ASSESSMENT OF TORSIONAL RESISTANCE OF *GLIDE PATH* ROTARY INSTRUMENTS

Graziella Pelegrini[1], Gabriel Barcelos Só[2], Murilo Alcalde[3], Rodrigo Vivan[4], Marco Antonio Hungaro Duarte[4], Fernando Branco Barletta[1]

1 Department of Endodontics, Lutheran University of Brazil, Canoas, Rio Grande do Sul, Brazil;
2 Masters in Endodontics, Federal University of Rio Grande do Sul, Porto Alegre, Rio Grande do Sul, Brazil;
3 Department of Endodontics, Sacred Heart University, Bauru, São Paulo, Brazil;
4 Department of Endodontics, University of São Paulo, Bauru, São Paulo, Brazil;

CORRESPONDING AUTHOR: graziella_pelegrini54@hotmail.com

ABSTRACT

Aims: The present study investigated the resistance to torsion and angular deflection of instruments destined for the glide path: ProGlider #16.02; T-File #17.02 and the MK Life #16.02.
Materials and methods: Thirty rotating NiTi glide path instruments (n=10) with 25mm lengths were selected. The torsion test was performed based ISO 3630-01 (1992). The last three millimeters of the instruments were attached to a load cell connected to the torsional shaft. Torsional strength and angular deflection were evaluated. Fracture surfaces were examined by scanning electron microscopy with magnifications of 1000x and 5000x in the cross section, and 50x in the lateral section. Statistical analysis was performed using the Kruskal-Wallis H test, followed by the Down's post hoc test.
Results: the highest values of torsional resistence were ProGlider, followed by T-File and MK Life ($P < 0.05$). T-File showed greater angular deflection ($p<0.05$) than the other groups tested.
Conclusion: It can be concluded that the ProGlider instrument presented greater torque for the fracture, while the T-File instrument presented greater angular deflection.
KEYWORDS: Nickel-titanium. Endodontic instruments. Heat treatment. Flexural fatigue.

INTRODUCTION

The maintenance of the initial trajectory of the root canal is essential and must be carried out with conventional manual stainless-steel files or NiTi mechanical instruments. Currently, the use of NiTi instruments has been recommended because they have flexibility, superelasticity and greater resistance to plastic deformation and fracture, in addition to providing faster treatment, as well as treatments with a better prognosis in curved and narrow canals[1,2], reduction in postoperative pain and preservation of root canal morphology[1].

On the other hand, it should be considered that the first instrument to be used in the instrumentation of root canals should be manual instruments, with small diameters (#06, #08, #10), facilitating the exploration of the root canal, especially in curved and/or narrow canals[3].

The instruments used to perform the glide path are the most susceptible to the risk of fracture, mainly because of high torsional stress[4]. Torsional fracture occurs when the instrument tip catches on the dentin wall and it continues its rotation until the moment when the elastic limit of the metal is exceeded, causing the fracture [5]. This can occur mainly during the preparation of narrow canals, where the instrument is susceptible to high torsional loads, that is, excessive apical force application during instrumentation [6,7].

For clinical practice, this property is considered a safety factor since the characteristic is reflected in the deformation of the instrument turns, being a visual sign prior to fracture[8].

Therefore, to minimize this disadvantage, manufacturers have developed new instruments with various cross sections, kinematics, designs and heat treatments[9,10]. These rotary instruments can be single or multiple systems. Some examples of these instruments include the ProGlider rotary glide path instrument #16.02 (Dentsply Sirona, Ballaugues, Switzerland), T-File #17.02 (Eurodonto, Curitiba, Paraná, Brazil) and MK Life #16.02 (MK Life, Porto Alegre, Rio Grande do Sul, Brazil).

The ProGlider rotary instrument features thermal treatment of the M-Wire® type, has a quadrangular cross section, the instrument tip is 16.02 mm in size, and has variable taper between 2% and 8% along the axis, being used at 300 rpm and 2 Ncm of torque[7].

The T-File, on the other hand, is a rotating instrument imported by a Brazilian company (Eurodonto, Curitiba, Brazil) and manufactured in China (Shenzhen, China). A new instrument for the glide path made in NiTi, featuring a triangular cross section, the instrument tip is 17.02 mm in size, being used at 300 rpm and 2 Ncm of torque.

MK Life's glide path rotary instrument, featuring a quadrangular cross-section, is made of conventional NiTi with heat treatment, flexible and resistant. The instrument tip is 16.02 mm in size, being used at 300 rpm and 2 Ncm of torque.

The advantages of performing the glide path are evident, however, unexpected fracture of the instrument may occur due to the anatomy of the root canal. The torsional properties of these instruments may vary depending on taper, tip size, design, and type of NiTi used during the manufacture[7, 11, 2]. For this reason, the torsional resistance test is very important since it simulates a clinical situation with a high-tension load, enabling safe and effective clinical use[11, 2, 12].

There is a lack of information comparing the torsional properties of these instruments, especially the glide path T-File (#17.02) and MK Life (#16.02) systems. Therefore, the aim of the present study was to evaluate the torsional strength (maximum torque and angular deflection) of the ProGlider, T-File and MK Life instruments.

MATERIALS AND METHODS

Thirty NiTi instruments (25mm lengths) from three different rotary glide path systems (n=10 per system) were selected: ProGlider (size 16 and taper 0.02), T-File (size 17 and taper 0.02) and MK Life (size 16 and taper 0.02). A single endodontist was previously trained and performed all laboratory procedures to standardize the tests. Prior to the mechanical test, all instruments were inspected under a stereomicroscope (Carla Zeiss, LLC, USA) at 16x magnification to detect possible defects or deformities; no instruments were discarded.

Torsional strength test

Torsional tests were performed based on the specification of the International Organization for Standardization (ISO) 3630-1 (1992). For the tests, a torsion machine described in detail in other studies was used[13, 14].

Before performing each test, the cable of each instrument was removed at the point where they will be attached to the torsion shaft. The 3 mm of the instrument tip was attached to a mandrel, coated with copper sheets so as not to induce tensions to the instruments by the apprehension, and was connected to the electric motor. The rotation speed was set at 2 rpm clockwise for all groups[13, 14]. Torque values were measured by the force exerted on a small load cell attached to a lever arm on the long axis of torsion. The measurement and control of the angle of rotation were performed by a resistive angular transducer connected to a process controller. Torque and angular deflection values were measured throughout the entire test. The maximum values of torque and angular deflection (°) were provided by the same torsion machine and by a specifically designed computer program (Analogica, Belo Horizonte, MG, Brazil).

Scanning electron microscopy (SEM) evaluation

Fractured instruments were evaluated under scanning electron microscopy (FEG MIRA 3, TESCAN, Brno-Kohoutovice, Czech Republic) to determine the topographic characteristics of the fractures after the torsional strength test. All instruments were immersed in saline solution for 3 minutes and cleaned in an ultrasonic device (L100, Schuster, Santa Maria, RS, Brazil) before microscopic analysis. The surface of instruments subjected to torsional strength was evaluated in magnifications of 1000x and 5000x in the center of the surfaces (cross section) and 50x in the lateral section, showing the plastic deformation of the instrument splatters.

Statistical analysis

Quantitative data were described as mean, standard deviation, median and minimum and maximum values. The groups were compared using the Kruskal-Wallis H test followed by Dunn's post hoc test to locate pairwise differences. Findings with a value of

Table 1. Different lowercase letters denote statistically significant differences in each column (p<0.05). The data showed non-normal distribuition, therefore, the Kruskal-Wallis test was used.

	Instruments						
	ProGlider		T-File		MK Life		
	Median	Min-Max	Median	Min-Max	Median	Min-Max	P
Torque (Ncm)	0,32[a]	0,29-0,38	0,23[b]	0,20-0,32	0,20[c]	0,17-0,21	<0,001
Angle (°)	382[a]	371-402	603[b]	556-702	389[a]	368-402	<0,001

p<0.05 were considered statistically significant. Data were analyzed using the SPSS version 25.0 version 4.0.

RESULTS

The values (mean and standard deviation) of the torsional resistance tests (maximum torque force and angular deflection) are shown in **Figure 1** and **Table 1**.

After the torsional resistance test, the ProGlider instrument showed a higher torque value compared to the other groups (p<0.05). The T-File was significantly higher only when compared with the MK Life (p<0.05).

The T-File instrument showed greater resistance to angular deflection when compared to the ProGlider and MK Life instruments (p<0.05). However, the ProGlider and MK Life showed similar values to each other (p>0.05).

Scanning electron microscopy evaluation of the fragment's surfaces revealed typical characteristics of torsional failure for all groups. The instruments showed abrasion marks and fibrous dimples near the center of rotation. Furthermore, in the cross section, it is possible to notice deformation of the instrument turns (**Figure 2**).

DISCUSSION

Performing a glide path, preceded by manual instruments, considerably reduces the possibility of fractures. However, when the fracture occurs, this fragment will hardly be removed, consequently, the sanitation will be deficient, which may compromise the success of the endodontic treatment. De-Deus et al.,[7] 2016, where they demonstrated that several factors could affect the clinical performance of instruments and should be analyzed to increase their safety and effectiveness, thus increasing their useful life. Thus, it is important to know the torsional resistance and angular deflection of new T-File and MK Life instruments for safe and effective clinical use[15].

The results showed that in the torsional resistance test, the ProGlider #16.02 instrument presented significantly higher torque compared to the tested groups (p<0.05), T-File #17.02 and MK Life #16.02, respectively (Tab.1). Although the ProGlider instrument presents similar characteristics regarding the taper relationship to the studied instruments, we believe that the heat treatment used during the manufacturing process (M-Wire®) influenced the fatigue resistance due to its mechanical properties. Agreeing with the research by Ye et al. [16] 2012, which analyzed instruments with different taper relationships and heat treatments, showing that an instrument with heat treatment of the M-Wire® type has greater torsional strength, which can be a determining factor in the choice of the instrument. The present study justifies the superiority for the ProGlider instrument.

Also, regarding the instrument properties, a recent study has shown that the thermal treatment of the M-Wire® type has influenced the mechanical properties and, therefore, the instrument fracture[17]. Its microstructural phases enable a superelastic state since it contains an austenitic phase with small amounts of martensitic and R phase, that is, it has superelasticity, making the instruments harder and more rigid, in addition to providing ductility to the instrument[15]. Consequently, these instruments have greater flexibility than conventional NiTi wire[15,16]. The clinical importance of obtaining the torsional strength of the instruments is that this condition is reflected in the

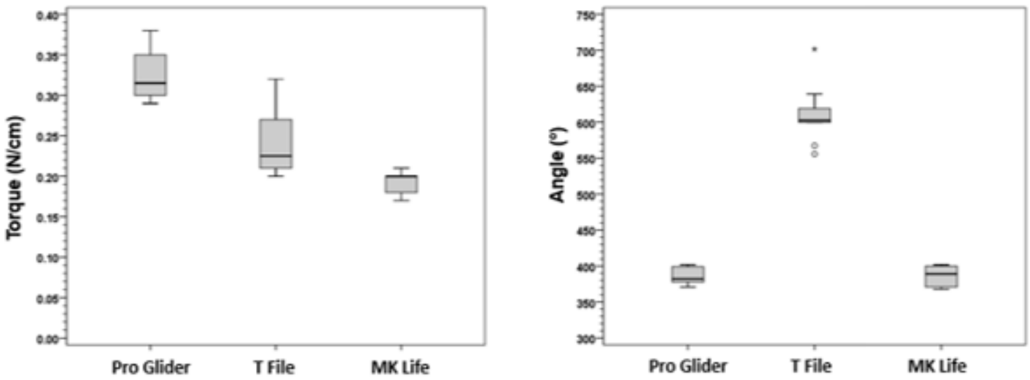

Figure 1. Torque (Ncm) and angular deflection (°) of the instruments tested.

initial deformation of the instrument turns before the fracture, being considered as a safety factor for use[8].

Thus, the ProGlider has superelasticity as its main property, while the T-File with Gold heat treatment has a greater amount of martensitic phase, that is, it tends to return to its original shape more easily[15]. We believe that this is the main reason for the ProGlider to present results superior to the T-File in the torsional resistance test[15].

Also, regarding the results of the torsional resistance test, it should be noted in relation to the T-File and MK Life instruments, that even with lower results than the ProGlider instrument, they were similar and significant to each other ($p<0.05$). The conventional NiTi manufacturing demonstrates that these instruments are effective in torsional strength testing. These results that we observed are in line with studies with other instruments, consecrated and manufactured in conventional NiTi[14,18].

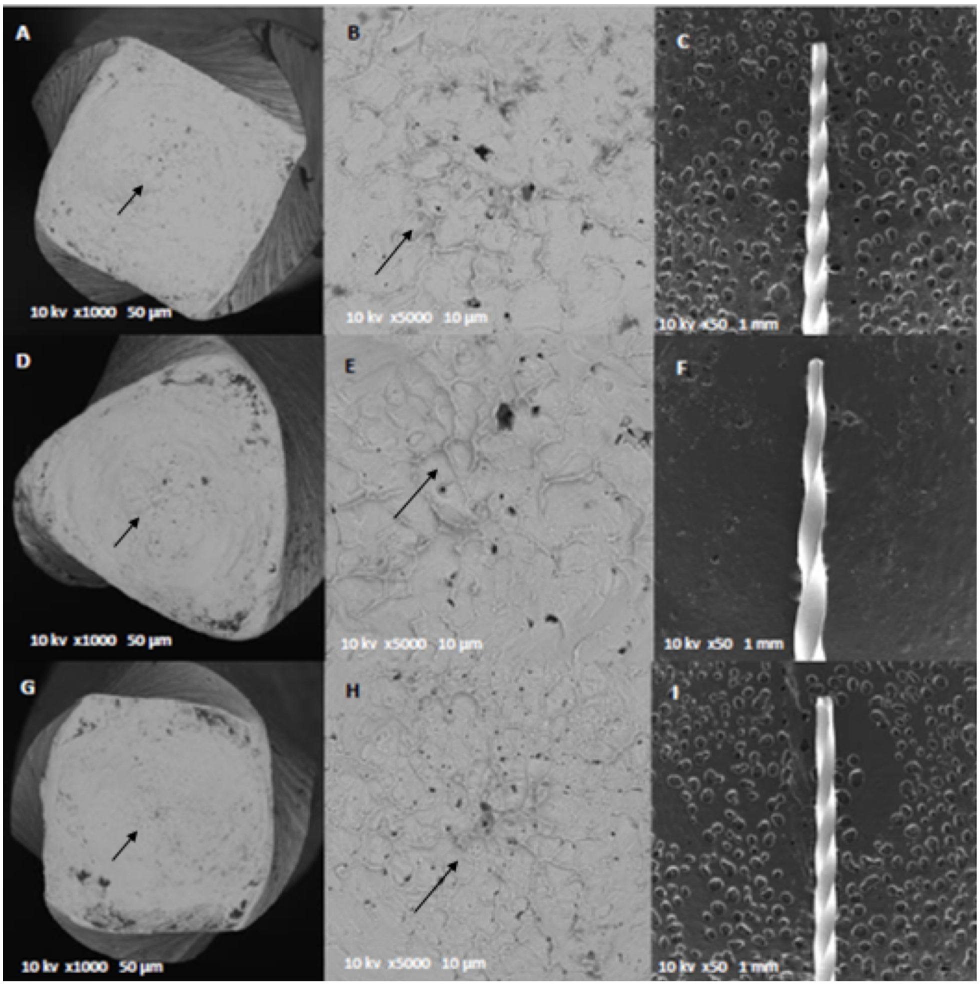

Figure 2. Scanning electron microscopy images of the fracture surfaces of the ProGlider (A, B, C) T-File (D, E, F) and MK Life (G, H, I) instruments with 1000x magnification, 5000x in the transversal section and 50x in the lateral section after the torsional resistance test.

However, the results regarding the angular deflection test in the present study revealed that the T-File #17.02 instrument demonstrated a significantly greater angular deflection when compared to the other groups tested ($P < 0.05$). On the other hand, the ProGlider #16.02 and MK Life #16.02 instruments presented similar values to each other. In this aspect, we can infer that the triangular cross-section of the T-File instrument may have been a factor that influenced the deflection resistance of the instrument in question. Some authors have already shown in the literature that instruments with a triangular cross-section have greater flexibility when compared to instruments with a square cross-section, that is, the square cross-section presents greater rigidity to angular deflection since the core area of the instrument presents a more consistent correlation with flexural stiffness than the cross-sectional area[19, 20].

According to the selection of instruments used in the present study, the ProGlider was selected because it is widely documented in the literature, demonstrating to be highly effective in torsional resistance tests[14]. The T-File and MK Life instruments, on the other hand, since they are new instruments on the market, do not yet have any research in the literature on torsional resistance. Since there are studies with other instruments established in the literature, we chose to choose these instruments because they present similar conicity relationships, in addition to presenting relevant cost-benefit to the professional.

With regard to the taper of the instruments, when they have variable taper along the axis, we will have a greater area of contact with the walls of the root canal due to the increased taper of the cutting blades along the axis, and this makes those most susceptible to fracture[11].

In the present study, two analyzed instruments have variable tapers, the ProGlider and T-File. We believe that this difference between the study mentioned was due to the applied methodology. Since we used a stabilized handpiece model with pre-defined conditions, the methodology used in the present study is enshrined in the literature for laboratory studies[13, 14].

However, flexible instruments can cause fewer unwanted changes in the shape of curved canals than those with greater resistance to deflection, while the increased torsional stiffness transfers the rotational cutting forces more efficiently. The clinical importance of obtaining the resistance to angular deflection of the instruments is that during instrumentation we can assess the amount of force that will be submitted, evaluating the convenience of its use, speed, and torque control[17].

It is important to emphasize in relation to the interpretation of data from the ProGlider and MK Life instruments during the angular deflection test, regarding the fact that there was a statistical numerical difference in relation to the T-File instrument, under the clinical aspect, we can interpret that these instruments can obtain favorable similar behavior when worked with the correct speed and torque control as per the manufacturer's recommendations.

Regarding the torsional resistance and angular deflection tests, we can consider that the results obtained were considered favorable if an initial analysis of the root canal anatomy and individual selection of the instrument for each case and question is carried out. And this is in agreement with the study by Lopes et al.,[1] 2010, who report that manual instrumentation followed by mechanical instrumentation protects the instrument from the risk of fractures, making its clinical use safer and more effective.

As for the methodology used, it was like that reported by Alcalde et al,[14] 2018 and Bahia and Buono[13] 2005, making the method reliable and scientifically supported. The importance of the instruments being mounted in a stabilized handpiece is unquestionable, allowing the instrument to rotate freely under specific pre-defined conditions. As a result, it becomes possible to increase the internal validity and reproducibility, better understanding the behavior of the instruments, minimizing speed and range of motion biases, which, although they can be reproduced in the dynamic model in clinical situations, are operator-dependent[21]. In addition, the study was carried out in accordance with the specification ISO Standard 3630-1 [14,9]. Thus, we justify that in the methodology used we followed an established and recognized standard. Sample calculation was performed previously, demonstrating that 10 experimental units per group provide significant statistical power to the study, and this is justified in the literature by Duque et al.,[22] 2020, and Alcalde et al.,[14] 2018.

Regarding the rotation speed of the instruments, Lopes et al.,[1] 2010, who report that the higher the rotation speed, the greater the friction of the instruments on the walls of the root canal and, therefore, the greater risk of fracture. And maybe this can explain and justify the higher incidence of fractures when compared to the use of higher speeds. We want to reinforce that the speed of the instruments used in the present study was 300 rpm clockwise, following the manufacturer´s instructions. However, in the torsional strength test 2 rpm was used since the torsional test was performed according to the specification ISO 3630-1, previously reported in the literature by Alcalde et al.,[14] 2018 and Bahia; Buono,[13] 2005.

In the present study, the instrument tip was fixed at 3mm, and the clockwise rotation was adjusted for all instruments. The 3mm tip was chosen because at this point the instrument is more susceptible to fracture than the 5mm one and because the ISO 3630-1 standard requires it. This pattern was also used by Alcalde et al.,[14] 2018 and Bahia; Buono,[13] 2005.

Regarding the scanning electron microscopy analysis of the instruments submitted to the torsional strength test, they revealed typical characteristics of torsional fracture in all groups, being observed in the 1000x and 5000x magnifications in the cross section (**Figure 2**), concentric abrasion marks and fibrous dimples in the center of rotation. These characteristics are in line with the results found in studies by Kim et al.,[23] 2012; Lopes et al.,[8] 2011; Pedulla et al.,[12] 2015; Silva et al.,[24] 2019, thus ensuring that our study presented specific results for this test. Thus, the fracture of the tested instruments presents morphological characteristics of the ductile type. In addition, in the lateral section of the instruments, analyzed at 50x magnification, the deformation of the instrument turns can be noted, especially in the group that presented a greater angle of rotation before the fracture (**Figure 2**), being similar to the result found in Alcalde et al. [14] 2018.

Therefore, a joint analysis of studies that analyzed the influence of torque on instruments destined for the glide path suggests that one of the ways to prevent mechanical stress and consequently instrument fracture is to use motors that operate below the permitted torque limit for each instrument, according to the manufacturer. These instruments are thinner than those used later. As a result, we will protect the instrument, reducing the risk of plastic deformation and risk of their fracture [1].

In the present study, the test did not simulate the clinical use of the instruments, however, it provided standardized conditions of high torsional loads for the studied groups[12]. A static model was adopted, allowing precise conditions for all instruments, reducing variables such as range of motion and amount of force applied in the apical direction, which are considered subjective in a clinical situation[25]. Considering that the standardization of strength and direction are essential to ensure accurate results[13].

CONCLUSION

Based on the results of the present study, it is possible to infer that the ProGlider instrument presented superior torsional strength, followed by the T-File and MK Life instruments, respectively. Regarding angular deflection, the T-File instrument showed a greater deflection angle in the groups tested, while the ProGlider and MK Life obtained similar results among themselves, and the scanning electron microscopy analysis demonstrated morphological characteristics of the ductile type.

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