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Research Article

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Effect of glide path preparation with PathFile and ProGlider on the cyclic fatigue resistance of WaveOne nickel-titanium files

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ABSTRACT

Objectives: The aim of this study was to investigate the effect of glide path preparation with PathFile and ProGlider nickel-titanium (NiTi) files on the cyclic fatigue resistance of WaveOne NiTi files.
Materials and Methods: Forty-four WaveOne Primary files were used and divided into four groups ($n = 11$). In the first group (0 WaveOne), the WaveOne Primary files served as a control group and were not used on acrylic blocks. In the 1 WaveOne Group, acrylic blocks were prepared using only WaveOne Primary files, and in the PF+WaveOne group and PG+WaveOne groups, acrylic blocks were first prepared with PathFile or ProGlider NiTi files, respectively, followed by the use of WaveOne Primary files. All the WaveOne Primary files were then subjected to cyclic fatigue testing. The number of cycles to failure was calculated and the data were statistically analyzed using one-way analysis of variance (ANOVA) and the Tukey honest significant difference multiple-comparison test at a 5% significance level.
Results: The highest number of cycles to failure was found in the control group, and the lowest numbers were found in the 1 WaveOne group and the PF+WaveOne group. Significant differences were found among the 1 WaveOne, PF+WaveOne, and control groups ($p < 0.05$). No statistically significant differences were found between the PG+WaveOne group and the other three groups ($p > 0.05$).
Conclusion: Glide path preparation with NiTi rotary files did not affect the cyclic fatigue resistance of WaveOne Primary files used on acrylic blocks.

Keywords: Endodontics; Fracture strength; Glide path; PathFile; ProGlider; WaveOn

INTRODUCTION

When compared to manual files, nickel-titanium (NiTi) rotary files offer easier and faster root canal preparation, as well as higher success rates and lower rates of preparation failure [1]. Despite their numerous advantages, NiTi rotary files are at risk for unexpected fracture during clinical use [2]. Failure of NiTi rotary files occurs due to torsional fatigue or cyclic fatigue [3]. Failure due to torsional fatigue occurs when the tip or another part of the file is stuck within the root canal while the instrument is rotating in the root canal. In cyclic fatigue

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failure, the instrument is exposed to repetitive compression and tension forces while the file is rotating within the curved root canal space [4].

Advances in NiTi file technology have led to the production of instruments with different kinematics and advanced alloys in order to improve resistance to cyclic fatigue failure [5]. In response to the recommendation to prepare root canals using a single file with reciprocating motion [6], single-file reciprocating systems, such as the WaveOne (WO) NiTi file system (Dentsply Sirona, Ballaigues, Switzerland), were introduced to the market [7].

The manufacturer recommends glide path preparation using rotary files or manual files before using the WO file [8]. The glide path is defined as an unimpeded path of access to the root canal from the canal orifice to the apical foramen [9]. It can be prepared using manual files or NiTi rotary files; however, glide path preparation using a manual file can be difficult and time-consuming, especially in curved and narrow root canals [10]. For this purpose, NiTi rotary files, such as PathFile (PF; Dentsply Sirona) and ProGlider (PG; Dentsply Sirona), were introduced. PF NiTi rotary files have a 2% taper and are composed of 3 files with a square horizontal cross-section. PF #1 has a 0.13 mm tip diameter, PF #2 has a 0.16 mm tip diameter, and PF #3 has a 0.19 mm tip diameter. The PG file is the only NiTi single-file system that is manufactured from heat-treated M-Wire alloy for glide path preparation. The PG has a tip diameter of 0.16 mm with a square horizontal cross-section and a taper between 2% and 8%.

The aim of the present study was to examine whether glide path preparation using PF or PG files had any effect on the cyclic fatigue failure resistance of the WO single-file system. The null hypothesis was that there would be no significant difference between glide path preparation using PF and PG files in terms of their effects on the resistance of the WO single-file system to cyclic fatigue failure.

MATERIALS AND METHODS

Preparation of samples and acrylic blocks

Based on a previous study [11], a power calculation was performed, and the results indicated that the sample size for each group should be a minimum of 9 NiTi files. Thus, 44 WO Primary (25/0.08) files were included and divided into 4 groups ($n = 11$). In the groups where a glide path would be prepared, a new glide path file was used in the preparation of each acrylic block. Before use, all the WO, PF, and PG NiTi files were examined at ×20 magnification using a stereomicroscope (Olympus BX43; Olympus Co., Tokyo, Japan) to identify any deformations. Because no deformations were observed, all the files were included in the present study.

In total, 33 J-shaped transparent acrylic blocks (Endo Training Blocks ISO 15; Dentsply Maillefer)—11 for each of the experimental groups—were used. The acrylic blocks were 17 mm in length and had a 2% constantly increasing taper, a 10 mm radius, and a 70° angle of curvature.

Eleven WO Primary files were assigned to the control group (the 0 WO group) for cyclic fatigue testing without being used in any acrylic block. The remaining 33 WO Primary files were evenly divided into 3 groups ($n = 11$ per group) to be used in acrylic blocks:

In the 1 WO group, the acrylic blocks were prepared using WO Primary files without using any rotary glide path file beforehand.

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In the PF + WO group, after glide path preparation using PF #1, #2, and #3 files, the blocks were prepared using WO Primary files.

In the PG + WO group, after glide path preparation using a PG file, the acrylic blocks were prepared using WO Primary files.

The preparation was started after manually checking the patency of the acrylic blocks using a #10 K-type (VDW, Munich, Germany) file. In accordance with the manufacturers' recommendations, the PF and PG files were used at 300 rpm and 5 Ncm, whereas the WO files were used with the WO ALL program in an endodontic motor (VDW Silver Reciproc, VDW). The WO files were used with a pecking motion during the preparation, and the files were removed from the canal after 3 or 4 reciprocating motions. Each time the file was taken out of the canal, the file was cleaned of debris using gauze and the canals were irrigated with ample distilled water.

Cyclic fatigue test

The 33 WO Primary files used to prepare the acrylic blocks and the 11 unused WO Primary files (control group) underwent cyclic fatigue testing. The device used for cyclic fatigue testing was a dynamic cyclic fatigue testing device consisting of a plastic support, where the handpiece is mounted, and segments where the stainless steel artificial canals are placed [12]. The starting point adjustment of the file can be set on the device. The time to failure (expressed in seconds) is monitored on the digital monitor; when the file fractures, the device stops and gives an audible alert. According to the criteria set by Pruett *et al.* [13], stainless-steel canals have a 60° angle of curvature and a 5 mm radius of curvature. The files were run with a 6:1 contra-angle handpiece (Sirona, Bensheim, Germany) in the WO all mode of the VDW Silver Reciproc device. The axial back-and-forth motion was set to be 3 mm/s on the device without any dwell time. To reduce the amount of heat occurring during the rotation of the file within the canal, the artificial canals were lubricated with synthetic oil (WD-40 Company Ltd, Milton Keynes, England). When the file fractured, the device automatically stopped and gave an audible alert. The time seen on the screen was recorded for each of the files. The number of cycles to failure (NCF) was calculated for each file by multiplying the rotational speed (rpm) by the time (minutes). The length of the fractured instruments was measured using a digital caliper.

To determine the type of failure, 2 files from each group were evaluated with a scanning electron microscope (SEM) (JEOL, JSM-7001F, Tokyo, Japan). The lubricant and debris on the fractured files were removed via activation with an ultrasonic device in ethyl alcohol for 30 minutes. Then, photomicrographs were taken of the fractured file surfaces under various magnifications (×120 to ×3,000).

Statistical analysis

The data obtained were analyzed using SPSS version 21.0 (IBM Corp., Armonk, NY, USA). The normal distribution of the data was confirmed using the Shapiro-Wilk normality test ($p > 0.05$), and the variance was confirmed to meet the homogeneity assumption using the Levene test ($p > 0.05$). In the present study, 1-way analysis of variance and the Tukey honest significant difference multiple-comparison test were used to assess the differences among the numbers of cycles in the experimental setup established for the 4 different groups of files. All results were examined at a significance level of $p < 0.05$.

Table 1. Mean and standard deviations (SDs) of the number of cycles to failure (NCF) and the fractured length (FL) (mm) of the tested WaveOne (WO) Primary files

Group	NCF	FL (mm)
0 WO	741.36[a] ± 71.52	6.24[a] ± 0.22
1 WO	605.28[b] ± 66.75	6.12[a] ± 0.18
PF + WO group	644.42[b] ± 81.97	6.05[a] ± 0.25
PG + WO group	668.18[a,b] ± 79.10	6.17[a] ± 0.19

Data are shown as mean ± SD. Different superscript letters indicate a statistically significant difference (p = 0.001).
PF, PathFile; PG, ProGlider.

RESULTS

A comparison of the groups' NCF values is presented in **Table 1**. Statistically significant differences were observed among the NCF values of the files in the 4 groups (p = 0.001). The highest number of cycles was observed in the control group (group 1), whereas the lowest numbers were found in experimental groups (the 1 WO group and the PF + WO group), and there were statistically significant differences between the 0 WO group ($p < 0.05$) and the 1 WO group and PF + WO group. No statistically significant difference was found between the PG + WO group and any other groups ($p > 0.05$).

In the SEM images of the fractured file surfaces, relatively flat areas were observed in the wide fibrous zone at the central position and at the edge zones. When the edge surfaces of files were examined under a high level of magnification, fatigue traces occurring due to cyclic fatigue could be observed (**Figure 1**).

DISCUSSION

NiTi files produced for single use reduce metal fatigue and, consequently, diminish the risk of failure, but the risk of failure within root canals cannot be totally eliminated [7]. For this reason, files produced for single use in the preparation of root canals are at risk for cyclic fatigue failure during clinical use depending on the curvature of the canal [7]. Rotary glide path files were introduced to the market to enlarge the glide path, which is prepared before using NiTi rotary files in the root canals. The aim of the present study was to examine the effects of using WO files in root canals with or without rotary glide path files on the cyclic fatigue resistance of WO files. Based on our results, the null hypothesis was rejected, because statistically significant differences were observed between the groups.

Cyclic fatigue tests can be performed with static or dynamic models. It is thought that the forces accumulating at a single point induce microstructural changes in the alloy, making it necessary to perform the preparation of curved canals with a continuous pecking motion [14]. Therefore, the present study employed a dynamic cyclic fatigue testing device to determine the files' resistance to cyclic fatigue failure.

Extracted teeth better reflect clinical conditions than artificial canals. Because 2 root canals are never identical to each other, they cannot be anatomically standardized, and they may include different variables that can influence the study results [15,16]. For this reason, artificial canals made of acrylic material were used in the present study in order to evaluate the effects of root canal preparation on the WO files.

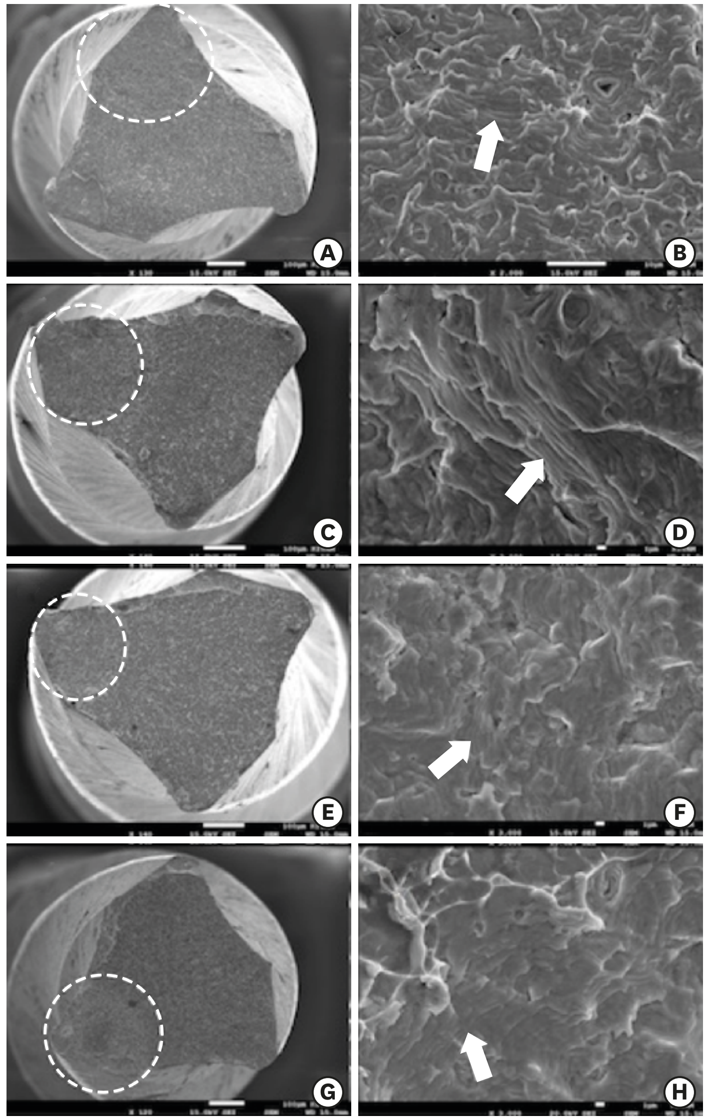

Figure 1. Scanning electron microscopic images of the WaveOne (WO) Primary files after cyclic fatigue testing. Views of the fractured surface in (A) the 0 WO group; (C) the 1 WO group; (E) the PF + WO group; (G) the PG + WO group, and high magnification views of (B) the 0 WO group; (D) the 1 WO group; (F) the PF + WO group; and (H) the PG + WO group showing typical fatigue striations indicative of cyclic fatigue.
PF, PathFile; PG, ProGlider.

It has been reported that glide path preparation and preliminary preflaring reduced stress on the files [17,18], resulting in a less dramatic pecking motion being needed to reach the apical segment and allowing the files to easily access the apex [19,20]. Berutti *et al.* [21] examined the level of torque, time, and pecking motion needed for ProTaper Next X1 (Dentsply Sirona) when the glide path was prepared on acrylic blocks using PG and PF files. The authors reported that ProTaper Next X1 files were exposed to lower stress levels and that the time needed to access the apex was shorter when a PG file was used for the preparation because of its higher level of expansion in the coronal and middle thirds of the root canal. It has also been reported that the increasing taper structure of PG files provides the file with more volume than files with a constantly increasing 2% taper [22]. In this case, the diameter of the PG file at 16 mm was 0.82 mm, whereas the diameter of PF #3 at 16 mm was 0.51 mm [23]. In the present study, it is thought that the high level of cyclic fatigue resistance observed in the

PF + WO group occurred because the PG file provided a greater width in the canal than the ProFile file due to the progressively increasing taper of the PG file, and because the WO files were used in wider canals.

In the present study, no statistically significant difference in terms of cyclic fatigue values was observed between the groups in which the preparation was performed. In a recently published study [24], in which the effects of glide path preparation with a PG file on the cyclic fatigue resistance of Reciproc (VDW) and Reciproc Blue (VDW) files were examined, similar results were observed. It was found that glide path preparation of a mandibular molar tooth using a PG file did not affect the cyclic fatigue resistance of Reciproc and Reciproc Blue files.

Türker *et al.* [25] examined the effects of glide path preparation using ProFile files on the surface topography and surface quality of WO and OneShape files used in one to three canals by using an atomic force microscope (AFM) that provided 3-dimensional images. Considering that defects on the surfaces might cause cracks to initiate, thus reducing the cyclic fatigue resistance of the files, AFM could provide valuable insights into the surface roughness ratios that might cause defect formation [26]. The results of the study of Türker *et al.* [25] showed that the preparation of a glide path did not result in a significant difference in the surface topographies of either single-file system when compared to the group in which no glide path was prepared. In this study, glide path preparation with NiTi rotary files did not affect the cyclic fatigue resistance of WO NiTi files at a statistically significant level. This may have occurred because preparation of the glide path did not affect the surface roughness values that could contribute to the early failure of the WO NiTi files used in acrylic canals.

No statistically significant difference was found in cyclic fatigue resistance between the WO group of files (PG + WO group), which were used on acrylic blocks in which a PG file was used previously, and the control group files (0 WO group), which were not used in any acrylic block preparation. No definitive interpretation can be made regarding how torsional stresses, to which WO files used in acrylic blocks before are exposed, affect the cyclic fatigue resistance of instruments. However, Cheung *et al.* [27] reported that torsional stress not exceeding the elastic limit could increase the cyclic fatigue resistance of an instrument. It is recommended that studies be carried out in the future to examine how exposure of thermo-mechanically treated files to different torsional stresses within the canal affects the cyclic fatigue resistances of files. It is also recommended that the effects of different alloys on cyclic fatigue resistance be metallurgically examined.

Cunha *et al.* [28] prospectively examined failure incidence of WO files during clinical use in 2,215 root canals (on 711 posterior teeth) for 18 months. After preparing the glide paths using K-type manual files or ProFile rotary files, depending on the clinical requirements, they prepared the canals using WO files. The incidence of instrument failure during usage was found to be 0.13%. It was concluded that the low failure incidence of WO files might have been related to their metallurgical properties, reciprocating motion, and the files' single-use character. Karova and Topalova-Pirinska [29] carried out a study on how many acrylic blocks could be prepared using WO files before failure when the glide path was prepared using a ProFile instrument, and they reported that many more acrylic blocks could be prepared if the glide path was prepared with a ProFile instrument.

Shen *et al.* [8] investigated the surface deformations of 438 WO files after single use by different operators in different clinics and found that 9.1% of the files (9.6% of which were found to have defects) were distorted and 0.5% were fractured. It is thought that the low failure incidence of WO files can be partially explained by the manufacturer's decision to produce them in single-use form. In the present study, preparation of the glide path using rotary NiTi files was found to have no effect on the cyclic fatigue resistance of WO Primary files used once in artificial canals. Corroborating the results obtained in previous studies, the results achieved in the present study are believed to be due to the fact that WO files are produced as single-use files.

CONCLUSIONS

Within the limitations of the study, the use of a NiTi rotary glide path file in root canal preparation had no significant effect on the cyclic fatigue resistance of WO files. However, glide path preparation using a PG file increased the cyclic fatigue resistance of WO files to the point of equaling the resistance of an unused WO file in an artificial canal.

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