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ORIGINAL ARTICLE

In vitro Evaluation of Cyclic Fatigue Resistance of Reciprocating and Rotary Single-file System

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ABSTRACT

Aim: *In vitro* study evaluation of the cyclic fatigue resistance of reciprocating and rotary single-file system [Wave One Gold (WOG), Reciproc, Hyflex electrical discharge machining (EDM) file systems] utilizing cyclic fatigue testing device.

Materials and methods: Three nickel–titanium rotary systems (Hyflex EDM size #25, 0.06 taper and Reciproc and WOG size #25, 0.06 taper) were used in this study. Ten files were used in each file system, which are 25 mm long and tested with cyclic fatigue and torsional resistance tests.

Results: Each file was tested in the simulated root canal until instrument fracture occurred. Hyflex EDM has high mean and standard deviation of 116.23 ± 4.41, followed by WOG (64.85 ± 3.34) and Reciproc (35.28 ± 2.32).

Conclusion: Within the limitations of this study, Hyflex EDM exhibited the greater cyclic fatigue resistance when compared with other rotary and reciprocating files.

Keywords: Cyclic fatigue resistance, Nickel–titanium rotary systems, Wave One gold.

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INTRODUCTION

The application of nickel–titanium (NiTi) in endodontic rotary instrumentation was first envisioned by Civjan, Huget, and DeSimon[1] in 1975. It was not until 1988, however, that Walia et al[2] established the feasibility of producing NiTi endodontic files. These new NiTi hand files exhibited significantly greater elasticity and superior resistance to torsional fracture compared with stainless steel files. The concepts of cleaning and shaping of the root canal system were established by Schilder.[3] For straight root canals, the stages of cleaning and shaping are relatively simple procedures, but the preparation of curved root canals may lead to ledging, perforation, or even instrument separation. Generally, these procedure failures are caused by the trend of the endodontic instrument to return to its original straight form when inserted into a curved root canal, due to the rigidity of the materials used for its manufacturing. Improvement in the manufacturing process or use of materials with superior mechanical properties might increase instrument resistance to failure. Since the introduction of NiTi in 1988, varied instrument designs with claims of superior cyclic fatigue resistance have been propagated. Torsional failure is characterized by a maximum torsional load and angle of rotation. This last property reveals the capability of the file to twist before fracture.[4-6] The purpose of this *in vitro* study is to evaluate the cyclic fatigue resistance of reciprocating and rotary single-file system [Wave One Gold (WOG), Reciproc, Hyflex electrical discharge machining (EDM) file systems] utilizing cyclic fatigue testing device.

MATERIALS AND METHODS

Three NiTi rotary systems (Hyflex EDM size #25, 0.06 taper and Reciproc and WOG size #25, 0.06 taper) were used in this study. Ten files were used in each file system, which are 25 mm long, and tested with cyclic fatigue and torsional resistance tests. Every instrument was inspected for defects or deformities before the experiment. The rotary files were used with an endodontic motor X-SMART and the reciprocating files were used with the endomotor X-SMART PLUS (Dentsply, Maillefer, Ballaigues, Switzerland) of 16:1 reduction hand piece at 300 rpm, according to manufacturer's specifications.

A static cyclic fatigue testing device was custom-fabricated for this study (Fig. 1). It consisted of a main metal frame made of iron to which an artificial canal system and a support for the hand piece were being attached. The canal system, which simulated a root canal, consisted of two adjustable metal frames made of steel that can accommodate any instrument to its exact size and taper. It was constructed with a 60° angle of curvature. The curvature started at 5 mm from the tip of the canal. The Endo motor hand piece was mounted over the support,

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Fig. 1: Cyclic fatigue testing device

which also ensured the correct positioning and placement of files to the same appropriate depth for all the samples. All the instruments were rotated or reciprocated until fracture occurred. To obviate errors, all files were tested by one operator, while the other operator was simultaneously operating the stopwatch. The broken fragments were tested using scanning electron microscope (SEM) to observe fracture lines. Statistical analysis was done by one-way analysis of variance (ANOVA) and *post hoc* Tukey's analysis and it was significant ($p \leq 0.05$).

RESULTS

Each file was tested in the simulated root canal until instrument fracture occurred. The time to fracture in seconds was multiplied by the number of rotation cycles per second (rpm/60) to obtain the number of cycles to fracture (NCF) for each instrument. According to the manufacturer, three reciprocating cycles describe a complete instrument rotation. The reciprocating movement cycle is characterized by a counterclockwise (CCW) rotation of 150° followed by a clockwise (CW) rotation of 30°.

Table 1: Mean time to fracture of different types of file systems

File systems	*Mean*	*f-value*	*p-value*	*Significance*
Hyflex EDM	116.23 ± 4.41	1963.7	0.001	Significant
Reciproc	35.28 ± 2.32			
Wave One Gold	64.85 ± 3.34			

$p \leq 0.05$, significant using one-way ANOVA

Table 1 and Fig. 2 illustrate the mean time to fracture of different file systems. Hyflex EDM has high mean and standard deviation of 116.23 ± 4.41, followed by WOG (64.85 ± 3.34) and Reciproc (35.28 ± 2.32). Table 2 illustrate *post hoc* tukey analysis of comparison of time to fracture of different type of file systems

DISCUSSION

In this study, cyclic fatigue resistance of rotary (Hyflex EDM) and reciprocating (Reciproc and WOG) file systems were tested under simulated condition. Cyclic fatigue resistance has been tested extensively for various NiTi rotary and reciprocating systems. An ideal fatigue model should involve instrumentation of curved root canals in natural teeth. However, such tests would be destructive for this ample (the tooth), and the curvature of the root canal can hardly be standardized.[4]

All the instruments were rotated or reciprocated until fracture occurred. To obviate errors, all files were tested by single operator, while the other operator was simultaneously operating the stopwatch. The broken fragments were tested using SEM to observe fracture lines.

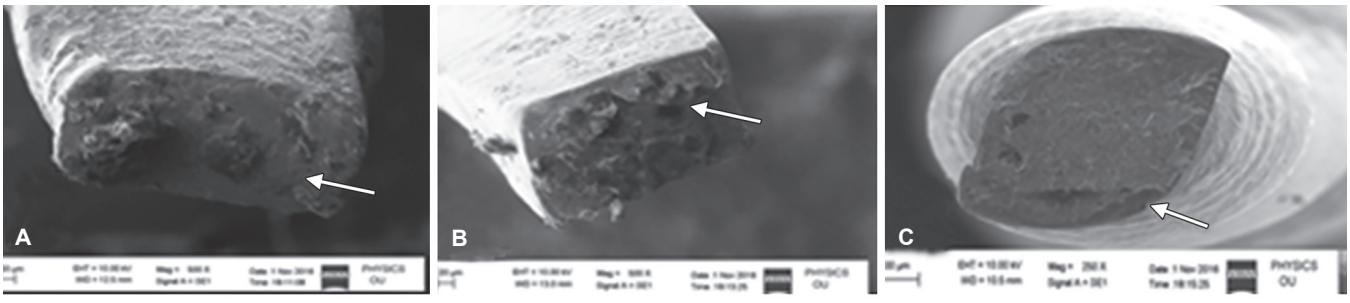
Recently, two M-wire NiTi endodontic file systems in reciprocating motion were introduced: Reciproc (VDW, Munich, Germany) and WOG (Dentsply Maillefer, Ballaigues, Switzerland). The reciprocating working motion consists of a CCW (cutting direction) and a CW motion (release of the instrument), while the angle of the CCW cutting direction is greater than the angle of the reverse direction.[7-10]

Figs 2A to C: Fracture time of different file systems: (A) WOG; (B) Reciproc; and (C) Hyflex EDM

Table 2: *Post hoc* Tukey analysis of comparison of time to fracture of different types of file systems (intergroup comparison)

File systems	*Hyflex EDM*	*Reciprocating*	*Wave One gold*
Hyflex EDM	–	Mean diff = 80.94 (p = 0.001)	Mean diff = 51.37 (p = 0.001)
Reciproc	–80.94 (p = 0.001)	–	–29.56 (p = 0.001)
Wave One gold	Mean diff = –51.37 (p = 0.001)	Mean diff = 29.56 (p = 0.001)	–

p ≤ 0.05, significant using one-way ANOVA



Figs 3A to C: Scanning electron microscopic appearances of cross-section of different file systems. (A) Hyflex EDM; (B) WOG; and (C) Reciproc. High-magnification (250×) view showing fatigue striations typical of cyclic fatigue (arrows)

In our study, we compared the cyclic fatigue resistance of Hyflex EDM, Reciproc, and WOG. Each file was tested in the simulated root canal until instrument fracture occurred. The time to fracture in seconds was multiplied by the number of rotation cycles per second (rpm/60) to obtain the NCF for each instrument (Kiefner 2014).[11-13] According to the results of the present study, the cyclic fatigue resistance of Hyflex EDM is higher compared with the other file systems used (Table 1). The difference was found to be statistically significant at $p < 0.001$ (f-value = 1963.7). The Hyflex EDM One File (HEDM; Coltene/Whaledent AG, Altstatten, Switzerland) is a novel instrument designed and marketed to shape root canals using a single-file technique in continuous rotation. The Hyflex EDM is manufactured using the technique of EDM. Electrical discharge machining can be used to manufacture all types of conductive materials (e.g., metals, alloys, graphite, ceramics, etc.) of any hardness with high precision.[14-17]

Figure 3 illustrates SEM analysis of the fracture surface confirmed typical features of cyclic fatigue failure. Voids and cracks can be identified on all fracture surfaces.

Pedulla et al[18] stated that the new Hyflex EDM instruments (controlled memory wire) have higher cyclic fatigue resistance and angle of rotation to fracture but lower torque to failure than Reciproc R25 and WO primary files (M-wire for both files). No studies about cyclic fatigue of One Shape and Hyflex EDM are available. Wave One Gold file exhibits greater cyclic fatigue resistance than Reciproc and WO files in the apical and coronal curvatures. This could be due to metallurgical differences between instruments. Reciproc R25 and One Shape files are made with M-wire NiTi alloy, whereas WOG file is made with gold alloy.

Based on the results in this study, Hyflex EDM has shown higher cyclic fatigue resistance compared with the other files. This could be due to the microstructure (micrographs obtained on new EDM files revealed an irregular and a "crater-like" surface, i.e., typical superficial morphology of EDM materials. This superficial aspect represents an innovation in comparison with conventional NiTi files) and mechanical behavior of NiTi materials because NiTi instruments were deformed until the complete transformation to martensite phase; after that failure occurred at the ultimate tensile strength of this phase. There is manufactural difference between files, whereas Hyflex EDM is manufactured by using the technique of EDM and also having the property of controlled memory.

CONCLUSION

Within the limitations of this study, Hyflex EDM exhibited greater cyclic fatigue resistance when compared with other rotary and reciprocating files used in this study. This can be owing to manufactured difference between files. Comparing the other systems, WO showed greater cyclic fatigue resistance than Reciproc file. However, more studies are required to determine the cyclic fatigue resistance of file systems.

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