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Cyclic Fatigue Resistance of Five Different Glidepath Files in a Double Curved Artificial Canal

Mohsen Aminsobhani [a,b], Naghmeh Meraji [c*], Elaheh Azizlou [d], Ehsan Sadri [e]

a Department of Endodontics, School of Dentistry, AJA University of Medical Sciences, Tehran, Iran; b Department of Endodontics, School of Dentistry, Tehran University of Medical Sciences, Tehran, Iran; c Board Certified Endodontist, Private Practice, Tehran, Iran; d Department of Endodontics, School of Dentistry, Iran University of Medical Sciences, Tehran, Iran; e Private Practice, Tehran, Iran

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**Corresponding author*: Naghmeh Meraji, Board Certified Endodontist, Private Practice, Tehran, Iran.

Tel: +98 21 88815100
E-mail: meraji_n@yahoo.com

Introduction: The aim of this study was to examine the cyclic fatigue resistances #16 ProGlider, #15.02 Scout RaCe, #15.03 NeoNiTi GPS, One G and Path-File NiTi glide path files in S-shaped artificial canals. **Materials and Methods:** Twenty files from each group were tested. An artificial groove simulating double (S-shaped) curved canal measuring 1.5 mm in width at the top level decreasing towards the apical reaching 0.3 mm at the tip having a 0.06 taper, 18 mm in length, and 1.5 in depth machined in a stainless steel block was used in this study. Resistance to cyclic fatigue was determined by counting the numbers of cycles to failure (NCF). Furthermore, the fragment length of the fractured tips and angle and radius of curvature formed by each file in each trajectory were evaluated. The data were analyzed using the one-way analysis of variance and Tukey's HSD test and the level of significance was set at 5%. **Results:** NeoNiti GPS and Scout RaCe glide path files showed significantly higher NCF values compared to other evaluated glide path files ($P<0.001$) but no significant difference when compared with each other ($P=0.67$). **Conclusion**: Based on this *in vitro* study NeoNiti GPS and Scout RaCe glide path files had the highest cyclic fatigue resistance in simulated double (S-shaped) curved artificial canals among the evaluated path finding files. Therefore, it seems that they can be used with more confidence in endodontic treatment of S-shaped canals clinically.

Keywords: Cyclic Fatigue Resistance; Nickel Titanium; Root Canal Preparation

Introduction

Recent studies have highlighted the complexity of the root canal system [1-3], which can cause significant difficulties in endodontic treatment. Multiple root canal curvatures are an example of such clinical challenges [4-6]. Simple straight root canals are more of an exception than a rule in the human teeth. Root canal systems frequently have highly complex curvatures in different planes [4]. Cleaning and shaping of root canals with curves in three-dimensional orientations is a clinical challenge very much prone to different iatrogenic mishaps. S-shaped canals have been shown to create more stress on nickel titanium (NiTi) rotary files compared to single-curvature canals, thus, use of rotary files in root canals with double curvatures can more easily cause fracture of files due to cyclic fatigue [7].

When cleaning and shaping the curved root canals, creating a glide path before using larger NiTi rotary instruments is recommended. Glide path is described as a smooth and centered radicular tunnel from the orifice to the apical foramen or physiologic terminus of the root canal [8]. Negotiation and glide path preparation is a vital step for the assessment of the root canal anatomy and the establishment of a repeatable patent access to the apical portion of the root canal. Creating a glide path in a S-shaped root canal may be difficult.

Glide path establishment using manual files is difficult, time-consuming and may lead to a less centered canal preparation [9] with canal transportation [10], greater amounts of apical debris extrusion [11], higher incidence of post-operative pain and slower symptom relief [12].

Creating a glide path using rotary NiTi files may be more predictable, especially in curved canals [9]. It can lead to less deviation from the original root canal anatomy in comparison to manual files [13]. Recently, many glide path NiTi rotary files have been introduced to the market for glide path enlargement.

Scout RaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland) system consists of three instruments: ISO 10/0.02,15/0.02 and

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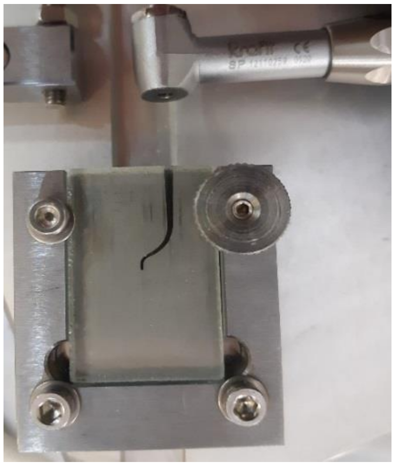

Figure 1. The artificial groove simulating a root canal with double (S-shaped) curvature used in this study

20/0.02 with a square cross-sectional design. These files are manufactured from conventional NiTi and have an alternating pitch between the flutes [14].

The PathFile (Dentsply Sirona, Ballaigues, Switzerland) NiTi rotary glide path file system consists of three files made of conventional NiTi alloy having different tip diameters (0.13, 0.16 and 0.19 mm). They have square cross-sections with four cutting edges and a 0.02 constant taper [13].

NeoNiti GPS is a NiTi glide path file which is manufactured using wire-cut electrical discharge machining (WEDM) process. It has a tip size of #15 with a 0.03 taper. The manufacturer claims that this file has undergone appropriate heat treatment that results in high flexibility and shape memory [15].

ProGlider (Dentsply Sirona, Ballaigues, Switzerland) is a rotary glide path instrument and is manufactured from heat-treated memory NiTi wire (M-wire). M-wire provides increased cyclic fatigue resistance compared to the conventional NiTi alloys [15, 16]. The ProGlider instrument has a tip diameter of 0.16 at D0, with progressive taper ranging from 0.02 to 0.08 and square cross-sectional shape [17].

One G (Micro-Mega, Besancon, France) is a glide path instrument manufactured from a conventional NiTi alloy with an asymmetrical cross-sectional shape, a 0.14-mm diameter at D0, and a constant 0.03 taper. The One G is designed with varying pitch lengths and different cutting blade dimensions to reduce the engagement of the instrument in the canals [18].

The aim of this study was to examine the cyclic fatigue resistances of #16 ProGlider, #15.02 Scout RaCe, #15.03 NeoNiti, One G and Path-File NiTi glide path files in S-shaped artificial canals. The null hypothesis was that there would be no significant difference between the cyclic fatigue resistances of the evaluated glide path files.

Materials and Methods

Since no extracted teeth or patients were needed in this study, no ethics committee approval was necessary. An artificial groove simulating double (S-shaped) curved canal was machined in a stainless steel block by computer-assisted milling and hardened with polished chrome plating. The groove measured 1.4 mm in width at the top level decreasing towards the apical reaching 0.3 mm at the tip having a 0.06 taper, 18 mm in length, and 1.5 in depth was used in this study. The first curvature was a coronal curve that had a 60° angle of curvature and a radius of 5 mm, and it was located 6 mm from the tip of the instrument. The second curvature was an apical curve that had a 70° angle of curvature and a radius of 2 mm, and it was located 2 mm from the tip (Figure 1) [19].

A 4-mm-thick glass was screwed in front of the simulated canal to prevent the instrument from slipping out.

The following NiTi rotary glide path files were evaluated in this study (*n*=20 each):

- NeoNiti GPS (Neolix, Châtres-la-Forêt, France) (tip size: 15, and 0.03 taper);
- One G MicroMega (Micro-Mega, Besancon, France) (tip size: 14, and 0.03 taper);
- Path File (Dentsply Sirona, Ballaigues, Switzerland) (tip size: 16, and 0.02 taper);
- ProGlider (Dentsply Sirona, Ballaigues, Switzer-land) (tip size: 16, with a variable taper);
- Scout RaCe (FKG Dentaire, La Chaux-de-Fonds, Switzerland) (tip size: 15, and 0.02 taper).

The handpiece of an endodontic electromotor (Endo E class, Marathon Saeyang Microtech, Daegu, Korea) with a reduction ratio of 1:16 was fixed above the block so cyclic fatigue could be assessed in a static mode.

After putting a glass slab on the block and fixing the hand-piece to the block with the file in it, the instruments freely rotated in a "static" mode (*i.e.,* without any pecking movement). To standardize the study a 300 rpm speed and 2 N/cm torque were applied for all glide path files. Liquid paraffin (Kimiagar Toos, Mashhad, Iran) was used as a lubricant during the file rotation and it was applied on the canal walls by a micro-brush [15]. The instruments were used until fracture occurred and the time to fracture was recorded in seconds by playing captured videos by Corel Video Studio ProX2 software (Corel Corp., Ottawa, Canada) and a chronometer with an accuracy of 0.1 sec. The number of cycles to fracture (NCF) was calculated using the following formula:

NCF=time (seconds) to fracture * rotational speed/60 [15]

The length of the fractured file tips was measured by Digimizer software version 5.4.1 (MedCalc Software, Ostend, Belgium).

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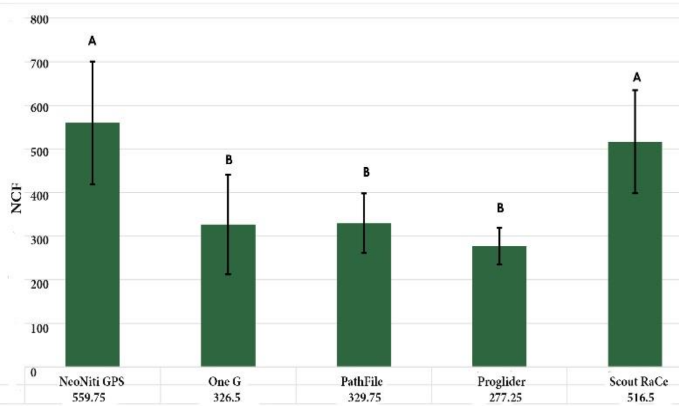

Figure 2. Mean NCF values of each experimental group. Groups with statistically significant differences are shown with different symbols (alphabets)

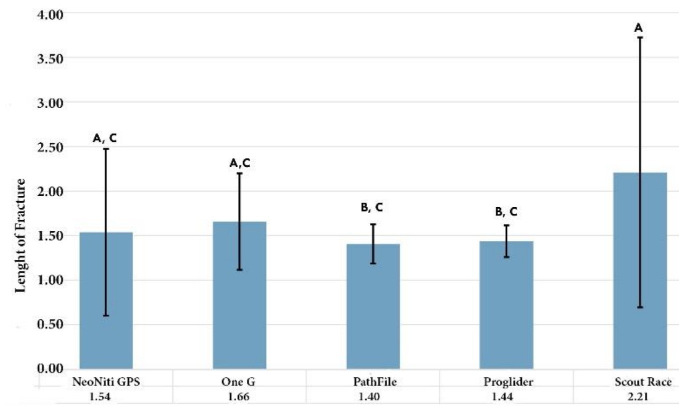

Figure 3. Mean length of facture of each experimental group (mm); Groups with statistically significant differences are shown with different symbols (alphabets)

Statistical analyses

Data were analyzed by one-way analysis of variance and Tukey's HSD test by SPSS version 22 software (Microsoft, IL, USA) to determine any significant differences between the groups, and the level of significance was set at 5%.

Results

The mean NCF values of each experimental group are shown in Figure 2. NeoNiti GPS and Scout RaCe glide path files showed significantly higher NCF values compared to other evaluated glide path files ($P<0.001$) but no significant difference when compared with each other ($P=0.67$). The NCF values of One G, Path File and ProGlider showed no significant difference with each other ($P>0.4$).

The mean length of facture of each experimental group are shown in Figure 3.

Most of the instruments broke at the first severe curvature. Two of GPS files and 5 of Scout RaCe files fractured at second curvature. One of the One G files fractured only after one sec that can be due to the manufacturing defects. When calculating the diameter of the files at the level of fracture, all file irrespective of the file type broke at the level having a diameter of 0.185-0.195 mm.

Discussion

Establishment of a glide path as the first step of root canal preparation can reduce the total torque generated by NiTi rotary files subsequently used in the root canal and the torsional stress on them [20, 21], thus can reduce risk of instrument failure [22]. However, glide path files themselves undergo cyclic fatigue during their use. It has been shown that cyclic fatigue resistance of files decrease in double curved root canals and fracture occur in shorter times in them compared to single curved canals [7]. The same is expected in the case of glide path rotary files.

Double (S-shaped) curvature was selected due to challenges in the preparation of these cases and its negative influence on the cyclic fatigue resistance of NiTi rotary instruments when compared with single-curved canals [7].

Occurrence of modifications in the root canal seems to be significantly reduced when glide path is established initially during canal preparation [23-25]. Furthermore, studies have reported no statistically significant differences in the angle of canal curvature and apical transportation when rotary or hand glide path files were used. However, the working time was significantly less when rotary glide path files were used [26, 27]. Therefore, in the current study rotary glide path files were evaluated. The aim of the current study was to compare the cyclic fatigue resistance of five NiTi rotary glide path files in simulated canals with double (S-shaped) curvatures.

In the current study, a stainless-steel artificial groove simulating double (S-shaped) curved canals was used instead of extracted human teeth as used in previous studies [7, 13, 15]. This substitution was made for better standardization of experimental conditions. One limitation of cyclic fatigue testing in steel canals, that instruments may fit loosely in the groove [28]. Small glide path files might not routinely encounter such conditions in clinical situations as in clinical conditions these files undergo torsional forces along their length simultaneously.

In the current study, the highest NCF values were seen in NeoNiti GPS and Scout RaCe. These values were significantly higher than other evaluated files, thus, the null hypothesis was rejected. Many factors have impact on the flexibility and cyclic fatigue resistance of instruments, including the type of alloy [29], heat treatment [30, 31], number of threads [32], helical angle [33], cross-sectional shape [32], and dimensions [34]. NeoNiti GPS files is manufactured of CM alloy that undergoes heat treatment, resulting in high flexibility and shape memory [15]. Previous

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studies have confirmed higher cyclic fatigue resistance in CM-wire rotary files [15, 35-38]. However, in the case of Scout RaCe, the high NCF values may be due to the 0.02 taper of this file making it flexible although made of conventional NiTi alloy [39]. Furthermore, some studies have shown that electro-polishing the surface of files, as seen in Scout RaCe, improves some of its working properties including failure resistance. Surface electro-polishing results in a smooth and homogeneous protective oxide layer on the surface of the files having less defects and residual surface stress [15].

According to the results of the current study, no significant difference was seen between the NCF values of One G, PathFile and ProGlider. Interestingly, ProGlider is manufactured of M-wire opposed to One G and PathFfile, which are made of conventional NiTi. Previous studies have shown M-wire alloy to have higher cyclic fatigue resistance compared to conventional NiTi [40, 41]. Considering the effect of taper on flexibility [39], the 0.02 taper of PathFfile versus 0.02 to 0.08 variable taper of ProGlider may justify the similarity seen between these two files despite of differences in alloy flexibility. Regarding One G has a three edge asymmetric cross section. Triangular cross-sectional geometries have been shown to exhibit higher cyclic fatigue resistance than a square cross section [42]. Furthermore, Inan *et al.* [43] reported One G to have smaller cross-sectional area than ProGlider when comparing corresponding points. For instance, at the D3 level, ProGlider had a cross-sectional area of approximately 26.500 μm^2 while this measure was approximately 19.500 μm^2 in One G at that level [43]. The smaller cross-sectional area of One G may compensate the effect of alloy on cyclic fatigue resistance causing similarity between these two files. Contrary to our results, some studies have reported higher cyclic fatigue resistance for ProGlider compared to PathFfile [40, 41] and One G files [44, 45]. These differences can be due to differences in methodology including angle and radius of curvature, number of curvatures (single *vs.* double) and distance of curvature from the apical end of the simulated canal.

Fragment length of the fractured tips is one of the factors influencing the success of the extracting or bypassing, then it has been investigated in this study. The longest broken piece was related to Scout RaCe (with an average of 2.21mm). In the study of Ya Shen *et al.*, length longer than 5 mm is one of the favorable factors for extracting or bypassing the fractured piece.[46] In the present study, most of the instruments broke at the first severe curvature irrespective of the file type. When calculating the diameter of the files at the level of fracture, all file irrespective of the file type broke at the level of having a diameter of 0.185-0.195 mm. Further studies are required regarding this matter. One of the One G files fractured only after one sec that can be due to the manufacturing defects.

Conclusion

NeoNiti GPS and Scout RaCe glide path files had the highest cyclic fatigue resistance among the evaluated path finding files. Therefore, it seems that they can be used with more confidence in endodontic treatment of S-shaped canals clinically.

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Conflict of Interest: ‘None declared’.

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