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Comparison of the cyclic fatigue resistance of WaveOne Gold, Reciproc Blue, and 2Shape NiTi systems in the root canal manipulation

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ABSTRACT: Mechanical files have drastically altered the treatment protocol in endodontics, allowing for quicker and easier treatment times and a more thorough debridement of the canal system. Despite the advantages of the Nickel-Titanium (NiTi) alloy files, instrument separation remains a major concern when using these files.The study aimed to compare the cyclic fatigue resistance of WaveOne Gold, Reciprocation (Reciproc) Blue, and 2Shape NiTi systems having a different design and metallurgic properties. The instruments were rotated in an artificial canal made of stainless steel with 45°angles and a radius of curvature of 8 mmand 5mm of curvature until fracture occurred, the time to fracture was recorded in seconds. Also, the number of cycles to fracture was calculated. Data were statistically analyzed using one way ANOVA and Bonferroni test. Reciproc Blue had the highest cyclic fatigue resistance in time to fracture compared to WaveOne Gold and 2Shape ($P < 0.05$), however, there was no significant difference between WaveOne Gold and 2Shape in terms of time to fracture ($P < 0.05$). No significant in the number of cycles to fracture when comparing WaveOne Gold with Reciproc Blue and 2Shape and highly significant difference when comparing Reciproc Blue with 2Shape. No significant in the length of fracture among group tested. The present study, Reciproc Blue NiTi files showed statistically higher cyclic fatigue resistance than the other Ni-Ti files tested.

KEYWORDS: Cyclic fatigue; WaveOne gold; Reciproc blue; 2Shape

I. INTRODUCTION

Nickel-titanium (NiTi) instruments are commonly used for shaping the root canal system which characterized by superelasticity and shape memory which give it greater flexibility and resiliency(Champa et al., 2017). NiTi instruments have advantages including maintain the original shape of the root canal and reducing the instrumentation error such as zipping, ledge formation, and perforation risk (Paqué, Ganahl, & Peters, 2009). Several root canal NiTi instrument systems have been introduced to improve the shaping procedure. However, all these systems recommended the use of a series of files to complete the instrumentation of the root canal (Zinge & Patil, 2017). Nowadays, single file systems are commonly used and being debated for its applicability in modern endodontics. The advantages of these single-file systems include prevention of cross-contamination, reduction in the working time and, improved safety of the

shaping procedures (Zinge & Patil, 2017).Several errors facing clinicians during cleaning and shaping of the root canals, one of these errors is the fracture of endodontic instruments within the root canal. A retained separated endodontic files impact treatment outcome and obstacle chemical and mechanical cleaning of a root canal (Pedir, Mahran, Beshr, & Baroudi, 2016).The fracture of NiTi files during clinic use occurs through two different mechanisms: cyclic fatigue and torsional fatigue. In cyclic fatigue, the file fractures because of repetitive compression and tension stress at the maximum curvature point of the canal, while torsional fatigue occurs when the torsional stress exceeds beyond the elastic limit of the file, it will plastically deform and then, if the stress is still maintained, it results in the fracture of the file (Gündoğar & Özyürek, 2017).The common causes of fracture of files are improper use, root canal anatomy, manufacturing defects, inadequate access, insufficient knowledge about the root canal morphology and its variations and, limitations in physical properties (Al-Qudah & Awawdeh, 2006). WaveOne Gold (Dentsply Maillefer), is one of the reciprocating single-file systems. The gold process is a post-manufacturing procedure in which the ground NiTi files are heat-treated and slowly cooled. It is available in four sizes as follows: small (20.07), primary (25.07), medium (35.06), and large (45.05). WaveOne Gold has a parallelogram cross-section with two cutting edges, alternate one, and two-point contact (Vallabhaneni, Fatima, & Kumar, 2017). Reciproc blue (VDW GmbH, Munich, Germany), a thermally treated NiTi file, is an improved version of the original Reciproc file. It has greater flexibility and more resistance to cyclic fatigue, the Reciproc blue instruments have an S-shaped cross-section(Yared, 2017). 2Shape (Micro Mega, Besancon, France) is a sequence consists of two shaping files in a continuous rotation that have been heat-treated using the T•Wire technology. 2Shape has a triple helix cross-section with 2 main cutting edges (Uslu, Özyürek, Gündoğar, & Yılmaz, 2018) .

II. LITERATURE REVIEW

The present study aimed to evaluate and compare the cyclic fatigue of Wave One Gold, Reciproc Blue, and 2Shape root canal files.

III. METHODOLOGY

Two simulated root canals in stainless blocks were used in this study Fig 1.The two canals had the same angle and different radii. The angle and radius of curvature were designed as described by Pruett et al (1997). The first canal had an angle 45^{o} and radius of curvature 8mm, the second canal had an angle 45^{o}, and radius of curvature 5mm, the overall length of the two canals were 20mm. At the narrowest end, the two canals had 0.4mm wide and had a constant taper of 0.09 over the all canal with an inner diameter of 1.5 mm. Each artificial canal was specifically designed for each file in terms of taper, giving it a precise trajectory. The diameter of the canals were larger than that of each file, allowing free rotation. The stainless steel block was covered with glass and fixed by two screws to better observe the fracture of files.

Three rotary instruments that were used in the present study were WaveOne Gold primary [0.07 taper, tip size 25] (Dentsply Maillefer, Switzerland); Reciproc blue 25 [0.08 taper, tip size 25] (VDW GmbH, Munich, Germany);and 2Shape TS2[0.06 taper, tip size 25] (Micro Mega, Besancon, France) single file system. Six different experimental groups were tested (n = 10) depending on the file type, WaveOne Gold (WOG), Reciproc Blue (RB) and 2Shape (TS), and the angle and radius of curvature tested (45°, 8mm, and 45°, 5mm) and underwent the following procedures. WOG Primary (25/0.07) were operated with X-smart IQ Endo motor (Dentsply Maillefer, Ballaiguis Switzerland) in "WaveOne gold" program, according to the manufacturers' recommendations, until the fracture occurred; RB R25 (25/0.08) were operated with IQ smart endodontic motor in "Reciproc Blue" program, according to the manufacturers' recommendations,

until the fracture occurred; TS (26/0.06) were operated with IQ smart endodontic motor at 350 rpm and 2.5 N cm torque values, according to the manufacturers' recommendations, until the fracture occurred.

Before the experiment, all NiTi files were examined under a stereomicroscope at ×20 magnification for any defect presence. Since there was no defect detected, all the files had undergone static cyclic fatigue testing. The simulated canal in the stainless steel block was filled with lubricant oil (Atlas co. Iran), to reduce friction between the instrument and the metal canal walls and reduce heat generation. A video for each file rotation was recorded by using Canon digital camera (Gündoğar & Özyürek, 2017). To making standard tests, no pecking motion was used, after fixation of the instrument within the canal and the camera was starting to record a video of each file, the time in seconds was recorded from starting until fracture occurred by using digital chronometer and timing stopped as the fracture is detected visually and/or audibly(Dagna et al., 2014). The recordings video was then observed to crosscheck the time of file fracture. For more standardization all testing of instruments done at room temperature. The time to fracture was recorded in second (from starting rotation /reciprocation within the canal until fracture occurred), then the time of fracture in second converted to minutes by dividing on 60 and then multiplied by the speed (revolution per minute RPM) to obtain the number of cycles to fracture for each instrument as in following equation (Dagna et al., 2014).

a. Number of Cycles to fracture (NCF) = speed (RPM) x Time to fracture in minute

Silva et al. (2016) stated that preset programs (Reciproc and WaveOne modes) of reciprocating motion preset different angles of rotation and speed (i.e. 150° counterclockwise and then 30° clockwise rotation with a speed of 300 rpm for the "Reciproc" mode and 170° counterclockwise and then 50° clockwise rotation with a speed of 350 rpm for the "WaveOne" mode)**,** forthese reasonsWaveOne Gold and 2Shape multiplied to 350 and for Reciproc Blue multiplied to 300. The length of fracture of each instrument obtained by measuring the fractured instrument (instrument after fractured) by digital microcaliper, measuring from tip of file to the fracture point.

b. Statistical analysis

Mean and standard deviations of the data obtained were analyzed using the Statistical Package for Social Sciences version 25 (SPSS 25; IMB Corp, USA). The comparison of time to fracture (TTF), number of cycles to fracture (NCF) and length of the fracture (LF) between groups was examined in an independent t-test. The TTF, NCF, and LF among groups were examined in One-way ANOVA and between- group comparisons in the Bonferroni correction test. The significant difference was determined in a P-value of less than 0.05.

IV. RESULTS

Tables 1 and 2 present the mean and standard deviation of the TTF, NCF, and LF values for each instrument in both canals. When comparing the TTF and NCF of all the instruments tested in the artificial canal with angle 45°, radius 8 mm and radius 5 mm curvature, RB had shown more resistance to cyclic fatigue and no significant difference between WOG and TS.Regarding NCF, no significant when comparing WOG with RB and TS and RB showed more resistance than TS. All the tested files showed statistically significant lower fatigue resistance in artificial canals with

45°, radius 5 mm curvature compared to artificial canals with angle 45°, radius 8 mm curvature.There was no significant difference length of fracture between all files tested.

VI. DISCUSSION

Instrument fracture remains a major concern in endodontics as the unexpected fracture may occur during clinical practice (Inan & Gonulol, 2009). It has been reported that cyclic fatigue is the main cause of fracture of the files during clinical use (Cheung, Peng, Bian, Shen, & Darvell, 2005; Inan & Gonulol, 2009). For this reason, many studies have been performed on the cyclic fatigue resistance of NiTi rotary files (Gündoğar & Özyürek, 2017; Topçuoğlu, Topçuoğlu, & Aktı, 2016). Manufacturers aim to improve the cyclic fatigue resistance of NiTi rotary files by altering the design, metallurgy, and kinematics of the files and heat treatments of the files(Ferreira et al., 2017; Shen, Coil, Zhou, Zheng, & Haapasalo, 2013). The present study aimed to compare the cyclic fatigue resistance of three single endodontic files, WaveOne Gold Primary, Reciproc Blue R25 and ٢Shape TS2 NiTi single files in two artificial canals with 45^{o} angle, radius 8mm and 5 mm of curvature, These files were selected because they are currently one of the common single files commercially available and have different thermal treatment and different cross-section. Even thoughreal teeth better represent the clinical conditions, it is difficult to select real canals, standardizing the same curvature in terms of angle and diameter, due to the variation in root canal anatomy (Saleh, Gilani, Tavanafar, & Schäfer, 2015), for this reason in the present study, stainless steel artificial canals were used to standardize cyclic fatigue tests (Gündoğar & Özyürek, 2017; Özyürek, 2016; Topçuoğlu et al., 2016).

Cyclic fatigue test devices could be used using either static or dynamic test models. In static models, the instrument rotates in the fixed length in the artificial canal with no axial movement. In dynamic test inserted into canal with axial movement. Files were held in a static position, while allowed to rotate against the metal block of the canal, creating tension and compression on the outer and inner aspects of the file respectively at the area of maximum curvature (Parashos, Gordon, & Messer, 2004)(.These cumulative compression-tension cycles created with each rotation, resulted in propagation of preexisting cracks or flaws when the stress reached a critical level and eventually lead to fracture of the instrument(Kuhn, Tavernier, & Jordan, 2001). Along the experimental procedure the time to fracture was recorded and number of cycles to fracture was determined afterwards. To asses cyclic fatigue resistance, these two parameters have been used, in which time presents more clinically relevant information, as time is much easier for the operator to observe than the NCF the instrument endures. The NCF provide more pertinent information regarding the ability of the instrument design to withstand cyclic fatigue(Wan, Rasimick, Musikant, & Deutsch, 2011). Resistance to cyclic fatigue depends on several factors such as metal mass, diameter, flexibility, cross-sectional section, and NiTi alloy (da Silva et al., 2018). The result of the present study demonstrated that RB NiTi files presented a significantly higher cyclic fatigue resistance than the other tested files in both angles of curvature tested. This confirms the results obtained in a previous study reporting that RB files were statistically significantly more resistant to cyclic fatigue than WOG and TS files. The probable explanation of the outcome of this study could be due to the differences in the metallurgical characteristics, cross-sectional designs, and kinematic properties of the NiTi files among instruments tested. Reciproc Blue is manufactured from a novel alloy that is coated by an oxide layer as a result of the thermomechanical process, this novel system is much more flexible than its predecessor Reciproc files. It is also more resistant to cyclic fatigue-related fractures and has reduced surface

micro-hardness (Adıguzel & Tufenkci, 2018). In previous studies, WaveOne Gold file showed more resistance to cyclic fatigue than M-Wire R files (Elnaghy & Elsaka, 2017; Topçuoğlu, Düzgün, Aktı, & Topçuoğlu, 2017)and M-Wire WO (Gianluca Plotino, Grande, Bellido, Testarelli, & Gambarini, 2017),thus confirming that the new metal treatments pr-obably represent the most important variable that permits to improve the cyclic fatigue resistance of NiTi files(De-Deus et al., 2017). Other factor affect the result was different cross-section design of files tested, the cross-section design has an impact on the stress developed by an instrument under either tension or bending(Zhang, Cheung, & Zheng, 2010). Reciproc Blue have S-shaped cross-section, S-shaped horizontal cross-section provided better cyclic fatigue resistance than horizontal rectangular or triangular cross-sectional design(Cheung, Zhang, & Zheng, 2011; G Plotino, Grande, Testarelli, & Gambarini, 2012). In the present study, no statistically significant difference in terms of cyclic fatigue resistance was found between WOG file running on reciprocating motion and that of TS file running on continuous rotation, the result is in agreement withOzyürek*et al*., (2018). It can be speculated that the smaller core volume given by the triple helix with two main cutting edges for cutting efficiency and one secondary edge for improved removal of debris cross section of TS files and the T-Wire technology used in the production of TS files is claimed to in-crease the cyclic fatigue resistance of files (Uslu et al., 2018),compared with WOG cross section that have a novel parallelogram-shaped cross section with two cutting edges and an alternate one-point contact (Keskin, Inan, Demiral, & Keleş, 2017), and WaveOne Gold is manufactured from Gold wire using advanced metallurgy and heat treatment to increase the flexibility of the instrument. The effect of thermomechanical treatment applied to Gold wire has been evaluated using differential scanning calorimetry, and higher cyclic fatigue resistance values have been associated with 2-stage specific transformation behavior (Keskin et al., 2017).

Movement kinematics has also been regarded to affect the cyclic fatigue resistance of NiTi instruments(Castelló-Escrivá, Alegre-Domingo, Faus-Matoses, Román-Richon, & Faus-Llácer, 2012) . Previous studies showed that reciprocating motion improve the cyclic fatigue resistance of NiTi instruments (Ferreira et al., 2017; Pedullà, Grande, Plotino, Gambarini, & Rapisarda, 2013; Webber, 2015). The time to fracture of all instrument system decreased in canal with radius 5 mm of curvature in compared to 8 mm ,as increase of angle and radius of curvature results in a decreased lifespan, an increase in angle of curvature is related with the decrease of time to fracture (Wan et al., 2011), and also an increasing radius of curvature was proven to decrease time to fracture (Inan & Gonulol, 2009; Tripi, Bonaccorso, & Condorelli, 2006). There no significant difference when comparing WaveOne Gold with Reciproc Blue and 2Shape,and highly significant difference between Reciproc Blue and 2Shape in term of number of cycles to fracture, the result may be due to different revolutions per minute (RPM), differences in the metallurgical characteristics, cross-sectional designs, and kinematic properties of the NiTi files between instruments tested. According to the result, there was no significant difference among three groups (WOG, RB and TS) in length fracture at the same canal this mean that the files positioned correctly at the same level inside the canal and demonstrated that similar stresses were induced during the test, the result agrees with previous study(Gündoğar & Özyürek, 2017; Topçuoğlu et al., 2017). The length of fracture all three groups was significantly difference between two canals, because of different center of curvature of each canals, as instrument fractured at point of curvature.

VII. CONCLUSION

Within the limitations of the present study, Reciproc Blue NiTi files showed more resistance to cyclic fatigue than WaveOne Gold and 2Shape and no significant difference between WaveOne Gold and 2Shape, the increase in the angle of curvature of artificial canals negatively affects the cyclic fatigue resistance, no significant difference in fracture length among all groups.

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Table and figures:

Table 1: Comparison of time, number of cycles, and length of fracture among groups WaveOne Gold, Reciproc blue and 2Shape files in canal angle45^{o} and 8mm radius of curvature

Indicators	Groups	Mean	P-Value
Time (Second)	WaveOne Gold[a]	136.00±57.03	<0.001
	Reciprocblue[b]	195.70±51.65	
	2Shape[a]	92.50±22.11	
Number of Cycle(No.)	WaveOne Gold[a]	775.82±345.96	0.003
	Reciprocblue[b]	978.50±258.25	
	2Shape[a]	539.58±128.98	
Fracture Length(mm)	WaveOne Gold[a]	8.79±1.05	0.286
	Reciprocblue[a]	8.66±0.65	
	2Shape[a]	8.22±0.727	

Different superscript letters in the same column indicate statistical differences among groups ($p < 0.05$)

Table 2: Comparison of time, number of cycles, and length of fracture among groups WaveOne Gold, Reciproc blue and 2Shape files in canal angle45^{o} and 5mm radius of curvature

Indicators	Group	Mean	P-Value
Time (Second)	WaveOne Gold[a]	40.90±13.042	0. 000
	Reciprocblue[b]	68.20±36.459	
	2Shape[a]	20.00±6.896	
Number of Cycle (No.)	WaveOne Gold[a]	237.46±76.469	0.001
	Reciprocblue[b]	341.00±182.297	
	2Shape[a]	116.66±40.227	
Fracture Length (mm)	WaveOne Gold[a]	6.25±0.766	0.898
	Reciprocblue[a]	6.16±0.967	
	2Shape[a]	6.34±0.850	

Different superscript letters in the same column indicate statistical differences among groups ($p < 0.05$)

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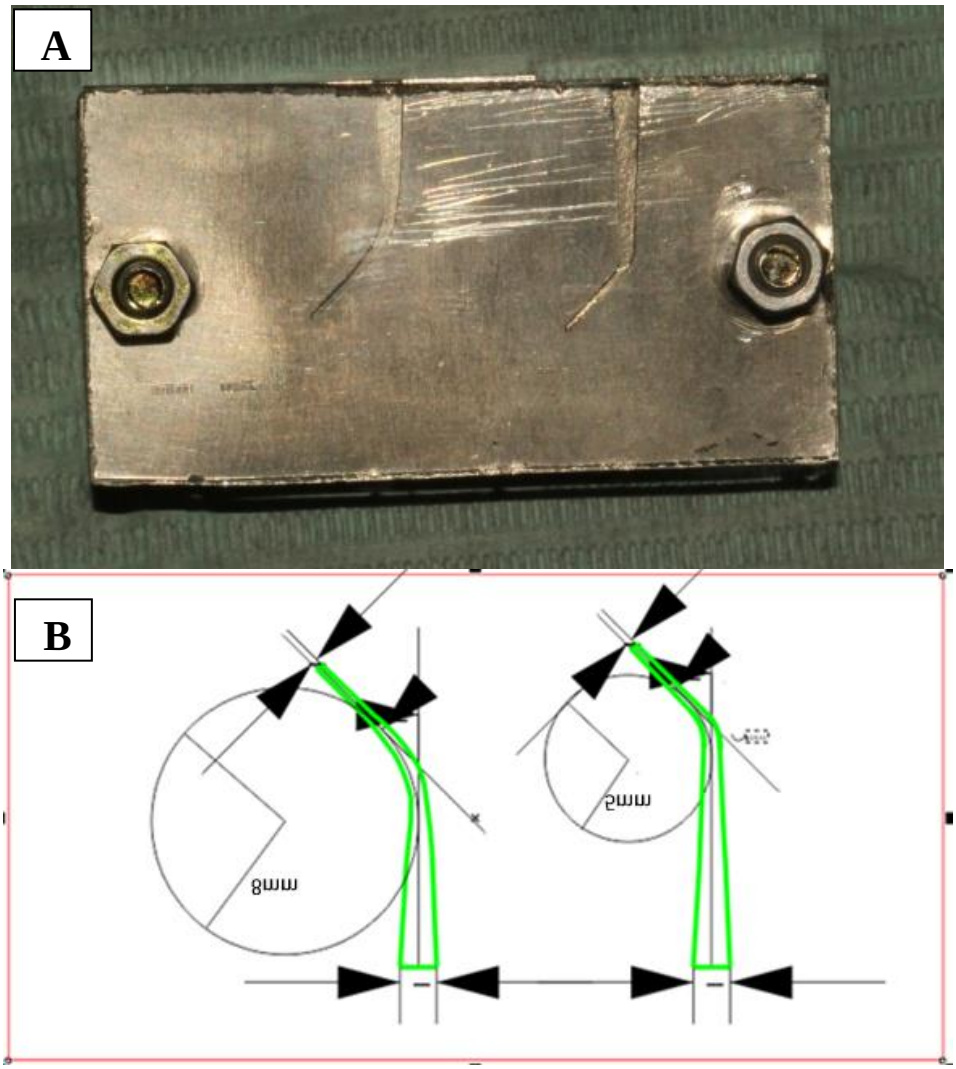

Figure 1: Custom made stainless steel block with two artificial canals (A); Measurements of the metal block (B).