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Global Dentistry

Shaping Ability of Several Nickel-Titanium Systems in Severely Curved Simulated Canals

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Abstract

Introduction: *The aim of this study was to compare the shaping abilities of four various continuous rotation systems in severely curved simulated canals.*

Methods: *Sixty single-curved canals in resin blocks were prepared to an apical size of 25 using Twisted File (TF) (Sybron Endo, USA), Protaper Next (PTN) (Dentsply Maillefer, Switzerland), Hyflex CM (HCM) (Coltone, Switzerland), and Mtwo (VDW, Germany) systems (n=15 canals per group). Composite images were prepared by superimposing pre- and post-instrumentation images. Resin removal by each system was recorded, as were canal aberrations and preparation times. Differences between groups were determined using the Kruskal–Wallis test and Bonferroni correction. Statistical significance was set to 5%.*

Results: *Nickel-titanium file fracture was not observed during shaping of simulated canals. Instrumentation was more rapid with TF than with PTN, HCM, or Mtwo. After preparation, there were no significant differences in working lengths of the canals in each group. Reduction of resin block weight in the Mtwo group was significantly greater than that in the TF, PTN, and HCM groups. In the apical part of the curvature, the TF group had the least root-canal deviation; root-canal deviation in the Mtwo group was greater than that in the TF, PTN, and HCM groups at each measurement point.*

Conclusions: *These four systems are appropriate for clinical preparation of curved canals. However, the centring abilities of TF, HCM, and PTN systems were superior to that of the Mtwo system. The TF system demonstrated superior shaping ability in the apical portion in curved canals.*

Keywords: *continuous rotation, curved root canal, nickel-titanium instrument, shaping ability, root canal preparation*

Introduction

Cleaning and shaping of the root canal is an essential component of root-canal therapy. The primary goals of canal instrumentation are thorough debridement of the root canal while maintaining optimal form and the original configuration [1]. However, during preparation, particularly when preparing curved canals, some iatrogenic errors may occur, including ledges, zips, perforations, or root-canal deviation [2]. All types of nickel-titanium (Ni-Ti) systems result in various degrees of deviation during the preparation of curved root canals [3,4]. To avoid this deviation, the correct operation must be performed using a preparation system with excellent performance. Various innovative Ni-Ti files have been developed to meet the demand for more flexible, fracture-resistant, and efficient instruments. These developments have included optimizing the devices' mechanical properties through various thermomechanical treatments to improve centring ability. Thus far, three main phases of Ni-Ti wire microstructure have been described: austenite, martensite, and R-phase. In the austenite phase, the Ni-Ti alloy displays strength and rigidity, whereas it displays ductility and flexibility when in the martensite phase [5].

At present, several continuous rotary Ni-Ti systems are commonly used in the preparation of curved root canals: 1) Mtwo files are made of traditional Ni-Ti alloy. The spiral concave surface is narrow, ensuring the cutting force and flexibility of the instrument itself. 2) Twisted File (TF) is made using R-phase heat treatment and is twisted. The instrument's flexibility is sufficient to maintain the original canal centre and minimize canal transportation, even in severely curved canals [6]. 3)The Protaper Next (PTN) instrument is made of M-Wire alloy, using a patented thermomechanical process for Ni-Ti wires. 4) Hyflex CM (HCM) is a relatively new Ni-Ti rotary system that uses Controlled Memory (CM) alloy, for which the transformation temperature from the austenite phase to the martensite phase is lower than body temperature (37°C). Files made of CM alloy can be pre-curved at room temperature and do not exhibit the shape memory found in traditional Ni-Ti files.

The flexibilities of instruments made of different alloys may vary, leading to differing degrees of root-canal transportation during preparation of curved canal [6-10]. To the best of our knowledge, no previous studies have assessed or compared the canal transportation and centring abilities of the above four systems (TF, PTN, HCM, and Mtwo) used for severely curved simulated canals. The aim of this study was to compare the shaping abilities (change of block weight and working length, canal deviation, preparation time, and incidence of instrument separation) of these four Ni-Ti systems used for severely curved canals. We sought to provide a reference for dentists to select Ni-Ti devices during curve canal instrument.

Materials and methods

Sample selection

CSixty single-curved simulated root canals (Dentsply Maillefer, Switzerland) with a 0.10-mm apical diameter, 0.02 taper, 16-mm working length, 45° curvature (Schneider method [11]), and 3-mm radius were selected. The working lengths of the canals were confirmed by passing a size-10 K-file just beyond the apex; the simulated canal was numbered and marked with a "+" as the positioning marker for overlapping images.

Canal imaging

To acquire standardized photographs of each canal, a specific platform was built to precisely position the camera and simulated canal before and after shaping. For calibration, a measuring ruler fixed adjacent to the resin block served as a size reference, thereby ensuring the efficiency and accuracy of the image-overlay process. A white board made of PVC was placed behind plastic blocks to avoid bias due to background colour. The shooting view is shown in figure 1.

Before instrumentation, all canals were stained with black ink (Pilot, Japan) to obtain clear preoperative images. The canals were photographed using a camera (CANON 70D) with constant settings. After preparation, the canals were stained with red ink (Pilot, Japan), then photographed again under identical conditions. Each canal was then rinsed with distilled water until it was colourless and transparent.

A #25 K-file was inserted into the apex of each prepared canal. The canals were then placed in the platform and photographed to measure the working length of the canal after preparation.

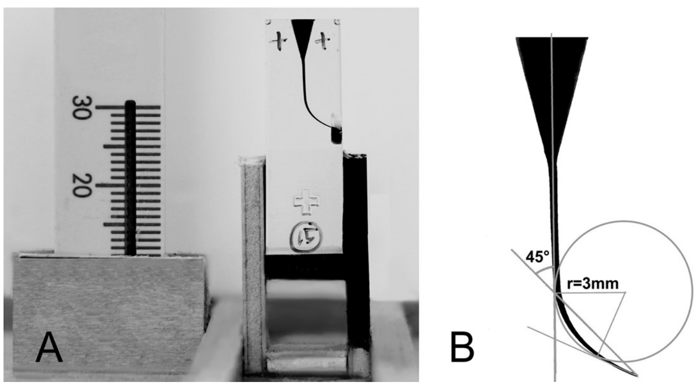

Figure 1.*Resin block in the custom platform. (a) Photo of resin block injected with black ink before instrumentation. (b) The curvature of the simulated canal (curvature 45°, radius:3mm): magnifying from the (a).*

Table 1. *The root canal preparation procedure*

Group	Motor	Procedure (speed;torque)
Group 1: TF (SybronEndo, USA)	VDW Silver motor (VDW, Germany)	25, .08 → 25, .04 → 25, .06
Group 2: HCM (Coltone, Switzer-land)	VDW Silver motor (VDW, Germany)	25, .08 → 20, .04 → 20, .06 → 25, .04 (500 rpm; 2.5 N·cm)
Group 3: PTN (Dentsply Maillefer, Switzerland)	VDW Silver motor (VDW, Germany)	17, .04 → 25, .06 (300 rpm; 2 N·cm)
Group 4: Mtwo (VDW)	VDW Silver motor (VDW, Germany)	10, .04 (280 rpm; 1.2 N·cm) →15, .05 (280 rpm; 1.3 N·cm) →20, .06(280 rpm ; 2.1 N·cm) →25, .06(280 rpm; 2.3 N·cm)

Canal preparation

Sixty single-curved canals in resin blocks were divided into four groups (n=15 canals per group) (Table 1).

Root canal preparation was performed by the same operator. During the preparation process, the instruments drew 17% EDTA gel (PULPDENT, USA) into the root canal. After preparation, a cotton ball with 75% alcohol was used to wipe the instrument, and the root canals were rinsed with 2 ml of distilled water. All instruments were discarded after preparing 3 canals. The root-canal preparation time (including the time to rinse and change the instrument) was recorded by an assistant with a stopwatch.

Measurement points

Using the marked "+" as the positioning standard, Adobe Photoshop CS6 Extended (Adobe Systems Inc., USA) was used to combine images of the same canal before and after preparation and mark the measurement points. Ten measurement points, determined in 1-mm intervals (D0-D9), started with the apex and stopped at the D9 point. The processed images were imported into ImageJ (Media Cybernetics Inc., USA) to calculate the amount of resin removal from the inner and outer walls of the canal at each measurement point. D0 to D3 were located in the apical curvature portion of the canal, D4 to D6 were in the coronal curvature portion, and D7 to D9 were in the coronal plane portion.

Statistical analysis

Statistical analyses of data obtained in this study were performed using SPSS software (version 17.0, IBM Corp., USA). The Shapiro–Wilk test was used to determine whether the data showed a normal distribution; differences between groups were determined using the Kruskal–Wallis test and Bonferroni correction. The level of statistical significance was set to 5%.

Result

Changes in working length

Changes in the working length of the canals after preparation using the four Ni-Ti instruments are shown in table 2. There were no significant differences among the groups after preparation with respect to root-canal working length (P>0.05).

Table 2. *The change of working length (mm, x±s)*

Group	Change of working length
Group 1: TF	0.249±0.181
Group 2: HCM	0.249±0.112
Group 3: PTN	0.227±0.137
Group 4: Mtwo	0.218±0.158

Table 3. *The quality change of resin block (mm, x±s)*

Group	Change of weight
Group 1: TF	$0.0393^{a}\pm0.1819$
Group 2: HCM	$0.0786^{a}\pm0.0922$
Group 3: PTN	$0.0650^{a}\pm0.0537$
Group 4: Mtwo	$0.2750^{c}\pm0.9693$

a, b, c: Different superscript letters indicate significant differences among the instruments (P < 0.05)

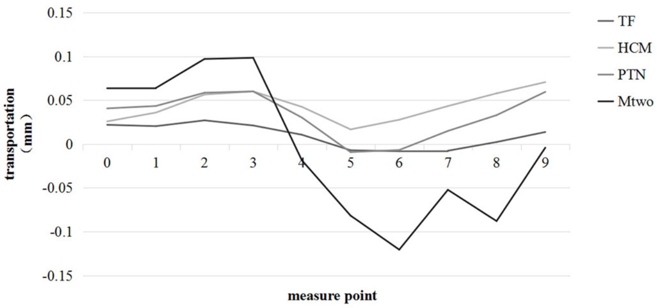

Figure 2. *A line chart demonstrating the direction and amount of canal deviation (mm) at the different measurement points. Value were calculated by subtracting the amount of resin removed at the inner side of the simulated canal from the amount of resin removed at the outer side.*

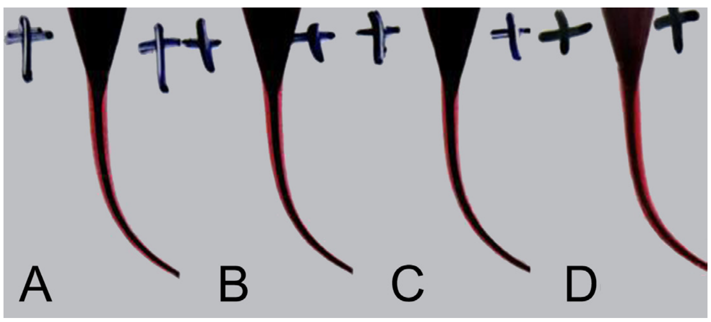

Figure 3. *Representative image of simulated canal before and after preparation using (a)TF; (b) HCM; (c) PTN; (d) Mtwo (Pre-preparation stained with black inc; Post-preparation stained with red inc)*

Table 4. *Canal preparation time (s, x±s)*

Group	Preparation time
Group 1: TF	75.49[a]±11.05
Group 2: HCM	149.62[b]±8.85
Group 3: PTN	88.70[c]±14.55
Group 4: Mtwo	157.73[b]±10.66

a, b, c: Different superscript letters indicate significant differences among the instruments ($P < 0.05$)

Root-canal deviation at different measurement points

Root-canal deviation at different measurement points is shown in figure 2. There were no significant differences of the four Ni-Ti instruments at the apical foramen (D0). In the apical curvature portion of the canal (D1-D2, i.e. 1~2 mm from the apex), the TF group had the least root-canal deviation, as the instrument had better central positioning ability than the other three. Root-canal deviation in the Mtwo group was greater than in the other 3 groups, both in the apical curvature portion of the canal (D1-D3) and in the coronal curvature portion (D5-D6) (P<0.05). In the straight section (D7-D9, i.e. the 7~9 mm part), there were no significant differences of the four instruments. Except at D5, there were no statistically significant differences in root-canal deviation of the HCM and PTN instruments at the other measurement points.

Quality change of resin block

The mass change values of the resin block are shown in table 3. The quality change in the Mtwo group was 0.2750±0.9693 g (P<0.05); there were no statistical differences among the other three groups.

Preparation time

The preparation times of the four Ni-Ti instruments are shown in table 4. The preparation time of the TF group (75.49±11.05 s) was the shortest, followed by that of the PTN group (88.70±14.55 s); there was no significant difference between the preparation time of the HCM group (149.62±8.85 s) and that of the Mtwo group (157.73±10.66 s). There were no instrument fractures or root canal irregularities observed in any groups during preparation. The overlapping images of canals before and after preparation using the four instruments are shown in figure 3.

Discussion

Simulated canals in resin blocks have been recognized as valid study models [12], as the apical diameter, working length, taper, curvature, and other parameters can be standardized in simulated canals to facilitate sample uniformity, which is difficult to achieve when using human teeth [13].

A camera was used to take the pre- and post-preparation images and measure root-canal deviation, as similar cameras have been widely used in other studies and are considered accurate and reliable [14-16]. However, when measuring root-canal transportation, it is essential that the pre- and post-preparation images be taken at exactly the same angle. In accordance with the method of Mathieu et al. [17], we designed and built a specific platform (as shown in Figure 1) to ensure that the pre- and post-preparation images of the root canal were consistent (perpendicular to the central axis of the root canal).

Flexibility of the preparation instruments depends on a variety of factors, including the cross-sectional design of the instrument, taper, metallurgical properties, and metal surface treatment processes. Among these factors, the taper of the instrument is considered a main aspect affecting apical transportation, as increased taper reduces the instrument's flexibility [18]. Thus, the canals were prepared to essentially identical final diameters and tapers in this study, which facilitated accurate comparison of their shaping abilities.

We compared preparation times to evaluate the efficiencies of the four instruments, which could be a useful indicator directing dentist to select proper instruments. The TF and PTN groups showed greater efficiency (75.49±11.05 s; 88.70±14.55 s) than the other two groups. The significantly reduced time required for preparation in the TF group may be related to the instrument's lower number of files and high rotation speed. The HCM system requires four files; thus, the preparation time for the HCM group was longer (149.62±8.85 s) than that for the TF and PTN groups. However, the Mtwo group demonstrated the longest preparation time (157.73±10.66 s), which may be related to the large number of files and the time required to change the parameters (e.g., torque and rotation speed) when replacing the files (Table 1).

There were no ledges, zips, or perforations happened during preparation, which is potentially because these Ni-Ti systems were designed with non-cutting guided tips to reduce pressure on the tip of the instrument, thus maintaining the original path of the canal [7] (Figure 3).

Our results showed that the amount of resin cutting in the Mtwo group was larger than that of the other three groups (P<0.05), while the differences among the other three groups were not statistically significant. We speculate this result may be related to the Mtwo instrument's metallurgical properties (traditional Ni-Ti alloy), which is less flexible than that of other innovative Ni-Ti alloys. Because the instrument tends to resume its original shape in the root canal, the outer side wall of the curved lower section and the inner side wall of the curved upper section may be cut excessively.

The present study showed that all four instruments could maintain the original morphology of the curved canal, although TF proved superior in the apical portion. However, there was considerable transportation in the Mtwo group, both in the coronal curvature portion and in the apical curvature portion. This is potentially because the Mtwo instrument is made of traditional Ni-Ti alloy, which remains mainly in the austenite phase at room temperature, thus providing less flexibility. In a comparison of the centring ability of HCM, TF, and stainless-steel K-files in mandibular single premolars using spiral computed tomography, the shaping and centring ability of TF and HCM were determined to be higher than those of the stainless-steel K-file, whereas the differences between TF and HCM systems were not statistically significant19. In a comparison of the shaping abilities of PTN and HCM in the proximal buccal canals of 60 mandibular molars with severely curved root canals (25-35°), both PTN and HCM were found to maintain the original shape of the root canal, particularly in the apical curvature portion; moreover, there were no significant differences between PTN and HCM7. The results of the present study are consistent with those of Kumar and Saber [7,19].

Canal transportation during the preparation of curved root canals will affect sealing and thus impact the clinical prognosis [20]. Leakage occurs more frequently when the apical transportation index is >0.3 mm [21]. However, transportations of up to 0.15 mm may be considered acceptable [22]. Our results showed that the transportations of these four instruments did not exceed 0.15 mm at any measurement point, indicating that the four instruments are effective for clinical preparation.

During preparation of a root canal, the instrument is bent; it is pressed at the inner side of the curved section to generate compressive stress, and the outer side is subjected to resistance to generate tensile stress. Because of this stress, the instrument tends to return to its original linear shape, thus excessively cutting the outer side wall of the apical curvature portion and the inner side wall of the coronal curvature portion [23], this causes canal transportation. Our results showed that M-wire alloy, CM-wire alloy, and R-phase alloy Ni-Ti systems had better flexibility than traditional alloy systems. Moreover, the centring ability of Ni-Ti alloy is superior to that of traditional alloy. Among the four tested groups, TF caused the least amount of transportation in the apical portion of the canal. The results obtained in this study should be verified in future clinical studies or on extracted teeth.

In conclusion, our results indicated that the four systems are appropriate for clinical preparation of curved canals. However, the centring abilities of the TF, HCM and PTN systems were superior to that of the Mtwo system. Furthermore, the TF system demonstrated superior shaping ability in the apical portion in curved canals, compared with the other three systems.

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