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Cleaning ability and Apically Extruded Debris of Three Single file Rotary Nickel Titanium systems (an in vitro study)

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Abstract

Background: The aim of this study was to evaluate three single rotary NiTi systems regarding their cleaning ability and the amount apically extruded debris.

Methodology: A total of forty five extracted permanent mature lower anteriors were divided then instrumented in three groups (n = 15): Fanta AF F One file, OneShape file and OneCurve file. 2.5% Sodium hypochlorite was used as an irrigant. preweighets and postweights were recorded for apical extrusion. Teeth were longitudinally splited into two halves. Images were taken then analysed for debris percentage using J image software. Intergroup comparisons and intragroup comparisons were done using one-way ANOVA followed by Tukey's post hoc test.

Results: The apical extrusion results showed that the highest mean value of apically extruded debris was found in Fanta AF F One group followed by OneCurve group, while the least value was found in OneShape group. Regarding the cleaning ability, none of the tested instrument showed complete cleaning of the canal walls. The three file systems showed better cleaning ability in the coronal and the middle while a less cleaning ability was in the apical thirds of the root canals. Fanta AF F One file showed better cleaning ability compared to Oneshape and OneCurve file systems.

Conclusions: Under the conditions of this study, Fanta AF F One file produced more debris than the One Shape and OneCurve file systems. While it showed a better cleaning ability compared to the other file systems.

Keywords : Keywords: Apical Extrusion, Cleaning ability, Fanta AF F One, OneShape, OneCurve.

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Introduction

The major goal of the root canal treatment is to remove infected, necrotic tissues and debris, shape the root canals and provide an adequate seal of the root canals system. Provide proper any infection inside the canal and provide space for the irrigation, intracanal medication, and the obturation material. (1)

Cutting throughout the dentin causes apical extrusion of debris and the presence of debris inside the root canal system. None of the used techniques was able to prevent the apical extrusion of debris, however, their amount is variable. The extrusion of debris, bacteria, and irrigant beyond the apex may have some undesirable consequences such as induction of inflammation, postoperative pain, and delay of periapical healing. (2)

Up till now, no instrument was able to totally clean the root canal system. (3,4) however, there are advancements in the development of Ni-Ti rotary instruments in recent years, many attempts were made to change the file design, and simplify and reduce the number of instruments used during the preparation. (5,6)

Among NiTi rotary instruments, Fanta AF F One file (Shanghai Fanta Dental Materials Co., LTD) Patent flat design: The manufacturer claims that the vertical blades can sweep the debris from flutes to the relieving area, having an S-shaped cross-section design, It's made of conventional NiTi alloy. (7)

The One-Shape file MicroMega (Besancon Cedex, France). Having a variable cross-section as well as variable pitch along with the file with a non-cutting tip. The file comes in sizes 25 and 0.06 taper, made from conventional NiTi alloy having an asymmetrical cross-sectional design. (8)

One Curve (Micro Mega) file. The triangular cross-section provides a better cleaning ability. The instrument is manufactured from a heat-treated NiTi called C-Wire working in continuous rotational motion. It is a single file that comes in sizes 25 and 0.06 taper. (9)
There was no research done on the Fanta AF F One file system regarding its cleaning ability and the amount of apically extruded debris.

So, the purpose of this study was to compare the amount of apically extruded debris and the cleaning ability of three NiTi single-file systems.
Null Hypothesis: there is no difference between the three rotary NiTi file systems regarding the cleaning ability and the apical extrusion of debris.

Materials and Methods:

Selection of Samples:

Forty-five human sound permanent lower anterior teeth with mature apices were used in this study, collected from an outpatient clinic at the Oral and Maxillofacial Department, Faculty of Dentistry, Ain shams University. Any soft and hard calcareous remnants were removed using an Ultrasonic scaler and were immersed in 5.25% sodium hypochlorite (NaOCl) for 10 minutes, to remove any soft tissue debris that remained on the root surfaces. Then the prepared teeth were stored in distilled water until use.

Sample preparation:

Standardized coronal access cavity preparation was accomplished using tapered round diamond stone and a tapered stone mounted in a high-speed handpiece with an electric controlled torque endodontic motor. Then glide path using the #10 k file was created with a gentle watch-winding motion to get a patent pathway for rotary files on the previously estimated working length. The working length for each sample was estimated by inserting size #10 k file until it appeared at the apex of the root, this length was measured and 1 mm was subtracted to

obtain the working length of the tooth. Then the incisal edges of the samples were flattened to establish an easily reproducible reference point and to standardize the length to be 16 mm.

Canal diameter was standardized by selecting roots fitting initial apical file #15 k file.

Pre-weighting to each Eppendorf tube was done using a digital microbalance with a precision of 0.0001 grams to measure the weight of each tube. Three consecutive readings were taken to calculate the mean reading for each Eppendorf tube.

Sample Classification and Instrumentation:

After the preparation of the teeth, the Eppendorf cap was cut (was taken from another Eppendorf tube) and it was modified by cutting holes corresponding to the sample being tested.

Then each sample was inserted tightly into the hole of the modified cap up to the level of the cement-enamel junction. Furthermore, before measuring a 30-gauge needle was inserted alongside the sample inside the hole to equalize the pressure inside and outside the Eppendorf tube. The discrepancies between the sample, needle, and hole were sealed using a composite resin material. Then, the modified cap with the tooth and the needle was inserted into the Eppendorf tube, so that the root hung in the Eppendorf tube without touching the tube. Furthermore, the Eppendorf tube with the attached tooth was fitted into a larger dark glass vial to prevent the operator from touching the tube directly and also to keep the root apex remained hidden during instrumentation to eliminate bias. Then the teeth were instrumented to the working length mentioned before and they were irrigated with the irrigation solution.

Group 1 (Fanta AF F One): fifteen roots were prepared using Fanta AF F One. NiTi Master Apical File size 25/0.06 was used in pecking motion until the working length was reached. As recommended by the manufacturer, the instrument was used at a rotational speed of 500 rpm and a torque of 2.6 Ncm.

Group 2 (OneShape): fifteen roots were prepared using OneShape. NiTi Master Apical File size 25/0.06 was used in pecking motion until the working length was reached. As recommended by the manufacturer, the instrument was used in a continuous rotary motion at a speed of 400 rpm and a torque of 4 Ncm.

Group 3 (OneCurve): fifteen roots were prepared using OneCurve. NiTi Master Apical File size 25/0.06 was used in direct downward movement in three waves till reaching the working length. As recommended by the manufacturer, the instrument was used at a rotational speed of 350 rpm and a torque of 2.5 Ncm.

Irrigation Protocol for all groups:

All irrigation procedures were accomplished using a gauge 30 needle (Fanta Dental) mounted in a leur-lock plastic syringe (Ameco, Egypt) using 2.25% sodium hypochlorite (NaOCl). The total amount of irrigation was 5 ml for all groups delivered thought out the preparation procedure of the canal.

Methods of evaluation:

Debris Collection:

Pre-weighting of each Eppendorf tube was done using a digital microbalance (Sartorius Corporation, Göttingen, Germany) with a precision of 0.0001 grams to measure the weight of each tube. Three consecutive readings were taken to calculate the mean reading for each Eppendorf tube. After the preparation of the teeth, the Eppendorf cap was cut (was taken from another Eppendorf tube) and it was modified by cutting holes corresponding to the sample being tested.

Then each sample was inserted tightly into the hole of the modified cap up

to the level of the cement-enamel junction. Furthermore, before measuring a 30-gauge needle was inserted alongside the sample inside the hole to equalize the pressure inside and outside the Eppendorf tube. The discrepancies between the sample, needle, and hole were sealed using a composite resin material. Then, the modified cap with the tooth and the needle was inserted into the Eppendorf tube, so that the root hung in the Eppendorf tube without touching the tube. Furthermore, the Eppendorf tube with the attached tooth was fitted into a larger dark glass vial to prevent the operator from touching the tube directly and to eliminate bias.

After instrumentation, the modified cap with the attached sample and the needle was partially removed from the Eppendorf tube and the root apex was lightly flushed with 1 ml of the same irrigant and the return were collected in the Eppendorf tube to ensure any attached debris on the root surface were collected.

The collection of apically extruded debris was done according to Myers & Montgomery method.(10)
Following that, the Eppendorf tubes were removed from the glass vial and stored in the incubator at 37 degrees Celsius for 15 days to allow the NaOCl to desiccate.
Three consecutive readings were taken for each tube to calculate the mean value. Then the Initial weight was subtracted from the final weight of the extruded debris.
Weight of extruded debris = final weight – initial weight
Then mean value was calculated.

Cleaning Ability:

All teeth were longitudinally sectioned according to Caron et al. (11) By performing buccal and lingual grooves using a diamond cutting disc. The NiTi rotary master apical file (size 25, 0.06 taper) was inserted into the prepared canal. The root was then ground until the file appeared. Buccal and lingual grooves were performed using the disc without introducing the debris inside the canal then the roots were split into two halves using dental chisels to avoid intrusion of dentin debris during sectioning by the disc.

The cleaning efficiency was evaluated in terms of the amount of dentin debris remnants on the inner canal wall. The roots were divided into three equal segments (coronal, middle, and apical). The longitudinal section was photographed using the Digital microscope. Three images were taken with a magnification of 200 X for each segment (coronal, middle, and apical) to allow a complete view of the segment to determine canal cleanliness, and one image with a magnification of 50X to allow an overview of the whole canal. A digital camera was used.

The images were analyzed using image processing software Image J (National Institutes of health, v1.39a) to get the amount of debris in each segment. The percentage of debris was calculated for each third and all over the canal.
Percentage of debris = Total surface area of the debris / Total surface area of the canal
Statistical analysis was performed using the SPSS program of windows 19.0(SPSS, Illinois, USA).

Statistical Analysis of the data:

Numerical data were explored for normality by checking the data distribution, calculating the mean values, and using the Shapiro-Wilk test. Data showed parametric distribution so; it was represented by mean and standard deviation (SD) values. Intergroup comparisons and intragroup comparisons were done using one-way ANOVA followed by Tukey's post hoc test. The significance level was set at $P \leq 0.05$ within all tests. Statistical analysis was performed with IBM SPSS (IBM Corporation, NY, USA) statistics version 26 for windows.

Results:

Extrusion of debris:

Data were collected, tabulated, statistically analyzed, and shown in table (1).

The Mean (SD) of the extruded debris for the Fanta AF F One file group was (0.0142 ±0.00438) grams, the OneShape file group was (0.0094 ±0.00273) grams while the OneCurve file group was (0.0135 ±0.00248) grams.

OneShape file group was significantly lower in the mean value of the apically extruded debris compared to the mean values of the Fanta AF F filegroup and OneCurve file group where there was no significant difference between them.

Table (1): Mean±Standard deviation of the apically extruded debris.

Groups	Mean±St
Fanta AF F One	0.0142 ±0.00438 [a]
OneShape	0.0094 ±0.00273 [b]
OneCurve	0.0135 ±0.00248 [a]
P-Value	0.001

Means that do not share the same letter are significantly different.

Cleaning Ability:

Data were collected, tabulated, statistically analyzed and shown in tables (2,3) and figures (1-3)

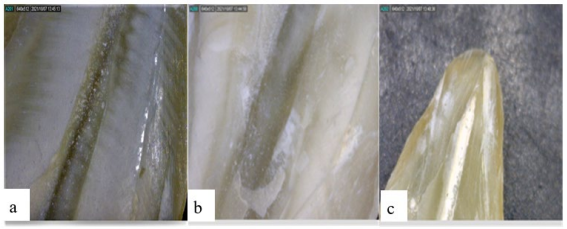

Figure (1): captured images were taken by a digital microscope at 200X viewing each segment of the canal instrumented by the Fanta AF F group. a: image showing the coronal segment, b: image showing the middle segment, c: image showing the apical segment.

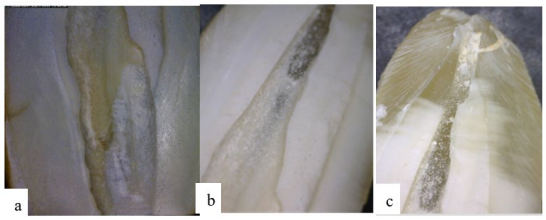

Figure (2): captured images were taken by a digital microscope at 200X viewing each segment of the canal instrumented by the OneShape file. a: image showing the coronal segment, b: image showing the middle segment, c: image showing the apical segment.

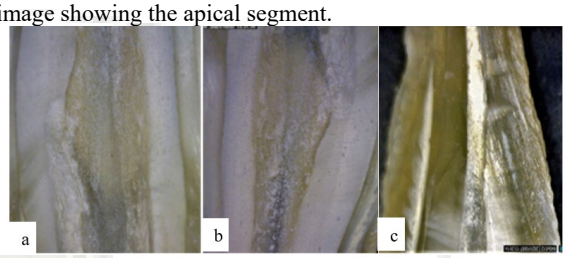

Figure (3): captured images were taken by a digital microscope at 200X viewing each segment of the canal instrumented by the OneCurve file. a: image showing the coronal segment, b: image showing the middle segment, c: image showing the apical segment.

I. Effect of file type on canal cleanliness: (area)

a) Apical:

Fanta AF F One group (26.14 ± 1.321) has a significantly lower mean value compared to the mean values of the OneShape (50.48±1.211) and OneCurve group (50.48±1.184) while there was no significant difference between them.

b) Middle:

There was no significant difference in the values of remaining debris in the three groups. The highest values were found in the group cleaned with OneCurve (29.56±1.440) followed by the OneShape group (28.56 ±1.442), while the lowest values were found in the group cleaned with Fanta AF F (21.61 ±1.268).

c) Coronal:

There was no significant difference in the values of remaining debris in the three groups. The highest values were found in the group cleaned with OneCurve (29.56±1.440) followed by the OneShape group (28.56±1.442), while the lowest values were

found in the group cleaned with Fanta AF F (21.61±1.268).

II. Effect of region on canal cleanliness:

a) Fanta AF F One:

There was no significant difference in the percentage of the remaining debris measured at different sections. The highest value was measured in the apical section (26.14 ± 1.321) while the lowest value was measured in the coronal section (20.22±8.648).

b) OneShape:

There was a significant difference in the percentage of the remaining debris between the three sections. The apical section (50.48±1.211) showed a higher mean value compared to the middle (28.56±1.442) and the coronal sections (26.91±1.470).

c) OneCurve:

There was a significant difference in the percentage of the remaining debris between the three sections. The apical section (50.48±1.184) showed a higher mean value compared to the middle section (29.56±1.440) and the coronal section (27.93±1.570) while there was no significant difference between them.

Table (2): Mean± Standard deviation of the percentage of the remaining debris showing the effect of file type and region on canal cleanliness.

Section	Fanta AF F One	OneShape	OneCurve	P-Value
	Mean ± SD	Mean± SD	Mean± SD	
Apical	26.14 ±1.321 $^{a\,A}$	50.48 ±1.211 $^{b\,A}$	50.48 ±1.184 $^{b\,A}$	>0.001
Middle	21.61 ±1.268 $^{a\,A}$	28.56 ±1.442 $^{a\,B}$	29.56 ±1.440 $^{a\,B}$	0.208
Coronal	20.22 ±8.648 $^{a\,A}$	26.91 ±1.470 $^{a\,B}$	27.93 ±1.570 $^{a\,B}$	0.239
P-Value	0.358	>0.001	>0.001	

Means that do not share same small letter are significantly different within the same row. Means that do not share same capital letter are significantly different within the same column. P<0.05 is considered significant.

d) Overall:

The Mean (SD) of the Fanta AF F One group was (22.66 ±1.170), the OneShape group was (33.97 ±1.720) while the OneCurve group was (35.99±1.723).

No significant difference in the values of remaining debris was found in the OneShape and the OneCurve groups. Fanta AF F One (22.66 ±1.170) was significantly lower than OneShape (33.97±1.720) and OneCurve (35.99±1.723).

Table (3): Mean± Standard deviation of the overall remaining debris showing the effect of file type on canal cleanliness.

Section	Fanta AF F One	OneShape	OneCurve	P-Value
	Mean± SD	Mean± SD	Mean± SD	
Overall	22.66 ±1.170 ^{a}	33.97 ±1.720 ^{b}	35.99 ±1.723 ^{b}	>0.001

Means that do not share the same letter are significantly different.

Discussion:

Leaving the root canal system free from any vital and/or necrotic pulp tissue, infected dentine, and dentine debris as well as the microorganisms is of prime importance during instrumentation of the root canal. (12)

Single-use and single-file systems allow for easier treatment of the root canal by lowering the number of files used as well as decreasing the stresses and procedural errors. (13)

Single-use and single-file NiTi systems are available as OneShape (OS; Micro Méga, Besançon, France) is a single file used in rotational motion. (14)

Also, OneCurve (OC) (Micro-Mega SA Besancon Cedex, France) is a single file system. It is a nickel-titanium file made from C wire, for better flexibility and fracture resistance. (15)

The selection of Fanta AF F One was due to the fact it was a new file presented in the market and no research was done to know the cleaning ability as well as its extrusion of debris apically.

So this study aimed to evaluate the cleaning ability and the amount of extruded debris using three NiTi single files.

Human extracted teeth were selected to mimic the clinical situation. (5) Sample size of 45 teeth was used in this study based on the power analysis done on the data obtained by a previous study by Burklein and Schafer. (11) Moreover, Single rooted teeth with single root canals and curvature between 00-100 were used for standardization and to avoid any complications associated with curved multi-rooted teeth. (12,13)

The incisal edges of the samples were flattened to establish a reference point at 16 mm in length. (13)To avoid any inaccuracy during files comparison, the root canal preparation ended at 25/0.06 for all the samples. (14) As it is the most commonly used size and taper.

The irrigant of choice during mechanical procedures was 2.5% Sodium hypochlorite having an antibacterial and low toxicity effect on the tissues and lubricant action. (15,16) And to see the action of the three file systems only on the canal. (17,18)

Regarding the incubation of the samples, incubation of the empty Eppendorf tubes was done at 370c for 15 days. (12,19)
The experimental model used in this study to assess the amount of apically extruded debris was the one described by Myers and Montgomery. (5) When weighing the samples, a microbalance with an accuracy of 10-4 g was used.

In this Study, Debris accumulation has been assessed using a digital microscope. The greatest advantage of using it is the complete picture of the canal rather than seeing part for SEM assessment, which might not represent the overall debris distribution.

The quantification using computerized software has better accuracy, reliability, and non-subjective evaluation compared to the traditional scoring system. (20)

Images were analyzed by Image J software as the method used in previous reports. (14)

The Null hypothesis was rejected as there was a significant difference between the three file rotary NiTi systems regarding their cleaning ability and the amount of apically extruded debris.

Regarding the cleaning ability results, none of the tested rotary instruments was able to clean the dentinal wall at any level of the root canal.

These results came in agreement with other studies which show that no instrument can completely clean the dentinal walls. (16,17)

The best results of cleaning ability were found in the coronal thirds followed by the middle while the least results of cleaning ability were found in the apical thirds of all the canals tested. It may be due to the complex root canal apical anatomy and the difficulty for the irrigant to reach the apical section. (18,19,20) It could also be due to the torque control handpiece wouldn't be able to adequately clean the apical. (21)

Although we used files with a 25 size file with 0.06 taper, the irrigant penetration wasn't enough to completely clean the apical third. This is in agreement with previous studies done. (16,17,22)
Apical vapor lock also results in gas entrapment in the apical portion which prevents the instrument from reaching such area. (23)

Regarding the results of the Fanta AF F One file in the present study, it might be due to the flat side-cut design offering a better space for the irrigant to be placed during root canal preparation. The file will not touch all the canal walls at the same time which results

in superior apical cleaning ability also in relation to the other files tested.

The difference in the results between the three-thirds of the root canal may be due to the difference in cross-section across the file length. Fanta AF F One File has an S-Shaped flat-sided cross-section but after a cut, the section of each point is different. (7)

The progressively changing tapers along the lengths of the cutting blades lower the amount of contact between the file and the dentinal surface which may lead to less debris removal in the apical area. In addition, the middle and apical thirds demonstrate higher debris scores when compared to the coronal third as the irrigants do not penetrate these zones which have a narrow diameter than the coronal thirds.

Regarding the OneShape file results in the present study, The OneShape file progressively changes from an asymmetrical three cutting edge design to two cutting edges which lead to less amount residual debris coronally.

The low tendency of the presence of apical debris of the OneShape may be due to increased chip space, transporting the debris coronally, and also the presence of the variable pitch and helix angle.

The results came in accordance with Koçak et al.(24) Also Al-Dulaimi et al.(20) found that no instrument could totally remove all the debris from the canal walls.

Regarding the results of the OneCurve file in the present study: It has an asymmetrical cross-section with a variable pitch between each cutting edge, which limits its screwing effect.

OneCurve file has a triangular cross-section with the conversions of the cutting edges from three at the apical part into two at the middle and the coronal part helps to transport the debris coronally. (25)This is in agreement with a study done to compare italic S-shaped files (MTwo and Reciproc) with a triangular-shaped file (ProTaper) which showed that S-shaped files had better cleaning results. (26)

Regarding Extrusion of Debris results, the present study showed that all the extrusion of debris happened with all the tested file systems. That was in acceptance with the studies reviling that no method can totally stop the apically extruded debris. (23) The Extrusion of debris may be clarified by the small variations in the cross-sectional design of the file systems.

Regarding Fanta AF F One file: The vertical blades can sweep the debris from flutes to the relieving area, having a flat-sided design. Providing more cutting efficiency, so that the debris can be transported to the relief areas via vertical blades, and then coronally. So more debris removal during instrumentation and less debris accumulation around the file, and a better cleaning ability are achieved.

Regarding the OneShape file: the design of the OneShape file starts with three cutting edges at the apical part then it turns to two cutting edges at the middle and the coronal part, facilitating the upward transportation of the debris coronally. (27) The variable helix angle also acts to prevent the downward placement of the debris. (28)

Regarding OneCurve File: the presence of two cutting edges in the middle section of the file makes the file asymmetrical. In addition to a non-cutting safety tip that provides an effective apical progression to prevent any blockage which results in instrument separation, providing cantering ability in the apical third and the upward debris transportation coronally. (29)

Conclusion:

Under the condition of this study, none of the tested files showed complete cleaning of the root canal. However, Fanta AF F One file had better results in cleaning compared to the other two files which had nearly the same results.

References:

1. Kumar A, Tamanna S, Iftekhar H. Intracanal medicaments – Their use in modern endodontics: A narrative review. J Oral Res Rev [serial online] 2019 [cited 2022 Mar 27];11:94-9.
2. Tanalp, J.; Güngör, T. (2014). Apical extrusion of debris: a literature review of an inherent occurrence during root canal treatment. International Endodontic Journal, 47(3), 211–221. doi:10.1111/iej.12137.
3. Haapasalo M, Endal U, Zandi H, Coil JM. Eradication of endodontic infection by instrumentation and irrigation solutions. Endodontic Topics. 2005; 10(1):77–102.
4. Arvaniti IS, Khabbaz MG. Influence of root canal taper on its cleanliness: a scanning electron microscopic study. Jornal of Endodontics. 2011; 37(6):871–874.
5. Peters OA, Paque F. Current developments in rotary root canal instrument technology and clinical use: a review. Quintessence International. 2010; 41(6):479–488.
6. Shen Y, Zhou HM, Zheng YF, Peng B, Haapasalo M. Current challenges and concepts of the thermomechanical treatment of nickel-titanium instruments. Jornal of Endodontics. 2013; 39(2):163–172.
7. Tomer AK, Mangat P, Mullick S, Dubey S, Chauhan P, Kumari A, Rana S, Vaidya S. "Quantitative evaluation of apically extruded debris of different single file systems: Wave one gold, one shape, F360, and reciproc: An in vitro Study." International Jornal of Care and Research. 2017; 5: 1-3.
8. Christian R. Gernhardt. One Shape- a single file NiTi system for root canal instrumentation used in continuous rotation.ENDO (Lond Engl) 2013;7(3):211-216.
9. Saricam E, Kayaoglu G. Comparison of OneShape, 2Shape and One Curve endodontic instruments for debris and irrigant extrusion. Dent Med Probl. 2020;57(3):255–259. doi:10.17219/dmp/119771.
10. Myers GL, Montgomery S. A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. Journal of endodontics. 1991; 17(6):275-9.
11. Caron G, Nham K, Bronnec F. Effectiveness of different final irrigant activation protocols on smear layer removal in curved canals. J Endod 2010; 36: 1361–1366.
12. Hinrichs RE, Walker WA, Schindler WG. A comparison of amounts of apically extruded debris using handpiece-driven nickel-titanium instrument systems. Journal of endodontics. 1998; 24(2):102-6.
13. Fayyad DM, Sabet NE, El-Hafiz ES. Computed tomographic evaluation of the apical shaping ability of Hero Shaper and Revo-S. Endodontic Practice Today. 2012; 6(2).
14. Saini M, Kumari M, Taneja S. Comparative evaluation of the efficacy of three different irrigation devices in removal of debris from root canal at two different levels: An in vitro study. Journal of conservative dentistry: JCD. 2013; 16(6):509.
15. Moorer WR, Wesselink PR. Factors promoting the tissue dissolving capability of sodium hypochlorite. International Endodontic Journal. 1982; 15(4):187-96.
16. Ramachandran SS, Koshy CR, Narayanan S, Venkatesh B, Sundaran RM, Karumaran CS. Evaluation of Cleaning Efficacy of S-One and WaveOne File Systems Using Scanning Electron Microscopy Analysis: An In Vitro Study. The Journal of Contemporary Dental Practice. 2020; 21(8):841-5.
17. Foschi F, Nucci C, Montebugnoli L, Marchionni S, Breschi L, Malagnino VA, Prati C. SEM evaluation of canal wall dentine following use of Mtwo and ProTaper NiTi rotary instruments. International Endodontic Journal. 2004; 37(12):832-9.
18. Mandke L, Padhye L. Apical vapour lock effect in endodontics–a review. International Journal of Contemporary Medical Research. 2018; 5(2): 14-7.
19. Gambarini G, Miccoli G, Seracchiani M, Khrenova T, Donfrancesco O, D'Angelo M, Galli M, Di Nardo D, Testarelli L. Role of the flat-designed surface in improving the cyclic fatigue resistance of endodontic NiTi rotary instruments. Materials. 2019; 12(16):2523.

20. Al-Dulaimi LA, Al-Gharrawi HA. Evaluation of the cleaning effciency of Oneshape, WaveOne, Reciproc and ProTaper systems using digital image morphometric analysis (an in vitro study). Iraqi Association for Oral Research. 2017; 4(2):169-83.
21. Al-Khafaji HA, Al-Huwaizi HF. Cleaning Efficiency of Root Canals using Different Rotary Instrumentation Systems: A Comparative In vitro Study. International Journal of Medical Research & Health Sciences. 2019;8(1):89-93.
22. Herisa M, Maharani N, Meidyawati R, Artiningsih DA, Nazar K. Smear layer reduction in root canals prepared with triangular and rectangular files as evaluated by scanning electron microscopy. International Journal of Applied Pharmaceutics. 2020; 12(2):27-30.
23. Tomer AK, Mangat P, Mullick S, Dubey S, Chauhan P, Kumari A, Rana S, Vaidya S. "Quantitative evaluation of apically extruded debris of different single file systems: Wave one gold, one shape, F360, and reciproc: An in vitro Study." International Jornal of Care and Research. 2017; 5: 1-3.
24. Koçak MM, Koçak S, Saglam BC, Türker SA. Smear Layer and Debris Removal Following use of WaveOne and OneShape Single-File Systems: SEM Study. International Journal of Experimental Dental Science. 2014; 3(2):77.
25. Girgis DY, Sadek HS, Roshdy NN. Comparative Assessment of the Shaping andCleaning Abilities of M-Pro and Revo-S versus ProTaper Next Rotary Ni-Ti Systems(An In Vitro study). Advanced Dental Journal.2020; 4 (2): 162-176.
26. Herisa M, Maharani N, Meidyawati R, Artiningsih DA, Nazar K. Smear layer reduction in root canals prepared with triangular and rectangular files as evaluated by scanning electron microscopy. International Journal of Applied Pharmaceutics. 2020; 12(2):27-30.
27. Uzunoglu E, Sevinc AT, Melahat G. "Effects of different rotary files combined with different irrigation needles on apically extruded debris." Brazilian dental journal. 2015; 26: 347-350.
28. Ferraz CC, Gomes NV, Gomes BP, Zaia AA, Teixeira FB, Souza-Filho FJ. Apical extrusion of debris and irrigants using two hand and three engine-driven instrumentation techniques. International endodontic journal. 2001; 34(5):354-8.
29. Kumari H, Prasad DS, Kumar SC, Vamsee KN. "Comparative Evaluation of Apical Extrusion of Debris During Root Canal Preparation Using two Rotary Systems -An In vitro Study". Acta Scientific Dental Sciences. 2019; 3 (12): 139-143.