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Shaping Ability of ProTaper Next, Hyflex CM, and V-Taper 2H Nickel-Titanium Files in Mandibular Molars: A Micro-computed Tomographic Study

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ABSTRACT

Introduction: Although micro-computed tomography (MCT) evaluation of the shaping ability of ProTaper Next (PTN) and Hyflex CM (HCM) files has been reported, to our knowledge, no study has assessed the performance of V-Taper 2H (VT) files. The aim of this study was to evaluate and compare the shaping ability of PTN, HCM, and VT systems in the mesial canals of mandibular molars using MCT. **Methods and Materials:** Thirty extracted first and second mandibular molars were scanned using MCT and randomly assigned to HCM, PTN, and VT groups. Images obtained before and after preparation were evaluated for the increase in the root canal volume, untouched surface area, and amount of accumulated hard tissue debris. One-way analysis of variance (ANOVA) and Kruskal-Wallis test were used to compare the variables in the groups (α=5%). **Results:** There were no statistically significant between-group differences in the postoperative measurements (P>0.05). The canal volume increased in all three groups: PTN (73.84%), VT (73.48%), and HCM (49.29%). The largest and smallest untouched areas were observed in the PTN (41.37%) and VT (30.85%) groups, respectively (P>0.05). The debris formed during canal preparation was 1.84%, 2.16%, and 2.42% in the VT, PTN, and HCM groups, respectively (P>0.05). **Conclusions:** Based on our *in vitro* study, the PTN, HCM, and VT systems showed similar shaping abilities. None of the tested canals were completely free from debris, while the untouched surface area was considerably large. The VT system had the most favorable results with the smallest untouched surface area and least debris were. We would recommend further trials to endorse these findings.

Keywords: Micro-computed Tomography; Nickel-Titanium Instruments; Root Canal Preparation; Rotary Instrumentation

Introduction

Cleaning and shaping of the root canal system are crucial steps during endodontic treatment. Chemo-mechanical preparation with preservation of the original canal anatomy, without iatrogenic events, allows adequate irrigation and canal obturation [1-3]. The introduction of rotary nickel–titanium (NiTi) files has reduced the working time and minimized the risk of procedural errors. Over the years, many rotary systems have been introduced, with files showing variations in the taper, cross-section of the working part, shape of the tip and cutting edges, composition of the NiTi alloy, and manufacturing process [4].

However, most of the available rotary systems, both continuous and reciprocating, have failed to achieve complete debridement of the canal space. They tend to leave areas of untouched walls and accumulated hard tissue debris in irregularities, which lead to residual bacteria and further infection [5]. Thus, the optimal preparation of root canals remains a challenge.

The ProTaper Next (PTN) (PTN, Dentsply Sirona, Ballaigues, Switzerland) system comprises five files (X1-X5) made from M-

Wire, a metallurgically improved version of NiTi. The instruments are characterized by a variable taper on a single file and an offset mass of rotation [6]. These features serve to decrease engagement and increase flexibility and the capacity to extract debris from canals without changing the shaping ability [7].

Hyflex CM (HCM) files (Coltene-Whaledent, Allstätten, Switzerland) are manufactured from a NiTi alloy with a lower percentage weight of nickel (52%) [8]. The files can be precurved before use and are more flexible. HCM files respond to pressure by lengthening their spirals, which prevents binding of the files to the walls. Heat treatment (*e.g.* during autoclaving) enables recovery of the original shape and reuse of the instruments. The basic set includes six NiTi instruments that are available in two lengths: 21 and 25 mm. Only the orifice opener (25/0.08) is 19 mm long [9].

V-Taper 2H (VT) files (SS White Dental Inc., Lakewood, NJ, USA) are made from CM-wire and exhibit a noncutting tip, variable taper, and variable pitch design. The parabolic core design enables high flexibility for the successful negotiation of curved canals and strengthens the files against separation [10]. The files can selectively remove dentin, which leads to the preservation of more tissue during the procedure [16]. The "VT Standard Kit" comprises six files.

Several methodologies have been used for the evaluation of the shaping ability of endodontic instruments. Among these, micro-computed tomography (MCT) has become the gold standard and shown to be an accurate method for the evaluation of the three-dimensional (3D) aspects of root canal shaping, such as the increase in the root canal volume, untouched surface area, and amount of accumulated hard tissue debris [5, 11]. Although MCT evaluation of the shaping ability of PTN [7, 12-14] and HCM [9] files has been reported, to our knowledge, no study has assessed the performance and effectiveness of VT files. The aim of this study was to evaluate and compare the shaping ability of PTN, HCM, and VT systems in the mesial canals of mandibular molars using MCT. The null hypothesis was that there is no difference between the three NiTi systems in terms of the 3D shaping parameters.

Materials and Methods

Sample selection

After local research ethics committee approval (RNN/35/20/KE), we selected 30 freshly extracted first and second mandibular molars and stored them in a 0.5% thymol solution before the experiment. A sample size calculation was conducted in each group and was considered an alpha of 5% and power of 80% or upper, which resulted in five samples. To make our results stronger, we have chosen 10 samples for each group.

The inclusion criteria were fully formed roots, curvatures between 10° and 30° [15], and an initial foramen diameter equivalent to that of a size 10 K-file (Dentsply Sirona Endodontics, Ballaigues, Switzerland).

After endodontic access, we inserted a size 10 K-file (Dentsply Sirona Endodontics, Ballaigues, Switzerland) into the mesial canals until its tip could be seen to exit the apical foramen. The working length (WL) was established 1 mm short of the apical foramen. After sectioning the distal root of the specimen, we scaled the surface of the mesial root with periodontal curettes.

Pre-instrumentation MCT images

Before instrumentation, we scanned the mesial roots of all specimens using MCT (SkyScan 1272; Bruker, Kontich, Belgium) under the following scanning conditions: X-ray source voltage, 90 kV; X-ray source current, 111 µA; and pixel size, 21 µm. Rotation of 180° was performed with a rotation step of 0.5°, and a copper (0.038 mm)+aluminum (0.5 mm) filter was selected. Before instrumentation, the initial volume (mm^3), volume of dentine (mm^3), and surface area of dentine (mm^2) were calculated, and the samples were randomly divided into three groups including PTN, HCM, and VT groups (n=10).

Root canal preparation

The same experienced operator instrumented the canals by using the X-smart Endodontic Motor (Dentsply Sirona Endodontics, Ballaigues, Switzerland) according to the manufacturer's instructions. In all groups, a glide path was created by scouting the canals to an apical size of 15 using C-pilot (VDW, Munich, Germany). Apical patency was controlled with a size 10 K-file (Dentsply Sirona Endodontics, Ballaigues, Switzerland).

PTN group

The PTN files were used with a constant speed of 300 revolutions per min (rpm) and torque set up to 2 N/cm. The sequence was as follows: X1 (size 17/0.04 taper), X2 (size 25/0.06 taper), and X3 (size 30/0.07 taper) up to the full WL.

HCM group

The HCM files were used with a constant speed of 500 rpm and torque set up to 2.5 N/cm. The operating sequence was as follows: 25/0.08 up to one third of WL, followed by 20/0.04, 25/0.04, 20/0.06, and 30/0.04 up to the full WL.

VT group

VT files were used with a constant speed of 300 rpm and torque set up to 3.0 N/cm. The following sequence was used: 17/0.04, 20/0.06, 25/0.06, and 30/0.06 up to the full WL.

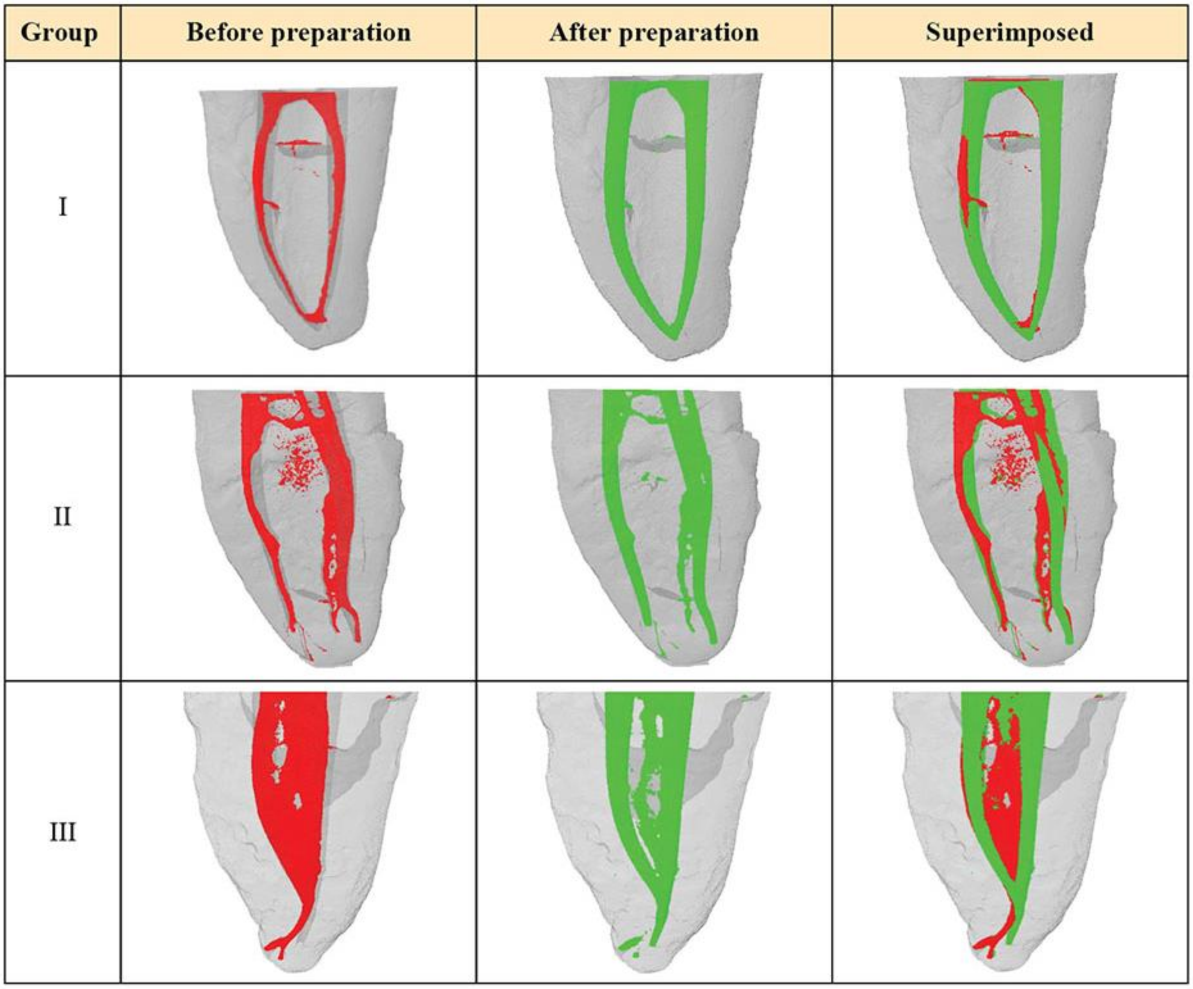

Figure 1. Three-dimensional reconstruction of canals before (red) and after (green) preparation with the different systems. The red color on the superimposed images represents the untouched surface area. I: ProTaper Next, II: Hyflex CM, III: V-Taper 2H

In each group, we prepared the canals to an apical size of 30. Each set of instruments was used to enlarge two root canals in one root and discarded. After the use of each instrument, we irrigated the canals with 1 mL of 5.25% NaOCl. The final irrigation protocol was standardized for every canal in each group: 10 mL of 5.25% of NaOCl, followed by 5 mL of 17% EDTA for 3 min and, finally, 5 mL of 0.9% saline. We irrigated the canals using a 5-mL disposable plastic syringe with a 30-gauge Endo-Eze Tip (Ultradent, South Jordan, UT, USA) that was passively placed without binding in the canal, up to 2 mm from the apical foramen. Finally, we dried the canals with absorbent paper points. After root canal preparation, postoperative MCT scans of each specimen were acquired using the previously described parameters.

MCT evaluation

The images were reconstructed using NRecon v.1.6.0 software (Bruker, Kontich, Belgium), and the parameters were calculated using CTAn v1.14.4 software (Bruker, Kontich, Belgium). We established a region of interest (ROI) from the furcation level to the apex of the root. 3D visualization was achieved using CTvol v2.3.2.0 software (Bruker, Kontich, Belgium).

Statistical analysis

All data are presented as mean values with standard deviations. Normality testing was performed using the Shapiro–Wilk test. One-way analysis of variance (one-way ANOVA) was used for comparison of the percentage of untouched surface area among the three groups, while the percentage increase in the canal volume and the percentage of accumulated debris were compared using the Kruskal–Wallis test. A *P*-value less than 0.05 was considered statistically significant. All calculations and statistical analyses were performed using SPSS Statistics version 25 (IBM, IL, USA).

Results

Statistical analysis [Shapiro-Wilk, and one-way ANOVA] revealed that there were no significant differences in the evaluated parameters among the three groups before preparation (P>0.05; Table 1). The results of 3D analysis are presented in Table 2. There were no significant differences among the three NiTi systems in terms of the postoperative 3D measurements including increase in the root canal volume, untouched canal surface area, and accumulated hard tissue debris (P>0.05). The 3D reconstruction of representative specimens in each group is shown in Figure 1.

Discussion

The results of this study indicated no statistically differences among the PTN, VT, and HCM systems in terms of all 3D parameters related to their shaping ability. Thus, the null hypothesis was accepted. Two experimental models are most frequently used for the evaluation of root canal preparations: simulated root canals in resin blocks or root canals in extracted human teeth [9, 16]. Even though resin blocks ensure the standardization of evaluated parameters, we chosed human teeth for the present study because they reflect more realistic clinical conditions due to the properties of dentine [17].

In the present study, the following 3D parameters were assessed using MCT: increase in the canal volume, untouched surface area, and the amount of hard tissue debris formed during instrumentation.

Regarding the canal volume, there was an increase in all three systems: PTN, 73.84%; VT, 73.48%; and HCM, 49.29%. The size of the file tip was the same in all three groups (size 30); thus, the increase in volume was most likely affected by the file taper. We surmised that a smaller diameter increases for every millimeter of the working part in the specimens prepared with HCM files (0.04) resulted in a smaller change in the canal volume.

Assessment of the untouched surface area and the amount of hard tissue debris accumulated during root canal shaping is extremely important in the evaluation of the long-term results of endodontic treatment, because debris and untreated surfaces could serve as a scaffold for residual bacteria and their growth, thus contributing to the complications after treatment [7, 12, 18, 19].

Despite continuous technological progress, it has not been possible to introduce a NiTi system that prepares most of the canal surfaces. In previous studies, the percentage area of untreated canal walls ranged from 9.6% to 79% [9, 20-22]. These differences are primarily attributed to the anatomy of the tested roots. The mandibular molars are most used tooth. The complexity of the root canal anatomy and the presence of structural irregularities (*i.e.*, isthmuses, anastomoses, and additional canals) could contribute to an increase in the untouched surface area and may be the reason for more accumulated debris during shaping, which cannot be removed from such areas. It should be emphasized that the cross-section of root canals is rarely round, and their shape enables preparation with rotary files. In the present study, none of the systems exhibited an effective shaping ability. The largest and smallest untouched areas were observed in the PTN (41.37%)

Table 1. Evaluation of preoperative (A) and postoperative (B) parameters between the tested systems; the data are presented as mean (SD)

		System			*P*-value
		ProTaper Next (I)	**Hyflex CM (II)**	**V-Taper 2H (III)**	
Dentine (mm^3)	**A**	206.42 (24.68)	212.13 (28.50)	208.35 (43.06)	0.925
	B	197.14 (23.16)	207.52 (30.86)	198.23 (40.93)	
Volume (mm^3)	**A**	7.92 (2.43)	6.17 (2.43)	5.54 (2.76)	0.115
	B	13.76 (2.74)	9.22 (1.93)	9.61 (2.93)	
Surface area (mm^2)	**A**	83.97 (24.09)	75.03 (25.77)	63.82 (11.90)	0.130
	B	94.05 (14.56)	81.03 (14.45)	70.84 (14.34)	

Table 2. Mean values and standard deviations for the percentage increase in the canal volume, percentage of untouched surface area, and percentage of debris formed during canal preparation with the tested systems

	System			*P*-value
	ProTaper Next (I)	**Hyflex CM (II)**	**V-Taper 2H (III)**	
% Increase in the canal volume	73.84 (50.57)	49.29 (31.71)	73.48 (81.27)	0.576
% Untouched surface area	41.37 (12.84)	31.67 (12.16)	30.85 (19.83)	0.251
% Of debris	2.16 (0.44)	2.42 (0.79)	1.84 (0.33)	0.116

and VT (30.85%) groups, respectively. In general, files with a greater taper should prepare a larger surface area [4]; this was not observed in the present study. The PTN files, which have the maximum taper (0.07), left the largest area unprepared. This result could be explained by the largest pre-instrumentation surface area of the canals in the PTN group (83.97 mm^2), which probably resulted in more canal irregularities and a larger untouched area during shaping. Our observations are consistent with those of Paqué *et al.* [23] and Drukteinis *et al.* [7], who concluded that the degree of taper was not the most important factor for determining the ability to prepare a larger surface area. In addition, Gagliardi *et al.* [24] observed a significantly larger percentage of untouched area with the PTN system than with the ProTaper Gold and ProTaper Universal systems; this was because of the reduced contact area in the canal wall.

The debris formed during canal preparation was reported as 1.84% for VT files, 2.16% for PTN files, and 2.42% for HCM files. Lopes *et al.* [21] noticed a smaller amount of debris after preparation with PTN files (0.10%). According to the authors, the difference between systems may result from the irrigation protocol used during shaping, such as the total volume of rinsing solution per canal, time of irrigation, and positioning of the irrigation needle. In the literature, the taper, final tip size, and cross-section of the files used for instrumentation are considered factors influencing the amount of debris. Shaheen [25] concluded that greater accumulation of debris in the canal, particularly in the apical part, may be affected by greater taper of the files. The author observed a larger amount of debris after shaping with WaveOne files (0.08) compared with One Shape files (0.06). In addition, he noticed that the offset design of the file, which provides a larger space for chips, contributes to lesser accumulation of residue and its transport in the coronal direction. These findings are not consistent with those in our study, where HCM files with a 0.04 taper resulted in greater debris accumulation (2.42%) than did PTN and HCM files with 0.07 and 0.06 tapers, respectively. The offset design of PTN files does not maximize debris elimination from canals [21]. Xu *et al.* [19] compared the efficacy of hard-tissue debris removal from the mandibular first molars prepared to various apical sizes and summarized that a greater final apical size resulted in significantly lower debris accumulation. It should be considered that root canal preparation using NiTi files with a large taper (>.06) might reduce the resistance of roots and increase the risk of fracture [26].

Conclusions

Our *in vitro* study showed similar shaping abilities for the PTN, HCM, and VT rotary systems. None of the tested canals were completely free from debris, while the untouched surface area was considerably large. It seems that other measures such as irrigation and use of intracanal dressings are necessary to achieve the optimal chemo-mechanical canal preparation and disinfection.

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Conflict of Interest: 'None declared'.

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