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Comparative evaluation of apically extruded debris during root canal instrumentation using different file systems: An In Vitro Study

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ABSTRACT

Objective- To compare the amount of debris extruded by Hand K file, Neoendo Flex, Protaper Next, XP Endo Shaper files.

Materials and methods- 100 human extracted mandibular premolar with single canal similar length of 15mm were grouped as hand-K File(n=25), Neo Endo Flex(n=25), Protaper Next(n=25) and XP endo Shaper(n=25). Separate Eppendorf tube were used for each sample to collect debris. Pre-weight of effendorf tube were taken. After instrumentation, eppendorf tubes were incubated at 68^0 C for 5 days. Post-weight of Eppendorf tubes were taken again . The weight of debris was calculated by subtracting pre-weight from post-weight.

Statistical Analysis used- results obtained were tabulated and statistical analysis was performed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL). Apical extrusion of the four different root canal preparation systems was performed by using One-way ANOVA analysis. A Post-hoc Boneferroni test was used for multiple comparisons. The level of significance was set at $P<0.05$.

Results- Maximum amount of apical debris extrusion was seen in Group I (K-file) followed by Group II (Neoendo Flex), Group IV (XP), Group III (Protaper Next).

Conclusion- All the instrument used in this study showed apical debris extrusion.

INTRODUCTION

The main aim of endodontic therapy is complete debridement of the root canal system using endodontic files and irrigating solutions to obtain a three-dimensional seal.[1] The objective of biomechanical preparation is to remove infected soft and hard tissues, to facilitate the

delivery of root canal irrigants and medicaments to the apical area of the root canal system, and to preserve the integrity of the root canal structure. This objective can be achieved by cleaning and shaping the root canal from a reference point (ie: a point on the sound tooth structure) to slightly short (0.5-1 mm) of the canal terminus i.e. the apical foramen.[2]

For completing the instrumentation procedure, there is a range of hand instrument preparation and manipulation techniques to mechanically remove canal contents and infected dentine, e.g., crown-down, step-back, and hybrid techniques, using reaming, filing, watch-winding, circumferential filing, and the balanced force manipulations. K type hand instruments are most commonly used during root canal preparation procedures.[2] Hand files are recommended for initial canal negotiation and preparation prior to the use of rotary files to further enlarge the canal.[3] If rotary instrumentation techniques are used, it is also recommended that hand files should be used in between rotary file applications to help prevent any blockage of the canal system with debris created by a rotary file system.[2]

During cleaning and shaping of the root canal system, dentine, pulp tissue debris, microorganisms, and irrigating solutions can extrude into the peri-radicular tissues.[1] Complication such as inflammation, infection, postoperative pain, and flare-up is associated with the extrusion of intracanal debris which can possibly delay the healing process.[4]

The amount of debris extruded differs with preparation technique because of various available designs and kinematics of the endodontic file systems and irrigation devices available in the market.[5] The choice of root canal preparation technique is dictated by the design and shape of the instrument.[6]

Chapman et al. first documented extrusion of infective material from the root canal system during instrumentation.[7] The incidence of pain and edema due to an inflammatory response is associated with extrusion of debris ranging between 1.4% and 16%.[8] According to Vande Visse and Brilliant, biomechanical preparation with an irrigant extruded debris apically, while instrumentation without an irrigant did not produce collectible debris.[9]

Reducing the amount of extruded debris during endodontic treatment is proposed as a method of preventing inter-appointment and post-treatment pain and flare-up.[10]

Advancements in rotary instruments have facilitated and fastened the root canal procedures and resulted in less iatrogenic error.[11]

In recent times, a new root canal instrumentation system, ProTaper Next (Dentsply Maillefer, Ballaigues, Switzerland), was introduced. This system is made with M-wire nickel-titanium alloy. The advantages of this M-wire alloy are increased flexibility and greater resistance to cyclic fatigue of the instruments. The ProTaper Next instruments are designed with variable tapers and an off-centered rectangular cross section. This design makes it possible to completely prepare root canals using fewer instruments. Moreover, an offset design maximizes the augering of debris out of the canal, compared with a file with a centered mass and axis of rotation.[12] This system is used with continuous rotation, and have a snake like swaggering movement.[13]

Neoendo Flex (Orikam Health-care India Pvt. Ltd) utilizes a proprietary heat treatment which provides it a unique flexibility.[14] These have alternating cutting edges which have two functions: (i) to eliminate screwing and blocking in continuous rotation and (ii) to reduce the working torque. Its triangular cross- section makes a three-point contact with the dentinal wall during its rotation in the canal which scrape the dentin instead of cutting, hence the debris is pushed more coronally.[15]

Contemporary advancements in NiTi file production contributed to the evolvement of single NiTi systems, in which the mechanical preparation of the root canal is completed using one file. The use of single NiTi files is considered beneficial as it reduces the preparation time, cost, and risk of cross-contamination.[16]

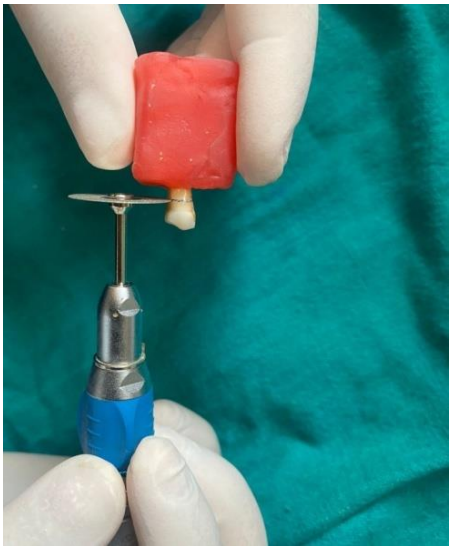
XP-Eno Shaper (XPS; FKG Dentaire SA, La Chaux-de- Fonds, Switzerland) is a single-file system that is used in a continuous rotary movement. This file is snake shaped with a triangular cross-section. It has an apical diameter of 0.27 mm and a fixed taper of 0.01. The MaxWire technology involved in the production of this file provides it super-elasticity and shape memory properties.[17] Upon exposure to body temperature (35°C), the martensite phase of the file converts to the austenite phase, and the taper increases to 0.04 according to the molecular memory of the A phase.[18]

The file presents a six-blade tip, the Booster tip, that allows it to start shaping the canal after a manual glide path of at least size ISO 15 and to gradually increase the apical size to achieve an ISO size 30. XPS achieves a final apical preparation of at least 30/0.04.[19] XPS was found to have superior cyclic fatigue with the off-centered design which preserves the dentine and produce minimum debris apically.[20]

Therefore, this study aims to compare the amount of debris extruded apically by different instrumentation technique: Hand K file (Mani), Neoendo Flex, Protaper Next, XP Endo Shaper Files.

MATERIALS AND METHODS

For this study 100 extracted human mandibular premolars were collected. Radiographs in buccolingual and mesiodistal direction were taken. Teeth with single canal, single foramen and mature foramen were included and teeth with calcified canal or atypical canal morphology were excluded. Samples were decoronated to a stranded lengeth of 15mm. Hundred teeth were randomly divided into four (n=25) experimental groups.For debris collection separate preweighed eppendorf tubes were used for each specimen. Teeth were mounted in the cap and a 27 G- needle was placed through the cap to balance the internal and external air pressures. Using a #10 K file, apical patency was checked. #15 K file was inserted into the root canal till the tip of files was seen at the root apex, stopper was adjusted and the length of the file was measured with the help of endodontic gauge. Working length was 1mm short of this measured length.



Decoronation of Tooth

Setup for debris Collection (Eppendorf tube with mounted tooth and 27-G needle)

INSTRUMENTATION

Group I (n=25): HAND FILE: K-File

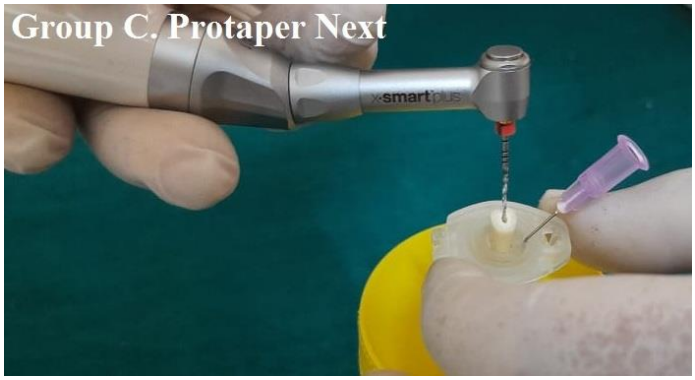
Apical preparation was done upto size 30. (Sequence: #15, #20, #25, #30). After each filing, the canal was irrigated with 1ml of distilled water.

Group II (n=25): NEOENDO FLEX:

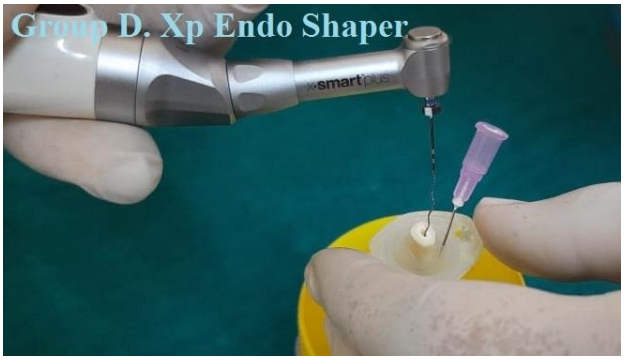
Preparation was done using Neoendo Flex files upto size 30 and taper 0.06 at a speed of 350 rpm and torque of 1.5 Ncm. (Sequence: 17.04, 20.04, 25.04, 30.04, 30.06). The canal was irrigated with 1ml of distilled water after each instrumentation.

Group III (n=25): PROTAPER NEXT:

Preparation was done using the ProTaper Next system upto X3 (30.07) with 300 rpm torque 2 Ncm. (Sequence: **X1**-17.04, **X2**-25.06, **X3**-30.07). The canal was irrigated with 1ml of distilled water after each instrumentation.



Group IV (n=25): XP ENDO SHAPER:
XP-Endo Shaper file #30.04 was used with the same endodontic motor, with continuous rotation at 800 rpm and 1 Ncm torque values. A total of 1ml distilled water was then used as a final rinse.



After preparation, the root canal was irrigated with 1 ml distilled water. The debris adhering to the apical part of the roots was washed with 1 ml distilled water to collect in the eppendorf tube. After collecting the extruded debris, the eppendorf tubes were removed from the experimental model and placed in incubator at 68^{o} C for 5 days to get the dry debris. The tubes were weighed after evaporation to calculate the amount of extruded debris. The consecutive measurements were obtained, and recorded for each tube. The weight of the dry debris was calculated by subtracting the pre-weight from the post-weight.
The readings thus obtained were recorded and subjected to statistical analysis.

RESULTS
The results obtained were tabulated and statistical analysis was performed using the statistical package SPSS 26.0 (SPSS Inc., Chicago, IL).Apical extrusion of the four different root canal preparation systems was performed by using One-way ANOVA analysis (table 1). Comparative analysis for samples, mean values and standard deviation was calculated (table-2). A Post-hoc Boneferroni test was used for multiple comparisons. The level of significance was set at $P<0.05$.. Maximum amount of apical debris extrusion was seen in Group I (K-file) followed by Group II (Neoendo Flex), Group IV (XP), Group III (Protaper Next). When Group I (Hand K- file) was compared to Group IV (XP) and Group III (Protaper Next) significant difference was found. When Group I (Hand K- file) was compared with Group II (Neoendo flex) no significant different was found.

TABLE 1
ANOVA

Hand file					
	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	.010	3	.003	9.026	**.000**
Within Groups	.037	96	.000		
Total	.048	99			

TABLE 2

COMPARISION OF APICALLY EXTRUDED DEBRIS USING DIFFERENT ROOT CANAL FILE SYSTEM

Descriptives

	N	**Mean**	**Std. Deviation**	**Std. Error**	**95% Confidence Interval for Mean**		**Minimum**	**Maximum**
					Lower Bound	**Upper Bound**		
Hand File	25	.0400	.02913	.00582	.0279	.0520	.0007	.0982
XP	25	.0201	.01418	.00283	.0142	.0260	.0000	.0404
Protaper Next	25	.0164	.00640	.00128	.0137	.0190	.0000	.0253
Neoendo Flex	25	.0368	.02133	.00426	.0280	.0457	.0034	.0972
Total	100	.0283	.02192	.00219	.0240	.0327	.0000	.0982

TABLE 3

POST HOC MULTIPLE COMPARISON TEST OF APICAL EXTRUDED DEBRIS FOR DIFFERENT FILE SYSTEM USED IN THE STUDY

Multiple Comparisons

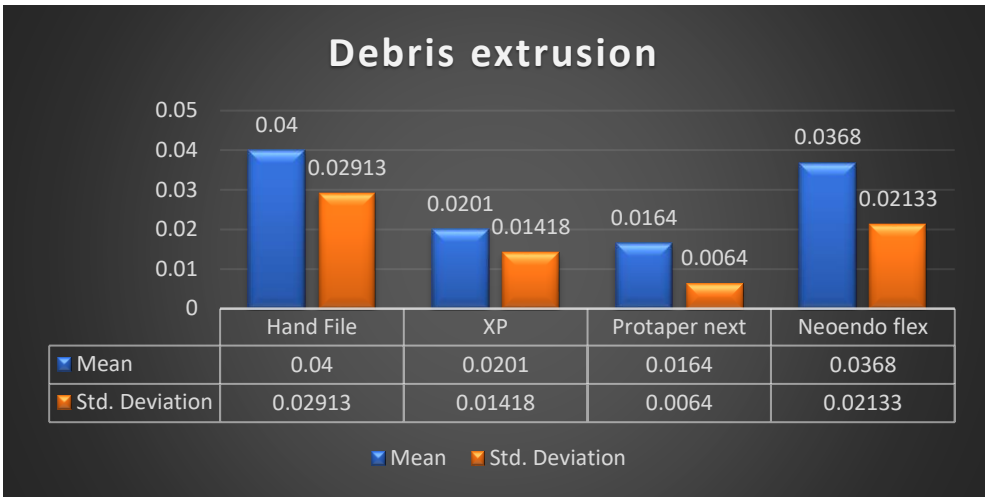
Dependent Variable: Hand file

Bonferroni

(I) VAR00001	**(J) VAR00001**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Hand File	XP	.01987*	.0055613	**.003**	.004890	.034854
	Protaper Next	.023600	.0055613	**.000**	.008618	.038582
	Neoendo Flex	.003128	.0055613	1.000	-.011854	.018110
XP	Hand File	-.01987*	.0055613	**.003**	-.034854	-.004890
	Protaper Next	.003728	.0055613	1.000	-.011254	.018710
	Neoendo Flex	-.0167440*	.0055613	**.020**	-.031726	-.001762
Protaper Next	Hand File	-.0236000*	.0055613	**.000**	-.038582	-.008618
	XP	-.0037280	.0055613	1.000	-.018710	.011254
	Neoendo Flex	-.0204720*	.0055613	**.002**	-.035454	-.005490
Neoendo Flex	Hand File	-.0031280	.0055613	1.000	-.018110	.011854
	XP	.0167440*	.0055613	**.020**	.001762	.031726
	Protaper Next	.0204720*	.0055613	**.002**	.005490	.035454

*. The mean difference is significant at the 0.05 level.

GRAPHICAL REPRESENTATION OF DEBRIS EXTRUDED



DISCUSSION

Postoperative pain and swelling are frequently associated with instrumentation procedures because of host immune response to extruded irrigating solutions, microorganisms, over-instrumentation, and foreign body reactions to root canal filling materials. Cleaning and shaping of the root canals may trigger an inflammatory reaction by forcing the contents of the root canals such as dentin particles, necrotic pulp tissues, or microorganisms to the periapical region.[21] In addition, the inflammatory reactions may be exacerbated by an increase in the amount of debris extruded from the apex.[22]

The apical extrusion of bacteria and/or debris usually occurs during every root canal preparation technique; nonetheless, the quantity of extruded material differs from each instrumentation technique and file system used. And, the debris or irritants which have extruded apically may result in recurrence of infection and pain after the operative procedure. Several conditions, such as design and speed of instruments, type of irrigants used etc, contribute to the apical extrusion.[23]

Formerly, hand files made up of stainless steel were widely used for cleaning and shaping. Due to failures associated with iatrogenic causes like canal transportation, ledging, apical extrusion, zipping, and blockage resulting from these files, there has been an extensive quest for advanced materials, special techniques, and innovative instruments which help to obtain a clean sterile canal without debris and to reduce or avoid apical extrusion. Every system has its own merits and demerits.[24]

Diverse rotary instrumentation systems have different properties and shapes that affect the consequence of their actions, and apical extrusion is one such consequence of using rotary instruments. The factors that contribute to apical extrusion include size and type of files, instrumentation techniques, and irrigant solution[25] and the amount of debris extrusion is affected by factors such as the kinematics, preparation technique, design and the number of instruments used in each system. However, bacterial content and antigenic characteristics of extruded material might be more crucial than the total amount of material extruded in terms of initiation of periapical response.[26]

The virulence and volume of the microorganisms are considered key factors for the degree of acute infection or flare-ups. The factors that affect the amount of apical extrusion could be classified into: (i) physical factors such as the amount and velocity of irrigant, size of apical constriction, hardness of dentin, and tooth position, (ii) mechanical factors such as the amount of irrigant used, final size of file, motion kinematics, and file design.[27]

So this study was done to compare the amount of apically extruded debris using Hand k file, NeoEndo Flex, ProTaper Next and XP Endo Shaper. For this study the experimental model by Myers and Montgomery[28] was used. According to this model, teeth were mounted into a hole in eppendorf tube and a 27 gauge needle was used to balance internal and external pressure.

In this study, mandibular premolars teeth with a single and straight canals were used to avoid working length loss or non-standardized preparation. Additionally, the application of only one kind of tooth can help increase the similarity between the samples.

A 10-K file was used to maintain the apical patency in all the samples to attain apical diameter standardization. It was demonstrated by Tinaz et al.[29] that the debris extrusion increased with increase in the diameter of patency of the apex, whereas Lambrianidis et al.[30] reported that even when constriction of the apex remained intact, the amount of apical extrusion increased.

The tooth length was standardised to 15 mm to eliminate variables associated with the working length of each tooth that might manifest as differences in debris extrusion. In order to prevent any differences associated with the quantity of extruded debris and apical size enlargement, the apical size of all master apical file was maintained at ISO size 30 consistently in all groups. Thus, the quantity of apically extruded debris from the root canals could be ascribed to the technique and design of the corresponding instrument used in a specific group.[31]

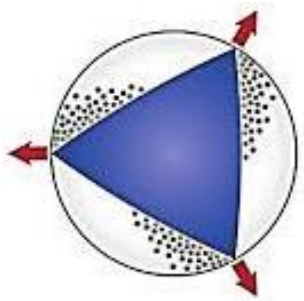
Since sodium hypochlorite could replace the amount of extruded dentin debris by crystallisation so distilled water was used as an irrigant solution.[26]

In this study, the least quantity of apical extrusion was demonstrated by ProTaper Next and the highest apical extrusion by Hand K file. This is in accordance to the finding reported by Alireza Adl et al,[32]where they concluded that the engine-driven techniques extruded less debris compared to hand technique, presumably due to the rotary motion, which directs debris towards the coronal orifice, avoiding its compaction in the root canal.

The maximum amount of extrusion in the hand K file group can be attributed to the fact that the hand K- file acts as a plunger to force the debris ahead of the file, through the patent apical foramen, and out into what would be the periradicular area.

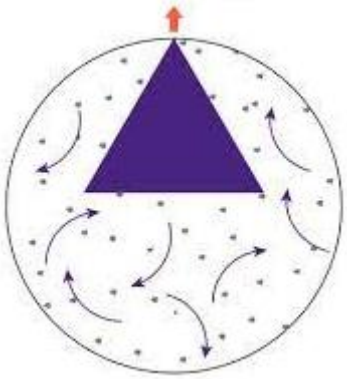
In this study ProTaper Next, Xp endo shaper and NeoEndo flex were used as engine driven based root canal instrumentation technique and as Beeson et al (1998)[33] stated that the engine- driven techniques extruded reduced amounts of debris apically. The rotary motion, tends to direct debris toward the orifice, avoiding its compaction in the root canal, whereas utilizing the crown-down technique improve instrument control during preparation of the apical third of the canal.[34]

Neoendo Flex Files have triangular cross section with sharp cutting edges which increases cutting efficiency. They also have non-cutting tip which avoids apical transportation. The extreme flexibility of these files favours negotiation of any canal,[35] Due to triangular cross-section, it makes a three-point contact with the dentinal wall during its rotation in the canal which scrape the dentin instead of cutting, hence the debris are pushed more coronally,[36] thus it causes less extrusion of debris as compared to hand K file.



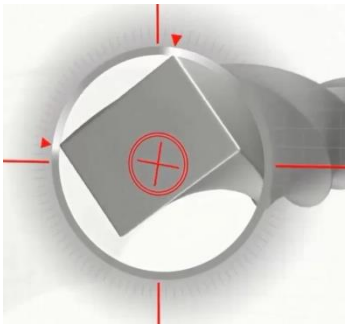
CROSS SECTION OF NEOENDO FLEX SHOWING THREE POINT CONTACT AND DEBRIS ACCUMULATION

XP-Endo Shaper significantly produced less amount of debris than NeoEndo Flex this may be due to the MaxWire (martensite-austenite-electropolish file X) technology that contains both martensitic (20°C) and austenitic (35°C) phases. Max wire instruments possess martensitic stable phase at room temperature. When it is placed inside the canal due to intracanal temperature changes, it transforms the phase into austenitic state. Thus, it exhibits both shape memory and superelastic property and changes its shape according to change in intracanal temperature. It is the shape memory and the off-centered design which preserves the dentine and produce minimum debris apically.[37]



CROSS SECTION OF XP ENDO SHAPER SHOWING ONE POINT CONTACT AND NO DEBRIS ACCUMULATION

In studies by Kocak,[38] Ozsu[39] and Cicek,[40] they concluded that ProTaper Next rotary file system extruded less debris apically because of its off-centered rectangular cross section as shown in figure 13 and also it has snake-like swaggering motion which leads to debris removal in a coronal direction resulting in less debris extrusion apically. The less amount of debris by ProTaper Next can also be explained by the fact that Protaper Next files are manufactured from M-Wire NiTi technology which provide better fl xi ili y and cyclic fatigue resistance.[41]



CROSS SECTION OF PROTAPER NEXT SHOWING TWO POINT CONTACT

In the present study least extrusion was seen with ProTaper Next and XP Endo Shaper and greater extrusion with multiple file systems like Neoendo Flex File and Hand K file. This is in accordance with the study by Ruddle et al[42] who reported in their study that increased number of files may be a factor for the greater amount of debris extrusion.

In the present study, all instrumentation caused apical debris extrusion some more or other less; however, they possess different design features which may cause different amounts of apically extruded debris[43]

Even though this study permits file system comparison under indistinguishable environments, there were still some drawbacks. The main demerit of the method is that apical vital tissues could not be imitated. Additionally, this study restricted to the use of the teeth with fully formed root morphology. The results thus obtained can not be applied to teeth with open apex and incompletely formed roots. Moreover, for flare-ups there could be other factors, such as intracanal medication, bacterial virulence, extruded irrigant, and the host response that can activate such flare-up.

There is a need for additional investigations to evaluate the extrusion of solid debris along with intracanal irrigants. Further in vivo studies are also required to evaluate post-instrumentation pain with these instrumentation systems.

CONCLUSION

Within the limits of present study, it can be concluded that:

1. It is the instrumentation of root canal which is responsible for the extrusion of debris.
2. All the instrument used in this study showed apical debris extrusion. Though among various file, PTN showed lesser extrusion of debris.
3. Highest mean apical debris was extruded by Hand K file.

A definite conclusion as to which file should be preferred between PTN, Neoendo, XPendo shaper can be done after correlating the findings of present study with other clinical studies. Therefore more studies are advocated to reach a definite conclusion.

REFERENCES

1. Seltzer S, Naidorf IJ. Flare-ups in endodontics: I. Etiological factors. J Endod 1985;11:472-8.
2. Peters O, Peters C. Cleaning and shaping of the root canal system. Cohen’s Pathways of the Pulp. 10th ed. USA: Mosby Elsevier 2010; pp. 283-348
3. Saunders E. Hand instrumentation in root canal preparation. Endod Topics 2005; 10(1): 163-7
4. Siqueira Jr JF. Microbial causes of endodontic flare-ups. Int Endod J 2003 Jul;36(7):453-63.
5. Koçak S, Koçak MM, Sağlam BC, Türker SA, Sağsen B, Er Ö. Apical extrusion of debris using self-adjusting file, reciprocating single-file, and 2 rotary instrumentation systems. J Endod. 2013 Oct 1;39(10):1278-80.
6. Ingle JI, Bakland LK, Baumgartner JC. Ingle's endodontics 6th ed. USA: BC Decker. 2008;1053.
7. Chapman CE, Collee JG, Beagrie GS. A preliminary report on the correlation between apical infection and instrumentation in endodontics. J Br Endod Soc 1968 Jan;2(1):7-11.
8. Torabinejad M, Eby WC, Naidorf IJ. Inflammatory and immunological aspects of the pathogenesis of human periapical lesions. J Endod 1985 Nov 1;11(11):479-88.
9. Brilliant JD, Vandevisse JE. Effect of irrigation on the production of extruded material at the root apex during instrumentation. J Endod 1975;1:243-6.
10. Adl A, Sahebi S, Moazami F, Niknam M. Comparison of apical debris extrusion using a

conventional and two rotary techniques. Iran Endod J 2009;4(4):135.
11. Harrington GW, Natkin E. Midtreatment flare-ups. Dent Clin North Am 1992 Apr 1;36(2):409-23.
12. Ruddle CJ, Machtou P, West JD. The shaping movement 5th generation technology. Dent Today. 2013 Apr;32(4):94.
13. Ozsu D, Karatas E, Arslan H, Topcu MC. Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems. Eur J Dent. 2014 Oct;8(04):504-8.
14. Ahangar FA, Sajad M, Purra AR, Farooq R. Evaluation of centering ability of four thermally treated nickel titanium rotary files for root canal preparation in moderately curved root canals: An in vitro cone beam computed tomography assessment. Ann. Int. Med. Den. Res. 2018;4(5):DE15-DE20
15. Tomer AK, Gupta R, Behera A, Mittal N, Raina AA, Ramachandran M, et al. An in vitro evaluation of remaining dentin thickness through CBCT using different file. Int J Appl Dent Sci 2018;4:09-13
16. Yared G. Canal preparation using only one Ni-Ti rotary instrument: preliminary observations. Int Endod J 2008 Apr;41(4):339-44.
17. XP-Endo solutions, 2020, https://www.fkg.ch/products/endodontics/canal-shaping-and-cleaning/xp-endo-shaper
18. Bayram HM, Bayram E, Ocak M, Uygun AD, Celik HH. Effect of ProTaper Gold, Self-Adjusting File, and XP-endo Shaper instruments on dentinal microcrack formation: a micro–computed tomographic study. J Endod. 2017 Jul 1;43(7):1166-9.
19. Elnaghy A, Elsaka S. Cyclic fatigue resistance of XP-endo Shaper compared with different nickel-titanium alloy instruments. Clinic oral investig 2018 Apr;22:1433-7.
20. Keskin C, Inan U, Guler DH, Kalyoncuoğlu E. Cyclic fatigue resistance of XP-Endo Shaper, K3XF, and ProTaper Gold nickel- titanium instruments. J Endod 2018 Jul 1;44(7):1164-7.
21. Ruiz-Hubard EE, Gutmann JL, Wagner MJ. A quantitative assessment of canal debris forced periapically during root canal instrumentation using two different techniques. J Endod 1987 Dec 1;13(12):554-8.
22. Sjögren U, Sundqvist G, Nair PR. Tissue reaction to gutta-percha particles of various sizes when implanted subcutaneously in guinea pigs. Eur J Oral Sci 1995 Oct;103(5):313-21.
23. Radeva EN, Vassileva RI. Comparative study of apically extruded debris and irrigant after using two rotary systems (K3, Race). Eur J Oral Sci 2014 Mar 10;20(1):459-63.
24. Patel AR, Ujariya UM, Kothari AK, Bharatiya RP. Comparative evaluation of apical debris extrusion during root canal preparation using three different file systems: An: in vitro: study. Endodontology. 2020 Jan 1;32(1):20-5.
25. Alani MA, Al-Huwaizi H. Evaluation of apically extruded debris and irrigants during root canal preparation using different rotary instrumentation systems: An in vitro comparative study. Int J Med Res Health Sci 2019;8(2):21–26
26. Tanalp J, Güngör T. Apical extrusion of debris: a literature review of an inherent occurrence during root canal treatment. Int Endod J 2014 Mar;47(3):211-21.
27. Kumar GP, Godavarthy DS, Yarlagadda M, Beesetty N, Killi N. Apical Extrusion of Debris in Mesiobuccal Root of Maxillary Molars with Five Rotary File Systems. J Clin Diagnostic Res 2018 May 1;12(5).
28. Myers GL, Montgomery S. A comparison of weights of debris extruded apically by conventional filing and Canal Master techniques. J Endod 1991 Jun 1;17(6):275-9.
29. Tinaz AC, Alacam T, Uzun O, Maden M, Kayaoglu G. The effect of disruption of apical constriction on periapical extrusion. J Endod 2005 Jul 1;31(7):533-5.

30. Lambrianidis T, Tosounidou E, Tzoanopoulou M. The effect of maintaining apical patency on periapical extrusion. J Endod 2001 Nov 1;27(11):696-8.
31. Sadique M, Dm A, Sv R, Elsy P, Lal S. Comparative evaluation of apical extrusion of E Faecalis using hand and rotary systems. Saudi J Oral Dent Res. 2016;1(2):84-9.
32. Alireza A, Safoora S, Mahnaz N. Comparison of apical debris extrusion using a conventional and two rotary techniques. Iran Endod J. 2009; 4 (4):135-138
33. Beeson TJ, Hartwell GR, Thornton JD, Gunsolley JC. Comparison of debris extruded apically in straight canals: conventional filing versus profile. 04 Taper series 29. J Endod 1998 Jan 1;24(1):18-22.
34. Goerig AC, Michelich RJ, Schultz HH. Instrumentation of root canals in molar using the step-down technique. J Endod 1982 Dec 1;8(12):550-4.
35. http://neoendo.com/india/products/flexfiles
36. Guha A, Shivangi S, Jain R, Rao RD, Verma MR, Jain AK. Comparative evaluation of apically extruded debris during root canal instrumentation using Neoendo Flex, Pro-HS, and Mani Silk: An: in vitro: study. Endodontology. 2021 Oct 1;33(4):227-31.
37. Taher A, Ruba M, Rami A, Hamza E, Waheeb K, Ahmed J. Debris extrusion using Reciproc blue and XP endo shaper systems in root canal retreatment. Int J Dent 2021;(3):1-5.
38. Koçak MM, Çiçek E, Koçak S, Sağlam BC, Yılmaz N. Apical extrusion of debris using ProTaper Universal and ProTaper Next rotary systems. Int Endod J 2015 Mar;48(3):283-6.
39. Ozsu D, Karatas E, Arslan H, Topcu MC. Quantitative evaluation of apically extruded debris during root canal instrumentation with ProTaper Universal, ProTaper Next, WaveOne, and self-adjusting file systems. Eur J Dent. 2014 Oct;8(04):504-8.
40. Çiçek E, Akkocan O, Furuncuoglu F. Comparison of apically extruded debris associated with several nickel-titanium systems after determining working length by apex locator. J Cons Dent 2016 Jan;19(1):68.
41. Çırakoglu NY, Özbay Y. Apically extruded debris associated with ProTaper Next, ProTaper Gold and TruNatomy systems: An in vitro study. J Dent Res Dent Clin Dent Prospects 2021;15(1):30.
42. Ruddle CJ, Machtou P, West JD. The shaping movement 5th generation technology. Dent Today. 2013 Apr;32(4):94.
43. Logani A, Shah N. Apically extruded debris with three contemporary Ni-Ti instrumentation systems: An: ex vivo: comparative study. Ind J Dent Res 2008 Jul 1;19(3):182-5.