Study Concerning the Cyclical Fatigue of Endodontic Instruments of the Reciproc System

**Abstract:** In routine endodontic practice, attempts are made to reach a file system for biochemical preparation of the root canals which provides better conditions for the irrigating solution to clean and disinfect the root canals, trying as much as possible to preserve the quality of the preparation. The root canal shaping time has been drastically decreased with the aid of mechanized instrumentation, especially with the reciprocal movement of a single file, providing much more comfort for the patient as for the professionals involved in the process. Nevertheless, the concern with the capacity to withstand cyclic fatigue still remains, since once within the root canals all instruments may be prone to fracture. This study aimed to review the current literature concerning the cyclic fatigue of endodontic instruments in the Reciproc system. For the accomplishment of this work, PubMed database was used, and the set of cyclic fatigue descriptors as well, namely: Reciproc, NiTi and their similars, only in English. The readings of the abstracts were conducted according to the inclusion criteria, which was the gathering of the journals which carried out experimental studies in vitro, with instruments belonging to the Reciproc system, from the periods ranging from 2012 and 2019. It was concluded that the reciprocating instruments from Reciproc System (VDW, Munich, Germany) that presented the best performance quality, after scrutinizing several aspects, was the Reciproc Blue R25 instrument (25/0.8).

**Keywords:** Cyclic fatigue. Reciproc. NiTi.

**INTRODUCTION**

Root canal preparation is essential for root canal therapy simply because so the forthcoming steps depend on it, in order to achieve success. Flaws or defective procedures may not only jeopardize the final outcome or the endodontic treatment, as it may also cause the unviability of the tooth in question. Therefore, Endodontics has progressively been improve materials and instrumentals that may not only enhance routine clinical practice, as also offer better results to the patients. In this sense, a new technique using only one single file associated with the reciprocating movement, based on Roane's alternating movement, alternating clockwise and counterclockwise, has become widely used in order to decrease the cyclic fatigue rate of the instruments; allowing and a faster but equally effective mechanical preparation (PEREIRA, 2012). Reciprocating instrumentation had initially been proposed in Canada, by Yared, in 2008. The first generation of reciprocating instruments manufactured by VDW was named Reciproc and the following, Reciproc Blue. Reciproc instruments are made of Nickel-Titanium (NiTi) alloy registered with the fancy name “M-Wire nickel titanium”, which underwent thermal treatment process that, according to the manufacturer’s instructions (VDW, 2015), offers resistance to cyclic fatigue and flexibility superior to traditional NiTi alloys. Reciproc Blue instruments are subjected to a much more complex cooling and thermal treatment that results in a titanium oxide layer visible on the instrument's surface. Such process controls the transition temperatures, creating a shape memory alloy, which is guaranteed by the manufacturer to result in improved mechanical properties, better than other endodontic instruments (DE-DEUS, 2017).
LITERATURE REVIEW

The superiority of Reciproc has been demonstrated by the majority of the studies mentioned in this review. For instance, Arslan et al., (2016), compared the cyclic fatigue resistance of Reciproc® instruments when used with different kinematics (150° counterclockwise (CCW) - 30° clockwise (CW), 270° CCW - 30° CW, 360° CCW - 30° CW and continuous rotation). Several kinematics were tested on steel canals with a 3 mm radius and curvature angle of 60° as follows (n = 20): 150° CCW - 30° CW, 270° CCW - 30° CW, 360° CCW - 30° CW and 360° CCW (rotary movement). The Reciproc R25 instruments were used until the moment the fracture occurred. The fracture time was recorded in seconds. The data were analyzed statistically by means of variance analysis and Tukey’s post-hoc tests (P = 0.05). The resistance to cyclic fatigue of Reciproc R25® instruments used with various kinematics in decreasing order was as the following: 150° CCW - 30° CW & gt; 270° CCW - 30° CW = 360° CCW - 30° CW & gt; 360° CCW rotary motion. At 150° CCW - 30° CW reciprocating motion had the best performance when fracturing. All rotational motion recipes (150° CCW - 30° CW, 270° CCW - 30° CW and 360° CCW - 30° CW) resulted in a longer average failure duration compared to the CCW rotary motion.

Alcalde et al., (2017) evaluated the resistance to cyclic fatigue of reciprocal file systems: Reciproc Blue 25.08 (VDW GmbH, Munich, Germany), Prodesign R 25.06 (Easy Dental Equipment, Belo Horizonte, Brazil), and WaveOne Gold 25.07 (Dentsply / Tusa Dental Especialidades, Tuka, OK, USA). Sixty alternative instruments from the Reciproc Blue R25 (RB # 25.08 taper), Prodesign R (PDR # 25.06 taper), and WaveOne Gold (WOG # 25.07 taper) systems (n = 20) were used. The stress test cyclic fatigue was performed by measuring the time failure in an artificial stainless steel canal, with a curvature angle of 60° and a radius of 5 mm, being the tip located at 5 mm (n = 10). The fractured surface of each fragment was also observed using scanning electron microscopy (SEM); in addition, a complementary examination was performed to measure the cross-sectional area of each instrument 3 and 5 mm from the tip. The data were analyzed by using the one-way ANOVA test and Tukey’s test, and the level of significance adopted was 5%. As a result, the values of resistance to cyclic fatigue of the PDR 25.06 were significantly higher (P & lt; 0.05). RB 25.08 showed greater resistance to fatigue than WOG 25.07 (P & lt; 0.05). It could be concluded that PDR 25.06 presented the highest resistance to cyclic fatigue until fracture happened in relation to RB 25.08 and WOG 25.07. In routine endodontic practice, alternative thermal-treated instruments have been used for the preparation of curved and constricted s; therefore, these instruments must have high flexibility and resistance to adequate tension to minimize the risk of instrumental fracture.

Topcuoglu et al., (2017) compared the resistance to cyclic fatigue of the WaveOne Gold, Reciproc and WaveOne instruments in s with a double curvature. It was found that the WOG Primary (apical curvature: 928.87 293.69; coronal curvature 1102.32 397.39 NCF) showed higher resistance to cyclic fatigue than did Reciproc R25 and WO Primary in the apical third, as well as in coronal curvatures (P & lt; 0.05). Reciproc R25 instruments (745.63 253.49 NCF) had higher resistance to cyclic fatigue than did primary WO (583.89 183.38 NCF), in apical curvatures (P & lt; 0.05). There was no significant difference in the resistance to cyclic fatigue of the Reciproc R25 and WO files in coronal curvatures (883.63 282.56 and 916.53 268.21 NCF, respectively) (P & gt; 0.05). There was no difference concerning the lengths of the fractured fragments of the primary WOG, Reciproc R25, and primary WO in any apical or coronal curvature (P & gt; 0.05).

Keskin et al., (2017) analyzed the resistance to cyclic fatigue of Reciproc Blue, Reciproc, and WaveOne Gold reciprocating instruments. They were collected and tested in a dynamic device, composed of a tube with a 60° curvature angle and a 5 mm curvature radius. All instruments were operated until the fracture took place. Reciproc Blue R25 exhibited the highest resistance to cyclic fatigue (P & lt; 0.05). The fatigue strength values of WaveOne Gold Primary were significantly higher than those of Reciproc R25 (P & lt; 0.05). There was no significant difference in the average length of the fractured fragments among the instruments (P & gt; 0.05). De-Deus et al., (2017) evaluated the influence of the Blue thermal treatment on flexural strength and cyclic fatigue of conventional M-Wire reciprocals (VDW, Munich, Germany). In addition to resistance to cyclic fatigue, fracture time was measured in an artificial stainless steel with a 60° angle and a 5 mm radius of curvature. The surface fractures of all fragments were examined with a scanning electron microscope. As a result, the Reciproc Blue instrument showed significantly greater resistance to cyclic fatigue than the original Reciproc instrument (P & lt; 0.05).

De-Deus et al., (2017) assessed the influence of the Blue Thermal treatment on flexural strength and cyclic fatigue of conventional M-Wire reciprocals (VDW, Munich, Germany). In addition to resistance to cyclic fatigue, fracture time was measured in an artificial stainless steel device with a 60° angle and a 5 mm curvature. The surface fractures of all fragments were scrutinized with a scanning electron microscope. As a result, the Reciproc Blue instrument showed significantly higher resistance to cyclic fatigue than did the original Reciproc instrument (P & lt; 0.05). Özyürek et al., (2017) compared the resistance to cyclic fatigue, resistance to flexion and the transversal

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areas of the Reciproc Blue (RPC Blue), WaveOne Gold (WOG) and Genius File (GF) NiTi Systems. 40 RPC Blue R25 (25 / .08), 40 WOG Primary (25 / .07) and 40 GF (25 / .04) files were used. File flexibility was determined by the 45° flexion test. The instruments were also submitted to resistance to cyclic fatigue, by calculating the number of fracture cycles (NCF), in an S-shaped artificial stainless steel. The lengths of the tips of the fractured files were measured. The fracture surface of all fragments was examined with a scanning electron microscope. The data were analyzed statistically using one-way ANOVA and post hoc Tukey tests. As a result, in apical and coronal curvatures, the NCF of GF was significantly higher than that of RPC Blue and WOG files. There was no statistically significant difference between GF, WOG and Reciproc Blue files in relation to the lengths of fragments of files fractured in the apical or coronal curvature. The flexural strength of GF was significantly higher than that of RPC Blue and WOG files. The RPC Blue had the largest cross-sectional area, and the GF had the smallest cross-sectional area. It was concluded, within the limitations of that study, that the GF NiTi system exhibited the highest resistance rates among the experimental groups.

Topcuoglu et al. (2017) evaluated the cyclic fatigue of Reciproc (R25 and R40; VDW Munich, Germany) and Reciproc Blue (R25 and R40, VDW) used in the S-shaped artificial. As a result, among the R25 files, the Reciproc Blue instruments demonstrated greater resistance to cyclic fatigue than Reciproc files, in the apical third and in the coronal curve (P & lt; 0.05). Among R40 files, the Reciproc Blue instruments showed a longer time to fracture in the apical and coronal curves (P & lt; 0.05). There was no difference in the lengths of the fractured fragments of the Blue Reciproc files compared with the Reciproc files (P &gt; 0.05). Inan et al. (2018) studied the resistance to cyclic fatigue of Reciproc and Reciproc Blue through tests on severe apical curvature. Eighteen Reciproc R25 (25.08) and Reciproc Blue (25.08) instruments were subjected to cyclic fatigue tests at body temperature (37 °C) using a stainless steel block with an artificial device with a 90° curvature angle and curvature radius of 2 mm. As a result, it was found that the NCF values (number of fracture cycles) of Reciproc R25 were significantly lower than Reciproc Blue R25 (P &lt; 0.05). There was no significant difference between the instruments, regarding the length of the fractured fragments (P &gt; 0.05).

Plotino et al. (2018) investigated the impact of ambient temperature on cyclic fatigue of reciprocating nickel-titanium (NiTi) endodontic instruments Reciproc and Reciproc Blue. The tests were carried out on artificial stainless steel. During the experiment, 4 different temperatures (0°C, 20°C, 35°C and 39°C) were used in a thermostatic bath and the instruments were returned in the artificial until fracture occurred. As a result, Reciproc Blue instruments were significantly more resistant to cyclic fatigue than Reciproc at all temperatures tested (P &lt; 0.05). The fatigue resistance was proportionally greater, as the ambient temperature decreased (0°C &gt; 20°C &gt; 35°C &gt; 39°C). No statistically significant difference was recorded for the length of the fractured fragment of both instruments, at all temperatures tested (P &gt; 0.05).

Klymus et al. (2018) evaluated the impact of body temperature on the resistance to cyclic fatigue of different reciprocating instruments with thermomechanical treatment. Cyclic fatigue tests were performed at room temperature (20 ° ± 1 ° C) and at body temperature (37 ° ± 1 ° C). The instruments were activated until the fracture occurred in an artificial stainless steel device with a 60° angle and a 5 mm curvature radius. As a result, the cyclic fatigue test at 20° C showed that Reciproc Blue 25 (0.8) and X1 25 (0.6) had TTF (fracture time) and NCF (number of fracture cycles) significantly higher than WOG 25, 7 (P &lt; 0.05) at 37 °C. All groups showed a significant reduction in TTF and NCF (P &gt; 0.05). The Reciproc Blue 25 (0.8) had a higher TTF than WOG 25, 7 (P &lt; 0.05). As for the NCF, there was no significant difference between the groups (P &gt; 0.05). WOG 25, 7 showed the lowest percentage reduction in cyclic fatigue (P &lt; 0.05).

Muhammad et al. (2018) evaluated the resistance to cyclic fatigue of reciprocating nickel-titanium (NiTi) files (Wave One Gold and Reciproc Blue) and the effect of glycerol and sodium hypochlorite at 5.25% during the test. A total of 80 WaveOne Gold and Reciproc Blue R25 instruments were tested. The 40 files of the same brand were randomly distributed in four groups (n = 8) and submitted to the irrigation protocol as follows: Group 1: Test with no irrigation, Group 2: Test with glycerol, Group 3: Test with sodium hypochlorite 5.25% gel, Group 4: Test with 5.25% liquid sodium hypochlorite, Group 5: test with normal saline solution (control). The fatigue test was performed using the appropriate predefined reciprocating mode ("RECIPROC ALL" or 'WAVEONE ALL') on a specially designed endodontic engine. Fracture resistance was determined by recording time. The Instruments were tested in an artificial stainless steel device with a 60° curvature angle and a 5 mm curvature radius. The resistance to cyclic fatigue of the same NiTi instrument was affected by the irrigated medium. Reciproc Blue R25 was associated with greater resistance to cyclic fatigue in all groups compared to WaveOne Gold Primary. The study concluded that glycerol, 5.25% sodium hypochlorite in gel and liquid can significantly reduce the cyclic fatigue resistance of WaveOne Gold and Reciproc Blue significantly. However, the type of alternative instrument influenced the resistance to cyclic fatigue. Reciproc Blue R25 was considered stronger than WaveOne Gold Primary.
Pedulla et al., (2018) compared the cyclic fatigue of Reciproc (REC; VDW, Munich, Germany) and Reciproc blue (REB; VDW) with different file access angles. The cyclical aspect of the maximum resistance of 120 files REC R25 and REB R25 (REB) were tested. The instruments were divided into 8 groups based on the access angle inside the tested ciliary artificial canal (n = 15): groups 1, 2, 3 and 4 included REC tested at 0, 10, 20 and 30, respectively, and the groups 5, 6, 7 and 8 consisted of REB tested at 0.10, 20 and 30, respectively. The results of resistance to cyclic fatigue was determined by recording the fracture time in an artificial stainless steel with a curvature of 60°C and a radius of 5 mm using a custom test device. Data were analyzed by using bidirectional analysis of variance (ANOVA) with a significance level of 5%. The fracture surface of the fragments was examined with a scanning electron microscope. As a result, the cyclic fatigue of the REC was reduced at each insertion angle, while REB reduced its fatigue strength when 20 or 30 access slopes were tested. REB exhibited greater cyclic fatigue than REC when the angle of access to the file was 0 and 10 (P < 0.05), while there was no difference between the instruments tested at 20. REC showed greater resistance less than REB at 30 (P < 0.05). It is concluded that REB files showed greater resistance to cyclic fatigue than REC, when access to the canal was straight or with a limited slope.

Kelles et al., (2019), compared the cyclic fatigue resistance of four reciprocal single file systems in artificial stainless steel, at two temperatures using different kinematics. A total of 240 instruments, Reciproc Blue, Reciproc, Waveone Gold, Waveone, (60 each), were tested at room and intracanal temperature using a static and dynamic model (n = 15), in an artificial stainless steel with internal diameter of 1.5 mm, curvature angle of 60°C and 5 mm curvature radius until fracture took place. The fracture time was measured in seconds using a digital stopwatch and the data were analyzed by using a variance analysis and Bonferroni tests. As a result, WaveOne instruments had significantly less resistance to fatigue than did the other systems in all conditions (P < 0.05). Comparison of the results of the static and dynamic models in both temperatures revealed that fatigue strength was significantly increased in the dynamic model for all instrument systems (P < 0.05). The temperature did not influence the fatigue cyclic resistance results (P < 0.05). There were no significant differences in the average length of the fractured segments of the different instruments tested (P < 0.05). It was concluded that Waveone files had the shortest cyclic fatigue time. The temperature did not significantly affect cyclic fatigue of nickel titanium files.

DISCUSSION

Reciproc Blue instruments have been regarded as very resistant by most of the articles that assess cyclic fatigue. The present literature review has confirmed the Reciproc Blue 25.08 instrument (VDW, Munich, Germany) as the most resistant to cyclic fatigue, in laboratorial conditions, considering different dependent variables. The Reciproc Blue (REB) 25.08 is an instrument activated by reciprocating movement consisting of a nickel-titanium alloy that receives a differentiated thermal-mechanical treatment, named BLUE, with molecular structure that provides memory control, additional flexibility and the results confirmed less cyclic fatigue and, therefore, less fracture scores.

Many studies have accounted for the time required for the fracture of this instrument (NFC = number of cycles for fracture) compared with others with similar structural characteristics, in devices that simulate the average morphology of the root canal, presenting unique curvatures of 60 or 90. When compared to the Wave One Gold primary (WOG) file (Dentsply Maillefer, Baillagues, Switzerland), REB R25 showed significantly superior results (P < 0.05) (MUHAMMAD et al., 2018; ÖZYÜREK et al., 2018) . In one of these experiments, in an attempt to simulate what occurs in the clinic endodontic routine, cyclic fatigue was also tested in the presence of glycerol and sodium hypochlorite at 5.25%, as an auxiliary chemical. Both substances decreased the fracture resistance of files, with statistically significant results (P < 0.05) (MUHAMMAD et al., 2018), warning operators for this reduction in safety.

Even when REB R25 was compared with the instrument from its previous generation, known as Reciproc R25 Classic, with surface design, cross section, and similar operating modes, however, manufactured with NiTi M-Wire alloy, it showed superior performance as well (DE-DEUS et al., 2017; PEDULLA et al., 2018), which can only be justified, due to its exclusive thermal treatment of the alloy. In another study, the same reciprocating instruments, REB R25 and WOG primary also showed greater resistance to cyclic fatigue, with a statistically significant difference (P < 0.05) when compared to the scores displayed by the classic Reciproc R25 (P < 0.05). Once again, thermal treatment has demonstrated that it is a significant differential (KESKIN et al., 2017). Nevertheless, even with Instruments that also had similar thermal treatment, such as HyFlex EDM (HEDM; Coltene / Whaledent, Altstätten, Switzerland) and 2Shape (TS; Micro-Mega, Besancon, France), REB showed greater resistance to cyclic fatigue, with a statistically significant difference (P < 0.05) when tested in artificial root canals, with 45° and 90° of curvature (ÖZÜREK et al., 2018). These instruments are used in continuous rotation, which may explain their low performance, as this kinematics is prone to greater risks, in relation to the reciprocating movement.
Other research has examined cyclic fatigue in more challenging devices that simulate severe curvature in the apical segment, as they are occasionally found in the root canals. Regardless of this condition, REB stood out (INAN et al., 2018).

Another study compared the Reciproc classic instruments with the Blue one, both in diameter 25/0.8 and 40/0.6. Once again, the thermal treatment of Blue files stood out with results statistically superior to Reciproc Classic (P &lt; 0.5) (TOPCUTOGLU et al., 2016). This time, an artificial S-shaped was used which increased the difficulty degree and made the operative activity more stressful in relation to the single curve, as it is known that an instrument is exposed to greater compression and traction stresses when its curvature is increased. Even with larger diameter files (40 / 0.6) with consequent less flexibility, REB still offered adequate root canal preparation with less risk for iatrogenic errors.

One experiment used the EVO and X-Smart Plus engines as a variable, which performed reciprocating movement and were used to activate the instruments during endodontic treatment, to evaluate WaveOne (first generation), WaveOne Gold, Reciproc classic and Reciproc Blue. Regardless of the engine used, the REB instruments were significantly more resistant than the others (IACONO et al., 2018).

Other authors tested Mtwo files (M25 and M40) (VDW Munich, Germany) which are nickel-titanium instruments morphologically similar to Reciproc classic files (R25 and R40) (PEDULLA et al., 2013) and Genius File (GF) (ÖZÜREK et al., 2017), with Reciproc Blue. The calculation of the cycle number of until the fracture revealed superiority of the REB files in the first test, however the Genius files showed significantly better results. Perhaps, due to the reciprocity angle (90 ° clockwise and 30 ° counterclockwise) that was less than that recommended for the WOG instrument (150 ° counterclockwise and 30 ° clockwise) and RPB (120 ° clockwise and 30 ° clockwise). Some authors believe that the smaller the angle of movement, the lower the risk of fracturing the instruments.

Other works, beyond verifying the cyclic fatigue of the instruments themselves, also evaluated the fragments of these files after their fracture. Most authors, after analyzing the roughness through scanning electron microscopy, formation of macro-cracks and micro cracks, concluded that there was no significant difference between the sizes of the fractured fragments (P &gt; 0.05) and that they did not obey a standardization model (KIEFNER et al., 2014; PLOTINO et al., 2012; KESKIN et al., 2017; TOPCUTOGLU et al., 2017; IACONO et al., 2018; INAN et al., 2018; PLOTINO et al., 2018).

In endodontics, an attempt is made to find a file system for instrumentation that provides better conditions for the irrigator to act in the root canals, trying to preserve the quality of the preparation. Modeling time has been dramatically reduced with the use of mechanized instrumentation and mainly with the reciprocal movement of a single file, providing greater comfort for the patient and the professional. However, there is still concern about the capacity to withstand cyclic fatigue, since within it all instruments are subject to fracture. This result may be associated with the effect of the thermal treatment of the Reciproc Blue instrument (REB) and its manufacturing process, which provided an excellent performance, and revealed in this study its superiority, despite the limitations imposed on laboratorial research. Therefore, there is an urgent need to develop more examinations, preferably clinical research, in search of the best scientific evidence.

**CONCLUSION**

Despite the limitations of the present study, it is concluded that the reciprocating instrument showed the best significant performance. After analyzing several aspects, Reciproc Blue R25 instruments showed the best cyclic fatigue resistance (P &gt; 0.05).

**REFERENCES**


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