Cyclic Fatigue Resistance of OneShape, HyFlex EDM, WaveOne Gold, and Reciproc Blue Nickel-titanium Instruments

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Introduction: The purpose of this study was to compare the cyclic fatigue resistances of Reciproc Blue (VDW, Munich, Germany), HyFlex EDM (Coltene/Whaledent, Altstätten, Switzerland), WaveOne Gold (Dentsply Maillefer, Ballaigues, Switzerland), and OneShape (Micro Mega, Besancon, France) single-file NiTi systems. **Methods:** Thirty Reciproc Blue R25 (25/.08), 30 HyFlex EDM (25/.∼), 30 WaveOne Gold Primary (25/.07), and 30 OneShape (25/.06) instruments were included in this study. All the instruments were rotated in artificial canals, which were made of stainless steel with an inner diameter of 1.5 mm, a 60° angle of curvature, and radii of curvatures of 5 mm until fracture occurred, and the time to fracture was recorded in seconds using a digital chronometer. The data were analyzed statistically using Kruskal-Wallis and post hoc Dunn tests via SPSS 21.0 software (SPSS Inc, Chicago, IL). The statistical significance level was set at 5%. **Results:** The HyFlex EDM file (3456.33 ± 633.37) file had the statistically highest fatigue resistance, and the OneShape file (1221.63 ± 812.4) had the least fatigue resistance ($P < .05$). The mean number of cycles to fracture of the Reciproc Blue file (2875.89 ± 105.35) file was statistically higher than the WaveOne Gold file (1737.00 ± 376.32) ($P < .05$). There was no statistically significant difference ($P > .05$) in the mean length of the fractured fragments of the files ($P > .05$). **Conclusion:** Within the limitations of the present *in vitro* study, it was found that cyclic fatigue resistance of HyFlex EDM files was higher than the cyclic fatigue resistances of OneShape, Reciproc Blue, and WaveOne Gold files. *(J Endod 2017;43:1192–1196)*

Key Words

Artificial canals, cyclic fatigue resistance, endodontics, nickel-titanium, single-file systems

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 Reciproc Blue.

Nickel-titanium (NiTi) rotary files became more widely used in endodontics for preparing root canals. With the use of NiTi rotary files, the complications that can be observed when using stainless steel files such as ledges, zips, perforations, and straightened root canals started to be seen less frequently (1, 2). Despite the advantages of NiTi files, the fracture risk of NiTi rotary files, especially in curved canals, is significantly high (3, 4). Fractured NiTi files might affect the success of root canal treatment. The fractures of NiTi files might occur due to either torsional or cyclic fatigue (5, 6). Many methods are developed and tried in order to prevent the fracture of NiTi rotary file systems. Alteration of the cross sections of files, heat treatments, and electropolishing are some of the methods used to develop the cyclic fatigue resistance of files (7). It has also been shown that the kinematics of NiTi files is important for the cyclic fatigue life of NiTi files; reciprocation motion was especially shown to increase the cyclic fatigue life of NiTi files (8).

Reciproc Blue (RPC Blue; VDW, Munich, Germany) and WaveOne Gold (WOG; Dentsply Maillefer, Ballaigues, Switzerland) are new-generation single-file systems that perform reciprocal motion and were recently introduced to the market. RPC Blue is the latest version of files known as Reciproc (RPC, VDW). As an RPC file, RPC Blue has an S-shaped cross section, 2 cutting edges, and a noncutting tip. However, RPC Blue files are manufactured by altering the molecular structure through a new heat treatment in order to increase the cyclic fatigue resistance. This new heat treatment gives the file its blue color. According to the manufacturer, RPC Blue files have approximately 2 times higher cyclic fatigue resistance than RPC files (9). WOG files are the updated version of WaveOne files (Dentsply Maillefer). While maintaining the reciprocation motion of files, their dimensions, cross section, and geometry were altered. The cross section of the file was modified to a parallelogram, having 2 cutting edges. Moreover, the off-center design used in ProTaper Next (PTN, Dentsply Maillefer) files is also used in WOG files. The files are manufactured using gold heat treatment. On the contrary, with M-Wire technology based on heat treatment before production, gold heat treatment is performed by heating and then slowly cooling the file after production. The manufacturer company claims that the new heat treatment increases the flexibility of files (10).

HyFlex EDM (HEDM; Coltene/Whaledent, Altstätten, Switzerland) and One Shape (OS; Micro Mega, Besancon, France) are new-generation single-file systems with continuous rotation motion. HEDM files are made of a controlled memory alloy using electrodischarge machining technology. Thus, it was reported that the mechanical

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properties of HEDM files were significantly improved (11). HEDM (25/.∼) files have constant 8% taper in the apical 4 mm; the taper decreases to 4% toward the coronal region. Throughout the entire working part of the file, there are 3 different horizontal cross sections: a quadratic cross section in the apical region, a trapezoidal cross section in the middle region, and an almost triangular cross section in the coronal region (5). An OS file is made of conventional NiTi alloys, and it has a 0.25-mm tip diameter and 6% constant taper throughout the shaft. Its most important characteristic is the design, with an asymmetric horizontal cross section. OS has 3 cutting edges and an almost triangular cross section in the tip region; the cross section progressively changes from 3 to 2 cutting edges between the apical and coronal parts and becomes a modified S-shaped cross section with 2 cutting edges in the coronal region.

In a comprehensive literature review, no study examining the cyclic fatigue resistance of the RPC Blue NiTi file could be found. Thus, the aim of the present study was to compare the cyclic fatigue resistances of the RPC Blue, HEDM, WOG, and OS single-file NiTi systems, which have different metallurgic properties and different kinematics. The null hypothesis of the present study was that there would be no difference between the cyclic fatigue resistances of the tested NiTi files.

Materials and Methods

Thirty RPC Blue R25 (25/.08), 30 HEDM (25/.∼), 30 WOG Primary (25/.07), and 30 OS (25/.06) files were included in the present study. Before the cyclic fatigue test, the files were examined using a stereomicroscope (Leica Imaging Systems Ltd, Cambridge, England) in terms of deformation; all of the files were involved because there was no deformation. For the static cyclic fatigue resistance test, a stainless steel artificial canal with a 5-mm radius of curvature, a 60° angle of curvature, and a 1.5-mm inner diameter was used (12). Moreover, the center of curvature that the canal had was located at 5 mm coronal to the apical ending point. In all of the groups, the files were lubricated using synthetic lubricant (WD-40 Company, Milton Keynes, England) in order to minimize the friction between the canal and files and to ensure the free rotation of files within the artificial canal. In order to better observe the fracture of files, the top of the stainless steel block was covered with glass (Fig. 1).

The files were divided into 4 experiment groups, and the following procedures were performed:

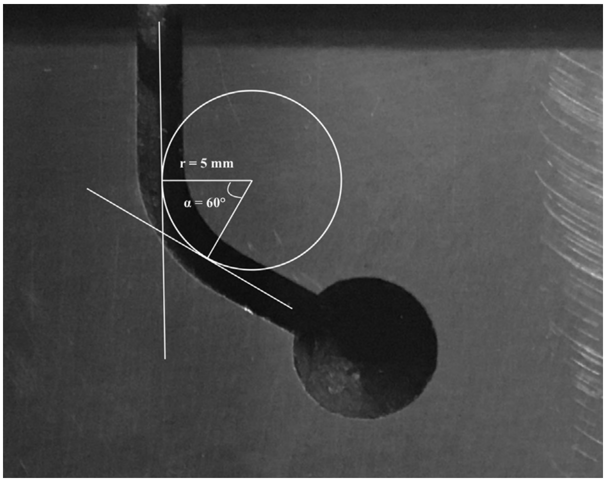

Figure 1. The artificial canal used in the present study.

1. Group 1: Reciproc Blue R25. The files in this group were used with the VDW Reciproc Gold (VDW) endodontic motor mounted on a cyclic fatigue test device in the "Reciproc ALL" program until the fracture occurred.
2. Group 2: WaveOne Gold Primary. The files in this group were used with the VDW Reciproc Gold endodontic motor mounted on a cyclic fatigue test device in the "WaveOne ALL" program until the fracture occurred.
3. Group 3: HyFlex EDM (25/.∼). The files in this group were used with the VDW Reciproc Gold endodontic motor mounted on a cyclic fatigue test device at 500 rpm and 2.5 g/cm torque until the fracture occurred.
4. Group 4: One Shape. The files in this group were used with the VDW Reciproc Gold endodontic motor mounted on a cyclic fatigue test device at 400 rpm and 4 g/cm torque until the fracture occurred.

All of the files were used in the artificial canals program until the fracture occurred, and the time to fracture was recorded using digital chronometer. Using the time data, the numbers of cycles to failure (NCFs) were calculated according to the following formula: NCFs = revolutions per minute × time to fracture (seconds)/60. The lengths of fractured parts were measured using a digital caliper. In total, 8 files (n = 2 for each group) were examined under a scanning electron microscope (JSM-7001F; JEOL, Tokyo, Japan) in order to confirm that the files fractured because of the cyclic fatigue.

Statistical Analyses

The data were firstly analyzed using the Shapiro-Wilk test in order to verify the assumption of normality. Kruskal-Wallis post hoc Dunn tests were performed for statistically analyzing the data using SPSS 21.0 software (IBM-SPSS Inc, Chicago, IL). The statistical significance level was set at 5%.

Results

The means and standard deviations of the NCF values and the lengths of fractured segments are shown in Table 1. The HEDM file (3456.33 ± 633.37) had the statistically highest fatigue resistance, and the OS file (1221.63 ± 812.4) had the least fatigue resistance (P < .05). The mean NCF of the RPC Blue file (2875.89 ± 105.35) was statistically higher than the WOG file (1737.00 ± 376.32) (P < .05).

The mean lengths of the fractured segments were recorded in order to evaluate the correct positioning of the tested files inside the canal curvature. There was no statistically significant difference (P > .05) in the mean length of the fractured fragments of the files (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. 2*A–H*).

TABLE 1. Mean and Standard Deviations of the Number of Cycles to Failure and the Length of the Fractured Fragment of the Tested Nickel-titanium Files

	Number of cycles to failure	Fractured length (mm)
OneShape	1221.63 ± 812.4[a]	5.73 ± 0.54
WaveOne Gold	1737.00 ± 376.32[b]	5.76 ± 0.57
Hyflex EDM	3456.33 ± 633.37[c]	5.77 ± 0.52
Reciproc Blue	2875.89 ± 105.35[d]	5.72 ± 0.53
P value	<.05	>.5

Different superscripts indicate a statistically significant difference (P < .05).

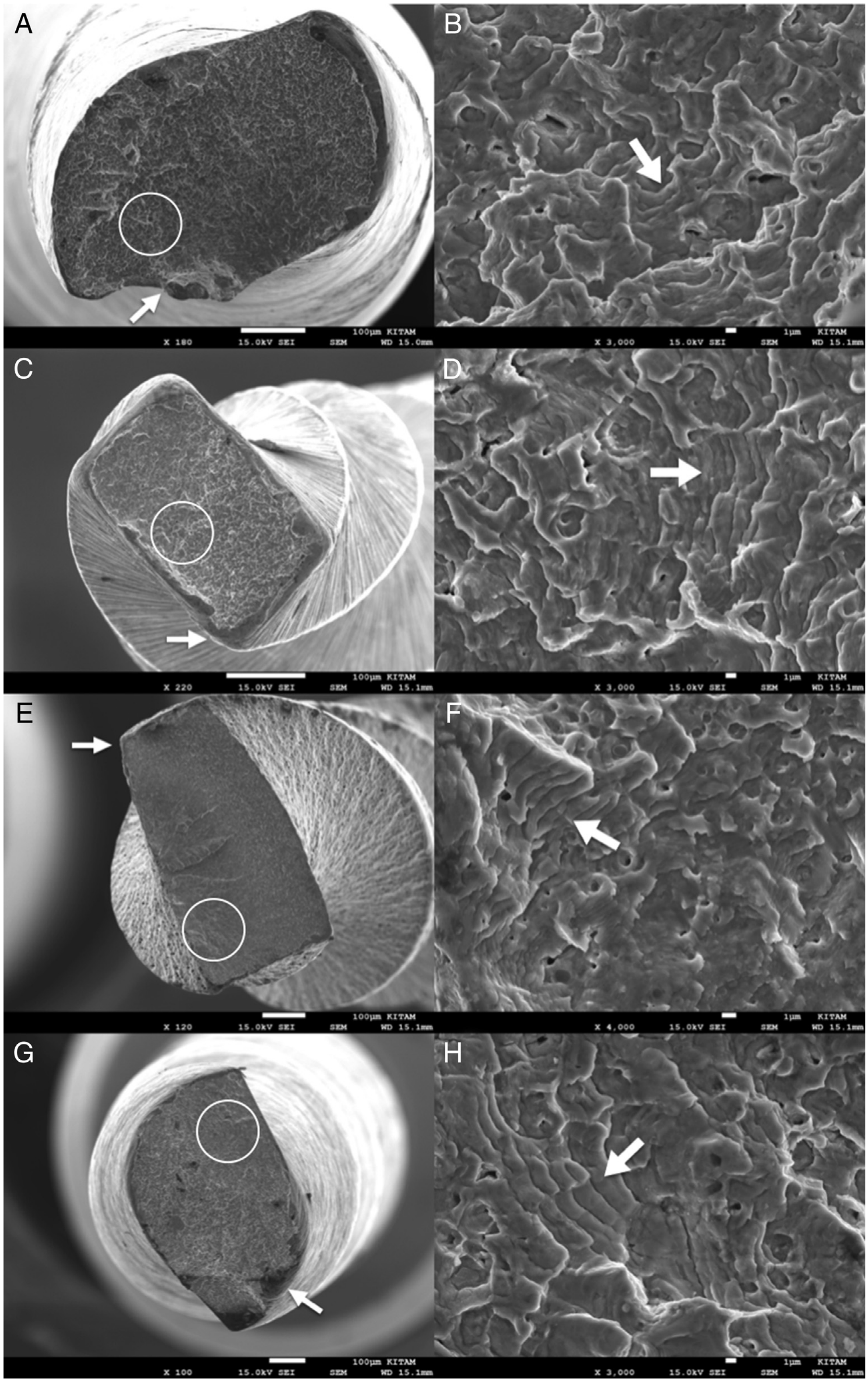

Figure 2. Scanning electron microscopic appearances of the OS, WOG, HEDM, and RPC Blue files after cyclic fatigue testing. The fracture surface view of (*A*) OS, (*C*) WOG, (*E*) HEDM, and (*G*) RPC Blue and a high-magnification view of (*B*) OS, (*D*) WOG, (*F*) HEDM, and (*H*) RPC Blue instruments. The crack initiation origin (*arrows*) and the surface pattern with dimples and cones (*circled area*) are observed in the same fracture surface.

Discussion

One of the most important complications during root canal preparation when using NiTi rotary files is that the files fracture during the procedure (13). It was reported that the files, which fractured during clinical use, mainly fracture because of cyclic fatigue (14, 15). For this reason, many studies were performed on the cyclic fatigue resistance of

NiTi rotary files (16, 17). Manufacturers aim to improve the cyclic fatigue resistance of NiTi rotary files by altering the metallurgy, design, and kinematics of the files and through the heat treatments applied to the files (8, 18). In a comprehensive literature review, there was no study examining the cyclic fatigue resistance of RPC Blue files. For this reason, the aim of present study was to compare the cyclic fatigue resistances of RPC Blue, HEDM, WOG, and OS NiTi rotary file systems. According to the results of the present study, the HEDM file system was found to be statistically significantly more resistant to cyclic fatigue than RCP Blue, WOG, and OS files. For this reason, the null hypothesis of the present study was rejected. The mean lengths of the fractured segments in all the groups did not show any significant difference. This showed that the tested instruments were correctly positioned within the canal curvature and also demonstrated that similar stresses were being induced.

According to the results of the present study, the HEDM file showed the highest resistance to cyclic fatigue. Similarly, Pirani et al (19) reported the cyclic fatigue resistance of HEDM files to be higher than HyFlex CM (HCM, Coltene/Whaledent) files. In another study, Kaval et al (20) reported that the cyclic fatigue resistance of HEDM was significantly higher than ProTaper Universal (Dentsply Maillefer) and ProTaper Gold (Dentsply Maillefer) files. The reason for HEDM files having a higher cyclic fatigue resistance might be the electrodischarge machining procedure performed during the production. The file's manufactured alloy is not the only factor influencing the cyclic fatigue resistance of the instruments. The cross section type, area, and usage speed of the file may influence the cyclic fatigue life of the file. Despite the results of the present study, a finite elemental analysis study showed that NiTi instruments having a triangular cross-sectional geometry showed better fatigue resistance than a square cross section (21). In previous studies, the reciprocation motion was reported to increase the cyclic fatigue resistance of NiTi files when compared with rotary motion (22–25), but similarly with the results of the present study, Pedullà et al (5) reported the cyclic fatigue resistance of HEDM files to be higher than that of RPC and WaveOne files performing reciprocal motion. In the present study, the HEDM rotary file system was found to be resistant to cyclic fatigue more than the RPC Blue and WOG files. It is believed that the reason for this result originates from the alloys used in the manufacturing process and the differences in heat treatments applied.

Because there is no study examining the cyclic fatigue resistance of RPC Blue files, the results cannot be directly compared with the other study results. According to the results of the present study, the cyclic fatigue resistance of RCP Blue files was significantly higher than WOG files. The gold heat treatment used in the production of WOG files was reported to increase the flexibility of files (25). In previous studies, the cyclic fatigue resistance of WOG files was reported to be higher than that of RPC files (17, 26, 27). According to the manufacturer, the RPC Blue file has all of the mechanical properties of the RPC file. However, the new heat treatment used during the production of the RPC file altered the molecular structure of the file. Besides RPC Blue's novel heat treatment manufacturing method, its S-shaped cross section was found to show better cyclic fatigue resistance than the rectangular cross section (21). It is believed that the reason for RCP Blue files having higher cyclic fatigue resistance than WOG files is the different heat treatments used during their production processes and their S-shaped cross section.

Capar et al (28) reported that the cyclic fatigue resistance of HCM was higher than OS files. Topçuoğlu et al (27) found the cyclic fatigue resistance of OS and ProTaper Universal files, which are made of the conventional NiTi alloy, to be higher than HCM and ProTaper Next files. In another study, Neelakantan et al (29) reported the cyclic fatigue resistance of RPC files to be higher than that of OS files. Similarly, Dagna et al (30) found the cyclic fatigue resistance of RPC files to be higher than that of OS files. According to the results of the present study, OS files showed the lowest cyclic fatigue resistance among the tested NiTi files. In previous studies, the files made of controlled memory were reported to have higher cyclic fatigue resistance than those made of the conventional NiTi alloy (7, 28, 31–33). The fact that the same results were found in the present study is believed to originate from the production of OS files using the conventional NiTi alloy.

In previous studies, stainless steel artificial canals were used to compare different NiTi instruments' cyclic fatigue resistance (16, 20, 24). Although the standardized stainless steel artificial canal is unable to provide clinical conditions, it minimizes the influence of other variables of file fracture other than cyclic fatigue (34, 35). Therefore, in the present study, a standardized artificial canal was used to standardize the cyclic fatigue test.

Conclusion

Within the limitations of the present *in vitro* study, HEDM instruments resisted static cyclic fatigue significantly more than OS, RPC Blue, and WOG instruments. The novel NiTi rotary instrument Reciproc Blue showed better cyclic fatigue resistance than WOG and OS instruments.

Acknowledgments

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

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