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Influence of motion pattern on apical transportation and centering ability of WaveOne single-file technique in curved root canals

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ABSTRACT

Background: The aim of this study was to evaluate apical transportation and centering ability of single-file instruments, WaveOne primary, with full rotation versus reciprocation movement using cone-beam computed tomography (CBCT) analysis in curved mesiobuccal (MB) root canal of human mandibular molars.

Materials and Methods: Thirty MB canals of mandibular molars were randomly divided into two groups according to the instrument motion (n = 15): Group 1, reciprocation/WaveOne primary; Group 2, continuous rotation/WaveOne primary. After preparation, the amount of apical transportation and centering ability were assessed by evaluating pre- and post-instrumentation CBCT scans in three section (1, 3, and 5 mm from apical foramen). Statistical analysis of the data was performed using Mann-Whitney U-test and Friedman test (α = 0.05).

Results: There was no statistically significant difference between two experimental groups in terms of apical transportation and centering ratio at 1, 3, and 5 mm from apical foramen ($P > 0.05$).

Conclusion: Apical transportation and centering ability of WaveOne primary reciprocating instrument did not significantly differ between two motion patterns.

Key Words: Apical, cone-beam computed tomography, full, reciprocating, rotation, single, transportation

INTRODUCTION

The goal of root canal treatment is to remove infected and necrotic pulpal remnants and eliminate microorganisms. Preserving the radicular anatomy while cleaning and shaping of the root canal is an important phase of a successful endodontic treatment.[1] Although several preparation techniques have been developed to overcome procedural errors such as apical transportation, there are still some difficulties with endodontic treatment of curved root canals. Since the introduction of nickel-titanium (NiTi) rotary instruments in the 1990s, studies have shown that these instruments maintain original canal shape and therefore allow for a safer, more rapid, more centered and easier preparation of severely curved root canals.[2-5]

WaveOne (Dentsply Maillefer, Ballaigues, Switzerland), a recent NiTi system with a left-handed angulation of the blades to be used in reciprocation motion, is made of a special alloy called M-wire,

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which is produced by application of an innovative thermal-treatment process to NiTi wire blanks, which may improve their fatigue lifespan, flexibility, and torsional resistance.[6-10] Reciprocal motion consists of a larger counterclockwise rotating angle, which allows the instrument to cut the dentin and a smaller clockwise angle to disengage; due to the greater counterclockwise angle, the instrument continuously progresses toward the apex of the root canal.[11-13]

Better results have been suggested for a single NiTi instrument with reciprocating motion than conventional continuous rotation method in the preparation of curved root canals. The reciprocal motion is claimed to relieve stress on the instrument, minimize the risk of fracture, and improve cyclic fatigue resistance and lifespan of NiTi instruments.[11,13] On the other hand, full-clockwise rotation instruments, OneShape (MicroMega, Besancon, France) and F360 (Komet Brasseler, Lemgo, Germany), are recently introduced to single-file instrumentation concept; these instruments are safe and able to respect the original canal curvature well compared with Reciproc (VDW, Munich, Germany) and Mtwo (VDW, Munich, Germany).[14]

Cone-beam computed tomography (CBCT), a nondestructive high-resolution scanning system, has been used for evaluation of the exact location and anatomy of the root canal system, quality of root canal preparation, and to take measurements of root canal system before and after instrumentation.[15]

Considering the improved flexibility and fatigue lifespan of M-wire alloy, we assumed that WaveOne instruments might be used in continuous rotation for root canal preparation. Until now no study has been reported on full rotation of WaveOne. Therefore, the purpose of this study was to compare apical transportation and centering ability of WaveOne instrument between reciprocation and full rotation in curved mesiobuccal (MB) root canals of human mandibular molars by means of CBCT.

MATERIALS AND METHODS

Thirty human mandibular molars with completely formed apices that were extracted due to severe periodontal problems were used for this study. The external surface of the roots was planned with periodontal curettes (Medesy, Maniago, Italy); teeth were immersed in 5.25% sodium hypochlorite (NaOCl, Cerkamed, Poland) for 30 min and kept moist throughout the study. The teeth were inspected for absence of resorption, root fractures, root caries and then, they were accessed to determine the degree of the curvature of the MB canals according to Schneider's technique.[16] The teeth should have separate, 20-45° curved MB canals for inclusion in the study. All root canals had a diameter compatible with size #15. On the basis of the degree and radius of curvature and working length, the teeth were randomly allocated to experimental groups (pair matched) of 15 each:

1. WaveOne/reciprocation and
2. WaveOne/full rotation.

Working length was measured by subtracting 1 mm of the recorded length when tip of a #15 K-file (Dentsply Maillefer, Ballaigues, Switzerland) was flush with the apical foramen. Pre- and post-instrumentation three-dimensional CBCT scans (NewTom VGI, QR srl, Verona, Italy) were instructed to compare apical transportation at 1, 3 and 5 mm from the apical foramen. For accurate reading of the scans, the coronal portions of the teeth were secured to silicone-based impression material, leaving the roots oriented upward. The pre- and post-instrumentation scans were identical in position of the specimens and set up of CBCT machine (voxel size = 0.1 mm, field of view = 6 cm × 6 cm, denture scan mode). The crowns of the teeth were maintained to resemble the clinical circumstances. MB root canals in Group 1 were prepared by using WaveOne primary instruments (25/08) operated in a X-smart plus Endo Motor (Dentsply Maillefer, Ballaigues, Switzerland) with manufacturer's recommended setting "WaveOne All" mode. In Group 2, WaveOne primary instruments were operated with Endo IT motor (Aseptico Inc., Woodinville, WA, USA) at 3 Ncm torque and 350 rpm; the motor was set on reverse action to generate effective continuous rotation because of the left-handed cutting blade design of the instrument. All of the root canals were prepared by the same operator, using a slow in-and-out pecking motion; the flutes of the instrument were cleaned after three pecks. 5 ml of 5.25% NaOCl solution was used as an endodontic irrigant for each canal. Each WaveOne primary instrument was used to prepare four root canals.

One independent endodontist assessed pre- and post-instrumentation CBCT scans simultaneously on a 22-inch flat-screen panel (Samsung Inc., Suwon-Si, South Korea) using the manufacturer's software (NNT Viewer, QR srl, Verona, Italy). The shortest distance from the edge of uninstrumented/instrumented root canal to the mesial and distal periphery of the root

was measured on axial view. The following formula was used to evaluate apical transportation at 1, 3, and 5 mm from apical foramen: |(a1 – a2) – (b1 – b2)|, where a1 is the shortest distance from the mesial edge of the root to the mesial edge of the un-instrumented canal, b1 is the shortest distance from distal edge of the root to the distal edge of the un-instrumented canal, a2 is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, and b2 is the shortest distance from distal edge of the root to the distal edge of the instrumented canal [Figure 1]. According to this formula, a result other than 0 indicates that the transportation has occurred in the canal.[17] Mean centering ratio indicates the ability of the instrument to stay centered in the root canal. The ratio was calculated for each section by using the following ratio: (a1 – a2)/(b1 – b2) or (b1 – b2)/(a1 – a2). If these numbers are not equal, the lower figure is considered as the numerator of the ratio. By using this formula, the result of 1:1 for the centering ratio indicates perfect centering. Lower scores indicate better instrument centering in the canal.

The Mann-Whitney U-test was conducted to explore a difference in canal transportation and centering ratio between the two groups. In order to analyze the difference of transportation between 1, 3 and 5 mm intervals, the Friedman test was used. Significance level was set at 0.05 ($\alpha = 0.05$).

RESULTS

Root canal transportation

Table 1 shows the apical transportation mean values of WaveOne/reciprocation and WaveOne/full rotation groups. There was no significant difference in apical transportation between the two groups ($P > 0.05$). Apical transportation showed no significant difference between distinct intervals ($P > 0.05$).

Centering ratio

Table 2 shows centering ratio values for WaveOne/reciprocation and WaveOne/full rotation groups. There was no significant difference in centering ratio between the two groups ($P > 0.05$). Centering ratio showed no significant difference between distinct intervals ($P > 0.05$). No instrument separation occurred during preparation of the root canals.

DISCUSSION

Transportation can be defined as excessive dentin removal in a single direction within the canal rather than in all directions equidistantly from the main tooth axis. It can lead to inappropriate dentin removal, with a high risk of straightening the original canal curvature and forming ledges in the dentin wall.[18,19] Apical transportation results in inadequate cleaning of the root canal, poor sealing efficiency with a high rate of debris extrusion and postoperative discomfort, which may adversely affect the prognosis of the treatment.[20,21]

The recently introduced WaveOne system provides faster root canal preparation using only one single shaping instrument. The significant characteristics of the system are single use, a reciprocating action, and M-wire technology alloy manufacturing.

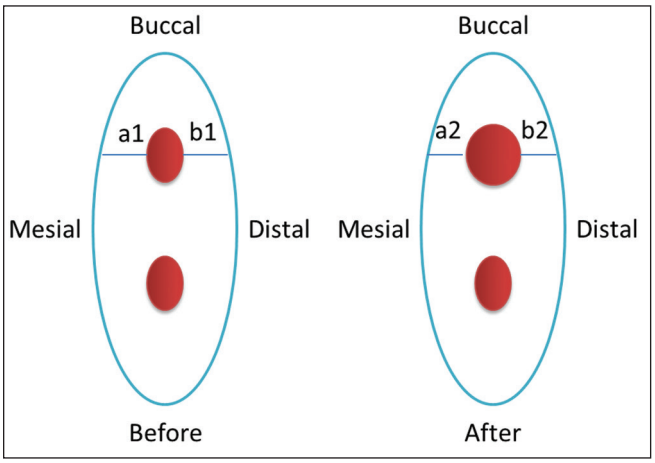

Figure 1: Schematic view of measurements for evaluation of apical transportation and centering ability.

Table 1: Apical transportation mean values and SD and median of two experimental groups at different intervals

Group	Transport Mean ± SD (median)		
	T1 mm	T3 mm	T5 mm
WaveOne/reciprocation	0.05±0.04 (0)	0.13±0.08 (0.1)	0.12±0.11 (0.1)
WaveOne/full rotation	0.12±0.11 (0)	0.14±0.09 (0.1)	0.12±0.12 (0.1)
P	0.16	0.3	0.93

SD: Standard deviation.

Table 2: Centering ability mean values and SD and median of two experimental groups at different intervals

Group	Centering ratio Mean ± SD (median)		
	R1 mm	R3 mm	R5 mm
WaveOne/ reciprocation	0.66±0.43 (0.65)	0.34±0.33 (0.3)	0.53±0.40 (0.5)
WaveOne/full rotation	0.45±0.43 (0.4)	0.35±0.32 (0.3)	0.62±0.33 (0.6)
P	0.21	0.96	0.56

SD: Standard deviation.

Regarding screwing-in and instrument fracture, the reciprocating movement may produce a positive effect due to the utilization of the smaller angle in the opposite direction.[22] The concept underlines immediate disengagement of the instrument and safe progress along the canal path. Several studies have reported that reciprocating motion decreased the impact of cyclic fatigue, minimized torsional and flexural stresses, and increased the canal centering ability compared with continuous rotating motion.[23,24] This is the first study evaluating apical transportation after instrumentation by a single-file system, that is, WaveOne primary under both reciprocation and continuous rotation; such an approach eliminates the possible interventions of alloy type, file design and size of preparation and permits to analyze the pure effect of motion patterns on apical transportation in single-file technique. The WaveOne was chosen because of mechanical improvements of M-wire alloy[25] to afford enough cyclic fatigue and torsional resistance to full rotation during the instrumentation of curved root canals. Increased torsional resistance (up to 400%) has been reported for M-wire instruments.[7,25] In addition, CBCT was used as a noninvasive method to measure apical transportation and centering ability. CBCT scanning provides a three-dimensional morphologic view (axial, sagittal, and coronal sections), which is considered superior to conventional radiographs and digital radiographic techniques. Reciprocation has been showed to increase fatigue life regardless of the instrument brand and NiTi alloy type.[24] However, the findings of the present study revealed no significant difference in apical transportation and centering ability of WaveOne between reciprocation and continuous rotation. This result shows that the motion pattern may not affect apical transportation and centering ability of single-file systems when the other influencing factors are identical. You *et al*.[26] reported similar transportation for reciprocation motion and conventional continuous rotation technique using ProTaper rotary instruments. Bürklein *et al*.[14] compared shaping ability of different single-file systems in severely curved root canals and showed no difference between Reciproc, F360, and OneShape systems regarding canal straightening. They reported that all single-file systems maintained root canal curvature well and were safe. Although two aforementioned studies used different techniques and/or systems, the core belief is similar and their findings basically correspond to this study. On the contrary, Berutti *et al*.[27] reported that WaveOne primary reciprocating single-file better maintained the original canal anatomy, with less modification of the canal curvature compared with the ProTaper system up to F2. The most likely rationale behind this heterogeneity is probably the fact that Berutti *et al*. conducted their study on the training resin blocks instead of natural teeth; furthermore, they compared WaveOne single-file system with ProTaper full-sequence rotary approach.

In this study, neither reciprocation nor full rotation caused separation of WaveOne primary instruments during preparation of four curved root canals, which can be due to M-wire's mechanical improvements of the alloy.

CONCLUSION

Within the limits of this study, full rotation single-file technique resulted in similar amounts of apical transportation and centering ratio compared to reciprocation using WaveOne primary instruments. It seems that the pattern of motion is of little importance concerning apical transportation and centering ability in this single-file technique.

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Conflicts of interest
The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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