Cone-beam Computed Tomographic Analysis of Canal Transportation and Centering Ability of Single-file Systems

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Abstract

Introduction: The purpose of this study was to compare canal transportation and the centering ability of Reciproc (VDW, Munich, Germany), WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), and EdgeFile (EdgeEndo, Albuquerque, NM) rotary systems using cone-beam computed tomographic imaging. **Methods:** Ninety mesiobuccal mandibular first molar uncalcified canals with at least a 19-mm length, a canal curvature of 15°–30° (the Schneider method), and a mature apex were selected. Canals were randomly divided into 3 groups of 30 teeth, and canal preparation with the Reciproc, WaveOne, and EdgeFile systems was performed according to the manufacturers' instructions. Cone-beam computed tomographic images were taken before and after instrumentation in the same position. Apical transportation was calculated in the distances of 2, 3, and 4 mm from the apex. Kruskal-Wallis and Mann-Whitney *U* tests were used to statistically analyze the data. **Results:** The mean canal transportation was significantly lower with EdgeFile ($P < .001$) followed by the WaveOne rotary system. Moreover, the centering ability of the EdgeFile system was higher than that of the WaveOne and Reciproc systems. **Conclusions:** The EdgeFile rotary system showed the lowest transportation in both the mesiodistal and buccolingual directions and the highest centering ability. The Reciproc system showed the highest transportation and the lowest centering ability. *(J Endod 2018;■:1–4)*

Key Words

EdgeFile, Reciproc, single file, transportation, WaveOne

Significance

The present study aimed to compare canal transportation and the centering ability of 3 single-file reciprocating rotary systems (Reciproc, WaveOne, and EdgeFile) using CBCT imaging.

The primary goal in cleaning and shaping root canals is the removal of bacterial and dentinal debris while the initial path and shape of the root canal is preserved (1). However, this may be difficult, especially in curved canals, because all instrumentation techniques tend to alter the canal curvature and pathway (2). Changes in the initial pathway of root canals may lead to ledge formation, zipping, or strip perforation. Also, it leaves some parts of the root canal system untouched. Bacteria may remain in these areas and cause endodontic failures (2).

The introduction of rotary nickel-titanium (NiTi) instruments to modern endodontics allows faster canal preparation with fewer procedural errors (3). The shaping ability and transportation of different instruments are discussed in the literature.

Manufacturers attempt to produce different rotary instruments providing fewer procedural errors and easier application and reducing preparation time (4). Reciproc (VDW, Munich, Germany) is a single-file system made from M-Wire NiTi alloy with increased flexibility and cyclic fatigue resistance. This rotary system is based on reciprocating motion enabling the instrument to move through the root canal without a glide path (5). WaveOne (Dentsply Maillefer, Ballaigues, Switzerland) is another single-file system made by M-Wire NiTi alloy. This rotary system works based on balanced force reciprocation motion and provides resistance to cyclic fatigue, deeper flutes, and increased flexibility, which allows its application in curved canals (5). EdgeFile (EdgeEndo, Albuquerque, NM) is another available single-file rotary instrument that can be used by reciprocation motion (6).

Cone-beam computed tomographic (CBCT) imaging is the modality of choice in sectional imaging for endodontic diagnosis. It can be helpful for differential diagnosis of periapical lesions, demonstration of the complex anatomy of the root canal system, internal and external resorptions, vertical root fracture detection, and the identification of lateral and accessory canals (6). The present study aimed to compare canal transportation and the centering ability of 3 single-file reciprocating rotary systems (Reciproc, WaveOne, and EdgeFile) using CBCT imaging.

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Materials and Methods

Sample Selection

The protocol of the present study was approved by the vice-chancellor of Isfahan University of Medical Sciences, Isfahan, Iran.

Ninety mesiobuccal root canals from 90 extracted mandibular first molars were selected for this study. The selection criteria for this study were a complete apex, 15°–30° canal curvature (according to the Schneider method) (7), curvature radius <10°, a minimum length of 19 mm, uncalcified canals, and type IV Vertucci canals (2 separated canals) (8). The teeth were kept in normal saline until the examination.

Sample Preparation

The access cavity was prepared using a round carbide bur #4 (Dentsply Maillefer, Ballaigues, Switzerland). In order to determine the working length, a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was placed into the root canal. When the file reached the apical foramen, the working length was determined by subtracting 0.5 mm from this length. Reference points were marked on the tooth surfaces during working length determination. Then, the teeth were randomly mounted on a plastic mold with hinge jaws to the cementoenamel junction level. This phantom model was selected because of simulation of jaw positions for acquiring CBCT images. To allow easy placement of the teeth in the mold, the teeth were hemisected with the distal halves being removed and the mesial halves mounted parallel to each other and to the mold walls. The crown was not removed in order to allow identification of the buccal side for further procedures. Then, they were stabilized using putty silicone impression material (Speedex; Coltene/Whaledent, Altstatten, Switzerland). All teeth were then scanned with the Gallileos CBCT device (Sirona Dental System Inc, Bensheim, Germany) with 85 kV, 21 mA, and a 17-second exposure setting. Because most teeth are curved in their apical third (approximately 5 mm from apex), 2-, 3-, and 4-mm distances from the apex were examined in this study. A number from 1 to 90 was assigned to each tooth, and the teeth were allocated to 3 groups using random number production.

Root Canal Preparation

Root canal preparation in all groups was performed by 1 investigator (a senior postgraduate student of endodontics). The following rotary files were used in the study:

1. Reciproc with an 8% taper and a 0.25-mm tip size
2. WaveOne with an 8% taper and a 0.25-mm tip size
3. EdgeFile with a 6% taper and a 0.25-mm tip size

Each file in each system was used for 5 teeth and then discarded. In all groups, the instruments were placed in a 16:1 handpiece with a Silver Reciproc electric motor (VDW). For the Reciproc group, the Reciproc option was selected on the motor monitor, and for the WaveOne and EdgeFile systems, the WaveOne option was selected. Rotating files were inserted into the root canals in a slow inward-outward motion. After 3 inward-outward motions, the instrument was retrieved from the root canal, the canal was irrigated with 2 mL 2.5% normal saline, and file flutes were cleaned from debris. The instrument was again inserted into the root canal, and this was repeated until the file reached the working length.

Evaluation of Canal Transportation and Centering Ability

After preparation of the root canals, CBCT images were repeated for all teeth with the same exposure parameters as the preoperative scan. Mesiodistal and buccolingual diameters were recorded at 2, 3, and 4 mm from the apex in both the preoperative and postoperative CBCT images. Apical transportation was determined using the following formulas (Fig. 1):

$$(a_1 - a_2) - (b_1 - b_2)$$

In this formula, a_1 is the least distance between mesial borders of the root and the canal before instrumentation, a_2 is the least distance between mesial borders of the root and the canal after instrumentation, b_1 is the least distance between distal borders of the root and the canal before instrumentation, and b_2 is the least distance between distal borders of the root and the canal after instrumentation.

$$(c_1 - c_2) - (d_1 - d_2)$$

In this formula, c_1 is the least distance between the buccal borders of the root and the canal before instrumentation, c_2 is the least distance between the buccal borders of the root and the canal after instrumentation, d_1 is the least distance between the lingual borders of the root and the canal before instrumentation, and d_2 is the least distance between the lingual borders of the root and the canal after instrumentation.

According to these formulas, 0 means no canal transportation, whereas positive and negative values show mesial and buccal and distal or lingual transportation, respectively.

Centering ability was determined by a_1-a_2/b_1-b_2 or b_1-b_2/a_1-a_2 formulas. In these formulas, the fraction with the lesser value was selected for statistical analysis. According to these formulas, 1 represents complete centering, whereas other values show changes in the canal pathway (8).

Statistical Analysis

Statistical analysis was performed with the Mann-Whitney *U* test using SPSS software (IBM Inc, Armonk, NY).

Results

In this study, in all 3 distances (2, 3, and 4 mm from the apex), the Reciproc system had the highest transportation, whereas EdgeFile had the lowest (Table 1). The difference in transportation amounts in the 3 groups was statistically significant ($P < .001$), except for the 4-mm distance from the apex in which the buccolingual transportation was not statistically significant between the Reciproc and WaveOne groups ($P = .589$). EdgeFile showed the highest centering ability, whereas Reciproc had the lowest (Table 1). The difference in the centering ability in the 3 groups was statistically significant ($P < .001$).

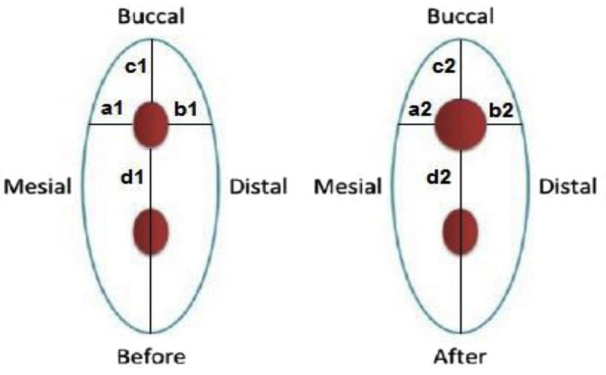

Figure 1. A schematic presentation of the parameters of canal transportation.

TABLE 1. The Mean Values of Mesiodistal and Buccolingual Transportation and the Centering Ratio in 3 Rotary Systems

Rotary systems	Distance from apex	Mesiodistal transportation (mm), mean (SD)	Buccolingual transportation (mm), mean (SD)	Centering ratio, mean (SD)
Reciproc	2 mm	0.09 (0.021)	0.08 (0.020)	0.52 (0.058)
	3 mm	0.08 (0.028)	0.06 (0.017)	0.54 (0.081)
	4 mm	0.06 (0.018)	0.05 (0.018)	0.59 (0.071)
WaveOne	2 mm	0.05 (0.016)	0.05 (0.022)	0.61 (0.052)
	3 mm	0.04 (0.018)	0.04 (0.018)	0.64 (0.078)
	4 mm	0.04 (0.014)	0.04 (0.021)	0.70 (0.071)
EdgeFile	2 mm	0.03 (0.012)	0.02 (0.013)	0.91 (0.051)
	3 mm	0.03 (0.012)	0.02 (0.010)	0.93 (0.056)
	4 mm	0.02 (0.010)	0.01 (0.010)	0.93 (0.062)

SD, standard deviation.

Discussion

The objective of mechanical preparation of root canals is the cleaning of all canal walls while maintaining the original anatomy. This leads to preparation of root canal–enabling irrigation, intracanal medicament, and 3-dimensional obturation (9). Curved canals provide a challenge for endodontic preparation (10) because it is proven that all instruments and preparation techniques tend to alter the pathway of the root canal. Canals are curved mostly in the apical third (11).

Transportation of root canals during root canal preparation occurs mainly because of the rigid nature of endodontic instruments. It may lead to nonuniform distribution of stress in contact points of the instrument and the root canal. Therefore, the instrument tends to regain its straight form in the canal, which causes higher forces in the external surface of the curve (ie, the concave surface) (12). Transportation is the iatrogenic change in the physiologic pathway of the root canal, mainly in the external surface of the curve. Different types of transport can occur from type I (mild form) to type III (severe form). Only type I transportation can be managed by nonsurgical endodontics (13). Transportation of the root canal may lead to several problems and errors. It can cause inadequate debridement of the apical region and excessive removal of dentin in the coronal region of the concave surface of the root curvature. Moreover, continuing the incorrect pathway may lead to zipping of the apical foramen or perforation (14).

Among the techniques available for the evaluation of canal preparation, the use of resin blocks and extracted natural teeth are more common. The advantages of simulated root canals in resin blocks include standardization of the root canal diameter, length, and curvature in terms of angle and radius, standardization of the research method and exclusion of parameters that could influence the preparation outcome, and high credibility as an ideal experimental model for the analysis of the endodontic preparation technique. However, 1 important problem with resin blocks is their different mechanical properties compared with dentin. For instance, the microhardness of the dentin around the pulp is twice that of resin blocks. This means that higher stress values are applied on instruments during root canal preparation in natural teeth compared with resin blocks. Moreover, the particle size of the resin blocks is higher than dentin. Therefore, they may block the root canals and interfere with insertion and action of the instruments. On the other hand, although extracted natural teeth almost precisely simulate the microenvironment of root canal preparation in the clinical condition, the major disadvantages of their application for studies is the standardization of teeth in apical patency, the compatibility of the apex to a specified instrument size, and the angle of curvature (15).

When using extracted natural teeth for the preparation of root canals, imaging techniques (CBCT imaging being the most available and accurate for endodontic purposes) may provide more reliable results in the evaluation of root canal transportation for application in the clinical arena (16).

Several studies aimed to compare apical transportation in rotary instruments with rotational and reciprocal motions. Most studies reported the superiority of reciprocal motion (17–20). However, You et al (21) found no difference between the 2 motions in apical transportation, and some other studies reported that rotational motion leads to less apical transportation (22, 23). Most studies suggest that reciprocal motion is more effective in the prevention of apical transportation. Single-file rotary systems are receiving attention because of the following factors: fewer procedural errors, less preparation time, and easier application (24, 25). Therefore, in the present study, 3 single-file rotary systems based on reciprocating motion were chosen. It is important to note that the instruments' cross section, flexibility, and alloy type are effective in the performance of endodontic instruments (26, 27).

In the present study, EdgeFile had the lowest transportation and the highest centering ability. According to the manufacturer, this may be caused by its special design with a 6% taper and a hyperbolic cross section. Also, it is made of annealed heat-treated Firewire NiTi with claimed increased flexibility. Further studies must be performed in order to prove the manufacturer's claims. The Reciproc and WaveOne systems are made of M-Wire, which is only in the austenitic phase (28). Studies have been performed on the flexibility of the M-Wire NiTi alloy (29, 30). Based on our knowledge, no previous study has compared the apical transportation of EdgeFile with Reciproc and WaveOne. However, the Reciproc and WaveOne systems have been compared in the literature. Ferreira et al (29) concluded that the WaveOne rotary system is more effective in preventing transportation of the root canal and maintaining its central position. This finding is consistent with the present study. Gergi et al (31) reported that the centering ability in the WaveOne system is higher than the Reciproc system, which is also similar to the findings of the present study. Another study by Capar et al (32) compared 6 different rotary systems in transportation, canal curvature, centering ratio, surface area, and volumetric changes of severely curved root canals using CBCT images. They stated that no significant difference exists in the performance of these rotary systems in endodontic preparation. Moreover, according to Wu et al (33), apical transportation more than 0.3 mm may affect the success of endodontic treatment by compromising the seal of the obturating material. In this study, none of the systems had caused this amount of transportation.

This study has the limitation of *in vitro* studies in which the simulation of clinical scenarios is difficult. Also, because of the lack of information regarding EdgeFile rotary instruments in the literature, a comparison of the results obtained in this study with other studies was not possible. It is recommended that more studies would be performed evaluating different aspects of performance of this endodontic rotary system.

Conclusion

The EdgeFile rotary system possessed the lowest transportation in both the mesiodistal and buccolingual directions and the highest centering ability, whereas the Reciproc system showed the highest transportation and the lowest centering ability.

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

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