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A COMPARATIVE EVALUATION OF CYCLIC FATIGUE RESISTANCE OF DIFFERENT CONTINUOUS ROTATION AND RECIPROCATING FILE SYSTEMS

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ABSTRACT :AIM AND OBJECTIVE : The aim of this in-vitro study was to compare the cyclic fatigue resistance of two continuous rotation file systems (HyFlex EDM and TwoShape) and two reciprocating file systems (Reciproc Blue and WaveOne Gold) in canals with different angulations.

Materials and Method: Thirty files each of HyFlex EDM (25,~), TwoShape (25,0.06), Reciproc Blue R25 (25/0.08) and WaveOne Gold Primary (25/0.07) were included in this study. All the instruments were used according to manufacturers' instructions in an endodontic fatigue testing block with three artificial grooves simulating root canals having angulations of 45°, 60° and 90°. The files were allowed to rotate in the grooves, until fracture occurred and the time to fracture was recorded in seconds using digital chronometer. The data were analyzed statistically using one-way ANOVA followed by Post hoc Tukey test .

Results: Amongst the continuous rotation file systems, Hyflex EDM while amongst the reciprocating file systems Reciproc Blue showed significantly higher cyclic fatigue resistance at all angles of curvature i.e. 45°, 60° and 90° ($p < 0.05$). On comparing all the four file systems, Hyflex EDM at 45° angle of curvature whereas Reciproc Blue at 60° and 90° angles of curvature presented with highest cyclic fatigue resistance ($p < 0.05$).

Conclusions: Within the limitations of the present in vitro study, it may be concluded that HyFlex EDM tends to be more resistant to fracture in canals with a gentle curvature, while Reciproc Blue may be more suited in canals with sharp and acute curvatures.

Key words :
Angle of curvature, cyclic fatigue resistance, nickel-titanium

Conflict of interest: Nil
No conflicts of interest : Nil

INTRODUCTION : Recent advancements in the metallurgy of rotary nickel-titanium (NiTi) instruments have led to their increased popularity due to superior flexibility, ability to maintain canal curvature, superior cutting efficiency, faster canal preparation and overall higher success rate because of reduction in procedural mishaps. [1],[2],[3]

Despite these advantages, rotary NiTi files demonstrate an increased risk of fracture especially in curved root canals. The fracture of these NiTi files during clinical use occurs by two different mechanisms i.e. Torsional fatigue and Cyclic fatigue. [4]

Torsional fatigue fracture occurs when the torsional stress exceeds the elastic limit of the file whereas, Cyclic fatigue fracture occurs due to alternating tension – compression cycles, at the apical third of severely curved root canals.[5] To prevent this, the manufacturers' modify the metallurgy by incorporating different combination of alloys, by altering the design properties and also by incorporating various heat treatments and kinematics . [6],[7],[8],[9]

HyFlex EDM (HEDM; Coltene/Whaledent, Altst€atten, Switzerland) and TwoShape (TS; Micro-Mega, Besancon, France) were used in the present study in continuous rotation motion. HEDM files are manufactured from controlled memory alloy using electro-discharge machining technology, while TS is produced by a proprietary heat treatment (T-Wire) which according to the manufacturer, aims to improve both flexibility and cyclic fatigue resistance (CFR). [10],[11],[12]

Reciproc Blue (RB; VDW, Munich, Germany) and WaveOne Gold (WOG; Dentsply Maillefer, Ballaigues, Switzerland) are new-generation single-file systems which use reciprocating motion. RB is manufactured by altering the molecular structure through a novel blue heat treatment in order to increase the CFR which gives the file its blue color.[13] The WOG files are manufactured using gold heat treatment which involves heating and then slowly cooling the file after production, thus increasing the flexibility of file. [14]

In a comprehensive literature review, there has been no previous study examining the cyclic fatigue resistance of TwoShape and Reciproc Blue at 45°, 60° and 90° canal curvatures. The aim of the present study therefore, was to compare the cyclic fatigue resistance of two continuous rotation files, HEDM and TS and two reciprocating files RB and WOG in simulated canals with different angulations (45°, 60° and 90°). The null hypothesis was that there would be no significant difference in the cyclic fatigue resistance among the continuous rotation and reciprocating motion NiTi files when rotated in simulated canals at different canal angulations.

MATERIALS AND METHOD

Thirty files each of HyFlex EDM (25,~), TwoShape (25,0.06), Reciproc Blue R25 (25/0.08) and WaveOne Gold Primary(25/0.07) of length 25 mm were included in the present study. For standardization and reliability of the experiment, the instruments tested were examined for defects under a stereomicroscope (Zoom Stereo Binocular Microscope {ZSM-111}, Hicksville, NY, USA) with ×20 magnification for any visible signs of defects. The files were stabilized inside simulating root canals having an angulations of 45°, 60° and 90° respectively for a locking system and thereby standardizing their positions in an endodontic fatigue testing block as shown in Figure 1.[15]

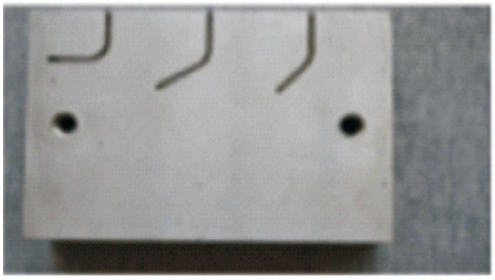

Figure 1 Endodontic fatigue testing block

Using glycerine (Glycerine Pure; AB Enterprises Mumbai, India) as a lubricant the files were rotated in grooves, having an inner diameter of 1.5 mm, length of 20 mm, angles of curvature 45°, 60°, 90° and a radius of curvature of 5 mm until fracture occurred. In order to observe the fracture of files, top of the endodontic fatigue testing block was covered with a glass.

During mechanical testing, 120 NiTi rotary files were divided into two experimental groups based on their movement kinematics into Group-I i.e. Continuous rotation motion files (n = 60) and Group-II i.e. Reciprocating motion files (n = 60). Group-I was further subdivided into IA (n=30) and IB (n=30) represented by HEDM and TS files respectively while Group-II was further subdivided into IIA (n=30) and IIB (n=30) represented by RB and WOG files respectively. Ten files each from the different subgroups were used in every individual artificial groove created at angulations of 45°, 60°and 90° respectively.

The files, with their working lengths standardized at 18 mm, were activated using a 6:1 reduction handpiece powered by a torque controlled motor (X-Smart Plus; Dentsply Maillefer, Switzerland). HEDM files were operated in continuous rotation at 500 rpm and 2.5 N cm torque values, TS at 300 rpm and 2.5 N cm, RB R25 in “Reciproc All” program and WOG Primary in “WaveOne All” program, according to the manufacturers' recommendations. The endodontic motor was recalibrated after the use of each instrument in order to avoid measure errors due to motor mechanics.

The handpiece of the endomotor was locked in a reproducible position and files of each group were used freely in the simulated canals created in an endodontic fatigue testing block as shown in Figure 2, until fracture occurred. This testing procedure was performed by a single operator to avoid interoperator variability.

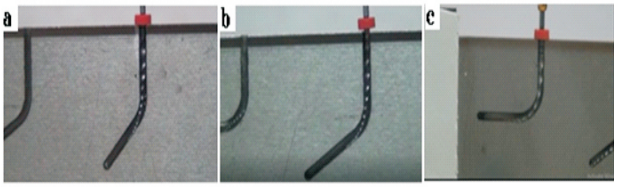

Figure 2 Cyclic fatigue testing in an endodontic fatigue testing block (a, b and c) shows NiTi files being tested at 45°, 60°and 90°canal angulation

The instrument fracture was detected visually using a videocamera Cannon EOS 700D (Canon Inc; Tokyo, Kanto; JP) on a tripod stand and time to fracture for each instrument was recorded by a digital chronometer. Using the time data, the number of cycles to failure (NCF) was determined to evaluate the cyclic fatigue resistance (CFR) of different NiTi files using the formula: NCF = Revolution per minute (rpm) x Time to fracture in seconds (sec) / 60.

STATISTICAL ANALYSIS

The NCF data were first analysed using the Shapiro-Wilk test to verify the assumption of normality. One-way ANOVA followed by Post hoc Tukey test were performed to statistically analyse the data using SPSS 21.0 software (IBM-SPSS Inc, Chicago, IL, USA) with the significance level established at 5% ($p < 0.05$).

RESULTS

The mean and standard deviations of the number of cycles to failure (NCF) of the groups tested are presented in Table 1.

Table 1. The mean and standard deviations of the number of cycles to failure (NCF) of NiTi instruments tested at three different canal curvatures (45°, 60°and 90°)

Angles of Curvature		45°	60°	90°
	IA			
Continuous rotation motion group (Group I) NCF	(Hyflex EDM)	$^{a}3541.6\pm683.0^{A}$	$^{a}980.0\pm310.4^{B}$	$^{a}790.0\pm104.7^{C}$
	IB			
	(TwoShape)	$^{b}431.0\pm58.2^{A}$	$^{b}315.1\pm68.6^{B}$	$^{b}216.0\pm52.6^{C}$
	IIA			
Reciprocating motion group (Group II) NCF	(Reciproc Blue)	$^{c}2616.5\pm279.7^{A}$	$^{c}1456.9\pm307.6^{B}$	$^{c}908.5\pm95.3^{C}$
	IIB			
	(WaveOne Gold)	$^{d}927.7\pm100.1^{A}$	$^{d}701.6\pm87.7^{B}$	$^{d}416.1\pm85.1^{C}$

Data were shown with means ± standard deviations

Different superscript lower letters in the same column show statistically significant difference ($p < 0.05$).

Different superscript capital letters in the same row show statistically significant difference ($p < 0.05$).

Among the continuous rotation files, the NCF value of HEDM and among the reciprocating files, the NCF value of RB showed significantly higher CFR in comparison to TS and WOG respectively at all the angles of curvature ($p < 0.05$). At 45° angle, HEDM showed highest CFR ($P < 0.05$) followed by RB; which again was higher than WOG with TS showing the lowest CFR ($p < 0.05$) and the difference was found to be statistically significant. At 60° and 90°angles of curvature, RB showed highest CFR followed by HEDM, WOG and TS ($p < 0.05$) with the differences being statistically significant. CFR at 60° and 90° curvatures were significantly lower as compared to 45° canal curvature ($p < 0.05$).

DISCUSSION :

Cyclic fatigue has been reported to be one of the major factors resulting in file separation in curved canals, thus justifying the need for studies comparing the CFR of NiTi rotary files at different canal angulations. [16]

The use of natural teeth was avoided because it is difficult to standardize root canal length, degree and radius of curvature as well as dentin hardness.[17] Although the simulated canal created in a non tooth device is unable to replicate clinical conditions, it minimizes the impact of other variables that may influence file fracture, thus facilitating standardization.[18],[19],[20] Cyclic fatigue resistance using non tooth device has been previously tested in both static and dynamic models. Although a dynamic model could closely replicate a clinical pecking motion, it's drawback is that instruments being tested are not limited in a precise trajectory. In a dynamic model study, the amplitude as well as speed of axial movement is standardized. However, in clinical practice, both amplitude and speed of axial motion are variable and subjective, as the pecking motion is manually controlled.[21] The results of such studies must however, be extrapolated to clinical conditions keeping in mind the contrast between the properties of a stainless steel block and dentin.

On the basis of the findings, null hypothesis was rejected, as a significant difference in CFR was obtained among the different file systems at different canal curvatures.

Among the two continuous rotation files, HEDM showed significantly higher CFR as compared to TS at all the canal curvatures.[12] The result may be attributed to the superior fatigue properties of controlled memory alloy used in HEDM when compared to T-wire used in TS file. Since very few studies are present examining the CFR of TS files, these results cannot be specifically compared to those with other investigations.

Among the reciprocating files, RB showed higher CFR at all curvatures i.e. the Novel Blue heat treatment that alters the molecular structure of RB showed superior results when compared to gold heat treatment used in the production of WOG files. While some studies have reported that, cross-section design of files has no effect on CFR, others have confirmed their influence on fracture resistance of the files.[22],[23],[24],[25] The S-shaped cross-section design of RB was found to show better CFR than the parallelogram cross-section design of WOG.[20] Based on the findings of the present study, it could be said that the metal alloy as well

as the cross-section design might influence the CFR of files.

At 45° angle of curvature, HEDM had highest CFR when compared to RB, WOG and TS which is in contrast to the results obtained in a previous study conducted by Özyürek et al that reported significantly higher CFR of RB files in comparison to HEDM files at 45° and 90° angles of curvature.[12] It may be speculated that different assessment methods were employed in the two different studies. Whereas, NCF was calculated in the present study, in the previously conducted study, total time to fracture (TTF) was assessed. The probable reason for the results obtained in the present study may be attributed to the alloy used in the manufacturing process i.e. controlled memory along with the electrodischarge machining procedure performed during the manufacturing of HEDM. However, it may be considered that not only the alloy used in the manufacturing of files, but the cross-section design and area, as well as the usage speed of the file also exerts an influence in its cyclic fatigue life .

At 60° and 90° angles of curvature, RB presented with highest CFR which may be attributed to the superior fatigue properties imparted by Novel Blue heat treatment which is a proprietary-specific oxide surface layer producing thermomechanical manufacturing process altering the molecular structure and imparting a blue color to the instrument. [3]

In the present study, a statistically significant difference in terms of CFR was found between WOG files used in reciprocating motion and that of TS files used in continuous rotation motion at all angles of curvature. With very few studies examining the CFR of TS files, it may be postulated that gold heat treatment in WOG might have an influence on CFR. Moreover, further studies are needed to evaluate the properties of T-Wire alloy used in TS file.

According to the results of the present study, all the experimental groups revealed a greater CFR at 45° angle of curvature as compared to 60° and 90° angles of curvature which is in accordance with the previous study by Peng et al which postulated that at 45° angle of curvature, the CFR of NiTi files was found to be significantly higher than their resistance in canals with 60° and 90° angles of curvature. [25] The results of the present study confirmed the findings of previous studies that the CFR of NiTi files is strongly influenced by the angle of curvature of the artificial canal used. [26],[27]

CONCLUSIONS :

Within the limitations of the present in vitro study, it may be concluded that among the continuous rotation file systems, HEDM showed significantly higher CFR at 45°, 60° and 90° angles of curvature and among the reciprocating file systems RB showed highest CFR at different canal curvatures. At 45°, HEDM instruments resisted cyclic fatigue significantly more than RB followed by WOG and TS instruments. Considering that majority of root canals are closer to being 45°, HEDM may be used in canals with gentle curvature. However, at 60° and 90° angles of curvature the novel NiTi rotary instrument, RB showed higher CFR when compared to HEDM, WOG and TS instruments, which makes them more appropriate to be used in canals with sharp and acute curvatures. It may also be concluded, that the increase in angle of curvature of artificial canals negatively affects the CFR of NiTi instruments.

REFERENCES

1. Kim HC, Kwak SW, , Ko DH, Chung SM, Lee W. Cyclic fatigue and torsional resistance of two new nickel-titanium instruments used in reciprocation motion: Reciproc versus WaveOne. J Endod. 2012;38(4):541-4.
2. Fabio de Almeida-Gomes, Humberto Ramah Menezes de Matos, Rodrigo Ferreira Lopes Arrais Nunes, Ariel Moura Arrais, Claudio Ferreira-Maniglia, Marcelo de Morais Vitoriano, Eduardo Diogo Gurgel-Filho Cyclic fatigue resistance of different continuous rotation and reciprocating endodontic systems. IJDR 2016
3. Gündo ar M , Özyürek T. Cyclic Fatigue Resistance of OneShape, HyFlex EDM, WaveOne Gold, and Reciproc Blue Nickel-titanium Instruments Journal of Endodontics 2017; 43(7)1192-119 -2
4. Gianluca Plotino, Nicola M. Grande, Massimo Cordaro, Luca Testarelli, and Gianluca Gambarini, A Review of Cyclic Fatigue Testing of Nickel-Titanium Rotary Instruments.JOE2009:35:1
5. Kiefner P, Ban M, De-Deus G.Is the reciprocating movement per se able to improve the cyclic fatigue resistance of instruments? Int Endod J. 2014;47(5):430-6.

6. Testarelli L, Plotino G, Al-Sudani D. Bending properties of a new nickel-titanium alloy with a lower percent by weight of nickel. J Endod. 2011;37:1293–5
7. Peters O, Gluskin A, Weiss R, Han J. An in vitro assessment of the physical properties of novel Hyflex nickel–titanium rotary instruments. Int Endod J. 2012;45:1027–34
8. Plotino G, Grande NM, Cotti E, Testarelli L, Gambarini G. Blue treatment enhances cyclic fatigue resistance of vortex nickel titanium rotary files. J Endod. 2014;40:1451–3.
9. Sandhya Anand Khasnis et al Rotary science and its impact on instrument separation: A focused review. JCD 2018
10. Haapasalo M and Shen Y (2013) Evolution of nickel-titanium instruments: from past to future. Endodontic Topics 29,3-17
11. Pedullà E, Savio FL, Boninelli S, Plotino G. Torsional and cyclic fatigue resistance of a new nickel- titanium instrument manufactured by electrical discharge machining. J Endod. 2016;42:156–9.
12. Özyürek T Cyclic fatigue resistances of Hyflex EDM, WaveOne Gold, Reciproc blue and 2shape NiTi rotary files in different artificial canals,odontology 2018
13. De-Deus G, Silva E, Vieira V, Belladonna F, Elias C. Blue Thermomechanical Treatment Optimizes Fatigue Resistance and Flexibility of the Reciproc Files. Journal of Endodontics. 2017;43(3):462-466.
14. Plotino G, Grande NM, Bellido MM, Testarelli L, Gambarini G. Infuence of temperature on cyclic fatigue resistance of ProTaper gold and ProTaper Universal rotary fles. J Endod. 2017;43:200–2
15. Modesto T, Acosta E, Resende P, Pereira É, Peixoto I, Buono V et al. Cyclic flexural fatigue resistance of NiTi Controlled Memory and Blue Technology instruments after torsional preloading. Journal of Applied Oral Science. 2018;26
16. Cheng Peng, WU Hui, Lei Wang. Cyclic fatigue resistance of two nickel-titanium instruments in different curving angles: a comparative study. Braz oral research 2015
17. Saleh AM, Gilani PV, Tavanafar S, Schäfer E. Shaping ability of 4 different single-file systems in simulated S-shaped canals. J Endod. 2015;41:548–52
18. Özyürek T. Cyclic fatigue resistance of Reciproc, WaveOne, and WaveOne gold nickel-titanium instruments. J Endod. 2016;42:1536–9
19. Topçuo lu H, Topçuo lu G, Akt A. Comparative evaluation of cyclic fatigue resistance of D-RaCe and ProTaper retreatment instruments in curved artificial canals. Int Endod J. 2015;49:604–
20. Plotino G, Costanzo A, Grande NM. Experimental evaluation on the influence of autoclave sterilization on the cyclic fatigue of new nickel-titanium rotary instruments. J Endod. 2012;38:222–5
21. Pedullà E, Grande N, Plotino G, Gambarini G and Rapisarda E (2013) Influence of Continuous or Reciprocating Motion on Cyclic Fatigue Resistance of 4 Different Nickel-Titanium Rotary Instruments. Journal of Endodontics 39, 258-261.
22. De Melo MCC, de Azevedo Bahia MG, Buono VTL. Fatigue resistance of engine driven rotary nickel-titanium endodontic instruments. J Endod 2002;28:765-769
23. Cheung G, Darvell B. Low- cycle fatigue of NiTi rotary instruments of various cross- sectional shapes. Int Endod J. 2007;40:626-632
24. Tripi TR, Bonaccorso A, Condorelli GG. Cyclic fatigue of different nickel- titanium endodontic rotary instruments. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2006;102:e106-e114
25. Grande N, Plotino G, Pecci R, et al. Cyclic fatigue resistance and three- dimensional analysis of instruments from two nickel–titanium rotary

systems. Int Endod J. 2006;39:755-763

26. Y lmaz K andÖzyürek T (2017) Cyclic fatigue life of Tango-Endo, WaveOne GOLD, and Reciproc NiTi instruments. Restorative Dentistry & Endodontics 42,134.
27. Plotino G, Grande NM, Melo MC. Cyclic fatigue of NiTi rotary instruments in a simulated apical abrupt curvature. Int Endod J. 2010;43:226–30.

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