EGYPTIAN DENTAL JOURNAL
www.eda-egypt.org
VOL. 70, 2835:2842, JULY, 2024
PRINT ISSN 0070-9484 • ONLINE ISSN 2090-2360
CONSERVATIVE DENTISTRY AND ENDODONTICS
Submit Date : 05-02-2024 • Accept Date : 21-04-2024 • Available online: 10-07-2024 • DOI : 10.21608/EDJ.2024.266146.2921

COMPARISON OF THE CYCLIC FATIGUE & THE CUTTING EFFICIENCY OF TWO ROTARY NITI SYSTEMS

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ABSTRACT

Purpose: This study compares cyclic fatigue and cutting efficiency of two types of NiTi Rotary files, namely AF one files with a constant 4% taper and Hyflex EDM Files with a variable taper. **Materials and Methods:** Forty files, twenty of each brand, were examined under a microscope to ensure their integrity before testing. The evaluation focused on cyclic fatigue and cutting efficiency.

Cyclic fatigue testing utilized a specialized block simulating dental canals, following Grande et al.'s prescribed design. Lubricating oil flooded the artificial canals, and files were tested at specified RPM and torque until breakage, with recorded breakage times. Cutting efficiency testing involved using plexiglass blocks, and measuring the length of cut during 1 minute. A dedicated device facilitated testing, including an air compressor for debris clearance.

Results: Data from both tests were collected and analyzed, revealing that Hyflex EDM files demonstrated superior resistance to cyclic fatigue compared to AF one files($p<0.001$). However, AF one files exhibited higher cutting efficiency than Hyflex EDM ($p= 0.001$), with statistically significant differences in both results. These findings are crucial for dentists in making informed decisions about the choice of files for root canal treatment in their practice.

KEYWORDS: Endodontics; Root canal treatment; Rotary Files; CM Files

INTRODUCTION

Root canal shaping is a crucial step during endodontic treatment that greatly helps achieve proper root canal disinfection and obturation [(1)]. The goal of shaping the root canal is to develop a continuously shaped three-dimensional conical form from the apex of the root to the crown. During shaping, the canal anatomy should be maintained, and tooth structure should be conserved.

As much as the NiTi rotary instruments offered some advantages over stainless steel files when it comes to flexibility, time-saving, and some errors.

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Yet the defects and fracture occurrence of NiTi rotary files are still significantly higher than stainless steel manual files. The main challenge remains that most NiTi Rotary files do not show visible defects before fracture.[2]

Files separation of NiTi rotary instruments is still a significant issue during clinical application. Files separation usually occurs due to torsional fatigue or cyclic fatigue. Cyclic fatigue fracture of rotary files happens due to continuous tension and compression repeated cycles at the point of maximum flexure when the file rotates in a severely curved canal. [3] [4]The file separation is not the main concern, being able to disinfect or clean the below area remains the main challenge. Avoiding such complications always remains the clinician's daily goal.

Also, cutting efficiency is one of the challenges and parameters used to know the performance of an endodontic rotary file. As being able to cut through the dentin, and remove the infected layers, creating space for the irrigants to go through the canals and clean through them remains an important objective of root canal treatment.

Therefore, manufacturers are always introducing new technologies and designs targeting impro ved accuracy, reduced chances of errors, and minimum time needed during root canal shaping. Examples include new heat treatments, different metallurgies, and different cross-sectional designs of the endodontic files.

In 2010, CM wires were introduced. When compared to other NiTi files, they contain a reduced nickel content (52 percent wt.). These files are given a specific thermo-mechanical treatment to increase their flexibility while also improving their shape memory effect. As a result, they do not rebound after unloading, and their original shape is restored following the application of heat or the autoclaving method. Pre-bending this file before placing it in a curved canal has clinical benefits, especially for patients with limited mouth opening and curved roots. Because of their unique manufacturing method, CM instruments are also more resistant to cycle fatigue (300–800 percent more fatigue resistant), as they do not rebound to their previous shape.[4] They do, however, have one big disadvantage: a higher likelihood of permanent plastic deformation following usage. [5]

The new design of flat side rotary files is one of the very recent Niti designs showing another enhancement which is a better shaping ability. it is also showing less canal transportation, the flat side rotary file is a recent design of having one side of the rotary file flat and non-working. It is believed that it does also minimize the file engagement in the root canal being shaped by having fewer contact points than conventional files. [6]

Recently, a new thermally treated NiTi rotary instrument, AF-One (Fanta Dental, Shanghai, China), characterized by a flat designed and S-shaped cross section has been developed. These characteristics confer lots of advantages such as reducing blade engagement, increasing fatigue lifespan, and taking out the debris from the prepared area.[7]

Hyflex EDM One-File (HEDM, Coltene, Whaledent, Altstatten, Switzerland) is manufactured through electro-discharge machining (EDM) using a special NiTi alloy. The manufacturer claims that the special alloy and EDM have improved the instrument's characteristics in terms of resistance to cyclic fatigue, controlled memory, and pre-bendability.[8]

So, the evaluation of the cutting efficiency of these two newly introduced rotary files systems and determination of the safety limit before cyclic fatigue is reached and the file fractures would be so helpful to ensure the achievement of successful endodontic treatment without any errors or defects jeopardizing the success of root canal treatment.

MATERIALS AND METHODS

The sample size was calculated using jamovi priori sample size calculator for independent samples t-test *(jamovi version 2.3)*. Using the probability of type I Error of 0.05, the power of 0.9, and the anticipated effect size of 1.8, the analysis generated a minimum required sample size of 8 observations. The used effect size was based on previous research done by Gambarini et al. [10]

A comprehensive sample of forty files (twenty of each brand) with ISO size #25 underwent meticulous inspection under an 8X magnification digital microscope to ensure their integrity. Sample classification involved two main groups: AF One and Hyflex EDM, each further stratified into subgroups (A1, A2, B1, and B2) based on the specific tests performed. The cyclic fatigue tests employed a custom-designed stainless-steel block simulating canals, adhering to Grande et al.'s design. [17] Files were subjected to testing using an E-Connect endodontic motor, with AF one files at 500 rpm and 1.5 N.cm torque. The design of the simulated canal incorporated a 60-degree curvature and a 5mm radius, following Pruett's curvature technique, [23] with a missing side for easy monitoring and file replacement. Statistical analyses, conducted using JASP version 0.16.3, included independent samples t-tests to compare mean cycles till fracture and mean length cut per minute. Data was collected and the number of cycles till fracture was calculated based on the equation**: Number of cycles till fracture (NCF) = rpm x time taken to fracture (in seconds).**

In the cutting efficiency evaluation, a specialized device resembling the one described by Rubini et al. [9] was employed, comprising a main frame with a mobile plastic handpiece support and a stainless-steel block containing a Plexiglas surface against which the cutting efficiency of the instruments was assessed. This study utilized 20 Plexiglass blocks, each dedicated to testing a single file, ensuring precision and consistency. A computerized program with a 0.1 mm precision measured the length of the block cut in 1 minute, using the same weight for all instruments. To prevent instrument slippage, a 1 mm notch was strategically created on the lateral wall of the 1-mm-thick Plexiglas. The plastic support facilitated precise three-dimensional alignment and positioning of the instrument, ensuring contact with the Plexiglas notch without bending. An air compressor was employed to remove plastic debris during testing, and each instrument underwent linear cutting in a unidirectional lateral motion. Standardized fixed positions and torque-controlled electric motors provided predictable and reproducible evaluations of cutting ability. Data analysis involved calculating means and standard deviations for each group, and statistical comparisons were conducted to assess the cutting efficiency of the tested files.

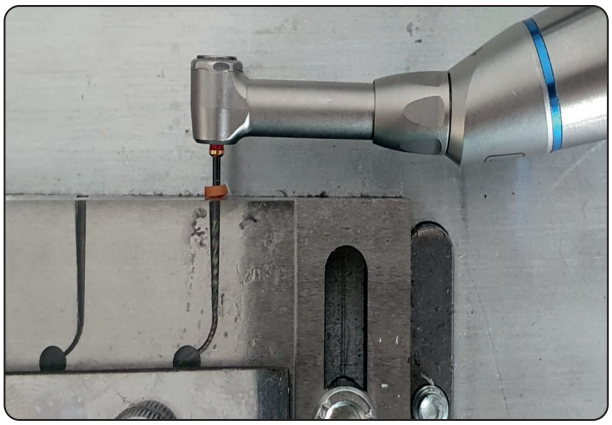

Fig. (1) Cyclic Fatigue Test Device

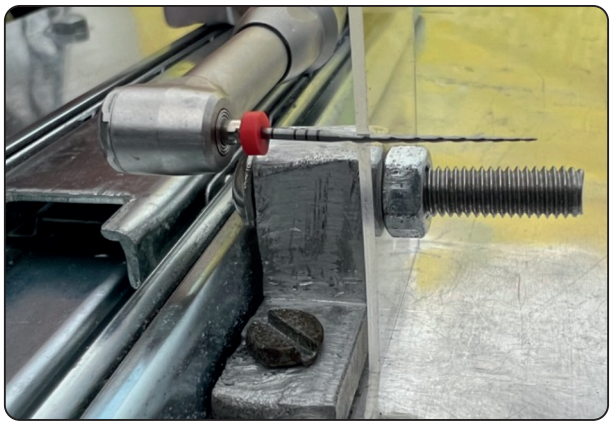

Fig. (2) Cutting Efficiency Test Device

RESULTS

Cutting efficiency test results showed that the average cutting length per minute AF Fanta (2.892± 0.346) was statistically significantly higher compared to Hyflex EDM files (2.282± 0.356) (p= 0.001), ie 1.66 times higher which denotes the cutting efficiency of AF Fanta was higher than the average cutting length per minute of Hyflex EDM). (Table 1)

Table (1) Comparison of Cutting length per minute of AF Fanta files vs Hyflex EDM file

		Mean ± SD	P Value***
Length cut/ minute	**AF Fanta**	2.892 ± 0.346	p= 0.001
	Hyflex	2.282 ± 0.356	

(P=0.001), a statistically significant difference was found

Cyclic fatigue test results showed that Hyflex EDM (62900±14027.354) had a statistically significant higher number of cycles till fracture compared to AF Fanta (191850±45112.237) (t=8.631, p<0.001).

The average cycles till the fracture of AF Fanta were 3.69 times lower than the average cycles till the fracture of Hyflex EDM. (Table 2)

Table (2) Comparison of cycles till fracture of AF files vs Hyflex EDM files

		Mean ± SD	P Value***
Cycles till fracture	**AF Fanta**	62900 ±14027.354	P <0.001
	Hyflex	191850 ± 45112.237	

(p<0.001) a statistically significant difference was found.

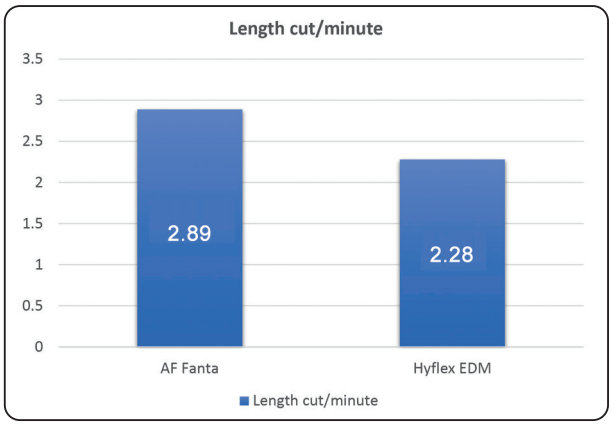

Fig. (3) Bar chart of length cut per minute of AF Fanta & Hyflex EDM rotary files.

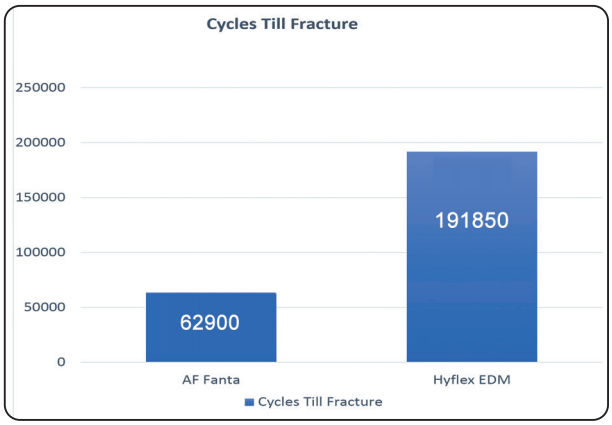

Fig. (4) Bar chart of cycles till fracture of AF Fanta & Hyflex EDM rotary files

DISCUSSION

During root canal treatment, procedural errors like ledging, zipping, perforations, root canal transportation, and instrument separation can occur more often in curved canals. Instrument separation, especially of rotary nickel-titanium files, is a major complication due to cyclic fatigue, where the instrument fractures from repeated compression and tension cycles.[2] Separated instruments compromise treatment success, and removal is challenging with no guarantee of 100% success. Thus, preventing rotary nickel-titanium file breakage is a clinical goal. Efforts have been made to reduce the risk of separation through improvements in instrument design, manufacturing, and movement kinetics.[3]

Another important attribute of an endodontic file is cutting efficiency to ensure its advancement into the root canal without the application of excessive pressing forces. The cutting action of NiTi files is affected by several factors including file designs, angle of file access, and kinematics. [2][3]

I have chosen to compare the AF ONE Flat side rotary files for this study for their unique features such as a flat noncutting side and an S-shaped cross-sectional design with two active cutting points and a non-cutting tip. Additionally, it is a single file system with a new heat treatment called AF-R wire, which is claimed by the manufacturer to provide higher cutting efficiency and increased cyclic fatigue and torsional resistance compared to other NiTi files. [10] By comparing this file with the HyFlex EDM, which is manufactured via electro-discharge machining (EDM) using a non-contact thermal erosion process that partially melts and evaporates the wire, we can determine the effectiveness of this novel manufacturing technique on endodontic instruments. The HyFlex EDM has been shown to greatly increase the resistance of the instrument against cyclic fatigue throughout various studies, which could be considered more of a gold standard for CM rotary files. [8]

Both the AF ONE Flat side file and the HyFlex EDM are Controlled Memory wires and innovations in comparison to conventional NiTi files, and they have demonstrated increased resistance to cyclic fatigue. However, the AF ONE Flat side file has a different design and manufacturing process than the HyFlex EDM, and it is claimed to provide higher cutting efficiency.[8] Therefore, this study was conducted to evaluate the cyclic fatigue and cutting efficiency of the two rotary files AF One (Fanta Dental, Shanghai) and Hyflex EDM (Coltene, Whaledent).

In this study, AF Fanta Files and Hyflex EDM rotary files were tested using Plexiglass blocks. 20 blocks were made for the study, using each file once on a separate block. The cutting test device had a main frame with a plastic support for the handpiece and a stainless-steel block with a Plexiglas surface for testing cutting efficiency. the length of the block cut in 1 minute was measured with a computer program accurate to 0.1mm. To prevent slipping, a 1mm notch was made on the Plexiglas wall. An air compressor removed debris. [9]. All files were positioned and operated at a specific torque using an electric motor. We measured the length of the block cut in 1 minute for each group and statistically analyzed the data for means and standard deviations.

Regarding cutting efficiency, the results of this study show that AF one had higher statistically significant cutting efficiency when compared to Hyflex Edm. This may be due to their distinctive positive cutting angles and the unique geometric design. The flat side-cut contributes to a small cross section, creating greater space between canal walls and the file, which allows for more debris collection and removal capability [11]. This ability to remove debris also adds to the efficiency of mechanical instruments, because the removal of cut dentin chips reduces clogging of the cutting blades [12]. This feature kept the flutes unclogged and always ready for more dentin cutting.

This finding agrees with a study conducted by Kataia et al. [13] which also found the AF one when compared to other rotary files was found to have a higher cutting efficiency. Which authors concluded that might be attributed to the cross-section of the file. Wan et al [14] also found a higher cutting efficiency when comparing Safesiders, which is also another flat-side rotary file, a similar design of the AF One files, to other files. Likewise, Pedulla et al[15] Özyürek et al [16] when comparing Hyflex EDM with different rotary files concluded that Hylfex had lower cutting efficiency compared to other files.

In this study, static cyclic fatigue testing was performed on various files at specified rpm and torque based on manufacturer instructions. An artificial canal, designed to closely mimic

real-world canals, was fabricated from stainless steel and used in the testing. The canal was designed to follow the design proposed by Grande et al.[17] and was 16mm in length with a 60-degree curvature and 5mm radius. The canal had a missing side which was covered by glass to contain the file during testing and to aid in changing the files between test rounds. The endodontic motor used in the study was E-Connect with a 1:1 reduction handpiece, and the settings of the motor were adjusted according to manufacturer instructions for each file. The testing process involved introducing the file into the canal, activating the endodontic motor, and observing the file until it fractured. The fractured time was recorded with a digital stopwatch and the data was collected in an Excel sheet. The number of cycles till fracture was calculated based on the equation of *the number of cycles till fracture (NCF) = rpm x time taken to fracture (in seconds).*

Regarding cyclic fatigue, the results of this study showed a statistically significant difference favoring Hyflex EDM files over AF one files, this could be attributed to their transformation temperature, which is higher than that of the other files tested. Moreover, the electro-discharge machining procedure implemented during the production of these files might have contributed to the cyclic fatigue of the files.[8]

The results of this study regarding the higher cyclic fatigue resistance of Hyflex EDM compared to AF ONE files are consistent with the findings of several previous studies. Shams et al. [18] reported that Hyflex EDM exhibited greater cyclic fatigue resistance compared to other rotary files, including AF One. This superiority was rooted in using EDM-manufactured C-wires and optimal selection of cross-section, diameter, and rotational speed. [18] Additionally, the study conducted by Abd ElHamid (19) comparing 3 Groups: M3 Pro Gold, AF One & Hyflex EDM found that Hyflex EDM had a statistically significant higher cyclic fatigue resistance value compared to AF One & M3 Pro Gold files. These results are probably due to the different NiTi alloys treatment temperature and the differences in surface coating and treatment. [19] Our study used a similar experimental setup and methodology as that of Shams et al. [18] and Abd ElHamid [19]. The cyclic fatigue test was performed by introducing the file into an artificial canal using an endodontic motor, and the time to failure was recorded. The cutting efficiency was evaluated by measuring the weight of dentin debris generated during canal shaping using each rotary file.

The results of this study were also in agreement with previous studies that have reported the higher cyclic fatigue resistance of HyFlex EDM files. For instance, a study conducted by Özyürek et al. [16]. found that HyFlex EDM files had a significantly higher resistance to cyclic fatigue compared to other files tested. Similarly, a study by Gündoğar et al. [20] reported that HyFlex EDM files had a significantly longer lifespan than other files tested. Pedullà et al. [21]. evaluated the resistance to cyclic fatigue of 4 heat-treated single files and HyFlex EDM also showed higher time to fracture than other files. These studies support the notion that the electro-discharge machining process used in the manufacture of HyFlex EDM files enhances their cyclic fatigue resistance.

Despite the statistically significant difference found in this study favoring the HyFlex EDM files over AF One files in terms of cyclic fatigue resistance, it is important to consider the disagreement with other studies that have evaluated AF One files. For example, a study conducted by Gambarini et al. [22] showed that the AF One files had the highest cyclic fatigue resistance when compared to other rotary NiTi files. This difference can be explained by the difference in methodology as their study compared the file to a prototype which might be the reason the AF one files gave higher resistance.[22]

CONCLUSION

Under the limitations of this present study, it can be concluded that Hyflex EDM showed higher resistance to cyclic fatigue when compared to AF one files which could make it more favorable in curved canals.

AF One showed higher cutting efficiency when compared to Hyflex EDM which might result in better debris and affected dentin removal to ensure optimum shaping and cleaning of canals.

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