Investigation on the Shaping Ability of Nickel-Titanium Files When Used with a Reciprocating Motion

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Abstract

Introduction: The introduction of nickel-titanium (NiTi) files into clinical practice has improved the quality of canal shaping, but increasing the curvature of the root canal (or the diameter of the master instrument that prepares the full working length) could result in more transportation, straightening, and aberration of the canal. Nickel-titanium instruments are significantly safer and have an extended cyclic fatigue life when used with a reciprocating movement. The purpose of this study was to compare the shaping ability of FlexMaster NiTi instruments when used in either continuous or reciprocating movements. Methods: Thirty-two Endo Training Blocks ISO 15, 2% taper, 10-mm radius of curvature, and 70° angle of curvature were prepared, according to the group, with FlexMaster NiTi instruments either in continuous rotation or in reciprocating (60° clockwise, 40° counterclockwise) movement. Preoperative and postoperative images of the simulated canals were taken under standardized conditions. The preoperative and postoperative images were combined exactly. The amount of resin removed was determined both for the preoperative and postoperative images. The amount of resin removed was compared with alternating rotation than with continuous rotation (9).

Results: In the most apical third of the canal, the Continuous group produced the largest enlargement of the canal as compared with the Reciprocating group (P < .05). In the apical third, the Continuous group displayed significantly greater enlargement of the canal at the external side. Conclusions: The shaping of simulated canals is more centered by using a reciprocating motion when compared with continuous rotation, but the reciprocating motion could be more time-consuming. (J Endod 2011;37:1398–1401)

Key Words

Dental instruments, dental models, instrumentation methods, NiTi

A continuously tapering funnel shape that follows initial anatomy, with the smallest diameter at the end point and the largest at the orifice, is a prerequisite to remove all the pulp tissue, bacteria, and their by-products, while providing adequate canal shape to fill the canal (1, 2).

The introduction of rotary nickel-titanium (NiTi) endodontic instruments (also called files) into clinical practice has improved the efficacy of endodontic practice in terms of procedural time, accuracy, and risk reduction, compared with the previously used manual stainless steel files (3–5).

Because of their flexural properties, coupled with the design of the blades, it is feasible to use NiTi files with a handpiece in a rotary motion to prepare root canals (6). Meanwhile, almost all published findings are in consensus that increasing the curvature of the root canal or the diameter of the master instrument that prepares the full working length (WL) results in more transportation, straightening, and aberration (7). Usually NiTi instruments were designed for use with continuous rotation movement at low speed.

Malentacca and Lalli (8) observed that NiTi instruments were significantly safer when used with a reciprocating movement than when used with continuous rotation. A subsequent study showed that the incidence of instrument fracture in blocks of resin was lower with alternating rotation than with continuous rotation (9).

The reciprocating movement also promotes an extended cyclic fatigue life of the instruments when compared with conventional rotation (10, 11).

Yared (12) proposed a shaping technique based on the use of a F2 ProTaper (Tulsa Dentsply, Tulsa, OK) with reciprocating movement. Flex Master instruments have the same cross section as ProTaper, but they have a continuous taper throughout the whole length of the instrument rather than a variable taper.

No studies are currently available on the shaping ability of files designed for the continuous rotation when they are used with reciprocating movement.

The aim of this study was to compare the shaping ability of Flex Master NiTi instruments by using 2 different rotation movements, with the working hypothesis that they have a similar shaping performance.

Materials and Methods

Thirty-two Endo Training Blocks ISO 15 (Dentsply Maillefer, Ballaigues, Switzerland), 2% taper, 10-mm radius of curvature, and 70° angle of curvature, were used to assess instrumentation.

Specimens were randomly assigned to 2 different groups by using a random generated numbers table. Each specimen was mounted in a support, which was made for the study, in a stable vertical position and digitally photographed consistently under the same light condition before starting the instrumentation phase.

Preparation of Simulated Canals

After photography, the transparent blocks were covered with black adhesive tape to conceal the preparation during the instrumentation stage. The simulated canals were prepared, according to the group, with FlexMaster NiTi instruments (VDW, Munich, Germany) either in continuous rotation or in reciprocating (60° clockwise, 40° counterclockwise) movement. Glycerin was used as a lubricant, and copious irrigation with
water was performed after the use of each file. Canal patency was checked between instrument changes with a K-Flexofile #10 (Dentsply Maillefer).

**Continuous Group**

FlexMaster instruments were set into continuous rotation (280 rpm) with a 6:1 reduction handpiece (Sirona, Bensheim, Germany) powered by a torque-limited electric motor (VDW silver) with the appropriate torque for each file (90 g-cm for 0.06 taper (T) size 25, 60 g-cm for 0.04T size 25, 30 g-cm for 0.04T size 15), as recommended by the manufacturer. The motor was set to work with the Automatic Stop and Reverse function on (ie, when the preset torque is reached, the micro-motor will turn automatically in reverse direction until the file no longer encounters resistance, at which point it will automatically revert to forward rotation). Instrumentation was completed by using a gentle in-and-out motion.

The adopted file sequence was 0.04T size 15 (at WL), 0.06T size 25 (5 mm short of the WL), 0.04T size 25 (at WL), and 0.06T size 25 (at WL).

**Reciprocating Group**

FlexMaster instruments were set into reciprocating movement (60° clockwise, 40° counterclockwise, 280 rpm) with a 16:1 reduction handpiece (Sirona) powered by a torque-limited electric motor (Sirona Pocket; Sirona). The maximum torque (5 Ncm) was used for all the instruments. Instrumentation was completed by using a gentle in-and-out motion. Instruments were withdrawn when resistance was felt.

The same file sequence as in the Continuous Group was used.

All canals were shaped by an operator experienced in NiTi instrumentation. All instruments were used to shape 2 canals only. Measurements of the canals were carried out by a second examiner who was blinded with respect to all the experimental groups.

**Assessment of Canal Preparation**

Preoperative and postoperative images of the simulated canals were taken under standardized conditions with a digital reflex (Fuji S2 Pro; Fujifilm, Tokyo, Japan), mounted on an operative microscope (Leica M655; Leica Microsystems, Wetzlar, Germany).

The postoperative images were taken when the 0.06T size 25 reached the WL. The preoperative and postoperative images were combined exactly in 2 different layers by using Photoshop software (Adobe Systems, San Jose, CA).

![Figure 1](image-url)

**Figure 1.** (A) Mean total enlargement of canal produced by the 2 techniques. In the most apical third, the continuous technique produced a significantly greater enlargement as compared with the reciprocating technique. (B) Mean variation at inner and outer sides of the canal, expressed as percentage of baseline width. The trend is not the same for inner and outer sides, while it is similar between the 2 techniques, although significant differences were found according to the region of the canal. est, outer side; int, internal side.

**Instrument Failure**

Instruments were examined under microscopic magnification (Leica M655) after every use. In case of deformation or fracture of an instrument before the end of the second shaping procedure, the Endo Training Block would be substituted, and the shaping would be repeated by using a new instrument.

**Preparation Time**

The effective working time (considering only the operative phases, when the instrument was actually working inside the simulated root canal) was recorded with a digital chronograph with a precision of 0.1 seconds.

**Canal Blockage**

In case of excessive formation of resin debris in the canal that prevented the completion of the procedure, the canal would be discarded and not considered for the analysis.

**Recording, Storage, and Analysis of Data**

The assessment of preparation shape was carried out with the computer program Image (UTHSCSA Image Tool version 3.00 for Windows; University of Texas Health Science Center in San Antonio, TX). The amount of resin removed, eg, the difference between the canal configuration before and after instrumentation, was determined for both the inner (convex) and the outer (concave) sides of the curvature. Measurements were performed in correspondence of 10 consecutive points on the outer and the inner surfaces of the canal. To facilitate the measurement procedure, a grid composed of 10 consecutive concentric circles was superimposed to each image. The distance between any 2 consecutive points was 1 mm. Measurements started 1 mm away from the apical end of the canal. The linear distance between the intersection of each circle line with the border of the original canal shape and the corresponding point on the canal after preparation, along the line orthogonal to the canal axis, was measured. A total of 20 distances at 20 measuring points (10 on the inner side and 10 on the outer side) were recorded for each canal. Each measurement had an accuracy of ±0.01 mm (13–15). Mean values and standard deviations were calculated for each measurement point. The unpaired Student’s *t* test was used to compare results between the 2 groups. The differences between the results at the inner and outer sides of the canal within each group were analyzed with the paired Student’s *t* test. A value of *P* = .05 was used as the significance level. The data will be discussed...
by dividing the canal into 3 zones: most apical, middle, and most coronal thirds.

**Results**

No canal was discarded because of blockage caused by instrument separation.

In the most apical third of the canal (points 1–3) the instrumentation of the Continuous group produced a greater enlargement of the canal as compared with the Reciprocating group (*P < .05*). In the middle (points 4–7) and the most coronal (points 8–10) thirds of the canal, the overall enlargement produced by the 2 techniques was not different, as shown in **Figure 1A**. The results for shaping measures are listed in **Table 1**.

Considering separately the results obtained at the inner and outer sides of the canal, in the apical third the Continuous group displayed separation.

In the most coronal third of the canal, a substantial equivalence between the 2 groups was observed. As can also be appreciated from **Figure 1B**, the variations recorded for the Reciprocating group were lower as compared with the Continuous group on the external side and for the Continuous group on the internal side.

In the most coronal third of the canal, the overall enlargement produced by the 2 techniques was not different, as shown in Figure 1A. The results for shaping measures are listed in Table 1.

Considering total time needed for instrumentation, the Reciprocating group was significantly slower than Continuous group. The working time was 3 minutes 52 seconds 3 tenths of a second and 2 minutes 47 seconds 7 tenths of a second for the Reciprocating group and Continuous group, respectively. When instrumentation time for each instrument was considered, the instruments with thinner taper (0.04T size 15, 0.04T size 25) were significantly different between the 2 groups, whereas the larger taper (0.06T size 25) was not significantly different between the 2 groups. The results for time of instrumentation are listed in **Table 2**.

**Discussion**

In this study FlexMaster NiTi instruments were used because of their convex triangular section, which enables them to cut in both clockwise and counterclockwise directions. FlexMaster instruments are very similar to ProTaper instruments, with the same section and a nonactive tip, but they differ in having a continuous taper rather than a variable taper. In previous studies FlexMaster showed a good capacity to shape plastic blocks without aberrations or procedural errors; nonetheless, even if the obtained shaping is better than that achieved with manual instruments, they are not perfectly centered (14).

The choice of asymmetric alternating rotation is based on results obtained in other studies in which it was shown that symmetrical rotation makes progression along the canal more laborious.

For the reciprocating movement we used the Sirona Pocket Endo motor set at values of 60° clockwise—40° counterclockwise. With this motor it is not possible to set the values of clockwise-counterclockwise at 60°—45° as in the other studies (16), so it was set at the closest values. The use of simulated canals in resin blocks does not fully reflect the action of the instruments in root canals of real teeth (13). However, resin blocks allow a direct comparison of the shapes obtained with different movements. A major drawback of using rotary instruments in resin blocks is the heat generated, which might soften the resin material (17). This might interfere with the progression of the instrument along the simulated canal.

When analyzing the quality of root canal preparation created by instruments and techniques, several parameters are of special interest, particularly their shaping ability.

**Table 1.** Mean Values and Standard Deviations of Canal Enlargement at Both Inner and Outer Sides

<table>
<thead>
<tr>
<th>Measurement point</th>
<th>Reciprocating group</th>
<th>Continuous group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inner side (mm)</td>
<td>Outer side (mm)</td>
</tr>
<tr>
<td>1</td>
<td>0.07 ± 0.01</td>
<td>0.10 ± 0.02</td>
</tr>
<tr>
<td>2</td>
<td>0.08 ± 0.02</td>
<td>0.16 ± 0.03</td>
</tr>
<tr>
<td>3</td>
<td>0.09 ± 0.02</td>
<td>0.18 ± 0.03</td>
</tr>
<tr>
<td>4</td>
<td>0.15 ± 0.03</td>
<td>0.15 ± 0.03</td>
</tr>
<tr>
<td>5</td>
<td>0.23 ± 0.03</td>
<td>0.11 ± 0.02</td>
</tr>
<tr>
<td>6</td>
<td>0.22 ± 0.03</td>
<td>0.15 ± 0.03</td>
</tr>
<tr>
<td>7</td>
<td>0.20 ± 0.03</td>
<td>0.24 ± 0.03</td>
</tr>
<tr>
<td>8</td>
<td>0.21 ± 0.04</td>
<td>0.28 ± 0.04</td>
</tr>
<tr>
<td>9</td>
<td>0.23 ± 0.05</td>
<td>0.32 ± 0.06</td>
</tr>
<tr>
<td>10</td>
<td>0.25 ± 0.05</td>
<td>0.34 ± 0.07</td>
</tr>
<tr>
<td></td>
<td>0.07 ± 0.01</td>
<td>0.15 ± 0.03</td>
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<tr>
<td></td>
<td>0.08 ± 0.01</td>
<td>0.24 ± 0.07</td>
</tr>
<tr>
<td></td>
<td>0.09 ± 0.01</td>
<td>0.25 ± 0.05</td>
</tr>
<tr>
<td></td>
<td>0.12 ± 0.03*</td>
<td>0.20 ± 0.03</td>
</tr>
<tr>
<td></td>
<td>0.24 ± 0.03*</td>
<td>0.10 ± 0.02</td>
</tr>
<tr>
<td></td>
<td>0.27 ± 0.03*</td>
<td>0.12 ± 0.03*</td>
</tr>
<tr>
<td></td>
<td>0.24 ± 0.03*</td>
<td>0.19 ± 0.04*</td>
</tr>
<tr>
<td></td>
<td>0.24 ± 0.04</td>
<td>0.26 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>0.24 ± 0.05</td>
<td>0.31 ± 0.04</td>
</tr>
<tr>
<td></td>
<td>0.27 ± 0.04</td>
<td>0.33 ± 0.05</td>
</tr>
</tbody>
</table>

*Significant difference between Reciprocating and Continuous groups, which is only indicated in the Continuous group columns.

**Table 2.** Mean Values and Standard Deviations of Time Needed for Instrumentation

<table>
<thead>
<tr>
<th>Instrument used in each step</th>
<th>Reciprocating group, time (seconds)</th>
<th>Continuous group, time (seconds)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 15/0.04</td>
<td>66.35 ± 17.86</td>
<td>41.06 ± 13.77*</td>
</tr>
<tr>
<td>Change</td>
<td>11.82 ± 6.41</td>
<td>15.67 ± 2.32*</td>
</tr>
<tr>
<td>T1 25/0.06</td>
<td>14.65 ± 3.72</td>
<td>25.29 ± 15.77*</td>
</tr>
<tr>
<td>Change</td>
<td>9.65 ± 4.89</td>
<td>16.27 ± 2.19*</td>
</tr>
<tr>
<td>T1 25/0.04</td>
<td>80.82 ± 28.56</td>
<td>35.82 ± 18.55*</td>
</tr>
<tr>
<td>Change</td>
<td>9.71 ± 2.59</td>
<td>16.00 ± 2.22*</td>
</tr>
<tr>
<td>T1 25/0.06</td>
<td>70.47 ± 18.03</td>
<td>83.00 ± 16.93</td>
</tr>
<tr>
<td>Total</td>
<td>263.47 ± 39.62</td>
<td>214.60 ± 34.69*</td>
</tr>
<tr>
<td>Working time</td>
<td>232.29 ± 40.51</td>
<td>167.73 ± 33.31*</td>
</tr>
</tbody>
</table>

*Each consecutive step in instrumentation is detailed.

*Significant difference between Reciprocating and Continuous groups, which is only indicated in the Continuous group columns.
The use of simulated resin root canals allows standardization of degree, location, and radius of root canal curvature as well as the width of the root canals. The preoperative and postoperative root canal outlines can be compared by superimposing them by using digital microphotographs, and they can be analyzed by using digital measurements for deviations at any point of the root canals. This model guarantees a high degree of reproducibility and standardization of the experimental design.

When considering the apical third of the canal (points 1–3), the instrumentation with continuous rotation produced a greater enlargement of the canal compared with the reciprocating motion ($P < .05$). This can be explained with the number of total rotations that the instruments do while shaping the canal. Whereas the instruments make a $360^\circ$ turn for every cycle in the continuous movement, in the same timespan with the reciprocating movement, the instruments do a $20^\circ$ turn.

In the apical third of the canal there are statistically significant differences on both the inner and the outer sides of the curve.

On the outer side the continuous movement produced a greater enlargement of the canal; conversely, on the inner side the reciprocating movement enlarged more. This can be explained with the observation that the continuous movement shifted toward the outer part of the curve, thus minimally shaping the inner part of the curve and resulting in a preparation that experienced transportation. The reciprocating movement shaped a preparation in a more uniform manner centered on the original canal, and so it enlarged almost equally in both the inner and outer directions. This action would result in a greater contact area between the instrument and the canal walls, thus producing a debride-ment quality as effective as the continuous rotation when considering round canals.

In oval canals, the debridement quality obtained by NiTi instruments, either in continuous or in reciprocating movement, seems to be suboptimal (18). In recent studies an innovative self-adjusting file system showed promising performance in terms of canal shaping and debridement as compared with NiTi rotary instruments used in continuous movement (19). More studies are needed to confirm these results, which also compare self-adjusting file with NiTi files used with reciprocating movement.

Cimilli and Kartal (20) demonstrated that the continuous rotation movement tends to shift the center of the preparation in a clockwise direction. With a movement more symmetrical like the reciprocating movement in which the instruments cut in both directions, this tendency should be reduced. More investigations are needed to test this hypothesis.

Roane et al (21) described an effective way to prepare curved canals by using hand files in a clockwise-counterclockwise movement. With NiTi instruments the concept of the balanced force is still valid; the instrument would engage dentin at its tip during the clockwise movement, whereas the counterclockwise movement would disengage the instrument immediately afterward. These alternating movements would theoretically reduce the incidence of torsional fracture by taper lock.

This issue is currently under investigation by the same authors.

The instruments used in this study have a symmetrical section, with an active cutting angle that can cut dentin in both directions. Thus, the slight apical pressure on the instrument makes it work even in the dis-engaging movement. This action is more relevant with instruments of bigger taper, when more blades are engaged in the canal walls. The time needed to shape the canal does not differ significantly when instruments of bigger taper are used with the different motions.

The results of this study suggest that the use of dedicated instruments for reciprocating motion is not mandatory. Even if the total shaping time is longer with the reciprocating motion, the effective rotations of the instruments are less than with the continuous movement. This should affect the resistance to flexural separations of the instruments. This issue is also currently under investigation by the same authors.

Within the limits of this investigation, the shaping of simulated canals is more centered by using a reciprocating motion when compared with continuous rotation, but the reciprocating motion could be more time-consuming.

Acknowledgments

The authors deny any conflicts of interest related to this study.


References