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Topographic analysis of HyFlex EDM Glide Path, ProGlider, TruNatomy Glider, and WaveOne Gold Glider after micro-glide path preparation in simulated root canals with single curvature

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Purpose: This study aimed to compare HyFlex electrical discharge machining Glide Path, ProGlider, TruNatomy Glider, and WaveOne Gold Glider in terms of topographic changes after instrumentation.

Methods: Simulated canals with 40° curvature were used to analyze the surface behavior of four brands of micro-glide path files (n = 36 in total, n = 3/subgroup). The files were used in single or three simulated canals for micro- glide path preparation. Surface topographies were evaluated using atomic force microscopy. The data were analyzed with Shapiro–Wilk and two-way robust analysis of variance tests.

Results: RMS median values did not differ according to the file groups ($p = 0.448$) and use ($p = 0.055$). There was a significant difference between the intact WaveOne Gold Glider group and the use of 3 times ($p = 0.002$).

Conclusion: The tested files exhibited acceptable surface behavior considering single use but in multi-rooted teeth. However, it should be considered that more surface distortion occurs on the surface of heat-treated files when used for multiple roots, especially curved ones.

Keywords: Endodontics; HyFlex electrical discharge machining glide path file; micro-glide path; ProGlider; TruNatomy glider; WaveOne Gold glider.

Introduction

The fundamental goal of root canal treatment is the removal of all pulp tissue and residues, existing bacteria, debris, and the three-dimensional obturation of the system. There is an anatomical pathway in the root canal system due to the neurovascular bundle entering through the apical opening of the tooth and reaching the Raschkow plexus (1). When the instrumentation procedure has been completed, the root canal should have an incessantly tapered tunnel form from the canal orifice to the apex to provide a sufficient place for endodontic filling materials and preserve the original root canal anatomy (2). Since the development of nickel-titanium (NiTi) metallurgy, shaping protocols have shifted from stainless steel files to NiTi engine-driven file systems to reduce instrumentation time and facilitate root canal preparation (3). However, the most common disadvantage of NiTi instruments is the high risk of instrument fracture, especially when preparing curved or narrow root

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canals (4). Besides, before the shaping process, it can be challenging to negotiate within the anatomical path using endodontic instruments, especially in curved and narrow ones (1,5). The glide path is defined as a smoothly centered tunnel from the canal orifice to its terminus, and the instrument should follow the root canal walls without interruption (1). Creating a glide path has been shown to decrease the prevalence of instrument fracture and shaping complications, thereby being recommended as a clinical primary step for root canal preparation (6-8).

Instead of a glide path performed with hand files only, the new concept is a micro-glide path defined as automated glide path preparation using various kinematics with many brands of file systems produced from different heat-treated alloys.

ProGlider (PG, Dentsply Sirona, Ballaigues, Switzerland) is a glide path instrument using rotational movement made of M-Wire NiTi alloy with an ISO size 16 tip diameter, 2–8% variable taper, and the cross-section of the file is square horizontal (9).

WaveOne Gold Glider (WGG, Dentsply Sirona, Ballaigues, Switzerland) is a glide path file using reciprocating movement manufactured with a special heat-treated NiTi alloy known as Gold-Wire. WGG file has a parallelogram cross-section, ISO size 15 tip diameter with 2–6% variable taper (10).

HyFlex electrical discharge machining (EDM) (Coltene/Whaledent AG, Altstatten, Switzerland) instruments are manufactured with a thermo-mechanically treated alloy (Controlled Memory-Wire) using EDM where sparks are produced by high-energy and high-frequency electric discharges to lead melting and evaporation on the surface of the alloy. HyFlex EDM Glide Path File (HG) has ISO 10 tip diameter and variable horizontal cross-section along the cutting edges with a 3% constant taper. The cross-sections of the file are triangular in the coronal third, trapezoidal in the middle, and quadratic in the apical part (11).

TruNatomy (Dentsply Sirona Ballaigues, Switzerland) is made of a thin (0.8 mm) NiTi wire that becomes Super-Flex NiTi alloy by a post-manufacturing thermal treatment. TruNatomy Glider (TG) (Dentsply Sirona) has an ISO tip size of 17 and a regressive taper that averages 2%. The instrument cross-section design is an off-centered parallelogram and the maximum flute diameter (0.8 mm) is smaller than compared to the other glide path files (1.1 mm) (12).

To date, there are several methods to investigate the surface properties of NiTi instruments such as scanning electron microscopy, stereomicroscope, or atomic force microscopy (AFM) (13). AFM reconstructs three-dimensional imaging of the instrument surface and provides qualitative and quantitative data about the topography (14).

Despite a considerable amount of research investigating the surface properties of various file systems available, studies with glide path instruments are limited in the literature, especially the recently introduced TG instrument. Thus, this study aimed to compare PG, WGG, HyFlex EDM Glide Path File, and TG instruments in terms of their topographic changes on the surface after use for single and multiple canals with AFM. In this context, this study design was based on a null hypothesis that the absence of variations in surface deformation on different micro-glide path engine-driven files.

Materials and Methods

Sample Selection

Four commercially available brands of glide path files were used in the study as follows: PG 0.02/16 (PG, Dentsply Maillefer), WaveOne Gold Glider 0.02/15 (Dentsply Maillefer), HyFlex EDM Glide Path File 0.05/10 (Coltene/Whaledent, Altstätten, Switzerland), and TG 0.02/17 (Dentsply Maillefer). The files were examined using a stereomicroscope (Olympus SZ61 stereomicroscope: Olympus, Tokyo, Japan) under ×20 magnification for any existing surface defects. The samples demonstrating any deformations were excluded from the study. In a total of 36 samples, 9 in each brand used. Three of files were selected from each group as control and the others were allocated into two subgroups for evaluation of topography after single and there-times use (n = 3/subgroup) (Fig. 1).

Experimental Setup and Glide path preparation

Forty-eight fabricated endotraining resin J-type blocks (1 × 1 × 3 cm; canal length 16 mm, Dentsply Maillefer, Ballaigues, Switzerland) to simulate curved canals in a stan-

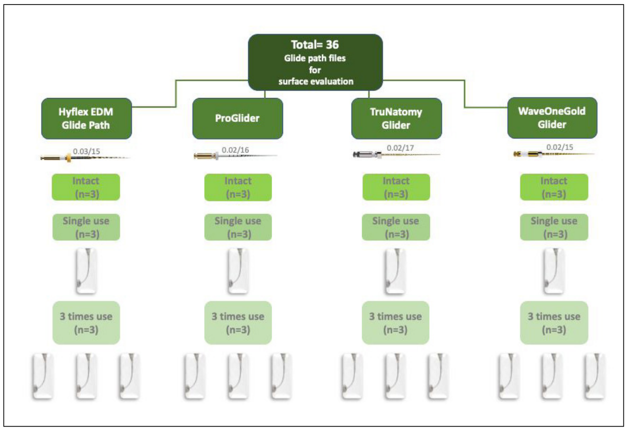

Fig. 1. Representative experimental setup of the sample distribution and the study design.

Table 1. Mean and standard deviation of RMS values according to groups and usage

Number of usages	Group				Total
	Hyflex EDM Glide Path File	ProGlider	Trunatomy Glider File	WaveOneGold Glider File	
0	57.4 ± 21.5	61.5 ± 24.7	67.1 ± 21.3	34.2 ± 7.1	55.0 ± 23.0
1	57.5 ± 15.9	64.8 ± 37.2	69.0 ± 18.2	64.7 ± 32.4	64.0 ± 27.3
3	59.1 ± 32.4	86.5 ± 40.5	69.0 ± 47.6	69.6 ± 17.8	71.0 ± 37.0
Total	58.1 ± 24.3	72.8 ± 37.7	68.6 ± 33.1	60.5 ± 26.9	65.0 ± 31.3

	Test statistics	Sd	p
Group	0.885	3	0.448
Number of usages	2.910	2	0.055
Group * Number of usage	20.678	6	0.002

*Robust 2-way ANOVA.

Table 2. Descriptive statistics and multiple comparison results of RMS values by groups and usage

Number of usages	Group				Total
	Hyflex EDM Glide Path File	ProGlider	Trunatomy Glider File	WaveOneGold Glider File	
0	48.9 (34.4 – 96.1) ab	56.2 (24.3 – 98.4) ab	59.9 (29.3 – 90.9) ab	34.1 (25.9 – 45.4) b	48.0 (24.3 – 98.4)
1	53.4 (38.8 – 104.3) a	51.3 (20.8 – 164.7) ab	71.8 (21.6 – 108.7) a	66.9 (23.5 – 141.4) ab	59.7 (20.8 – 164.7)
3	54.6 (21.7 – 127.6) ab	78.2 (36.3 – 190.7) a	53.8 (27.9 – 234.7) ab	67.5 (25.9 – 108.6) a	67.5 (21.7 – 234.7)
Total	49.9 (21.7 – 127.6)	66.8 (20.8 – 190.7)	61.0 (21.6 – 234.7)	61.2 (23.5 – 141.4)	59.9 (20.8 – 234.7)

[a-b]No difference between interactions with the same letter. The significance level was set as $p<0.05$.

dardized manner were selected. The diameter and taper of all artificial canals were equivalent to a standard ISO size #10. The artificial canals of the blocks have 11-mm long the straight part while the curved part was 5-mm long and the curvature angle was 40°. The canals were controlled for apical patency with a #6 K file. The working length was determined as 0.5-mm short of the apical exit under a stereomicroscope for a length of 15.5 mm. The glide path preparation was conducted according to the manufacturer's recommendation of each brand with an endodontic handpiece (X-Smart Plus, Dentsply Maillefer) for single or three simulated canals.

- Group 1: HyFlex EDM Glide Path file (300 rpm/1.8 Ncm) with rotational movement
- Group 2: PG file (300 rpm/5 Ncm) with rotational movement
- Group 3: TG file (500 rpm/1.5 Ncm) with rotational movement
- Group 4: WaveOne Gold Glider (WAVE ONE ALL mode/170°CCW, 50°CW) with reciprocating movement

The glide path procedure comprised pecking depth limited to <2 mm. The debris was removed from the surface of the file following every 3 strokes, and the simulated canals were flushed with saline. After glide path creation at the working length, the file surface was irrigated with saline and allowed to dry. The samples of the groups were mounted to a metal base with cyanoacrylate rapid-drying glue. Topographic surface evaluation of each instrument was accomplished using AFM (Multi-Mode 8, Veeco Ins., Santa Barbara, CA, USA). The surface analysis was conducted at 3-mm tip of files on 11 different randomized points. The digital AFM imaging (5 μm × 5 μm) of the instruments was obtained using the non-contact mode operation under ambient conditions. The root mean square (RMS) values of the instruments' topography were recorded for the deterioration caused by instrumentation.

Statistical Analysis

Statistical analyses were performed with R-Project Software for Mac OS (www.R-project.org). Data were presented as mean, median, and standard deviation values. RMS data were analyzed using the Shapiro–Wilk test to verify the assumption of normality. A two-way robust analysis of variance test was used using the WRS2 package to compare values according to group and usage. The significance level was taken as $p < 0.05$.

Results

RMS median values did not differ according to the groups ($p = 0.448$). There was no statistically significant difference between RMS values according to use ($p = 0.055$). RMS median values differ according to the group and usage time interactions ($p = 0.002$) (Table 1). The highest median value was 78.2 in the 3 use of the PG group, while the lowest median value was 34.1 in the 0 use of the WGG group. There was a significant difference between the WGG control group and the use of 3 times. Detailed statistic report is shown in Table 2. Section analysis and three-dimensional AFM images at apical 1–3 mm level of glide path files of groups are presented in Figs. 2 and 3.

Discussion

Over the years, various efforts have been made to improve the safety and mechanical efficiency of NiTi endodontic file systems, but there are still risks of fracture for various reasons. To reduce the risk of fracture of NiTi shaping instruments, the importance of preparing a glide path beforehand has been emphasized (15-17). However, considering the need to create a glide path in the calcified, narrow, or curved root canals initially, the instruments are likely to be exposed to frictional forces or torsional and cyclic stresses due to contact with entire dentin walls. Torsional stresses accumulate during Ni-Ti rotary instruments advance through the root canal which can be classified as dynamic or static (18,19). Dynamic torsional stress resulting from frictional forces is related resistance of dentin to cutting action. Static torsional stress occurs when the tip of the rotating NiTi instrument is stuck inside the root canal when the coronal part of the instrument continues to rotate. Repetitive cycles of compression and tension, when they rotate inside curved canals, may cause flexural stress (cyclic fatigue) accumulated in NiTi rotary instruments that can result in irreversible damage to the structure of the instrument (20,21). The majority of glide path files have a small taper and small cross-section size. It was reported that the files used for glide path preparation have sufficient flexibility and fatigue fracture resistance, however, vulnerable to torsional stress (22). In a recent study, it was found that flexural stress affects torsional stress negatively (20). Therefore, curved canals were used in the present study to take into account the flexural and frictional stresses. The artificial root canals in the casting resin provide standardization of the root canal diameter, curvature, and length. Considering that changes in root canal volume or diameter of natural teeth may cause differences in results, resin blocks were used in the study (23).

Sodium hypochlorite is an essential agent for root canal treatment with its antibacterial, organic tissue dissolution, as well as lubricant characteristics (2). However, the solution may cause deformation on the file surface (24). To exclude additional abrasions that may occur on the file surface due to different factors, in this study, the irrigation during preparation was conducted using saline solution.

Although single-use of NiTi files is widely recommended and safe, clinicians often use the file in 4 different canals when treating multirooted teeth. It was reported that NiTi files can be used up to 3 times in root canals; therefore, in multiple rooted teeth, the suitability of a file for reuse is often determined by simple visual inspection (24). A previous study showed that rotary files had 16.2% and 22.9% defects when assessed with a naked-eye examination and using a stereomicroscope, respectively (25). Therefore, it was aimed for this study to evaluate the surface change of the files after multiple uses with AFM, considering and mimicking the clinical usage for multi-rooted teeth.

Initial surface topography before clinical use may differ due to variations in the manufacturing process and polishing procedures used by manufacturers (26). This situation does not indicate the mechanical resistance or endurance capacity of the instruments. However, the degree of surface deformation after clinical use may signalize the fatigue level. Lopes et al. (27) reported that the increase in surface roughness of instruments shortens the fatigue life.

In a surface topography evaluation conducted by Keskin et al. (21), the similarity between the parameters of surface roughness of new and used PG instruments was reported. Similarly, the present study presented no significant surface deterioration when used in single or three canals compared to intact ones, except for the WGG instrument. According to the findings in the literature, WGG was reported to have lower buckling and bending strength compared to PG (28). The authors concluded that the lower bending strength means that the WGG file is more flexible than the PG file and it is possible to state that the instruments, which have superior flexible characteristics, have lower resistance to bending. For glide path instruments to approach the apical region, high buckling resistance is preferred during root canal negotiation (29). In the present study, there was no difference in surface deterioration between WGG and PG instruments in 1 and 3 times multiple uses. Using the WGG file 3 times in curved canals increased surface deterioration compared to intact ones. The bending and buckling resistance may be affected by instrument diameter, cross-section, taper, and NiTi alloy, which are difficult to standardize (28,30,31). The diameters and tapers of PG, WGG, and TNG files are similar, while the HG file has a smaller diameter and larger taper compared to other instruments. Despite the different cross-sections, HG showed similar surface degradation with the others in both intact, single, and multiple uses. Each of the files used in this study was produced with different thermally treated alloy techniques. Instruments produced by applying special heat treatment have been mentioned to present similar or higher torsional strength compared with traditional NiTi instruments despite similar cross-sectional features (22,32-34). In a study evaluating different glide path systems produced from M-Wire, CM-Wire, and conventional NiTi alloy, it was found that files produced with heat-treated alloy had similar torsional strength values, and their torsional strengths were higher than traditional NiTi alloy (35). In another study, Yılmaz et al. (36) investigated the cyclic fatigue resistance of PG and HG files and found that they were similar. Consistently, surface distortions of HG produced with CM-Wire with EDM and PG produced with M-Wire were found to be similar in this study. The fact that there is no difference in the surface roughness of the files in the intact, 1, and 3 times multiple uses may be related to the special heat treatment applied to the alloy. However, although there is no difference in WGG files when compared with other glide path files, there was a statistically significant difference between the intact and 3 times multiple uses. Increased surface degradation, when used 3 times of WGG instruments, may be correlated to the Gold-Wire technology, which provides more flexibility and, as a result, less rigidity (37). Either, the surface coating may have been abraded without mechanical distortion of the file. Although WaveOne Gold and Reciproc Blue were reported to be more resistant compared to each other, WaveOne and Reciproc among themselves (38), the findings of the study by AlRahabi and Atta also support the proposition mentioned above (26). Their study showed that WaveOne and Reciproc files had significantly lower levels of surface distortion after root canal instrumentation compared to surface heat-treated equivalents such as WaveOne Gold and Reciproc Blue.

In a recent study, TruNatomy and WaveOne Gold shaping files were examined with a profilometer in terms of surface roughness. It was reported that the tested files showed similar surface behavior after 1 and 2 times usage on curved artificial canals (39). Similarly, in the present study, no difference was found between the glide path files of TruNatomy and WaveOne Gold in terms of surface deterioration in a single use.

Pre-clinical studies reflect the situations in a standardized manner; therefore, clinical variables are kept as constant as possible, ensuring clear answers to questions asked about the material being studied. These studies are the first step of material studies; however, the data obtained from laboratory studies do not fully reflect clinical outcomes. Therefore, the main limitation of this study is the use of simulated root canals. For the limitations and the clinical implication of the experimental setup, further investigations are required to assess its correlation with the cutting efficiency, the risk of fracture, and metallurgic response, as well as clinical behavior in vitro and in vivo.

Conclusion

The tested files exhibited acceptable surface behavior considering single use in multi-rooted teeth. However, it should be considered that more surface distortion occurs when using the surface of gold heat-treated files on multiple roots, especially curved ones. Clinicians have to consider that the files used for micro-glide path preparation always have a tendency to deformation after multiple use they have been used.

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