Comparison of the Cyclic Fatigue Resistance of 5 Different Rotary Pathfinding Instruments Made of Conventional Nickel-Titanium Wire, M-wire, and Controlled Memory Wire

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Abstract

Introduction: This study compared the cyclic fatigue resistance of current nickel-titanium rotary path-finding instruments. **Methods:** Five types of nickel-titanium rotary pathfinding instruments were used in steel canals with a 90° curvature and a curvature radius of 3 mm (n = 10) and 5 mm (n = 10). The cyclic fatigue of the following instruments was tested at 4 mm from the tip: PathFile (#16 and a .02 taper; Dentsply Maillefer, Ballaigues, Switzerland), G-File (#12 and a .03 taper; Micro-Mega, Besançon Cedex, France), Scout Race (#15 and a .02 taper; FKG Dentaire, La Chaux-de-Fonds, Switzerland), HyFlex GPF (#15 and a .02 taper; Coltene-Whaledent, Allstetten, Switzerland), and ProGlider (#16 with a mean taper of .04125 and a .02 at the first 4 mm from the tip, Dentsply Maillefer). The length of the fractured parts was measured, and the number of cycles to fracture (NCF) was calculated. The data were statistically analyzed using Kruskal-Wallis and Mann-Whitney tests (α = .05). After Bonferroni correction, the new P value was set as .005. **Results:** The difference in the cyclic fatigue of all the files at both curvatures was statistically significant (P values from .0035 to less than .0001). The ranking of the instruments from the highest to the lowest NCF was as follows: HyFlex GPF, G files, ProGlider, PathFile, and Scout Race. The length of the fractured part of the instruments was similar in all the groups ($P > .05$). All the tested instruments had a lower NCF at a curvature radius of 3 mm when compared with a curvature radius of 5 mm ($P < .0001$). **Conclusions:** Within the limitations of this study, the cyclic fatigue resistance of the HyFlex GPF instrument was the highest, and the curvature radius had a significant effect on the fatigue resistance. *(J Endod 2015;41:535–538)*

Key Words

Cyclic fatigue, endodontics, glide path, G-File, HyFlex GPF, nickel-titanium rotary instruments, PathFile, ProGlider, Scout Race

The endodontic glide path, which has been described as the sufficient patency from the canal orifice to the apical foramen, is important for safe root canal shaping procedures (1, 2). This initial root canal preparation is performed using small-sized and slightly tapered nickel-titanium (NiTi) rotary instruments or stainless steel files (3). The glide path preparation facilitates root canal preparation when NiTi instruments with larger tapers are used (4), and it can reduce the incidence of procedural errors (1, 5). Endodontic glide path preparation using hand files can be difficult and time-consuming for clinicians, especially in teeth with calcified and/or severely curved canals (6). Therefore, in recent years, investigations have focused on the instruments designed for glide path preparation with NiTi rotary instruments.

Instrument separation is the main problem with NiTi rotary instrumentation techniques. Cyclic and torsional fatigues are the 2 main mechanisms that may lead to instrument separation (7, 8). During root canal shaping procedures, part of the instrument binds to the dentin, and the rest of the file continues to rotate, resulting in torsional fatigue (8). When the instrument rotates in a curvature, it generates tension/compression cycles in the region of maximum flexure, and cyclic fatigue occurs (7). In actual clinical situations, rotary instruments are subject to varying loads, and fractures occur because of a combination of repetitive cyclic and torsional stresses (9).

PathFile (Dentsply Maillefer, Ballaigues, Switzerland), G-File (Micro-Mega, Besançon Cedex, France), and Scout Race (FKG Dentaire, La Chaux-de-Fonds, Switzerland) are endodontic rotary pathfinding instruments manufactured from conventional NiTi. PathFile and Scout Race instruments have 4 cutting edges with a square cross section. G-File has 3 cutting edges and an off-centered design, which generates traveling waves of motion along the active part of the file. Unlike PathFile and G-file, Scout Race has an alternating pitch between the flutes.

Recent technological advancements have produced NiTi instruments with improved alloys, which purportedly increase the cyclic fatigue resistance of the instruments. Several new NiTi rotary systems with fewer instruments have been developed to make instrumentation easier. ProGlider (Dentsply Maillefer) is a novel single-file rotary pathfinding system manufactured from heat-treated M-wire alloy. Unlike the other pathfinding instruments, ProGlider has a progressive taper from 2%–8% over its length and 4 cutting edges with a square cross section. HyFlex GPF (Coltene-Whaledent, Allstetten, Switzerland) is another novel rotary pathfinding system manufactured from a controlled memory NiTi wire. The control memory feature of these instruments make them extremely flexible and more resistant to cyclic fatigue than noncontrol memory NiTi instruments (10). Similar to PathFile and Scout Race instruments, ProGlider and HyFlex GPF instruments have 4 cutting edges with a square cross section.

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0099-2399/$ - see front matter

http://dx.doi.org/10.1016/j.joen.2014.11.008

In the literature, there are no current data on ProGlider and HyFlex GPF instruments. Therefore, the purpose of this study was to compare the cyclic fatigue resistance of these new pathfinding instruments with that of PathFile, Scout Race, and G-file instruments.

Materials and Methods

The cyclic fatigue of the following rotary NiTi pathfinding instruments was tested: PathFile (#16 and a .02 taper), G-file (#12 and a .03 taper), Scout Race (#15 and a .02 taper), HyFlex GPF (#15 and a .02 taper), and ProGlider (#16 with a mean taper of .04125 and a .02 at the first 4 mm from the tip). The cyclic fatigue life span of rotary instruments decreases with increasing instrument diameters (11). Because of the variety in apical size and taper designs, a common region (at 4 mm from the tip) having a similar diameter was determined in each pathfinding system by calculating the cross-sectional diameter. The cross-sectional diameter of each system was determined using the apical sizes and tapers of each system that were defined by the manufacturers. According to the preliminary data, for cyclic fatigue testing, the appropriate file size of each system was selected as having a similar diameter (0.235 $\pm$ 0.005 mm) at 4 mm from the tip. For standardization of the stress region of the instruments, a pilot study was performed to determine the working length of the instruments in the steel canals. In the study, before the main cyclic fatigue testing, samples from each brand of instrument were subjected to the testing apparatus described later. The working length of the instruments in the steel canals was set so the instruments were fractured approximately at 4 mm from the tip (Table 1).

Cyclic fatigue testing was performed on artificially constructed stainless steel canals (with an inner diameter of 1.5 mm) at a 90° angle of curvature and a curvatures radius of either 3 mm (n = 10) or 5 mm (n = 10) in air at a temperature of 23° $\pm$ 2°C. During the testing, a special oil (WD-40 Company, Milton Keynes, England) was used for lubrication. All the instruments were operated with a low-torque motor (VDW Silver; VDW, Munich, Germany) and were used according to the manufacturers' recommendations as follows: the PathFile, ProGlider, and HyFlex GPF at 300 rpm; the G-File at 400 rpm; and the Scout Race at 800 rpm. The instruments were rotated until fracture occurred, and the time to fracture was recorded in seconds. The length of the fractured file tip was measured with a digital microcaliper.

The number of cycles to fracture (NCF) was then calculated using the following formula: NCF = time (seconds) to failure $\times$ rotational speed/60. The data on the NCF and the length of the fractured parts of the instruments were subjected to the Shapiro-Wilk test to analyze the normality of the continuous variables and the Levene test to analyze the homogeneity of variances among the groups.

Because of the significant differences among the variances of the groups, a nonparametric analysis of variance test (Kruskal-Wallis) was used (P = .05). The Mann-Whitney U test was then used for multiple comparisons with Bonferroni correction, which reduced the P value to .005.

Results

The NCF and the length of the fractured part of the instruments for each brand are presented in Table 1. At both curvatures, there were statistically significant differences among the instruments. The HyFlex GPF had the highest NCF. The ranking of the other instruments was as follows: G-File > ProGlider > PathFile > Scout Race (P values from .0035 to less than .0001). In addition, the cyclic fatigue resistance of the instruments working in the canals with a radius of 5 mm was significantly higher than the ones with a radius of 3 mm (P < .0001). The length of the fractured part of the instruments was similar among all the groups (P > .05).

Discussion

Removing separated fragments is a challenging procedure, especially if the fragment is located in the apical third of the root canal. If an instrument fractures during glide path preparation and the fractured fragment cannot be removed, other instruments cannot reach the apex. Consequently, the root canal system cannot be completely cleaned. It is known that the cyclic fatigue of rotary instruments decreases with increasing instrument diameters (11). The metal mass of the instrument at the maximum stressed point also influences the cyclic life span (12). Because of the varying apical size and taper designs of the pathfinding instruments, in the present study instruments having different apical size were tested to get a similar instrument diameter at the maximum stress point. Recently, Capar et al (13) showed that different instruments subjected to the same cyclic fatigue testing setup (same working length) fractured at different working lengths. The researchers attributed their results to differences in the bending moments of the instruments, which were manufactured from different alloys and had varied taper designs. Thus, in the present study, the working length of the instruments was first determined in a pilot study to obtain a similar fracture point. Moreover, we ensured that the diameter of all the instruments was the same at the maximum point of stress (4 mm from the tip). However, the experimental set-up of the present study shows that use of different working lengths cannot be extrapolated to the clinical situations in which clinical files are introduced to the same working length in a canal. Therefore, further studies could be conducted comparing rotary NiTi pathfinding instruments using the same working length.

Different methods have been used to evaluate the cyclic fatigue resistance of NiTi files (14–16). Many studies have evaluated cyclic fatigue resistance by rotating NiTi files until fracture in a simulated canal machined in a steel block (16–20), as in the present study. One limitation of cyclic fatigue testing in steel canals, that instruments may fit loosely in the groove, was discussed previously in a review (21). Moreover, in this experimental design, the simulated canal would

TABLE 1. Mean Values ($\pm$ standard deviation) for Number of Cycles to Fracture (NCF), Fragment Length, and Working Length

Radius	Groups	n	NCF	Fragment length (mm)	Working length (mm)
3 mm	Pathfile	10	512 $\pm$ 82[a]	4.03 $\pm$ 0.16[a]	19.5
	Scout Race	10	372 $\pm$ 80[b]	4.14 $\pm$ 0.23[a]	19.5
	ProGlider	10	656 $\pm$ 92[c]	4.20 $\pm$ 0.29[a]	17.5
	G File	10	873 $\pm$ 147[d]	4.09 $\pm$ 0.26[a]	19.5
	HyFlex GPF	10	2059 $\pm$ 602[e]	4.23 $\pm$ 0.22[a]	18.5
5 mm	Pathfile	10	733 $\pm$ 104[a]	4.16 $\pm$ 0.13[a]	20.0
	Scout Race	10	588 $\pm$ 88[b]	4.24 $\pm$ 0.32[a]	20.0
	ProGlider	10	1056 $\pm$ 114[c]	4.14 $\pm$ 0.16[a]	17.0
	G File	10	1803 $\pm$ 417[d]	4.07 $\pm$ 0.18[a]	20.0
	HyFlex GPF	10	12887 $\pm$ 1851[e]	4.15 $\pm$ 0.12[a]	19.0

Different superscript letters indicate a significant difference between groups.