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Cyclic fatigue resistance of Hyflex EDM NiTi rotary files in different distances of pecking motion

Verônica Magalhães Lima Nunes[1], Tânia Nunes Soares[1], Viviane Rangel do Couto[1], Luiz Meton Horta dos Santos[1], Maria Alejandra Portillo Martinez[1], Paula Avelar da Silva Ribeiro Goular[1], Aline Cristine Gomes Matta[2]*, Adriana de Jesus Soares[2], Marcos Roberto dos Santos Frozoni[1]

[1] Departament of Endodontics, Centro de Pesquisas Odontológicas São Leopoldo Mandic, Campinas, São Paulo, Brazil.

[2] Department of Restorative Dentistry, Division of Endodontics, Faculdade de Odontologia de Piracicaba (FOP), Universidade Estadual de Campinas (UNICAMP), Piracicaba, São Paulo, Brazil.

Corresponding author:
Aline Cristine Gomes Matta
Faculdade de Odontologia de Piracicaba - UNICAMP
Avenida Limeira, 901
CEP: 13.414-903 – Piracicaba, SP - Brasil
Phone: +55 (19) 2106-5706
E-mail: linecristine@msn.com

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Aim: The purpose of this study was to evaluate the effect of different distances of pecking motion on the cyclic fatigue of Hyflex EDM OneFile (Coltene/Whaledent AG, Altstatten, Switzerland) in simulated curved canal. **Methods:** Sixty Hyflex EDM OneFile (#25/0.08) files were tested at three different pecking depths: G(1): 1-mm depth, G(2): 2-mm depth, G(3): 3-mm depth, and G(4): 4-mm depth. Cyclic fatigue resistance was tested measuring the time to fracture and the number of cycles to failure (NCF) in an artificial canal with a 60° angle and a 3-mm radius of curvature. Data were analyzed using the analysis of variance test and the Student-Newman-Keuls test for multiple comparisons. **Results:** There was a significant difference between the four groups for the NCF ($p < 0.05$). G(1) group had lower NCF compared to the other groups. There was a significant difference between group 4 (1278.9) and the others ($p < 0.05$). Groups 2 and 3, with NCF means of 714.4 and 872.2, respectively, did not show any significant difference between them ($p > 0.05$). **Conclusion:** The results showed that different pecking distances can significantly extend the life span of Hyflex EDM rotary files. Our results suggest that a longer pecking depth may reduce the risk of instrument fracture.

Keywords: Root canal preparation. Dental instruments. Fatigue. Nickel. Titanium.

Introduction

Despite their numerous advantages, such as modification of instrument design, and heat treatment of the alloy, NiTi instruments present risk of fracture during its use in curved canals, which might compromise the prognosis of root canal treatment[1,2]. Fracture occurs by two different mechanisms: cyclic fatigue and torsional stress[3,4]. Cyclic fatigue is the result of the rotation of the instrument inside a curved root channel in which it is exposed to tension-compression strain cycles in the area of maximum root canal curvature[5]. Cyclic fatigue failure may occur unexpectedly without any sign of previous permanent plastic deformation[6].

The Hyflex EDM OneFile (HEDM; Coltene/Whaledent AG, Altstatten, Switzerland) have a tip size of 25 with a continuous 0.08 taper in in the last apical 4mm of the file but reduces gradually up to 0.04 in the coronal portion of the file[3]. HEDM are the first endodontic instruments manufactured with EDM (Eletro Discharge Machining) fabrication process[7]. The superficial aspect of new EDM files represents a novelty in comparison with conventional NiTi files, and cyclic fatigue tests showed that the EDM process increased the flexibility and resistance of the instruments[3,8].

The pecking motion is a motion used during rotary instrumentation and can be done with different amplitudes, and these different amplitudes can influence the Cyclic Fatigue Resistance of the Rotary Files[9]. To date, there is no work in the literature that has analyzed the influence of the amplitude of the pecking movement on the Cyclic Fatigue Resistance of Hyflex EDM NiTi Rotary Files.

To simulate the under clinical conditions, cyclic fatigue tests are performed at a simulated body temperature and with back-and-forth axial movement in the root canal[10,11]. The manufacturers of NiTi instruments recommend this method of instrumenting to increase the time interval until the instrument passes through the highest stress area highest stress area and increases the time until fracture occurs[12,13].

The objective of this study was to the effect of different amplitudes of pecking motion (in-and-out axial movement) on the cyclic fatigue of Hyflex EDM OneFile in simulated curved canal at body temperature. The null hypothesis is that the different pecking distances does not significantly affect the time to failure or the number of cycles to fracture (NCF) of Hyflex EDM NiTi endodontic files.

Material and Methods

Sixty NiTi files HEDM size #25, 0.08 taper were used in this study. All files used were 25-mm long. Every instrument was inspected for defects or deformities before the experiment under an operative microscope at 40x; none were discarded.

The sample size calculation was performed for a multiple comparison of means, using ANOVA, in a total of four groups, with a significance level to 5%, a test power of 80%, a maximum standard deviation of 0.62 and maximum difference between means of 0.80, the sample size was 15 for each group. Previous studies were used as reference[3,10,14].

Sixty new Hyflex EDM OneFile (#25/0.08) files were tested in each group (n = 15) at three different pecking amplitudes with the same pecking speed of 3-mm/s: G(1): 1-mm depth, G(2): 2-mm depth, G(3): 3-mm depth, and G(4): 4-mm depth.

Dynamic Cyclic Fatigue Test

The cyclic fatigue tests were performed using a custom-made device that allowed a reproducible simulation of an instrument inside of an artificial curved canal as described anteriorly[15-17]. The canal was 24.8 mm long and 3.5 mm deep, with a straight cervical segment of 13.35 mm, 2.5 mm radius of curvature, 69° angle of curvature, a curved 2.15-mm long segment, and a straight apical segment of 7.5 mm. The canal was 2.0 mm wide in the widest coronal portion, tapering to 1.0 mm in the narrowest apical portion.

The canal was covered with an acrylic plate. The stainless-steel metal block with the simulated canal was positioned on a hotplate stirrer (Fisatom, São Paulo, SP, Brazil). The temperature inside the artificial canal was taken with a laser thermometer (G-TECH, Duque de Caxias, RJ, Brasil) and was kept constant at 36 ± 1^{o}C.

The instruments were entered 22 mm into the artificial canal; a silicone stop was used on each instrument to ensure that depth. The HEDM files was inserted to a 6:1 reduction handpiece (Sirona Dental Systems GmbH, Bensheim, Germany), which was aligned to the axis of the simulated canal. The motor (Silver Reciproc; VDW, Munich, Germany) was used to test the HEDM instruments in continuous rotation at 500 rpm according to the manufacturers' recommendations. The handpiece was fixed in a mobile unit powered by an electronically controlled servomotor (SAVOX SC-12 56T69; Savox, Taichung, Taiwan) to allow a precise and reproducible continuous up-and-down pecking movement of each file inside the artificial canal.

A synthetic oil (Super Oil, Singer Co Ltd, Elizabethport, NJ) was applied to reduce attrition of the HEDM instruments as it touched the simulated canal walls.

The instruments rotated freely inside the simulated curved canal with different distances of pecking motion (1.0, 2.0, 3.0 and 4.0mm) until fracture occurred. A video camera (Iphone11, Apple, Califórnia, EUA) was used to ensure an accurate analysis of the time to fracture (TtF), analyzing the videos in the exact moment of the fracture of the files (Figure 1). The number of cycles to failure (NCF) was calculated for each instrument multiplying the time to fracture in seconds by the rotational speed (rpm) and dividing by 60 (number of seconds per minute).

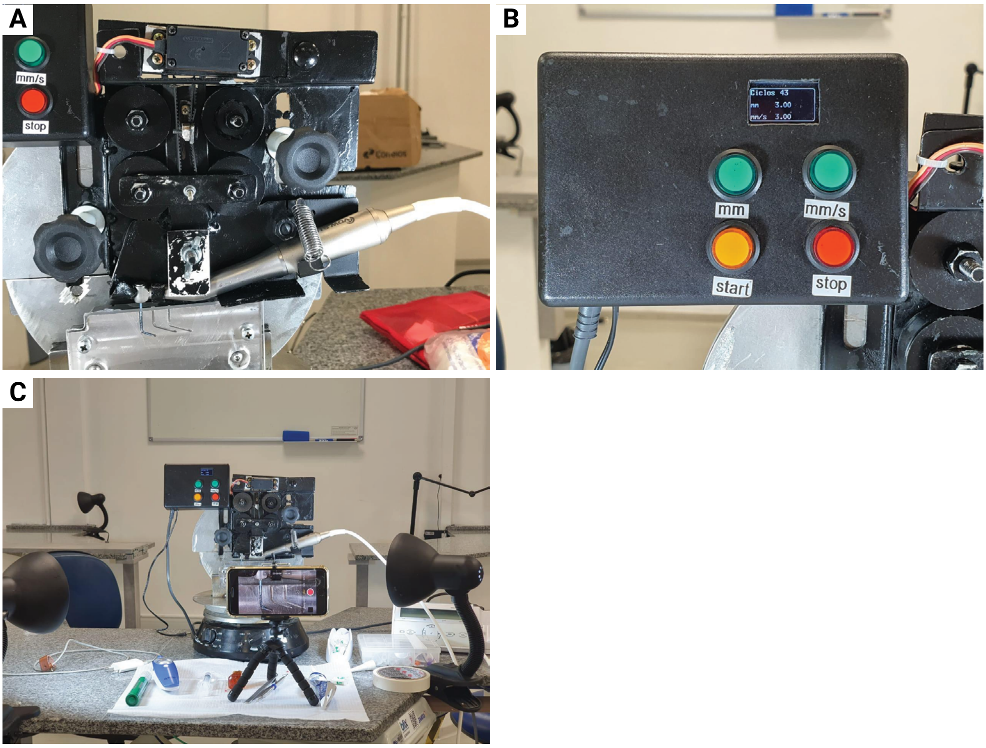

Figure 1. A -The handpiece was fixed in a mobile unit powered by an electronically controlled servomotor (ECS). B - ECS display that sets the continuous up and down pecking movement of each file within the artificial canal, starting and stopping the test. C - The entire cyclic fatigue test system and filming set up to start the test.

Scanning Electron Microscopy analysis

After cyclic fatigue tests, instruments of the groups tested were placed in an ultrasonic bath to remove debris. The fragment length of the fractured instruments was measured using digital caliper to verify the correct positioning of the files in the artificial canal. The axial and longitudinal views of the fractured instruments from each experimental group were examined with scanning electron microscopy (Evo 15; Zeiss, Cambridge, UK). The pattern of fracture length of the files in each group and location of the point of maximum tension in the artificial test canal were analyzed. Data were analyzed using analysis of variance and Student-Newman-Keuls tests, with a significance level at 5% ($P < 0.05$).

Results

The mean and stand deviations of the NCF and fractured instrument length for the 4 different pecking distances are shown in Table 1. Significant difference among the four groups was observed ($p < 0.05$). Group 1 (1mm amplitude) had a mean value of NCF (444.4) being the lowest among the groups. There was a significant difference between group 4 (1278.9) and the others ($p < 0.05$). Groups 2 and 3, with

NCF means of 714.4 and 872.2, respectively, did not show any significant difference between them ($p > 0.05$).

Table 1. The NCF and fractured instrument length (Mean ± Standard Deviation SD) of different groups with different pecking distances

Amplitude	Number of Cycles to Fracture (NCF)				Fractured Instrument Length			
	Mean	SD	Min	Max	Mean	SD	Min	Max
G1 (1 mm)	$444,4_a$	134,4	275,0	841,7	$6,80_b$	0,72	6,13	8,22
G2 (2 mm)	$714,4_b$	84,0	608,3	850,0	$6,22_{ab}$	0,44	5,53	7,28
G3 (3 mm)	$872,2_b$	248,5	633,3	1558,3	$6,75_b$	0,93	5,38	7,97
G4 (4 mm)	$1278,9_c$	388,7	816,7	2191,7	$6,04_a$	0,67	4,84	7,25

Different subscript letters in the same column indicate a significant difference amongst the groups (*p < 0,05*).

The mean length of the fractured fragment was significantly different in the amplitudes tested ($p < .05$) (Table 1). There was a significant difference between Group 1 and Group 4 ($p < 0.05$), but there was no significant difference between Group 1 and 3 ($p > 0.05$). There was no significant difference between group 2 and the other groups ($p > 0.05$). SEM images of the fracture surface exhibit similar and typical features of cyclic fatigue for the all instruments (Figure 2).

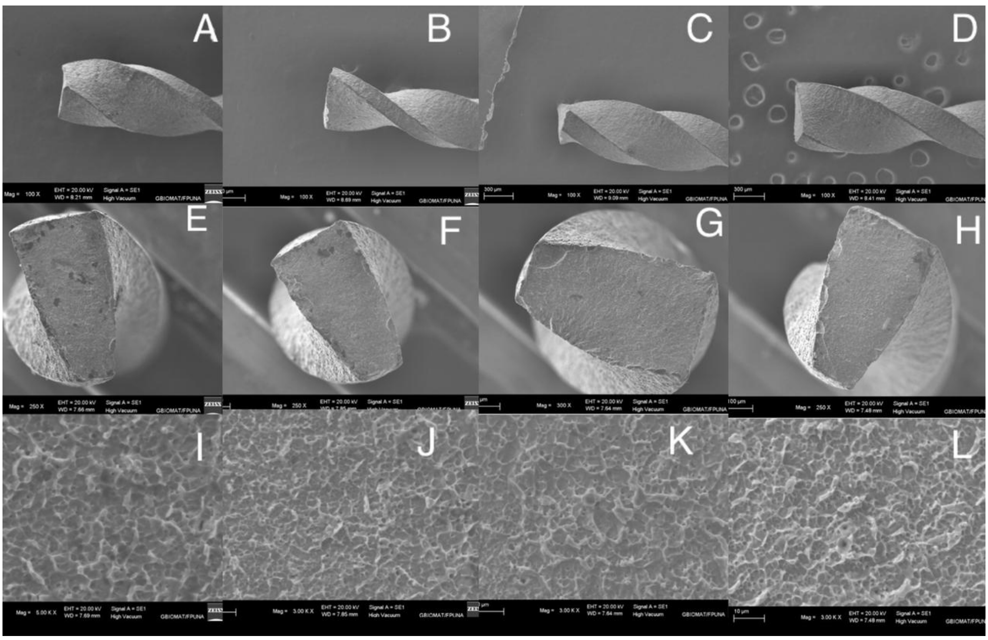

Figure 2. SEM images of the surfaces of the Hyflex EDM OneFile instruments. Longitudinal images of the fragments of the 1mm (A), 2mm(B), 3mm(C) and 4mm(D) groups, no torsional fatigue characteristics (x100). Cross-sectional images of fragments from 1mm (E), 2mm(F), 3mm(G) and 4mm(H) groups (x 300), showing cyclic fatigue fracture characteristics. Images (x 1000) showing the presence of dimples1mm (I), 2mm(J), 3mm(K) and 4mm(L) groups.

Discussion

Cyclic fatigue resistance of rotary instruments is affected by the radius and bending angle of the canal[18,19]. In curved root canals stresses are concentrated in the part of the instrument at the point of greater curvature[2,20]. Simulating a clinical condition, this study used an artificial canal, with a radius of curvature of 2.5 mm and a curvature angle of 69°.

In earlier studies, NCF of the Hyflex EDM was significantly higher than of the others tested rotary instruments or reciprocating instruments, using the dynamic cyclic fatigue resistance test 20 . Also, in tests performed by Thu et al.[21] (2020), there was significant difference in the mean length of fracture fragments between the tested files, as in the present study. This may occur due the design of the instrument, with 3 variations on its long axis.

In vitro study assessed differences in cyclic fatigue of this instruments at room and body temperatures and show that Hyflex EDM had a long fatigue life and the life span not differed for HEDM between room or body temperature[22]. Simulating a clinical condition, in the current study, dynamic cyclic fatigue of the instruments was tested at 36 ± 1°C[11,23].

The cyclic axial movement plays an important role in preventing t the cyclic fracture of instruments in curved canals. By avoiding the stress concentration in the same area, the fatigue life of the instrument is extended[12]. In dynamic cyclic fatigue tests, the instrument moves axially along the curvature of the canal, which allows stresses to be distributed along the instrument's shaft. Axial in-and-out movements with a distances of 1, 2, 3 and 4 mm were performed in this study during the cyclic fatigue assessment. Other studies tested the axial movements ranging from 1 to 8 mm[2,12,20,24-27].

The time to fracture and the NCF decreased significantly with decreasing pecking distance, rejecting the null hypothesis tested. The NCF and time to fracture were significantly smaller in G (1) compared to the others pecking distances. The longer pecking depth allows a longer time interval before the instrument once again passes through the highest stress area 20 . This may distribute the stress and prevents the concentration of tensile and compressive stresses within the curved section, increasing the NCF[12].

The results of this study agree with an anterior study that performed cyclic fatigue tests in simulated canals[20]. However, under these conditions, stress generation in the file and in the dentin at different pecking depths is not tested. Considering the differences between a real clinical situation and the *in vitro* conditions performed in the present experiment, future studies (*in vivo or ex vivo*) could evaluate the effects of different amplitudes on the cyclic fatigue resistance of NiTi instruments in curved root canals.

In conclusion, under the limited conditions of this study, our results suggest that a longer pecking depth using the Hyflex EDM OneFile may decrease the risk of instrument fracture.

Conflict of Interest

The authors have no conflict of interest to disclose.

Data availability

Datasets related to this article will be available to the corresponding author upon request.

Author Contribution

Verônica Magalhães Lima Nunes: Conception and design of the study, Data Analysis, Interpretation and Statistics; **Tânia Nunes Soares:** Data Analysis, Interpretation and Statistics; **Viviane Rangel do Couto:** Conception and design of the study, Data Analysis; **Luiz Meton Horta dos Santos:** Review and Editing, Interpretation and Statistic; **Maria Alejandra Portillo Martinez:** Data Collection, Review and editing; **Paula Avelar da Silva Ribeiro Goulart:** Data Collection, Review and editing; **Aline Cristine Gomes Matta:** Review and Editing, Writing the manuscript; **Adriana de Jesus Soares:** Review and Editing; **Marcos Roberto dos Santos Frozoni:** Conception and design of the study, Data Analysis, Review and Editing. All authors actively revised and approved the final version of the manuscript.

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