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ORIGINAL RESEARCH

A Comparative Evaluation of Cleaning Efficacy (Debris and Smear Layer Removal) of Hand and Two NiTi Rotary Instrumentation Systems (K3 and ProTaper): A SEM Study

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ABSTRACT

Objectives: The present study was conducted to compare the cleaning efficacy (debris and smear layer removal) of hand and two NiTi rotary instrumentation systems (K3 and ProTaper).

Materials and methods: Sixty single rooted human maxillary anterior teeth decoronated at the cementoenamel junction were used. All the specimens were divided into four groups of 15 teeth each, group I—ProTaper rotary instrumentation done, group II—K3 rotary instrumentation done, group III—Stainless steel K-file instrumentation done, group IV—root canal irrigation without instrumentation. Root canal preparation was done in a crown down manner and 3% sodium hypochlorite was used as irrigant after each file followed by final rinse with 5 ml of 17% EDTA solution, then specimens were scanning electron microscopic (SEM) examination.

Results: Statistical analysis was done using one-way ANOVA followed by post hoc Tukey's HSD test. Group I showed highly statistical significant difference compared to other groups. There was no statistically significant difference considering smear layer at any levels among the groups with no smear layer formation in group IV.

Conclusion: ProTaper rotary instrumentation showed the maximum cleaning efficacy followed by K3 rotary instrumentation in the coronal, middle and apical thirds of the root canal.

Clinical significance: ProTaper rotary instruments are more efficient than hand and K3 rotary instruments during root canal treatment.

Keywords: Debris, Smear layer, ProTaper, K3, Stainless steel K-files.

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INTRODUCTION

Successful root canal treatment depends among other factors on the chemomechanical instrumentation of the root canal system. All endodontic instruments create dentin debris and smear layer as a consequence of their action on root canal wall.[1,2] The quality of root canal cleaning is evaluated via debris and smear layer removal. The removal of debris depends not only on the irrigation method but also on the endodontic instruments, the way the instrument is used and the method of root canal preparation.[3,4]

This present *in vitro* study was conducted to compare the cleaning efficacy (debris and smear layer removal) of hand and two NiTi rotary instrumentation systems (K3 and Protaper).

MATERIALS AND METHODS

Sixty maxillary single-rooted anterior human teeth with straight roots were used in this study. The teeth were cleaned of soft tissue debris, calculus and stains and were stored in normal saline in a glass beaker till further use.The crowns of all the sixty specimens were decoronated at the level of the cementoenamel junction (Fig. 1). The patency of the canals was verified with a no. 10 K file.

All the specimens were then randomly divided into four groups with 15 specimens in each group.

- *Group I*: Root canal preparation was done by ProTaper rotary instrumentation.
- *Group II*: Root canal preparation was done by K3 rotary instrumentation.
- *Group III*: Root canal preparation was done by Stainless steel K-files.
- *Group IV*: Root canal irrigation without instrumentation.

Fig. 1: Decoronated specimens

Fig. 2: Cleaning and shaping with K3 rotary instruments

Group I (ProTaper Rotary Instrumentation System)

Canals were prepared by ProTaper rotary files in Anthogyr gear reduction handpiece in crown down technique. The canals were flooded with 2 ml of 3% sodium hypochlorite solution and 17% EDTA solution and dried with absorbent paper points. Preparation was done with SX, S1, S2, F1, F2, F3.

Group II (K3 Rotary Instrumentation System)

Canals were prepared by K3 rotary files in Anthogyr gear reduction handpiece in crown-down technique (Fig. 2). Irrigation was done with 2 ml of 3% sodium hypochlorite was used after each file and 5 ml of 17% EDTA solution was used as final rinse.

Preparation of coronal two-third of estimated working length was carried out in the following sequence:

- K3 30/0.06 to one half the working length.
- K3 30/0.04 to coronal two-third of the working length.
- K3 25/0.06 to coronal two-third of the working length.
- K3 25/0.04 to coronal two-thirds of the working length.

The apical third of the determined working length was prepared by shaping with:

- K3 20/0.04 to full working length.
- K3 25/0.04 to full working length.
- K3 30/0.04 to full working length.

Irrigation was done with 2 ml of 3% sodium hypochlorite was used after each file and 5 ml of 17% EDTA solution was used as final rinse and dried with absorbent paper points.

Group III (Stainless Steel K-Files)

Root canals were prepared by hand instrumentation with K-file according to crown-down technique. Irrigation was done with 2 ml of 3% sodium hypochlorite was used after each file and 5 ml of 17% EDTA solution was used as final rinse and dried with absorbent paper points.

Group IV (Negative Control)

Canal negotiation and working length determination were done in the same method as mentioned above. This is followed by irrigation with 2 ml of 3% sodium hypochlorite and 2 ml of normal saline alternatively. Final irrigation was done with 5 ml of 17% EDTA solution and dried with absorbent paper points.

Sectioning of the Root

Longitudinal grooves parallel to the longitudinal axis of the root were made on the buccal and lingual surface of each specimen using a diamond disk without entering the root canals.

The grooves were then used to split the specimen into two halves longitudinally, using pliers (Fig. 3). One segment from each split specimen was selected, based on how well the splitting was done on them and were prepared for scanning electron microscopic (SEM) examination.

Scanning Electron Microscopic Examination

Photomicrographs at 1300× and 5000× were taken at the three levels—coronal, middle and apical thirds of root canal for debris and smear layer evaluation.

Evaluations of photomicrographs were undertaken for residual debris and smear layer with a five score index for each, using reference photomicrographs (Figs 4 to 13). The observations were then tabulated and subjected to statistical analysis.

Scoring system proposed by Hulsmann et al were used and criteria for the scoring were as follows:

Hulsmann Scoring Criteria[5]

i. For residual debris:
   - *Score 1*: Clean root canal wall. Only few small debris particles.
   - *Score 2*: Few small agglomerations of debris.

Fig. 3: Vertically sectioned sample

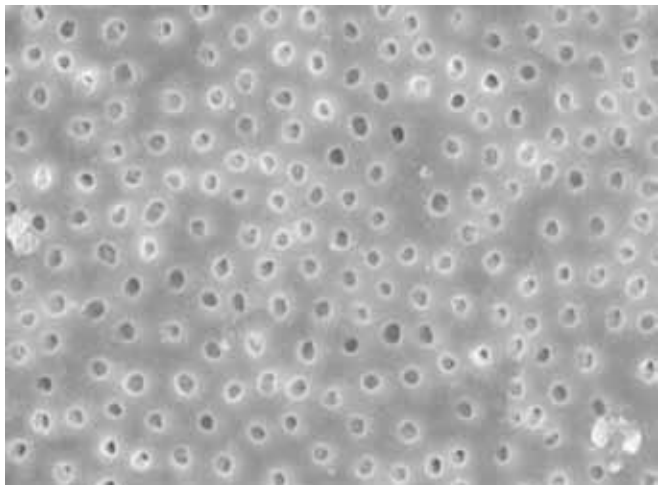

Fig. 4: Photomicrograph of group I coronal third at 1300×

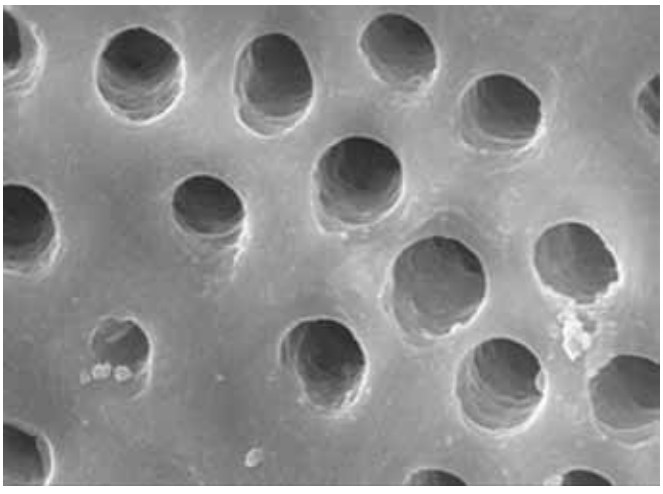

Fig. 5: Photomicrograph of group I coronal third at 5000×

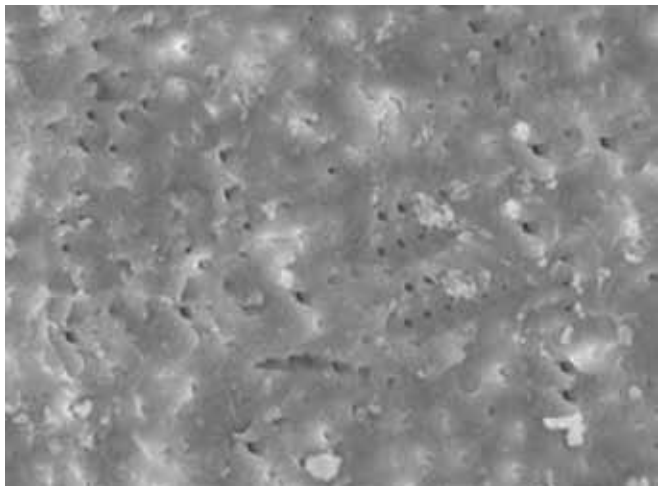

Fig. 6: Photomicrograph of group I middle third at 1300×

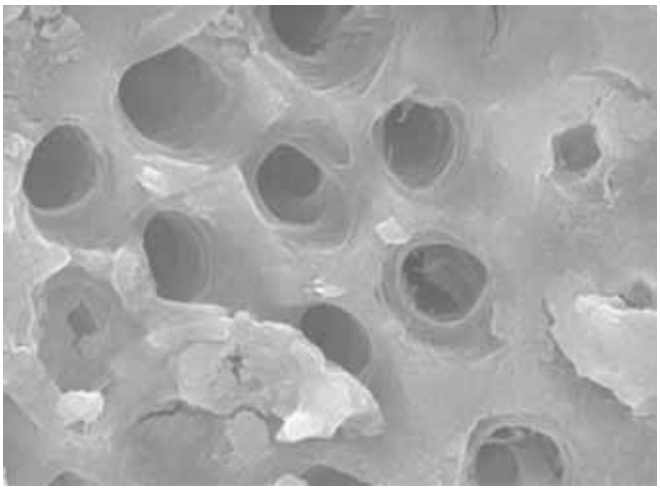

Fig. 7: Photomicrograph of group I middle third at 5000×

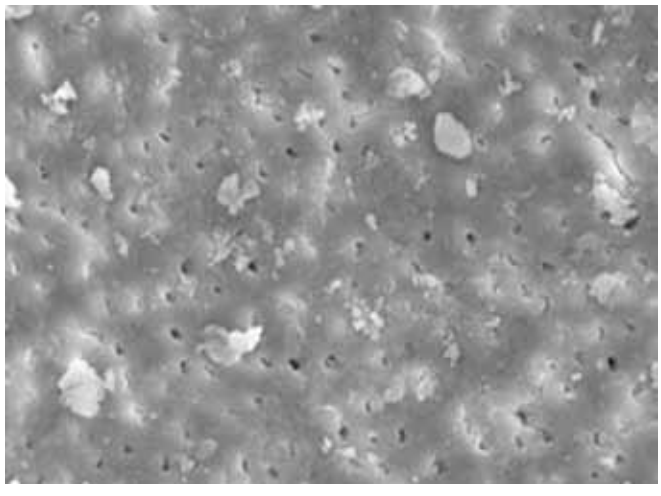

Fig. 8: Photomicrograph of group II coronal third at 1300×

- *Score 3*: Moderate amount of debris, less than 50% of the sample surface covered.
- *Score 4*: Substantial debris, more than 50% of the sample covered.
- *Score 5*: Complete or nearly complete sample surface covered by debris.

ii. For residual smear layer:

- *Score 1*: No smear layer, dentinal tubules open.
- *Score 2*: Small amount of smear layer, some dentinal tubules open.
- *Score 3*: Homogenous smear layer covering the major part of the surface, few dentinal tubules open.

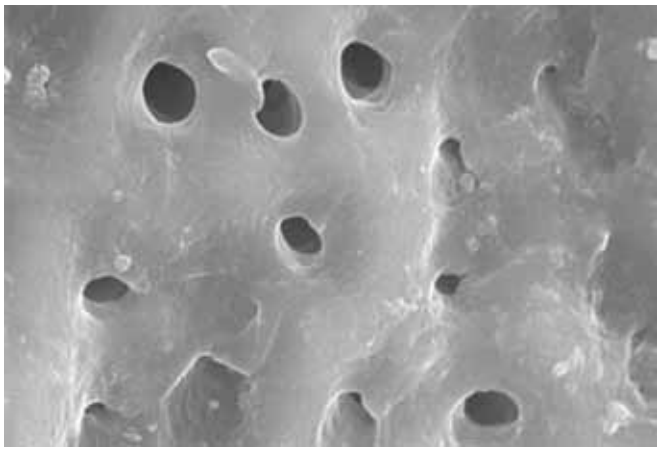

Fig. 9: Photomicrograph of group II coronal third at 5000×

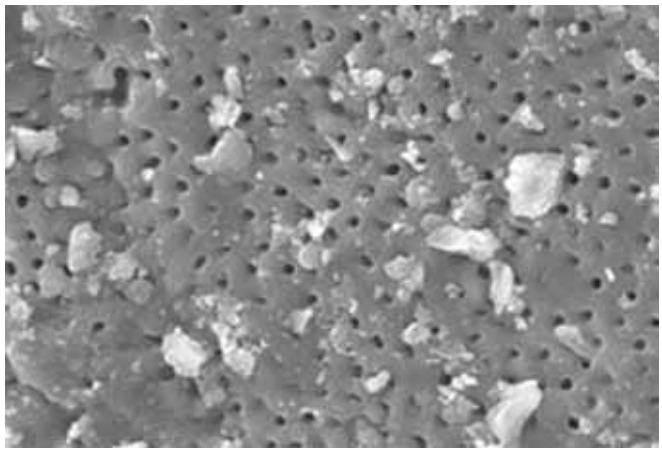

Fig. 10: Photomicrograph of group III coronal third at 1300×

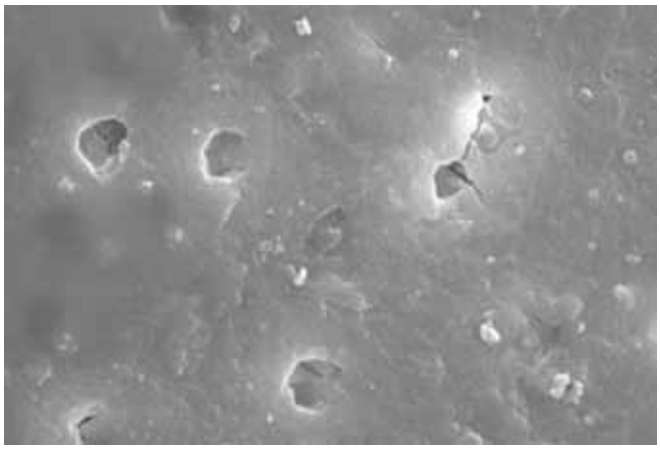

Fig. 11: Photomicrograph of group III coronal third at 5000×

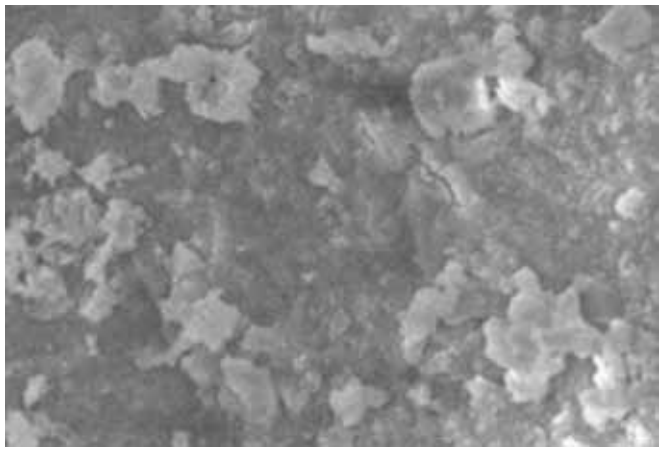

Fig. 12: Photomicrograph of group IV coronal third at 1300×

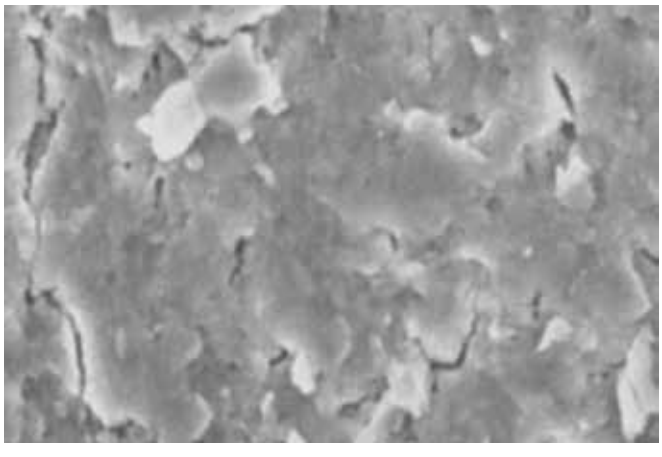

Fig. 13: Photomicrograph of group IV coronal third at 5000×

- *Score 4*: Homogenous smear layer covering the surface, no open dentinal tubules.
- *Score 5*: Heavy, nonhomogenous smear layer covering the surface.

The observations were statistically analyzed using one-way ANOVA at significant level of ($p < 0.05$) at each third of the root canal. Post-hoc Tukey's HSD test was also performed to compare the variation of amount of debris and smear layer removed among the groups. The software used is SSPS 16 for analyzing the data.

RESULTS

The amount of debris and smear layer removed using different instrumentation systems were measured in all specimens. The mean and standard deviation were calculated for each group (Tables 1 to 4). It was found that the group I showed maximum debris removal with statistically significant difference ($p < 0.05$) among the four groups. There was no smear layer formation and maximum amount of debris remaining in group IV (negative control group).

Group I showed highly statistical significant difference when compared to groups II, III and IV considering debris at any levels. There was no statistically significant difference among groups I, II and III considering smear layer at any levels. There was no smear layer formation in group IV. The average debris and smear layer were more in the apical region than the coronal and middle thirds.

DISCUSSION

In the current era of contemporary endodontics, the development in endodontic files has taken the front seat. These changes have brought endodontic practice to the 21st century with greater precision, less discomfort to the patient and faster case completion.

Table 1: Mean, standard deviation and test of significance of mean debris score between coronal, middle and apical thirds of root canal for different study groups

Groups	Site	N	Mean	SD	p-value*	Significance# groups at 5% level
I	Coronal	15	1.33	0.49	<0.001 (S)	3 > 1,2
	Middle	15	1.67	0.49		
	Apical	15	2.13	0.35		
II	Coronal	15	2.07	0.70	0.005 (S)	3 > 1
	Middle	15	2.47	0.74		
	Apical	15	2.93	0.59		
III	Coronal	15	2.73	0.88	0.005 (S)	3 > 1,2
	Middle	15	2.93	0.70		
	Apical	15	3.67	0.72		
IV	Coronal	15	4.47	0.52	0.547 (NS)	-
	Middle	15	4.60	0.51		
	Apical	15	4.67	0.49		

1: Coronal; 2: Middle; 3: Apical; *One-way ANOVA was used to calculate the p-value; #Post-hoc test was employed to identify the significant groups at 5% level; S: Significant; NS: Nonsignificant

Table 2: Mean, standard deviation and test of significance of mean smear layer score between coronal, middle and apical thirds of root canal for different study groups

Group	Site	N	Mean	SD	p-value*	Significance# groups at 5% level
I	Coronal	15	1.67	0.72	0.009 (S)	3 > 1
	Middle	15	2.00	0.76		
	Apical	15	2.47	0.52		
II	Coronal	15	2.13	0.64	0.008 (S)	3 > 1
	Middle	15	2.60	0.51		
	Apical	15	2.80	0.56		
III	Coronal	15	2.13	0.64	0.073 (NS)	–
	Middle	15	2.47	0.52		
	Apical	15	2.60	0.51		
IV	Coronal	15	1.00	0.00	–	–
	Middle	15	1.00	0.00		
	Apical	15	1.00	0.00		

1: Coronal; 2: Middle; 3: Apical; *One-way ANOVA was used to calculate the p-value; #Post hoc test was employed to identify the significant groups at 5% level; S: Significant; NS: Nonsignificant

What is taken out of the root canal is more important than what is put into it.[6] Thus, major factor affecting root canal success is cleaning and shaping.[7,8] This includes the removal of the infected dentin and organic tissue by shaping and dissolution.[1,2]

Various types of instruments and techniques have been used for cleaning and shaping of the root canal system. The mainstay for endodontic files has long been the traditional stainless steel hand files.

Over the past two decades, instrument design has been considerably modified; progress has been made in manufacturing as well as alloy processing.[9]

Different endodontic instruments have variable cutting efficiency. This depends upon cross section, flute design, tip design, pitch, rake angle and radial land of an instrument. So, amount of dentinal debris and smear layer is variable with different instrumentation systems.[10]

ProTaper instrument system, consisting of three 'shaping' and three 'finishing' files, was co-developed by Dr Clifford Ruddle, Dr John West, Dr PierreMactou, Dr Ben Johnson and was designed by Francois Aebyand Gilbert Rota of Dentsply/Maillefer in Switzerland. The distinguishing feature of the ProTaper system (Dentsply/Tulsa Dental) is the progressively variable tapers of each instrument that

Table 3: Mean, standard deviation and test of significance of mean debris score between different study groups for different sites

Site	Groups	N	Mean	SD	p-value*	Significance# groups at 5% level
Coronal third	I	15	1.33	0.49	<0.001 (S)	IV > III > II > I
	II	15	2.07	0.70		
	III	15	2.73	0.88		
	IV	15	4.47	0.52		
Middle third	I	15	1.67	0.49	<0.001 (S)	IV > III, II, I III > I II > I
	II	15	2.47	0.74		
	III	15	2.93	0.70		
	IV	15	4.60	0.51		
Apical third	1	15	2.13	0.35	<0.001 (S)	IV > III > II > I
	II	15	2.93	0.59		
	III	15	3.67	0.72		
	IV	15	4.67	0.49		

*One-way ANOVA was used to calculate the p-value; #Post hoc test was employed to identify the significant groups at 5% level; S: Significance

Table 4: Mean, standard deviation and test of significance of mean smear layer score between different study groups for different sites

Site	Groups	N	Mean	SD	p-value*	Significance# groups at 5% level
Coronal third	IV	15	1.67	0.72	<0.001 (S)	I, II, III > IV
	III	15	2.13	0.64		
	II	15	2.13	0.64		
	I	15	1.00	0.00		
Middle third	IV	15	2.00	0.76	<0.001 (S)	I, II, III > IV
	III	15	2.60	0.51		
	II	15	2.47	0.52		
	I	15	1.00	0.00		
Apical third	IV	15	2.47	0.52	<0.001 (S)	I, II, III > IV
	III	15	2.80	0.56		
	II	15	2.60	0.51		
	I	15	1.00	0.00		

*One-way ANOVA was used to calculate the p-value; #Post hoc test was employed to identify the significant groups at 5% level

develop a 'progressive preparation' in both vertical and horizontal directions. It has variable pitch and helical angle with progressive taper with no radial lands. Though it has negative cutting angle, its cutting efficiency improved due to modified K-blade design and progressive taper.[11,12]

The K3 endodontic NiTi rotary file system (Sybron endo, Orange, USA) was introduced in 2002. These files are designed with a wide radial land, which is meant to make the instrument more resistant to torstional and rotary stresses. It also features 'radial land relief', which aids in protecting the file from 'over engagement'. In the canal, thus, less instrument separation occurs. It has a variable pitch and helical angle with constant taper.[13,14]

The present study was carried out to evaluate the cleaning efficacy of manual and two rotary instrumentation systems, i.e. K3 and ProTaper rotary systems by observation of the residual debris and smear layer on the root canal walls under SEM.

Debris was defined as dentin chips and residual vital or necrotic pulp tissue attached to the root canal wall which in most cases is infected.[5]

Instrumentation during root canal therapy produces 1 to 2 µm thick irregular layer covering dentin, known as 'smear layer'.[15,16] Mc Comb and Smith[17] were the first to describe the smear layer on instrumented root canal walls. Smear layer is defined as 'an amorphous granular layer that

consists chiefly of hydroxyapatite and altered collagen along with ground dentin, predentin, inorganic debris and organic components, such as pulp tissue remnants, odontoblastic processes, saliva, blood cells and bacteria'. No smear layer is found on areas that are not instrumented.[18] According to many authors, this layer is directly created by instruments contacting the walls during canal preparation.[17,19]

Its removal is controversial. According to some authors, removal of smear layer improves the penetration of disinfecting agents, medicaments and obturating materials.[20] According toothers, its presence may prevent initial bacterial penetration of dentinal tubules.[21]

In order to dissolve debris and smear layer, chemical irrigation solutions are recommended along with mechanical instrumentation. In the present study, 3% sodium hypochlorite and 17% EDTA solutions were used for smear layer removal which is in accordance with the studies done previously.[22]

In the present study, it was observed that with none of the instrumentation systems, a completely clean root canal be achieved, which is in accordance with studies done previously[5,10] on root canal cleanliness.

In the present study, in each group average remaining debris and smear layer was greater in apical region than coronal and middle-third of the root canal. Normal root canal anatomy suggests that this apical region of the canal system is the narrowest portion. So, in this region, more contact with instruments produces more debris and also irrigation procedure cannot be successfully performed in this narrowest part. The difficulty in cleaning the apical third has also been reported.[4,5,23]

The SEM observations usually showed no debris and scattered areas of smear layer. These results were similar with studies done on cleaning efficacy of instruments.[24]

Scanning electron microscope analysis appears to be an adequate method to investigate the influence of endodontic instruments on the morphology of dentin surfaces and has been well described.

In the present study, it was seen that least debris and smear layer was obtained in the groups I than II, groups III and IV. This may be due its convex triangular cross-section that increases cutting efficiency and reduces the contact area against the canal wall and the absence of radial lands. This result is in accordance with the studies done previously where the cutting efficiency of K3 rotary instruments with stainless steel hand K-Flexo-file were compared under SEM and found more debris and smear layer in K3 rotary instrumentation group as they possess radial lands that make them less sharper and less efficient in cutting.[25]

There were no statistically significant differences between three groups—at any level concerning smear layer. As it has been shown that EDTA containing chelating agents may be partially responsible for effective cleaning of canal walls after instrumentation.

Moreover, the present study result indicates that on an average, the apical third of the canals was less clean (though statistically not significant) than the middle and coronal thirds regardless of the instrument used. This observation is also in accordance with other studies done on cleaning efficiency using different instrument systems.[5,14,22]

CONCLUSION

None of the instrumentation techniques cleaned the root canal completely. In the present study, however it was found that in groups I and II, root canal preparation was less time consuming and instrumentation more comfortable to work with while in group III, instrumentation is less expensive and provides better tactile sensation. Nevertheless, the result left an advantage to groups I and II concerning removal of debris and smear layer.

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