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ORIGINAL ARTICLE

Influence of sodium hypochlorite and chlorexidine on the dynamic cyclic fatigue resistance of XP-Endo Finisher instruments

ABSTRACT

Aim: *This study evaluated the cyclic fatigue resistance of XP-Endo Finisher (XPF), associated with two different irrigation solutions: sodium hypochlorite 6% (NaOCl) or chlorhexidine digluconate gel 2% (CHX) in a dynamic model. The null hypothesis tested was that there was no statistically significant difference.*

Methodology: *30 new files were divided into three groups (n=10) based on the irrigation solution used. Group 1: XPF using CHX as an irrigation solution; Group 2: XPF using NaOCl as an irrigation solution; Group 3 (control group): XPF using lubricating oil (LO). The artificial canal was manufactured measuring 1.5 mm wide, 20 mm long and 3.5 mm deep with a straight cervical segment measuring 14.29 mm. A curved apical segment 4.71 mm with 3 mm radius and 90° of curvature and an ending with straight apical portion measuring 1 mm long. Resistance to cyclic fatigue was determined by recording time to fracture, and the file surface was examined under scanning electron microscopy.*

Results: *Data were tabulated and subjected to statistical analysis of variance. Student-Newman-Keuls test for multiple comparisons, with a significance level of 5%. The average time took for file fracture was 306.7 seconds for 2% chlorhexidine and 67,6 for 6% sodium hypochlorite. 2% CHX was significantly different from the NaOCl and LO groups (P<.001).*

Conclusions: *XPF presented the best results of fracture time and number of cycles to fracture when used along with 2% chlorhexidine in canals with severe apical curvature, and there was no statistical difference on fragment size.*

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Received 2020, July 11
Accepted 2020, October 13

KEYWORDS *chlorhexidine, cyclic fatigue, dynamic fatigue tests, nickel-titanium instruments, sodium hypochlorite, XP-Endo Finisher*

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Peer review under responsibility of Società Italiana di Endodonzia
10.32067/GIE.2021.35.01.06

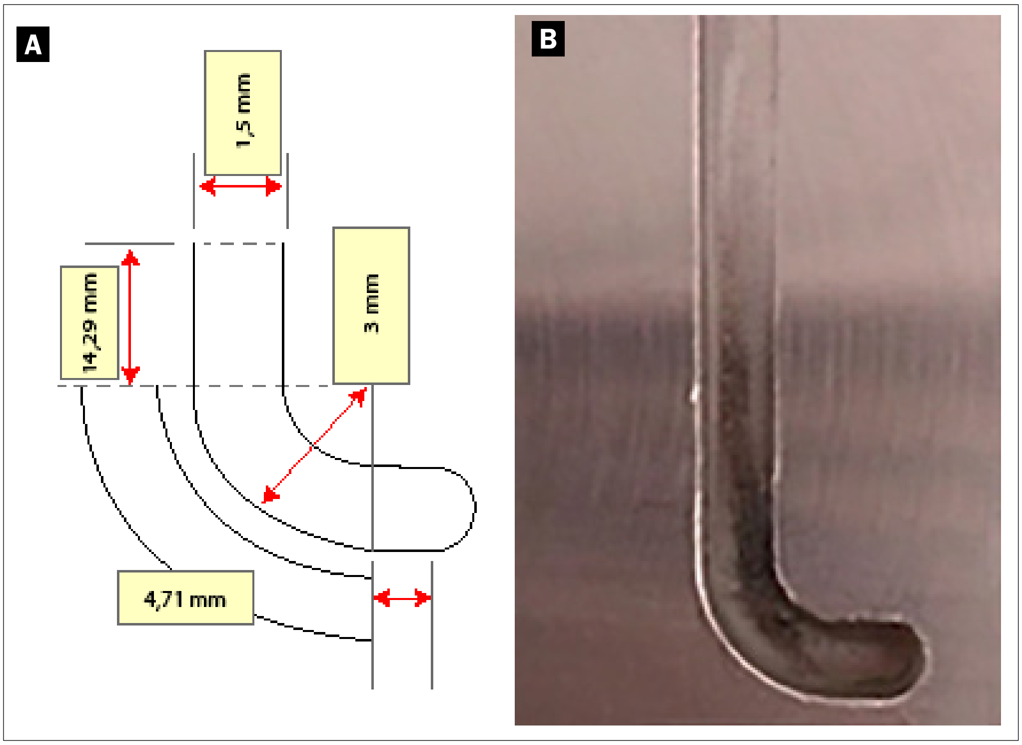
Introduction

The improvement of new thermal treatment of conventional NiTi alloy, corroborate with better execution of chemical mechanical preparation stages of the root canal, as well as its completion, improving fracture resistance. Thus, this evolution provided a higher index of success, improving the technique speed and rate of file fracture within the root canal (1). However, although advances have been achieved with the development of technological innovations in endodontics, nickel-titanium instruments fracture still occur and can be caused in two ways: torsional or bending fracture (2). XP-Endo Finisher (3) is a new instrument presented as a final step in the disinfection of the root canal system and finishing protocol. It is an instrument made of MaxWire alloy, triangular cross-section, which offers flexibility, cyclic fatigue resistance, and ability to penetrate the canals easily and quickly. With ISO #25 diameter and initial taper of .00, the XP-Endo Finisher expands when inserted into the root canal, at body temperature, respecting the original anatomy and effectively clearing irregular areas due to its greater flexibility (3). Several studies have been carried out in the search for irrigants that have better properties, including antimicrobial activity, low periapical toxicity, solubility and the ability to dissolve organic tissues (4). Of all the substances currently used, sodium hypochlorite (NaOCl) seems to be ideal because it covers more requirements for endodontic irrigator than any other known solution. Pitome et al. (5) evaluated concentrations of NaOCl as an irrigator in endodontics and showed that one of the characteristics of this substance is its ability to dissolve organic tissues, although this has been questioned. The antibacterial efficacy and tissue dissolution ability of NaOCl are related to concentration (6).
Chlorhexidine is a cationic compound, with excellent antibacterial properties, just like 5.25% NaOCl, and has a better residual effect because it shows substantivity (up to twenty-four hours), although it cannot dissolve the pulp tissue (7). The use of chlorhexidine in contact with vital tissues reveals biocompatibility. As an endodontic irrigant, it is used in concentrations of 2% and also presents excellent clinical performance and rheological action. Its lubricating action promotes a more significant intensification of the canal cleaning since it acts to reduce the friction of the file with the canal interface, reducing the fracture rate (8).
After immersion in chlorhexidine, no data were reported on the fatigue behavior of XPF instruments. Therefore, the aim of this study was to evaluate cyclic fatigue resistance of XPF-file in simulated canals with two different types of auxiliary chemical substances. The null hypothesis tested was that there was no statistically significant difference between NaOCl and CHX gel 2% in the dynamic cyclic fatigue resistance.

Materials and Methods

In this experiment, thirty new endodontic NiTi files XP-Endo finisher, with 0.25 mm tip diameter and 25mm length were divided into 3 groups (n=10) according to the auxiliary chemical substance used.
Group 1: XPF instruments using 2% chlorhexidine gel as an irrigation solution;
Group 2: XPF using 6% sodium hypochlorite as an irrigation solution;
Group 3 (control group): XPF instruments using lubricating oil (WD-40, Milton Keynes, UK).
For resistance to cyclic fatigue a stainless steel plate, with one artificial groove measuring 1.5 mm wide, 20 mm long and 3.5 mm deep with a straight cervical segment measuring 14.29 mm, with an arc length of curvature of 4.71 mm, with a radius of curvature of 3 mm, and ending in a linear apical segment of 1 mm simulating root canals was used according to Figure 1.
The purpose of these measurements is for the file to rotate freely in the same position in the canal. An acrylic plate was attached to the stainless-steel plate so that the separate fragment would not be lost and to contain the solution within the artificial canal.

Figure 1
Artificial canal:
A) Schematic drawing;
B) Simulated stainless steel root canal.
Source: Private Clinic in Rio Branco Laboratory, AC, place of tests.



Fatigue resistance test
The files were placed within the simulated canals and triggered by VDW reciprocating motor (VDW GmbH Munich, Germany) following the manufacturer's recommendations of programming, where the speed is 900 RPM and torque 1 Ncm. The oil that was used as a control and the different chemical substances were used in the canals.
The files were inserted in the simulated canals until the length of 20 mm, using a stop to register this length. All files were dynamically driven until a visual fracture occurred. The irrigant was taken to the artificial canal with Navi tip plastic needles, with a 21 mm long flexible tip penetrating 1 mm into the cervical region of the simulated canal with the needle tip without touching the moving file, maintaining the canal filled with the solution. All file rotation time within the simulated canal was recorded with iPhone 6s mobile device, (Apple Cupertino, California, USA) from the beginning of the rotational test until its fracture, to enable the timing of the fracture. The analysis was performed in movie maker program of Microsoft Corporation (Redmond, Washington, USA). The mathematical formula calculated the number of cycles for the fracture (NCF) is

NCF=Time to fracture (seconds)
x Rotation speed (RPM)/60

Evaluation of the fracture pattern under scanning electron microscopy
After collecting the samples, all fragments were cleaned in an ultrasonic vat and dried in an incubator at 37 °C for 24 hours, being separated in glass tubes containing the group identification and instrument number. Subsequently, they were analyzed under scanning electron microscopy. The fractured files were positioned on their long horizontal axis to verify if there was any plastic deformation; after the file was placed in a vertical position to observe the area of the fractured segment to verify if there was any fracture pattern between the endodontic files of each group (Figure 2).

Evaluation of the length of the file fragments
The fragments were measured with digital caliper 150 mm, with an accuracy of ±0.03

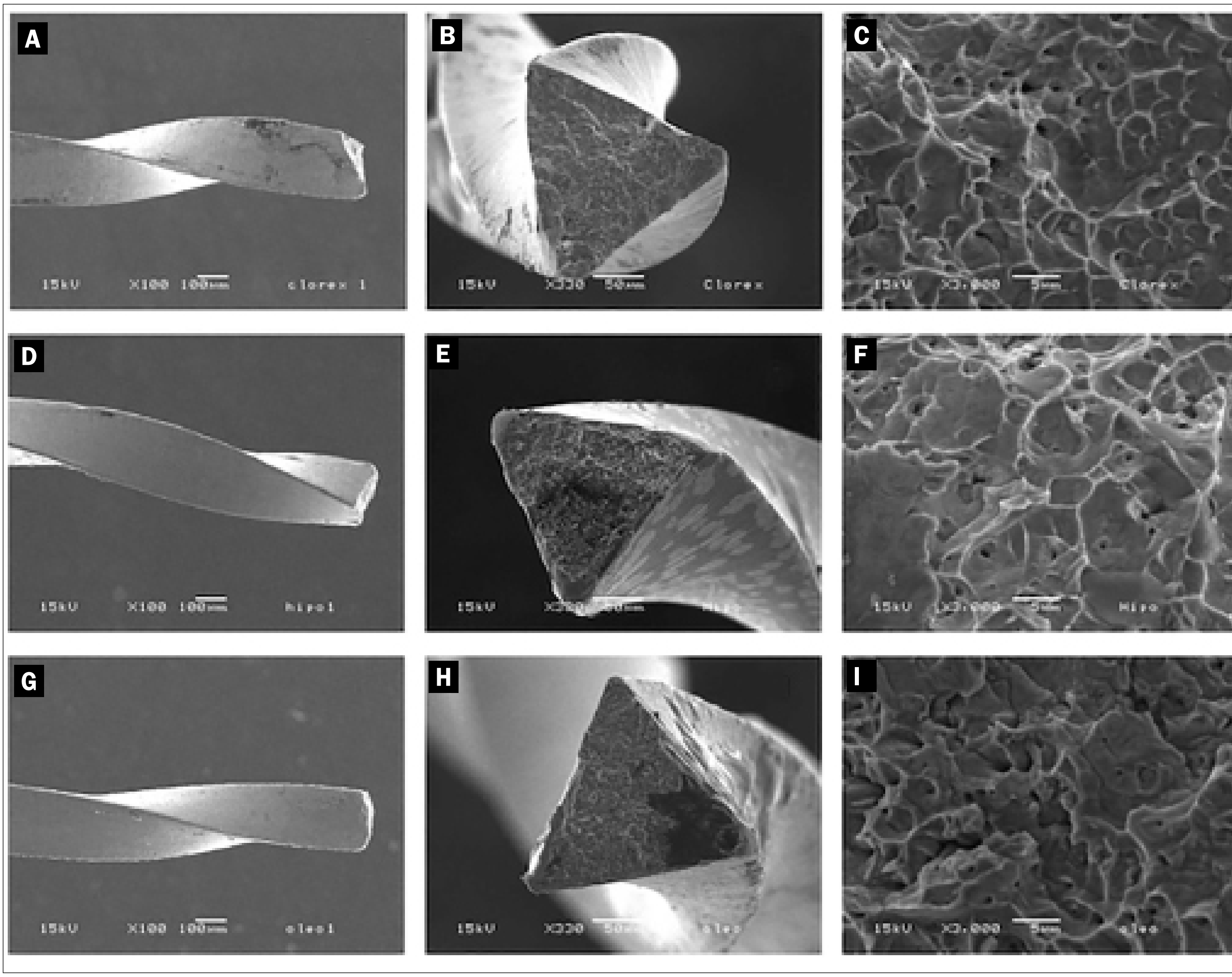


Figure 2
SEM images showing the cross-section of the fractured instrument. **(A, B, C)** CHX, **(D, E, F)** NaOCl, **(G, H, I)** LO. **(A, D, G)** Absence of plastic deformation in the helical shaft of all instruments. **(B, E, H)** ductile morphologic characteristics on fractured surfaces. **(C, F, I)** Magnified area of **(B, E, H)**.

mm/0.001. Fracture length patterns of the files of each group and the location of the maximum point in both artificial canals of the test were analyzed.

Statistical analysis

After collecting the fracture times of the files in each of the three groups, the data were tabulated and submitted to statistical analysis undergoing variance test and Student-Newman-Keuls test for multiple comparisons, with a significance level of 5%

The Kolmogorov Smirnov normality test (P<0.05) confirmed the normality of the data, thus using parametric tests to compare the means. The ANOVA test, followed by the Post-Hoc, Tukey, was used to compare the time means, cycle number until file fracture according to the type of irrigation substance (k groups=3).

Results

The mean and standard deviations of the variables studied, such as time and number of cycles to fracture (NCF) for each group, are shown in Table 1.

In the chlorhexidine group, the time ranged from 3.06 to 8.39 min and NCF from 2,790 to 7,785. With sodium hypochlorite group, the time ranged from 0.25 to 3.22 and NCF from 375 to 3,030. For the oil group, the time ranged from 0.23 to 1.45 and the NCF from 345 to 1,575.

The time and number of cycles until frac-

Table 1

Mean and standard deviation (SD) of time (minutes) to fracture and NCF for each type of irrigation substance

Irrigating solution	Time Mean (SD)	NCF Mean (SD)
CHX	4.99 (1.62)[a]	4558.5 (1495.33)[a]
NaOCl	0.92 (0.91)[b]	1014.00 (795.34)[b]
Oil	0.67 (0.41)[b]	832.50 (354.42)[b]
P-value	<.001	<.001

Note: Vertical, for columns, different lowercase letters indicate statistical difference, ANOVA test, with Post-hoc Tukey's test, P<0.05.

Table 2.

Mean and standard deviation (SD) of file fragments fracture size for each type of irrigation substance

	Fragments (mm) Mean (SD)
CHX	3.90 (0.188)
NaOCl	4.05 (0.236)[a]
LO	3.82 (0.187)
P valor	<.05

Note: Vertical, for columns, lowercase letters indicate statistical difference, ANOVA test, with Post-hoc Tukey's test, P<0.05.

ture (NCF) for chlorhexidine were statistically different from the other groups (P<.001). There was no significant difference between hypochlorite and oil in time (P=0.876), and also in NCF (P=0.913).
There were no significant differences among the groups in terms of the mean fracture length (4.5 mm) regardless of conditions (P>.05) (Table 2).

Discussion

This study was designed to compare cyclic fatigue resistance of the XPF instrument using two different substances (CHX or NaOCl) as irrigants. Lubricating oil was used as a control because it is a well-established substance that has been used in other experiments (9). The obtained fatigue tests results were evaluated according to the type of substance used. CHX was more effective in improving the instruments resistance to cyclic fatigue, so, the null hypothesis was rejected. Current findings might be explained by the corrosive effect of NaOCl on endodontic NiTi instruments (10), that may negatively affect their physical properties (11). Although NaOCl is the irrigation solution of choice for clinicians, CHX emerges as a new perspective in Endodontics, and when it is used in gel form facilitates root canal instrumentation (7).
Dynamic evaluation of a NiTi rotary files during root canal instrumentation is often recommended and could be performed evaluating the instrument shaping ability (12). The dynamic test was conducted in a standard metal canal to ensure the standardization of the experiment (13), such as the entire length of the canal, the length of the curvature ratios and the length of the arc (14). In the dynamic test, the instrument moves axially along within the canal, which allows stresses to be distributed along the instrument shaft, extending the fatigue life of the file (15). The fatigue life of the XPF was significantly higher when the CHX was used as opposed to NaOCl. Although comparing to static models, the dynamic model enhances fracture resistance (1), and could reproduce a clinical up and down motion (9) none of which influenced fracture morphology (15).
Files breaking in the root canal can influence treatment prognosis and is a challenge faced by clinicians, so reducing the risk of instrument fracture is critical to clinical success (16). The different pH of NaOCl could influence metal corrosion (17) and can explain the better results for the CHX. The instruments were exposed to the solutions at body temperature throughout the experiment to ensure better clinical condition, although this condition reduces fracture resistance (18) NaOCl is the irrigating substance most used for root canal irrigation in endodontics due to its properties. Despite this, the substance may cause micro cratering by removing nickel from the instrument surface (19), decreasing the resistance to cyclic fatigue. CHX

is a substance that has also been used in canal treatments, up to this moment no study has evaluated the effect of immersion in these substances in the cyclic fatigue resistance of XPF.

NaOCl, when compared with water, negatively affect the fatigue resistance of NiTi instruments (20), especially at higher concentrations. On the contrary, Cheung et al. (21) found that the immersion of instruments in NaOCl before cyclic fatigue testing for 3 to 5 minutes did not affect the cyclic fatigue of NiTi endodontic instrument. However, they do not reflect the real clinical condition of root canal preparation in that it is performed in the presence of the irrigants in the root canal.

Fatigue failure can be caused initially by cracking on the surface of the instrument, and this may be due to concentration of chloride ions in corrosion under a titanium gap (22), influencing fatigue resistance.

The radius and the angle of canal curvature are known to have a significant role in cyclic fatigue failure, so in this study, a severely curved at the apex artificial canal was used. The mean lengths of fractured segments were recorded to evaluate the correct positioning of the tested files inside the canal curvature. There was no significant difference between the groups regardless of the lengths of the broken pieces (≈3,92 mm). This matches with the location of the file at the maximum curvature (4.0 mm from the tip). The point of maximum stress was similar in each condition, suggesting the standardization of the experiment (23).

Two mechanisms are involved in the fracture of NiTi rotary files: cyclic fatigue and torsional failure. The morphological characteristics of the fracture surface can be characterized by a smooth, shiny, or ductile surface, with presenting hemispheric dimples (24, 25).

The use of different lubricants during testing may be responsible for inconsistent results (26). Our result may be due by the fact that CHX acts as an anti-corrosive agent, which can increase the cyclic fatigue resistance. Moreover, it has superior lubrication quality, reducing friction of the instrument with the surface of the artificial canal (27). Additionally, CHX did not cause surface damage to the NiTi alloy, in contrast, NaOCl and EDTA endodontic irrigants caused alterations in the surface of instruments (28).

In conclusion, results showed that XPF had a long fatigue life when CHX was used as an irrigant. The enhanced resistance may be associated with lubricant and non-corrosive properties of CHX gel. Although CHX increases cyclic resistance, it does not comply with all the requirements of an endodontic irrigant (no dissolving action). Further studies are required to evaluate other irrigation solutions and their influence on the cyclic fatigue behavior of XPF instruments.

Clinical Relevance

The present study has shown that XP-Endo Finisher exhibited higher dynamic cyclic fatigue resistance when used in association with 2% chlorhexidine gel as an irrigation solution in a severe curved simulated canal.

Conflict of Interest

The authors deny any conflicts of interest.

Acknowledgements

None.

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