Cone-beam computed tomography evaluation of curved root canals prepared using reciprocal rotary files and rotational rotary files

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Abstract

Aim: The aim of this study is to compare curved root canal preparation between reciprocal rotary files and rotational rotary files in extracted teeth using cone-beam computed tomography (CBCT). The independent variable was the file type (reciprocal vs. rotary), and the primary outcome variable was the centering ratio of distance change after canal preparation. Secondary outcomes were canal transportation in extension and direction and the preparation time.

Materials and Methods: Forty mesial root canals from extracted permanent molars with curvatures ranging between 25° and 45° were randomly divided into 4 groups. Canals were prepared with two types of reciprocal rotary files (WaveOne and Reciproc) and two types of rotational rotary files (ProTaper and Mtwo), ten canals in each group. The root canals were scanned before and after preparation using CBCT. Group differences in outcome variables were tested using ANOVA and 5% type I error probability.

Results: At the middle third of canals, reciprocal rotary files yielded the least amount of deviation from the center in inner–outer furcal direction (P < 0.001). Transportation was shown from the original canal shape in all directions in four groups. The reciprocal rotary files took the least amount of preparation time as well (P < 0.001).

Conclusions: Reciprocal files result in less transportation and working time than the rotational files.

Keywords: Cone-beam computed tomography; curved root canal; reciprocal files; rotary files; rotational files

INTRODUCTION

Curved root canals challenge the root canal preparation leading to possible iatrogenic damage when conventional instruments are used.1,2 Several instruments are available to reduce the procedural errors such as ledge, zip, elbow, and perforation in prepared canals. Nickel–titanium (NiTi) rotary files have shape memory and superelasticity and are useful in preparing curved root canals while maintaining the canal curvature.3 Recently introduced NiTi rotary files WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) and Reciproc files (VDW, Munich, Germany) are claimed to be able to completely clean and prepare root canals with only one instrument with minimal damage. These files are used in a reciprocating motion and made of M-wire using thermal-treatment process, resulting in increased flexibility and improved resistance to cyclic fatigue.4-6

Radiography is essential to successful diagnosis treatment of root canals. Cone-beam computed tomography (CBCT) is an imaging modality that provides high-quality, accurate, and three-dimensional representations of the osseous...
elements of the maxillofacial skeleton. CBCT images with sufficient spatial resolution is useful in endodontic diagnosis, treatment guidance, and posttreatment evaluation.[7,8] Although reciprocal NiTi rotary files and CBCT have become valuable tools in reducing complications, very few studies have addressed the shaping ability of these reciprocal NiTi rotary files in comparison with rotational NiTi rotary files using CBCT. Our aim was to compare the centering ratio, extension and direction of canal transportation, and working time of preparation of curved root canals between reciprocal rotary files (WaveOne and Reciproc) and rotational rotary files made by the same manufacturers (ProTaper and Mtwo) in extracted teeth using CBCT.

**MATERIALS AND METHODS**

**Sample preparation**
A total of 40 extracted human molar teeth with at least one curved mesial root and intact root apex were selected. Standardized radiographs were taken for root canal curvature evaluation. Only roots with curvature ranging from 25° to 45° according to Schneider’s method[9] were included in the study. Straight-line access was prepared using diamond burs. Only teeth with a K-file size 15 to the root apex were included in the study. Radiographs were taken with K-file size 15 inserted into the canals for working length determination at the apical foramen minus 1 mm. Teeth were embedded in self-cure acrylic resin which had underside grooves to prevent movement of the tooth within the model base [Figure 1a]. The four metal balls sized 1 mm<sup>3</sup> were fixed on the model for usage and to facilitate image analysis and to maintain a constant position for cone-beam computed tomography evaluation (b). The model base was fixed with a tripod and marked for replication (c).

**Preoperative cone-beam computed tomography evaluation**
The CBCT images were taken for preoperative assessment using a WhiteFox cone-beam CT scanner (Acteon, France) operating at 105 kV and 6.0 mA, with an exposure time of 6 s. The scans were produced according to the manufacturer’s recommendation. A field of view of 60 mm × 60 mm and high quality were used. The CBCT images were scanned and recorded.

**Root canal preparation**
Teeth were divided into four groups of ten canals that were balanced in regard to canal curvature, radius of curvature, and length of the root canal. Canals were prepared by the same operator as described below.

**WaveOne**
A size 25 WaveOne file with apical taper of 0.08 was used with the help of a torque-limited electric motor (WaveOne Endo Motor, Dentsply Maillefer, Ballaigues, Switzerland) following the manufacturer’s instructions with reciprocating technique and slow in-and-out pecking motion.

**Reciproc**
A size 25 R25 Reciproc file with a taper of 0.08 over the first 3 mm was used with a torque-limited electric motor (VDW. Silver Reciproc Endo Motor, VDW, Munich, Germany) following the manufacturer’s instructions with reciprocating technique and slow in-and-out pecking motion.

**ProTaper**
A ProTaper file was used with a torque-limited electric motor (WaveOne Endo Motor, Dentsply Maillefer, Ballaigues, Switzerland) following the manufacturer’s instructions with modified crown-down technique and gentle in-and-out motion. The file sequence used was S1, S2, F1, and F2.

**Mtwo**
Mtwo files were used a torque-limited electric motor (VDW. Silver Reciproc Endo Motor, VDW, Munich, Germany) according to the manufacturer’s instructions. The instrument was used to the full length of the canals (a single-length technique) with a gentle in-and-out motion. The file sequence used was No. 15, No. 20, and No. 25.

The ProTaper and Mtwo instruments were used to enlarge only four canals while the WaveOne and Reciproc instruments were cleaned after three pecks and used to enlarge one canal only. After each instrument was
removed, the root canal was flushed with 2 ml of a 2.5% NaOCl solution, and the apical patency of the canal was obtained using a size 10 K-file. All root canal preparations were completed by one operator. The total working time of each group was recorded.

**Evaluation of extension of canal transportation**

The extension of canal transportation after root canal preparation was compared to the original canal and calculated. A result other than 0 indicates that transportation has occurred in the canal, and numbers indicate the extension of canal transportation. These measurements were also repeated 5 times by the same evaluator.

**Evaluation of direction of canal transportation**

The direction of canal transportation was evaluated by superimposing the images before and after root canal preparation. Direction of canal transportation was recorded.

**Data analysis**

Measurements on 20% of the total samples were repeated by the same evaluator to assess the intra-rater reliability ($r = 0.948$). For inter-rater reliability test, the measurements were repeated 2 times by another evaluator and compared with the former evaluator using Pearson’s correlation coefficient which also yielded a high correlation ($r = 0.766$). The data for the mean centering ratio and extension of canal transportation and mean working time were statistically compared using one-way ANOVA and multiple comparisons (post hoc) with Tukey’s Test. Type I error was set to ≤5%.

**RESULTS**

There was no significant difference between all groups in canal curvature, radius of curvature, and length of the root canal ($P > 0.05$).

**Shaping ability**

**Centering ratio**

At the coronal and apical third of canals, there were no significant group differences in centering ratio [Table 1].
rotational files and reciprocal files from the same two manufactures showed that the reciprocal rotary files had a superior centering ratio than the rotational rotary files \( (P < 0.001) \) at the middle third of root canals in inner–outer furcal direction.

As there are variations in tooth morphology, four groups were balanced with respect to the canal curvature, radius of curvature, and length of the root canal. Our results are not due to operator differences either as all preparations were completed by one operator who underwent training in NiTi rotary instrumentation techniques that lead to higher inter- and intra-rater reliability.

Although CBCT provides high-quality three-dimensional images in a nondestructive manner\(^\text{[13]}\), the sample positions for image capture are technique sensitive. We used a model which consisted of a tooth embedded in resin, which had underside grooves for preventing the movement of sample within the model and fixed with a tripod for replication. Moreover, the four metal balls sized 1 mm\(^3\) were fixed on the model for usage and in order to refer to the position of the image analysis. This setup of samples brought a consistent position for each CBCT scan to produce reliable results.

The reciprocal rotary files maintained original canal curvature better. This finding is in agreement with previous studies\(^\text{[13-15]}\). This superiority may be explained by the reciprocating movement of the file. A large rotating angle in the counterclockwise motion determines how the instrument advances in the canal and engages dentin to cut it, whereas a smaller angle in the clockwise motion allows the file to be

\( P > 0.05 \). However, at the middle third, reciprocal files had significantly smaller centering ratios than the rotational rotary files in inner–outer furcal direction \( (P < 0.001) \). Reciproc group had a significantly lower mean centering ratio than the ProTaper group in buccolingual direction \( (P = 0.038) \).

**Extension of canal transportation**

At the coronal and apical third of canals, there were no significant group differences in extension of canal transportation [Table 2, \( P > 0.05 \)]. At the middle third, however, Reciproc group had a significantly lower mean of extension of the canal transportation compared to ProTaper in both directions \( (P = 0.038) \).

**Direction of canal transportation**

At the coronal and apical third of the root canal preparation, all four groups showed transportation from the original canal shape in all directions. Only the middle third of the root canal preparation tended to transport to the outer furcal direction with WaveOne 70%, Reciproc 70%, ProTaper 90%, and Mtwo 80%.

**Working time**

Reciprocal rotary files took significantly less time than the rotational rotary files [Table 2, \( P < 0.001 \)].

**DISCUSSION**

Preparation of curved root canals is a major challenge that can lead to errors and interfere with satisfactory treatment outcomes. New NiTi rotary instruments are claimed to help in this regard. Our comparison between

| Instrument groups | Mean±SD |
|-------------------|---------|
|                  | Coronal | Middle | Apical |
|                  | Inner-outer furcal | Buccolingual | Inner-outer furcal | Buccolingual | Inner-outer furcal | Buccolingual |
| WaveOne           | 0.13±0.04 | 0.15±0.07 | 0.15±0.06 | 0.15±0.05 | 0.14±0.07 | 0.14±0.05 | 7.20±0.95 |
| Reciproc          | 0.14±0.06 | 0.11±0.05 | 0.14±0.07 | 0.12±0.05 | 0.16±0.07 | 0.14±0.07 | 7.09±0.45 |
| ProTaper          | 0.17±0.05 | 0.18±0.08 | 0.23±0.09 | 0.21±0.08 | 0.17±0.07 | 0.14±0.05 | 13.18±0.82 |
| Mtwo              | 0.17±0.04 | 0.15±0.08 | 0.19±0.08 | 0.18±0.09 | 0.16±0.06 | 0.18±0.08 | 12.78±1.18 |
| \( P \)           | 0.139 | 0.145 | 0.038 | 0.038 | 0.895 | 0.421 | < 0.001 |

Values with the same superscript letters were statistically different at \( P < 0.05 \). SD: Standard deviation

| Instrument groups | Mean±SD |
|-------------------|---------|
|                  | Coronal | Middle | Apical |
|                  | Inner-outer furcal | Buccolingual | Inner-outer furcal | Buccolingual | Inner-outer furcal | Buccolingual |
| WaveOne           | 0.13±0.04 | 0.15±0.07 | 0.15±0.06 | 0.15±0.05 | 0.14±0.07 | 0.14±0.05 | 7.20±0.95 |
| Reciproc          | 0.14±0.06 | 0.11±0.05 | 0.14±0.07 | 0.12±0.05 | 0.16±0.07 | 0.14±0.07 | 7.09±0.45 |
| ProTaper          | 0.17±0.05 | 0.18±0.08 | 0.23±0.09 | 0.21±0.08 | 0.17±0.07 | 0.14±0.05 | 13.18±0.82 |
| Mtwo              | 0.17±0.04 | 0.15±0.08 | 0.19±0.08 | 0.18±0.09 | 0.16±0.06 | 0.18±0.08 | 12.78±1.18 |
| \( P \)           | 0.139 | 0.145 | 0.038 | 0.038 | 0.895 | 0.421 | < 0.001 |

Values with the same superscript letters were statistically different at \( P < 0.05 \). SD: Standard deviation

**Table 1: Mean centering ratio and standard deviation after root canal preparation with four instrument groups (\( n=10 \) root canals per group)**

**Table 2: Mean extension of canal transportation and standard deviation after root canal preparation with four instrument groups and preparation time in minute (\( n=10 \) root canals per group)**

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immediately disengaged and safely progress along the canal path to maintain the canal curvature. The advantages of the reciprocating movement are based on the laws of physics applied to root canal preparation, which results in a balanced force technique.\[16\] Using this method, curved canals may be prepared to the full working length without producing apical transportation.\[17,18\] In addition, the reciprocating movement is designed to reduce the screwing effect that can aid the instrument safety progress along the canal path.\[19\] However, we only saw differences at the middle third of canals. This may be due to the fact that most curved root canals reached the peak in the middle part. Since morphology of natural mesial root canals is curved in the inner furcal direction, canals prepared with alloy instruments that have elastic force tend to transport to the outer furcal direction.\[20\] Our study also showed the transportation at the middle third of root canals in outer furcal direction.

Preparation time is dependent on the numbers of instruments used, the preparation technique, the operator’s experience, and the study design.\[21\] The preparation time in this study included the time for changing instruments, cleaning the flutes, and irrigation. The results showed that reciprocal rotary files were significantly faster than rotational rotary files ($P < 0.001$) and were in agreement with a previous study.\[22\] The ProTaper system as used in this study consisted of five instruments and the Mtwo system consisted of six instruments for one canal preparation, compared to WaveOne and Reciproc system which used only one instrument. However, the use of reciprocal rotary files decreased the preparation time by $<50\%$ compared with rotational rotary files. This might be because of the less time taken for cleaning the flutes and irrigation of the canal.

Among the limitations of our study are the small sample size and the limited range of canal curvatures we selected. We only included canals with severe curvature (between $25^\circ$ and $45^\circ$). Analysis of images before and after preparation of the root canal using CBCT is clinically applicable compared to micro-CT that is limited to extracted teeth. With the CBCT, the complexity of root canal can be seen and evaluated before the treatment to obtain more information in order to get better outcomes.

**CONCLUSIONS**

The reciprocal rotary files are better for curved root canals as they maintain the original canal curvature better compared to rotational rotary files, which tend to transport toward the outer furcal canal wall of the curved canal. These files also require less working time. Our findings will be useful to the clinicians. Future studies can evaluate the clinical outcomes of root canal treatments on curved roots prepared using different types of files, using both retrospective and prospective designs.

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**Conflicts of interest**

There are no conflicts of interest.

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