Influence of Continuous or Reciprocating Motion on Cyclic Fatigue Resistance of 4 Different Nickel-Titanium Rotary Instruments

Eugenio Pedullà, PhD, DDS, Nicola M. Grande, PhD, DDS,† Gianluca Plotino, PhD, DDS,† Gianluca Gambarini, PhD, DDS, MD,† and Ernesto Rapisarda, MD, DDS**

Abstract

Introduction: The aim of this study was to evaluate the resistance to flexural fatigue of Reciproc R25 (VDW, Munich, Germany), WaveOne Primary (VDW, Munich, Germany), Mtwo (Sweden & Martina, Padova, Italy), and Twisted File (TF; SybronEndo, Orange, CA) instruments used in continuous rotation or in 2 different reciprocating motions. **Methods:** A total of 180 nickel-titanium files from 4 brands marketed, 2 for use in reciprocating motion (ie, Reciproc R25 and WaveOne Primary) and 2 for use in continuous rotation (ie, Mtwo and TF both taper .06/0.25 tip diameter), were tested. Forty-five instruments for each brand were divided into 3 groups ($n = 15$) on the basis of the motion tested: continuous rotation (group 1: 300 rpm) and reciprocal motion (group 2: "RECIPROC ALL" mode and group 3: "WAVEONE ALL" mode). The resistance to cyclic fatigue was determined by counting the number of cycles to failure in a 60° curve with a 5-mm radius. Data were analyzed through 2-way analyses of variance. **Results:** The cyclic fatigue resistance of the 2 reciprocating motion instruments (ie, "RECIPROC ALL" and "WAVEONE ALL") was significantly higher than the continuous rotation in each brand ($P < .001$). No significant difference was observed in cyclic fatigue between the 2 different reciprocal motions tested in each brand ($P > .05$). When considering the appropriate clinical motion for each brand, no significant difference in cyclic fatigue was found between TF, Mtwo, and Reciproc R25 instruments, whereas the cyclic fatigue resistance of WaveOne files was less than the other 3 brands ($P < .05$). **Conclusions:** Reciprocal motion showed a significantly higher cyclic fatigue resistance in all brands compared with continuous rotation. No differences were found between the 2 reciprocating motions. *(J Endod 2013;39:258–261)*

Key Words

Continuous rotation, cyclic fatigue, M-wire, nickel-titanium, reciprocating motion

The introduction of rotary nickel-titanium (NiTi) endodontic instruments (also called files) into clinical practice has improved the efficacy of endodontic treatments in terms of procedural time, accuracy, and risk reduction (1–3). Fracturing of Rotary NiTi instruments may take place because of torsion and/or flexion. Torsional fatigue occurs when the tip of the instrument binds in the root canal while the file continues to turn (4). Flexural fatigue develops when the instrument rotates inside a curved root canal and is subjected to an excessive number of tension-compression strain cycles in the region of maximum root canal curvature (5). To improve the fracture resistance of rotary NiTi files, manufacturers have introduced instruments made with new alloys and the use of reciprocating motion. The M-wire and R-phase NiTi files have shown a higher cyclic fatigue resistance than traditional files (6, 7).

Reciprocating motion can be described as an oscillating motion when an instrument rotates in 1 direction and then reverses direction before completing a full rotary cycle (8). The use of reciprocating motion was shown to extend the lifespan of a NiTi instrument and, therefore, the resistance to fatigue in comparison with continuous rotation (9, 10).

Many NiTi instruments including Mtwo (Sweden & Martina, Padova, Italy), Twisted File (TF; SybronEndo, Orange, CA), and ProTaper (Dentsply Maillefer, Ballaigues, Switzerland) were designed to be used with continuous rotation movement. Recently, 2 different reciprocating systems were introduced: Reciproc (VDW, Munich, Germany) and WaveOne (Dentsply Maillefer). The manufacturers recommended the use of these files by means of a specific motor and an unchangeable and appropriated setting (Reciproc files with the "RECIPROC ALL" mode and WaveOne files with the "WAVEONE ALL" mode). These 2 types of preset reciprocating motion have different angles of rotation and speed (the manufacturers claim 150° counterclockwise and then 30° clockwise rotation with a speed of 300 rpm for the "RECIPROC ALL" mode and 170° counterclockwise and then 50° clockwise rotation with a speed of 350 rpm for the "WAVEONE ALL" mode) (11). It is probable that the rotation type and rate can affect the fatigue resistance (11).

There is only limited information about the influence of continuous or different reciprocation motion on the cyclic fatigue of files made for continuous or reciprocating motion. The aim of the present study was to evaluate the resistance to flexural fatigue of Reciproc R25, WaveOne Primary, Mtwo, and TF NiTi files used in continuous rotation and in 2 different reciprocating motions. The null hypothesis tested was that no differences are present in the cyclic fatigue resistance of different NiTi instruments between the 3 types of motion tested.

From the *Department of Surgery, University of Catania, Catania, Italy; and †Department of Endodontics, Sapienza University of Rome, Rome, Italy.

Address requests for reprints to Dr Eugenio Pedullà, Via Cervignano, 29, 95129, Catania, Sicily, Italy. E-mail address: eugeniopedulla@gmail.com

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Materials and Methods

A total of 180 files for use in reciprocating motion (ie, Reciproc and WaveOne) and continuous rotation (ie, Mtwo and TF) were tested. Between the reciprocating instruments, Reciproc R25 and WaveOne Primary files, both of which had an ISO size 25 at the tip and a taper of .08 in the apical 3 mm with a following decreasing and variable taper up to the end of their working part, were selected. Between the continuous rotation instruments, Mtwo #25/0.06 taper and TF #25/0.06 taper were selected. Forty-five, 25-mm-long instruments for each brand were divided into 3 groups (n = 15) on the basis of the motion tested: continuous rotation (group 1: 300 rpm), reciprocal motion with the "RECIPROC ALL" mode (group 2), and reciprocal motion with the "WAVEONE ALL" mode (group 3). Every instrument was inspected for defects or deformities before the experiment under a stereomicroscope (SZR-10; Optika, Bergamo, Italy). A static model for cyclic fatigue testing was conducted in a custom-made device that allowed for a reproducible simulation of an instrument confined in a curved canal, which is similar to that described by Plotino et al (12) and has already been used in many published studies (13–15). The artificial canal was manufactured by reproducing the instrument's size and taper, thus providing the instrument with a suitable trajectory that conforms to the parameters of the chosen curvature.

Computer-aided milling ensured that the following specifications in the artificial canal were used: a radius of curvature of 5 mm (measured at the internal concave surface of the artificial canal), an angle of curvature of 60° measured according to the method of Schneider (16), a center of curvature 5 mm from the tip of the instrument, and a curved segment of the canal approximately 5 mm in length. The canals were covered with glass to prevent the instruments from slipping out (17). The files were activated by using a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) powered by a torque-controlled motor (Silver Reciproc; VDW, Munich, Germany).

To reduce friction between the instrument and the metal canal walls, a special high-flow synthetic oil designed for the lubrication of mechanical parts (Super Oil; Singer Co Ltd, Elizabethport, NJ) was applied. All instruments were rotated until a fracture occurred. The time was recorded and stopped as soon as a fracture was detected visually and/or audibly. To avoid human error, video recording was performed simultaneously, and the recordings were then observed to cross-check the time of file separation.

The number of cycles to failure (NCF) for each instrument was calculated by multiplying the time (in seconds) to failure by the number of rotations or cycles per second regardless of the rotational direction. (The manufacturers claim that the "RECIPROC ALL" mode has a speed of 300 rpm and the "WAVEONE ALL" mode has a speed of 350 rpm). The length of the fractured file tip was measured by using a digital microcaliper (Mitutoyo Italiana srl, Lainate, Italy).

NCF data were analyzed by using 2-way analysis of variance and the Bonferroni post hoc test at 0.05 (Prism 5.0; GraphPad Software, Inc, La Jolla, CA). The NCF was variable dependent, whereas the brand of files and the type of rotation/reciprocation were independent measurements.

Results

The NCF and the length of the fractured fragment for each brand in continuous or reciprocating motion are presented in Table 1. The inferential analysis revealed statistically significant differences among the 3 groups of the same brand when considering the type of rotation/reciprocation as the independent variable (2-way analysis of variance, $P < .001$; interaction = 0.41). Moreover, there were statistically significant differences between the same groups when considering the brand as the independent variable (2-way analysis of variance, $P < .001$).

Post ad hoc analyses showed a significantly higher cyclic fatigue resistance between the 2 types of reciprocating motion (ie, "RECIPROC ALL" [group 2] and "WAVEONE ALL" [group 3]) when compared with continuous rotation in every brand ($P < .001$). No significant difference was found in cyclic fatigue between the 2 different reciprocal motions tested (group 2 vs group 3) in every brand ($P > .05$).

Among the brands used, TF instruments had the best overall results, especially in reciprocating motion, followed by the Mtwo, Reciproc R25, and WaveOne Primary files. Significant differences were found by comparing the same type of rotation/reciprocation (the same group) when using Reciproc R25 and WaveOne Primary files (Reciproc showed a higher cyclic fatigue resistance than WaveOne). A comparison between the same group of TF and Mtwo instruments did not reach a level of significance.

When considering the appropriate clinical motion for each brand (continuous for TF and Mtwo files, "RECIPROC ALL" for Reciproc, and "WAVEONE ALL" for WaveOne), no significant difference was found in cyclic fatigue between the TF, Mtwo, and Reciproc R25 instruments, whereas the cyclic fatigue resistance of WaveOne files was found to be less than the other 3 brands ($P < .05$). The mean length of the fractured fragments of the 4 brands used did not show any statistical difference ($P > .05$).

Discussion

This study compares the resistance to flexural fatigue of Reciproc R25, WaveOne Primary, Mtwo, and TF NiTi instruments used in continuous rotation and in 2 different reciprocating motions. In this research, the null hypothesis was rejected because the results showed that the kinematics of movements of NiTi rotary instruments influences significantly the cyclic fatigue of the 4 different NiTi files tested. The 2 reciprocating instruments (Reciproc and WaveOne) used in the present study were selected because to date they are the only ones commercially available that are designed specifically to be used in reciprocating motion. Among the instruments specifically designed for continuous rotation, Mtwo was selected because it has a cross-section similar to Reciproc. The TF was chosen because it showed the best results in previous cyclic fatigue resistance studies (12, 18, 19). Moreover, we tested M-wire (ie, Reciproc and WaveOne), traditional NiTi (ie, Mtwo), and R-phase (ie, TF) instruments in order to check if continuous rotation and reciprocating motion influence different endodontic files manufactured with different alloys in the same way.

According to Yao et al (20), the use of standardized artificial canals in cyclic fatigue experiments minimizes the influence of other variables. In this study, the artificial canal used was manufactured reproducing the instrument's size and taper to standardize the conditions.

Several nontooth devices (21) were used to investigate *in vitro* cyclic fatigue resistance in both static and dynamic models. Although a dynamic model could closely approximate a clinical brushing or pecking motion (22), it has limitations because the instruments being tested are not constrained in a precise trajectory. Moreover, the amplitude and speed of the axial movements could be standardized in a dynamic model study, but these variables are completely subjective, and it is doubtful that they are constant and reproducible in clinical practice because this kind of up and down motion is manually controlled (8).

Thus, we chose a static model in order to rule out confounding causes by other mechanisms of instrument separation apart from cyclic fatigue. The results show that both reciprocal motions (ie, "RECIPROC ALL" and "WAVEONE ALL") significantly increased the cyclic fatigue

TABLE 1. Descriptive Statistics of Cyclic Fatigue Resistance: Numbers of Cycles to Failure (NCF) for Instruments

Brand	Group	*n*	Mean (NCF)	Median	Standard deviation	Fragment length mean (mm)	Standard deviation	Min	Max
Reciproc	1	15	459.00[a1]	450	61.27	5.08	0.15	420	560
	2	15	617.70[b2]	605	55.67	5.13	0.09	560	780
	3	15	611.80[b3]	613	61.07	5.28	0.07	525	695
WaveOne	1	15	293.00[a4]	280	67.69	5.14	0.19	227	478
	2	15	509.70[b5]	495	87.84	5.19	0.22	280	665
	3	15	490.70[b6]	489	75.75	5.05	0.18	385	612
Mtwo	1	15	602.00[a7]	575	54.21	5.15	0.26	550	720
	2	15	819.30[b8]	840	92.13	5.32	0.16	585	870
	3	15	806.20[b9]	848	53.15	5.43	0.30	620	855
TF	1	15	677.30[a7]	680	54.11	5.21	0.14	570	750
	2	15	870.00[b8]	895	95.23	5.37	0.27	620	985
	3	15	851.30[b9]	851	60.31	5.28	0.31	645	910

Group 1, continuous rotation; group 2, reciprocating motion with "RECIPROC ALL" mode; and group 3, reciprocating motion with "WAVEONE ALL" mode.

The same letters show differences not statistically significant ($P > .05$) in comparison with different groups of the same brand; the same number show differences not statistically significant ($P > .05$) in comparison with the same group of different brands.

resistance of all brands tested compared with continuous rotation independently from different cross-sections or alloys. In agreement with these results, other recent articles reported a higher cyclic fatigue resistance of reciprocating motion than continuous rotation in instruments specifically designed to be used in reciprocal motion as well as in those manufactured for continuous rotation use (23, 24). It has been postulated that the increased fatigue resistance occurs because of the release of reaction stresses built up in the material by reversing the rotational direction (9, 10, 23).

In a recent study, Plotino et al (12) found a higher cyclic fatigue resistance of Reciproc R25 compared with WaveOne Primary files in an *in vitro* static model study similar to this report. The authors concluded that the differences found could be related to the different cross-sectional design and/or the different reciprocating movement (ie, "RECIPROC ALL" and "WAVEONE ALL") of the instruments (12).

In this study, the NCF obtained with the 2 types of reciprocating motion tested was not significantly different among any of the brands. Therefore, a possible explanation of the different results among the instruments tested in this study can be related to the different cross-sectional designs. Reciproc instruments have an S-shaped cross-section with 2 cutting blades that is similar to the cross-section of the Mtwo NiTi rotary instruments (12). The TF instrument has an equilateral triangular cross-section, whereas WaveOne files have a modified convex triangular cross-section at the tip and a convex triangular cross-section in the middle and coronal portion of the instrument (25, 26).

Under these experimental conditions, no significant differences in cyclic fatigue resistance were noted between the continuous instruments (ie, Mtwo and TF) when comparing the same group (ie, the same type of reciprocation/rotation tested). However, Reciproc R25 files showed a higher cyclic fatigue resistance than WaveOne Primary files when the same groups were compared. Although a comparison among the different brands is difficult to make because of their differences in design and cross-sectional areas, the results presented here can be useful for clinical practice.

When used with their appropriate clinical rotation, the cyclic fatigue resistance of Reciproc R25 was not significantly different from that of the TF and Mtwo ($P > .05$). Only WaveOne Primary files showed a lower fatigue resistance than the other 3 brands ($P < .05$). The lower NCF shown by WaveOne Primary compared with Reciproc R25 files was probably caused by the different synergistic effects of the different cross-section and reciprocating motion.

In conclusion, under these experimental conditions, the reciprocal motions tested (ie, "RECIPROC ALL" and "WAVEONE ALL") significantly increased the cyclic fatigue resistance of all brands tested compared with continuous rotation independently from their cross-section or alloy. No differences were found between the 2 reciprocating motions tested. However, when the appropriate clinical rotation was used, cyclic fatigue resistance was not significantly different among instruments with the exception of WaveOne Primary files, which showed the lowest NCF value.

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

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