Effect of immersion in sodium hypochlorite on the cyclic fatigue resistance of three rotary instruments

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Abstract

Context: It is essential to know if the immersion in sodium hypochlorite (NaOCl) influences the cyclic fatigue resistance of nickel-titanium (NiTi) files.

Aim: This study was aimed to evaluate the resistance to the cyclic fatigue of three NiTi systems, as well as the influence of 5.25% NaOCl on their resistance.

Methods: Files from the Sequence Rotary File (MK life, Porto Alegre, Brazil), ProTaper Next (PTN) (Dentsply, Maillefer, Baillagues, Switzerland), and HyFlex EDM (Coltène Whaledent, Allstatten, Switzerland) systems were tested and separated into Group 1)-without immersion in NaOCl solution and Group 2 and Group 3-immersed in 5.25% NaOCl solution, for 1 min, and 5 min, respectively. All instruments were submitted to the cyclic fatigue test. Images of the instruments were observed by scanning electron microscopy, to evaluate the type of defect presented on the fractured surface. The test performed for the analysis of two independent factors was a two-way analysis of variance.

Results: HyFlex EDM presented a greater number of cycles until fracture when compared to others (P < 0.001). The control group showed a greater number of cycles until fracture than the same instruments submitted to NaOCl (P < 0.001). Sequence instruments showed the lowest values of cycles until fracture (P < 0.001). There was no statistically significant difference between treatments (P = 0.998). PTN, showed intermediate values of fracture resistance when compared to the HyFlex EDM and sequence instruments (P < 0.001), but without intragroup differences (P = 0.437).

Conclusions: Hyflex EDM instruments were the most resistant to cyclic fatigue.

Keywords: Corrosion; cyclic fatigue; rotary nickel-titanium instruments; sodium hypochlorite

INTRODUCTION

The introduction of nickel titanium (NiTi) alloy in the manufacture of endodontic instruments represented a breakthrough in endodontics. Its favorable mechanical properties allowed the fabrication of instruments with new designs, greater taper, alternative systems, and the introduction of a continuous rotation movement for the cleaning and shaping the root canals.[1,2] Despite the greater flexibility and resistance, the fracture of the instruments is still a worrying factor.[3] Several strategies have been used by manufacturers to improve fatigue strength, including different designs in cross-sections, alloys with different mechanical properties, or optimized manufacturing processes.[4] The new NiTi alloys, such as M-wire, Phase-R, and CM-wire, exhibit properties, such as superior flexibility and higher fracture resistance, advantageous characteristics for the instrumentation of more complex root canals. Torsional

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fatigue and cyclic fatigue are the most common fracture causes in NiTi rotary instruments. Among the factors that may influence the resistance of the endodontic instrument are the anatomical conditions, such as radii and angles of curvature of the root canal, the number of uses of the instrument, the torque used, and the ability of the operator. The speed of rotation employed, the number of sterilization cycles and the type of irrigation substance can also influence the cyclic fatigue resistance of the NiTi instruments.

Of the irrigating solutions currently used in endodontic treatment, sodium hypochlorite (NaOCl) satisfies most of the requirements and, due to its effective antimicrobial action, and mainly due to its capacity for tissue dissolution, has become the most used by endodontic professionals. NiTi instruments with CM-wire offer better performance and safety. The surface treatment makes the files more flexible, more resistant to fatigue, and efficient in cutting.\(^8\)

The objective of this work was to evaluate and compare the cyclic fatigue strength of three systems with different alloys and heat treatments, after immersion in 5.25% NaOCl. The null hypotheses tested were as follows:

1. That there would be no difference between the cyclic fatigue resistance of sequence rotary file, HyFlex EDM, and ProTaper Next (PTN)
2. The immersion of the instruments into the NaOCl would not affect the cyclic fatigue resistance.

**METHODS**

A total of ninety new files of three different instruments, sequence rotary file (SEQ group-MK life, Porto Alegre, Brazil), HyFlex EDM (EDM group-Coltèné Whaledent, Allstatten, Switzerland), and (PTN group-Dentsply Maillefer, Baillagues, Switzerland) were select for the test. The thirty files of each group were separated into three sub-groups \((n = 10)\). Group 1-(SEQ1, EDM1, PTN1)-which were not immersed in 5.25% NaOCl solution, Group 2-(SEQ2, EDM2, PTN2): immersed in hypochlorite solution of Sodium 5.25% for 1 min and Group 3: (SEQ3, EDM3, PTN3)-immersed in 5.25% NaOCl solution for 5 min. All the instruments were previously analyzed using the optical microscope Opto (Opto, São Carlos, Brazil) with a \(\times 10\), to discard those with deformities.

The endodontic instruments were fixed to the X-Smart electric motor (Dentsply Maillefer, Baillagues, Switzerland) and operated at a constant speed according to the manufacturers’ recommendations (Sequence Rotary File-400 RPM and 2.0 Ncm, Hyflex EDM-500 RPM and 2.5 Ncm, and PTN -300 RPM and 2.0 Ncm). The instruments were inserted 19 mm from its tip, into a recipient that was filled with the amount of 5.25% NaOCl. After immersion, the instruments were washed in distilled water to neutralize any effect of the solution. All instruments were subjected to the cyclic fatigue test in a device with a simulated artificial stainless steel canal and the ability to fix the handpiece of the X-Smart electric motor (Dentsply Maillefer, Baillagues, Switzerland), allowing the test in a statistically. The instruments were positioned and operated at speed recommended by the manufacturer, and the time elapsed between the beginning of the experiment, and the time of the fracture was registered (Vollo VL-501 Stopwatch). During the test, to reduce friction between the instruments and the canal walls, dental material lubricant was used (Pana Spray Plus-NSK GmbH Germany).

For each instrument, the number of cycles up to the fracture was calculated by multiplying the time in seconds until the fracture time by the number of revolutions per second. The results were analyzed using the GraphPad Prism program, version 6.01. The fracture surfaces of the files of each group were observed under a scanning electron microscope (Zeiss EVO 50) at \(\times 200\), \(\times 500\), \(\times 1.000\) and \(\times 3.000\), to determine fracture patterns after immersion in 5.25% NaOCl.

**RESULTS**

The number of cycles until fracture of the instruments, measured in the different groups, is shown in Table 1.

The analysis of variance (ANOVA) for two independent factors (two-way ANOVA) revealed that the HyFlex instruments presented a greater number of cycles until the fracture when compared to the others, regardless of the treatment to which they were submitted \((P < 0.001)\). The control group showed a greater number of cycles until the fracture occurs than the same instruments submitted to NaOCl \((P < 0.001)\); these, in turn, were also statistically different from each other \((P < 0.001)\).

Sequence instruments showed the lowest values of cycles until a fracture occurs \((P < 0.001)\). There was no significant difference between treatments \((P = 0.998)\). The same was observed in the group formed by the PTN instruments, which showed intermediate values of fracture resistance when compared to the HyFlex and Sequence instruments \((P < 0.001)\), but without intragroup differences \((P = 0.437)\).

The power reached in the analysis between different instruments submitted to different treatments, with ten samples per group, was 99.99%.

The sizes of the instruments fragments measured in the different groups are shown in Table 2.

The data were referring to the number of cycles until the fracture of the instruments were tested about their sample distribution. The Shapiro–Wilk test showed a normal
Two-way ANOVA for two independent factors, type of instrument and treatment, revealed that in the control group, and the fragments of the instruments presented different sizes among each other ($P < 0.001$). In NaOCl-treated groups, HyFlex and Sequence instruments presented similar fragment sizes ($P > 0.05$), whereas PTN instruments had significantly smaller fragment sizes ($P < 0.001$).

The fracture of the sequence system occurred before the point of curvature, the Hyflex EDM system had the fracture located at the maximum point of curvature, and the PTN fractured after the point of curvature.

The fracture pattern of the species observed using the scanning electron microscopy corresponds to the fracture characteristics due to cyclic fatigue [Figure 1].

**DISCUSSION**

This study was aimed to evaluate and compare the cyclic fatigue strength of three systems with different alloys and heat treatments (sequence rotary file, HyFlex EDM, and PTN) after immersion in 5.25% NaOCl in two different times, 1 and 5 min, compared to no immersion. Up to this moment, no study has evaluated the cyclic fatigue resistance of these three instruments after immersion in NaOCl.

Corroborating with previous studies, [9-11] the Hyflex EDM instruments presented greater resistance to cyclic fatigue than PTN, and this can be justified by their new thermal treatment. [10,12] Thus, the first hypothesis tested should be rejected. Similarly, Güngör and Özyürek [13] investigated the cyclic fatigue resistance of the OneShape, HyFlex EDM, WaveOne Gold, and Reciproc Blue systems, where Hyflex EDM was superior to the other systems tested. Hyflex EDM showed an increase in fatigue strength of up to 700% when compared to the Hyflex CM system. [10] The unusual structural properties (a new shape adjustment and file surface hardness) may be the reason why the number of cycles of this system has been considerably larger when compared to the other two systems tested in the present study. [12] Cyclic fatigue resistance of instruments after immersion in NaOCl with different protocols presented conflicting results in previous studies. [14,15] In this study, the fatigue resistance was negatively affected when the instruments were immersed in NaOCl compared to those in which were not immersed. Thus, the second hypothesis tested should be rejected. The D-RaCe instruments had the highest cyclic fatigue resistance than ProTaper and Mtwo after immersion in NaOCl. [16] The endodontic instruments K3, K3XF, and Vortex, presented lower resistance to cyclic fatigue when exposed to 5.25% NaOCl, with temperature variation at 22°C, 37°C, and 60°C. [17] Moreover, the NaOCl caused deteriorations and irregularities in the surface of wave one and reciproc files, predisposing the instruments to possible unexpected fractures. [18] Erik and Özyürek [19] evaluated the effect of irrigating solutions on the cyclic fatigue resistance of the HyFlex EDM, WaveOne...
Gold, and Reciproc Blue instruments, using the association of 6% NaOCl solution with 18% etidronic acid. Hyflex EDM was significantly more resistant than the other groups under all conditions tested. In the intragroup comparison, all groups showed a significant reduction in resistance to cyclic fatigue when in contact with the combination of NaOCl and etidronic acid. The use of this solution caused corrosion in the systems tested and may have been the factor causing the reduction in the resistance to cyclic fatigue of the files.[19]

NaOCl at different concentrations and temperatures influenced the cyclic fatigue resistance of the ProTaper Gold system,[20] agreeing with the results of PTN and Sequence presented in this study. NaOCl did not have any effect on the cyclic fatigue resistance of the WaveOne and WaveOne Gold instruments. Twisted File and Hyflex CM22 instruments, corroborating the results found in the Hyflex EDM system.

Regarding immersion in NaOCl solution, the studies present controversial results, in which some concluded that the NaOCl reduces the resistance to cyclic fatigue of the tested instruments,[16,17,19,20] and others indicated that the solution did not change the resistance of the systems tested.[21,22] This discrepancy in the results observed in the literature can be explained by the different methodologies and immersion protocols used, making further studies necessary to standardize the methods and devices used.

CONCLUSIONS

Hyflex EDM instruments were the most resistant to cyclic fatigue after immersion in 5.25% NaOCl. The PTN instruments had the intermediate values and the sequence instruments had the lowest values of resistance to cyclic fatigue.

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Conflicts of interest
There are no conflicts of interest.

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