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A micro-computed tomography study of morphological aspect of root canal instrumentation with ProTaper Next and One Shape New Generation in mandibular molars

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Abstract

ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland) (PTN) and One Shape New Generation (MicroMéga, Besançon, France) (OSNG) belong to a relatively new generation of rotary nickel–titanium (NiTi) files. Scientists keep improving features of endodontic files in order to obtain anatomically shaped and cleaned root canals and avoid canal transportation, for a better outcome of the endodontic treatment. For the current study, the aim was to evaluate and assess the changes in root canal morphology after instrumentation with PTN and OSNG by using micro-computed tomography (CT). This high-tech resolution tomography allows a much more detailed analysis of the root canal anatomy and its transformation after rotary instrumentation. We have selected 10 mandibular molars; before and after canal preparation, the samples were distributed in two homogeneous groups (PTN and OSNG groups) and submitted to standardized radiographs and micro-CT (SkyScan1172, Kontich, Belgium). From the three-dimensional (3D) images obtained from the scanning, we were able to perform a two-dimensional (2D) (perimeter, area and roundness), respectively a 3D (volume, surface area, structure model index) analysis, before and after root canal instrumentation. Results did not revealed important statistical differences among the two groups in relation to the curvature and volume of the root canals before instrumentation; after rotary instrumentation, there was a substantially increase of volume and surface area for all the samples ($p<0.05$). The two types of instruments preserved the original canal path, maintaining a continuous, safe and adequate shape and taper of the root canals.

Keywords: micro-CT, morphological aspects, NiTi files, root canal preparation.

Introduction

During the last decade the introduction of micro-computed tomography (CT) in endodontics, a non-invasive and non-destructive imagistic investigation method, allowed a more detailed analysis of root canal anatomy and its alteration after rotary instrumentation [1].

Every image resulted from the scanning represents a virtual cut plane and it allows a highly precise positioning of the sample, respecting the length of the root canal and its exact angles of curvatures [2].

Micro-CT has the great advantage that it is able to prevent radiographic or photographic transfer error by permitting accessible three-dimensional (3D) evaluation of the entire root canal system as well as easy measurements of root canal transformation [3–6].

Different rotary file systems, each with their unique features were popularized to endodontics during the past decade [7, 8].

Due to the super elasticity of the nickel–titanium (NiTi) alloy, the endodontic files have a heightened flexibility that allows them to respect the original root canal path [3] growing into critical tools in endodontic therapy. Nevertheless, depending not only on the practician's clinical ability, but also on some characteristic features of the instruments, when it comes to advanced angles of root canal curvature, aberrations of the anatomical canal shape might appear [4, 7].

The new and innovative generation of NiTi files has the ability to preserve the original shape of the root canals, diminishing canal transportation regardless of how prominent the angle of curvature in root canal can be.

The effect of instrumentation on root canal anatomy may be assessed from cross-section by using Bramante *et al.* technique [9] from double exposure radiographs and from cone-beam computed tomography (CBCT) scan.

The aim of our paper was to analyze the changes produced in root canal geometry after instrumentation with two file systems by using high-tech resolution tomography, micro-CT.

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Materials and Methods

Selection of teeth

The study sample for the present research contains 16 human mandibular molars; the teeth were not extracted specifically for this study and until used, they were stored in 0.1% thymol.

Each molar was cleaned from the debris and soft-tissue remnants on the external root surface and washed in running water, then dried and each tooth was radiographed (Vatech Co., Ltd., Korea) in buccolingual and mesiodistal projections in order to detect any possible root canal obstruction, internal resorption, caries and mesial canals with independent apical foramina. Using a special open source image analysis program, we were able to analyze the curvature angle of the root canals (EasyDent V4 Viewer *v.* 4.1.5.0, Vatech Co., Ltd., Korea) and only teeth with moderate curvature ranging from 10° to 40° have been selected. From the 16 teeth, 10 met our selection criteria and were distributed in two groups, according to the angle of root canal curvature. Only teeth with two separate mesial canals were included.

Micro-CT scans

Each tooth was placed upside down inside a custom-made polyvinyl siloxane holder, with 18 mm diameter, in order to fit into the sample holder of the micro-CT device. This custom-made support allowed us to fix each tooth in the same position during the two scans. In order to avoid modifying the canal's anatomy, teeth were scanned using micro-CT without probing the canals.

Root canal instrumentation

After the first micro-CT scans, the access cavity was prepared using high-speed round, long neck diamond burs (Dentsply Maillefer, Ballaigues, Switzerland). Endo Z burs (Dentsply Maillefer) completed the coronal flaring. Irrigation was performed with 5 mL of 5.25% NaOCl delivered in a syringe with a close-ended side vented irrigation needle (Endo-Top, PPH Cerkamed, Stalowa Wola, Poland). Afterwards, a size #10 K-file ISO (Dentsply Maillefer) was used for canal patency; by subtracting 1 mm from the visible tip of the file at the apical foramen level, we were able to determine the working length (WL); then a glide path was established to size #10 K-file.

Based on the rotary instrumentation files, the molars were randomly assigned to two experimental groups:

- Group A: Pro Taper Next (Dentsply Maillefer, Ballaigues, Switzerland) (PTN);
- Group B: One Shape New Generation (#25/06) (MicroMéga, Besançon, France) (OSNG).

Instrumentation of all the root canals was performed by an endodontist.

Each instrument was replaced after preparing five canals. The pulp chamber was filled with 5.25% NaOCl (Chloraxid, Cerkamed, Stalowa Wola, Poland) throughout instrumentation. After that, we used 5 mL of 5.25% NaOCl to irrigate the canal for five minutes, followed by 5 mL of 17% ethylenediaminetetraacetic acid (EDTA) (Meta Biomed MD Cleanser Solution, South Korea) for three minutes. Before entering the root canal, each file was coated with 17% EDTA gel (Meta Biomed MD ChelCream, South Korea).

In the *ProTaper Next group*, once a #10 SS K-file was confirmed loose at length the PTN X1 file was used to prepare the shape of the root canal following the glide path, until a full working-length was reached. After the canal was irrigated, #10 K-file was again used to recapitulate to break up residual debris and move it into solution. The next file used was PTN X2 also until the working-length. The apical foramen in the mesial canals was determined to be a #25/06 size, while the distal ones were #30/07 for which PTN X3 was utilized.

In the *One Shape New Generation group*, after the canals were first prepared with NiTi K-files (Dentsply Maillefer) to #15 K-file, root canal preparation was performed next to the WL level with OSNG rotary file #25.06.

Assessment of the root canal instrumentation

The images that were acquired prior micro-CT scanning were recreated from the cemento–enamel junction to the apex, using NRecon *v.* 1.6.1.5 (SkyScan, Kontich, Belgium) software and stored as bitmap files; the internal configuration of the root canal was revealed by axial cross-sections. With the help of CTAn 1.12 software (Brukner microCT), about 600 slices per sample for the entire canal length lead to a succinct two-dimensional (2D) and 3D analysis of each molar.

3D analysis allowed volume, surface area and structure model index (SMI) assessment, while 2D analysis determined the perimeter, area and roundness of the root canals.

Materialise Interactive Medical Image Control System (MIMICS) Research 17.0 for X64 Platform 17.0.0.435 software was utilized for 3D determination and advanced evaluation of the root canals, before and after instrumentation. Corel PHOTO-PAINT X4 is another programme that was used to analyze the superimposed images of the root canals, also before and after root canal preparation. In order to facilitate a qualitative comparison of the equaled canals, we decided to apply red color for the untreated root canal surfaces, respectively blue color for the treated root canal surfaces.

Statistical analysis

Assumptions of normality were established, thus the data was reported as mean ± standard deviation (SD). The statistical analysis was completed with IBM Statistical Package for the Social Sciences (SPSS) 24. The significance level was set at 95% for all tests. Normality distribution regarding length, surface area, volume, SMI perimeter, roundness was verified using Kolmogorov–Smirnov and Shapiro–Wilk tests. The independent sample Student's *t*-test (two-tailed) was used to compare the pre- and post-preparation parameters between and within group.

Results

In Table 1, mean ± SD of root canals of mandibular molars before and after preparation with One Shape New Generation and ProTaper Next are presented in 2D evaluation. *Perimeter*, *area*, *roundness*, and *average area per slice* represent the 2D parameters that were investigated.

Table 1 – ***2D evaluation***

Parameters		One Shape NG	ProTaper Next
		Mean±SD	*Mean±SD*
Perimeter [mm]	Before	2.4±0.33	2.48±1.4
	After	3.29±0.99	2.97±1.44
	Increase [%]	38.87±49.88	22.81±9.13
Area [mm^2]	Before	0.38±0.16	0.4±0.34
	After	0.48±0.04	0.48±0.28
	Increase [%]	30.64±25.27	60.07±16.68
Roundness	Before	0.51±0.2	0.54±0.27
	After	0.66±0.06	0.63±0.2
	Increase [%]	42.7±53.71	24.41±21.53
Average area per slice [mm^2]	Before	0.36±0.12	0.33±0.28
	After	0.45±0.02	0.41±0.22
	Increase [%]	30.79±37.26	50.72±50.01

2D: Two-dimensional; NG: New Generation; SD: Standard deviation.

The measurements were obtained from the virtual slices at 1 mm distance selected from the apex until the cemento–enamel junction and in 3D after root canal segmentation; the numbers represent the mean and SD.

There can be observed that after preparation of the root canal there is a slight mean increase in every parameter: 38.87 for OSNG and 22.81 for PTN (perimeter, mm); 30.64 for OSNG and 60.07 for PTN (area, mm^2); 42.7 for OSNG and 24.41 for PTN (roundness); 30.79 for OSNG and 50.72 for PTN (average area per slice, mm^2) (p>0.05).

In Table 2, the before and after parameters that were measured for the root canals of mandibular molars are presented in 3D evaluation: *length*, *volume*, *surface area* and *SMI*.

In terms of volume and surface area, we observe a larger increase in these parameters for One Shape NG prepared root canals than those prepared with ProTaper Next, but without a statistically significant difference: 57.75 for OSNG and 48.75 for PTN (volume, mm^3); 25.64 for OSNG and 23.42 for PTN (surface area, mm^2).

SMI analysis revealed statistical significant difference within the group instrumented with One Shape NG (p<0.05): 71.13 for OSNG and 5.39 for PTN.

Table 2 – ***3D evaluation***

Parameters		One Shape NG		ProTaper Next		*p*
		Mean ±SD	*Median*	*Mean ±SD*	*Median*	
Length [mm]	Before	14.05 ±0.48	14.26	13.39 ±1.49	12.97	0.53
Volume [mm^3]	Before	3.7 ±1.67	3.65	3.93 ±2.95	2.82	0.87
	After	5.84 ±2.13	5.56	5.34 ±3.36	3.99	0.73
	Increase [%]	57.75 ±74.55	51.32	48.75 ±26.99	46.67	0.37
Surface area [mm^2]	Before	34.58 ±14.12	32.64	35.56 ±15.73	33.83	0.9
	After	44.73 ±25.84	36.28	43.77 ±19.8	41.57	0.94
	Increase [%]	25.64 ±18.75	25.07	23.42 ±7.22	24.85	0.78
SMI	Before	2.55 ±0.72	2.65	2.86 ±1.51	3.33	0.88
	After	3.95 ±1.03	3.41	2.94 ±1.06	3.37	0.29
	Increase [%]	71.13 ±80.65	55.92	5.39 ±9.44	6.52	0.12

3D: Three-dimensional; NG: New Generation; SD: Standard deviation; SMI: Structure model index.

Figure 1 shows the preinstrumented (A), postinstrumented (B) and superimposed scans of the root canal system of a mandibular molar in 3D. The areas in red on the reconstruction represent the preinstrumented root canals; the areas in blue represent the postinstrumented root canals. In order to highlight the morphology of the root canal system and for a better visualization, transparency was applied for each molar.

Based on postoperative micro-CT reconstructions and calculations, a progressive increase in root canal size was discovered, which was more obvious after preparation with One Shape NG. Red and blue coloring of the super-imposed images before and after rotary preparation revealed an increase in instrumented canal surface, depicted in blue color (Figure 2).

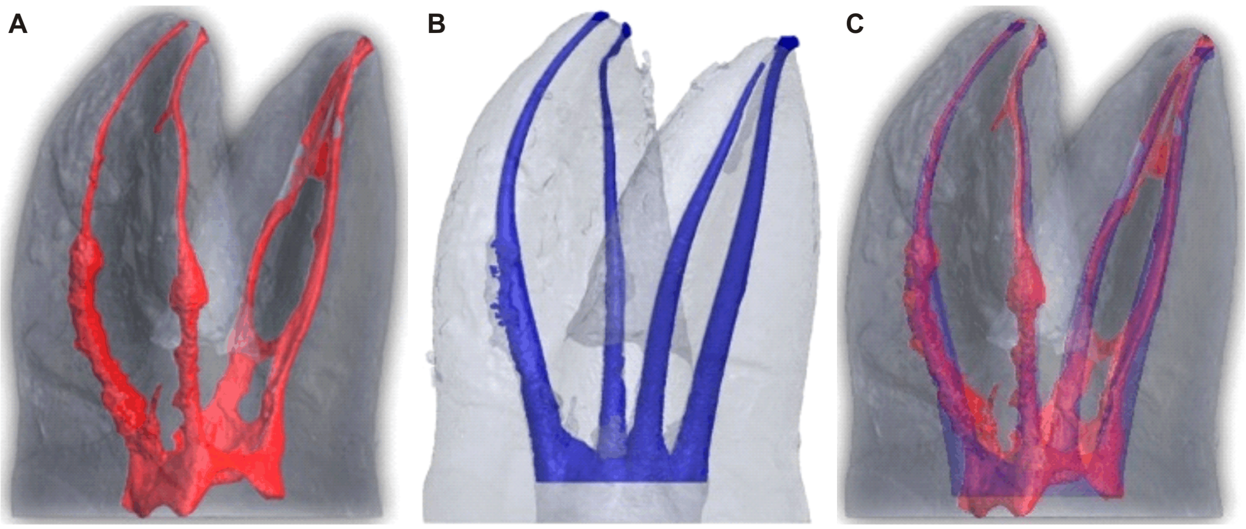

Figure 1 – ***Three-dimensional reconstructed panel of a mandibular molar root canal system: (A) Preoperative constructions; (B) Postoperative constructions; (C) Superimposed reconstructions (red indicates preoperative area; blue indicates postoperative area). Transparency was applied to the surface to reveal the canal morphology before and after instrumentation. The file used for this molar was One Shape New Generation.***

Figure 2 – ***Apical cutaway view that highlights the root canal instrumentation – slices at 2 mm from apex before (A) and after (B) instrumentation; the differences (C) represent the transportation.***

Overall, postoperative shapes were visibly error-free, relatively round in cross-sections and there were not any instruments or fragments remained in the root canals. The canal shaping was sufficient, with almost identical amounts of dentin eliminated around the perimeter in most cross-sections and there were completely instrumented canal surface areas.

Discussions

Our study evaluated the changes in the morphology of the root canals of the lower molars after their instrumentation with two NiTi rotary systems investigated by micro-CT analysis.

The distribution in the two study groups was initially based on radiographs and then based on micro-CT scanning. This is because it has been shown that the root canal morphology recording by radiological examination is reduced [10].

Since the late 90's, micro-CT was used to investigate the root canal morphology as shown by Peters *et al.* [5]. The improvement of resolution of micro-CT for *in vitro* studies allows the acquisition of images with voxel size decreasing to approximately 30 μm. This slice thickness allows obtaining a very good quality image of root canal anatomy [5]. We have used the same selected parameters, before and after root canal preparation, in accordance with De-Deus *et al.* study from 2014 [6].

One of the systems used in our research is a single file system (One Shape NG), while the second one is a multi-file system (ProTaper Next). The single file technique was introduced to the endodontic therapy over the past decade, showing a similar capacity for endodontic system instrumentation as conventional NiTi systems [11].

There are differences between the two systems in terms of design, One Shape NG has a variable three cutting-edge at the tip region and two cutting-edge at the shaft region and an asymmetric cross-sectional geometry [12], while ProTaper Next has an offset asymmetric design, swaggering movement and an increasing and decreasing tapers. Previous studies demonstrated that PTN obtains a homogenous increase in canal taper and less invasive preparation [13]. There are studies according to which the design of the instrument affects the shaping ability of NiTi system [14] and others that show the opposite [15, 16].

Mean increase (D) of each parameter was analyzed using Versiani *et al.* (2011) formula $\%D = (A\times100/B) - 100$, where A stands for the score *after* root canal instrumentation and B represents the score calculated *before* the preparation of the root canal [17].

In our study, the comparison between the two groups did not show a significant difference in the volume and surface area increase of the root canals.

The increase in these parameters is slightly higher for One Shape NG (57.75% and 26.64%, respectively) than for ProTaper Next (48.75% and 23.42%, respectively), this being explained by the fact that the first one has a constant taper of 0.06, while the second system has a variable taper. This is in accordance with earlier considerations [18] that demonstrated that the two systems remove similar amounts of dentin when instrumenting root canal (shaping and cleaning ability). The percentage increase in surface area is not high (25.64% for OSNG, respectively 23.42% for PTN), which shows a less invasive preparation of root canals that will not decrease the tooth resistance.

The cross-sectional appearance has been described by roundness, whose values can go from 0 to 1, where 1 signifies a perfect circle. The values of this parameter increased for both systems after instrumentation of the root canals: 0.66 (42.7%) for One Shape NG and 0.63 (24.41%) for the PTN, respectively, which signifies the shape change on the section of the root canals, getting a circumference closer to that of a circle. The change in root-canal shape after PTN instrumentation was also revealed in other studies [19], and the values were close to those obtained in our study (0.82).

Regarding the roundness, the One Shape NG group showed a difference between the original canal and the canal after instrumentation similar to the results obtained in previous studies (0.78 to d=5) [20].

SMI refers to a determination of convexity of a specific surface related to a 3D system. SMI values for an ideal plate, cylinder and sphere are 0, 3 and 4, respectively [21]. In our study, the initial values of the SMI (Table 2) show a long oval shaped root canal. After instrumentation, these values increased significantly for root canals prepared with One Shape NG (3.95) than for those prepared with ProTaper Next (2.94). This change in SMI shows that these canals become closer to the tapered shape after preparation.

A possible impediment of this study represents the rather limited sample size of 10 molars in total, but it is still comparable to previous micro-CT based studies [22–25].

Conclusions

Our study shows that the shaping and cleaning ability of the two NiTi rotary systems is similar, they remove almost the same amounts of dentin when instrumenting root canals. The comparison between the two groups did not show a significant difference in the volume and surface area increase of the root canals. The high-resolution images provided by micro-CT offer a very good support for the endodontic therapy, revealing very detailed information about the complexity of the endodontic system, even though one of the main disadvantages of this examination is the limitation to *in vitro* studies.

Conflict of interests

The authors declare that they have no conflict of interests.

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