

Comparison of Cyclic Fatigue Resistance of Heat-Treated Nickel-Titanium Reciprocating Instruments at the Intracanal Temperature

SUMMARY

Background/Aim: The aim of the present study was to compare the cyclic fatigue resistance of NiTi files running with reciprocal motion and having different characteristics (RPC Blue, WOG, EndoArt Wise Reciproc Gold, EndoArt Wise Reciproc Blue) at the intracanal temperature (35°C) by using NaOCl irrigation solution. **Material and Methods:** Totally 60 WaveOne GOLD (Dentsply-Sirona, Ballaigues, Switzerland), Reciproc Blue (VDW, Munich, Germany), EndoArt Wise Reciproc Gold, and EndoArt Wise Blue (Inci Dental Productions Co, Istanbul, Turkey) (n= 15) files were used. Each of the rotary files were tested at the intracanal temperature (35°C) using a dynamic model in a stainless-steel artificial canal with an inner diameter of 1.5 mm, 60° angle of curvature, and 2mm radius of curvature until fracture occurred. The device automatically stopped at the moment of fracture and the number of cycles to the fracture was calculated as per second. The lengths of fractured parts were measured using a digital microcaliper. The One-Way Analysis of Variance (ANOVA) and Tukey's post-hoc tests were used for intergroup comparisons. **Results:** In 2 mm Radius of curvature, the EndoArt Wise Reciproc Blue group had a significantly higher time to fracture followed by the EndoArt Wise Reciproc Gold, Resiproc Blue, WaveOne Gold. No significant difference was found between EndoArt Wise Reciproc Gold and Resiproc Blue groups ($P>0.05$). Among the groups, there was no statistically significant difference in the lengths of fractured parts of the instruments ($P>0.05$). **Conclusions:** EndoArt Wise Reciproc Blue files exhibited significantly higher cyclic fatigue resistance compared with other files tested in a 2-mm radius of curvature and a 60° angle in an artificial canal at the intracanal temperature.

Key words: NiTi, Cyclic Fatigue, EndoArt Wise Reciproc Blue, WaveOne Gold, EndoArt Wise Reciproc Gold

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Introduction

Despite the advantages of rotary NiTi file systems, the most important problem experienced with these files is their unexpected failure during clinical use¹. The rotary NiTi file systems' failure occurs because of either torsional or cyclic fatigue¹⁻³. The torsional fatigue failure occurs when the drill continues rotating while the tip of file was stuck within the root canal⁴. However, the cyclic fatigue failure occurs as a result of repetitive compaction

and tensile forces in the maximum curvature area while the file rotates within the curved canal⁵.

Various factors such as preparation method, instrument design, size, production method, usage, number, canal shape⁶, and rotation direction⁵ may cause of failure. For this reason, the innovations are designed for the kinematic, metallurgic, and surface characteristics and designs of NiTi files in order to perform effective and rapid shaping in curved canals and to increase the failure resistance⁷. The kinematic movements play a significant role in the cyclic fatigue of files⁸. With clockwise and

counterclockwise movements, the reciprocal motion prolongs the lifetime of files by reducing the stress on the file and increasing the cyclic fatigue failure⁹. In previous studies, it was reported that the reciprocal motion increases the cyclic fatigue resistance when compared to the continuous rotation motion^{8, 10-13}. Besides that, new file systems with reciprocal motion were developed by altering the metallurgic characteristics of files. The new generation Reciproc Blue (RPC Blue; VDW, Munich, Germany) files are the updated form of Reciproc (RPC; VDW) file system. Moreover, RPC Blue is produced using a new heat treatment causing molecular structure changes in order to increase the cyclic fatigue resistance. Known as blue treatment, this new heat treatment gives the file a blue color¹⁴. WaveOne Gold (WOG; Dentsply Sirona, Ballaigues, Switzerland) files are the single-file systems introduced by updating the cross-section, diameter, geometry, and metallurgic characteristics of WaveOne (WO; Dentsply Sirona) files. WOG files are produced using heat treatment named Gold treatment¹⁵.

Thermomechanical treatments applied to NiTi alloys influence transformation behaviors. In previous studies, it was reported that the alloys (gold and blue) containing higher martensite percentage at room temperature are more resistant to cyclic fatigue^{16,17}. Nowadays, the EndoArt Wise Reciproc Blue (Inci Dental Productions Co, Istanbul, Turkey) files running with reciprocal motion, having tetragonal shape, and having Controlled Memory and blue treatment features and the EndoArt Wise Reciproc Gold (Inci Dental Productions Co, Istanbul, Turkey) files having Controlled Memory and gold treatment features were recently introduced to the market. In the literature, there is no study examining the cyclic fatigue resistance of EndoArt Wise files running with reciprocal motion.

The aim of the present study is to compare the cyclic fatigue resistance of NiTi files running with reciprocal motion and having different characteristics (RPC Blue, WOG, EndoArt Wise Reciproc Gold, EndoArt Wise Reciproc Blue) at the intracanal temperature (35°C) by using NaOCl irrigation solution. The null hypothesis of the present study is that there would be no difference between the cyclic fatigue resistances of files having different metallurgic properties.

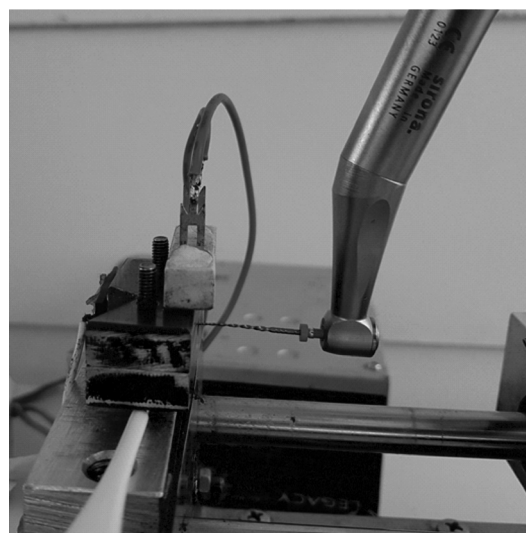
Material and Methods

In the present study, 60 ($n=15$) rotary NiTi file systems running with reciprocal motion were involved. Group 1: Rpc Blue (25.08); Group 2: WOG (25.07); Group 3: EndoArt Blue (25.07); Group 4: EndoArt Gold (25.07). The sample size was calculated using G*Power v3.1 for Mac (Heinrich Heine, University of Dusseldorf). The presence of any defect on the files was tested under

X20 magnification using stereomicroscope (Olympus BX43; Olympus Co, Tokyo, Japan). Since no defect was observed on the files that were used in the present study, all the files were used in the cyclic fatigue tests.

All the files were run in the artificial canals with 60° curvature angle and 2 mm radius⁶ until failure. The dynamic cyclic fatigue test was performed at the intracanal temperature (35°C±1) (Figure 1)¹⁸. The temperature was monitored throughout the experiment by using a digital thermometer. A stone (wire) resistor and thermostat were used to increase the temperature of artificial canal or metal block to 35.5°C and maintain this temperature. Current was passed through a 27 ohm 5W stone resistor by a voltage source, and the stone resistor transferred the waste heat it generated to the metal block in contact with the transmission, causing the temperature of the metal block to increase. After the reach 35.5°C thermostat was used to stop further increases and maintain the temperature. Thermostat work by breaking the circuit when a certain temperature is reached, thus preventing current from passing through the resistor. When the metal block's temperature drops below the desired value, the circuit become operational again. In order to test the files by fixing them, they were attached to a micro motor with torque and speed adjustment and 6:1 reduction and a drill (VDW Silver Reciproc, VDW Munich, Germany), then connected to a test device and run at torque and speed rates recommended by the manufacturer. 2 ml 5.25% sodium hypochlorite (NaOCl; CanalPro; Coltene-Whaledent, Allstetten, Switzerland) was injected into the canals. The devices fixed on the experimental setting were run with pecking motion at 2 mm/sec. speed in order to mimic the clinical use. At the moment of failure, the device stopped automatically and the Time to Fracture (TTF) was calculated as per second. The lengths of fractured (FL) parts were measured using a digital microcaliper.

Figure 1. Dynamic cyclic fatigue-testing device



Eight pieces of fractured files (two pieces from

each group) were examined under a scanning electron microscope (SEM) (Quanta 450 FEG, Oregon, USA) to confirm the type of fracture as flexural, and photomicrographs were taken from the fractured surfaces under different magnifications (x720 to x10.000) (Figure 2).

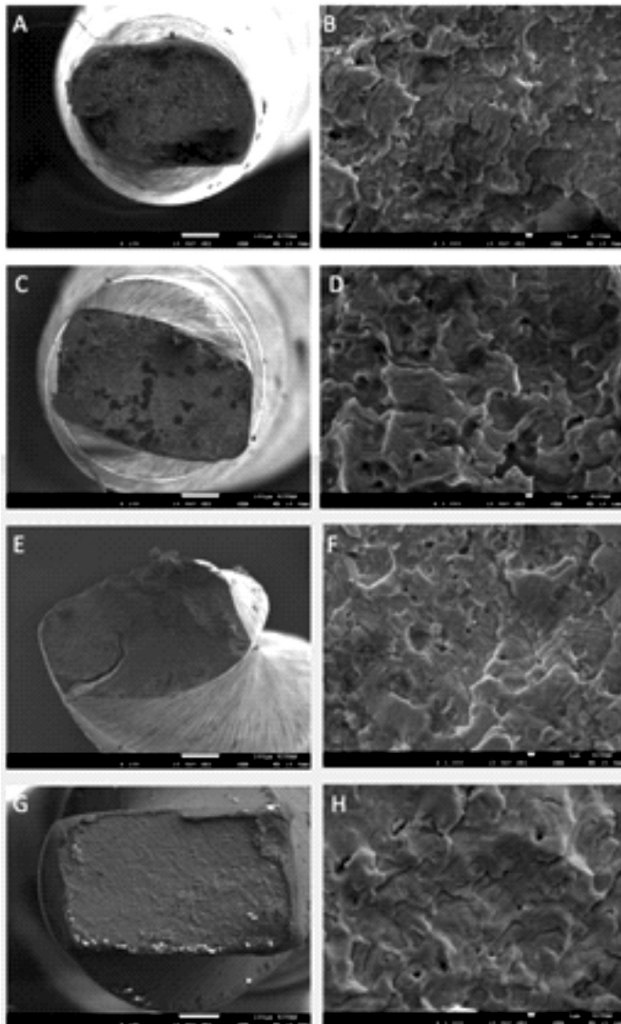


Figure 2. Scanning electron micrographs of the fractured instruments: A. Rpc Blue 25.08 (150-300 X Magnification); C-D. EndoArt Wise Gold 25.07 (150-3000 X Magnification); E-F. EndoArt Wise Blue 25.07 (150-3000 X Magnification); G-H. WOG 25.07 (160-3000 X Magnification) showing fatigue striations

Statistical Analysis

Data were evaluated using IBM SPSS version 21 software (IBM SPSS, Chicago, IL, USA). Following the confirmation of the normal distribution of the data using the Shapiro–Wilk test, the intergroup comparisons were performed using one-way analysis of variance and the post hoc Tukey tests. The statistical significance was set at 95% confidence level.

Results

The mean and standard deviation of the Time to Fracture (TTF) and Fracture Length (FL) of the groups tested are shown in Table 1 ($P < 0.05$). At 2 mm radius of curvature, the EndoArt Wise Blue group had a significantly higher mean time to fracture followed by the EndoArt Wise Gold, Reciproc Blue, WaveOne Gold. No significant difference between EndoArt Wise Gold and Reciproc Blue groups was found ($P > 0.05$). WaveOne Gold was significantly lower than the EndoArt Gold and Reciproc Blue groups ($P < 0.05$). Among the groups, there was no statistically significant difference in the fracture lengths ($P > 0.05$).

Table 1. The Mean and Standard Deviation of Time to Fracture (TTF) and Fracture Length (FL) of the Tested Nickel-titanium Instruments in %5.25 NaOCl (Mean \pm SD)

Instruments	NCF	FL
Reciproc Blue	2367 \pm 760 ^x	3.35 \pm 0.1 ^x
WaveOne Gold	1145 \pm 112 ^y	3.36 \pm 0.2 ^x
EndoArt Wise Blue	5646 \pm 166 ^z	3.35 \pm 0.3 ^x
EndoArt Wise Gold	2806 \pm 609 ^x	3.36 \pm 0.1 ^x

Different superscript letters indicate statistically significant differences between groups ($P < 0.05$) (^{x,y,z}columns)

Discussion

Manufacturers aim to improve the cyclic fatigue resistance of NiTi files by altering the metallurgic structures, heat treatments applied to files, and designs and kinematic characteristics of NiTi files^{8,19}. The clinicians should be aware of the advantages and disadvantages arising from the modifications made on the files²⁰. For this purpose, the present study compares the cyclic fatigue resistances of new EndoArt Wise Reciproc Blue and Gold files with those of WOG and RCP Blue files. According to the results of the present study, the cyclic fatigue resistance of EndoArt Wise Reciproc Blue files was found to be statistically significantly higher than that of other file groups. Thus, the null hypothesis of the present study was rejected.

In order to mimic the clinical conditions and to distribute the stress on the file, the experimental setting was designed according to the dynamic model rather than the static one. Researchers reported that preventing the stress accumulation increases the failure resistance of file^{21,22}. The NiTi rotary file systems contact solutions, which are used for irrigation purposes, during the root canal preparation. The corrosions and deformations develop after this contact and they may cause undesired fractures²³. In order to mimic the clinical conditions,

the cyclic fatigue tests were performed by irrigating the artificial canals with 2 ml NaOCl.

When compared to the other files, EndoArt Wise Blue failed after a longer time. EndoArt Wise Blue files may be more flexible since they have controlled memory and blue treatment features. Although EndoArt Wise Blue and RPC files failed after a longer time than WOG files did, the difference was statistically insignificant. These findings are corroborated by previous studies²⁴⁻²⁹. As RPC does, the RPC Blue file system has an S-shaped transverse cross-section and 2 cutting edges and it is more resistant than RPC file³⁰. WOG, however, has a non-parallel cutting edge and, because of this design, it has an active cutting edge with contact at a single point. There is no consensus on if the difference between the cross-sections of files influences the cyclic fatigue. Some of the studies advocate that the cross-sectional properties influence the cyclic fatigue resistance of files^{31,32}, whereas some others argue the opposite^{33,34}.

The modifications in the crystal structure of files affect their flexibility. During clinical use, the Blue is at the martensitic phase. At this phase, the file becomes softer and more ductile. The temperature of transition between austenitic and martensitic phases is measured just below the body temperature³⁵. Most of the previous studies compared the cyclic fatigue resistances of NiTi files at the room temperature. In previous studies, it was reported that the temperature affected the cyclic fatigue resistance of files^{8,36-38}. Some of the studies argued that the room temperature and intracanal temperature did not affect the cyclic fatigue resistance of files^{25,39}. In the present study, since the intracanal temperature, the devices clinically used at was approx. 35°C, the dynamic test was performed at dynamic test⁴⁰.

In the clinics, the file failures occur together with the accumulation of torsional stress and cyclic fatigue. Further study methods should be developed in order to test the resistance of NiTi filed in the way representing the clinical conditions.

Conclusions

EndoArt Wise Reciproc Blue files displayed a significantly higher cyclic fatigue resistance and, hence, a superior fracture resistance than Reciproc Blue, WaveOne Gold Primary, Endoart Wise Reciproc Gold tested in an artificial canal at intracanal temperature.

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