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Comparing the cyclic fatigue resistances of Reciproc Blue and Rotate instruments in simulated severe apical curvature

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Purpose: This study primarily aims to evaluate the cyclic fatigue resistance of Reciproc Blue (VDW, Munich, Germany) and Rotate (VDW, Munich, Germany) instruments by testing them in a severe apical curvature at intracanal temperature.

Methods: In total, 12 Reciproc Blue (25.08) and Rotate (25.06) instruments were tested in a cyclic fatigue device at intracanal temperature (37°C). The instruments were tested in a stainless steel block with an artificial canal with a curvature angle of 90° and a radius of curvature of 2 mm. The instruments were operated until fracture occurred; then, the time for fracture (TF) was calculated. The length of the fractured tips was measured using a digital caliper. The data were analyzed using Student's t-tests, with significance level set at $p< 0.05$.

Results: The TF values of Reciproc Blue (450.60 ± 34.36 s) were found to be significantly higher than Rotate (315.70 ± 70.89 s) ($p< 0.05$). Moreover, no significant difference was observed between the instruments as regards the length of the fractured fragments [Reciproc Blue: 3.11 ± 0.25 mm, Rotate: 2.97 ± 0.27 mm, ($p> 0.05$)].

Conclusion: Reciproc Blue displayed significantly higher cyclic fatigue resistance values than Rotate files when tested in the artificial canal with acute apical curvature.

Keywords: Cyclic fatigue, endodontics, Reciproc Blue.

Introduction

Clinicians often prefer nickel–titanium (Ni–Ti) instruments for canal treatment of curved canals due to their elasticity and shape memory effect (1). Despite the increased physical properties of Ni–Ti, they still may fracture within the root canal during treatment without any previous signs of permanent deformation (2,3). Fracture of Ni–Ti rotary instruments occurs through two different mechanisms: torsional fracture and cyclic fatigue (4). The blockage of the endodontic files can cause torsional overload during rotational movement (5). Cyclic fatigue failure often occurs when the instrument rotates freely in a curvature, generating repetitive tension and compression cycles in the region of maximum flexure until fracture (6). There are factors related to the cyclic fatigue resistance of Ni–Ti endodontic rotary files, including its cross-sectional design (7), the diameter of the inner and outer core (8,9), the operating speed and torque (5,10), radius and angle

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of curvature (11), operator capability (12), an anatomical configuration of the root canal system (13), irrigation solutions (14), sterilization cycles (15), and Ni–Ti alloy.

Manufacturers also aim to increase the cyclic fatigue resistance of files by changing the latter's kinematics, since it has been shown that reciprocating rotation improved the survival rate of the instrument compared to continuous rotation (16). Reciproc Blue (RPC Blue; VDW, Munich, Germany) is a new-generation single-file system that performs reciprocal motion and was recently introduced to the market. RPC Blue is the latest version of files known as Reciproc (RPC, VDW). RPC Blue has an S-shaped cross-section, two cutting edges, and a noncutting tip like RPC file. RPC Blue files are manufactured by altering the molecular structure through a new heat treatment in order to increase the cyclic fatigue resistance (17,18). This new heat treatment gives the file its blue color. According to the manufacturer, RPC Blue files have approximately two times higher cyclic fatigue resistance compared to RPC files (17,18).

Rotate (VDW, Munich, Germany) is a new file system working with continuous rotation, which is known to have increased fracture resistance and flexibility with special heat treatment. Rotate (VDW, Munich, Germany) file, which has high flexibility thanks to its unique heat treatment application, has a blue color along the grooved part of the tool, while the shaft part of the file is colored gray. Blue color occurs as a result of the oxide layer accumulating on the surface with the application of heat treatment after grinding. The color difference between the parts of the tool is due to the different thicknesses of the oxide layer on the part of the grooves and the rest of the shaft. It shows two cutting edges and an S-shaped section design, similar to that of Reciproc Blue files (19,20).

Studies have shown that as the curvature angle increases and the curvature radius decreases, the cyclic fatigue resistance of the instruments decreases (21). In an apical third of root canal systems, severe curvatures can often be found that are not detected in diagnostic radiography (22).These curvatures expose Ni–Ti files to more stress, thus leading to cyclic fatigue fractures (23,24). Another factor affecting the cyclic fatigue resistance of rotary system Ni–Ti files is the temperature of the environment where the tests are carried out. It has been reported that testing at body temperature reduces the cyclic fatigue resistance of Ni–Ti files and better reflects clinical conditions (25,26).

The aim of this study was to evaluate the cyclic fatigue resistance of two different files with similar geometric design, that is, Reciproc Blue (VDW, Munich, Germany) and Rotate (VDW, Munich, Germany), by testing them in a severe apical curvature at intracanal temperature. The null hypothesis of this present study was that there would be no significant difference between the cyclic fatigue resistances of the tested Ni–Ti files.

Materials and Methods

The total sample size calculation for the cyclic fatigue testing was performed using the effect size results of a previous study (27). An a priori ANOVA (fixed effects, omnibus, one-way) was selected from the F-test family using an alpha-type error by 0.05 and power beta of 0.95 (G*Power 3.1 for Macintosh, Heinrich Heine, Universitat Dusseldorf, Dusseldorf, Germany); in total, 12 samples were indicated as the minimum ideal size required to observe the same effect. Twelve unused Reciproc Blue and Rotate files were selected to be tested at body temperature (37°C) in the cyclic fatigue experimental setup.

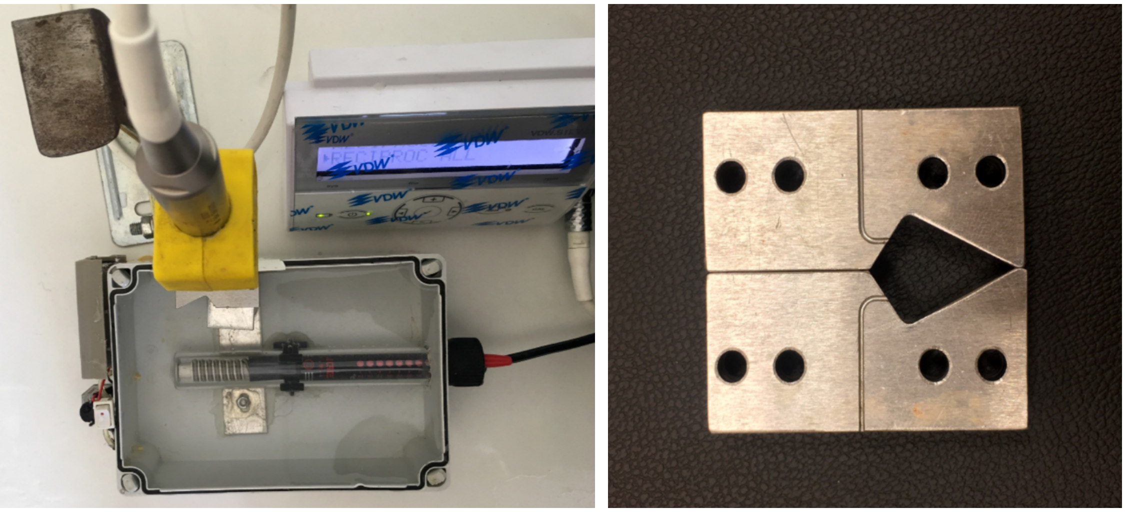

Fig. 1. Experimental setup.

Before the cyclic fatigue test, the files were examined using a stereomicroscope (Nikon SMZ 745T; Tokyo, Japan), and files without any visible defects were included in the study.

A stainless steel block with an artificial canal with a curvature angle of 90° and a curvature radius of 2 mm was mounted in a plastic container measuring 15 × 10 × 4 cm. The plastic container was filled with 600 ml of 5.25% sodium hypochlorite (NaOCl) solution and heated to 37°C ± 1°C using a heater (AquaTop, CA, USA). The temperature of the testing block and solution was measured with thermocouples and controlled via thermostats (Fig. 1).

The files were used until the fracture occurred with the VDW Silver Reciproc endodontic motor (VDW, Munich, Germany) mounted on the cyclic fatigue tester in accordance with the manufacturer's recommendations (Reciproc Blue in "Reciproc ALL" mode – Rotate files continuous rotation motion at 300 rpm and 2.3 Ncm.).

The time required for fracture (TF) in seconds was measured to the 1/100 s using a digital chronometer.

Table 1. Mean and standard deviation values for TF (s) and length of the fractured fragment (mm) of the tested instruments

	Time for failure (sec)	Fragment length mean (mm)	N
Rotate	315.70 ± 70.89	2.97 ± 0.27	12
Reciproc Blue	450.60 ± 34.36	3.11 ± 0.25	12

The mean lengths of the fractured segments were then recorded using a digital caliper in order to evaluate the correct positioning of the tested files inside the canal curvature.

In each group, two of the fractured instruments were examined under a scanning electron microscope (JSM-7001F; JEOL, Tokyo, Japan) in order to confirm that the files fractured due to cyclic fatigue (Figs. 2, 3).

Statistical analysis

The data were analyzed using Student's t-tests with significance level set at $p< 0.05$.

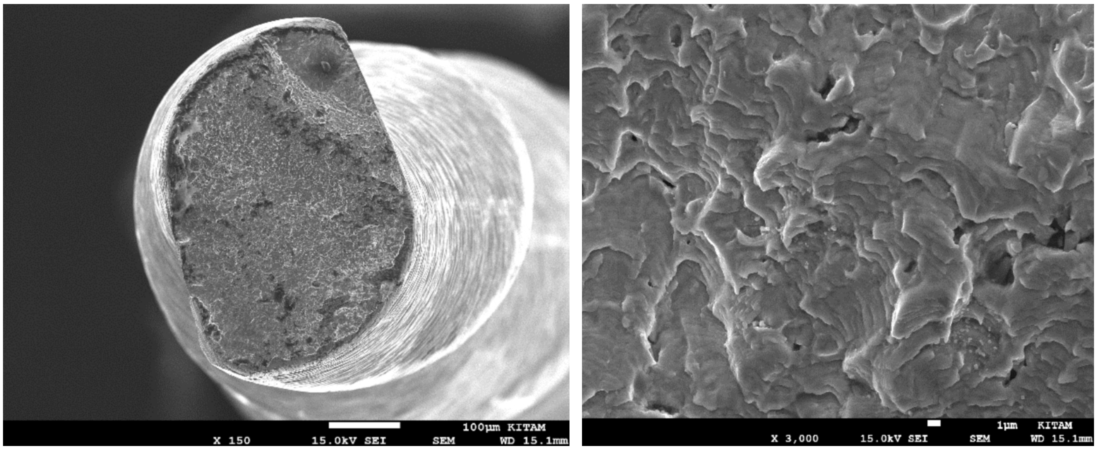

Fig. 2. SEM surface images of the Reciproc Blue.

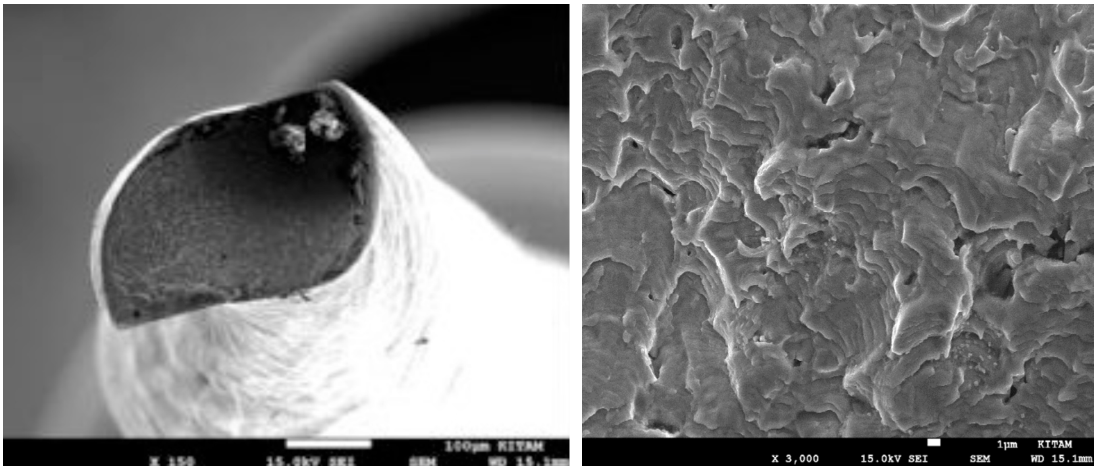

Fig. 3. SEM surface images of the Rotate.

Results

The mean TF of the files, the mean lengths of the broken fragments, and standard deviations are shown in Table 1. As per our findings, the TF values of Reciproc Blue (450.60 ± 34.36 sec) were significantly higher than Rotate (315.70 ± 70.89 sec) ($p < 0.05$).

There was no statistical difference between the instruments regarding the length of fractured fragments (Reciproc Blue: 3.11 ± 0.25 mm, Rotate: 2.97 ± 0.27 mm) ($p > 0.05$).

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.

Discussion

Manufacturers aim to increase cyclic fatigue resistance by altering the metallurgy, design, and kinematics of the files and through the heat treatments applied to the files.

For this reason, many studies have focused on the cyclic fatigue resistance of Ni–Ti files (12,29). In this study, the cyclic fatigue resistance of two rotary system files with similar design features (S-shaped cross-section), but different rotations (reciprocal and continuous rotation), were evaluated.

Previous studies determined that stainless steel blocks with an angle of curvature of 60° and a radius of curvature of 5 mm were used in cyclic fatigue tests (21,24). However, in the apical third of root canal systems, abrupt curvatures are often found that cannot be detected on diagnostic radiographs (22). These severe curvatures expose Ni–Ti files to more stress, which, in turn, could lead to cyclic fatigue fractures (23). For this purpose, in this present study, an artificial canal with a 90° curvature angle and a 2 mm radius of curvature was used to simulate these sudden curvatures.

Environment temperature has been identified as one of the factors affecting cyclic fatigue (15). Previous studies have reported that increasing the temperature of the environment in which the test was carried out significantly reduced the cyclic fatigue resistance (15, 24–26).

It has also been reported that the file is in a liquid environment during testing also changes its cyclic fatigue resistance (20). To better stimulate the clinical environment, this present study was conducted in a NaOCl heated to 37°C (body temperature).

Previous studies have reported that heat-treated files provide higher cyclic fatigue resistance than conventional Ni–Ti files (20,29). Heat-treated files with similar cross-sectional area were used in our study.

In previous studies, the reciprocation motion was reported to increase the cyclic fatigue resistance of Ni–Ti files when compared with rotary motion (13,16,28). This has been attributed to the spread of the tensile force of the file to different points in the reciprocal motion of the file (29). Our findings are consistent with the results of previous studies.

When the lengths of the broken pieces of the files were examined, it was seen that the fractures were in the severe curvature region. No statistical difference was found between Rotate and Reciproc files in terms of the length of the broken fragment.

When the fracture surfaces are examined by SEM in failures due to cyclic fatigue, the fracture initiation areas are determined as the smooth surfaces in the periphery. Fatigue lines are observed in SEM images as typical evidence that fracture is due to cyclic failure (30). It was observed that the fracture surfaces of the files we used in our study exhibited a typical cyclic fatigue-related fracture pattern in the SEM images.

Conclusion

Within the limitations of this present study, Reciproc Blue displayed significantly higher cyclic fatigue resistance values than Rotate files when tested in the artificial canal with acute apical curvature.

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