CYCLIC FATIGUE RESISTANCE OF CONTINUOUS ROTATION VERSUS RECIPROCATING GLIDE PATH NICKEL TITANIUM FILES IN ARTIFICIAL S-SHAPED CANALS (IN VITRO STUDY)

Hashem R Sherif [1*] BDS, Amr M Abdallah [2] PhD, Nihal A. Leheta [3] PhD

Introduction: A secure reproducible glide path is an essential prerequisite for introducing “Rotary nickel titanium” files into a canal. With the rise of engine driven instruments over the past decade, the creation of a Glide path “GP” using “Rotary nickel titanium” files would seem to be an easier and simpler approach whenever possible.
Aim of the study: To Examine and note the similarities or differences in cyclic fatigue “CF” resistance between two continuous rotation and two reciprocating GP “Rotary nickel titanium” files in artificial S-shaped canals.
Materials and methods: Four different GP files were used on forty artificial resin blocks. The files used were “Proglider” and “One G” files for continuous rotation files and “WaveOne Gold Glider” and “R-pilot” for reciprocating files. CF resistance was assessed through recording the time taken for each file to fracture inside the S-shaped canals in addition to the length of each fractured fragment. One-way ANOVA test was applied to compare between four subgroups of the two different filing techniques, followed by Tukey post hoc test to analyze the data.
Results: The number of cycles to fracture in the Reciprocating GP “Rotary NiTi” files were found to be statistically significa1*1**ntly higher when compared to Continuous rotation GP “Rotary NiTi” files (P value ≤ 0.05).
Conclusion: Reciprocating GP files promoted higher CF resistance than continuous rotation GP files.
Keywords: Cyclic fatigue, Glide path, Reciprocating, Continuous rotation.

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1 BDS, Faculty of Dentistry, Pharaohs University, Alexandria, Egypt.
2 Professor of Endodontics, Faculty of Dentistry, Alexandria University, Egypt.
3 Lecturer of Endodontics, Faculty of Dentistry, Alexandria University, Egypt.

***Corresponding author**
Email: *hashemrsherif@gmail.com*

INTRODUCTION

Over the past few decades, the manufacturer’s main goal while designing new “Nickel-Titanium (NiTi) Rotary” instruments had been to efficiently decrease the incidence of file separation inside the canal. Many different innovative designs and manufacturing processes had been used and tested only to confirm that CF and torsional fatigue (TF) were the two pivotal factors that would result in instrument separation inside the canal (1). However, canal curvature will always be the predominant risk factor for increased bending stresses, which may render the clinician to have no control over this (2).

Creating a secure GP is one of the suggestions to try to decrease the chance of instrument separation (3). This secure reproducible GP, which is known as gaining adequate patency along the canal till the apical foramen, is done by utilizing stainless-steel manual files or small-sized and slightly tapered “NiTi Rotary instruments” (3). The formation of that GP will provide an easier canal preparation when “NiTi” files with larger tapers are later introduced into the canal (4,5).

Since NiTi alloys were introduced in Endodontics for root canal preparation, a major drawback was realized due to the separation of a file inside the canal lacking previous warning (6). Different factors such as the kinematics of the instrument, the alloy from which it was manufactured, the operational settings used as well as the metallurgical properties of the instrument contribute to CF resistance of an instrument. This encouraged manufacturers to be creative when designing new instruments as well as considering factors such as; surface and thermal treatments for “NiTi” alloys, and also the hybridization of new movement schemes in shaping systems (7-9).

There are currently, more than one hundred and sixty automated instrumentation systems available all over the world, all created with different “NiTi” alloys(1). These alloys can vary from being heat-treated with both shape memory and super-elastic properties to being used as reciprocating or rotational kinetics to eccentric or centric motion with each technique possessing its advantages and disadvantages (9,10).

The “ProGlider” (Dentsply Sirona; Dubai, UAE) is a GP file, designed from an M-Wire alloy with a square cross-section. It possesses a progressive taper varying from 2% to 8%. The “ProGlider” has four cutting edges with a diameter of 0.16 mm at its tip. Proglider could perform easier canal preparation in the coronal portion owing to its progressive taper design. Hence it allows the progression of larger files inside the canal (10).

“One G” (Micro-Mega; Besançon, France) is a GP file of a conventional NiTi alloy, designed with an asymmetric cross-section. It has a triple cutting edge with a diameter of 0.14 mm at the tip and 3% constant taper along the shaft. The pitch of the “One G” files differs between the triple cutting blades that results in reducing the screwing effect and efficient elimination of the debris (10).

“Rotary NiTi” files with continuous rotation movement first pioneered this technique, then in 2008 “NiTi” files with reciprocating motion were stated to increase CF resistance by relaying less stress to the instrument than the continuous rotation files (11,12).

The “R-Pilot” (VDW; Munich, Germany) instrument is designed from an M-Wire alloy. It is characterized by a constant taper of 4% and an S-shaped cross-section with diameter of 0.12 mm at the tip (13).

Moreover, another reciprocating GP instrument, the “WaveOne Gold Glider” (Dentsply Sirona; Dubai, UAE) exhibited a variable taper (2-6%) with a tip diameter of 0.15 mm, however it is designed with different flute diameters (14).

Could the difference in cutting motions and alloy treatments be the deciding factor?

Accordingly, the objective of this study was to compare CF resistance between two continuous rotation and two reciprocating GP “Rotary nickel titanium” files in artificial S-shaped canals.

In the current study, the null hypothesis was that there would be no difference in cyclic fatigue resistance between reciprocating glide path files and continuous rotation glide path files.

MATERIALS AND METHODS

The current study obtained the ethical approval from the Research Ethics Committee, Faculty of Dentistry, Alexandria University, Egypt. Based on data from previous studies, forty files in total were used. Four groups of ten files each were used in transparent resin blocks with S-shaped canals supplied by Dentsply Sirona. These artificial canals had 16 mm length and 0.02 taper, exhibiting double curves, one coronal and one apical. The first curve in the coronal portion had a 30° angle of curvature with a radius of 3 mm, located 8 mm from the tip of the instrument, and the second curve was located in the apical portion with a 25° angle of curvature and a radius of curvature of 2 mm, found 2 mm from the tip (Figure 1, 2).

In order to prevent files from extruding beyond the apical foramen during preparation of the canal, cyanoacrylate adhesive was painted on the resin blocks around the apical foramen to allow the entire resin block to be exposed to visually observe the working files inside the clear resin blocks. The adhesive was then left to set for 24 hours.

Forty instruments were subjected accordingly to rotation or reciprocation at a fixed speed of 300 rpm with the “X-Smart IQ” endodontic motor (Dentsply Sirona, The Bay Gate - Dubai - United Arab Emirates). Each file was used in recommendation with the manufacturer’s instructions for speed and torque (300 rpm).

Torque was then adjusted to 2 N/cm so that it could minimize the friction of the file against the canal walls. The canals were irrigated by ethyl alcohol for lubrication. For each tested instrument, the time in seconds was recorded as the test was initiated using a digital stopwatch HS-3V-IRDT (Casio, Shibuya, Tokyo, Japan). Times recorded were input as (minutes: seconds: centi-seconds) and then transformed into seconds. Times recorded were then multiplied by the endodontic motor speed (300 rpm) to obtain the number of cycles to fracture according to the following formula (13):

NCF “Number of cycles to fracture” = “Number of rotations per second” (300 rpm) X Time till fracture (seconds). After each file fracture, the fractured segments, from the apex to the point of separation were measured using a digital caliper (Mitutoyo Corporation, Tokyo, Japan). The length of each fragment was recorded.

Statistical analysis

Mean values and standard deviations (SD) were calculated for each group. Data was analyzed using IBM SPSS software package version 22.0 (Armonk, NY: IBM Corp). CF data was then analyzed by One-way ANOVA test to compare between the four subgroups of the two different filing techniques, followed by Tukey post hoc test. Statistically significant level was set at p value ≤0.05.

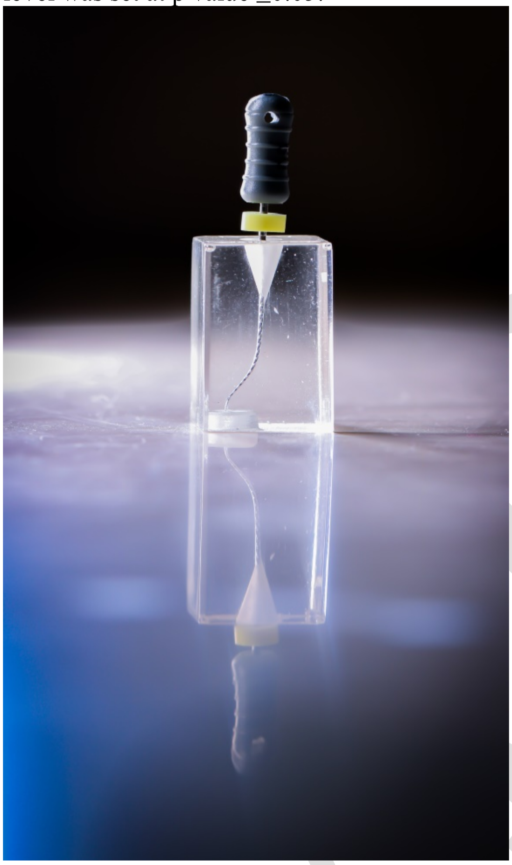

Figure 1: Transparent Resin Block with #8 file showing the S-shaped curve.

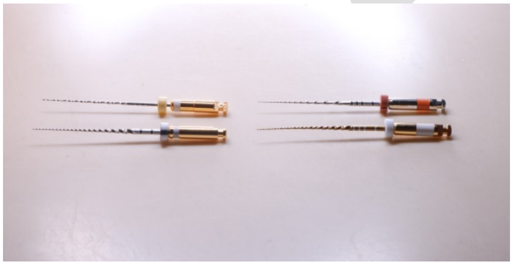

Figure 2: A= ProGlider, B= One G, C= R-Pilot, D= WaveOne GoldGlider.

RESULTS

(Table 1) displays Mean values ± SD expressed as NCF. A higher NCF was correlated with a higher resistance to CF of the tested instruments.

NCF in the Reciprocating GP "Rotary NiTi" files was found to be statistically higher significantly when compared to Continuous rotation GP "Rotary NiTi" files. The length of the separated fragment in the "WaveOne GoldGlider" files was found to be statistically significantly higher when compared with the other three subgroups, it was followed by "ProGlider" files which was found to be statistically significantly higher than "One G" files group and "R-Pilot" files group. There was no significant difference between "One G" files group and "R-Pilot" files group (Table 1).

Table 1: Mean (SD), minimum and maximum values of NCF and Fragment Length (FL) in mm registered during CF Testing in the S-Shaped canals.

Number of cycles to fracture (NCF)	ProGlider (n=10)	One G (n=10)	WaveOne GoldGlider (n=10)	R-Pilot (n=10)
Mean (SD)	1167.9 (106.6)	650.1 (104.2)	2336.3 (129.9)	731.8 (116.7)
Minimum	957	507	2118	1554
Maximum	1320	849	2548	1949
Length of the separated fragment (mm)	ProGlider (n=10)	One G (n=10)	WaveOne GoldGlider (n=10)	R-Pilot (n=10)
Mean (SD)	.1 (.336)	.9 (.310)	5.9 (.217)	.6 (.260)
Minimum	4.6	4.5	5.6	4.2
Maximum	5.6	5.6	6.3	5.0

*Statistically significant at *P* value ≤0.05

DISCUSSION

Endodontic GP is the creation of a safe reproducible pathway from the apex up to the canal orifice, which can be created either manually or with small tapered "NiTi Rotary" instruments.

GP creation is necessary for prevention of file separation inside the canal and to allow the use of "NiTi" rotary to maximum efficiency. It is generally accepted that a micro glide path prepared with size 8-10 hand K-files should be a prerequisite for any narrow root canals. It is accepted that the minimum acceptable size for a secure reproducible GP is for a size 10 K-file to be completely loose when centered inside the canal (3).

After which, preparation of a macro GP can be carried on either with hand files or with special rotary glide path NiTi files that would do the job faster. Among these rotary files, some depend on the concept of continuous rotation while others depend on the concept of reciprocation (14).

Using mechanical rotary path files to expand the micro GP would subject these files to different forms of stresses including CF and torsional loading. These stresses increase with the increase in the degree of canal curvatures and its anatomy. The presence of double curves like bayonet curves or S-shaped canals would further increase those stresses and would double the risk of rotary GP files separation during that step, as these complex curves and anatomies have proven to be some of the most difficult clinical situations exaggerating the CF effect on the files during preparation (14).

Cyclic fatigue tests are important to give the clinician an idea about the cyclic fatigue resistance of the file. However, the major disadvantage of most laboratory studies testing cyclic fatigue of rotary NiTi files is that there are many different factors and variables that can contribute to instrument separation inside the canal such as instrument design, cross-section and dimensions. These factors can't be eliminated which makes it extremely difficult to quantify the effect of a single variable on cyclic fatigue resistance of rotary NiTi files

Recently, reciprocation motion was added to newly created systems with the primary intention of shaping root canals by using only one file. According to the manufacturer's claims, this would allow clinicians to save time and cost for when performing routine root canal treatment. However, to achieve an accepted root canal preparation by using only one file would expose it to CF and TF (15). In the present study "ProGlider" "Rotary nickel titanium" files (2%-8% variable taper) and "One G" "Rotary nickel titanium" files (3% taper) were used to highlight the concept of GP preparation using continuous rotation. While, "Wave-One GoldGlider" "Rotary nickel titanium" files (2–6% variable taper) and "R-pilot" "Rotary nickel titanium" files (4% taper) were used to highlight the concept of GP preparation using reciprocating motion.

Ideally, In-vitro cyclic fatigue tests should be exhibited in curved canals of natural teeth. However, using natural teeth in such studies would make it impossible to standardize the experimental conditions as the natural canal geometry is variable and would be almost impossible to imitate. Therefore the decision to use standardized artificial canals in this study was made to minimize the influence of such variables not related to the mechanical and physical properties of the instrument itself.

Heat treatment of the cold-worked NiTi alloy in a temperature range around 450–550 °C is able to release the internal stresses and reduces the defects of the crystal lattice by giving the atoms enough thermal energy to rearrange themselves(2). Consequently, heat-treated NiTi alloy has significantly increased cyclic fatigue resistance and higher transformation temperatures than not heat-treated NiTi alloy(2,3). Additionally to the heat treatment procedure, the superelastic properties of NiTi alloy can be trained by thermal cycling under mechanical stress (usually in a cold bath at about 0–10 °C and a hot bath at about 100–180 °C under constraint elongation at 1–4%) resulting in an easier formation of the 'trained' martensite upon loading. The mechanical properties, transformation temperatures and phase compositions of NiTi endodontic alloy are mainly influenced by the unknown, proprietary thermomechanical treatment rather than the elemental composition (4).

According to a study conducted by Yao et al (16), the testing of standardized artificial canals in CF tests will hinder the effect of other variables. In the present study, the artificial S-shaped canals being tested was designed and created by mimicking the size and taper of the tested instruments to allow for testing under standard conditions.

In this study all four files were allowed to rotate or reciprocate in artificial canals in clear transparent resin blocks with S-shaped canals having 16 mm length and 0.02 taper supplied by Dentsply Maillefer. The degree of taper of these canals (0.02) did not allow path files with larger degree of taper to be seated at length. For the files to reach full length, each file was manipulated until it reached full working length and then it was allowed to keep working until file separation occurred. Allowing the files to rotate or reciprocate at the canal terminus without moving them in a vertical or an axial direction granted the reflection of CF on each file.

In the present study, the fabricated resin blocks were found to be ideal for testing CF as it simulated a complexity in the S-shaped canal anatomy exhibiting two curves; 30° coronal curvature and 25° apical curvature.

This allowed the files to be able to rotate or reciprocate freely inside the canal without having an abrupt curve leading to their premature separation. Other CF studies have used different angles of curvature for testing, ranging from 30° to as sharp as 90°. Sharper curvatures would of course impact the CF resistance of the tested instruments. (17-19).

Furthermore, the simulated two curves inside the resin block represented the following: the first curve at the coronal portion was located 8 mm from the tip of the instrument, while the second curve was located apically 2 mm from the tip.

Clinically, a curvature in the middle part of the canal would be defined as "The point of maximum curvature". While abrupt apical curvatures may be encountered clinically, they may not always be visible on the radiograph if the canal is curved in a buccal or lingual direction. Therefore "NiTi" rotary instruments must be designed with such flexibility to allow the clinician to operate safely even if there is an abrupt curve present inside the canal (20).

The "One G" file displayed the least number of cycles to fracture (NCF), which coincides with a study carried by Yilmaz et al (18), which compared the CF resistance of the "One G file" with that of the "ProGlider", "Hyflex EDM" and "R-pilot" GP NiTi files. These results would be attributed to the alloy as well as the design of the "One G" file which is created from a conventional NiTi alloy and designed to have an asymmetric cross-section (10).

Another GP "Rotary NiTi" file which utilized continuous rotation in this study was the "ProGlider", which exhibited a significant difference in the number of cycles to fracture (NCF) compared to the "One G" file. This was also concluded in another study conducted by Uslu et al (21), in which the CF resistance of the "ProGlider" file was compared with that of the "One G"files.

In another study conducted by Lee et al (10), which demonstrated similar results, the decisive factor was the M-wire alloy of the "ProGlider" files.

The principal features of the "ProGlider" are: A square cross-section with a semi-active tip, manufactured from an M-wire alloy. It also has 2-8% progressive taper along the shaft of the file. (10).

Another NiTi file made of M-wire alloy used in this study was the "R-pilot"; a reciprocating file which has a 0.12-mm tip diameter with constant 4% taper and an S-shaped cross-section (13).

The "R-pilot" exhibited a higher number of cycles to fracture (NCF) than the "ProGlider" file as also shown in a study conducted by Yilmaz et al (20) which stated that the reciprocating motion had been shown to increase the CF life of files and to prevent the accumulation of stress on the instruments (19,22,23).

The "R-pilot" had lower number of cycles to fracture (NCF) in this study when compared to "WaveOne" Gold although they both utilize reciprocating motion. These results were also demonstrated in a study made by Topçuoğlu et al (14) which stated that the greater CF resistance, achieved with the "Waveone GoldGlider" file, compared with the "R-pilot file", may be associated with the shape memory property of the "WaveOne Gold Glider" file being less than the "R-Pilot". It was also deemed that the alloy of an instrument may have a significant impact on its CF resistance (24,25). The alloys of the files tested in the present study were not similar. The "R-Pilot" was fabricated from an M-wire alloy, whereas the "WaveOne Gold Glider" was produced with gold-wire metallurgy.

Finally, results of the current study rejected the null hypothesis which postulated that there would be no significant difference in cyclic fatigue resistance between reciprocating files and continuously rotating ones. The sort of the alloy from which the file is made would be another important factor. New martensitic files would definitely improve the performance of "Rotary NiTi files" in canals with difficult anatomy.

CONCLUSIONS

Under the conditions of the present study, the following was concluded:

Reciprocating GP files have higher CF resistance than continuously rotating files.

Gold-wire heat treated files have a higher CF resistance than M-wire.

M-wire alloy files have a higher CF resistance than convention Niti files when used in continuous rotation.

S-shaped canals in resin blocks are a reliable method that can be used for testing the performance of rotary files.

CONFLICT OF INTEREST

The authors deny any conflict of interests related to the current study.

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