COMPARISON OF THE CYCLIC FATIGUE RESISTANCE BETWEEN THE RECIPROCANT SYSTEMS, RECIPROC® BLUE AND WAVE ONE® GOLD, BY A DYNAMIC TEST, SUBMITTED TO IMMERSION IN SODIUM HYPOCHLORITE AND / OR STERILIZATION

ABSTRACT

Introduction: The purpose of the following research was to determine the resistance to cyclic fatigue of the RECIPROC® Blue (VDW, Munich, Germany) and Wave-One® Gold (Dentsply Maillefer, Ballaigues, Switzerland) instruments, under a dynamic cyclic fatigue test. **Materials and Methods:** 15 RECIPROC® Blue "R25" files and 15 Wave-One® Gold "Primary" files were tested on a dynamic cyclic fatigue test with a simulated canal with a curvature of 60 ° and a 5 mm curvature radius. The instruments were used until the fracture occurs; the time and length of the fractured fragment were recorded by a video camera. For resistance due to cyclic fatigue and data on the length of the fractured fragments, the normality hypothesis is tested using the Shapiro-Wilk test. The data obtained on the lengths of the fragments are also subjected of a 1-way analysis of variance. The cyclic fatigue resistance values are analyzed using the Mann Whitney U test and SPSS with a 5% level of significance**. Results:** RECIPROC® Blue "R25" presented higher values of resistance to cyclic fatigue than WaveOne® Gold "Primary" instruments ($P < .05$). There were no significant differences between the groups in terms of the average length of the fragments ($p > 0.05$). **Conclusions:** The RECIPROC® Blue "R25" instruments were significantly more resistant to cyclic fatigue than WaveOne® Gold "Primary" instruments.

Key words: cyclic fatigue, bending resistance, Reciproc blue, wave one gold, dynamic test, simulated canals

INTRODUCTION

Endodontic rotary instruments made of a nickel-titanium alloy (Ni-Ti), have a number of advantages over conventional stainless steel instruments, such as greater flexibility, faster and more focused root canal preparation and control of the working length Therefore, a variety of products have been developed that differ in their design characteristics (taper, cross section, shape of cutting edges, helical angles) and manufacturing processes (thermo-mechanical processing application); with the objective of improving the precision and efficiency of the preparation of the root canal system [1]. However, despite the advantages of Ni-Ti instruments; these are subject to an unexpected fracture that can be attributed to fatigue due to flexion or torsional overload. To mitigate this risk, recently, manufacturers invested in the development of innovative instrument designs and heat treatments [2].

The fracture of the titanium nickel (Ni-Ti) rotary instruments is one of the main concerns of endodontic practice. This complication may occur mainly due to two different mechanical deficiencies: (a) torsional fatigue or (b) cyclic flexural fatigue [3]. Torsional fatigue occurs when the apical part of the instrument is locked within the walls of the root canal while the lima stem continues to rotate. When the elastic limit of the metal is exceeded, the fracture is an inevitable event [4,5]. In addition, cyclic flexural fatigue is associated with repeated cycles of tension / compression that occur at the point of maximum flexion of the instrument; when the file is rotating inside a curved root canal until the fracture occurs [5,6].

Another factor that potentially limits fatigue resistance and torsional fracture is the corrosion that can occur in the presence of a sodium hypochlorite solution. Sodium hypochlorite (NaOCl) is the most common irrigant; used in endodontic treatment, this tends to corrode surgical instruments [7].

Corrosion can negatively affect the physical properties of Ni-Ti instruments [7]; since it selectively removes nickel from the surface of the instrument and causes micro-bites, which negatively affects the physical and mechanical properties of Ni-Ti files [8] causing micro structural defects that can lead to areas of tension accumulation and cracking, weakening the structure of the instrument [9]. This corrosive effect of NaOCl on Ni-Ti instruments has been previously studied; Haikel et al used manual instruments totally submerged in a 2.5% solution for 24 to 48 hours and did not detect obvious corrosion. Busslinger et al, used 5% NaOCl for 30 or 60 minutes on Lightspeed rotary instruments and found corrosion patterns, even if the authors were not sure of the clinical implications. However, these studies provide a contact between endodontic instruments and hypochlorite in static mode and at different times. In fact, the functional part of endodontic instruments dynamically contacts the NaOCl solution for a few minutes during the biomechanical preparation. For this reason, if present, corrosion can adversely affect physical properties [10].

Possible explanations for these results; They are the different test and immersion protocols used. The immersion varied substantially (between 5 minutes and 48 hours) as long as the instrument was completely and statically submerged in the solution. These conditions, which mimic those used during instrument cleaning procedures and that involve NaOCl as a disinfectant agent, are very unlikely in clinical practice when the shaft is completely housed inside the head of the handpiece and the file rotates throughout the treatment [1].

An additional factor that can contribute to torsional fatigue and cyclic fatigue is sterilization. Repetitive cycles affect the crystalline phases of the Ni-Ti alloy. These changes result in improved physical properties, such as increased cutting efficiency and fracture resistance [11]. Yahata et al. (2009) suggested that additional heat retreatment of Ni-Ti instruments during autoclave sterilization can increase this flexibility. Silvaggio and Hicks (1997) showed that 10 cycles of heat sterilization of the instruments (Dentsply Maillefer, Ballaigues, Switzerland), did not increase the probability of fracture. Autoclave sterilization was performed at 134 ° C, with a pressure of 30 psi, for 5 min [12]. Other researchers reported that " additional heat treatment ', during autoclave sterilization can improve the flexibility of files, and sterilization of files by using dry hot air and an autoclave, would have a positive effect on resistance. to cyclic fatigue [13].

To improve the mechanical properties of Ni-Ti instruments, different strategies have been proposed, such as electro-polishing treatments, ion implantation, surface coatings and thermal treatments of the instrument with the aim of preventing fracture of the systems of files [14].

In addition to the modifications mentioned above, the introduction of a reciprocating motion kinematics has had a positive impact on the life of Ni-Ti endodontics instruments compared to continuous rotation systems [5,15]. The reciprocal dynamic implies a clockwise movement, intended to perform the cutting action, followed by an anti-clockwise movement to release the file from the dentine walls. The reciprocating movement is greater in the anti-clockwise direction (cutting direction) and inverse movement in the clockwise direction (instrument release), therefore, generates lower voltage values in the instruments and prevents cyclic fatigue for a prolonged period of time [15,16].

RECIPROC® (VDW, Munich, Germany) and Wave One® (Dentsply Maillefer, Ballaigues, Switzerland) are the main examples of reciprocating systems and, since the philosophy of the system primarily attempts to use a single file, the endodontic procedure is reduce in time. Both instruments are manufactured with M-Wire technology, characterized by a heat treatment that provides changes in the volume of the instrument with the appearance of the R phase and a lime surface richer in TiO2, designed to optimize super elasticity and memory in the form of endodontic files, which in turn improves the fracture resistance of Ni-Ti file systems [14,17]

RECIPROC® Blue is the newest version of the RECIPROC® file system. The RECIPROC® Blue system includes 3 instruments ("R25" 25 / 0.08 for small ducts, "R40" 40 / 0.06 for medium ducts and "R50" 50 / 0.05 designed for large ducts), which use a 150 ° directional movement Anti-clockwise and 30 ° rotation clockwise at 300 rpm (5). All RECIPROC® Blue instruments have an S-shaped cross section, 2 cutting angles and a non-cutting tip. Unlike the RECIPROC®

system, RECIPROC® Blue files are manufactured by altering the molecular structure through a new heat treatment that gives the files their blue color and increases resistance to cyclic fatigue [18,19].

Wave One Gold® (Dentsply Maillefer, Ballaigues, Switzerland) is the latest version of Wave One® files. The series of files Wave One Gold® includes 4 instruments ("Small" 20 / .07, "Prima river" 25 / .07, "Medium" 35 / .06 and "large" 45 / .05) designed for that alternate movements of 15 0º counterclockwise and 3 0º clockwise at 350 rpm. The cross section of the Wave One Gold® files is a parallelogram with a positive cutting angle of 85 degrees and an alternating contact of one or two points. Contrary to M Wire technology, which uses heat treatment before production, Wave One Gold® files are manufactured by heating and then slowly cooling the file after production which increases its flexibility [19, 20,21] .

In the last 10 years, several proprietary processing procedures for nickel titanium alloy (Ni-Ti) were developed in order to improve the mechanical properties of Ni-Ti endodontic instruments. The Ni-Ti alloys used for endodontic instruments can be subdivided into instruments that contain mainly the austenitic phase (conventional Ni-Ti, M-Wire, R-Phase) and those that contain mainly the martensive phase (CM Wire, Gold and Blue heat) [22] .

Wave One Gold and Reciproc Blue are manufactured from CM wire alloy. Wire controlled memory (CM) which was introduced in 2010, is the first endodontic Ni-Ti alloy which has no mechanically treated properties super wi r elastic (Zhou et to the. , 2012). Due to a modified phase composition, CM Wire instruments may deform due to reorientation of martensite variants (Shen et al. 2013). Therefore, unlike austenitic Ni-Ti files, CM Wire instruments do not tend to straighten completely during the preparation of curved root canals. All files with Gold and Blue heat treatment demonstrated greater flexibility and fatigue resistance compared to conventional Ni-Ti and M-Wire instruments [23] .

Conventional Ni-Ti endodontic instruments contain approximately 56% by weight nickel and 44% by weight titanium (Thompson 2000). In the case of CM wire alloy to be able to have memory control, the nickel weight was reduced to 52% [22] .

Fatig resistance to cyclic limes rotary Ni - Ti , usually tested with test rotational flexure. According to the No. 28 ANSI / ADA (American National Standards Institute / American Dental Association) specification these tests , should be performed in a static condition in which the rotary files can be rotated freely in a metal device or artificial glass different geometric curvature until the fracture occurs (without involving the axial oscillation commonly used during clinical endodontic instrumentation techniques with Ni - Ti rotary files) [3] .

However, several studies have concluded that dynamic tests of cyclic fatigue in which files are operated with axial oscillation motion simultaneous to free rotation within the artificial device, provide more reliable results regarding resistance to cyclic fatigue and they also better represent the clinical reality [24,25] .

In view of the above, the main objective of this study was to compare the resistance to cyclic fatigue of the RECIPROC ® Blue "R25" and Wave One® Gold "Primary" instruments under a dynamic cyclic fatigue test , which were subjected to immersion in 5.25% sodium hypochlorite and sterilization cycles.

MATERIALS AND METHODS

A total of 30 new files RE CIPROC® Blue "R25" 25 / .08 and 30 Wave One Gold® "Primary" 25 / .07 were selected in this in vitro experimental study. Of these instruments , 30 were examined previously with increased x160 ba jo an electron microscope scanning (JEOL JSM 6490), in terms of structural deformation. None of the instruments examined had visible defects. Therefore, all files were subjected to a dynamic cyclic fatigue test.

All instruments were randomly assigned in 7 groups (n = 15) for each brand. Group 1 (control group) included instruments new q ue NaOCl were not immersed in or subjected s to autoclaving.

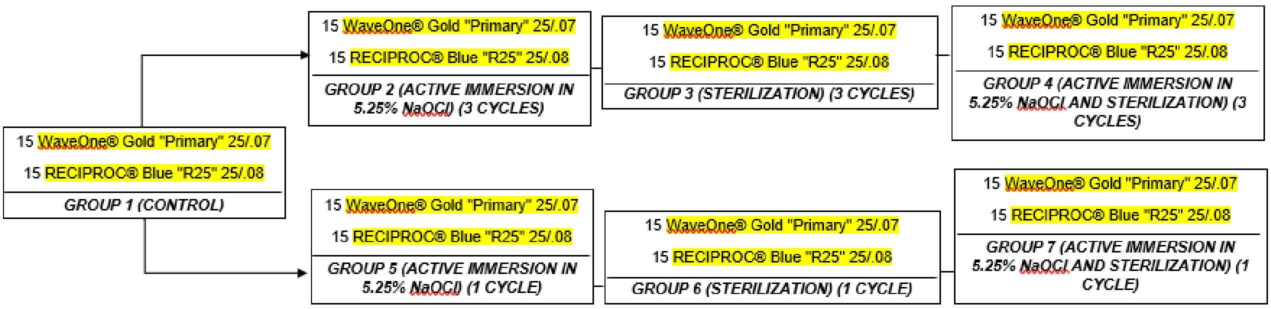

Figure 1: Random distribution of Reciproc Blue and Wave One Gold instruments in 7 study groups.

15 RECIPROC® Blue "R25" 25 / .08 files and 15 Wave One® Gold "Primary" 25 / .07 files were included in Group 2. All the s files were placed in small glass containers with the amount of solution of Na OCl necessary to contact the 16 mm of the active part of the instrument; s e allowed dynamic immersion, activating

endodontic instruments with a handpiece (Si rona Dental Systems GmbH, Bensheim, Germany); Powered by the VDW Silver Reciproc engine (VDW, Munich, Germany) . These files were subjected to active immersion 3 times for 3 minutes in 5.25% sodium hypochlorite; the hypochlorite solution was removed with physiological serum after each cycle to neutralize the effect of NaOCl; They were dried and stored in containers identified with the file number, type of system and number of dives in NaOCl.

They waited 24 hours for their dive into a new cycle until the number of required dives was completed. Subsequently, the cyclic fatigue test was performed in the simulation model , where only 22 mm of its length was introduced .

In group 5, 1 5 RECIPROC® Blue "R25" 25 / .08 files and 15 Wave One® Gold "Primary" 25 / .07 files were included. All the s files were placed in small glass containers with the amount of solution of Na OCl necessary to contact the 16 mm of the active part of the instrument; s and allowed dynamic immersion, activating endodontic instruments with a handpiece (Sirona Dental Systems GmbH, Bensheim, Germany); Powered by the VDW Silver Reciproc engine (VDW, Munich, Germany).These files were subject to active immersion 1 time for 3 minutes in 5.25% sodium hypochlorite; the hypochlorite solution was removed with physiological serum to neutralize the effect of NaOCl; They were dried and stored in containers identified with the file number, type of system and number of dives in NaOCl. 24 hours were expected to perform the cyclic fatigue test in the simulation model , where only 22 mm of its length was introduced .

The dynamic cyclic fatigue test was performed on a 300 series stainless steel artificial channel, with an internal diameter of 1.5 mm, a curvature angle of 60 ° and a radius of curvature of 5 mm (Fig. 1). The tip of the instrument is 7 mm in the middle of the curved segment [3] . All instruments were used with a Silver Reciproc endodontic engine (VDW, Munich, Germany) connected to the dynamic cyclic fatigue test device (Fig. 2) using the "Reciproc ALL" program designed specifically for RECIPROC® and the "Wave One ALL "designed specifically for Wave One® instruments. All instruments with a fixed length of 22 mm were operated with an axial movement of 3 mm / s until the instrument fractured.

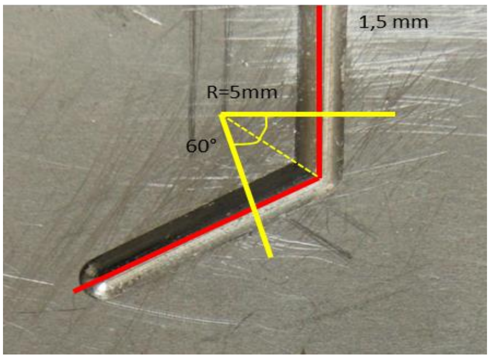

Figure 2: Artificial stainless steel channel

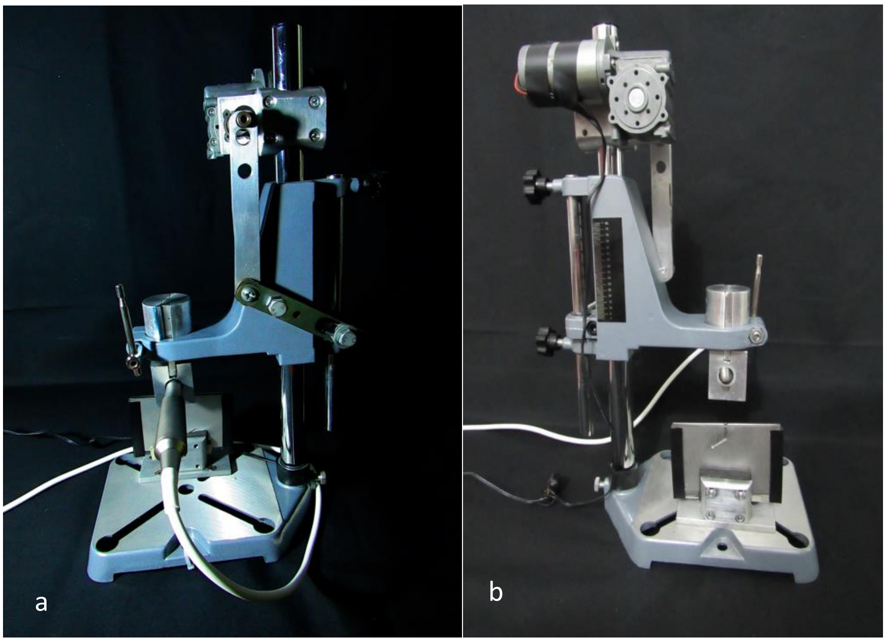

Figure 3: (a) Cyclic fatigue test simulation model, with VDW Silver Reciproc handpiece. (b) Cyclic fatigue test simulation model in which the artificial stainless steel channel is observed.

The fracture time (TF) for each lime tested was recorded in seconds using a stopwatch; In addition, a video record was made for each instrument to verify the fracture time. The length of the fractured fragment was measured in mm for each instrument with a digital microcaliper. After the fracture occurred, the degree of deformation suffered by the instruments was ev idenciado by observation in the Scanning Electron Microscope of electrons (JEOL JSM 6490-LV model, Andes University) ; the type of fracture was analyzed , and photomicrographs of the fractured surfaces with different magnifications (× 120 to × 6 00) were taken .

STATISTIC ANALYSIS

Data obtained for resistance to cyclic fatigue and fracture length, the normality hypothesis , was tested using the Shapiro-Wilk test. Data obtained from fragment lengths were subjected to a 1-way analysis of variance. Cyclic fatigue resistance values were analyzed using the Mann Whitney U test and SPSS based on a 5% level of significance.

RESULTS

Table 1 represents the values of fracture time, apical fragment and coronal fragment for each instrument, in which no normality of the groups was found ($p < 0.05$, Shapiro Wilk Test); consequently, it is decided to compare the groups with the use of non-parametric statistics.

Table 1: Normality test of the evaluated variables

	Shapiro-Wilk		
	Statistical	gl	S.I.G.
FRACTURE TIME	, 901	60	, 000
APICAL FRAG	, 926	60	, 001
CORONAL FRAG	, 906	60	, 000

The inferential analysis revealed statistically significant differences between the different groups considering the type of instrument as the independent variable ($P < .05$).

Table 2 represents the differences in the distribution of the medians between the Reciproc Blue and Wave One Gold groups subjected to immersion in 5.25% sodium hypochlorite; in which it is concluded that between time, apical fragment and coronal fragment there are statistically significant differences.

Table 2: Comparison between Reciproc Blue and Wave One Gold files subjected to immersion in 5.25% sodium hypochlorite

FILE	**Average Time (SD)**	**APICAL FRAG average (DE)**	**CORONAL FRAG (DE) average**
RB	343.13 (204.9) a	10.96 (2.5) a	16.23 (2.7) b
WOG	161.2 6 (67.8) b	6.86 (1.7) b	18.26 (1.8) a
	p value 0.001	p value 0.002	p value 0.021

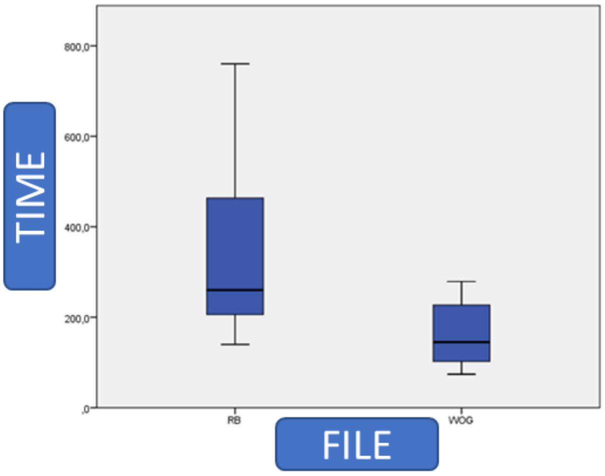

Figure 4: Comparison of the fracture time between files submitted to immersion in 5.25% sodium hypochlorite

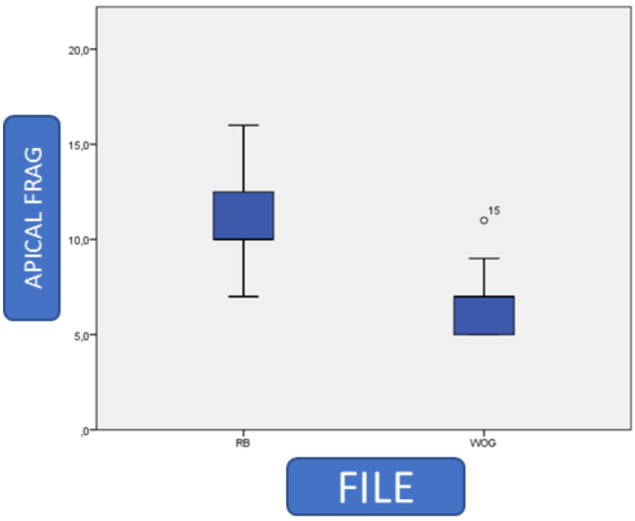

Figure 5: Comparison of the apical fragments of files submitted to immersion in 5.25% sodium hypochlorite

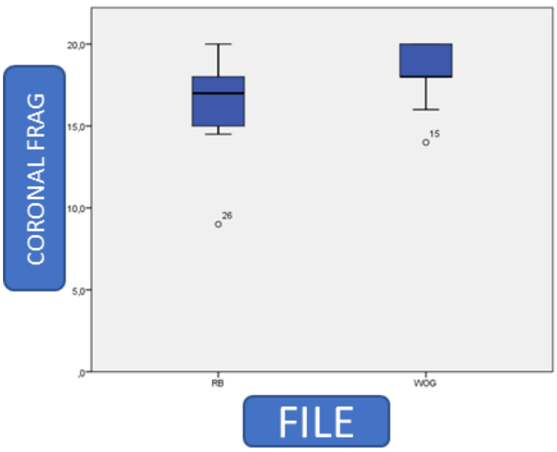

Figure 6: Comparison of the coronal fragments of the files submitted to immersion in 5.25% sodium hypochlorite

Table 3: Comparison between Reciproc Blue and Wave One Gold files submitted to three immersions in 5.25% sodium hypochlorite

FILE	Average Time (SD)	APICAL FRAG average (DE)	CORONAL FRAG (DE) average
RB	514.53 (77.3) a	6.93 (1.3) a	17.8 (1.6) a
WOG	233.86 (59.5) b	5.9 (1.7) a	18.83 (1.3) a
	p value 0.0001	p value 0.161	p value 0.161

According to the results obtained for group 2 (in immersion in hypochlorite 3 times), the hypothesis of differences in the distribution of the medians between the groups R eciproc B lue and W ave O ne G old is contrasted with the test of U Mann Whitney. The statistical test shows a p value lower than the alpha of 0.05 ($p < 0.05$); Therefore, it is concluded that there are statistically significant differences between the groups over time.

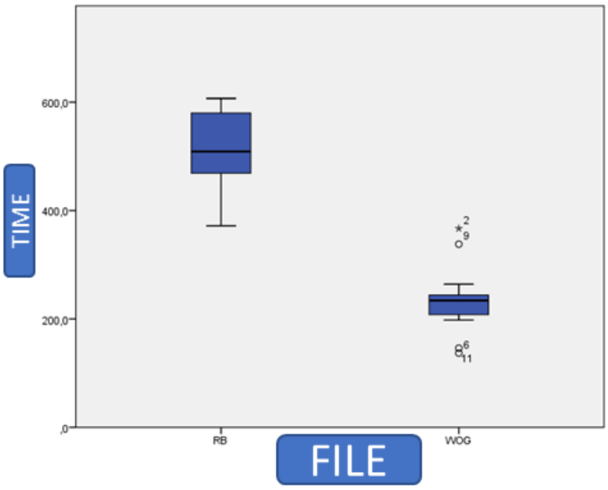

Figure 7: Comparison between Reciproc Blue and Wave One Gold systems, which were subjected to three immersion in 5.25% sodium hypochlorite

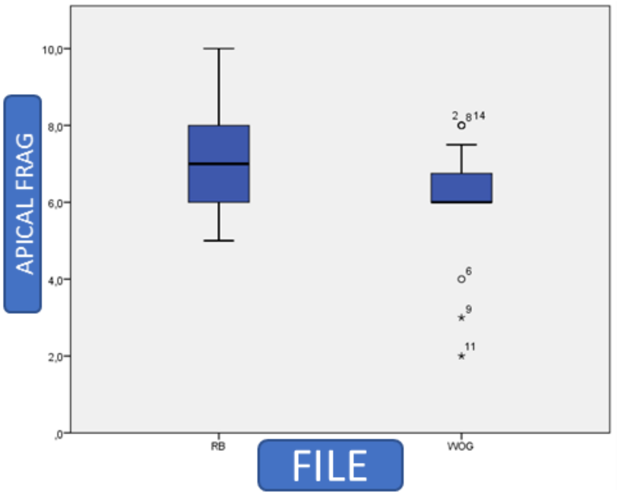

Figure 8: Comparison of the apical fragments of the files submitted to three immersions in 5.25% sodium hypochlorite

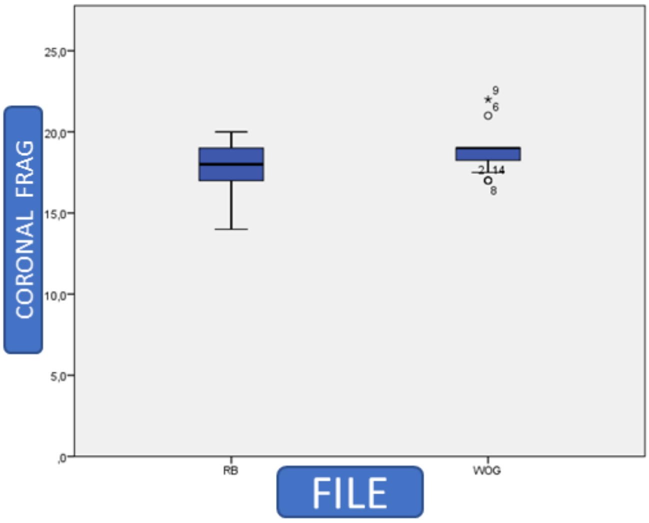

Figure 9: Comparison of coronal fragments of files submitted to three immersions in 5.25% sodium hypochlorite

Table 3 compares the Reciproc Blue and Wave One Gold instruments with the number of dives they were subjected to before performing the dynamic cyclic fatigue test. The U Mann Whitney statistical test was performed; which showed a p value lower than the alpha of 0.05 ($p < 0.05$), in the comparisons of time and apical fragment. Therefore, it is concluded that both in time and in the length of the apical fragment there are statistically significant differences between dives only for the Reciproc Blue group.

Table 3: Average number of immersions in 5.25% sodium hypochlorite for Reciproc Blue and Wave One Gold.

	TIME AVERAGE	APICAL FRAG average	CORONAL FRAG average
RB	**428.83 (175.3)**	**8.95 (2.8)**	**17.01 (2.3)**
1	343.13 (204.9) a	10.96 (2.5) a	16.23 (2.7) a
3	514.53 (77.3) b	6.93 (1.3) b	17.8 (1.6) a
WOG	**197.56 (72.8)**	**6.38 (1.7)**	**18.55 (1.6)**
1	161.26 (67.89) b	6.86 (1.7) a	18.26 (1.8) b
3	233.86 (59.5) a	5.9 (1.7) a	18.83 (1.3) b

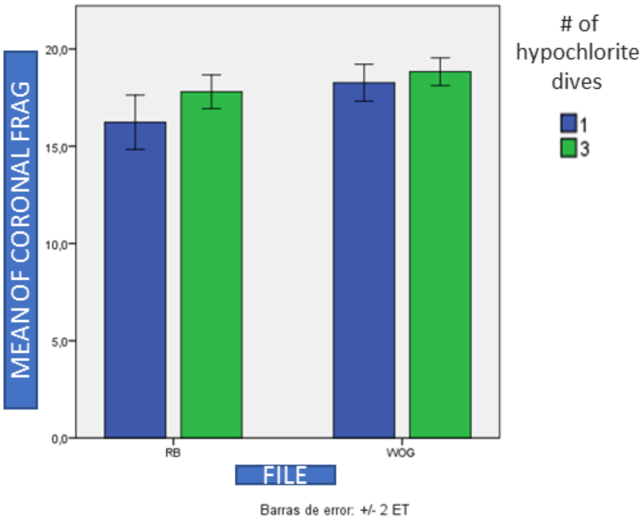

Figure 10: Average of the coronal fragments of Reciproc Blue and Wave One Gold files submitted to one or three dips in 5.25% sodium hypochlorite

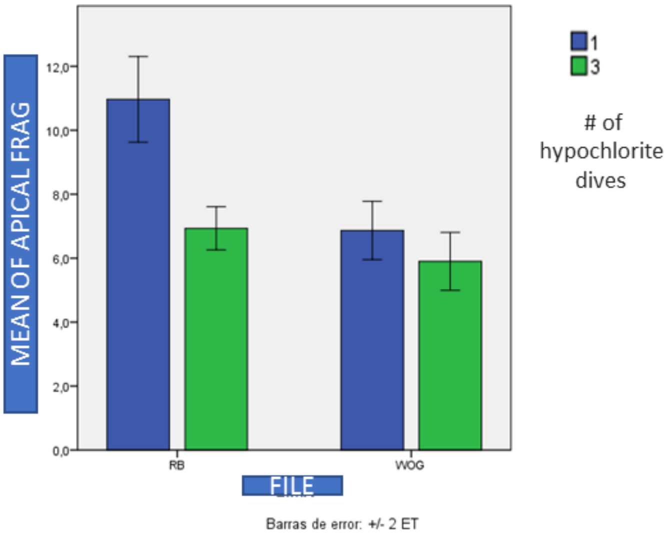

Figure 11: Average of the apical fragments of Reciproc Blue and Wave One Gold files submitted to one or three immersions in 5.25% sodium hypochlorite

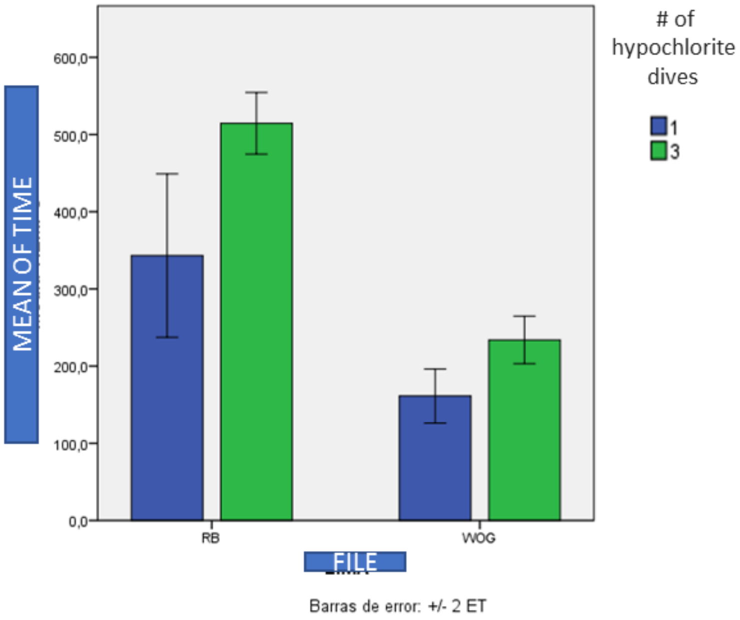

Figure 12: Average time it took to fracture Reciproc Blue and Wave One Gold files submitted to one or three dips in 5.25% sodium hypochlorite

DISCUSSION

This "in vitro" experimental study was carried out based on the comparison of the cyclic fatigue resistance of the reciprocating systems , RECIPROC Blue and Wave One Gold, when evaluated under a dynamic test and immersion in sodium hypochlorite at 5.25 % and autoclave sterilization .

Cyclic fatigue of rotary instruments is influenced by several factors; such as the speed of the files, the angles of curvature, the torque , the design characteristics of the instrument and the alloy in which they are manufactured [26] . The kinematic reci proca nte was specially developed to reduce the incidence of fractures instruments the influence resistance to cyclic fatigue of nickel titanium instrument [5,26] . Patented processes are highly influenced by temperature and time intervals. Any additional machining process will affect the transition temperatures and the percentage of alloy phases. This can explain why the performance of Ni - Ti instruments can be influenced by the quality of manufacturing processes and different heat treatments [13] . The assumptions to account for these results are multiple, including the fact that reciprocating instruments rotate a shorter circumferential distance compared to continuous rotation kinematics, therefore subjecting the file to much lower voltage values [27] .

In this study, the dynamic cyclic fatigue test was carried out using the preset motor programs (Silver Reciproc, VDW, Munich, Germany) "Reciproc ALL" to activate RECIPROC Blue 25 / .08 and "Wave One ALL" to activate WaveOne Gold Primary 25/07. The preset mode "Reciproc ALL" has an angle of 1 50 ° rotation counterclockwise (CCW) and 30 ° clockwise (CW) and 300 rpm. On the other hand, the preset mode "wave-one all" has rotation angles of 170 ° CCW and 50 ° CW and 350 rpm (fig. 4) [28] . Previous studies have revealed that the greater rotation of the angles during reciprocating movement and higher speeds tend to decrease the resistance time to cyclic fatigue of the instruments [29,30] .

However, some authors have reported that the preset modes "Reciproc ALL" and "Wave One ALL" do not influence the cyclic fatigue resistance of the instruments [28,31] ; conclusion that has become contradictory according to other authors who reported that the alteration of the amplitude of reciprocal movement represents a factor that can significantly influence the life of the cyclic fatigue of the Ni - Ti archives [26,27] . These last studies agree with the present investigation ; and observed that instruments with less range Stretch , ud takes n more cycles to fracture than those with wide range s, indicating that the amplitude of l range and the rpm influence fracture thereof .

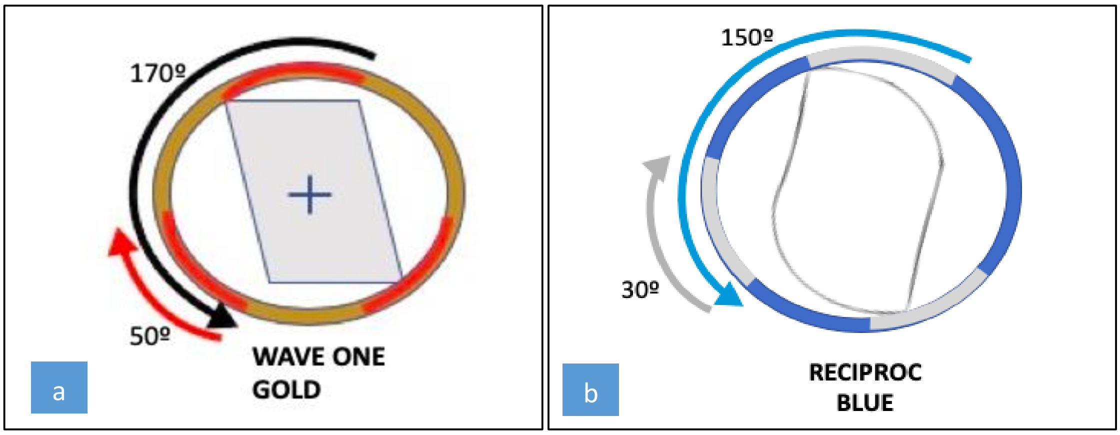

Figure 13 : Alternate reciprocating motion (a) rotation angles of the Wave One All system , 170° counterclockwise (CCW), 50 ° clockwise (CW); (b) Reciproc Blue system rotation angles, 150° counterclockwise (CCW), 30 ° clockwise (CW)

Otherwise, although the instruments tested in this investigation have the same diameters at the tip (# 25); The design of the cross section and the heat treatment of these instruments are different from each other. RECIPROC Blue "R25" and Wave One Gold "Primary" have taper of .08 and .07 respectively, in the first 3 mm apical. In general, instruments with inferior conicities guarantee greater resistance to cyclic fatigue [28]; however, according to the results of the present study, the Reciproc Blue R25 / 0.8 instruments showed greater resistance to cyclic fatigue than the Wave One Gold "Primary" / 07. These results are in accordance with the report by Gündoğar and Özyürek T. , 2017; Özyürek T et al., 2018 and Özyürek T et al., 2017 [19, 32] . Therefore, conicities would not be considered a variable that influenced cyclic fatigue resistance values in this study ; p ecause have the same taper at 7 mm , where the two files fractured or simply the area which receives voltage is the one right where the curve ends; however, some fractured faster than the others .

Other variables, such as the heat treatment of the instruments and the cross-sectional design , represent an important factor in the results of this research. As mentioned earlier, both instruments chosen have different types of alloys. Heat treated Ni - Ti instruments show phase transformation changes that improve flexibility and fatigue resistance of instruments [33] . RECIPROC Blue presents a newly developed alloy , obtained through a thermo-mechanical manufacturing process; in which a patented oxide surface layer is added, and has demonstrated an improved overall performance compared to the different alloys (conventional Ni - Ti, M-Wire) that demonstrate greater flexibility and fatigue resistance . This alloy has reduced micro hardness while maintaining the similar characteristics of its surface [18].

On the other hand, the Wave One Gold® system is manufactured with "Gold" heat treatment. Unlike M-Wire technology based on heat treatment before production, the "Gold" treatment is carried out by slowly heating and cooling the file after its production. Manufacturers claim that such heat treatment increases the flexibility of the instruments [34].

Given the findings and results of this research and previous research, it was shown that RECIPROC® Blue files could benefit from their manufacturing process. It is likely that different heat treatments between them may lead to different transformations of the martensitic phase and could induce different dissipations of the energy required for the formation and / or propagation of fissures during cyclic fatigue tests [25,35]. However, this must be confirmed by additional research.

Cyclic fatigue is also influenced by the dimensions and design of the cross-section of the instruments [4,6]. RECIPROC® Blue 25 / .08 has an italic "S" cross-sectional design, while Wave One Gold ® 25 / .07 has a parallelogram-shaped cross section . Previous studies have shown that a greater volume of metal mass at the maximum point of tension of the instruments affects the resistance to cyclic fatigue [28]. Therefore, a different cross-sectional design may be a determining factor in the cyclic fatigue resistance of different files [6.28].

It is necessary to emphasize that, within the limitations of this study, the characteristics of the instruments, such as heat treatments and cross-sectional design, had a significant influence on the mechanical properties of the instruments evaluated. The results showed that RECIPROC® Blue 25 / .08 has the highest resistance to cyclic fatigue compared to Wave One® Gold 25 / .07.

For cyclic fatigue tests, different devices with static and dynamic models have been used. In static models, the instrument rotates to a fixed length in the artificial channel without any axial movement [3 7]. While in dynamic models there is an axial movement up and down of the instrument with an amplitude of 3 mm, as established in this research, and as has been used in previous studies [24, 38,39, 40]. Dynamic devices have been used recently because that test represents clinical practice better a bit more than static cyclic fatigue test devices [41,42].

In these dynamic models, the fracture time value increases, because the tension is distributed in the areas of tension and compression during the movement, compared to static test models in which the tension is concentrated in a constant area and specific to the instrument [37, 38,41].

Ni-Ti instruments are reused frequently, which leads to a decrease in resistance to cyclic fatigue. Material fatigue seems to be an important reason for fracture of instruments during clinical use [13].

Therefore, in the present study, the effect of immersion in 5.25% NaOCl and autoclaving at 132 ° C for 45 minutes was investigated for the resistance to cyclic fatigue of 2 thermally treated Ni - Ti instruments. To approach clinical conditions, the protocol of this study provided a dynamic immersion in 5.25% NaOCl for 3 minutes in its active part (16 mm). To simulate a realistic number of times that the instruments can be reused, 1 to 3 cycles of sterilization and / or immersion in NaOCl were chosen. Dynamic simulation model was constructed with an artificial conduit with an angle of curvature of 60 ° and a radius of curvature of 5 mm and most previous studies on cyclic fatigue bas arons ba jo parameters [13].

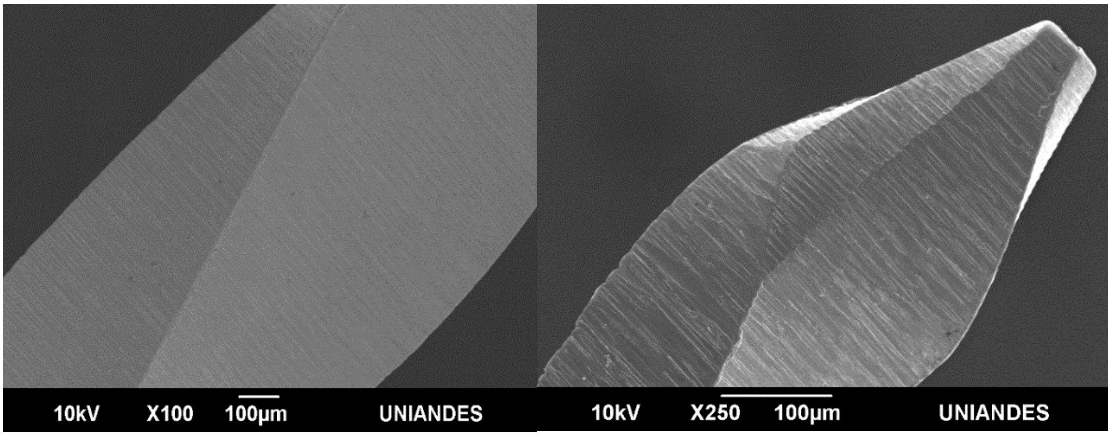

Figure 15: Scanning electron microscopy analysis performed in WaveOne Gold lime before immersion in 5.25% sodium hypochlorite to verify structural defects.

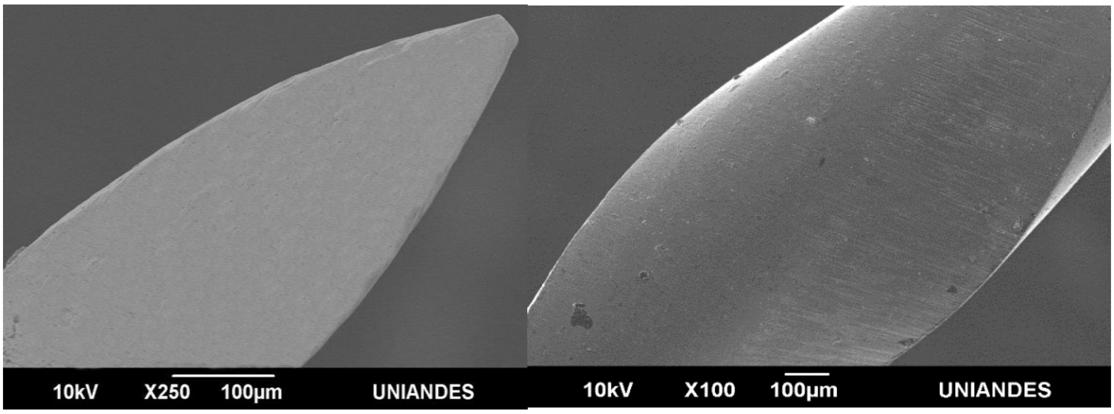

Figure 16: Scanning electron microscopy analysis performed in Reciproc Blue file before immersion in 5.25% sodium hypochlorite to verify structural defects.

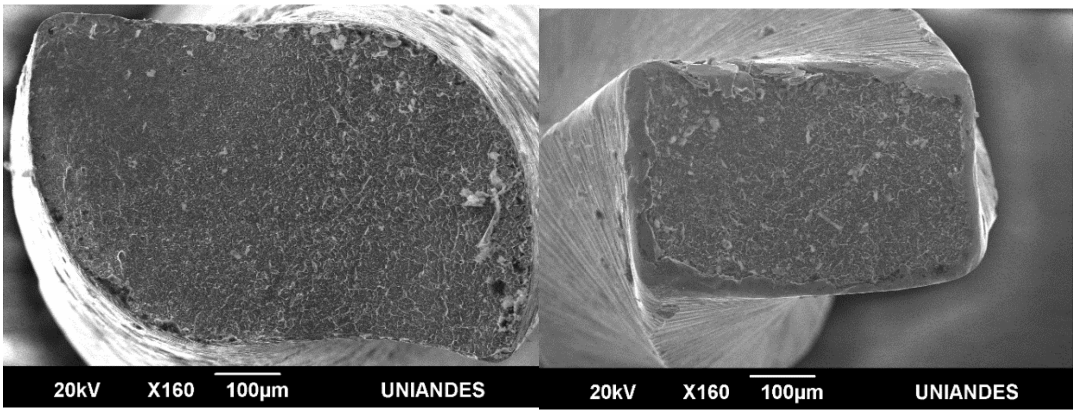

Figure 17: Analysis of scanning electron microscopy performed on fractured samples (axial view) to 160 RB (A) and limes (B) Wave One Gold dynamically immersed for 3 minutes in NaOCl 5,25 % 3 times.

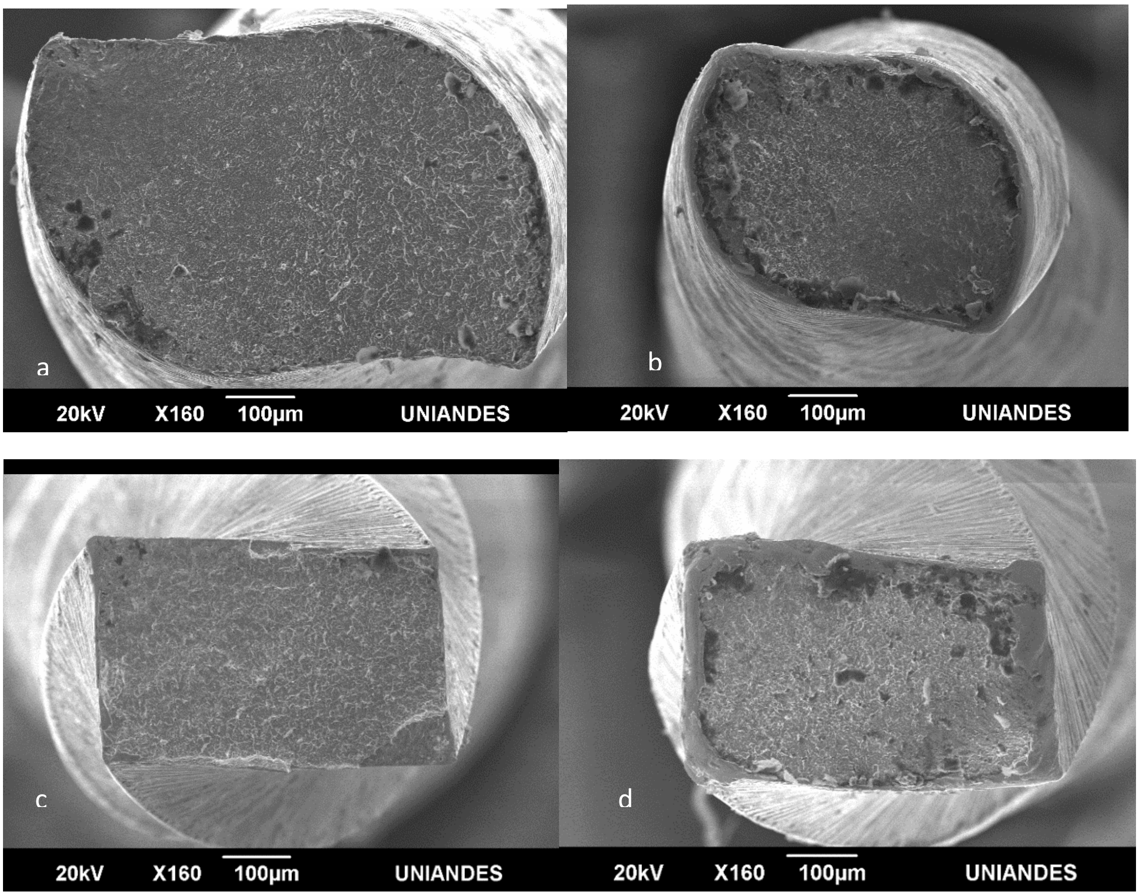

Figure 18: Scanning electron microscopy analysis performed on fractured samples (axial views) at 160 RB (A and B) and Wave One Gold files (CYD) dynamically submerged for 3 minutes in 5,25 % NaOCl 1 time.

CONCLUSIONS

RECIPROC® Blue "R25" instruments were significantly more resistant to cyclic fatigue than Wave One Gold Primary instruments. The resistance can be associated with the different thermal manufacturing processes and the different cross-sectional designs thereof. As for the length of the fragments, there were no significant statistical differences. And as for the deformation suffered by the instruments, all the surfaces evaluated showed similar ductile morphological characteristics.

RECIPROC® Blue "R25" instruments exhibited greater resistance to cyclic fatigue than Wave One Gold® "Primary" when subjected to immersion and / or autoclave sterilization. These results could be attributed to the different thermo-mechanical treatments after machining ; to which the Ni - Ti alloy is subjected during its manufacture. In addition , the lengths of the fragments are different, since the apical fractured fragments of RECIPROC® Blue "R25" average 9 mm compared to those of Wave One Gold® "Primary" which are 6 mm, which creates a difference statistically significant.

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