity because of the conventional NiTi alloy is the main cause for the disadvantageous shaping ability of Mtwo instruments. The elastic modulus of CM-wire and M-wire is lower than conventional NiTi alloy that can be paraphrased as an increase in the flexibility of the thermomechanically treated PTN and HyFlex CM instruments compared with Mtwo instruments as described by Shim et al.[17].

In this study, the instrumentation time was mainly related to the number of files used in each system. PTN group, that consisted of three files, required significantly less instrumentation time as compared with HyFlex CM and Mtwo groups. HyFlex CM instruments were slower than Mtwo instruments with no significant difference in the mean preparation time between the two groups. The comparable results of Mtwo and HyFlex CM systems are supported by those of Bürklein et al.[18].

In contrary to the results of the present study, Koring et al.[19] compared the preparation time of Mtwo, PTN and HyFlex CM with two other NiTi rotary systems in simulated S-shaped canals. HyFlex CM and Mtwo files worked slower than PTN files. However, HyFlex CM files were faster than Mtwo files. This difference in results may be due to the more complex anatomy of the S-shaped canals making HyFlex CM instruments benefit from a higher cutting efficiency than Mtwo as a result of their greater flexibility allowing files to reach the working length faster. Besides, in the present study each file was used to prepare five canals rather than one canal. During instrumentation, HyFlex CM reacts to resistance by unwinding of the spirals and the files regain their original shape during sterilization through temporary transition to the austenite phase. HyFlex CM file deformation due to multiple use in this study could have affected its cutting efficiency making it slower.

No instrument fractured during the present study. All instruments were used to prepare five curved canals; therefore, these files could be used to enlarge at least five canals using the instrumentation sequence described in this study without an increased risk of instrument failure. This means a molar tooth that have four root canals or more can be prepared with one rotary file sequence.

In this study, SEM evaluation of the remaining debris and smear layer has been used as criteria for the cleaning efficiency assessment of the tested instruments because debris mainly consists of dentin chips, residual vital or necrotic pulp tissue attached to the root canal wall that could be infected. The evaluation of SEM results is subjected to potential bias in field selection and observer interpretation of the results and it also requires splitting the root to expose the canal for observation that is difficult to perform reproducibly in thin and curved roots. However, this method is considered to be the gold standard for the efficiency of root canal cleaning.

In the current study, no significant difference was found in the coronal third of the canals between the three groups and the canal cleanliness decreased from the coronal to the apical part of the root canal. These observations come in accordance with the results of researches conducted by Girgis et al.[20] and Machado et al.[21]. This could be due to the relatively wider diameter and proximity to irrigation devices that render the coronal third more susceptible to irrigation technique rather than the preparation technique.

According to the results of this study, there was no significant difference in debris scores between Mtwo and PTN groups when comparing coronal, middle and apical thirds ($P > 0.05$). HyFlex CM group showed significantly higher debris scores than other tested groups in the middle and apical thirds of the canals ($P < 0.05$) making HyFlex CM less effective in root canal cleaning. These results corroborate those of Poggio et al.[22]. The results for HyFlex CM come in accordance with the results of Jayakumaar et al.[23] who compared the root canal cleaning produced by XP-endo Finisher, PTN and HyFlex CM in mandibular premolar teeth under similar irrigation conditions. Similar to the present study, HyFlex CM group had higher debris scores compared with PTN and XP-endo Finisher groups.

This study showed no significant difference in smear layer scores between the three tested groups. These results are supported by Machado et al.[21].

A possible reason for this difference in the debris removal capacity of the tested instruments is their design features. The higher debris scores of HyFlex CM in this study especially at the apical third of the canal could be explained by the irregular geometry of the file design producing a nonuniform root canal shape, that could have hindered flushing of debris and smear layer adequately.

In this study, PTN instruments showed better debris and smear layer removal due to their off-centered rectangular cross section causing a snake-like swaggering movement of the file as it advances into the root canal that generates enlarged space for debris removal. This is supported by Girgis et al.[20] and Ismail et al.[24] who confirmed the superior cleaning effectiveness of PTN compared to other systems with different kinematics and design.

The present study showed that Mtwo instruments have good cleaning efficiency that can be attributed to their double-cutting edge S-shaped cross-sectional geometry with minimal radial contact and small core diameter. These design features reduce the transportation of debris towards the apex and guarantee enough space between the canal walls and the instrument resulting in great chip removal capability. The good cleaning effectiveness of Mtwo file system was also reported by Severino et al.[25].

Conclusions:

According to the results of this study, the null hypotheses were rejected and the following conclusions were drawn:

• All instruments were safe to use. HyFlex CM and ProTaper Next instruments respected the original canal curvature better than Mtwo instruments.

• The ProTaper Next instruments prepared the curved canals faster than Mtwo and HyFlex CM.

• Root canal preparation with Mtwo and ProTaper Next instruments resulted in better canal cleanliness in the apical and middle thirds compared with HyFlex CM instruments.

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