Mustansiria Dental Journal
MDJ

Vol.20, No.02, 12/2024
P- ISSN: 2618-0944
E- ISSN: 1813-8500

Effect of different heat treatments on the cyclic fatigue resistance of EdgeEndo files

Haneen N. Alshareefi[1], Maha M. Yahya[2], Abeer Saad Gawish[3]

[1]M. Sc student at College of Dentistry, Mustansiriyah University, Department of conservative, Iraq, E-mail: haneen.najih@uomustansiriyah.edu.iq , ORCID: https://orcid.org/0009-0009-5684-1830 .

[2]Assistant Professor at College of Dentistry, Mustansiriyah University, Department of Conservative, Iraq, B.D.S., M.Sc. in Conservative Dentistry, E-mail: Mahaalbazzaz@uomustansiriyah.edu.iq, ORCID: https://orcid.org/0000-0002-6350-3225.

[3]Dean of faculty of graduate studies.Sinai University ElArish& professor of oral medicine, periodontolgy, oral diagnosis and oral radiology, Faculty of dental medicine -girls branch AlAzhar University, Egypt, E-mail : Gawish27@gmail.com, ORCID : https://orcid.org/0000-0002-9932-1773.

Received 16/05/2024 ***Accepted in revised form 15/10/2024*** ***Published 30/12/2024***

Abstract:

Aim: The aim of this research is to evaluate and compare the cyclic fatigue fracture resistance of three different EdgeEndo file systems.

Method: A total of forty-five NiTi files of EdgeFile X7 (25 taper 6), EdgeX7 Utopia (25 taper 6), and EdgeOne Blaze Utopia (25 taper 8v) were used. Cyclic fatigue resistance was evaluated in a double-curved simulated artificial canal at 37°C temperature. An endodontic motor (x Smart Plus; dentsply) was used. The motor rotated the files at 350 rpm speed until they fractured. Fracture length, time, and number of cycles to fracture were documented. Files examined under SEM to identify the topographic characteristics of the fractured file fragments. The statistical analysis of the results was done using the one-way ANOVA analysis of variance with Tukey HSD.

Results: EdgeOne Blaze has demonstrated a significantly greater NCF compared to both EdgeX7 Utopia and EdgeX7 ($P < 0.05$). Additionally, there was a significant difference in the NCF among EdgeX7 Utopia and EdgeX7 ($P < 0.05$).

Conclusion: Cyclic fatigue resistance significantly improved in the new NiTi files that have FireWire Blaze heat treatment.

Key words: Cyclic fatigue; FireWire Blaze; EdgeOne Blaze Utopia; EdgeX7 Utopia; EdgeFileX7.

Introduction:

A new era in endodontic therapy began with the introduction of nickel-titanium in root canal files, which minimized the probability of treatment-related errors [1]. Since then, NiTi rotary file usage for root canal preparation has increased daily due to the fact that these files prominently have higher flexibility than stainless steel ones [2]. An ideal root canal instrument must have high flexibility, torsional strength, and angular deflection when subjected to torsional stress [3]. Intracanal instrument fracture during canal preparation is the most frequent problem caused either by torsional fatigue, cyclic fatigue, or both [4, 5]. Cyclic fatigue causes the file to deteriorate with the effect of alternative tension-compression cycles during bending, which leads to structural breakdown and fracture of the instrument. Clinically, this happens while shaping severely curved root canals [6, 7].

Factors including file form, alloy type, and manufacturing techniques have a substantial effect on the stress behaviour of NiTi files and the possibility of file fracture [8]. The NiTi alloy commonly undergoes heat treatment in order to enhance its microstructure and transformation behaviour, leading to improved shape memory characteristics and, subsequently, enhanced mechanical qualities [9]. In comparison to continuous rotation movement, reciprocating movement was found to be associated with extended lifetime NiTi rotary files [10, 11].

There is a variety of heat-treated NiTi file systems, each having its own unique metallurgic characteristics. EdgeFile X7 (EdgeEndo; Johnson City, TN, USA) is a rotary file system that utilizes a FireWire heat treatment, which involves the integration of heat treatment and cryogenic treatments, producing a FireWire NiTi alloy [12]. Edge X7 Utopia (Edge Endo; Switzerland), a novel file system, comes into the market in 2023. It delivers a Technology-Enhanced File with a prominent gold blade featuring a FireWire Blaze Heat treatment. The manufacturers claimed that FireWire Blaze proprietary heat treatment provides optimal fracture resistance while maintaining a super sharp cutting edge and flawless blade surface [13]. EdgeOne Blaze Utopia (Edge Endo; Albuquerque, NM, United States) is another new single-file reverse reciprocating motion system. It also features a FireWire Blaze Heat Treatment [14].

However, there is no data available about this new heat treatment, and according to the author's knowledge, there has been no study about the cyclic fatigue fracture resistance of these new file systems; this study aimed to investigate the cyclic fatigue fracture resistance of the new file systems and compare them with the traditional EdgeX7 file system at body temperature. The null hypothesis was that all tested NiTi file systems have the same cyclic fatigue resistance.

Material and Methods:

A total of forty-five NiTi files have been used. Files are grouped into three groups: EdgeFile X7 (25 taper 6), EdgeX7 Utopia (25 taper 6), and EdgeOne Blaze Utopia (25 taper 8v). Each group consisted of fifteen files, all of which were 25 mm in length. The cyclic fatigue fracture resistance of the files was assessed by inserting files into a simulated double-curved artificial canal. The canal was milled in a stainless steel plate using laser micromachining; the canal was stabilized

within a water bath set at a constant temperature (37 ℃). A dentsply endomotor (x Smart Plus) was positioned in a way that facilitated the downward insertion of the file into the canal until 18 mm of its length was reached. After that, the motor rotated the files at a 350 rpm speed until a fracture occurred. The fracture length in mm and time in minutes were recorded. NCF was calculated by multiplying the fracture time (in minuets) by 350 rpm.

SEM:

Two broken files were chosen from each group for scanning electron microscopic analysis to determine the fracture surface topographic features. The files underwent a three-minute cleaning process in an ultrasonic bath using pure alcohol prior to the microscopic analysis. The scanning electron microscope (SEM) captured photomicrographs at a magnification of 170x.

Data Analysis:

The SPSS (version -22, Chicago, Illinois, USA) was used in the data analysis and presentation. Cluster and simple bar charts were used to display the data. Standard deviation, standard error, minimum, and maximum were computed, in addition to a one-way ANOVA analysis of variance and Tukey HSD. Level of significance ($p < 0.05$) [Table 1]

Results:

The data exhibited a normal distribution when tested using the Shapiro-Wilk test. The minimum, maximum, mean, standard deviation, and standard error of the NCF, fracture time (in minutes), and FL for each file were computed and recorded in [Table 2]. ANOVA test revealed a significant difference (p-value less than 0.05) in the cyclic fatigue fracture resistance across the tested groups. The results of Tukey's test revealed that the NCF and fracture time of the EdgeOne Blaze group were considerably more significant than those of the other groups ($P < 0.05$). The NCF and fracture time of EdgeX7 Utopia and EdgeOne blaze files exhibited a considerably higher value compared to the EdgeFile X7 files ($P < 0.05$). The number of cycles to fracture and fracture time between EdgeX7 Utopia and EdgeOne Blaze files exhibited a statistically significant difference ($P < 0.05$). Fracture length of EdgeOne Blaze files was significantly greater than that of both EdgeX7 Utopia and EdgeFile X7 instruments ($P < 0.05$). [Figure 1]

The SEM analysis of fractured tip surfaces revealed consistent and characteristic signs of cyclic fatigue in all three file systems, including the beginning of cracks and the fast fracture zone caused by overload with irregular fractured surfaces. [Figure 2]

Discussion:

This study investigated the effect of the new heat treatment on the fracture resistance of the new NiTi systems by using cyclic fatigue tests and fractographic analysis. The difference in thermal treatments of the NiTi alloy constitutes one of the most significant technological advancements in mechanical file manufacturing. Their use enhances endodontic file cutting efficiency, canal-centering ability, fatigue resistance, flexibility and other mechanical features [15]. Firewire Blaze heat treatment is a new thermal treatment produced by Edge Endo for the new file systems; there has been a need for more information about this type of new heat treatment and its effect on the mechanical behaviour of the new NiTi instruments.

Multiple studies have revealed that the ambient temperature highly effects the mechanical behaviour of NiTi endodontic files due to differences in the metallurgical features of NiTi alloys [16]. In 2022, a systematic review found that the cyclic fatigue fracture resistance of heat-treated NiTi files falls dramatically when exposed to body temperature as opposed to room temperature [17]. Thus, this investigation was carried out at a regulated temperature that closely approximates the intracanal temperature of 37℃, which is the body temperature.

The EdgeFile X7 is produced using a FireWire™ Proprietary annealed heat treatment, which can increase flexibility and cyclic fatigue fracture resistance while reducing the shape memory effect that characterizes the NiTi files. Additionally, it features a continuous taper with a parabolic cross-section [18]. EdgeX7 Utopia has the same characteristic features as EdgeFile X7, but with FireWire™ Blaze heat treatment. EdgeOne Blaze Utopia has a FireWire™ Blaze heat treatment, an S-shaped cross-section and a variable taper and reciprocating movement [14].

The result of this study showed that EdgeX7 Utopia has high cyclic fracture resistance, which is twice that of EdgeFile X7, and this can be related to the new heat treatment. EdgeOne Blaze Utopia file has the highest number of fracture cycles in comparison to other files, which is 3 times greater than that of EdgeX7 and more than half the time of the EdgeX7 Utopia, and this can be related to the new heat treatment and type of movement because reciprocating files are more resistant to cyclic fatigue than rotating files [10]. The cross-sectional form of NiTi files significantly affects their cycle fatigue failure. Specifically, the S-shaped cross-section exhibits superior cyclic fatigue resistance compared to both the rectangular and convex triangular cross-sections [19,20]; this can also be the reason why the EdgeOne Blaze Utopia file showed the highest resistance to cyclic failure in contrast to other file systems.

The fracture length of the EdgeOne Blaze Utopia file was significantly greater than other files. This may be related to the difference in taper between files, as this file has 08 variables taper and the two other files used had 06 constant taper. This gives it flexibility in the apical part and less flexibility coronally that minimized bending resistance in the coronal curvature, which can be the reason why it fractured in the coronal curvature while the other two files fractured in the apical curvature.

Conclusion:

EdgeOne Blaze Utopia file showed significantly better cyclic fatigue failure resistance than other files; EdgeX7 Utopia file has a significantly greater resistance to fracture than EdgeFile X7. FireWire Blaze heat treatment showed a significant effect on the cyclic fatigue failure resistance of the studied NiTi files.

Conflict of interest

The authors reported that they have no conflicts of interest.

Acknowledgements

The authors would like to thank Mustansiriyah University (www.uomustansiriyah.edu.iq), Baghdad, Iraq, for their support in the present work.

References:

1- Almohareb RA, Barakat RM, Algahtani FN, Alkadi MF. Cyclic fatigue resistance of EdgeTaper Platinum, Protaper Gold, and

TruNatomy Prime rotary files before and after autoclave sterilization. *PeerJ*. 2023;11:e14656. Published 2023 Jan20. https://doi:10.7717/peerj.14656.

2- Gavini G, Santos MD, Caldeira CL, Machado MEL, Freire LG, Iglecias EF, Peters O, Candeiro GTM. Nickel-titanium instruments in endodontics: a concise review of the state of the art. *Brazilian oral research*. 2018; *32*(suppl 1), e67. https://doi.org/10.1590/1807-3107bor-2018.vol32.0067

3- Faus-Llácer V, Hamoud-Kharrat N, Marhuenda Ramos MT, Faus-Matoses I, Zubizarreta-Macho Á, Ruiz Sánchez C, Faus-Matoses V. Influence of the Geometrical Cross-Section Design on the Dynamic Cyclic Fatigue Resistance of NiTi Endodontic Rotary Files—An In Vitro Study. Journal of Clinical Medicine. 2021;10(20):4713. https://doi.org/10.3390/jcm10204713

4- Basturk FB, Özyürek T, Uslu G, Gündoğar M. Mechanical Properties of the New Generation RACE EVO and R-Motion Nickel-Titanium Instruments. *Materials (Basel, Switzerland)*. 2022;*15*(9), 3330. https://doi.org/10.3390/ma15093330

5- Silva E, Oliveira de Lima C, Vieira V, Antunes H, Lima Moreira EJ, Versiani M. Cyclic Fatigue and Torsional Resistance of Four Martensite-Based Nickel Titanium Reciprocating Instruments. Eur Endod J. 2020:Dec;5(3):231-235. https://doi:10.14744/eej.2020.16878. PMID: 33353907; PMCID: PMC7881387.

6- Pedullà E, Lo Savio F, Boninelli S, Plotino G, Grande NM, La Rosa G, Rapisarda E. Torsional and Cyclic Fatigue Resistance of a New Nickel-Titanium Instrument Manufactured by Electrical Discharge Machining. *Journal of endodontics*. 2016; *42*(1),156–159. https://doi.org/10.1016/j.joen.2015.10.004

7- Gündoğar M and Özyürek T. Cyclic fatigue resistance of OneShape, HyFlex EDM, WaveOne Gold, and Reciproc blue nickel-titanium instruments. J Endod. 2017; 43(7):1192–1196)

8- Almohareb RA, Barakat RM, Algahtani FN, Alkadi MF. Cyclic fatigue resistance of EdgeTaper Platinum, Protaper Gold, and TruNatomy Prime rotary files before and after autoclave sterilization. *PeerJ*. 2023;11:e14656. Published 2023 Jan20. https://doi:10.7717/peerj.14656.

9- Martins JNR, Silva EJNL, Marques D, Pereira MR, Vieira VTL, Arantes-Oliveira S, Martins RF, Braz Fernandes F, Versiani M. Design, Metallurgical Features, and Mechanical Behaviour of NiTi Endodontic Instruments from Five Different Heat-Treated Rotary Systems. *Materials*. 2022; 15(3):1009. https://doi.org/10.3390/ma15031009.

10- De Pedro-Muñoz A, Rico-Romano C, Sánchez-Llobet P, Montiel-Company JM, Mena-Álvarez J.

Cyclic Fatigue Resistance of Rotary versus Reciprocating Endodontic Files: A Systematic Review and Meta-Analysis. Journal of Clinical Medicine. 2024;13(3):882. https://doi.org/10.3390/jcm13030882

11- Ferreira F, Adeodato C, Barbosa I, Aboud L, Scelza P, Zaccaro Scelza M. Movement kinematics and cyclic fatigue of NiTi rotary instruments: a systematic review. *Int Endod J*. 2017;50(2):143-152. https://doi:10.1111/iej.12613.

12- Al-Amidi AH, Al-Gharrawi HA. Effect of autoclave sterilization on the cyclic fatigue resistance of EdgeFile X7, 2Shape, and F-one nickel-titanium endodontic instruments. J Conserv Dent. 2023 Jan-Feb;26(1):26-30. https://doi:10.4103/jcd.jcd_611_21. Epub 2022 Aug 17. PMID: 36908740; PMCID: PMC10003289.

13- EDGEENDO. EdgeX7 Utopia. Accessed 2023 3 December. https://www.edgeendo.com/wp-content/uploads/2024/01/EdgeX7-Utopia-Brochure-US-Rev-D-Jan-2024.pdf

14- EDGEENDO. EdgeOne Blaze Utopia. Accessed 2023 3 December. https://www.edgeendo.com/wp-content/uploads/2023/05/EdgeOne-Blaze-Utopia-Brochure-Rev-C-May-2023-1.pdf.

15- Di Nardo D, Miccoli G, Mazzoni A, Seracchiani M, Gambarini G, Testarelli L. Cyclic Fatigue of Reciproc and Reciproc Blue Nickel-titanium Reciprocating Files at Different Environmental Temperatures. *Journal of Endodontics*. 2018; vol. 44,10: 1549–1552. https://doi:10.1016/j.joen.2018.06.006.

16- Campos GO, Fontana CE, Vieira VTL, Elias CN, de Martin AS, Bueno CEDS. Influence of Heat Treatment of Nickel-Titanium Instruments on Cyclic Fatigue Resistance in Simulated Curved Canals. *Eur J Dent*. 2023;17(2):472-477. https://doi:10.1055/s-00421747952.

17- Savitha S, Sharma S, Kumar V, Chawla A, Vanamail P, Logani A. Effect of body temperature on the cyclic fatigue resistance of the nickel-titanium endodontic instruments: A systematic review and meta-analysis of *in vitro* studies. *J Conserv Dent*. 2022;25(4):338-346. https://doi:10.4103/jcd.jcd_55_22.

18- Sharroufna R, and Mashyakhy M. The Effect of Multiple Autoclave Sterilization on the Cyclic Fatigue of Three Heat-Treated Nickel-Titanium Rotary Files: EdgeFile X7, Vortex Blue, and TRUShape. Biomed Research International. 2020; 8826069. https://doi:10.1155/2020/8826069.

19- Sekar V, Kumar R, Nandini S, Ballal S, Velmurugan N. Assessment of the role of cross section on fatigue resistance of rotary files when used in reciprocation. *Eur. J. Dent.* 2016;10:541–545.

https://doi:10.4103/1305-7456.195171.

20- Faus-Llácer V, Hamoud-Kharrat N, Marhuenda Ramos MT, Faus-Matoses I, Zubizarreta-Macho Á, Ruiz Sánchez C, Faus-Matoses V. Influence of the Geometrical Cross-Section Design on the Dynamic Cyclic Fatigue Resistance of NiTi Endodontic Rotary Files—An In Vitro Study. *Journal of Clinical Medicine*. 2021;10(20):4713. https://doi.org/10.3390/jcm10204713

Table 1: Statistical test of cyclic fatigue among groups using One Way ANOVA.

		Sum of Squares	df	Mean Square	F	P value
Fracture Time (mins.)	Between Groups	23.348	2	11.674	161.528	**0.000**
	Within Groups	3.035	42	.072		
	Total	26.383	44			
NCF	Between Groups	2862079.460	2	1431039.730	161.334	**0.000**
	Within Groups	372542.674	42	8870.064		
	Total	3234622.134	44			
Fracture Length (mm)	Between Groups	383.394	2	191.697	4204.613	**0.000**
	Within Groups	1.915	42	.046		
	Total	385.309	44			

*df= degrees of freedom, F= ratio of two variances

Table 2: Descriptive statistics of cyclic fatigue among groups.

		N	Mean	±SD	±SE	Min.	Max.
Fracture Time (mins.)	Edge X7	15	0.963	0.304	0.078	0.611	1.535
	Edge X7 utopia	15	1.649	0.215	0.056	1.274	2.035
	Edge One Blaze utopia	15	2.714	0.280	0.072	2.259	3.063
NCF	Edge X7	15	336.701	106.532	27.506	213.960	536.900
	Edge X7 utopia	15	577.363	75.312	19.445	445.780	712.670
	Edge One Blaze utopia	15	949.748	97.925	25.284	790.710	1072.110
Fracture Length (mm)	Edge X7	15	1.485	0.267	0.069	1.060	1.850
	Edge X7 utopia	15	1.727	0.220	0.057	1.430	2.090
	Edge One Blaze utopia	15	7.794	0.132	0.034	7.470	7.960

*N= number of files used, Mean= mean of the results, SD= standard deviation, SE= standard error, Min= minimum result, Max= maximum result.

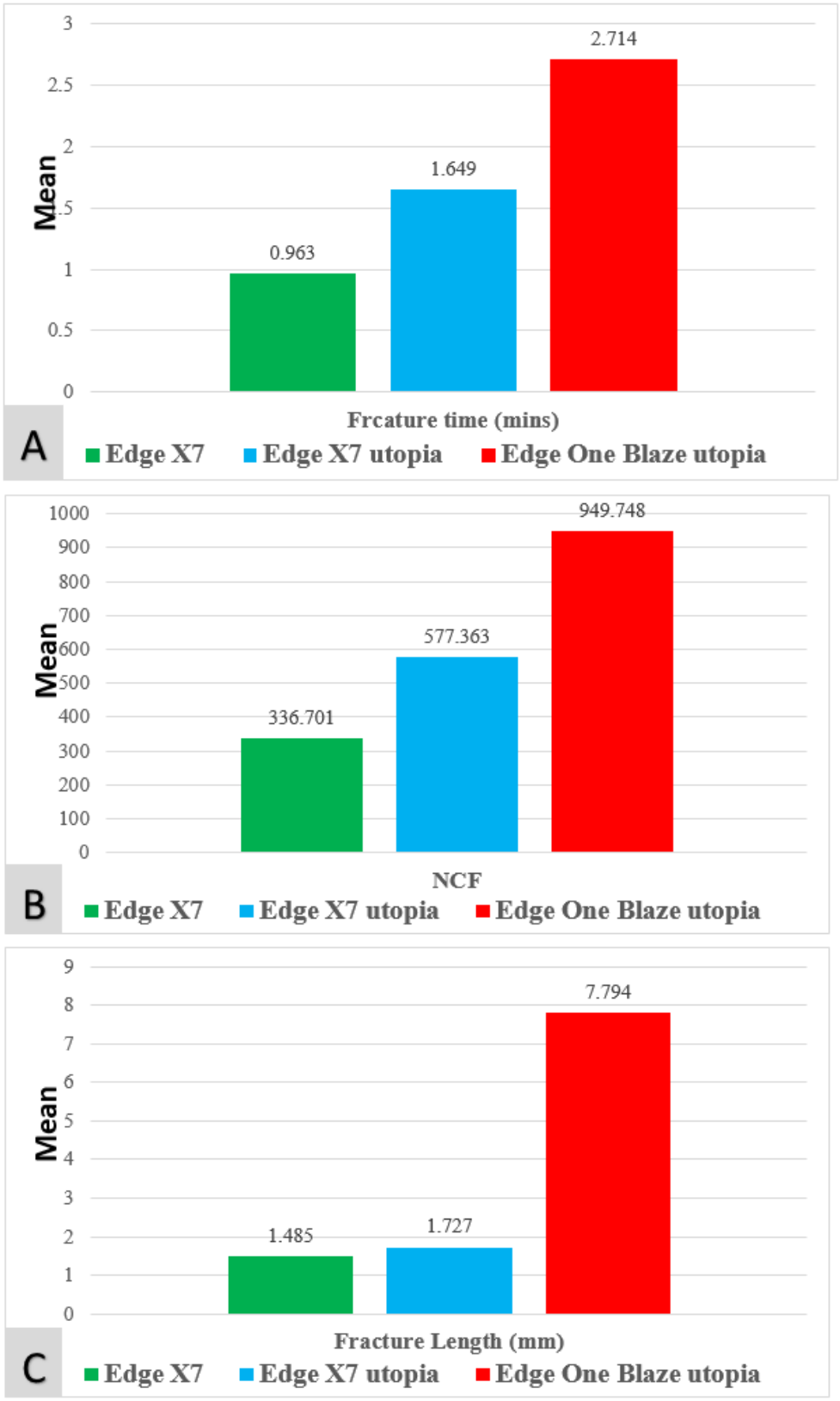
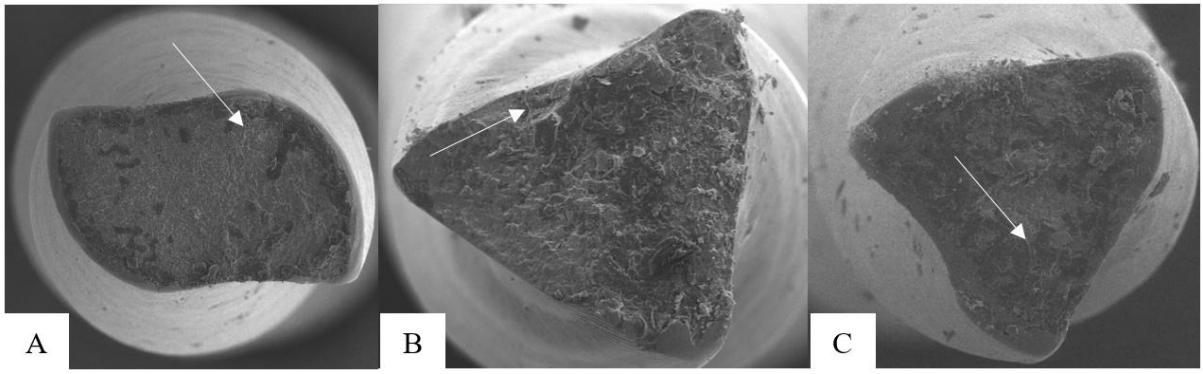


Figure1: (A) Represent time of fracture of the tested files, **(B)** Represent NCF of the tested files, **(C)** Represent fractured fragment length of the tested files, (*) significant differences ($p < 0.005$) arising from ANOVA test, Edge One Blaze utopia displayed higher values in all three tests.



Figur2: SEM fractographic analysis of fractured files tips (arrows pointing on the cracks lines); **(A)** fracture surface of EdgeOne Blaze Utopia file, **(B)** fracture surface of EdgeX7 Utopia file, **(C)** fracture surface of EdgeFile X7 file,