Influence of coronal pre-enlargement on cyclic fatigue resistance of heat-treated reciprocating instruments

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ABSTRACT

Objective: The aim of this study was to evaluate the influence of cervical pre-flaring on the cyclic fatigue resistance of two heat-treated reciprocating instruments. **Methods:** 20 Reciproc Blue (R25 Blue) instruments e 20 X1 Blue File (X1) were used to instrument resin blocks simulating an upper molar with 3 root canals. The specimens were divided into four groups (n=10) according the instrument and type of instrumentation used: R25 and X1 groups: root canal preparation with R25 Blue (25/0.08) ou X1 Blue (25/0.06), without cervical pre-flaring; R25 or X1 + cervical pre-flaring- pre-flaring with ProTaper Universal SX e S1 before instrumentation with R25 Blue or X1 blue. After instrumentation the instruments were tested for cyclic fatigue using a simulated stainless steel root canal with 86 degree bending angle and 6 mm bending radius. The instruments were triggered using the "RECIPROC ALL" motion of a reciprocating endodontic motor (VDW) and the instrumentation time until instrument fracture was accounted. Results were analyzed by Students t-test ($p<0.05$). **Results:** Statistical analysis showed that the X1 Blue showed higher resistance to cyclic fatigue than the R25 Blue under both conditions tested ($p<0.05$). There were no differences between the groups with and without coronary pre-flaring for the R25 Blue and X1 Blue ($p<0.05$). **Conclusion:** X1 Blue showed higher resistance to cyclic fatigue than the R25 Blue. The cervical pre-flaring did not increased the resistance to cyclic fatigue fracture of the tested instruments.

Keywords: Endodontics. Fatigue. Dentistry.

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Introduction

Nickel-titanium (NiTi) instruments are commonly used during the root canal preparation. The introduction of these instruments in endodontic practice provided several advantages, such as reduced preparation time, cutting efficiency and root canal centering ability when compared to stainless steel hand instruments.[1] Despite these advantages, these instruments seem to be vulnerable to deformations and/or fractures, which might compromise the prognosis of endodontic treatment.[2,3] To overcome these disadvantages, different designs, alloys with superior mechanical properties and kinematics improvements have been proposed.[4]

In 2008, Yared[5] used a single NiTi instrument in a new type of movement, called reciprocating movement, during root canal preparation and demonstrated that this new kinematics provided a quick preparation, good cost-benefit and low fracture rates. Many studies have demonstrated the efficiency, safety and benefits of reciprocating kinematics when compared to the continuous rotation movement.[6,7] In addition, the heat treatment of NiTi alloys (for example, Control Memory, Blue tecnology, Gold tecnology) have been proposed in order to improve the mechanical properties of endodontic instruments, such as fatigue resistance, flexibility, cutting efficiency and centering ability during root canal preparation.[8-11]

Reciproc Blue system (VDW, Munich, Germany) is produced with a heat treatment that results in a visible blue layer on the instrument surface and the X1 Blue File (MK Life, Porto Alegre, Brazil) is reciprocating instrument that presents different sizes # 20, # 25 and # 40 and taper .06, manufactured with heat treatment similar to that of blue technology (Blue Tecnology).[12] Previous studies have shown that heat-treated instruments have greater resistance to cyclic and torsional fatigue when compared to instruments without thermal treatment, however, no differences in root canal shaping ability was demonstrated.[12-18]

According to the manufacturers, a previous glide-path with hand instruments (size 10 or 15 K-file) can be performed, however, coronal pre-enlargement is unnecessary.[19] However, a recent study has shown that coronal pre-enlargement is able to increase the cyclic fatigue life of M-Wire Reciproc instruments.[20] Moreover, a previous study demonstrated that it is possible to reuse reciprocating instruments in up to 3 teeth safely.[21] Thereby a previous coronal pre-enlargement could provide more security during the reuse of these instruments. However, until now, no data about this issue has been conducted with Reciproc Blue or X1 Blue File instruments.

Thus, the aim of this study was to evaluate if the coronal pre-enlargement is capable to increase cyclic fracture resistance of Reciproc Blue and X1 Blue File systems. The null hypothesis tested was that there would be no difference between instruments regarding cyclic fatigue resistance after preparation with or without coronal pre-enlargement.

Material and Methods

The sample size was estimated based on a previous study[22] using the G * Power 3.1 software (Heinrich Heine University, Dusseldorf, Germany). Considering a significance level of 5% and a beta power of 95%, eight instruments were indicated as the ideal size in each group for observing significant differences. For compensate possible loss during the experiment, ten instruments were used in each group.

A total of 40 new instruments (25 mm in length) of two heat-treated NiTi reciprocating systems (n = 20) were used: Reciproc Blue R25 (size 25, 08v taper; lot number 37631) and X1 Blue File (size 25, .06 taper; lot number 20171010). All instruments were previously examined with × 20 magnification under a stereomicroscope (OPTZS; Opticam, São Paulo, Brazil) for visible defects or deformities. No defects were detected and all selected files were tested.

The Reciproc Blue (R25) and X1 Blue File (X1) systems were used to prepare resin blocks with pre-established shape, curvature, diameter and length simulating an upper molar with three root canals (Easy Equipamentos Odontológicos, Belo Horizonte, Brazil). Four groups were established according to the system used and the presence or absence of coronal pre-enlargement (n=10).

In R25 and X1 groups, resin blocks preparation was performed with R25 Blue (size 25, .08v taper) or X1 Blue (size 25, .06 taper), respectively, without previous coronal enlargement. In R25 or X1 groups + coronal pre-enlargement, a pre-enlargement was performed with ProTaper Universal SX and S1 instruments (Dentsply-Sirona, Baillagues, Switzerland) until two thirds of working length, previously to resin block preparation with R25 Blue or X1 Blue.

The instruments were used in a slow in-and-out pecking motion of about 3 mm in amplitude in a reciprocating motion “RECIPROC ALL” on the electric motor (VDW Silver; VDW). If the instruments were unable to reach the working length (WL) after three pecking motions, they were removed from the root canal, cleaned with sterile gaze and reintroduced. This procedure was repeated until the instrument reached the WL. Each instrument was used in a single resin block and then subjected to the cyclic fatigue test.

A size 10 K file (Dentsply-Sirona) was used to verify and maintain patency, 1 mm beyond WL, every time an instrument was removed from the resin blocks. The same irrigation protocol was used to all tested groups: saline solution was taken to the resin blocks using a 31-gauge needle (Navitip needle; Ultradent Products Inc, South Jordan, UT, USA) between each instrument. A total of 25 mL of saline solution was used per simulated resin block during preparation, similar to previous studies.[23,24]

Cyclic fatigue test

The cyclic fatigue test was performed using an artificial canal made of stainless steel with 86° angle of curvature and 6 mm radius of curvature, with the same dimensions as the artificial canals used in previous studies[25,26] The instruments were operated using a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany) powered by a torque-controlled motor (Silver Reciproc; VDW) using the predefined program “RECIPROC ALL” for all instruments. The electric handpiece was mounted on a device to allow accurate and reproducible position of each instrument in artificial canal. The instruments were activated until the fracture occurred and the experiment was stopped as soon as a fracture was detected visually and/or audibly. The fracture time was recorded in seconds for each instrument using a digital chronometer.

Scanning electron microscopy

The fracture surface of each tested instrument was analyzed by scanning electron microscopy (SEM) (JSM 5800; JEOL, Tokyo, Japan) at different magnifications (× 350).

Statistical analysis

The data were analyzed with the Biostat software (Instituto Mamiraua, Tefe, Brazil) and showed a normal distribution (Shapiro-Wilk test). The statistical analysis was performed by the parametric Student T test to compare different instruments used in the same working conditions (Reciproc Blue without pre-enlargement x X1 Blue without pre-enlargement / Reciproc Blue with pre-enlargement x X1 Blue with pre-enlargement) and the same instrument used under different conditions (Reciproc Blue without pre-enlargement X Reciproc Blue with pre-enlargement / X1 Blue without pre-enlargement x X1 Blue with pre-enlargement). The level of statistical significance was set at 5%.

Results

In X1 Blue file without coronal pre-enlargement group, two instrument fractures were verified. These instruments were discarded and new instruments and resin blocks were used. No fractures were observed in R25 groups.

The statistical analysis demonstrated that the X1 Blue File instruments showed greater cyclic fatigue resistance than Reciproc Blue instruments in both conditions tested ($P < 0.05$). There was no statistical difference between the groups with and without coronary pre-enlargement for Reciproc Blue and X1 Blue File instruments ($P > 0.05$). The results are summarized in Table 1.

Scanning electron microscopy of the fractured surfaces (Fig 1) showed similar and typical features of cyclic fatigue for all tested instruments. The fractured surfaces demonstrated characteristics of ductile type, with crack initiation areas and characteristic zones of quickly fractures due to overloads.

Table 1. Average time values and standard deviation (in seconds) of the tested instruments with and without coronal pre-enlargement.

Tested instruments	**With coronal pre-enlargment (seg)**	Without coronal pre-enlargment (seg)
Reciproc Blue	105 ± 19^{Aa}	97 ± 18^{Aa}
X1 Blue File	132 ± 22^{Ab}	125 ± 16^{Ab}

Different capital letters indicate statistical difference between the same instrument tested under different conditions (P <0.05). Different lower case letters indicate statistical difference from different instruments tested in the same condition (P <0.05).

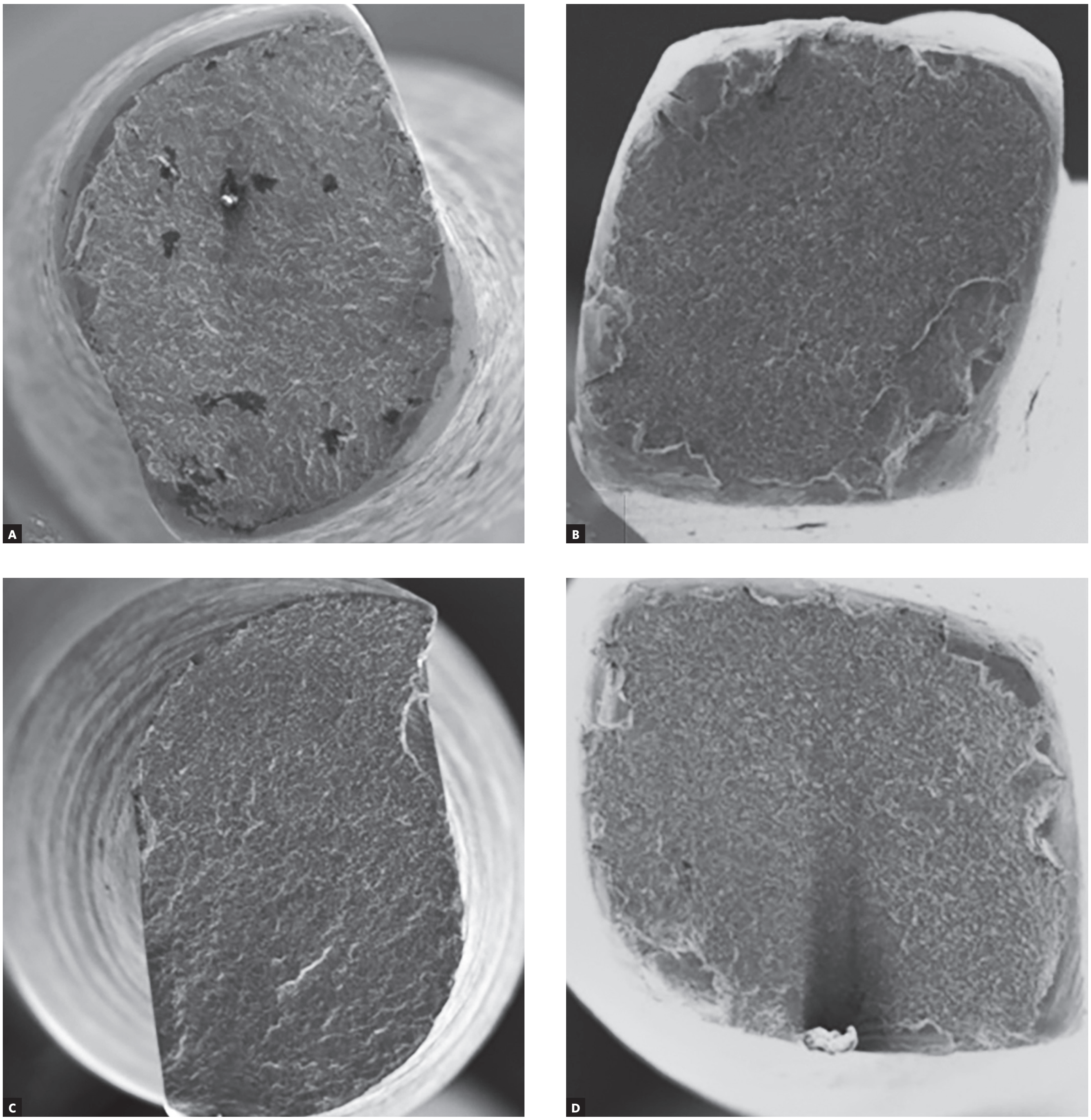

Figure 1. Scanning electron microscopy of the fractured surfaces of the tested instruments after cyclic fatigue test (x350) (**A**) Reciproc without pre-enlargement; (**B**) X1 Blue File without pre-enlargement; (**C**) Reciproc with pre-enlargement; and (**D**) X1 Blue File with pre-enlargement.

Discussion

Cyclic fatigue is one of the main cause of NiTi instrument fractures.[27] Several improvements have been made in design and manufacturing of instruments, such as the thermal treatment of NiTi alloys.[13,14]

Previous studies used a dynamic model to assess the cyclic fatigue of NiTi instruments[28,29] because they are similar to the "peck" movement made by the instrument during root canal preparation,[30] however, the speed and amplitude of the axial movements performed by the instrument in simulated canal model are subjective and inconsistent, and are not reproducible in clinical practice.[31] Therefore, in the present study, the cyclic fatigue resistance was evaluated through the static model, which has been used in several studies.[12-14] It is important to highlight that there are no specifications or international standards to assess the cyclic fatigue of NiTi endodontic instruments.

In the present study, irrigation was performed with saline solution based on previous studies that used the same irrigation model as saline or distilled water[23,24] because it better simulates the clinical conditions of the use of sodium hypochlorite when compared to glycerin. Moreover, simulated resin blocks were used due to their same size, shape, taper and curvature, which allows the standardization of samples and assessing the quality of preparation without anatomical bias.[22,32,33] However, since the hardness of resin blocks differs from human dentin, care must be taken when extrapolating these results to the clinical situation.[23]

In the present study, X1 Blue File demonstrated greater cyclic fatigue resistance when compared to Reciproc Blue, regardless of the presence or absence of coronal pre-enlargement (Table 1), which not corroborates with a previous study[12] that demonstrated similar results in cyclic fatigue resistance for X1 Blue File and Reciproc Blue instruments. This difference can be explained due to the fact that in the Klymus et al.[12] study, the instruments were removed from the manufacturer's box and subjected directly to the cyclic fatigue test, whereas in the present study, the instruments were previously used in resin blocks simulating a maxillary molar with 3 root canals.

The cyclic fatigue resistance of NiTi instruments depends on several factors, including diameter, metal mass, flexibility, cross-sectional design and NiTi alloy type. Yao et al.[34] demonstrated that instruments with greater taper, when used to prepare curved root canals, fractured after a significantly lower number of rotations. The variable and greater taper of the Reciproc Blue instruments (.08 taper) associated with the curved segment in the artificial canals used in the present study can be considered as a relevant factor to explain the lower values of Reciproc Blue in the cyclic fatigue test when compared to X1 Blue File (.06 taper).

Despite presenting better cyclic fatigue resistance, two X1 Blue File instruments fractured during the resin blocks preparation, while no Reciproc Blue instrument was fractured. The two instruments have similar heat treatments, however, the cross section design is different, which may explain the different results during the preparation. The X1 Blue File instrument has a triangular convex section and the Reciproc Blue has an S-shaped section, which facilitates penetration without fracture.

The SEM images of the fractured surfaces showed similar and typical characteristics of cyclic fatigue for the two tested instruments. The instruments presented initial areas of microcracks demonstrating that the heat treatment did not prevent, but delayed the instrument fracture, similar to previous studies.[14,35]

Coronal pre-enlargement aims to ensure that there is enough space for endodontic instrument penetration inside root canal and to reduce the risk of instrument fracture.[36] However, in the present study, it was found that regardless the instrument used (Reciproc Blue or X1 Blue File), the coronal pre-enlargement did not increase the cyclic fatigue resistance ($P > 0.05$), possibly due to the fact that the tested instruments have a reciprocating movement with heat treatment, which reduces the risk of fracture.[12-14] However, a previous study[20] demonstrated that coronal pre-enlargement increased cyclic fatigue resistance of Reciproc and Wave One instruments, which are produced by M-Wire alloy, without heat treatment, which may explain the difference with the present study.

Conclusion

XI Blue File showed higher cyclic fatigue resistance when compared to Reciproc Blue. Coronal pre-enlargement was not able to increase the cyclic fatigue resistance in any of the 2 instruments tested.

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