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Smear Layer Removal Using Different Nickel-Titanium Rotary Systems: (An in vitro study)

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Aim: to assess the removal of the smear layer using Protaper Gold (PTG), HyFlex EDM (HEDM) and K3XF.
Materials and methods: Forty-five permanent teeth were selected and randomly divided into three experimental groups (n=15 each). Group 1: PTG; group 2, HEDM; group 3, K3XF. Samples were instrumented according to the manufacturer instructions. The accumulated smear layer was assessed using scanning electron microscope (SEM).
Results: K3XF showed the least amount of remaining smear layer followed by PTG. HEDM showed the most accumulated smear layer.
Conclusions: Under the condition of the current study, complete smear layer removal cannot be achieved with root canal instrumentation solely. Additional strategies such as dental laser systems and irrigating solutions with tissue-dissolving capabilities should be employed for complete smear layer removal.

Keywords: Smear layer removal, Cleaning ability, Novel NiTi rotary files, Protaper Gold, HyFlex EDM, K3XF.

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Introduction

The design features of nickel titanium (NiTi) rotary instruments has been massively improved over the last years. The main concern of an endondontist during root canal procedure is the fracture resistance of the file and its cutting efficiency. Among the characteristic demands of the rotary system utilized, the cleaning capacity and competence to eliminate the smear layer should not be disregarded.

The so-called smear layer is created by the process of cutting of metallic instruments, whether they are made of stainless steel or NiTi. The smear layer has been revealed to be 1 to 5 µm thick. The smear layer prevents irrigants from penetrating deeper areas of the root dentin and reduces the permeability of the dentin as well as its bond strength to adhesives and sealants [1-5]. Generally, the smear layer is often thought to have potentially harmful consequences, thus removing it is demanded.

The design features of NiTi rotary instruments has been massively improved over the last years. The main concern of an endondontist during performing root canal treatment is the fracture resistance of the file and its cutting efficiency. The cleaning ability of the rotary system should not be over-looked among the characteristic demand of the rotary system used.

Recently new rotary NiTi rotary systems have been developed and the manufacturers claim that they have excellent cleaning ability. Among them are ProTaper Gold (PTG) (Dentsply Tulsa Dental Specialties, OK, USA), HyFlex EDM (HEDM) (Coltene/Whaledent, Altstätten, Switzerland) and K3XF (SybronEndo, Orange County, CA, USA).

PTG are newly introduced files with a convex triangular cross section that exhibit improved mechanical properties because of their novel metallurgy with high Af temperatures and 2-stage unique transformation behavior [6].

Electrical discharge machining (EDM) is a process used to improve the mechanical properties of controlled memory (CM) wires, from which HEDM files are generated [7]. In order to optimize flexibility, torsional resistance, and cycle resistance, the instrument also displays different cross-sectional forms that change from triangular to rectangular from shaft to tip [8, 9].

R-phase technology was used to create K3XF, a phase with a rhombohedral structure that exists in a very small temperature range between austenite and martensite. These files contain all of the original K3's fundamental features. As a result, according to the manufacturers, K3XF is more flexible and resistant to cyclic fatigue [10].

This, the removal of the smear layer using Protaper Gold (PTG), HyFlex EDM (HEDM) and K3XF was evaluated.

Materials and methods

Sample size calculation:

Smear layer removal efficacy was the primary outcome of power analysis, which was utilized to calculate the total sample size. With a power of 95% and the effect size (f) was 0.62. A total of 45 subjects was the minimum estimated sample size. The calculation relied on findings from an earlier study [11].

There will be fifteen subjects in each group, for a total sample size of 45 (Figure 1)

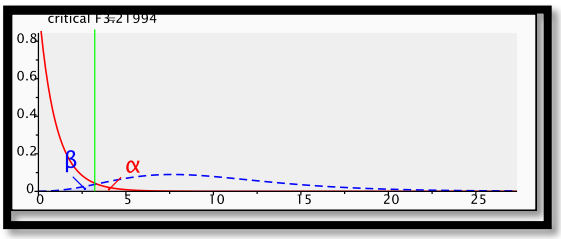

Figure 1: A plot showing Sample size calculation with an effect size (f) of 0.62.

Sample selection:

For this study, a number of 45 extracted permanent single-rooted teeth were selected. All selected teeth were intact .

Sample preparation:

The teeth were first cleaned for 30 minutes prior to usage by submerging them in 5.25% sodium hypochlorite. After that, teeth were scaled and cleaned to get rid of any calculus or surface deposits. In order to standardize the length of the teeth to an average of 16 mm, they were later sectioned to the cement-enamel junction by an isomet saw with water cooling.

Samples were stored in saline until the moment of use. Standard endodontic coronal access cavity was performed for the initial penetration followed by tapered diamond stone for finalization of the access cavity. All the cutting procedures were done with a high-speed handpiece under water coolant.

Sample grouping

Three groups were established according to the nickel-titanium rotary systems that were used as follows: Group one: ProTaper Gold (PTG), Group two: HyFlex EDM, Group three: K3XF. Each group was represented by 15 teeth.

Root canal enlargement

Each tooth was stabilized in a small vise grip during instrumentation. A hand file size 15 was used in order to assess patency. All teeth were cleaned and shaped according to the assigned group following the manufacturer's instructions.

PTG: Shaping files (SX, S1, and S2) were brushed on the withdrawal stroke in this group, using X-Smart endo motor that rotated at a steady 350 rpm per minute. The torque was set at 2 Ncm in accordance with the manufacturer's recommendations. There was no brushing motion while using finishing files F1 and F2.

HEDM: (Orifice Opener file, Glidepath File, and the 25/~ HyFlex one shaping file) was also used X-Smart endo motor that rotated at a steady 500 rpm. The torque was set at 2.5 Ncm in accordance with the manufacturer's recommendations.

K3XF: In this group, a K3XF orifice opener file (size 25/.10) was utilized with a gentle in and out motion at a speed of 400 rpm and torque was set at 2.5 to 3 Ncm. Then additional K3XF files (sizes 25/.04 and 25/.06) was employed.

Samples in each group were cleaned, shaped, and then flushed with normal saline.

SEM Examination

All teeth were sectioned longitudinally, and then evaluated with a scanning electron microscope (SEM).

Evaluation was performed using a scoring system [6]:

Score 1: Absence of smear layer with opened dentinal tubules.

Score 2: Presence of smear layer with less dentinal tubules.

Score 3: Presence of smear layer with very limited dentinal tubules.

Score 4: Presence of smear layer with absence of dentinal tubules.

Score 5: Complete coverage of smear layer.

Results

<u>In the apical area:</u>

The results showed that PTG had the least accumulated smear layer

followed by HEDM. K3XF had the highest accumulated smear layer, that was statistically significant difference (Table 1, Figure 2&3).

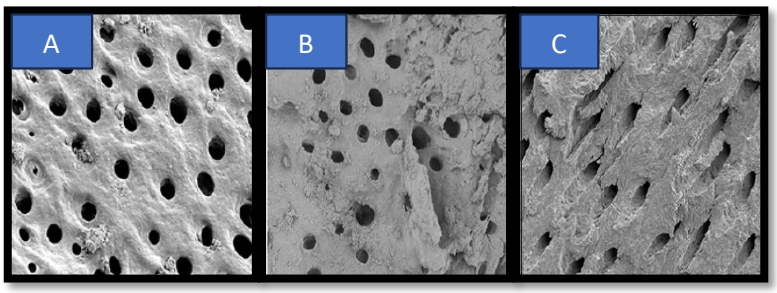

Figure (2): SEM images of accumulated smear layer of the three different groups; A) PTG, B) HEDM, & C) K3XF

Table (1): Results of comparison between the three groups

Groups	Apical		*Minimum*	*Maximum*	*P*-value
	Mean	St. dev.			
PTG	2.60 A	±0.632	2	4	0.058*
HEDM	3.00 B	±0.535	2	4	
K3XF	3.07 C	±0.704	2	4	

*: Significant at P ≤ 0.05

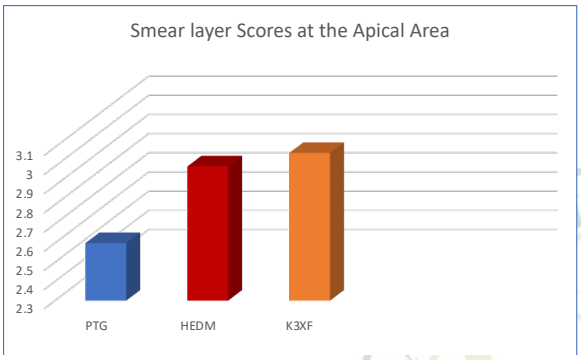

Figure (3): Bar chart representing accumulated Smear layer scores in the three groups

In the middle area:

The results showed that PTG had the least accumulated smear layer followed by HEDM. Also K3XF had the highest accumulated smear layer, that was also with a statistical significant difference (Table 2, Figure 4&5).

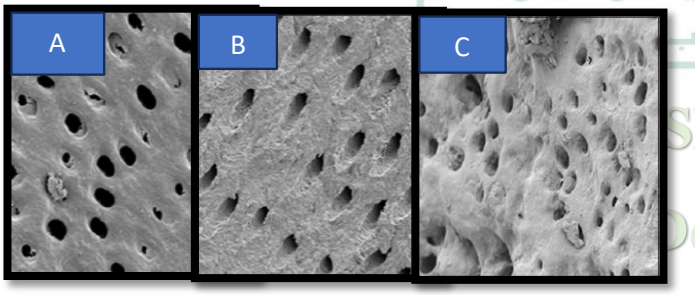

Figure (4): SEM images of accumulated smear layer of the three different groups; A) PTG, B) HEDM, & C) K3XF

Table (2): Results of comparison between the three groups

Groups	Middle		*Minimum*	*Maximum*	*P*-value
	Mean	St. dev.			
PTG	2.47	±0.640	1	3	0.242
HEDM	2.87	±0.640	1	4	
K3XF	2.93	±0.704	2	4	

*: Significant at P ≤ 0.05

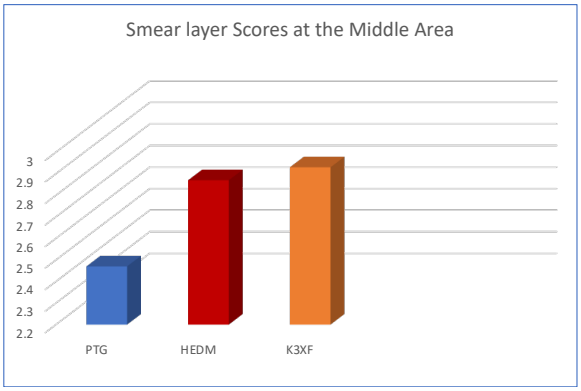

Figure (5): Bar chart representing accumulated Smear layer scores in the three groups

In the coronal area:

The results showed that PTG had the least accumulated smear layer followed by HEDM. The K3XF had the most accumulated smear layer with a statistical significant difference (*P*-value = 0.05) (Table3, Figure 6&7).

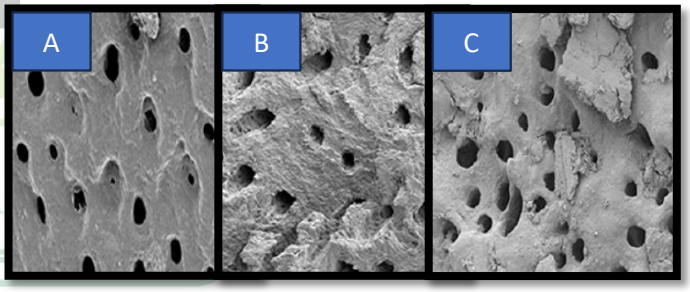

Figure (6): SEM images of accumulated smear layer of the three different groups; A) PTG, B) HEDM, & C) K3XF

Table (3): Results of comparison between the three groups

Groups	Coronal		*Minimum*	*Maximum*	*P*-value
	Mean	St. dev.			
PTG	2.00 A	±0.756	1	3	0.011*
HEDM	2.47 B	±0.516	2	3	
K3XF	2.67 C	±0.617	1	3	

*: Significant at P ≤ 0.05

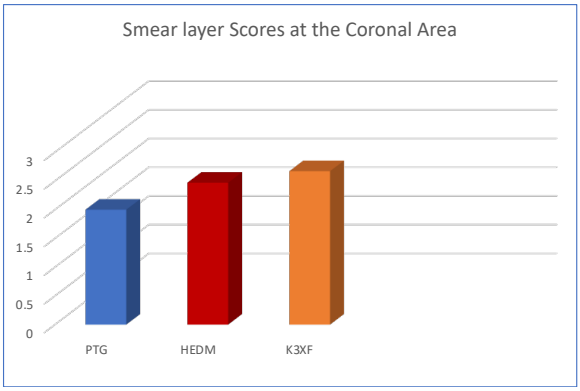

Figure (7): Bar chart representing accumulated Smear layer scores in the three groups

For the total area:

Regarding the mean of the accumulated smear layer scores for the total area the results have shown that PTG had the lowest mean smear layer scores, statistically significant. HEDM showed statistically significantly higher mean smear layer scores. K3XF system showed the the most accumulated smear layer with a statistical significant difference (Table4, Figure 8).

Table (4): Results of comparison between the three groups

Groups	Coronal		*Minimum*	*Maximum*	*P-value*
	Mean	St. dev.			
PTG	7.07 A	± 1.387	5	9	0.008*
HEDM	8.33 B	± 1.447	6	11	
K3XF	8.60 C	± 1.639	4	11	

*: Significant at P ≤ 0.05

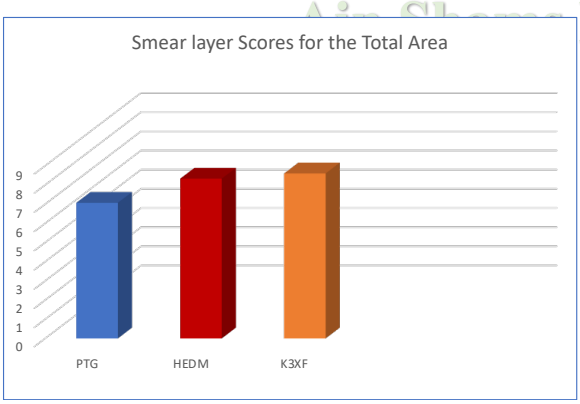

Figure (8): Bar chart representing accumulated Smear layer scores in the three groups

Discussion

The biological aim of endodontic treatment is to totally remove all pulpal tissues, bacteria and their byproducts. Removal of bacterial biofilms is also mandatory for adequate adaptation of the obturation material. Efforts and technology over the past years was focusing to efficiently clean the root canals, while minimizing the unnecessary removal of sound dentin, which may eventually result in minimally invasive endodontic therapy [12].

The smear layer accumulates as a result of root canal instrumentation. It was stated that the smear layer included pulp tissue, microorganisms, and residuals of odontoblastic processes in addition to dentin, as in the coronal smear layer.

The current study compared the removal of smear layers using various rotary file systems. In order to replicate clinical settings and provide electron microscopic inspection for canal cleanliness after canal preparation, extracted human teeth were employed in this work [13].

The PGT, HEDM, and K3XF rotary systems files were used in the present study. The PGT files was used to file F2 with a tip size of 25, HEDM system was used to file 25 and K3Xf system was used to file 25 to standardize the tip sizes.

Saline was the irrigant of choice in this study in order to reveal the effect of files only and exclude the role of the chemical agent [14].

The stereomicroscope and scanning electron microscopy (SEM) are two commonly used techniques for smear layer evaluation. The magnification range of a stereo microscope is 30X to 70X, but that of a SEM is 1000X to 3000X. SEM is capable of identifying the type of cleaned canal surface, remaining pulp tissue, and any bacterial biofilm, all of which are important for better assessing the smear layer and determining whether a layer of dentin was

removed [15].

Regarding the results of the current study, PTG rotary system had the least accumulated smear layer followed by HEDM. While K3XF had the highest accumulated smear layer with a statistical significance difference between all groups.

In this study the PTG file showed the the least accumulated smear layer among the tested NiTi files. This may be related to the progressive taper of these files, which increase the cutting efficiency, these files also had a constant convex triangular that increases the cutting efficiency [16]. In addition, they are characterized by the presence of deep flutes, which increases the displacement of debris coronally, all these contribute to the increased cutting efficiency of PTG [18]. While HyFlex EDM showed higher amount of smear layer accumulated, This might be explained by its EDM procedure, distinct cross-sectional shape, and higher austenite finish temperature (over 370°C), which at room temperature contains both austenite and martensitic structure mixes [19]. Because martensitic structure is less stiff than austenite's, files made with CM wires have more martensite than austenite, which reduces the capacity of the files to clean [20].

On the other hand, K3XF file showed the highest accumulated smear layer, A possible explanation for the inferiority of K3XF file might be related to the difference in its design features. Although it has radial lands which is responsible for the centric ability of the file, however the design also has radial land relief, which reduces friction on the canal wall, affecting its cutting efficiency. Also, it has third radial land that minimizes over engagement. Furthermore, the safe ended tip of the file leads to passive preparation [21, 22].

The smear layer could not be entirely eliminated by any of the examined systems. This could be explained by the fact that saline, which does not have the ability to dissolve tissue, was the only irrigant used in this study. Irrigants must be administered during or after root canal instrumentation to eliminate the smear layer. This demonstrates the importance and potency of chelating agents such citric acid, MTAD, and 17% EDTA as well as irrigation solutions in the removal of smear layers.

Therefore, it could be considered that PTG files have shown the best cutting efficiency because of their lowest amount of smear layer accumulated.

Conclusion

Under the condition of the current study, complete smear layer removal cannot be achieved with root canal instrumentation solely. Additional strategies such as dental laser systems and irrigating solutions with tissue-dissolving capabilities should be employed for complete smear layer removal.

References

1. Heard F, Walton RE. Scanning electron microscope study comparing four root canal preparation techniques in small curved canals. Int Endod J 1997;30,323-31.
2. Peters CA, Barbakow F. Effect of irrigation on debris and smear layer on canal walls prepared by two rotary techniques: a scanning electron microscopic study. J Endod 2000;25:6-10.
3. Saunders WP, Saunders EM. The effect of smear layer upon coronal leakage of gutta-percha fillings and a glass ionomer sealer. Int Endod J 1992;25:245-9.
4. Ullmann CJ, Peters OA. Effect of cyclic fatigue on static fracture loads in ProTaper nickel-titanium rotary instruments. J Endod 2005;31:183–6.
5. Peters OA. Current challenges and concepts in the preparation of root canal systems: a review. J Endod 2004;30:559–67.
6. Hulsmann M, Schade M, Schafers F. A comparative study of root canal preparation with HERO 642 and Quantec SC rotary Ni-Ti instruments. Int Endod J 2001;34:538-46.
7. Haikel Y, Serfaty R, Bateman G, Senger B, Allemann C. Dynamic and cyclic fatigue of engine-driven rotary nickel titanium endodontic instruments. J Endod. 1999; 25, 434–40.
8. Schnieder WE. A comparison of canal

preparations in straight and curved root canals. Oral Surg. 1971; 32: 27-5.
9. Ozyurek T. Cyclic fatigue resistance of Reciproc, WaveOne, and WaveOne Gold Nickel-titanium instruments. J Endod. 2016; 42:1536-1539.
10. Gundogar M and Ozyurek T. Cyclic fatigue resistance of OneShape, HyFlex EDM, WaveOneGold, and Reciproc Blue Nickel-titanium instruments. J Endod. 2017; 43:1192-1196.
11. Afreen L, Chandra R, Jain J, Mehrotra A. Comparative evaluation of removal of smear layer using newer rotary endodontic files: A scanning electron microscope study. J Conserv Dent. 2021 Nov-Dec;24(6):616-621.
12. Schafer E, Lohmann D. Efficiency of rotary nickel-titanium FlexMaster instruments compared with stainless steel hand K-Flexofile. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 2002;35:514-21.
13. Versumer J, Hulsmann M, Schafers F. A comparative study of root canal preparation using Profile .04 and Lightspeed rotary Ni-Ti instruments. Int Endod J 2002;35:37-46.
14. Schafer E, Schlingemann R. Efficiency of rotary nickel-titanium K3 instruments compared with stainless steel hand K-Flexofile. Part 2. Cleaning effectiveness and shaping ability in severely curved root canals of extracted teeth. Int Endod J 2003;36:208-17.
15. Prati C, Foschi F, Nucci C, Monteburgnoli L, Marchionni S, Appearance of the root canal walls after preparation with NiTi rotary instruments: a comparative SEM investigation. Clin Oral Investig 2004;8:102-10.
16. Xu X, Eng M, Zheng Y, Eng D. Comparative Study of Torsional and Bending Properties for Six Models of Nickel-Titanium Root Canal Instruments with Different Cross-sections. J Endod 2006; 32: 372-5.
17. Madarati AA, Watts DC, Qualtrough AJE. Factors contributing to the separation of endodontic files. B D J. 2008; 204(5): 241-245.
18. Hülsmann M., Donnermeyer D., Schäfer E. A critical appraisal of studies on cyclic fatigue resistance of engine-driven endodontic instruments. International Endodontic Journal. 2019;52(10):1427–1445.
19. Kim H. C., Kim H. J., Lee C. J., Kim B. M., Park J. K., Versluis A. Mechanical response of nickel-titanium instruments with different cross-sectional designs during shaping of simulated curved canals. International Endodontic Journal. 2009;42(7):593–602.
20. Gambarini G. Rationale for the use of low-torque endodontic motors in root canal instrumentation. Dental Traumatology. 2000;16(3):95–100.
21. Keskin C, Inan U, Guler DH, Kalyoncuoglu E. Cyclic fatigue resistance of XP-Endo Shaper, K3XF, and Protaper Gold Nickel-titanium instruments. J Endod. 2018; 44:1164-1167.
22. Zupanc J, Vahdat-Pajoh N, Schäfer E. New thermomechanically treated NiTi alloys a- Review. Int Endod J. 2018; 51(10): 1088-1103.