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Original Research Article

Cyclic and torsional fatigue resistance of two replicalike and original brand reciprocating system

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Abstract

Objective: The aim of this study was to evaluate the cyclic and torsional fatigue resistance of two replicalike in comparison of the original brand reciprocating system. **Material and methods:** A total of 60 reciprocating instruments were used to perform the cyclic and torsional fatigue test of following systems: Reciproc Blue 25.08 (RB 25.08), Only One File Blue (OFB 25.08) and RC Blue 25.08 (RCB 25.08) (n=20). The cyclic fatigue test was performed using an artificial stainless steel canal with 60° angle of curvature and a 5-mm radius of curvature. The instruments were activated until failure occurred. The time to failure (TF) and number of Cycles to failure (NCF) were evaluated. The torsional test was performed following the ISO 3630-1. Three millimeters of the instrument tip was fastened to a small load cell and the maximum torsional strength and angular deflection were recorded using the torsion testing machine software. The fractured surface of each instrument was assessed by scanning electron microscopy (SEM). The data were analyzed using one-way analysis of variance ANOVA and Tukey's test for Multiple comparisons at a significance level of 5%. **Results:** The cyclic fatigue tests demonstrated that OFB 25.08 had the highest TF and NCF than among the groups (P<0.05). RCB 25.08 exhibited lowest TF and NCF (P>0.05). Regarding the torsional test, the RCB 25.08 and OFB 25.08 had the highest torque than the other groups (P<0.05). Additionally, RB 25.08 and OFB 25.08 exhibited highest angular deflection values than the other groups (P<0.05). **Conclusion:** The OFB 25.08 demonstrated highest TF and NCF than the instruments tested. The RCB 25.08 exhibited lowest cyclic fatigue resistance and angular deflection.

Introduction

Since the introduction of reciprocating motion in endodontics by Yared [20], a huge number of researches were performed to evaluate the mechanical benefits, shaping ability and efficiency of filling material removal in comparison with continuous rotation [9, 5]. Several authors demonstrated that reciprocating motion enhances the resistance to cyclic fatigue, decrease screwing-in effects and less torsional forces than continuous rotation [5, 7, 9]. Also, the reciprocating motion is associated with a low incidence of instruments separation during root canal treatment and retreatment [3, 6, 18].

Over the last years, many dental companies have developed or producing reciprocating systems to be used for root canal preparation and endodontic retreatment. These systems can present similar characteristics to well-known brand, called replicalike systems, or was developed by themselves with a proprietary characteristic [13, 15]. Replicalike systems are considered engine-driven NiTi systems that present similar characteristics to the original ones, such as the number/sequence of instruments, nomenclature and color coding, however, using different commercial name [13]. The Reciproc Blue (VDW, Munich, Germany) is a well-known system and commercialized at worldwide. Also, a huge number of researches were performed evaluating the mechanical properties, shaping ability and clinical performance of these instruments. Thus, there are many replicalike or counterfeit systems of this brand that are commercialized or distributed by a local distributer or accessible via the internet [13, 15].

Previous authors have reported that some replicalike and counterfeit systems can present low control quality, different metallurgical features, lower mechanical properties and shaping ability [11, 13-15]. On the other hand, some replicalike system can present similar or better as abovementioned characteristics [13]. Therefore, it is important to highlight that the mechanical properties, metallurgical features and shaping ability should be undergone to a previous scientific evaluation in comparison with original brands, which is considered the Gold Standard [13, 15].

Currently, some Chinese Dental companies have started to distributing endodontic instruments on the Brazilian Market. These companies commercialize reciprocating and rotary replicalike systems or own engine-driven NiTi systems. The Only One File Blue (Shenzhen Denco Medical, Shenzhen, China) and RC Blue (Shenzhen Perfect Medical Instruments, Shenzhen, China) are two reciprocating NiTi replicalike system of Reciproc Blue (VDW, Munich, Germany) that is commercialized in Brazil. These system present instruments three instruments with 0.25, 0.40 and 0.50mm tip sizes and 0.08, 0.06 and 0.05mm/mm taper, respectively. Also, both are manufactured by thermal treatment that induces a Blue color in the NiTi surface. However, there are no reports of the mechanical properties of these systems. Therefore, the aim of this study was to evaluate the cyclic and torsional fatigue resistance of two replicalike system (Only One File Blue and RC Blue) and compare with the original brand (Reciproc Blue). The null hypotheses to be tested are as follows: (I) there is no difference among their cyclic fatigue resistance, (II) There is no difference among their torsional properties.

Material and methods

Sample size calculation

The G*Power v3.1 software for Mac (Heinrich Heine University of Düsseldorf), was used for sample size calculation. The alpha-type error level of 0.05, a beta power of 0.95, and an N2/N1 ratio of 1 in accordance with previous studies [1, 2]. The size indicated was 10 instruments per group.

Cyclic and torsional fatigue test

A total of 60 new 25 mm NiTi reciprocating instruments were used (n=20): Reciproc Blue 25.08 (VDW, Munich, Germany), RC Blue 25.08 (Shenzhen

Perfect Medical Instruments, Shenzhen, China) and Only One File Blue 25.08 (Shenzhen Denco Medical, Shenzhen, China). All instruments were meticulously inspected to detect possible defects or deformities under a stereomicroscope (Carl Zeiss, LLC, Oberkochen, Germany) at a magnification of 16x before mechanical tests, none instruments were discarded.

The cyclic fatigue test was performed using a customized device that was previously reported [1, 2]. An artificial canal made of stainless steel with a curvature angle of 60° and a curvature radius of 5 mm was used. All instruments were activated using the same reciprocating motion option ("RECIPROC ALL" – 300 Rotation per minute) of a VDW Silver Endodontic motor (VDW, Munich, Germany) (n=10). The moment of instrument failure was visually and audibly detected, and the time to fracture was recorded. The number of cycles to fracture (NCF) was calculated using the following formula: time to fracture (in seconds) X RPM/60.

The torsional resistance was carried out in accordance the guidelines stipulated in ISO3630-1, employing a specially design apparatus (Analógica, Belo Horizonte, MG, Brazil) as previously reported [1, 2]. The 3 mm of instrument tip was securely clamped between brass plates and subjected to counterclockwise rotation at a speed of 2 RPM until fracture occurred (n=10) per group). The maximum torsional strength (N.cm) and angular deflection (°) was recorded using a specially design software computer (Analógica, Belo Horizonte, MG, Brazil).

Scanning electron microscopy

The fractured fragments of cyclic and torsional tests of each experimental group were examined using a Scanning Electron Microscope (SEM – JSM-TLLOA; JEOL, Tokyo, Japan) to determine the topographic feature of fractured fragments at 200x and 500x magnifications.

Statistical analysis

The data normality was performed with the Kolmogorov smirnov test, showing that the data were normally distributed. The data were analyzed using one-way ANOVA and Tukey's tests, the level of significance was set 5%.

Results

The mean and standard deviation values of time to failure (TF), number of cycles to failure (NCF), maximum torsional strength (N.cm) and angular deflection (°) are show in table I.

Table I – Mean and standard deviation values of the cyclic and torsional fatigue of the instruments tested

Instruments	Cyclic fatigue		Torsional fatigue	
	Time (s)	NCF	Torque	Angular deflection
RB 25.08	596.7±57.33[a]	2984±286.7[a]	1.3±0.24[a]	530.9±22.64[a]
RCB 25.08	348.7±60.74[b]	1744±303.7[b]	1.6±0.27[c]	317.4±36.22[b]
OFB 25.08	718.5±47.53[c]	3593±283.7[c]	1.8±0.34[c]	548.6±51,25[a]

Different lowercase letter in columns indicate significant difference among the instruments (P<0.05)

The cyclic fatigue test demonstrated that OFB 25.08 exhibited the highest TF and NCF than the other groups, followed by RB 25.08 (P<0.05). The RCB 25.08 exhibited the lowest TF and NCF (P>0.05). Regarding the torsional test, the RCB 25.08 and OFB 25.08 exhibited highest maximum torsional strength, followed by RB 25.08 (P<0.05). Also, the RB 25.08 and OFB 25.08 presented similar angular deflection than RCB25.08 (P>0.05).

The scanning electron microscopy (SEM) analysis of the fractured surfaces of all instruments revealed similar and typical features of cyclic fatigue and torsional failure. After the cyclic fatigue test, typical patterns were observed with microvoids, and characteristic morphological features of ductile fracture (figure 1). After torsional tests, the instruments exhibited concentric abrasion marks, indicative of torsional stress and failure. Fibrous dimple marks were observed at the center of rotation, further confirming torsional failure (figure 2).

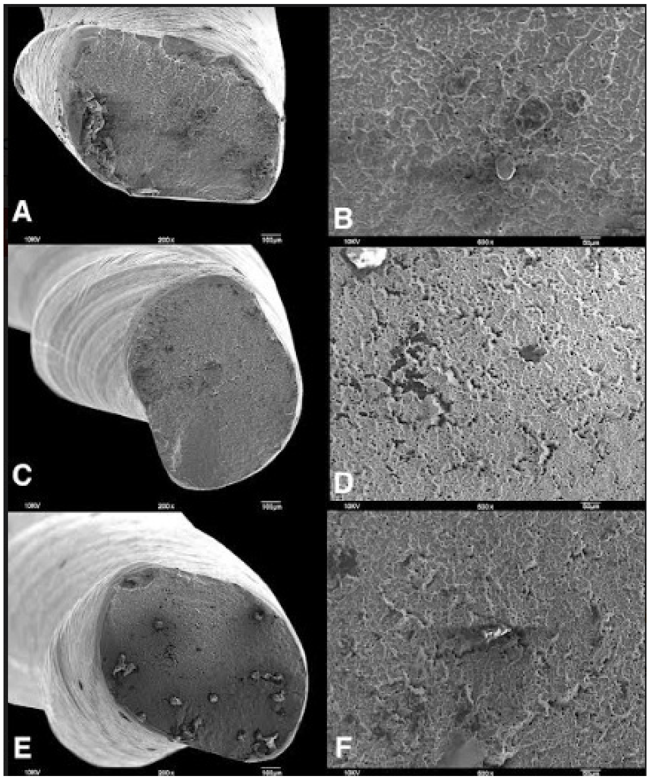

Figure 1 – Representative SEM imagens of the fractured surfaces of the reciprocating instruments after cyclic fatigue test. A-B) Reciproc Blue 25.08; C-D) Only One File 25.08; E-F) RC Blue 25.08. The first column (A, C and E) are representative images of fractured surfaces of the instruments at 200x of magnification. The second column (B, D and F) are representative images of fractured surfaces of the instruments at 500x of magnification

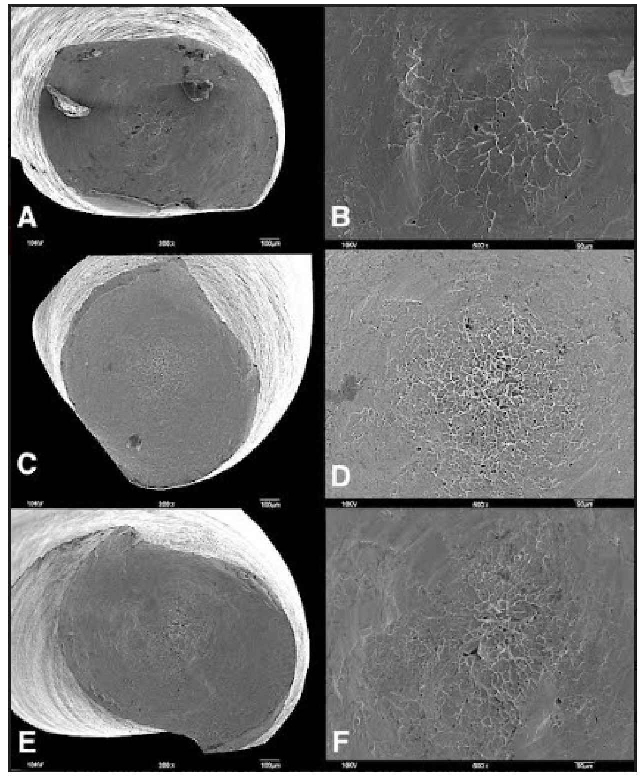

Figure 2 – Representative SEM imagens of the fractured surfaces of the reciprocating instruments after torsional fatigue test. A-B) Reciproc Blue 25.08; C-D) Only One File 25.08; E-F) RC Blue 25.08. The first column (A, C and E) are representative images of fractured surfaces of the instruments at 200x of magnification. The second column (B, D and F) are representative images of fractured surfaces of the instruments at 500x of magnification

Discussion

Currently, many replicalike engine-driven NiTi instruments have been commercialized or distributed without any scientific report, which can compromise the safety and efficiency of root canal treatment [11, 13-15]. The are some scientific reports comparing mechanical properties and shaping ability of Reciproc Blue with replicalike system [12, 13, 19]. Recently, two reciprocating replicalike system of Reciproc Blue was introduced in Brazil, such as Only One File Blue (Shenzhen Denco Medical, Shenzhen, China) and RC Blue (Shenzhen Perfect Medical Instruments, Shenzhen, China) and there are no scientific reports regarding their mechanical properties. Therefore, the aim of this study was to evaluate the cyclic and torsional fatigue resistance of two replicalike reciprocating systems (Only One File Blue and RC Blue) and compare with the original brand (Reciproc Blue).

The methodology employed in this study to assess the static cyclic fatigue resistance adhered to the guidelines specified in the revised ISO 3630-1 standard and was previously reported by other authors [1, 2]. The static cyclic fatigue test is widely used validated methodology because it is associated with a better-controlled laboratory environment, reducing the risk of some biases [1, 2, 15]. The torsional fatigue test was conducted following standard guidelines ISO 3630-3631 and was previously used by several authors [1, 2]. This evaluation aimed to determine the maximum torque (N.cm) and angular deflection on the first 3 mm of the instrument's tip. These both methodologies aimed to simulate a high flexural and torsional mechanical stress, which allow to stipulate the mechanical behavior of the instruments during preparation of curved or constricted canals [1, 2, 12].

The results of cyclic fatigue and torsional test demonstrated a significant difference among the instruments (P<0.05). Therefore, our two null hypotheses were rejected. Although the RB, OFB and RCB 25.08 present similar design characteristics (S-shaped cross-section, same tip size and taper), there was a significant difference among then. It was previously reported that the thermal treatments tend to increase the presence of R and Martensite phase, favoring higher instrument flexibility, cyclic fatigue resistance and angular deflection [12, 21]. Also, the mechanical properties are influenced by the core diameter and cross-section design due to can favor higher metal mass volume [4]. The same design characteristics among the instruments (taper, cross-section design and tip size) demonstrated that the thermal treatments and core diameter probably impacted in our results.

Previous studies reported that instruments with high flexibility tend to present high cyclic fatigue resistance, lower maximum torsional strength and high angular deflection [1, 2, 17]. However, in this study the OFB 25.08 contradicted these findings. Some authors claims that thermal treatments have a relevant impact on the cyclic fatigue resistance, while the instrument's design (cross-section and core diameter) on the torsional properties [10,4]. Therefore, the NiTi characteristics and core diameter of the OFB 25.08 provided a balanced mechanical properties. Additionally, corroborate to explain the different cyclic and torsional properties of RB 25.08 and RCB 25.08.

The results of this study corroborate with previous authors that demonstrated that replicalike system can present different mechanical properties in comparison of original brands [13-15]. Some authors claim that these different mechanical properties can be attributed by the thermal treatments of the NiTi and instruments design (cross-section and core diameter) [13, 15]. Our findings of cyclic fatigue results suggest that RB 25.08 and OFB 25.08 would be safer than RCB 25.08 during root canal preparation of curved canals. On the other hand, the OFB 25.08 and RCB 25.08 would be resist greater torsional forces, which is a relevant mechanical property during root canal preparation of constricted canals. Finally, the highest angular deflection of RB 25.08 and OFB 25.08 can be a safety characteristic because an occurrence of plastic deformation can be visualized and can be a warning that at torsional failure is imminent [16]. Future studies using multimethod analysis (Differential Scanning Calorimetry, X-Ray Diffractometry and Micro-CT) should be conduct for a better and deep comprehension of the difference the NiTi characteristics and if the different mechanical properties of these systems may impact in the shaping ability.

The scanning electron microscopy (SEM) analysis revealed that all instruments subjected to testing exhibited characteristic indications of cyclic and torsional fatigue, irrespective of their tip size (figures 1 and 2). In the case of instruments subjected to cyclic fatigue, the fractured surfaces displayed the presence of microvoids, a common hallmark of ductile fatigue. Meanwhile, during the torsional test, all instruments exhibited concentric abrasion marks and fibrous dimples at the central rotation point, indicating torsional fatigue [1, 2, 16].

Conclusion

In conclusion, with the limitation of this study, the two replicalike system presented different mechanical properties in comparison of the original brand. The OFB 25.08 presented the highest cyclic fatigue resistance while the RCB 25.08 the lowest. The OFB 25.08 and RB 25.08 presented similar angular deflection.

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