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ORIGINAL ARTICLE

Shaping Ability of F6 SkyTaper®, Hyflex® EDM One File, and One Curve®: A Micro-computed Tomographic Evaluation in Curved Root Canals

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ABSTRACT

Objective: The present study aimed to compare the shaping ability of the F6 SkyTaper® (F6S), HyFlex® EDM OneFile (HEDM), and One Curve® (OC) nickel-titanium single-file instruments using micro-computed tomography.

Methods: Fifty-two mesiobuccal roots of maxillary first molars, with a degree of curvature between 20° and 42°, were randomised into three experimental groups (n=15 per group): F6S, HEDM, and OC, and a non-instrumented control group (n=7). All specimens were scanned by micro-computed tomography before and after instrumentation. The following parameters were evaluated: preparation time, volume of dentine removed, cutting efficiency, unshaped surfaces, and canal transportation. Cutting efficiency was analysed using an ANOVA parametric test and Tukey's multiple comparison post hoc test. Other parameters were analysed using a non-parametric Kruskall-Wallis test followed by Dunn's multiple comparison post hoc test.

Results: No instrument separation occurred during instrumentation. No significant differences were found between the instrument groups with respect to all the parameters (p>0.05). All the instruments induced morphological changes in the root canal dentine (p<0.05) and tended to increase canal transportation toward the coronal portion of the root canals (p>0.05).

Conclusion: All instruments were able to shape curved canals and preserve their original anatomy. Single-file endodontic procedures with these instruments can be used with comparable changes in the root canal shape with minimal transportation.

Keywords: Canal transportation, cutting efficiency, micro-computed tomography, NiTi endodontic instrument, unshaped surface

HIGHLIGHTS

- This study provides evidence-based data on the shaping ability of the F6 SkyTaper®, HyFlex® EDM OneFile, and One Curve® nickel-titanium single-file instruments.
- Single-file endodontic procedures with these instruments can be assessed safely regarding the changes that they produce in the anatomy and the structure of the root canals.
- Canal transportation decreased toward the apical region.

INTRODUCTION

Most endodontic therapy is based on Schilder's concepts of cleaning, shaping, and filling the root canal (1). Shaping creates a funnel that can easily be irrigated to remove bacteria, toxins, and organic debris from the root canal to prevent and heal periapical pathologies. However, this must be done conservatively to avoid iatrogenic damage to the canal system and the root structure (2).

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Nickel-titanium (NiTi) instruments that have a high taper, display cyclic fatigue resistance, and are flexible, making it possible to attain these biomechanical goals (3), especially for the treatment of curved roots (4). In addition, single-file instruments (e.g., F6 SkyTaper®, HyFlex® EDM OneFile, One Curve®, etc.) were recently developed to facilitate the mechanical preparation of root canals by shortening preparation times, reducing the risk of failures, and preventing possible cross-contamination among patients (5).

F6 SkyTaper® (F6S; Komet, Lemgo, Germany) is a single-use NiTi single-file instrument available in five tip diameters (ISO 20, 25, 30, 35, and 40) and three lengths (21, 25, and 31 mm). It has an S-shaped cross-section with a 0.06 mm/mm constant taper (6). HyFlex® EDM OneFile (HEDM; Coltene-Whaledent, Altstätten, Switzerland) is a heat-treated reusable NiTi single-file instrument produced from a controlled memory wire and is manufactured by electro-discharge machining (7). The taper at the tip of the file starts at 0.08 mm/mm (diameter 25) and decreases until it reaches 0.04 mm/mm towards the coronal section. The cross-section is rectangular at the tip, trapezoidal in the middle, and almost triangular toward the coronal section (8). One Curve® (OC; Coltene-Whaledent Micro-Mega, Besançon, France) is a single-use heat-treated NiTi single-file instrument. Its C-wire alloy provides the instrument with a controlled memory and pre-curvature features (9). The 25/.06 tip of the file has a triangular-shaped cross-section that becomes S-shaped toward the coronal section.

To date, no studies have compared these recent instruments and the morphological changes they produce in the walls of root canals during cleaning and shaping. X-ray micro-computed tomography (micro-CT) is a precise, nondestructive, three-dimensional imaging technique (10), which makes it the most suitable method for assessing these changes before and after instrumentation (11).

The present study aimed to compare the shaping abilities of the F6S, HEDM, and OC instruments in curved root canals of human teeth using micro-CT. The null hypothesis tested was that there were no significant differences between the instruments in terms of preparation time, volume of dentine removed, cutting efficiency, percentage of unshaped surfaces, and canal transportation.

MATERIALS AND METHODS

Specimen Preparation

This research received ethics committee approval (DC-2008-642) and used mature human maxillary first molars extracted for reasons unrelated to the present study. A sample size calculation was performed using a free online tool (www.stat.ubc.ca) with a power of 0.90 and α=0.05, resulting in a required size of 14 samples and adjusted to 15 per group for a total sample of 52.

The teeth were decoronated using a diamond disk (A22D15; Dian Fong, Shenzhen, China) to remove coronal interferences and cut the mesiobuccal roots to the same length (15 mm). The specimens were stored in an isotonic saline solution. The root canal inlets were opened, and the patency of the canals was checked with a K-file #10 (MMC, Micro-Mega, Besançon, France). The working length was set at 1 mm less than this measure.

The specimens were scanned using a micro-CT device (Skycan 1172; Bruker, Kontich, Belgium) at 95 kV, 100 µA, an isotropic resolution of 21.9 µm, a 180° rotation with a 0.4° rotation step around the vertical axis, and a 0.5 mm aluminium and copper filter. Data were reconstructed using NRecon (version 1.7.4.6, Skyscan, Bruker, Kontich, Belgium) with 80% beam hardening, smoothing of 1, ring artefact correction of 2, and gray scale between 692 and 1818 Hounsfield. The regions of interest of the whole specimens were established using CTAn software (Version 1.20.2.0 (64-bit), Skyscan, Bruker, Kontich, Belgium) and were exported as BMP files.

The canal curvature and the radius of curvature ranged between 20° and 42° (Mean: 27.53°, SD: 5.60°) and between 2 and 12 mm (Mean: 7.22 mm, SD: 1.96 mm), respectively, according to Schneider's and Pruett's methods (12, 13) (Table 1). MB2 was found in 60% of the roots. The preoperative apical diameter ranged from 0.188 mm (SD: 0.031 mm) to 0.196 mm (SD: 0.031 mm), and the root canal volume ranged from 1.607 mm^3 (SD: 0.762 mm^3) to 1.739 mm^3 (SD: 0.920 mm^3).

Root Canal Preparation

One endodontist performed all the preparations using an X-Smart Plus motor (Dentsply-Sirona, Charlotte, NC, USA) and one instrument per specimen, following the manufacturer's instructions. A glide path was performed with a One G file 14/.03 (Micro-Mega, Besançon France) to standardise the canal morphology. The 52 specimens were randomised into three test groups (n=15 per group) according to the shaping system used (F6S #25/.06, HEDM #25/.08, and OC #25/.06) and one non-instrumented control group (n=7). Each instrument was used with an up-and-down motion following the manufacturer's instructions at a standardised speed and torque (300 rpm, 2.5 N.cm) until the working length was reached. The irrigation process was standardised using a syringe with a 30-G side ejection needle (Coltene-Whaledent, Altstätten, Switzerland) with 1 mL of 2.5% NaOCl between each instrumentation passage at 1 mm from the apical foramen. The final irrigation took 1 min and was performed with 0.6 mL of 17% EDTA. The canal was dried with paper tips (25/.06, Komet, Lemgo, Germany) and was rinsed with 3 mL of NaOCl.

Evaluation of the Parameters

All the specimens were scanned before and after instrumentation. Data were loaded into Avizo (v.2019.4, Thermo Fischer Scientific, Waltham, MA, USA)) software and were superimposed using the registration tool. The custom processing tool separated low-density voxels (pulp canal) from intermediate-density voxels (dentine) to generate 3D models. Root canal volume was isolated by segmentation for analysis, and all the procedure steps were carefully verified by the researchers. The total preparation time was measured, including the shaping, irrigation, control of apical patency, and drying of the root canals.

TABLE 1. Morphometric data (mean (SD)) of the samples before preparation

	Curvature degree (°)	Curvature radius (mm)	Apical diameter (mm)	Root canal volume (mm³)
F6S	27.3 (5.1)	7.1 (2.1)	0.188 (0.031)	1.739 (0.920)
HEDM	26.8 (5.0)	7.2 (2.0)	0.196 (0.031)	1.687 (0.635)
OC	28.5 (6.8)	7.4 (2.0)	0.193 (0.033)	1.607 (0.762)

SD: Standard deviation, F6S: F6 SkyTaper®, HEDM: HyFlex® EDM OneFile, OC: One Curve®

The 3D changes in the root canal geometry were quantified by comparing pre- and postoperative canal volumes. The following parameters were analysed (Figs. 1, 2):

- Volume of dentine removed (mm^3): the difference between final and initial canal volume
- Cutting efficiency (mm^3/min): the ratio of the volume of dentine removed to preparation time (14)
- Unshaped surfaces (%): the percentage of static voxel surfaces (voxels present in the same position on the canal surface before and after instrumentation) compared to the total number of voxels present on the canal surface (15)
- Canal transportation: distance of centres of gravity of the root canal (16) between pre- and post-instrumentation at 3, 5, and 7 mm from the apical foramen using CATIA R software (Version 5.20, Dassault Systèmes, Vélisy-Villacoublay, France).

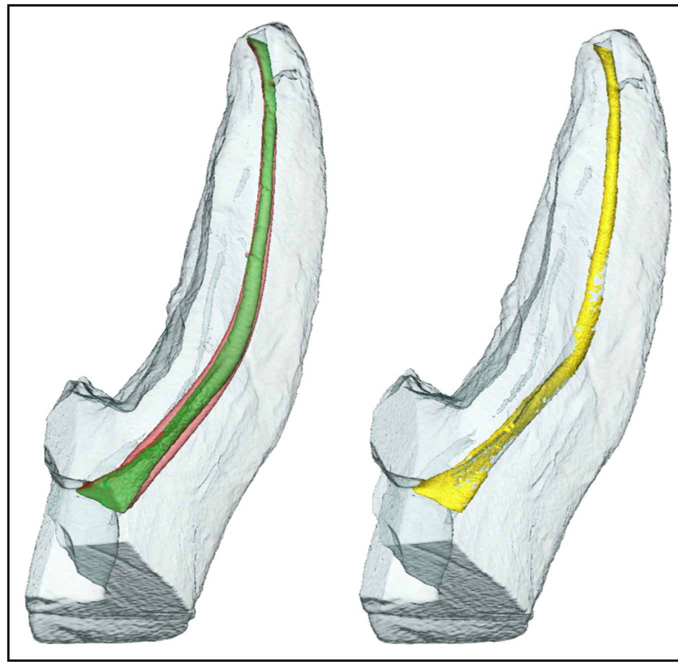

Figure 1. Representative example of micro-CT data of a mesiobuccal canal in a maxillary molar, initially (green) and prepared (red) root canal volumes, and unshaped surfaces (yellow) in the OC group

CT: Computed tomography, OC: One Curve®

Statistical Analysis

The data were analysed using GraphPad Prism 5 software (version 5.01, GraphPad Software, San Diego, CA, USA) (α=5%). The normality of the data distribution was assessed with the Kolmogorov-Smirnov test. A non-parametric Kruskal-Wallis test followed by Dunn's multiple comparison post hoc test was performed for the following parameters: preparation time, volume of dentine removed, percentage of unshaped surfaces, and canal transportation (considering instruments separately and all instruments together). Cutting efficiency was assessed using a one-way analysis of variance (ANOVA) followed by Tukey's multiple comparison post hoc test.

RESULTS

The results are presented in Table 2. No instrument separation, deformation, or root canal perforations were observed during canal instrumentation. There were no significant differences ($p>0.05$) among the three systems concerning preparation time and cutting efficiency. Preparations by all the NiTi systems increased the volume of dentine removed ($p<0.05$) and decreased the percentage of unshaped surfaces ($p<0.05$) compared to the control group but with no significant differences ($p>0.05$) between the systems. Canal transportation increased ($p<0.05$) compared to the control group for all the instruments except for F6S at 3 mm ($p>0.05$). Canal transportation at 7 mm of the apical foramen was higher than at 3 mm for all the instruments ($p>0.05$).

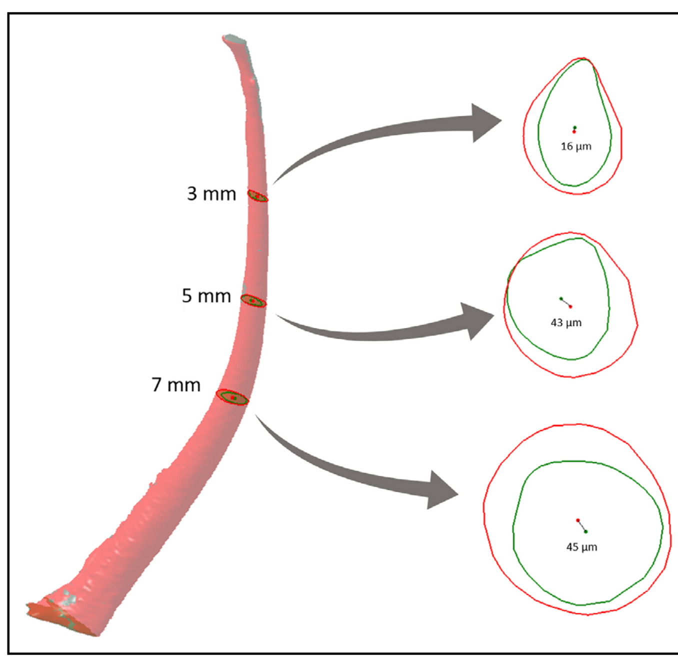

Figure 2. Measurement of the canal transportation at 3, 5 and 7 mm from the apical foramen: distance between pre- (green) and postoperative (red) centres of gravity of the root canal

TABLE 2. Summary of the results for each parameter based on the shaping system used

	Preparation time (s)	Volume of dentine removed (mm³)	Cutting efficiency (mm³/min)	Unshaped surfaces (%)	Canal transportation (mm)		
					3 mm	5 mm	7 mm
F6S							
Mean (SD)	236 (047)	1.492 (0.822)[a]	0.395 (0.221)	50.19 (21.92)[b]	0.062 (0.072)	0.110 (0.096)[d]	0.110 (0.078)[e]
Median (Q1; Q3)	229 (210; 246)	1.350 (0.930; 1.950)[a]	0.400 (0.239; 0.557)	52.48 (29.13; 68.53)[b]	0.025 (0.013; 0.074)	0.067 (0.049; 0.159)[d]	0.073 (0.050; 0.194)[e]
HEDM							
Mean (SD)	257 (058)	1.987 (0.893)[a]	0.453 (0.136)	36.16 (16.38)[b]	0.079 (0.076)[c]	0.073 (0.040)[d]	0.115 (0.118)[e]
Median (Q1; Q3)	247 (204; 300)	1.850 (1.320; 2.310)[a]	0.463 (0.393; 0.517)	41.17 (18.28; 49.00)[b]	0.050 (0.033; 0.095)[c]	0.065 (0.053; 0.091)[d]	0.078 (0.054; 0.137[e]
OC							
Mean (SD)	214 (034)	1.982 (0.873)[a]	0.575 (0.290)	43.17 (17.86)[b]	0.084 (0.050)[c]	0.094 (0.071)[d]	0.143 (0.077)[e]
Median (Q1; Q3)	203 (188; 244)	1.710 (1.250; 3.040)[a]	0.539 (0.322; 0.724)	47.42 (31.07; 61.21)[b]	0.062 (0.038; 0.128)[c]	0.085 (0.039; 0.131)[d]	0.133 (0.083; 0.182[e]
Control group							
Mean (SD)	NA	0.040 (0.069)	NA	99.80 (3.74)	0.014 (0.010)	0.017 (0.009)	0.023 (0.011)
Median (Q1; Q3)	NA	0.001 (0.000; 0.092)	NA	99.17 (92.26; 99.75)	0.013 (0.005; 0.023)	0.019 (0.004; 0.025)	0.029 (0.014; 0.032)
p	0.096	0.002	0.093	< 0.001	0.009	0.001	< 0.001

The same superscript letter indicates a significant difference from the control group in the same column (p<0.05). SD: Standard deviation, F6S: F6 SkyTaper®, HEDM: HyFlex® EDM OneFile, OC: One Curve®, NA: not applicable

DISCUSSION

The present study aimed to compare the shaping ability in continuous motion of three well-known NiTi single-file instruments composed of varying alloys, cross-sections, designs, and tapers. The null hypothesis was accepted, and the results showed that the instruments had comparable shaping abilities.

Micro-CT is the gold-standard technology for evaluating 3D morphological changes in mineralized tissue, making it suitable for measuring the volume of dentine removed, unshaped surfaces, and canal transportation caused by an endodontic instrument (10, 11).

Many comparative studies of endodontic instruments have used simulated resin root canals as they provide standardisation and reproducibility of specimens concerning working length, degree of curvature, and canal taper (17). However, resin is softer than dentine, and the heat generated by instrumentation can modify its properties, leading to instruments sticking to the canal walls, altering the canal path, and causing instrument separation (18). Hence, extracted human teeth were used in this study to replicate clinical conditions. The susceptibility of the protocol to variability was minimised by selecting maxillary first molars' mesiobuccal roots with a similar degree of curvature and evaluating the glide path before instrumentation. (19). In addition, the tip diameter, working length, rotation speed, and torque of movement were standardised within the range of the manufacturer's instructions to make it possible to compare the instruments.

The preparation times of the root canals were similar for all the instruments, ranging from 236 to 258 s, in agreement with Pedullà et al. (20), who reported no difference between the F6S and HEDM instruments. However, some studies have reported that the F6S instrument often has shorter preparation times (ranging from 75 to 103 s) (6, 21). This may be explained by the fact that the EDTA-rinsing step, followed by the drying of the canal and the final NaOCl rinse, which was not done in these studies, considerably increased the preparation time in the present study. Moreover, a lack of standardisation of resins (21) and irrigation solutions (NaOCl (5), distilled water or glycerin (21)) may also explain the differences in preparation times.

In the present study, all the instruments were similar regarding the volume of dentine removed and cutting efficiency. A previous study on HEDM reported a comparable volume of dentine removed (22). The volume of dentine removed mainly depends on the initial anatomy of human teeth (23), such as the type of tooth and the presence of oval, circular, or C-shaped canals. The working length of the specimen and the calculation technique are factors that can also affect the results. The definition of cutting efficiency often varies, but the ratio of the volume of dentine removed to the preparation time has been proposed as the most suitable way to assess it (14). Furthermore, heat treatments of alloys were assumed to improve the cutting efficiency of instruments (14), which could be expected for the heat-treated HEDM and OC instruments. In the present study, the cutting efficiencies of the HEDM and OC instruments were higher than that of the F6S instrument, although this was not statistically significant. This parameter should thus be further investigated.

None of the instruments studied could shape all the surfaces of the canal walls. In general, 10 to 50% of the canal walls remained unshaped after preparation (24). This can be explained by the complexity of the root canal anatomy, which makes many volumes, such as laminae, isthmuses, deltas, and accessory canals, inaccessible. Even though the differences were not significant, the HEDM instrument appeared to instrument the largest percentage of canal surface, possibly due to its high-taper design (25).

The canal transportation created by an instrument is an important parameter for assessing its ability to preserve the hard tissues of root canal walls (26). All the instruments tested produced similar canal transportation with no significant differences. The canal transportation values were minimal (below 0.15 mm), showing that the canal anatomy was well preserved and that the shaping was minimally invasive (27). Additionally, to avoid a negative impact on the prognosis of the treatment, as microorganisms can remain in this area, apical transportation must remain below 0.3 mm, which was attained by all the instruments tested in the present study (28). Overall, all the instruments tested trended to increase transportation towards the coronal part of the canal. High-taper instruments tend to straighten and transport the canal (29). In the present study, F6S did not increase canal transportation compared to the control at 3 mm and had the highest percentage of unshaped surfaces. However, it is important to approach this finding with caution as the transportation in this area could be smaller than the study's micro-CT resolution is capable of capturing. Moreover, higher preoperative major and minor diameters in this group could lead to less contact of F6S with the root canal walls. Further studies evaluating the percentage of unshaped surfaces from the same regions where canal transportation is calculated will help understand if the instruments present better shaping ability or if the root canals are underprepared.

Besides the advantages this highly standardised setup offers, the method also includes possible drawbacks. For example, the anatomic variability of the included teeth could impact the results. Moreover, the scan resolution used in this study was lower than in other studies evaluating root canal shaping (29), which can affect the measurements of dentine removed (30). However, 22 µm was previously shown to provide sufficient 3D data to study the anatomy of the root canal system (11).

Within the framework of the present study, all the instruments could safely shape curved root canals with low canal transportation. Furthermore, no significant differences were observed among the F6S, HEDM, and OC instruments regarding preparation time, volume of dentine removed, cutting efficiency, unshaped surfaces, and canal transportation.

Disclosures

Conflict of interest: The authors deny any conflict of interest.

Ethics Committee Approval: This study was approved by The French Ministry for Higher Education and Research Ethics Committee (Number: DC-2008-642).

Peer-review: Externally peer-reviewed.

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