Cyclic Fatigue Resistance of Reciproc, WaveOne, and WaveOne Gold Nickel-Titanium Instruments

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Abstract

Introduction: The purpose of this study was to compare the cyclic fatigue resistance of Reciproc R25 (VDW, Munich, Germany), WaveOne Primary (Dentsply Maillefer, Ballaigues, Switzerland), and WaveOne Gold Primary files (Dentsply Maillefer). **Methods:** Twenty Reciproc R25, 20 WaveOne Primary, and 20 WaveOne Gold Primary instruments were included in this study. The cyclic fatigue tests were performed using a cyclic fatigue testing device, which has an artificial stainless steel canal with a 60° angle of curvature and a 5-mm radius of curvature. The files were randomly divided into 3 groups (group 1: Reciproc R25; group 2: WaveOne Primary; and group 3: WaveOne Gold Primary). All the instruments were rotated until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer. The number of cycles to failure (NCF) was calculated. The data were analyzed statistically ($P < .05$). **Results:** There was a significant difference among the groups ($P < .05$). The WaveOne Gold Primary showed the greatest mean of NCF (1628 ± 107), and the WaveOne Primary showed the lowest mean of NCF (1153 ± 119.2). **Conclusions:** Within the limitations of this *in vitro* study, the cyclic fatigue resistance of the WaveOne Gold Primary single-file system was higher than the WaveOne Primary and Reciproc R25 single-file instruments. *(J Endod 2016;42:1536–1539)*

Key Words

Cyclic fatigue resistance, endodontics, Reciproc, static model, WaveOne Gold

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0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2016.06.019

Significance

To avoid or decrease the incidence of instrument fracture, different instruments have been developed by manufacturers. General dentists and endodontists should know the cyclic fatigue performance of these new instruments such as WaveOne Gold.

One of the most important disadvantages of nickel-titanium (NiTi) files is file failure during root canal preparation. Although many factors play a role in NiTi file failures, 2 of the most important reasons are cyclic and torsional fatigue (1). The operation speed, principle of NiTi file motion, metal surface finishing, and metallurgic characteristics are some of the factors that can cause cyclic fatigue of files (2). Many studies have shown that reciprocating motion increased the resistance to cyclic fatigue in proportion to that of rotation motion (3–5).

Reciproc R25 (VDW, Munich, Germany) and WaveOne Primary (Dentsply Maillefer, Ballaigues, Switzerland) are well-known single-file NiTi systems with reciprocating motion (6). Reciproc and WaveOne have the same tip diameter and taper angle (size 25 tip and size 0.08 taper). The tapers are fixed 3 mm from the apex of the files and decrease in the middle and coronal sections (7). The Reciproc file is S-shaped with 2 cutting edges, and the WaveOne file features a modified convex triangular cross section in the apex with a convex triangular cross section in the middle and coronal sections (8, 9). Both the Reciproc and WaveOne files are made of M-Wire alloy (10).

Recently, WaveOne Gold (Dentsply Maillefer) has been introduced. WaveOne Gold retains the reciprocating motion of the WaveOne file but has modified dimensions and geometry. The file is now a parallelogram with 2 cutting edges. The new WaveOne Gold files also feature the off-center design of ProTaper Next (Dentsply Maillefer) files. The files are manufactured with a gold heat treatment procedure. Gold heat treatment is executed manually by heating the file and then cooling slowly, in contrast to the premanufacturing heat treatment of M-Wire technology. According to the manufacturer, this new heat treatment improves the elasticity of the file (11).

According to a review of the literature, there have been no studies regarding the cyclic fatigue resistance of WaveOne Gold files. The aim of this study was to compare the cyclic fatigue resistance of Reciproc R25, WaveOne Primary, and WaveOne Gold Primary files, all of which operate with reciprocating motion. The null hypothesis of this study was that there would be no difference between the cyclic fatigue resistance of the Reciproc R25, WaveOne Primary, and WaveOne Gold Primary.

Materials and Methods

Twenty Reciproc R25 (25.08), 20 WaveOne Primary (25.08), and 20 WaveOne Gold Primary (25.07) instruments were included in this study. All the instruments were inspected under a stereomicroscope (Olympus BX43; Olympus Co, Tokyo, Japan) at 20× magnification to detect defects or irregularities. Because there were no defective instruments, none of the instruments were discarded.

An artificial canal, made of stainless steel with an inner diameter of 1.5 mm, a 60° angle of curvature, and a curvature radius of 5 mm, was used for static cyclic fatigue testing. The curvature of the artificial canal was located at the 5-mm coronal end of the canal. To reduce the friction of the files as they contacted the artificial walls of the canal, a synthetic oil (WD-40 Company, Milton Keynes, UK) was used for lubrication.

The files were divided into 3 experimental groups (n = 20 in each) and underwent the following procedures.

Group 1: Reciproc R25

The files were used with a VDW Silver Motor (VDW) connected to a cyclic fatigue testing instrument and operated at 300 rpm with the "Reciproc ALL" program until they broke.

Group 2: WaveOne Primary

The files were used with the VDW Silver Motor connected to the cyclic fatigue testing instrument and operated at 350 rpm with the "WaveOne ALL" program until they broke.

Group 3: WaveOne Gold Primary

The files were used with the VDW Silver Motor connected to the cyclic fatigue testing instrument and operated at 350 rpm with the "WaveOne ALL" program until they broke.

All the instruments were rotated until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer. The number of cycles to failure (NCF) of each file was then calculated using the following formula: NCF = revolution per minute (rpm) $\times$ time (seconds)/60. The lengths of the fractured segments were measured by a digital caliper.

Six pieces of fractured files, 2 pieces from each group, were examined with scanning electron microscopy (JEOL; JSM-7001F, Tokyo, Japan) to determine the fracture types of the files, and photomicrographs of the fractured surfaces were taken under different magnifications.

Statistical Analysis

The data were first analyzed using the Shapiro-Wilk test to verify the assumption of normality. The Kruskal-Wallis test and SPSS 21.0 software (IBM-SPSS Inc, Chicago, IL) were used to statistically analyze the data. The statistical significance level was set at $P < .05$.

Results

The means and standard deviation of the NCF data and lengths of the fractured segments are shown in Table 1. The WaveOne Gold (1628 $\pm$ 107) instrument had the highest fatigue resistance, and the WaveOne (1153 $\pm$ 119.2) instrument had the least fatigue resistance ($P < .05$). The mean NCF of the Reciproc (1323.7 $\pm$ 111.3) instrument was statistically higher than that of the WaveOne (1153 $\pm$ 119.2) instrument ($P < .05$).

The mean length of the fractured segments was recorded to evaluate the correct positioning of the tested instrument inside the canal curvature. There was no statistically significant difference ($P > .05$) in the mean length of the fractured fragments of the instruments (Table 1). The scanning electron microscopic images of the fracture surface revealed the nature of the mechanical characteristic of the cyclic fatigue failure in all the groups (Fig. 1*A–F*).

Discussion

Advances in metallurgy of NiTi files, finishing processes applied to files, and changes in file designs aim to decrease failures observed in NiTi files (2, 12–14). It is important for clinicians to be aware of the advantages and disadvantages of novel developments in file technologies (15). With this aim in mind, this study compared the cyclic fatigue resistance of novel WaveOne Gold files with those of WaveOne and Reciproc files. According to the results of the present study, the cyclic fatigue resistance of the WaveOne Gold system was higher than that of the WaveOne and Reciproc systems (Table 1). Thus, the null hypothesis of the present study was rejected.

According to the results of the present study, the Reciproc R25 file was more resistant than the WaveOne Primary file was to cyclic fatigue. In parallel with the findings of the present study, many previous studies reported that the resistance of Reciproc files to cyclic fatigue was greater than that of WaveOne files (7, 16–19). A study of the cyclic fatigue resistance of WaveOne files versus Reciproc files reported that the Reciproc file was more resistant (7). The researchers attributed their findings to the different cross sections of the files. The Reciproc file is S-shaped with 2 cutting edges, and the WaveOne has an apically modified convex triangular-shaped form with a convex triangular shape in the middle and coronal sections. There is no consensus on the effects of the different cross sections of files on cyclic fatigue resistance. Although some researchers reported that the cross section had no effect on cyclic fatigue resistance (20, 21), others found that it did have an impact (22–25). A comparison of the cyclic fatigue resistance of Mtwo (VDW) NiTi files with that of ProTaper Universal (Dentsply Maillefer) files found that the Mtwo files, which have a smaller core mass than the NiTi files, were more resistant to cyclic fatigue (23). Kim et al (17) reported that the cross-sectional area of the WaveOne file at the D5 level was larger (approximately 323,000 μm^2) than that of the cross-sectional area of the Reciproc (approximately 275,000 μm^2). In accordance with the results of that study and the findings of the present one, we believe that the superior cyclic fatigue resistance of the Reciproc file compared with the WaveOne system might be because of the Reciproc file's low core mass.

Thermomechanical treatment of NiTi alloys strongly influences their transformation behavior. In near-equiatomic NiTi alloys, martensitic transformation can occur as a single-stage transformation (austenite [A]-martensite [M]) or a 2-stage transformation (A-R-M), depending on the thermomechanical treatment (R stands for R-phase) (26). Usually, 1-stage A-to-M transformation occurs in nickel-rich NiTi alloys, and 2-stage A-R-M transformation occurs after additional heat treatment, which creates finely dispersed Ti_3Ni_4 precipitates in the austenitic matrix (26, 27). The change from 1-stage transformation to 2-stage transformation can be understood by considering that R-phase is another potential martensite phase and the relative preference of the R-phase over martensite in the presence of fine particles. Although Ti_3Ni_4 particles strongly resist the formation of martensite transformation, which is associated with large

TABLE 1. The Number of Cycles to Failure (NCF) and Length of Fractured Fragments (mm) of 3 Groups during Static Testing

Group	NCF			Length of fractured fragment		
	Mean	SD	*P* value	Mean	SD	*P* value
WaveOne Gold Primary	1628[a]	107		6.25[a]	0.27	
WaveOne Primary	1153[b]	119.2	<.05	6.03[a]	0.24	>.05
Reciproc R25	1323.7[c]	111.3		6.12[a]	0.16	

SD, standard deviation.

Different superscript letters indicate statistical significance ($P < .05$).

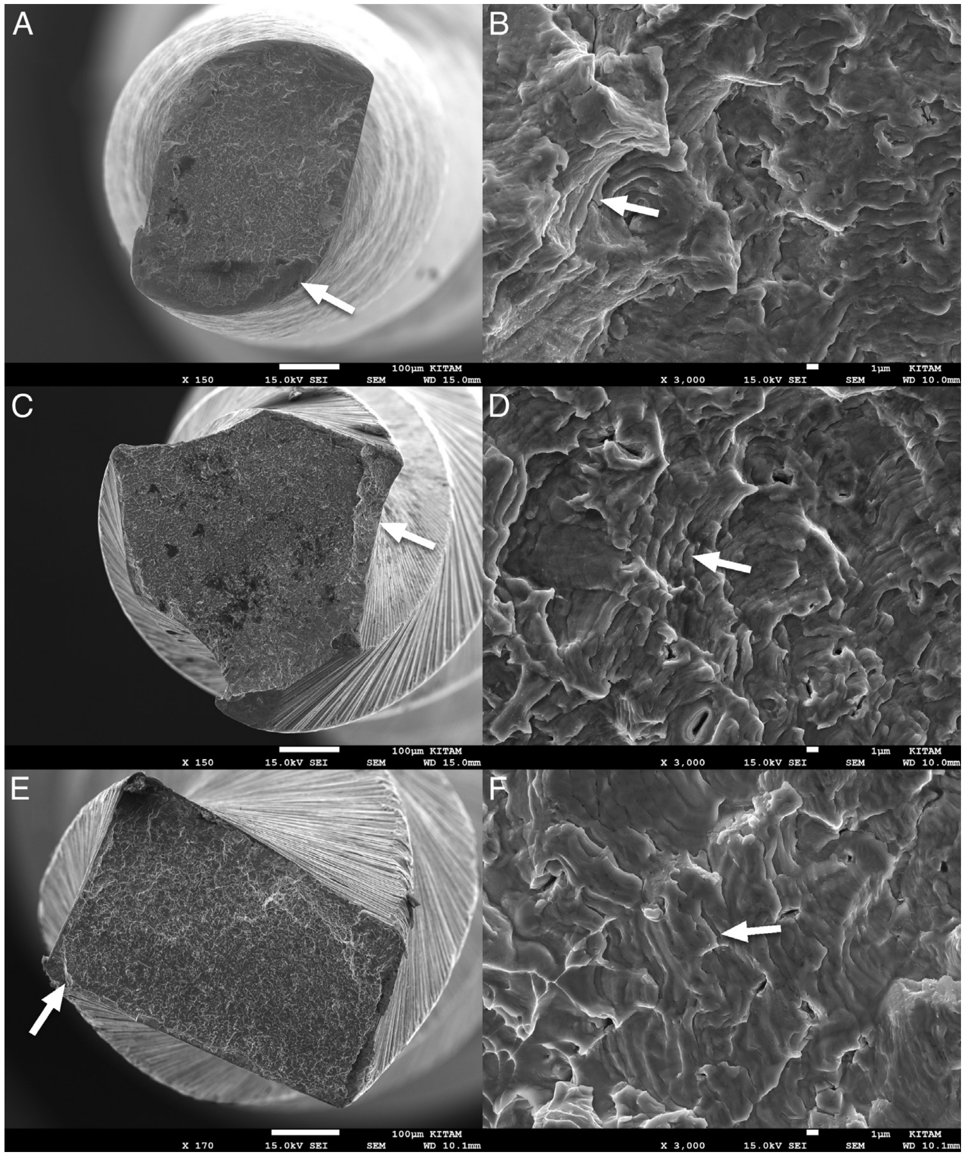

Figure 1. Scanning electron microscopic appearances of the Reciproc, WaveOne, and WaveOne Gold files after cyclic fatigue testing. General view of (*A*) Reciproc, (*C*) WaveOne, and (*E*) WaveOne Gold and high-magnification view of (*B*) Reciproc, (*D*) WaveOne, and (*F*) WaveOne Gold instruments showing fatigue striations typical of cyclic fatigue (*arrows*).

lattice deformation, they are much less resistant to the formation of R-phase, which is associated with significantly smaller lattice deformation. The presence of Ti_3Ni_4 particles favors the formation of R-phase, but the alloy requires further cooling for martensite transformation to occur. Therefore, martensitic transformation occurs in 2 steps: A-R-M (26). Superelasticity or pseudoelasticity is associated with the occurrence of phase transformation of the NiTi alloy upon application of stress above a critical level, which takes place when the ambient temperature is above the so-called A_f temperature of the material. Therefore, the working temperature for conventional superelastic NiTi files must be above the A_f to allow for pseudoelasticity. In a study of ProTaper Gold (Dentsply Maillefer) and ProTaper Universal files, Hieawy et al (28) reported that ProTaper Gold had a high A_f value, in common with all controlled memory files, and that it exhibited 2-stage transformation behavior. In the present study, the higher cyclic fatigue resistance of the WaveOne Gold file compared with that of the Reciproc and WaveOne files made of M-Wire compounds might be caused by WaveOne Gold file's high A_f value and 2-stage transformation behavior.

In the current study, there was no significant difference in the mean lengths of the fractured fragments of any of the files tested. The fractured length of each file was at the center of the curvature or just above this point, which confirms the positioning of the instruments in a precise trajectory.

Conclusion

Within the limitations of this *in vitro* study, the cyclic fatigue resistance of the WaveOne Gold Primary single-file system was better than that of the WaveOne Primary and Reciproc R25 single-file instruments.

Acknowledgments

The author denies any conflicts of interest related to this study.

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