ORIGINAL ARTICLE

Shaping ability of two M-wire and two traditional nickel-titanium instrumentation systems in S-shaped resin canals

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Abstract

Aims: The aim of this study was to evaluate the shaping effects of two M-wire and two traditional nickel-titanium (NiTi) rotary systems in simulated S-shaped resin canals.

Subjects and Methods: Forty simulated S-shaped canals in resin blocks were instrumented with two traditional (ProTaper, Sendoline S5) and two M-wire (WaveOne, GT series X) NiTi systems according to the manufacturers' instructions. Ten resin blocks were used for each system. Pre- and post-instrumentation images were captured using a stereomicroscope and superimposed with an image program. Canal transportation, material removal, and aberrations were evaluated and recorded as numeric parameters.

Statistical Analysis Used: Data were analyzed using one-way ANOVA and *post-hoc* Tukey tests with a 95% confidence interval.

Results: There were significant differences between systems in terms of transportation and material removal ($P < 0.05$). Coronal danger zone was the most common aberration.

Conclusions: Within the limits of this *ex vivo* study, it was found that the manufacturing methods (M-wire or traditional NiTi) and kinematics (rotary or reciprocating motion) did not affect the shaping abilities of the systems. The extended file designs of highly tapered NiTi systems (ProTaper, WaveOne) resulted in greater deviations from the original root canal trace and more material removal when compared to less tapered systems (Sendoline S5, GT series X).

Key words: Canal transportation, endodontic instruments, M-wire, nickel-titanium, S-curvature

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Introduction

Instrumentation is an important part of endodontic treatment that aims to provide an ideal canal shape, a continuously tapered funnel shape with the diameter increasing from the apex to the canal orifice, to facilitate irrigation and obturation.[1] Respecting the original canal shape is also important in order to avoid canal aberrations, such as transportation, ledge, zip, and elbow.[2,3] The prevalence of multiple curved canals is high in human teeth, and owing to the high complexity of canals with multiple curves in different planes, endodontic cleaning and shaping procedures become very difficult within the aforementioned norms.[4,5] Standardized simulated S-shaped (double curvature) resin blocks have been used to evaluate the shaping abilities of endodontic files in double curves.[6,7] These resin blocks allow the visualization of intracanal changes and reproducibility when compared to natural teeth.[8]

Nickel-titanium (NiTi) instrumentation systems have been shown to facilitate shaping and decrease

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procedural errors compared with hand instrumentation techniques.[9,10] There have been many improvements in file designs, manufacturing methods, and preparation techniques regarding rotary endodontic instruments made of NiTi alloy. Recently, a special NiTi wire called M-Wire (Sportswire LLCi Langely, OK, USA) was improved through a proprietary thermo-mechanical processing procedure. Studies have reported that this M-Wire technology provides more flexibility and resistance to cyclic fatigue as compared to non-M-wire NiTi instruments.[11,12]

New production methods and kinematics of NiTi rotary-reciprocating instruments may contribute to the development of canal preparation. However, there is limited information about the differences between the shaping effects of M-wire NiTi and those of traditional NiTi, and no studies have been performed on S-shaped resin blocks. Therefore, the objective of this study was to evaluate the shaping effects of two M-wires (WaveOne reciprocating, GT series X) and two traditional NiTi (ProTaper Universal [PTU], Sendoline S5) reciprocating-rotary systems in simulated S-shaped resin canals.

The null hypothesis tested was that there is no difference between two M-wire and two traditional NiTi instrumentation systems in terms of shaping effects in severely curved S-shaped resin blocks.

Subjects and Methods

Forty simulated S-shaped canals in resin blocks (Endo Training-Bloc, 0.02 Taper; Dentsply Maillefer, Ballaigues, Switzerland) were used for the study. The diameter and taper of the canals were equivalent to those of a standard size 15 instrument. The canal lengths were 17 mm, and the canals began after a 4.5 mm conical area. Before instrumentation, working lengths (WLs) were established to be 1 mm short of the apical end of resin canal using a size 15 K file. The resin blocks were randomly divided into four groups, and each group was instrumented with a ProTaper Universal (PTU, Dentsply Maillefer, Ballaigues, Switzerland), WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), Sendoline S5 (Sendoline, Täby, Sweden), or GT series X (GT-X, Dentsply Tulsa Dental, Tulsa, Oklahoma, USA) NiTi system by an experienced operator using the crown-down method. The resin canals were irrigated with 2 ml distilled water after each instrument, and a final flush with 5 ml distilled water was performed as well. The PTU and WaveOne instrumentations were finished with F1 and small file (0.06/21), respectively. The apical preparation size was set to 0.04/20 for the Sendoline S5 and GT-X groups. The instrumentations were made according to manufacturers' instructions [Table 1]. There was an apical binding to resin canals with a size 20 standard tapered K-file at WL after preparations. Therefore, the canals were accepted as fully shaped with tapered size 20 (21 for WaveOne) instruments.

The shaping effects of the instrumentation systems were analyzed using stereoscopic images of the resin blocks [Figure 1]. Pre- and post-instrumentation images were captured under a stereomicroscope (Leica, Weltzler, Germany) connected to a CCD camera (Leica, Weltzler, Germany) and superimposed with the Adobe Photoshop image program (version 5.0, Adobe Systems Incorporated, San Jose, CA, USA). A silicon template fitted to the stage plate of the stereomicroscope was created to provide image capture at the same position. Three circles were made on each resin block to serve as reference points for image superimposition. Canal transportation was calculated as the distance (in m8illimeters) from the pre- to the post-instrumented canal wall and measured in a plane perpendicular to the resin block's long axis at eight positions (1 mm intervals) on both the left and right proximal sides of the simulated canal. Levels 1–4 represented the apical curvature and levels 4–8 represented the coronal curvature. The left side of the resin block, "L," represented the inner aspect of the apical curve and the outer aspect of the coronal curve. The right side, "R," represented the reverse. Measurements were made using ImageJ 1.38x (National Institutes of Health, Bethesda, MD, USA) computer software with a ×2 magnification.

The final layered canal images were randomly presented for evaluation by an experienced clinician blinded to which instrument group was used. Transportation with direction, material removal, centering ratio, and aberrations (ledge, zip + elbow, file separation) were evaluated for changes and assessed according to following parameters:

Levels 1–8

Levels 1–8 indicate the measurement levels.

Transportation left

Amount of transportation measured on the left side of the resin canal.

Transportation right

Amount of transportation measured from the right side of the resin canal.

Total transportation

Total amount of transportation, calculated as the difference between transportation left (TL) and transportation right (TR). The absolute value of the calculation was recorded, along with the direction (left or right).

Material removal

The total resin removal from two aspects, calculated as TL + TR.

Aberrations

- The ledge: Defined as irregular resin removal from the outer canal wall, associated with a narrower region more coronal from the canal terminus
- The apical zip: Irregular widening of the outer wall near the canal terminus with excessive resin removal, associated with a narrower region coronally
- "Danger zone" widening: Excessive widening of the inner canal wall of the curvatures
- Intracanal file separation.

Statistical analysis

Statistical analysis was performed using SPSS 16.0 (Chicago Inc., USA) software. The material removal, transportation, and centering ratio data were analyzed. One-way ANOVA and *post-hoc* Tukey tests were used for statistical analysis. A confidence interval of 95% was used after performing a normality test to determine the normality of the studied variables.

Results

Transportation

Transportation was evaluated according to level and aspect. Figure 2 shows the amount of transportation generated by different rotary systems. There were significant differences for levels 3, 6–8 ($P < 0.05$). The PTU and WaveOne systems transported the resin canal significantly more than the GT-X system for level 3 ($P = 0.002$ for PTU-GTX, $P = 0.04$ for WaveOne-GTX) and level 6 ($P = 0.037$ for PTU-GTX, $P = 0.003$ for WaveOne-GTX), respectively. The WaveOne system generated significantly more transportation than the Sendoline S5 and GT-X systems for level 7 ($P < 0.001$ for both comparisons). There were significant differences between systems for level 8; the PTU system transported more of the resin canal than Sendoline S5 ($P = 0.005$), and the WaveOne system generated more transportation than the Sendoline S5 ($P < 0.001$) and GT-X ($P < 0.001$) systems.

Material removal

There were significant differences for levels 3–8 ($P < 0.05$) [Table 1]. The WaveOne system removed significantly more material than the other systems for all of these levels ($P < 0.05$). The PTU system removed significantly more material than Sendoline S5 for level 4, as well as more material than the Sendoline S5 and GT-X for levels 5–8 ($P < 0.05$). There was no significant difference between Sendoline S5 and GT-X for all levels. The inner aspects of apical and coronal curvatures (apical left, coronal right) were the sites of excessive material removal for all systems. There was a tendency to change curvatures into straight zones, and this tendency increased with the taper of the system [Figure 1].

Aberrations

There were no file separations for the evaluated systems. There were coronal danger zones for all evaluated systems (PTU: 5,

Table 1: Instrument sequences of the systems. WaveOne electric motor was used for instrumentations

ProTaper	WaveOne	Sendoline S5	GT series X
X: At two thirds of WL	Small file at WL	No. 1: At 1/3 of the WL	Size 20/.06 at 2/3 of the WL
S1: At WL		No. 2: At 2/3 of the WL	Size 20/.04 at WL
S2: At WL	WaveOne motor WaveOne All resiprocation mode	No. 3: At WL- 1mm	
F1: At WL		No. 4: At WL-1mm	300 rpm
Speed: 300 rpm		No. 5: At WL	Tork: 2 Ncm
Tork: 1,8-2,2 Ncm		Speed: 300 rpm	
		Tork: 0,5-4 Ncm	

WL=Working length; GT=Greater taper

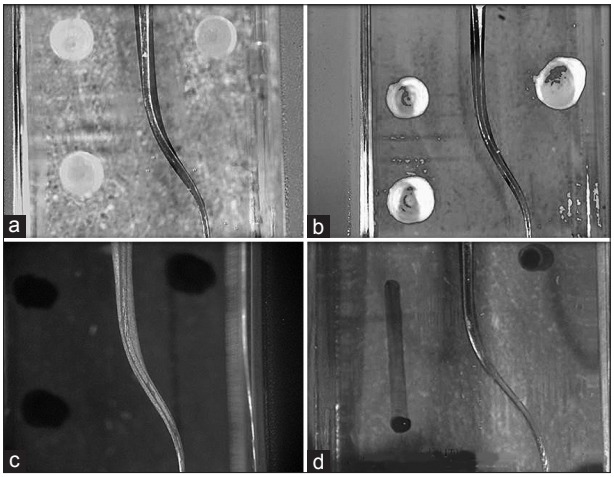

Figure 1: Superimposed stereoscopic images of the instrumentation systems. (a) ProTaper Universal, (b) Sendoline S5, (c) WaveOne, (d) GT series X

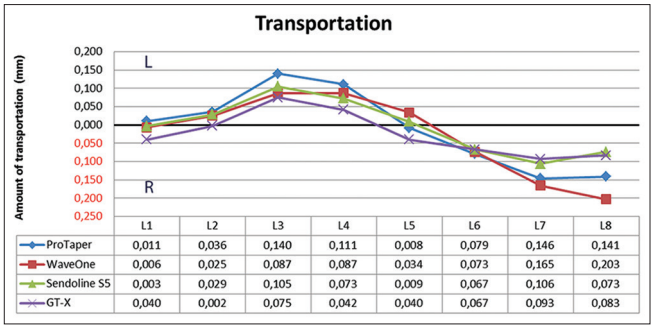

Figure 2: Amount and direction of transportation with the instrumentation systems. The measurements were made at eight different levels. "L" and "R" refers to the two sides of the resin blocks

WaveOne: 8, Sendoline S5: 3, GT-X: 4). Apical danger zones were less than those of coronal ones (PTU: 1, WaveOne: 1, Sendoline S5: 1, GT-X: 0). There were only 2 zip formations among all instrumented canals (WaveOne: 1, Sendoline S5: 1).

Discussion

In this study, the effects of four instrumentation systems that have different designs, manufacturing methods, number of files, and kinematics (continuous rotation, reciprocating motion) on canal transportation and volume of resin removal were compared. It is known that the hardness and other physical specifications of resin canal walls differ from those of the human root canal walls. It has been suggested that micro–computed tomographic three-dimensional analysis is more discriminative of changes in the canal spaces associated with repeated instrument use than photographic measurements.[13-15] Volumetric three-dimensional analysis is determinant in the study of the variability of anatomy of the human teeth with three-dimensional development of the canal path.[16] However, superimposed two-dimensional images (photographs, digital radiographs) can give comparable results for evaluation of shaping effects of the instruments.[17,18] In this study, the evaluation of the shaping effects of instruments was done using superimposed two-dimensional photographs of the simulated resin blocks. Resin blocks allow the visualization of intracanal changes, reproducibility, and the standardization of root canal morphology when compared to natural teeth.[8,19] Root canals of human teeth represent certain irregularities, such as multiple curvatures in different planes.[4,5] S-shaped resin blocks can simulate this challenge in a standardized condition for NiTi systems. Moreover, the use of simulated canals in resin blocks has the opportunity to standardize the research method and to exclude parameters that could influence the preparation outcome.[20]

The elimination of bacteria within the root canal system is one of the main goals of root canal treatment. These bacteria must be removed with a chemo-mechanical action of irrigants and instrumentation procedures.[21] However, almost all published findings agree that increasing the curve of the root canal or the diameter of the master instrument that prepares the full WL will result in greater transportation, straightening, and aberration.[22,23] According to Ruddle, a canal is accepted as fully shaped and ready for obturation following the use of F1 ProTaper, if a size 20 standard hand file (K-file or hedstroem) is snug at length.[24] Although tactile sensibility is not a sufficient determinant for apical preparation size of human teeth, it can be used for standard round shaped resin canals.[25]

There were significant differences for levels 3, 6–8 in terms of transportation ($P < 0.05$). All instrumentation systems caused transportation, especially towards the inner part of the curvatures, and the amount was increased synchronously with the cross-section of the instrument. This is due to the increased straightening tendencies of the instruments associated with the taper. The highly tapered NiTi systems (PTU, WaveOne) resulted in greater deviations from the original root canal trace when compared to less tapered Sendoline S5 and GT-X systems in the present study. Madureira *et al.* found increased transportation when flexibility decreased due to greater cross-sectional metal mass for a single manufactured metal.[26] Although proprietary thermo-mechanical processes applied to WaveOne and GT-X systems have been shown to increase cyclic fatigue resistance, there was no significant difference in terms of the transportation of these instruments when compared with traditional NiTi PTU and Sendoline S5 systems in the present study.

There were significant differences between levels 3–8 in terms of material removal. WaveOne and PTU systems demonstrated excessive material removal and transportation when compared to other less tapered systems (Sendoline S5, GT-X). WaveOne has a modified, convex, triangular cross-section with radial lands at the tip and a convex triangular cross-section in the middle and coronal portion of the instrument, similar to the PTU instruments.[27] In their study Capar *et al.* compared the similar tapered (0.08) instruments (OneShape, PTU, ProTaper Next, Reciproc, TF Adaptive, and WaveOne) with different kinematics for volumetric changes, the Resiproc instrument removed more dentin than ProTaper, whereas WaveOne exhibited similar performance with Reciproc and PTU.[28] In the present study, when transportation is considered, there were no significant differences between the PTU F1 and WaveOne small file, but there were significant differences in terms of material removal. Jeon *et al.* compared Reciproc and WaveOne and found that more repetitive pecking motions at the WL resulted in a significant change in the apical preparation size for both instrumentation systems.[29] Shaping the resin canal with the single small file of the WaveOne system requires the more repetitive use of an aggressively tapered single instrument than the sequential files (SX, S1, S2, F1) of the PTU system. Increasing core diameter and repeated use may be reasons for the greater material removal generated by the WaveOne system in the present study. The Sendoline S5 and GT-X systems had similar shaping abilities and removed less material than the other more highly tapered systems. This finding can be attributed to similar core diameters and kinematics of these instruments.

Aberrations in the form of coronal danger zones were especially common at higher levels (levels 6–8). This can be attributed to decreased flexibility of the instruments with the increasing core diameters. There were 5, 8, 3, and

4 coronal danger zones for the PTU, WaveOne, Sendoline S5, and GT-X systems, respectively. The coronal danger zone incidence increased with the increasing core diameters of the instruments. The WaveOne system caused the highest number of coronal danger zones. This finding can be attributed to its swift approach towards the apex using only a single file and the repeated use of this instrument, as mentioned, for material removal.

Within the limitations of this *ex vivo* study, there was no statistically significant difference between the shaping ability of the M-wire and traditional NiTi systems. Therefore, the null hpothesis was accepted. The highly tapered NiTi systems (PTU, WaveOne) resulted in greater deviations from the original root canal trace when compared to less tapered systems (Sendoline S5, GT-X). The WaveOne system removed more material than the other systems, probably due to the increasing core diameter of the small file and its repeated use.

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