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Comparative Analysis of the Efficacy of Different Types of Nickel-Titanium Rotary Systems in Shaping Simulated Root Canals

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ORIGINAL RESEARCH ARTICLE

Abstract

Objective. The aim of the present study was to assess the quality of the root canal shaping using rotary endodontic instruments manufactured from two types of nickel-titanium alloy.

Material and Methods. Twelve plastic blocks with simulated root canals were divided into 2 groups. Group 1 (n=6) was shaped using Hyflex EDM (Coltene/Whaledent), and Group 2 (n=6) using ProTaper Next X1-X2 (Dentsply Sirona) and ProGlider (Dentsply Sirona). The shaping time was recorded for each instrument and system. Pictures of the canals before and after instrumentation were digitally taken and analyzed using the Arhicad program. The trajectory of each root canal after shaping was superimposed over the initial one, and the diameters of the root canals were measured at 11 different points starting from the foramen, before and after shaping. The total area of each root canal after shaping was measured and a comparison between the two systems was made using Anova single factor statistical analysis.

Results. The mean total shaping time was 2.285 min for Hyflex EDM, and 2.225 min for ProTaper Next. The mean diameters variation was 0.12 mm at foramen and 0.785 mm at the coronal orifice for Group 1, and between 0.16 to 0.825 mm for Group 2. The total area varied between 0.2203-0.2259 mm^2 for Group 1, and between 0.2133-0.222 mm^2 for Group 2.

Conclusions. Although no significant differences regarding the time or shaping characteristics between the two systems were observed, ProTaper Next was faster and more conservative. Both respected the anatomy of the root canal.

Keywords: rotary instrumentation, nickel-titanium, ProTaper Next, Hyflex EDM.

I. INTRODUCTION

Nickel-titanium (NiTi) rotary instruments are widely used nowadays in root canal shaping due to their properties as higher fracture resistance, increased flexibility and better ability in cutting and maintaining the original anatomy of the root canal [1-3]. As industry focus has been directed to their cross-section modification, file design and mechanical characteristics [3, 4], the metallurgy of the NiTi alloy was also changed to improve their efficiency and safety in root canal shaping [5-7]. Due to different thermo-mechanical treatments, more flexible NiTi M-wire instruments are now available for more predictable endodontic treatments [7, 8]. Also, instruments with an offset center of rotation that allows a less engaging of the files and a reduced screw effect and taper lock, as ProTaper Next (Dentsply Sirona, Ballaigues, Switzerland) are widely used by clinicians [9-11]. The particularity of this system is represented not only by the off-centered, rectangular cross-section of the component instruments, but also by the swaggering, snake-like motion as they advance down the root canals [9-11]. The basic set consists of three instruments with progressive taper X1 017/.04, X2 025/.06 and X3 030/.07; instruments with bigger tip are also available for shaping larger canals (ProTaper Next brochure, Dentsply Sirona) [11].

An innovative way of manufacturing NiTi rotary instruments is represented by the *electrical discharge machining* process (EDM), offering the ability of

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manufacturing files with a more complex design, as Hyflex EDM (Coltene/Whaledent AG, Altstätten, Switzerland) [12-14]. The main shaping instrument marketed as the *OneFile* has a tip of 0.25 mm and a taper which is decreasing from 0.08 on the first 5 mm from its tip to 0.04 for the rest of the file, while its progressive cross-section is varying from a more rectangular shape at the tip to a more triangular towards the shank [12-14]. These particular characteristics are aimed to increase the fracture resistance of the file and to use it in almost any endodontic case. A *GlidePath File* and an *Orifice Opener* are also available for clinical use (HyFlex EDM brochure, Coltene/Whaledent) [12].

Aim of the study

The aim of the present study was to evaluate on simulated curved root canals the efficiency in shaping of two rotary endodontic systems manufactured differently from nickel-titanium alloys, ProTaper Next (Dentsply Sirona) and Hyflex EDM (Coltene/Whaledent), by comparing the differences in diameter and area at the end of the mechanical preparation and their ability to maintain the original trajectory of the root canals.

II. MATERIALS AND METHODS

Twelve plastic blocks with simulated curved root canals from the same manufacturer (Dentsply Maillefer, Ballaigues, Switzerland) were shaped under the endodontic operating microscope Alltion (Alltion, Wuzhou, China), at a magnification of 0.6x. Six simulated canals (Group 1) were shaped using the three instruments of the Hyflex EDM set (Coltene/Whaledent AG, Altstätten, Switzerland), with the characteristics *Orifice opener* 25/.12, *GlidePath File* 10/.05 and *OneFile* 25/~. For Group 2, X1 17/.04 and X2 25/.06 instruments of the ProTaper Next (PTN) system (Dentsply Sirona, Ballaigues, Switzerland) were used. Initial reproducible glide path was established for this Group with the ProGlider (Dentsply Sirona) instrument 16/.02v. All rotary files were fixed in the contra-angle piece of the X-Smart Plus endodontic motor (Dentsply Sirona) with the corresponding rotational speed and torque indicated by the producer, 500 rpm for Hyflex EDM (300 rpm for Glide Path File) and 300 rpm for ProTaper Next. Irrigation with ethanol was performed with a 30G irrigation needle (Endo-Top, Cerkamed, Polland) fixed on a 5 ml luer-lock syringe. The plastic blocks were initially photographed with the digital camera Cannon EOS 60D fixed on the endodontic microscope, and again after rotary shaping with each system. Images were stored on a computer (Figure 1). The pictures recorded under the microscope were imported in the Arhicad program (Graphisoft, Hungary, 2019) and redimensioned in order to corespond to the real size of the plastic blocks. The contour of the root canal was drawn following the original contour on the pictures using the *Polyline tool* function and the trajectory of the initial root canal (filled in black using the *Fill tool* function) was overlaped over the canal contour after shaping (filled in red using the same Arhicad function) (Figure 2).

The *Line tool* function was used to draw 11 equidistant lines perpendicular to the cross-section of the root canal, in order to measure the diameter in 11 points for each canal starting from its apex using the *Measuring tool* function. By calculating the differences between the measured final values and the initial ones, of the unshaped root canal, a shaping efficiency comparison was made between the two systems.

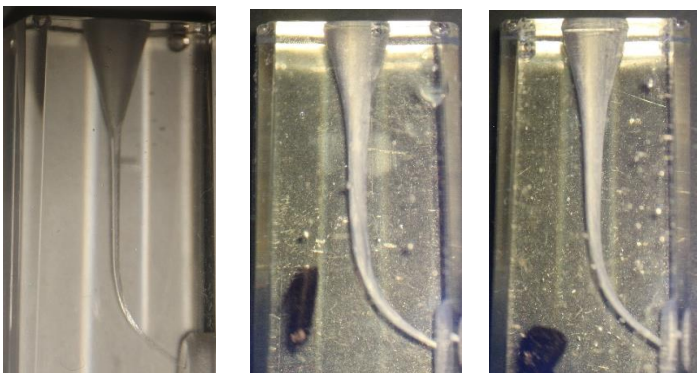

Figure 1 Pictures of the initial sample before shaping and of one shaped canal from each group: Hyflex EDM and ProTaper Next

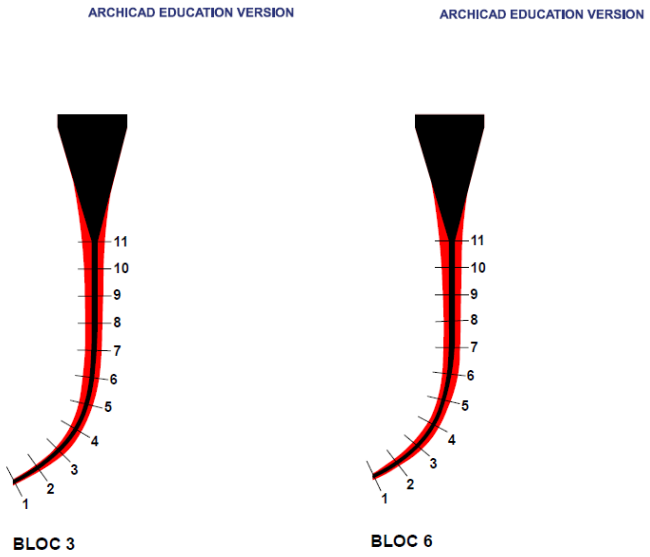

Figure 2 Digital measurements of the 11 diameters in the Arhicad program (sample 3-Group 1 and sample 6-Group 2)

III. RESULTS AND DISCUSSION

Comparative results after time analysis

The total shaping time varied between 1.38 and 3.59 min for Hyflex EDM (Group 1, Table 1) and between 1.37 and 4.77 min for the ProTaper Next system (Group 2, Table 2), with a mean shaping time of 2.285 and 2.225 min, respectively. For both systems, a longer shaping time was

recorded for the first two samples of each group; as the operator became more familiar with the NiTi system, the shaping time decreased in both groups. The comparative results between the two systems are graphically represented in Figure 3. In comparison, a slightly shorter shaping time was achieved using ProTaper Next.

	Hyflex EDM						
Time (min)	Sample No.	1	2	3	4	5	6
T1	Orifice Opener	1.28	0.36	0.4	0.32	0.41	0.31
T2	GlidePath File	1.23	1.24	1.12	0.56	0.54	0.71
T3	OneFile	1.08	1.52	0.83	0.5	0.56	0.74
Total		**3.59**	**3.12**	**2.35**	**1.38**	**1.51**	**1.76**
Mean	**2.285**						

Table 1. The shaping time for Hyflex EDM Group

	ProTaper Next						
Time (min)	Sample No.	7	8	9	10	11	12
T1	ProGlider	0.71	0.45	0.6	0.42	0.49	0.42
T2	X1	2.93	1.64	0.65	0.63	0.63	0.53
T3	X2	1.13	0.35	0.74	0.26	0.35	0.42
Total		**4.77**	**2.44**	**1.99**	**1.31**	**1.47**	**1.37**
Mean	**2.225**						

Table 2. The shaping time for ProTaper Next X1-X2+ProGlider Group

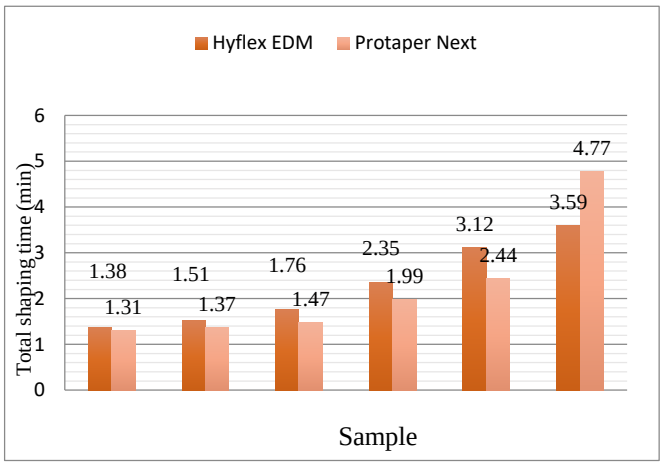

Figure 3 Comparative graphic representation of the total shaping time

Comparative results after diameters measurements

As diameters measured in the 11 points of the root canal before and after shaping, starting from the foramen to the coronal oriffice, the mean differences varied from 0.12 mm at foramen and 0.785 mm at the end of the root canal for Group 1, and between 0.16 and 0.825 mm for Group 2 (Table 3).

	MEAN										
	1	2	3	4	5	6	7	8	9	10	11
Initial canal	0.18	0.19	0.2	0.2	0.21	0.23	0.26	0.28	0.28	0.28	0.28
Samples 1-6	0.3	0.42	0.56	0.62	0.68	0.79	0.82	0.88	0.91	0.95	1.065
Difference (1-6)	0.12	0.23	0.36	0.42	0.47	0.55	0.56	0.6	0.63	0.67	0.785
Samples 7-12	0.34	0.375	0.435	0.51	0.6	0.67	0.74	0.815	0.885	0.97	1.105
Difference (7-12)	0.16	0.185	0.235	0.31	0.39	0.44	0.48	0.535	0.605	0.69	0.825

Table 3. The mean diameters measured in 11 points for each group and the increase in comparison with the initial canal

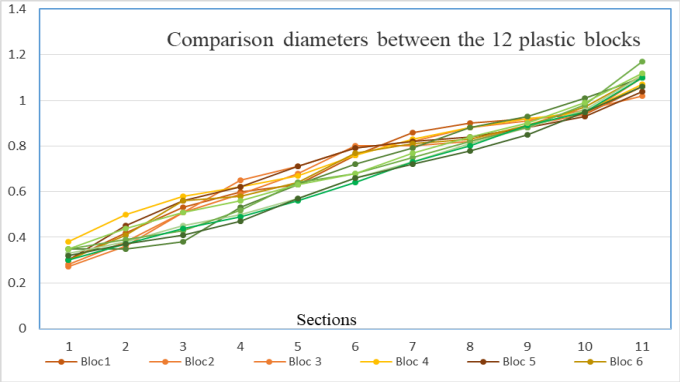

Figure 4 Graphic representation of the diameters increase for each sample at the 11 measuring points

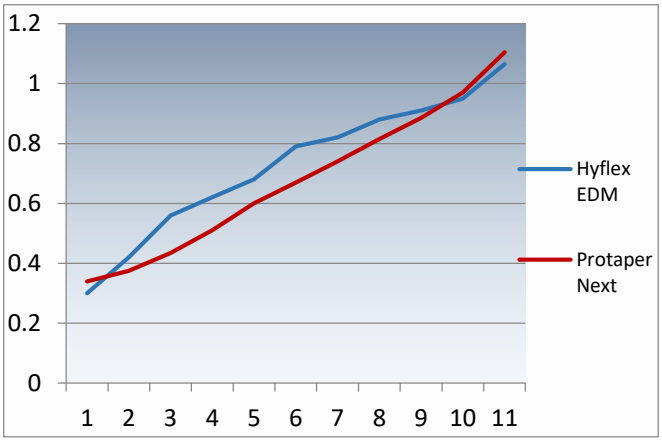

Figure 5 Linear representation of the mean diameter increase in 11 points for each Group

As observed on the two graphic representations for each sample (Figure 4) and as mean value of diameter increase as comparison between the two systems (Figure 5), Hyflex EDM was more conservative in shaping only at Level 1 (at the foramen), in the rest of the canal ProTaper Next determined a smaller enlargement. At the end of the root canal (Levels 10 and 11), Hyflex EDM recorded smaller mean values of diameter increase, thus being again more conservative.

Comparative results after area analysis

Using the *Fill tool* function of the Arhicad program, the total area was automatically calculated for each root canal. Data showed that the total area varied between 0.2203 to 0.2259 mm^2 for Group 1, and 0.2133 and 0.222 mm^2 for Group 2 (Table 4). In 4 of the 6 samples shaped with the ProTaper Next system, a smaller area after shaping was measured in comparison with Hyflex EDM (Figure 6), but no statistical significant differences between the two systems were observed at the One-way Anova single factor analysis, with a p-value set at 0.05 (Table 5).

Sample	1	2	3	4	5	6
Area	0.2208	0.2239	0.227	0.2203	0.2215	0.2259
Sample	7	8	9	10	11	12
Area	0.2177	0.2133	0.2206	0.216	0.222	0.2138

Table 4. Total area (mm^2) of the root canal for each sample (1-6 Hyflex EDM, 7-12 PTN)

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
a.	11	5.4	0.4904545	0.0386323
b.	11	4.86	0.4413636	0.0453405

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.0132545	1	0.0132545	0.3156869	0.580454	4.3512435
Within Groups	0.8397273	20	0.0419864			

Table 5. Anova Single Factor statistical analysis for Area comparison between Groups

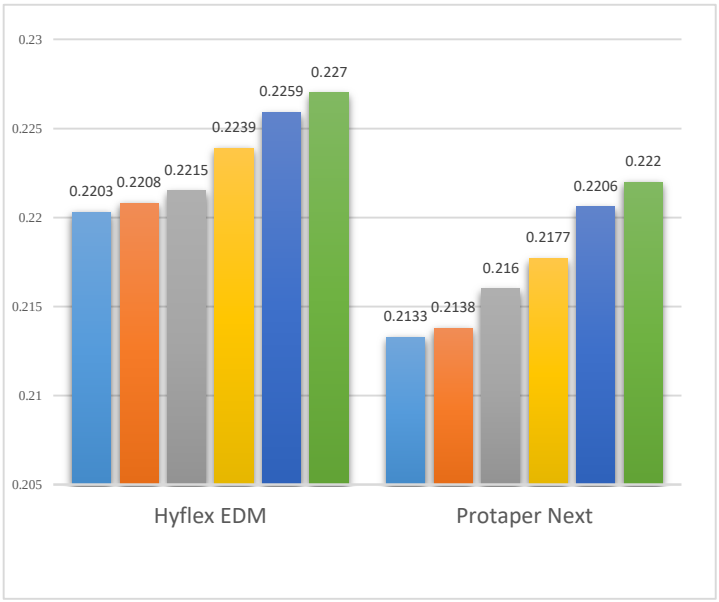

Fig. 6 Graphic representation of the total area (mm^2) for each sample

DISCUSSION

The present *in vitro* study aimed to compare on plastic blocks with simulated curved root canals the efficiency in shaping of two rotary systems: Protaper Next (Dentsply Sirona) and Hyflex EDM (Coltene/Whaledent). Both are mechanical NiTi systems working in full rotation, frequently used in clinical practice because of their advantages. Both systems are characterized by a reduced number of instruments and sequences in order to achieve the desired shape of the root canal. ProTaper Next instruments are manufactured by grinding from an improved thermo-mechanically treated NiTi alloy, the M-wire NiTi, which increses their flexibility and fracture resistance [7-9, 11]. Hyflex EDM is manufactured from a thermally improved controlled memory (CM) NiTi alloy as Hyflex CM (Coltene/Whaledent), but the main feature is represented by the innovative electrical discharge machining (EDM) process in manufacturing of the files [12-14]. The process uses sparks to melt and evaporate the surface of the alloy to give the final shape of the instruments [15]. According to the manufacturer, this will result in an increase of cutting efficiency, flexibility and reduces the risk of instruments fracture. Also, this allows a more complex cross-sectional file design, which varies from its tip to its end [12-14].

Different types of methods and models can be used in endodontics to evaluate and compare the efficiency of nickel-titanium instruments [16, 17]. In the present study, plastic blocks with simulated root canals were used to compare the efficiency of the two mentioned NiTi systems as in other experimental studies [18, 19]. The use of plastic blocks to compare the quality of shaping using different instruments allows a better standardization of the evaluated parameters (all canals have the same size, length, initial taper, curvature) and the material has the same hardness and consistency for all the samples, in comparison with the variety of human teeth [18-

20]; thus *in vitro* studies performed on simulated canals can be also validate for natural teeth [18].

When comparing the efficiency in shaping of different types of instruments, it is desirable that the instruments have similar sizes and will create a preparation with almost the same characteristics [20, 21]. In the present study, the last file from the ProTaper Next system, X2 025/.06 created an apical control zone of 0.25mm at foramen and a taper of 6% in the first 3mm, while Hyflex EDM finished the apical foramen also to an ISO size of 0.25mm, but with an apical taper of 8% for the first 4mm.

The results of the present study showed no significant shaping differences between the two systems, although they do not have the same taper and design. Analysing the increase in diameter along the 11 measured points, ProTaper Next, with a smaller taper at its tip, was more conservative starting only from the second apical level to the last 2 coronal, but enlarged more in the first mm in comparison with Hyflex EDM. This can be explained by the increased flexibility of Hyflex EDM in comparison with conventional or M-wire NiTi instruments [22, 23], thus being indicated in shaping canals with severe curvatures with less risk of apical transportation [21]. Because of its centered preparation, Hyflex EDM has an increase ability of respecting the original root canal anatomy [21].

The tendance of ProTaper Next to preflare the coronal third of the root canal was also observed by Huang et al. and Turkistani et al. in their studies [20, 21]. The coronal enlargement can be due to the unique design of these instruments which allows their contact with the root canal circumference in only two cutting points, and because of their swaggering motion. For this reason, care has to be taken when shaping the coronal third in order to conserve the pericervical dentin, which is important for the long term resistance to fracture of the treated tooth [20].

The analysis of the root canal areas at the end of the preparation allowed us to observe that Hyflex EDM induced a bigger area increase in comparison with ProTaper Next, without being statistically significant. This result can be explained by the bigger taper of the Hyflex *OneFile* (8% decreasing coronally) in comparison with ProTaper Next X2 (6% increasing-decreasing). Different studies aimed to compare *single file* systems (as Hyflex EDM) with ProTaper Next recorded similar results, but the conclusions cannot be generalized [21].

Regarding the shaping time, in both groups three instruments were used for shaping in order to achieve a final 0.25 apical size. For ProTaper Next, the use of the ProGlider instrument to expand the glide path after initial hand negotiation with K-file #10 allowed a faster preparation with the X1 and X2 instruments, but the total shaping time was insignificantly shorter than the one recorded for Hyflex EDM. The *GlidePath* File from the Hyflex EDM system, with a constant taper of 5%, necessitated a longer time to achieve a reproducible glide path after negotiation with hand K-file 010 in comparison with ProGlider, although preflaring was achieved for this file with the *Orifice Opener*. Once glide path was achieved, the final shape was cut with *OneFile* in a shorter time than X1 and X2 instruments combined. Systems using a *single file* technique (as Hyflex EDM) are prefered by many clinicians especially for this reason.

Both systems respected the original anatomy of the simulated canals and the position of the apical foramen, without transportation.

IV. CONCLUSIONS

Within the limitations of the present study, it can be concluded that both of the systems shaped root canals in a short period of time with minimal removal of substance. Although shorter shaping time and a smaller increase in diameter and area were achieved for ProTaper Next, no significant statistical differences were recorded when compared to Hyflex EDM.

Due to their flexibility, progressively decreasing taper and reduced number of instruments, both systems are recommended for clinical use.

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