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Comparison of Shaping Ability of Five Nickel-Titanium Rotary Instruments in Simulated Curved Canals

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Abstract

This study compared the shaping ability of five Ni-Ti rotary files (ProTaper Universal, Reciproc, Hyflex CM, ProTaper Next and TF Adaptive) in simulated root canals. Each group consisted of 10 root canals. Pre- and post-instrumentation photographs were taken using a precise camera and superimposed with Photoshop. Material removal from the inner and outer canal walls, transportation and centering ability were measured with Image Pro Plus software. The preparation time was compared. TF Adaptive produced less transportation at the apical curvature, followed by Reciproc and Hyflex CM. There were no significant differences in coronal curvature transportation (p>0.05) among the five groups. ProTaper Next and Hyflex CM had a significantly higher cutting efficacy than ProTaper Universal, Reciproc or TF Adaptive (p<0.05). In general, all five instruments respected the original canal curvature well and were safe to use.

Keywords: Apical transportation, Curved canals, Cutting efficiency, Nickel-titanium rotary instruments, Shaping ability

Introduction

Creating a continuous tapered shape and maintaining its original morphology with regards to the narrow and curved root canal is a major challenge. Traditionally, canal preparation using stainless steel hand instruments is time-consuming and it is difficult to achieve the criteria mentioned above in curved canals [1]. An ever increasing number of nickel-titanium (Ni-Ti) rotary file systems are currently available and new thermomechanical manufacturing processes producing rotary endodontic files with increased flexibility that better maintain the overall root canal shape have been introduced [2]. These newly developed Ni-Ti files possess a unique design property in terms of cross-sectional shape, taper, and the number and angle of flutes. These instruments are intended to reduce the incidence of fractures and canal aberrations, and also to allow fewer procedural steps.

The purpose of this study was to compare the shaping ability (preparation time, apical transportation, centering ratio, straightening of curved root canals) of several new rotary Ni-Ti systems: ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), Hyflex CM (Coltene-Whaledent, USA), TF Adaptive (SybronEndo, Orange, CA, USA) and Reciproc (VDW, Germany) in simulated curved root canals. ProTaper Universal (Dentsply Maillefer, Ballaigues, Switzerland) was included in this study as a control. The null hypothesis tested was that there is no difference in the shaping ability among the tested rotary Ni-Ti systems.

Materials and Methods

Root canal instrumentation

Black ink was injected with a 27-gauge needle into 50 simulated canals with an L-shaped curvature in clear resin blocks (15 / 0.02, VDW, Germany). Then each block was placed in a specially designed jig that allowed for resin block stabilization and image standardization, and pre-instrumentation photographs were captured using a precise camera (CANON 400D with SIGMA 105 mm F2.8 DG Macro EX lens). The specimens were randomly divided into five groups and prepared by five Ni-Ti rotary file systems (n=0). All of the plastic blocks were covered with aluminum foil during preparation [3]. Group A: ProTaper Universal instruments were used according to crown-down techniques. The instrumentation sequence was as follows: SX→S1→S2→F1→F2. Group B: Reciproc.

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R25 instrument was operated in a reciprocating motion powered by a torque-limited electric motor (VDW Silver, Germany). It was inserted in the apical direction by using an in-and-out pecking motion about 3 mm in amplitude with light apical pressure. After 3 pecking motions, the instrument was removed and cleaned. The above steps were repeated until the instrument arrived at the Working Length (WL). Group C: All Hyflex CM instruments were used in a gentle in-and-out motion with a rotational speed of 500 rpm, and the torque was adjusted to 2.5 Ncm. All instruments were used to the full length of the canals (single-length technique). The instrumentation sequence was: 15 / 0.04→ 20 / 0.04→25 / 0.04. Group D: All ProTaper Next instruments were used with a rotational speed of 300 rpm, and the torque was adjusted to 2.0 Ncm. All instruments were used to the full length of the canals (single-length technique). The instrumentation sequence was as follows: X1→X2. Group E: TF Adaptive with a new element motor (SybronEndo, Orange, CA, USA) featuring adaptive motion. The instrumentation sequence was as follows: SM1→SM2. For standardization of apical enlargement of all samples, the SM3 file was not selected for preparation in this study.

The final apical preparation was set to size 25. All canals were prepared by the same operator according to the manufacturer's recommendations. Each instrument was coated with EDTA cream (Dentsply, Switzerland) for lubrication before use. Following each file, patency was confirmed using a size 10 K-file (Dentsply, Switzerland), and canals were irrigated with 2 ml sterile water using a disposable syringe and 27-gauge side-vented needle placed to a depth just short of binding points? Flutes of the instruments were cleaned with moistened gauze to maintain cutting efficiency and to avoid exerting more apical pressure on the instrument. Copious irrigation with sterile water was performed as the final irrigation for all five groups. After drying the resin blocks, red ink was injected into the simulated artificial canals, and post-instrumentation photographs were taken.

Evaluations

All root canal preparations were completed by one operator, while the assessments of the canal morphology prior to and after instrumentation were carried out by a second examiner who was blind with respect to all the experimental groups.

1. **Time:** The total working time was recorded for each block. Time of shaping included instrumentation, irrigation and instrument cleaning.

2. **Shaping ability:** Pre- and post-instrumentation pictures were superimposed by Photoshop CS5 (Adobe system Inc, USA) (Figure 1) and the shaping ability of these instruments was analyzed by Image Pro plus 6.0 (Media Cyberntics Inc, USA) software. Image Pro Plus was used to measure each mm from D0 to D8 and levels 0 to 8 should correspond to the distance (in mm) from the canal terminus. Three measurements were recorded with 0.001 mm precision at each level for a total of 27 measurements per canal. The distance was measured between the inner limit of the initial canal and the inner limit of the instrumented canal (*X*inn), and between the outer limit of the initial canal and the outer limit of the instrumented canal (*X*out) (Figure 2). The following equations were used to determine Transportation and centering ability [4]:

Transportation: ∣Xinn – *X*out∣. (A result of '0' indicates no transportation)

Centering ability: *X*inn/*X*out *or X*out/*X*inn*.* (The smaller number was used as the numerator; a result of '1' indicated perfect centering ability).

3. Change of root curvature. Straightening was assessed by changes to the degree of curvature after instrumentation [5].

Statistical Analysis

Data were analyzed by parametric tests as normally distributed variables. All parameters were analyzed by analysis of variance (ANOVA) and Student-Newman- Keuls test with SPSS 13.0 software (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p<0.05$.

Results

During preparation of the curved canals, two Hyflex CM instruments (0.04 taper size 15 and 0.04 taper sizes 20) showed deformation. No instrument fractured and no deformation of other instruments was noted. All canals remained patent following the instrumentation. Thus none of the canals were blocked with debris.

The mean time taken to prepare the canals with the different instruments is shown in Table 1 Hyflex CM and ProTaper Next were significantly faster than ProTaper Universal, Reciproc or TF Adaptive ($p<0.05$). There was no significant difference between Hyflex CM and ProTaper Next ($p>0.05$).

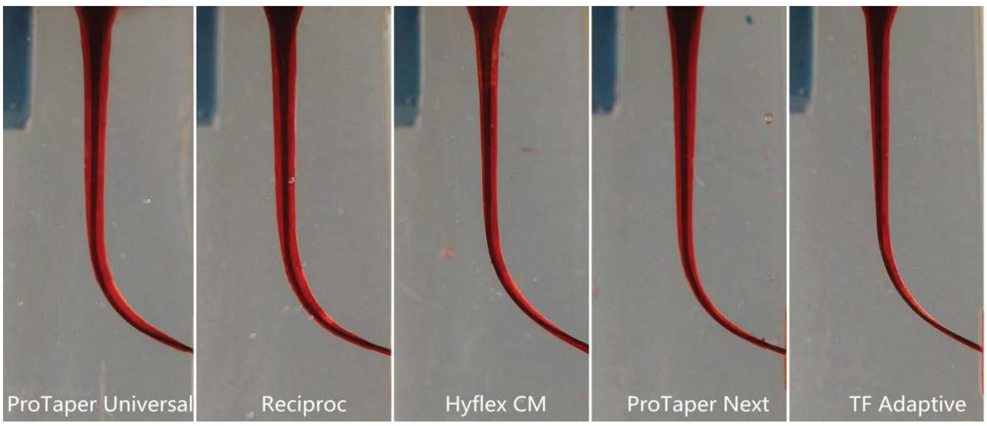

Figure 1:Pre- and post-instrumentation pictures were superimposed by Photoshop CS5.

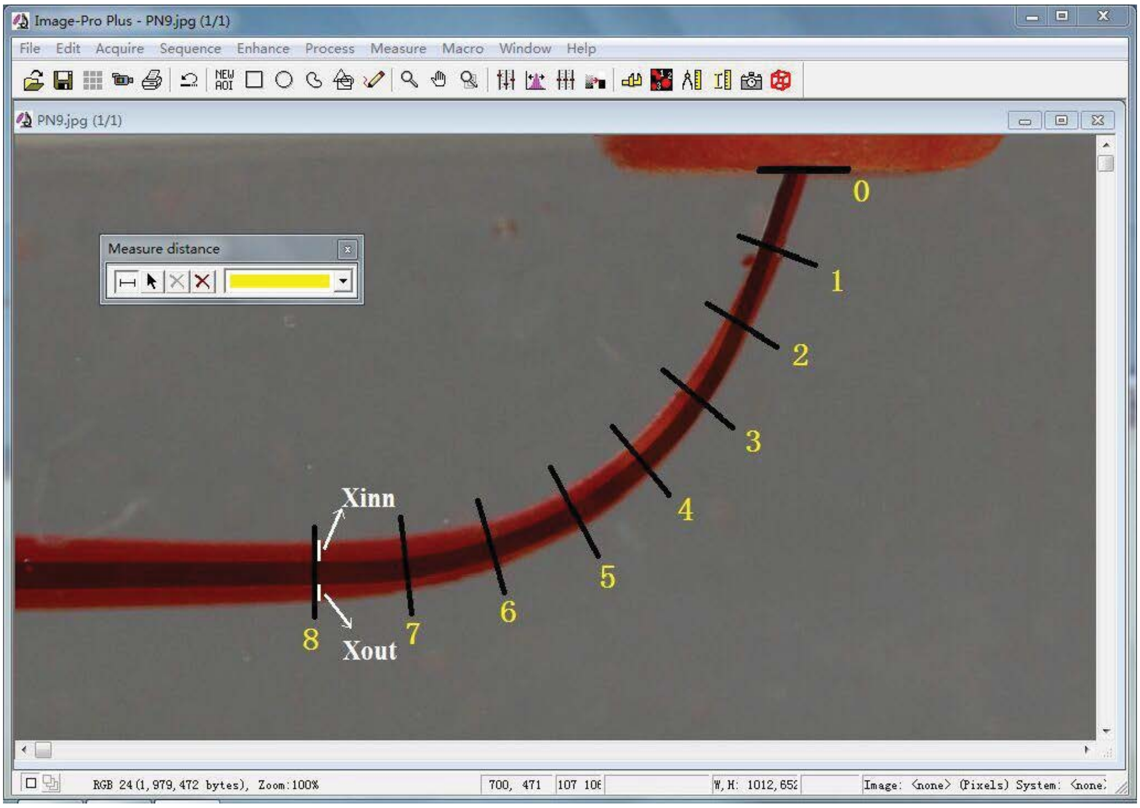

Figure 2: L-shaped simulated canals: superimposed image was measured with Image Pro Plus.

Instrument	Mean	SD
ProTaper	145.7[a]	8.3
Reciproc	108.2[b]	10.8
Hyflex CM	83.3[c]	6
ProTaper Next	80.8[c]	6.1
TF Adaptive	102.9[b]	6.9
*Values with the same superscript letters were not statistically different at p=0.05.		

The mean absolute values for transportation after instrumentation are listed in Table 2.

Table 1: Mean preparation time (sec) and SD with different instruments.

At the apical curvature, transportation was the lowest with TF Adaptive, followed by Reciproc and ProTaper Next (D0 and D2). At D3 and D4, TF Adaptive also showed the lowest transportation, followed by Reciproc and Hyflex CM. At the apical region, the canals prepared by ProTaper instruments yielded the largest mean value for transportation ($p<0.01$). At D5 to D8, there were no significant differences in canal transportation among the five groups.

Centering ability: At the foramen level there were no significant differences in centering ability among the five groups. At D3 and D4, TF Adaptive showed the best centering ability, followed by ProTaper Next and Reciproc, which was consistent with the transportation results described above. At the coronal curvature, ProTaper Next showed better centering ability than the other instruments did as shown in Figure 3 ($p<0.05$).

There was no significant difference ($p=0.608$) in changes to the degrees of the five groups: ProTaper: 3.11° ± 0.87; Reciproc: 2.84° ± 1.06; Hyflex CM: 2.51° ± 0.89; ProTaper Next: 2.96° ± 1.16; and TF Adaptive: 3.05° ± 0.35.

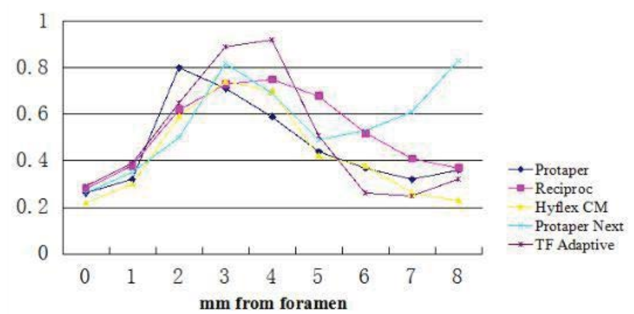

Figure 3: Mean centering ratio at different levels after root canal preparation.

Discussion

The ProTaper Next instruments are made from M-wire [6] to improve file flexibility and resistance to cyclic fatigue whilst retaining cutting efficiency [7]. These instruments are characterized by an innovative off-centered rectangular cross section [8] that is claimed to generate enlarged space for debris removal and to give the files a snake-like swaggering movement as it advances into the root canal. To increased flexibility, the Reciproc instrument is also made of an M-wire Ni-Ti alloy, and it is designed specifically for use in reciprocation instead of the conventional continuous rotation method [9,10]. In this study, ProTaper Next group at D0-D2, Reciproc group at D2-D4, and D6-D8 showed a low transportation value. This might be explained by the good flexibility of the M-wire Ni-Ti alloy and reciprocating movement.

Measure Points	Protaper	Reciproc	Hyflex CM	Protaper Next	TF Adaptive	P
0mm	0.149 ± 0.024	0.082 ± 0.018	0.165 ± 0.038	0.126 ± 0.031	0.070 ± 0.024	**
1mm	0.113 ± 0.042	0.110 ± 0.057	0.107 ± 0.069	0.107 ± 0.046	0.076 ± 0.034	0.498
2mm	0.234 ± 0.561	0.123 ± 0.094	0.159 ± 0.060	0.135 ± 0.048	0.068 ± 0.047	**
3mm	0.339 ± 0.035	0.185 ± 0.118	0.223 ± 0.044	0.225 ± 0.030	0.147 ± 0.038	**
4mm	0.372 ± 0.046	0.237 ± 0.163	0.255 ± 0.047	0.262 ± 0.048	0.179 ± 0.065	**
5mm	0.312 ± 0.112	0.298 ± 0.128	0.235 ± 0.107	0.283 ± 0.099	0.227 ± 0.089	0.304
6mm	0.267 ± 0.155	0.246 ± 0.095	0.208 ± 0.086	0.298 ± 0.099	0.297 ± 0.090	0.314
7mm	0.165 ± 0.118	0.132 ± 0.061	0.133 ± 0.066	0.231 ± 0.097	0.263 ± 0.094	**
8mm	0.133 ± 0.065	0.128 ± 0.092	0.112 ± 0.063	0.145 ± 0.101	0.199 ± 0.070	0.156
**: statistically significant difference (p<0.05).						

Table 2: Mean transportation ± standard deviation (in mm) measured at 9 points from the terminus of the post-instrumented canals.

The newly introduced TF Adaptive system uses an existing file set called Twisted Files in conjunction with the new Elements Motor featuring Adaptive Motion. According to the manufacturer, the Adaptive Motion relies on a patented algorithm that changes the motion of the file based on the applied load. When the file is not loaded or lightly loaded, it will rotate continuously in a clockwise direction with no backward movement. When the file is loaded, reciprocation angles vary: 370° forward and 20° to 50° backwards, based on the amount of pressure placed on the file. In this study, the results showed that TF Adaptive files produced significantly less transportation at apical curvature compared with the other instruments. The Adaptive technology combined with twisted file using R-phase treatment increases flexibility and allows the file to adjust to intra-canal torsional forces [11-13], which may explain the shaping results obtained with the TF Adaptive system. Further investigations are needed to understand whether the better performance of the instrument may be attributed to Adaptive Motion, section design, or the higher flexibility of the TF Adaptive files. The manufacturer claims that TF Adaptive will have better effects in eliminating infected root canal biofilm when using a definite brushing movement at the end of the preparation; this should be confirmed in future studies.

Taken together, the current study demonstrated that the use of Hyflex CM instruments resulted in significantly less canal straightening as compared to the use of ProTaper Universal ($p>0.05$). The Hyflex CM is a set of files with a unique process to control the material memory (a complex heating and cooling treatment) [14]. The CM-Wire alloy, together with the unique design features of the instruments, provides a superior flexibility, allowing better maintenance of the original canal curvature and superior centering ability compared with that of conventional Ni-Ti instruments [14,15]. The manufacturer states that deformed instruments will regain their original shape when sterilized at approximate 134°C. Although most instruments regained their original shape following sterilization, three instruments (all size 20, 0.04 taper) still remained in permanent deformation and were discarded in the study by Peters [15]. The authors recommended considering smaller Hyflex CM instruments for single-use [16].

In the current study, the preparation time included changing instruments, cleaning the flutes of the instruments and irrigation. ProTaper Next instruments required significantly less time to prepare the canals compared with all other instruments (Table 2). This difference was mainly due to the ProTaper Universal system, as used in this investigation, consisting of five instruments to prepare the root canal, while only two instruments were used for ProTaper Next. However, Reciproc consisted of only one instrument, but required significantly more time than ProTaper Next ($p<0.05$). This might be because the Reciproc instrument was removed and cleaned after three pecking motions, then the above steps were repeated, until the instrument arrives at the WL, which was more time-consuming. Preparation time is dependent on the operator's experience, the number of instruments, and the technique used. In summary, although significant differences regarding preparation time were obtained, from a clinical point of view these differences are of limited importance.

Studies often use simulated canals with standardized lengths, curvatures, and tapers in resin blocks to avoid bias caused by individual differences of natural teeth when investigating the shaping ability of endodontic files. These resin blocks offer the unique ability to visualize intracanal procedures [17]. L-shaped and S-shaped resin blocks have been used in several studies to test the shaping ability of files in which pre- and post-instrumentation images are acquired under magnification, layered, and then compared for excessive changes in canal transportation [2].

Although we set the final apical preparation to be size 25, it is currently impossible to standardize the final taper. This might be partly explained by the smaller apical taper of TF Adaptive (size 25 /.06) maintaining the original canal anatomy better with lower canal transportation values than ProTaper Universal (size 25/.08) and Reciproc (size 25/.08) [18]. In general, besides the different tapers, the shaping capability of endodontic instruments depended on complex factors including the metallurgical properties, instrument design, and the way the instruments were used [19]. It was previously reported that apical transportation of more than 0.3 mm could negatively affect the sealability of the obturating material [20]. Except for ProTaper Universal group at D3-D5, none of the apical transportation values recorded in this study exceeded this limit. In summary, the study provides a better understanding of the shaping ability of five instruments, all of which maintained the original canal curvature well without significant shaping errors.

Conclusions

Under the conditions of this study, TF Adaptive and ProTaper Next generated better performance. This study provides guidance in terms of root canal preparation.

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