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ORIGINAL RESEARCH

The Influence of Different Angles and Reciprocation on the Shaping Ability of Two Nickel-Titanium Rotary Root Canal Instruments

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ABSTRACT

Purpose: The purpose of the present study was to investigate and compare the effect of different reciprocating movements and angles on the shaping ability of the WaveOne and the single-file ProTaper F2 using cone beam computed tomography (CBCT).

Materials and methods: The mesiobuccal canals of 40 extracted maxillary molars, with curvatures of 20 to 45° were coded and randomly divided into 4 equal experimental groups according to the instrument used (ProTaper F2 file and WaveOne) and the reciprocation range, for both instruments, a 150° angle was used for cutting and a 30° angle was used for release. Group 1 — WaveOne primary 150° CCW rotation angle and 30° CW rotation angle; Group 2 — WaveOne 90° CCW rotation angle and 30° CW rotation angle; Group 3 — ProTaper F2 150° CW rotation angle and 30° CCW rotation angle; Group 4 — ProTaper F2 90° CW rotation angle and 30° CCW rotation angle. Canals were scanned before and after preparation using CBCT to evaluate the volumetric change, canal transportation and the canal centering ability at 2.6, 5.2 and 7.8 mm from the apex. The mean ± standard deviation (SD) values were analyzed, and the significance level was set at $p \leq 0.05$.

Results: There was no significant difference in the amount of dentin removed among the experimental groups, except that WaveOne 150°CCW 30°CW significantly showed the least volume of dentin removed (0.40 ± 0.9) at 7.8 mm. All rotary systems tested in the different groups resulted in canal transportation in different directions at all examined levels. WaveOne 150°CCW 30°CW, demonstrated the lowest mean value of root canal transportation in both the mesial and furcal directions and in both the coronal and apical directions compared to the other groups. At the 7.8 level, WaveOne 150°CCW 30°CW yielded the highest mean centering ratio, whereas ProTaper F2 CW 150° CCW 30° yielded the lowest, statistically significant at $p \leq 0.05$.

Conclusion: The results of the present study demonstrated that differences among various reciprocating motions and angles could affect the shaping ability of a single-file Nickel-titanium (NiTi) instrument.

Keywords: NiTi, Reciprocation, WaveOne, ProTaper F2, CBCT.

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INTRODUCTION

Cleaning and shaping of the root canal is considered critical to successful root canal therapy.[1] However, instrumentation remains one of the most difficult tasks in endodontic therapy.[2] Several techniques and instruments have been used to improve root canal preparation. Nickel-Titanium (NiTi) has become a standard and has improved cleaning and shaping of the root canal system, although it has encountered some limitations due to the complex anatomy of the root canal system.[3,4] Major changes have been made to improve the safety of NiTi instruments.[5] Recently, a new perspective for use of a NiTi rotary file has yielded a technique that enables different movements, leading to an evolving approach that entails using a single file to complete the root canal instrumentation with the help of reciprocating movement. The new motion based on the balanced force technique was proposed by Yared in 2008,[6] for which the single-file ProTaper F2 (Dentsply Maillefer, Ballaigues, Switzerland) NiTi rotary file was used in clockwise (CW) and counterclockwise (CCW) directions. This development was followed by the introduction of two reciprocating instruments, ReciProc (‘RECIPROC, VDW, Munich, Germany) and WaveOne (Dentsply Maillefer, Ballaigues, Switzerland). Compared to continuous rotation, the use of a reciprocating motion has been shown to extend the durability of NiTi rotary instruments and increase their resistance to fatigue.[6-8] The manufacturers of these NiTi reciprocating instruments have not clearly disclosed the optimal movement or angle of use; only the influence of different reciprocation movements and angles on the cyclic fatigue of the NiTi instruments has been tested.[9] Thus, there is no evidence that delineates the optimal reciprocating motion or angle for canal preparation. The purpose of the present study was to evaluate and compare the effect of different reciprocating movements and angles on the volume of dentin removal, canal transportation and the canal centering ability in extracted human mandibular molars using CBCT.

MATERIALS AND METHODS

The mesiobuccal canals of 40 extracted maxillary molars, with curvatures of 20 to 45° according to Schneider's method (10) and comparable root length. Teeth with two separate mesial canals, and apical foramina were selected. The cavities were accessed with #4 round burs, and the working lengths were determined as follows. A #10 K file was inserted into the root canal until the tip of the file was flush with the apical foramen, from that point, 1 mm was subtracted, and that length was defined as the working length of the root canal. After the working length was determined, a glide path was produced using a #15 K file. Specimens were coded and randomly divided into 4 equal experimental groups using 2 different NiTi systems with different reciprocating motions. Using the single-file technique with the ProTaper F2 file, as proposed by Yared,[6] utilizes CW rotation for dentinal wall cutting followed by CCW rotation for release. For each reciprocating group (n = 10), specific angles and a rotation angle were selected. However, for both groups, a 150° angle was used for cutting and a 30° angle was used for release, Group 1: WaveOne primary 150° CCW rotation angle and 30° CW rotation angle; Group 2: WaveOne 90° CCW rotation angle and 30° CW rotation angle; Group 3: ProTaper F2 150° CW rotation angle and 30° CCW rotation angle; Group 4: ProTaper F2 90° CW rotation angle and 30° CCW rotation angle. All canals were prepared by one experienced operator where instrumentation was performed with a pecking motion until the full working length was established. All files were operated by a 1:16 gear reduction handpiece powered by an electric torque control motor (Satelec Endo Dual, Acteon, France), which allows the user to modify and set the reciprocating angles in both CW and CCW directions. The speed was set at 300 rpm for all groups. Canal irrigation was performed with 5.25% NaOCl after the use of each file using a 27-G needle (Stropko NiTi Needle, SybronEndo), using a new file for each tooth.

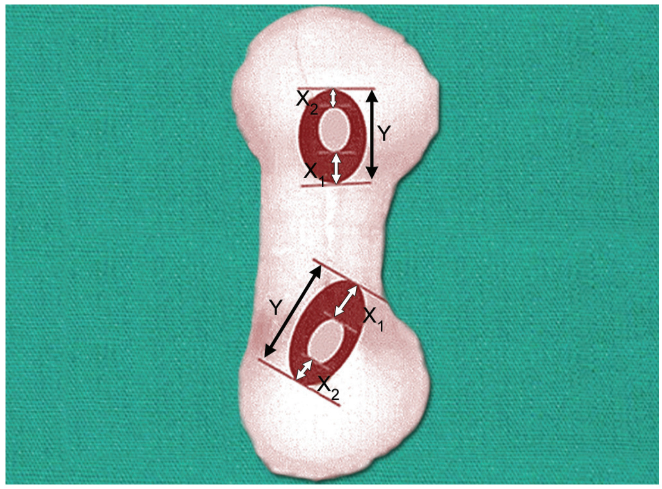

Fig. 1: Basic geometrical parameters

Image Analysis

The roots were positioned in a custom-made specimen holder in which they were aligned perpendicularly to the beam and scanned before and after instrumentation using the ILUMA Ultra Cone Beam CT Scanner (3M IMTEC Corporation, OK, US). The exposure parameters were 120 kV and 12 mA, with 640 × 640 pixel slices and a pixel size of 0.20 mm. The acquired data were viewed, and measurements were performed by ILUMA Vision software (3M IMTEC Corporation, OK, US) where the images were calibrated in mm. The mesiobuccal canal was traced, and the total volume was measured. Four cross-section planes were evaluated at different levels from the apex of 2.6, 5.2, and 7.8 mm. The shortest distance from the canal wall to the external root surface was measured in the mesial and distal directions for the mesiobuccal root canal. The distance was measured on the reconstructed two-dimensional image without reduction using the measuring tool (Fig. 1). Measurements were recorded before and after instrumentation to calculate the following: (1) the volume of removed dentin determined in mm^3 for each root canal by subtracting the uninstrumented canal volume from the instrumented canal volume, (2) the degree of canal transportation at each level according to the following formula:[11] $(x_1 - x_2) - (y_1 - y_2)$ and (3) the canal centering ratio at each level according to the following ratio:[11] $(x_1 - x_2)/(y_1 - y_2)$ or $(y_1 - y_2)/(x_1 - x_2)$, where x_1 is the shortest distance from the mesial edge of the root to the mesial edge of the uninstrumented canal, x_2 is the shortest distance from the mesial edge of the root to the mesial edge of the instrumented canal, y_1 is the shortest distance from the distal edge of the root to the distal edge of the uninstrumented canal, and y_2 is the shortest distance from the distal edge of the root to the distal edge of the instrumented canal.

RESULTS

The homogeneity of the groups, regarding preinstrumentation and canal curvature, was assessed by using the student test. The data were presented as the mean and standard deviation values. One-way analysis of variance (ANOVA) was used for comparison of the centering ratio and canal transportation in the studied groups. Analysis of variance was used to compare between-subject effects (group *vs* level), and the Duncan post-hoc test was used for pairwise comparisons between groups when the ANOVA test was significant.

Volume of Removed Dentin

WaveOne 150° CCW CW 30° significantly showed the least volume of dentin removed (0.40 ± 0.9) compared to the other groups ($p \leq 0.05$). However, WaveOne 90° CCW 30° CW, ProTaper F2150° CW 30° CCW and ProTaper F2 90° CW 30° CCW demonstrated greater changes in mean volume, although the differences were not significant (Table 1).

Transportation

All rotary systems tested in the different groups resulted in canal transportation in different directions at all examined levels (Table 2). One-way ANOVA showed no significant difference between the four groups when the mean root canal transportation was measured ($p = 0.3$). However, the interaction between the different levels and directions among the groups was statistically significant ($p \leq 0.05$). One-way ANOVA was used to compare the mean root canal transportation between the two directions (mesial and furcal) at each level (coronal, middle and apical). Group 1, WaveOne 150° CCW 30° CW, demonstrated the lowest mean value of root canal transportation in both the mesial and furcal directions and in both the coronal and apical directions, compared to the other groups ($p \leq 0.05$) (Table 2).

Centering Ratio

For the centering ratio, the lower the value of the ratio, the better the instrument centered. One-way ANOVA was used to compare the mean values of the centering ratios and suggested interaction between the different groups and levels ($p = 0.03$). WaveOne 150° CCW 30° CW recorded the highest centering ratio, statistically significant at $p \leq 0.05$ (Table 2).

ProTaper F2 150° CW 30° CCW yielded the lowest mean centering canal ratio in the coronal area (0.69 ± 0.4), statistically significant at $p \leq 0.05$. However, the difference in the middle and apical levels was not statistically significant compared to the other groups ($p > 0.5$).

Table 1: The mean and standard deviation values for the volume of removed dentin (mm^3)

Groups (150° or 30° angles for cutting, 30° release angles)	*N*	*Mean ± SD*
1. WaveOne CCW 150° CW 30°	10	0.40 ± 0.30° *
2. WaveOne CCW 90° CW 30°	10	0.71 ± 0.90
3. ProTaper F2 CW 150° CCW 30°	10	0.60 ± 0.14
4. ProTaper F2 CW 90° CCW 30°	10	0.69 ± 0.90
Total	40	

*Significant at p≤0.05

DISCUSSION

The recent use of reciprocation has provided a major advantage in extending instruments' cyclic fatigue life when compared with continuous rotation devices.[6,7,9,10,12-14] The term 'reciprocating motion' describes several possible movements and angles, each may influence the performance of NiTi instruments and their resistance to failure. There is not enough evidence to indicate the reciprocating motions and angles that result in a better canal preparation. The actual movements and angles for the newest commercially available reciprocating instrument are not clearly disclosed by the manufacturers. Therefore, two different movements and angles were used to test the WaveOne and ProTaper F2. To standardize the two groups, a 150° angle was used for cutting, and a 30° angle was used for release. Moreover, all files were operated using an electric torque control motor (Satelec Endo Dual, Acteon, France), which allows the user to modify and set the reciprocating angles in both CW and CCW directions. However, this compromized the WaveOne manufacturer's protocol for testing.

In the present study, WaveOne 150° CW 30° CCW yielded the lowest mean volume changes and the worst ability to stay centered coronally. This result could be explained by the ability of WaveOne instruments to complete 1 cutting cycle in 3 CCW-CW strokes. This outcome might result in reduced cutting efficiency of the instrument, as the same instrument with 90° CCW 30° CW showed the highest mean volume change compared to the other groups.

Table 2: Statistical analysis of mean root canal transportation (mm) and the centering ratio for the test groups

Groups	*Level*	*Centering*	*Mesial*	*Furcal*
1.	Coronal	1.87 ± 0.7*	0.50 ± 0.2	0.54 ± 0.3
	Middle	1.05 ± 0.7	0.42 ± 0.3	0.46 ± 0.4
	Apical	0.87 ± 0.48	0.29 ± 0.3*	0.30° ± 0.3*
2.	Coronal	0.91 ± 0.4	0.89 ± 0.2	1.06 ± 0.3
	Middle	1.16 ± 0.5	0.69 ± 0.2	0.67 ± 0.2
	Apical	1.17 ± 0.4	0.57 ± 0.2	0.57 ± 0.2
3.	Coronal	0.69 ± 0.4*	0.65 ± 0.1	0.18 ± 0.2
	Middle	0.90 ± 0.2	0.85 ± 0.2	0.70 ± 0.2
	Apical	0.86 ± 0.2	0.50 ± 0.3	0.63 ± 0.2
4.	Coronal	1.19 ± 0.3	0.79 ± 0.1	0.75 ± 0.6
	Middle	1.23 ± 0.5	0.74 ± 0.2	0.59 ± 0.2
	Apical	0.90 ± 0.5	0.55 ± 0.3	0.68 ± 0.2

*Significant at p≤0.05

All of the experimental groups resulted in canal transportation at all examined levels but did not reach the critical level of transportation. This is in consistent with other previous studies.[15,16] However, WaveOne 150° CCW 30° CW showed the poorest centering compared to the other groups. This finding could be attributed to the reciprocating movement and angle but not to the design, as the same file with a different angle and movement, 90° CCW 30° CW, showed better centering. However, a different instrument with the same movement, ProTaper F2 150° CW 30° CCW, also performed better coronally. Therefore, the combination of such a design with reciprocating movements and angles could have led to this effect. This result could be explained by the fact that instruments with increased taper and stiffness would result in reduced cutting efficiency when used with less continuous rotation movement and more reciprocating movement, which may affect centering within the canal. This is in agreement with the findings of Weine et al[17] and Al Omari.[18] Furthermore, this may also have occurred at the coronal level, as the cervical level of the tooth requires instruments with greater cutting efficiency. Therefore, increasing the CCW angle can decrease the cutting efficiency of the instrument.

The results showed that increasing the reciprocating angle of the WaveOne file affected the cutting efficiency and centering ability of the instrument; this result is in agreement with the study by Saber Sel and El Sadat,[19] who reported that decreasing the reciprocation range of WaveOne instruments resulted in more centered preparations. Therefore, altering the reciprocation range affected the cutting efficiency of the instrument. It has been reported that the only reason for applying the reciprocating file in a counterclockwise cutting direction is for safety purposes, to prevent the file from being misused during a continuous clockwise cutting rotation. Several studies have shown that reciprocation increases an instrument's number of cycles to failure.[6,7,9,12] However, the reciprocating angle should only be increased to serve this purpose, without compromising instrument performance. A study by Gambarini et al[14] revealed that an increase in the number of cycles to failure of the tested files was achieved when the CW angle was as small as 30°. In the present study, WaveOne 90° CCW 30° CW demons-trated a better cutting efficiency and centering ratio than did WaveOne 150° CCW 30° CW.

In light of the above, the CCW angle should not be inc-reased to a point at which instrument performance would be affected, because the shaping ability was affected by significant differences in reciprocating motions and angles of rotation. This outcome is in accordance with a study by Gambarini et al[14] and the result reported by De-Deus et al,[12] in which a reciprocating single-file preparation with the WaveOne was found to be safe when primarily using a reciprocating movement. This result was also in agreement with the 2012 study by Berutti et al,[20] who reported that the single-file technique using either the WaveOne Primary or the ProTaper F2 single-file technique maintained the original canal anatomy. Therefore, the ProTaper F2 single-file preparation with different reciprocating motions and angles has shown a similar shaping ability to that of the WaveOne. This result is in accordance with the study by Kim et al[21] who reported a lack of significant difference in the transportation value when comparing the WaveOne to the ProTaper F2 single-file technique. Therefore, all of the groups tested with different reciprocating movements and angles were similar in their shaping ability. However, increasing the CCW angle would challenge the shaping ability of the instrument. This property could be supported by the fact that the Technika (ATR, Pistoia, Italy) motor used originally by Yared in 2008[6] has specific reciprocating movements, with a CW angle that is approximately twice as large as the CCW angle. In addition, the study by Saber Sel and El Sadat[21] also reported that decreasing the reciprocation range of WaveOne instruments resulted in less canal transportation and more centered preparations, but with longer preparation times.

In conclusion, within the limitations of the study, the results demonstrated that differences among various reciprocating motions and angles could affect the shaping ability of a single-file NiTi instrument, significantly decreasing the reciprocation angle and improving the shaping ability of both instruments tested. Further studies are needed to determine the optimal reciprocating motion and angle for concurrent safety and shaping ability.

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