Shaping Ability of Reciprocating Motion in Curved Root Canals: A Comparative Study with Micro–Computed Tomography

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Abstract

Introduction: Recently, root canal shaping with reciprocating motion has been postulated to reduce the possibility of unexpected file fractures. However, there has been little information on the shaping capability of this reciprocating motion preparation technique. Therefore, the purpose of this study was to evaluate the shaping ability of reciprocating motion when compared with continuous rotation motion in curved root canals.

Methods: The mesiobuccal and distobuccal canals of 20 extracted maxillary molars with curvatures of 20–45 degrees were instrumented with a series of ProTaper rotary files. The canals in the continuous rotation motion (CM) group (n = 20) were prepared by using continuous rotation with pecking motion, whereas the canals in the reciprocating motion (RM) group (n = 20) were prepared with reciprocating motion (clockwise 140 degrees and counterclockwise 45 degrees). Basic geometric parameters such as curvature, root canal volume, surface area, and structure model index (SMI) before and after canal shaping were evaluated by using micro–computed tomography. The degrees and directions of transportation were also measured, and statistical analysis was carried out with one-way analysis of variance and Tukey post hoc tests.

Results: There were no significant differences between the 2 groups in canal curvature, volume, surface area, and SMI categories measured before preparation (P > .05). Changes in curvature, root canal volume, surface area, and SMI were not affected by the instrumentation technique used (P > .05). There were no significant differences in the degrees and directions of transportation between CM and RM groups (P > .05).

Conclusions: The application of reciprocating motion during instrumentation did not result in increased apical transportation when compared with continuous rotation motion, even in the apical part of curved canals. Reciprocating motion might be an attractive alternative method to prevent procedural errors during root canal shaping. (J Endod 2011;37:1296–1300)

Key Words
Continuous rotation motion, curved canal, micro–computed tomography, reciprocating motion, transportation

Root canal shaping is one of the most important procedures in endodontic treatment. This canal shaping procedure influences the results of the following steps of root canal irrigation and obturation (1, 2). Opposed to most root canals that are curved, endodontic instruments are made from straight metal blanks. They have a tendency of straightening the root canal during preparation and frequently result in procedural errors such as ledging, zipping, and transportation (3, 4). These aberrant results of root canal shaping make it difficult for clinicians to remove infected tissues and achieve a properly sealed root canal obturation (5) and might consequently increase the risk for root canal treatment failure.

For clinicians, proper root canal shaping without any procedural accidents such as perforation or file separation is of the utmost preference. Unfortunately, NiTi instruments have a higher risk of separation in the canal compared with hand files (6). Recently, root canal shaping with reciprocating motion has been postulated to reduce the possibility of unexpected file fractures, and there have been few studies on how this reciprocating motion offers superior fracture resistance (6–8). In fact, the NiTi instrument has brought about a huge development in the canal shaping procedure and immensely decreased the procedural errors especially in the apical area of the curved canal (9).

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Materials and Methods

Root Canal Shaping

The mesiobuccal and distobuccal canals of 20 extracted maxillary molars, with curvatures of 20–45 degrees according to the method of Schneider (16), were used in this study. The cavities were accessed with #330 burs, and the working lengths were determined in the following way. A #10 K-file was inserted into the root canal until it was visible through the apex, at which point 1 mm was deducted from that length. After measuring the working length, a glide path was formed by using a #15 K-file.

Forty canals from 20 extracted maxillary molars were divided randomly into 2 groups according to the rotation methods applied to

Figure 1. CT scan images before (A–D) and after (E–H) instrumentation under continuous rotation motion at 1 mm (A and E), 2 mm (B and F), 3 mm (C and G), and 5 mm (D and H) level from the apical foramen.

Figure 2. CT scan images before (A–D) and after (E–H) instrumentation under reciprocating motion at 1 mm (A and E), 2 mm (B and F), 3 mm (C and G), and 5 mm (D and H) level from the apical foramen.
the root canal shaping, continuous rotation motion (CM) group and reciprocating motion (RM) group. Each canal was prepared with a series of ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) files by using the Tecnika digital motor (ATR, Pistoia, Italy) at 300 rpm. Instrumentation was performed by using an SX, S1, S2, F1, and F2 sequence for both groups. The canals in the CM group (n = 20) were prepared by using continuous rotation with pecking motion, whereas the canals in the RM group (n = 20) were prepared with reciprocating motion (clockwise 140 degrees and counterclockwise 45 degrees). All canals were prepared by one experienced operator. RC-Prep (Premier Dental Products, Norristown, PA) was used in all canal preparations, and canal irrigation was performed with 3 mL of 5.25% NaOCl after the use of each file. New files were used for each tooth, and these files were observed for any signs of deformation and/or fracture.

**Micro-CT Analysis**

Before initial scanning, a customized jig was fabricated, and each tooth was mounted so that the tooth could be placed in the same position before and after preparation. All teeth were scanned by using the micro-CT system (SkyScan 1172; SkyScan b.v.b.a., Aartselaar, Belgium) at 100 kV and 100 μA with an isotropic resolution of 16 μm. For the three-dimensional root canal reconstruction, only the root from apex to furcation part of each tooth was selected.

The distribution of the initial values of the 2 groups concerning the basic geometric parameters such as curvature, root canal volume, surface area, and structure model index (SMI) before preparation were assessed by using the Mann-Whitney U test. SMI characterizes a structure as being ribbon-shaped versus cylindrical and is expressed in arbitrary units. The range is from 0 (parallel flat planes) to 4 (an ideal round ball). The Student’s t tests were used to compare the change of each value before and after instrumentations. The change of curvature is expressed as canal straightening; difference between preoperative and postoperative canal curvature in relation to preoperative canal curvature.

The amount of transportation was measured from the cross-sectional images before and after the canal preparation (Figs. 1 and 2) according to the following method modified by Gergi et al. (7). The shortest distance from the edge of the uninstrumented canal to the periphery of the root was compared with the value obtained from the postinstrumentation image (Fig. 3). The formula (a1-a2) – (b1-b2) was used to calculate the amount of transportation; a1 was the shortest distance from the lateral edge of the uninstrumented canal to the lateral edge of the root, b1 was the shortest distance from the medial edge of the uninstrumented canal to the medial edge of the root, a2 was the shortest distance from the lateral edge of the instrumented canal to the lateral edge of the root, and b2 was the shortest distance from the medial edge of the instrumented canal to the medial edge of the root.

The transportation values were analyzed in 2 ways. The degree of transportation was measured by calculating the absolute values that resulted from the above formula, and the tendency of the transportation direction was observed by using the total values obtained. The positive value obtained from the formula represents that transportation has occurred lateral to the curvature, whereas the negative value represents that transportation has occurred in the direction facing the furcation. Transportation in the 1-, 2-, 3-, and 5-mm points from the apical foramen was measured from each of its corresponding cross-section image. One-way analysis of variance and Tukey post hoc tests were used to compare the transportation.

**Results**

**Basic Geometric Parameters**

There were no significant differences between the 2 groups in the canal curvature, volume, surface area, and SMI categories measured before preparation (P > .05).

Canal preparation resulted in a loss of canal curvature in both groups. The CM group showed a straightening value of 24.70% ± 11.39%, whereas the RM group showed a straightening value of 21.27% ± 3.48% (Table 1), and there was no statistically significant difference between the 2 groups (P > .05).

The amount of root canal volume increase was 0.91 ± 0.45 mm³ and 1.16 ± 0.64 mm³ in CM group and RM group, respectively.

**TABLE 1. Mean Degree of Canal Straightening**

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>Straightening (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>20</td>
<td>24.70 ± 11.39</td>
</tr>
<tr>
<td>RM</td>
<td>20</td>
<td>21.27 ± 13.48</td>
</tr>
</tbody>
</table>

CM, continuous rotation motion; RM, reciprocating motion.

**Table 2. Changes in Root Canal Volume, Surface Area and Structure Model Index (SMI)**

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Postoperative</th>
<th>Changes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CM</td>
<td>RM</td>
<td>CM</td>
</tr>
<tr>
<td>Volume (mm³)</td>
<td>1.46 ± 0.64</td>
<td>1.64 ± 1.03</td>
<td>2.37 ± 0.70</td>
</tr>
<tr>
<td></td>
<td>0.91 ± 0.45</td>
<td>1.16 ± 0.64</td>
<td></td>
</tr>
<tr>
<td>Surface area (mm²)</td>
<td>18.75 ± 7.59</td>
<td>20.87 ± 9.66</td>
<td>23.07 ± 7.91</td>
</tr>
<tr>
<td></td>
<td>4.32 ± 3.57</td>
<td>6.02 ± 4.07</td>
<td></td>
</tr>
<tr>
<td>SMI</td>
<td>1.48 ± 0.72</td>
<td>1.21 ± 1.10</td>
<td>1.93 ± 1.77</td>
</tr>
<tr>
<td></td>
<td>0.45 ± 1.64</td>
<td>0.50 ± 1.67</td>
<td></td>
</tr>
</tbody>
</table>

CM, continuous rotation motion; RM, reciprocating motion.
Surface area was increased $4.32 \pm 3.57 \text{ mm}^2$ in CM group and $6.02 \pm 4.07 \text{ mm}^2$ in RM group. The increase in SMI in the CM group was $0.45 \pm 1.64$, whereas that of the RM group was $0.50 \pm 1.67$, indicating that the shapes of the canals in both groups became rounder after the instrumentation (Table 2). Changes in root canal volume, surface area, and SMI were not affected by the instrumentation technique used ($P > .05$).

### Degrees and Directions of Canal Transportation

At the level of 1, 2, 3, and 5 mm from the apical foramen, the mean degrees of canal transportation in the CM group were $0.06 \pm 0.06$, $0.08 \pm 0.05$, $0.11 \pm 0.11$, and $0.25 \pm 0.08$ mm, and the mean degrees of canal transportation in the RM group were $0.04 \pm 0.05$, $0.08 \pm 0.07$, $0.09 \pm 0.08$, and $0.24 \pm 0.11$ mm (Table 3). The Tukey post hoc test revealed that there were no differences in the amount of transportation between continuous rotation and reciprocating motion ($P > .05$).

The directions of transportation in each level of experimental groups are shown in Figure 4. Both CM and RM groups showed same tendencies of transportation toward the outer or lateral aspect of the curvature at 1- and 2-mm levels. The 3-mm level samples in RM group remained centered, whereas those in CM group showed transportation toward the inner aspect of the curvature. At the 5-mm level, the canal samples in both groups showed the same furcation-directed transportation tendency. The values between the 2 groups showed no significant differences ($P > .05$).

### Discussion

By repeating the clockwise and the counterclockwise rotation, reciprocating motion allows continuous release of the file when it is engaged in the inner surface of the root canal during the cutting and shaping procedure. This reciprocating motion imitates the balanced force technique but in the reverse direction (clockwise 140 degrees and counterclockwise 45 degrees). The balanced force technique is able to maintain the curvature without distorting the shape of the root canal (17). But it is unknown whether reciprocating motion with NiTi rotary files will demonstrate similar results as the balanced force technique with stainless steel hand files. With respect to this, it can be postulated that the continuous change in direction of the rotation under engine-driven reciprocating motion might cause uncontrolled movement, which could culminate in a greater amount of transportation.

We used high-resolution micro-CT in the evaluation of the basic geometric parameters and the degrees and directions of transportation. In this study, the changes of basic geometric parameters (canal curvature, volume, surface area, and SMI) under reciprocating motion preparation did not demonstrate any drastic differences when compared with continuous rotation or even with the result of previous studies (8, 18–20). When viewing the apical transportation at each level of cross-sectional images, both reciprocating motion and continuous rotation did not seem to show many differences. The transportation values created by reciprocating motion were in accordance with those of previous studies with conventional continuous rotation motion (9, 21), even though the measuring method was different. According to the study of Wu et al (5), apical transportation of more than $300 \mu\text{m}$ could negatively affect the sealing of the obturation, and none of the transportation values in this study exceeded this critical limit.

The differences in the direction of transportation between the 2 instrumentation techniques were insignificant. The values in the direction of transportation also seemed to correspond with the results of other studies (2, 22). It is conceived that the ProTaper file has a tendency to straighten curved canals and causes transportation toward the furcation at the middle coronal level, whereas transportation at the apical 1- to 3-mm levels occurs toward the outer aspect of the curvature. Overall, these results indicate that reciprocating motion did not cause excessive aberration even in the apical area of the curved canal.

Variables other than rotation motion (reciprocating versus continuous) are thought to have an effect on the results of this study. In this respect, the screw-in effect can be another reason for the transportation because it occurs frequently with active files that rotate under continuous rotation motion and results in overinstrumentation beyond the apical foramen during canal preparation (23). Many diverse attempts have been made to reduce this unpleasant screw-in effect by changing the instrument design, the helical angle, the radial land, the pitch length, and/or the taper of the file (21–23). Likewise, the application of a new instrumentation technique such as reciprocating motion is expected to produce a beneficial shaping result by reducing the screw-in effect. However, the ProTaper file itself has the effect of reducing the screw-in effect because of its variable taper design (21). As a result, the effect...

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**Table 3.** Mean Degrees of Transportation (mm) in Each Level of the Samples

<table>
<thead>
<tr>
<th>Group</th>
<th>n</th>
<th>1 mm</th>
<th>2 mm</th>
<th>3 mm</th>
<th>5 mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM</td>
<td>20</td>
<td>0.06 ± 0.06</td>
<td>0.08 ± 0.05</td>
<td>0.11 ± 0.11</td>
<td>0.25 ± 0.08</td>
</tr>
<tr>
<td>RM</td>
<td>20</td>
<td>0.04 ± 0.05</td>
<td>0.08 ± 0.07</td>
<td>0.09 ± 0.08</td>
<td>0.24 ± 0.11</td>
</tr>
</tbody>
</table>

CM, continuous rotation motion; RM, reciprocating motion.

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**Figure 4.** Transportation tendencies of groups in each section (negative value indicates the transportation tendency toward the inner aspect of the curvature).
of reciprocating motion on preventing this phenomenon seems to have diminished slightly in this study. When using a file that does not reduce the screw-in effect by itself, the reduction of the screw-in effect by the reciprocating motion would become more apparent.

Considering the current trends, where operators are choosing instrumentation technique by using only a small number of NiTi rotary files, perhaps with the help of reciprocating motion, more studies are required because fast approaches toward the apex with fewer instruments and sharp cutting edges are known to produce aberrations (24). Accomplishing the canal shaping procedure with reciprocating motion is very appealing (14), and it is reported that the ProTaper files can be adequately used in this manner because of their higher resistance to fracture and extended life span (11–13). If there is any instrument or instrumentation technique that shows a comparable efficiency with increased life span, then this file or method would be highly recommended in everyday clinical practice.

In conclusion, our study demonstrated that the application of reciprocating motion during instrumentation with ProTaper NiTi rotary files might not result in an increased apical transportation when compared with canal shaping with continuous rotation motion, even in the apical part of the curved canals. Therefore, reciprocating motion might be a good alternative method to prevent procedural errors during root canal shaping.

Acknowledgments

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

References