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ISSN No: 2319-5886

International Journal of Medical Research & Health Sciences, 2018, 7(11): 72-78

Cyclic Fatigue of Different Glide Path Systems in Single and Double Curved Simulated Canal: A Comparative Study

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ABSTRACT

Objective: *The study aims to compare the cyclic fatigue resistance of One G, ProGlider, HyFlex EDM gpf, WaveOne Gold Glider in a single and double curved simulated canals.* ***Method:*** *Total 120 glide path files were included and divided into 4 groups (n=30), and were then subdivided into 2 group (n=15) and were used in single and doubled curved canals. The NCF (number of cycles to fracture) was recorded and measured the fragmented length. Data were analyzed using ANOVA, post-hoc Tukey.* ***Result:*** *NCF were lower in double curved canal compared to the single curved canal (p<0.05) in all the groups. Both single and double-curved canals, NCF of WOG Glider group was significantly higher than other groups (p<0.05). In the doubled curved canal, NCF of HEDM gpf was higher than PG group (p<0.05), while in single curved canal value of HEDM gpf group was non-significantly different than PG group (p>0.05). In both single and double-curved canals, NCF of the PG group was higher than the OG group. No statistical difference in fragment length among instruments was used in single and double curved artificial canals.* ***Conclusion:*** *WOG Glider had a higher cyclic fatigue resistance than another glide path in single and doubled curved artificial canals.*

Keywords: Cyclic fatigue, Double curvature, WOG glider, HyFlex EDM, One G, ProGlider

INTRODUCTION

Even if Nickel-Titanium (NiTi) rotary endodontic instruments offer a greater advantage over stainless steel (S.S.) which allow proper canal shaping and reduce canal transportation, separation via torsional and cyclic fatigue is still a risk with NiTi instrument [1]. The superelasticity of NiTi allows fully recoverable deformation up to 8% strain as compared to 1% in stainless steel [2].

Although this flexibility is an important property that allows preparation of curved canals while minimizing transportation, NiTi instruments have a high risk of separation due to cyclic or torsional fatigue [3,4]. Fractures due to cyclic fatigue occur because of metal fatigue and are more prevalent in curved canals [5]. Removing separated instrument is a challenging procedure, especially if the fragment is located in the apical part of the root canal. If an instrument fracture during the preparation of the glide path and the fracture fragment cannot be removed, another instrument cannot reach the apex [6].

The glide path concept is defined as the space from the orifice to the apex, which is of significant importance for shaping the root canals safely [7]. The glide path is achieved when small-size flexible file slip, slide and glide through centerized canal [8]. Glide path management is the single most important step that influences the successful root canal treatment [9]. Hand file can be eliminated and replaced with a significantly more flexible, more comfortable NiTi mechanical glide path files [10]. It has been shown that mechanical glide path significantly reduce flare up, procedure error and chair time [11].

Many NiTi glide path files in the market facilitate the glide path management. ProGlider (PG; Dentsplysirona, Switzerland) PG was made of M-Wire alloy with square cross-section [12]. One G (OG; Micro-Mega, Besancon, France) OG made from conventional stainless steel had asymmetric cross-section [13].

HyFlex EDM (HEDM; Coltene/Whaledent, Altstätten, Switzerland) NiTi file is manufactured using the electrical discharge machining (EDM), the cross-sections had 3 different shapes along the shaft; quadratic in apical, trapezoidal in middle and triangular in coronal [14]. Recently WaveOne Gold Glider (WOG Glider, Dentsplysirona, Switzerland) increases patient safety with enhanced flexibility and reduces breakage. The WaveOne Gold Glider parallelogram cross-section is only for use in a reciprocating motion with compatible Dentsply Sirona motors [15].

MATERIALS AND METHODS

Total 120 path files were used in the study and assorted into 4 group (n=30) for each group, each group was then subdivided into 2 groups (n=15) for each subgroup:

- Group A: 31 G path files (14/0.03)
- Group B: 30 ProGlider path files (16/0.02)
- Group C: 30 HyFlex EDM path files (10/0.05)
- Group D: 30 WaveOne Gold Glider path files (15/0.02)

Criteria for Drawing Canal Curvature

To detect the curvatures of the artificial canals used in the study the canals were defined by both the radius and angle of curvature. Radii measured the inner aspect of the curve of the canal; the shape of canal curvature was more accurately described using 2 parameters:

The angle of curvature (a), and Radius of curvature (r) [16].

According to Pruett method, a straight line was drawn along the axis of the coronal part of the canal. A second line is drawn along the apical part of the canal. The curved portion of the canal is represented by a circle that touches at points (a) and (b), in which point a represents the beginning of canal curvature, and the point b represents the ending of curvature. The angle of curvature was the number of degrees on the arc of the circle between points (a) and (b). A circle which had these two points was traced, and the angle of curvature was measured as the angle formed by the circle at these two points. The radius of curvature corresponds to the radius of this circle [16].

Method of Canal Manufacture and Design

The canals were drawn in AutoCAD 2017 and then transferred to be analyzed by hyper spark laser machine. The two artificial canals were milled in S.S. (316) (Figure 1).

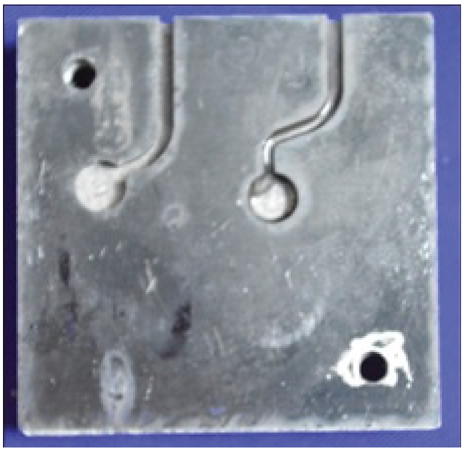

Figure 1 Block used in the study

The double-curved artificial canal had a coronal curve which had a 60° angle of curvature with 5 mm radius and the center of the curvature will locate 8 mm distant from the canal tip and the curve was 5.25 mm in length, while the second apical curve has a 70° angle of curvature with 2 mm radius and the center of the curvature was located 2 mm distant from the tip and the curve was 2.4 mm in length, the working length of the artificial canal was 18 mm, with 1.5 mm inner diameter of the canal [17]. The single-curved artificial canal had 60° angle of curvature with 5 mm radius, and the center of the curvature was located 5 mm from the tip of the canal and the length of the curve was 5.25 mm.

The working length of the artificial canal was 18 mm, 1.5 mm diameter of the canal. The end of each canal had a circle milled for standardization [18].

The artificial canal was covered with glass to prevent slipping of the instruments and allows for observation of the instrument during working and when a fracture happens, so the fragment was easily visible because the instruments were observed through the glass window [19].

Method

In the beginning, all the instruments were examined by microscope to see any deformation for exclusion, no instruments were discarded. The hand-piece (Wave one Electric motor, Dentsplysirona, Switzerland) was mounted on surveyor that control the dynamic hand-piece movement, and allows simple and precise placement of each instrument inside the artificial canals, ensuring 3-dimensional alignment of the instruments to the same depth each time [20].

The glass cover face was fixed on the block by bench vise and one screw after each test when the instruments fracture occurs, the block removed the cover swivel from the stainless-steel block, and then the fragment was removed from the canal by a tweezer. The block was fixed by bench vise to prevent movement and have a standard relation between the block and the surveyor through hand-piece for standardization, a wood was crafted so the block fit on it.

Each canal was filled with glycerin completely, before introducing each instrument to the exacted length (18 mm) inside the canal to reduce heat generation [21]. The files were activated inside the canals with no pecking motion using a 6:1 reduction handpiece powered by a torque-controlled motor device at speed recommended by the manufacturer

- Group 1: OG at 300 rpm and 1.2 gcm torque
- Group 2: PG at 300 revolutions per minute (rpm) and 200 gcm torque
- Group 3 HEDM pf at 300 rpm 1.8 gcm torque
- Group 4: WaveOne Gold Glider (reciprocation) 350 rpm

To prevent the human error and for standardization of this test, video recording was carried out at the same time for cross-checking the time of file fracture [22].

Measuring the Number of Cycles to Fracture

The time of fracture was recorded in seconds (from starting rotation within a canal until a fracture occurs) on a digital timer [18], and then the time was multiplied by the recommended speed (rpm) used to obtain the number of cycles to fracture (NCF) for each instrument as in this equation Fracture.

Measuring the Fracture Fragment

The fractured fragment length of each instrument was obtained by measuring the fractured instrument by digital Vernier, then subtracted from the instrument original length [23]:

Fractured fragment=original length - length of instrument after fracture.

Statistical Analysis

The NCF and the FL data were analyzed by using one-way analysis of variance (ANOVA), post-hoc Tukey tests. All of the analyses were performed using SPSS version 21 software (IBM-SPSS Inc., Chicago, IL, USA), and the statistical significance level was set at 5%.

RESULTS

In all the groups, NCF were significantly lower in double-curved canals when compared to single-curved canals ($p<0.05$). Both the single and double-curved canals, NCF of WOG Glider group was significantly higher than NCF of OG, HEDM gpf and PG groups ($p<0.05$). In doubled curved artificial canal, NCF of HEDM gpf group was significantly higher than PG group ($p<0.05$), while in single curved canal NCF of HEDM gpf group was found to be non-significantly different from PG group ($p>0.05$). Both of single and double curved canals, NCF of PG group was significantly higher than OG group ($p<0.05$). There was no statistical difference in fragment length among rotary instrument used in single and double curved artificial canal (Tables 1 and 2).

Table 1 Mean and standard deviation of the (NCF) in second and the fragment length in mm of the double-curved artificial canal

Glide Path File	Time to Fracture (sec)	Fragment Length (mm)
One G	225.400 ± 034.980	2.000 ± 0.185
ProGlider	369.860 ± 043.940	2.040 ± 0.223
HEDM gpf	525.800 ± 134.780	2.087 ± 0.220
WOG Glider	001.333 ± 000.172	2.060 ± 0.234

Table 2 Mean and slandered deviation of the (NCF) in second and the fragment length in mm of the single curved artificial canal

Glide path file	Time to Fracture (sec)	Fragment Length (mm)
One G	1303.20 ± 173.30	5.060 ± 0.209
ProGlider	1873.20 ± 257.05	4.773 ± 0.402
HEDM gpf	2006.60 ± 267.30	4.893 ± 0.332
WOG Glider	6563.07 ± 522.60	5.013 ± 0.253

DISCUSSION

The superelasticity of NiTi instruments allow clinicians to prepare well-centered curved root canals with reduced risk of ledging, perforation, and transportation compared with stainless steel files [24]. Nevertheless, there is a risk of instrument failure with NiTi files. To perform safe and efficient enlargement in curved root canals, it is recommended to create glide paths before the use of larger NiTi instruments. Since it is difficult to retrieve the fractured files from root canals and sometimes impossible as the remained fractured instruments may have an adverse effect on the root canal treatments outcome, therefore overcoming or reducing the risk of this problem is of great clinical importance [25]. Even if the extracted teeth models more extremely resembles the clinical situation, it wasn't an excellent model because no two root canals were exactly identical and the aim of many studies was to determine the NiTi files pure physical properties [3].

Artificial canals made from S.S were used extensively in laboratory studies to evaluate the fatigue resistance of NiTi files to ensure standardization of experimental conditions [26]. However, the results of studies that used artificial canals must be compared to clinical conditions with care because of the differences between dentine and an S.S. block [27]. There are two test S.S models: dynamic and static models. In a dynamic model, stress is distributed along the length of the shaft of the file during insertion and removal in the axial direction, while the concentration of stress on one area of the shaft of the file in static models [28]. The current study used a static test model since the dynamic test models may not actually be that useful in replicating the clinical situations, as clinicians are not able to control a pecking motion precisely [29].

According to the clinical situation, double curvatures might exist at the same time in the same canal [17]. Radiographic studies examining the degree and frequency of canal curvatures report that almost all canals have secondary curvatures [30]. Different glide path files selected depends on different manufacture metallurgy and they consist of a single file only.

Metal treatment had a greater influence on the bending properties of the files. The WaveOne Gold Glider file was manufactured using a proprietary novel heat-treatment technology [31]. Contrary, to the M-Wire that was a pre-production heat-treatment, the WOG Gilder file was produced by heating and slowly cooling the alloy after the production of the file [32]. Moreover, the metal alloy of endodontic files may affect the cyclic fatigue resistance of the file. The greater resistance to cyclic fatigue, accomplished with the WOG Glider file, compared with the R-pilot file, in 60° angles canals, may be associated with the reduced shape memory of the WOG Glider file [33]. As a consequence, the lower bending resistance of WOG Glider path files made from this proprietary thermo-mechanically treated alloy when compared to R-Pilot path files made from M-Wire alloy might be mainly attributed to the metallurgical properties of these path files [29]. Another reason for this result may be related to the angular progression of files performing reciprocal motion is less than that of files performing continuous rotation motion, the file is exposed to less stress within the canal and thus their cyclic fatigue life increases [19].

HyFlex EDM glide path files made with EDM treatment from a controlled memory (CM) alloy had cyclic fatigue resistance higher than M-Wire ProGlider and conventional NiTi One G path files. The cyclic fatigue resistances of rotary path files: G Files, HyFlex GPF, PG, PathFile and ScoutRaCe using the artificial canal and reported that HyFlex GPF made of CM alloy had the greatest resistance to cyclic fatigue [34]. Cyclic fatigue resistance of HyFlex EDM gpf was significantly greater than the PathFile due to a porous ‘crater-like’ surface that maintained without any change to the cutting blades after being used in curved root canals [35]. HyFlex EDM’s cyclic fatigue resistance, when compared to HyFlex CM files, was reported to be 700% greater [14].

ProGlider made from M-Wire alloy was 400% higher than those made of conventional NiTi alloy [36]. Some previous studies that compared traditional NiTi instruments with M-Wire rotary instruments found that M-Wire improves resistance to cyclic fatigue stress enhanced the mechanical properties, including bending properties and higher flexibility [28]. Cyclic fatigue resistance in S-shaped artificial canals using PG, PathFile and ScoutRaCe files. The greater fatigue resistance was for PG files which were made from M-Wire alloy than those of ScoutRaCe and PathFile which was made from conventional NiTi alloy [37]. It is thought that the alloy characteristics and kinematic properties of the files influenced the findings of the study.

There was no difference statistically in fragment length among rotary instrument used in single and double curved canal, this may be due to the same simulated canals used for all instrument that had the same point of maximum curvature.

CONCLUSION

The NCF for glide path file within double curved canal was lower than the single curved canal. WOG Glider system showed more resistance to cyclic fracture than that of PG, HEDM gpf and OG, in both single and double curved canals.

DECLARATIONS

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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