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ORIGINAL RESEARCH

Comparative Evaluation of Smear Layer and Debris on the Canal Walls prepared with a Combination of Hand and Rotary ProTaper Technique using Scanning Electron Microscope

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ABSTRACT

Introduction: The effect of smear layer and debris on the success rate of endodontic treatment has not yet been definitely determined. So the present study was aimed to evaluate the amount of smear layer and debris on the canal walls prepared with a combination of hand and rotary ProTaper technique using NaOCl and ethylenediaminetetraacetic acid (EDTA) alternately as root canal irrigants using scanning electron microscope (SEM).

Materials and methods: Eighty intact freshly extracted human permanent mandibular premolar teeth were collected and randomly divided equally into four groups. In group I canals were prepared with hand K-Flexofiles; group II with rotary ProTaper instruments; group III with rotary ProTaper instruments and final instrumentation was done with hand K-Flexofile; group IV with rotary ProTaper instruments and final instrumentation was done with RC-Prep and irrigated with 1 mL of normal saline. In all groups canals were irrigated using NaOCl and EDTA alternately. After instrumentation, the teeth were prepared for SEM examination using five-score indices for debris and smear layer at coronal, middle, and apical third levels. Statistical analysis was performed using chi-square test ($p < 0.05$) and Kruskal-Wallis test ($p < 0.05$).

Results: Statistically significant difference was observed between the groups in cleaning the apical third. Groups I and III showed better canal cleanliness compared to group II. The use of EDTA and NaOCl in group III was more effective in removing debris and smear layer compared to EDTA and normal saline in group IV. Regardless of the instrumentation technique employed and the irrigant used, the cleaning ability decreased in the apical third, resulting in higher debris and smear layer scores compared to coronal and middle third levels.

Conclusion: None of the instrumentation techniques in the present study could completely eliminate the smear layer and debris from the canal walls. Instrumentation of the canals with hand files after automated rotary preparation could result in cleaner canal walls.

Clinical significance: Alternate irrigation with NaOCl and EDTA is effective in the removal of debris and smear layer in the coronal and middle level, but the effectiveness in the apical third is less.

Keywords: Debris, Nickel–Titanium instruments, Rotary ProTaper, Scanning electron microscope, Smear layer.

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INTRODUCTION

Success in endodontic treatment depends on adequate preparation of the root canal space, reduction in the number of microorganisms, and obturation of the root canal system.[1] It is important that endodontic instruments remove dentin and pulpal debris from the entire root canal wall and create a canal free from bacteria. However, all endodontic instruments create dentin debris and smear

layer as a consequence of their action on root canal walls. Smear layer differs from the "dusty" pattern of superficial debris in that it is a layer of "muddy" material, composed of an amorphous layer of organic and inorganic debris and sometimes bacteria which is compacted against the dentin walls as a result of the rasping and trowelling action of endodontic instrument.[2]

Though the influence of smear layer on the success rate of endodontic treatment has not yet been definitely determined, it is currently considered important to promote techniques and products that can prevent the formation of layer, or eliminate this layer.[3]

Numerous studies using scanning electron microscope (SEM) indicate that irrigation with sodium hypochlorite (NaOCl) is effective in removing debris and cleaning organic matter from root canals. They also show that this type of irrigation leaves the prepared canal walls covered with a smear layer.[3] Smear layer is composed of both organic and inorganic substances and its removal usually requires a combination of NaOCl and acids or chelating agents (e.g., Ethylenediaminetetraacetic acid or EDTA).[4]

Although, effective in removing smear layer from coronal and middle third of the root canal, the combination of NaOCl and chelating agent was not effective in completely eliminating smear layer from the apical third of the root canal. Baker et al[5] concluded that the volume of irrigant was more important than the type of irrigant and recommended the use of biologically compatible solution, such as, physiological saline.

Both hand and automated rotary shaping of the root canals produce smear layer and debris but the amount of smear layer and debris produced is less by hand instrumentation technique than by automated rotary NiTi systems.[6] So it is important to develop a hybrid technique for endodontic treatment that will combine the advantages of both hand and automated rotary NiTi techniques and produce a minimal amount of smear layer and debris.

The purpose of this study was to evaluate using SEM the amount of smear layer and debris on the canal walls prepared with a combination of hand and automated rotary NiTi technique using NaOCl and EDTA alternately as root canal irrigants.

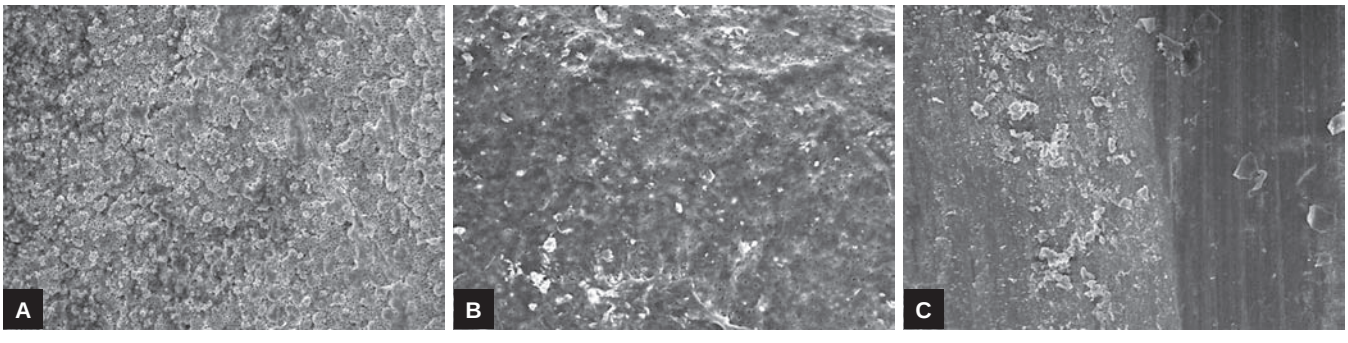
MATERIALS AND METHODS

The study samples comprised of 80 intact freshly extracted human permanent mandibular premolar teeth that were free of caries and restorations. The teeth were randomly divided into four groups, each group containing 20 teeth. Access cavities were prepared and working length (WL) was determined by a standard protocol where 10 K-file was inserted until it was just visible at the apical foramen and 1 mm was subtracted from this length.

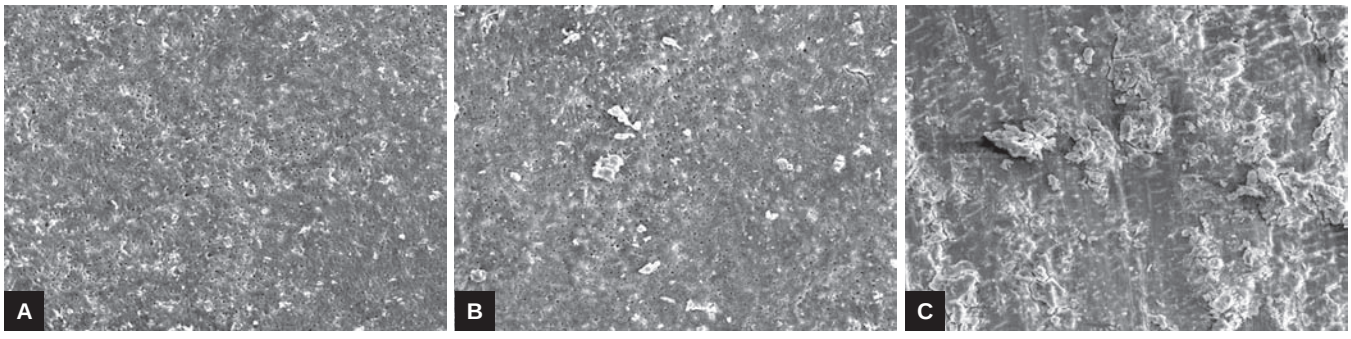
Group I: The manual group was hand instrumented with stainless steel K-Flexofiles by conventional mode of filing. The K-Flexofiles were inserted into the WL, twisted or bound and withdrawn by forcing them against the walls. Canals were enlarged apically using files in numerical sequence, from size 15 to size 25 K-Flexofiles. Each file was passively placed to WL, then filed peripherally until loose in the canal. Instruments were stepped back in 1 mm increments for three sizes. Coronal flaring was then performed with Hedstrom files before completing apical preparation with size 30 K-Flexofile. All canals were shaped and cleaned using files coated with RC-Prep and irrigated with 1 mL of 3% sodium hypochlorite after each instrument was used (Figs 1A to C).

Group II: The ProTaper group was instrumented with rotary ProTaper files in Anthogyr (1:128) reduction gear handpiece at 300 rpm by using crown-down technique. All the instruments were coated with RC-Prep prior to instrumentation and were used with a continuous, slight in and out passive movement. Irrigation of canals was carried with 1 mL of 3% sodium hypochlorite after each instrument was used. The instruments were never forced apically (Figs 2A to C).

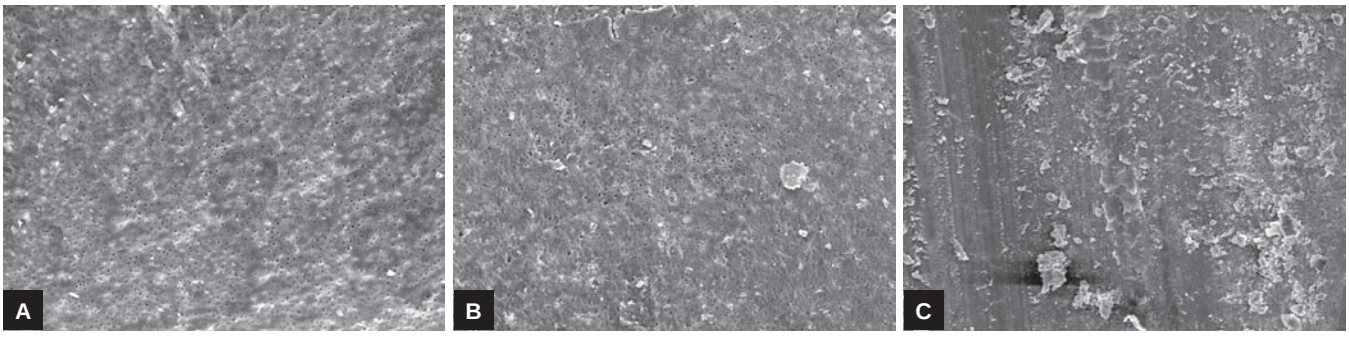
Group III: This experimental group was instrumented following the same protocol as in group II. Final instrumentation of the canal was completed with size 30



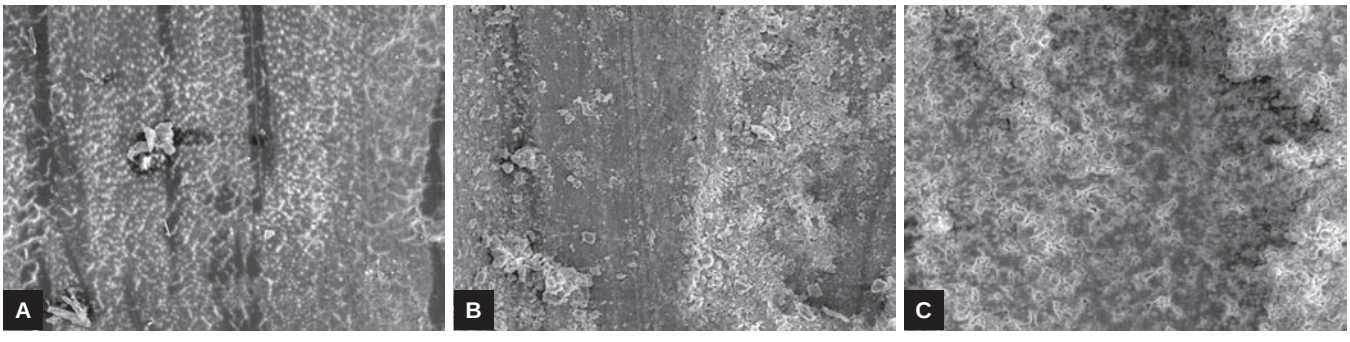
Figs 1A to C: Scanning electron microscopy photomicrographs of group I specimen: (A) Coronal third; (B) middle third; and (C) apical third



Figs 2A to C: Scanning electron microscopy photomicrographs of group II specimen: (A) Coronal third; (B) middle third; and (C) apical third



Figs 3A to C: Scanning electron microscopy photomicrographs of group III specimen: (A) Coronal third; (B) middle third; and (C) apical third



Figs 4A to C: Scanning electron microscopy photomicrographs of group IV specimen: (A) Coronal third; (B) middle third; and (C) apical third

K-Flexofile. If the 30 K-Flexofile was loose at the apex, then the final instrumentation was completed with 35 K-Flexofile. The hand filing was done in a circumferential filing motion. All canals were shaped and cleaned using files coated with RC-Prep and irrigated with 1 mL of 3% sodium hypochlorite after each instrument was used (Figs 3A to C).

Group IV: This experimental group was instrumented following the same protocol as in group II. All canals were shaped and cleaned using files coated with RC-Prep and irrigated with 1 mL of normal saline after each instrument was used (Figs 4A to C).

To neutralize the action of the irrigants, final irrigation for all the groups was carried out with 5 mL of normal saline solution. Absorbent sterile paper points were used to dry all the canals. The roots were sectioned in a longitudinal direction with the help of tapering fissure diamond bur along the groove on the buccal and lingual surface of the tooth. One half of each tooth was selected to examine the entire surface and each region (apical, middle, and coronal) of each canal using SEM (JEOL, JSM-840, Tokyo, Japan). The canal walls were quantitatively assessed for the amount of debris and smear layer. Debris were scored as follows:[7]

Score 1: Clean root canal wall, very slight debris.

Score 2: Slight debris.

Score 3: Moderate amount of debris, < 50% of the sample surface covered.

Score 4: Substantial debris, > 50% of the sample surface covered.

Score 5: Root canal sample was almost completely covered with debris.

Smear layer was scored as follows:[7]

Score 1: No smear layer, open dentinal tubuli.

Score 2: Slight smear layer, most tubuli were open.

Score 3: Homogeneous smear layer covering the major part of the surface, a few dentinal tubuli open.

Score 4: Homogeneous smear layer covering the surface, no open dentinal tubuli.

Score 5: Thick nonhomogeneous smear layer covering the surface.

The apical, middle, and coronal regions of the canal surface were graded (1–5) for debris and smear layer, assessed, and recorded. A statistical analysis was performed using chi-square test and Kruskal-Wallis test, to find out the significant difference between the study groups. The p-value of less than 0.05 was accepted as statistically significant.

RESULTS

None of the instrumentation techniques have been shown to completely clean the root canals. On average, more effective cleaning was observed in the coronal and the middle thirds of the canals as compared to the apical third. The scores for debris and smear layer are detailed in Tables 1 to 6. Comparison of scores for smear layer and debris at coronal, middle, and apical level is presented in Table 7. Table 1 shows the proportion of samples scored for smear layer at the coronal third level. Scores 1 and 2

Table 1: Proportion of samples scored for smear layer at the coronal level

	Coronal smear layer score					
Groups	*1*	*2*	*3*	*Total*	*Chi-square value*	*p-value*
I	7	12	1	20	6.685	0.351
	35.0%	60.0%	5.0%	100.0%		
II	4	14	2	20		
	20.0%	70.0%	10.0%	100.0%		
III	4	15	1	20		
	20.0%	75.0%	5.0%	100.0%		
IV	1	16	3	20		
	5.0%	80.0%	15.0%	100.0%		
Total	16	57	7	80		
	20.0%	71.3%	8.8%	100.0%		

Table 2: Proportion of samples scored for debris at the coronal level

	Coronal debris score					
Groups	*1*	*2*	*3*	*Total*	*Chi-square value*	*p-value*
I	6	13	1	20	8.105	0.231
	30.0%	65.0%	5.0%	100.0%		
II	3	12	5	20		
	15.0%	60.0%	25.0%	100.0%		
III	3	14	3	20		
	15.0%	70.0%	15.0%	100.0%		
IV	1	17	2	20		
	5.0%	85.0%	10.0%	100.0%		
Total	13	56	11	80		
	16.3%	70.0%	13.8%	100.0%		

Table 3: Proportion of samples scored for smear layer at the middle level

	Middle smear layer score						
Groups	*1*	*2*	*3*	*4*	*Total*	*Chi-square value*	*p-value*
I	1	9	10		20	7.455	0.590
	5.0%	45.0%	50.0%		100.0%		
II		13	6	1	20		
		65.0%	30.0%	5.0%	100.0%		
III	1	13	6		20		
	5.0%	65.0%	30.0%		100.0%		
IV	1	9	10		20		
	5.0%	45.0%	50.0%		100.0%		
Total	3	44	32	1	80		
	3.8%	55.0%	40.0%	1.3%	100.0%		

Table 4: Proportion of samples scored for debris at the middle level

	Middle debris score						
Groups	*2*	*3*	*4*	*5*	*Total*	*Chi-square value*	*p-value*
I	4	14	2		20	7.298	0.606
	20.0%	70.0%	10.0%		100.0%		
II	5	14	1		20		
	25.0%	70.0%	5.0%		100.0%		
III	6	14			20		
	30.0%	70.0%			100.0%		
IV	4	15		1	20		
	20.0%	75.0%		5.0%	100.0%		
Total	19	57	3	1	80		
	23.8%	71.3%	3.8%	1.3%	100.0%		

Table 5: Proportion of samples scored for smear layer at the apical level

	Apical smear layer score					
Groups	*3*	*4*	*5*	*Total*	*Chi-square value*	*p-value*
I	17	3		20	34.385	0.000*
	85.0%	15.0%		100.0%		
II	4	11	5	20		
	20.0%	55.0%	25.0%	100.0%		
III	19		1	20		
	95.0%		5.0%	100.0%		
IV	14	6		20		
	70.0%	30.0%		100.0%		
Total	54	20	6	80		
	67.5%	25.0%	7.5%	100.0%		

*Statistically significant

Table 6: Proportion of samples scored for debris at the apical level

	Apical debris score					
Groups	*3*	*4*	*5*	*Total*	*Chi-square value*	*p-value*
I	16	2	2	20	39.506	0.000*
	80.0%	10.0%	10.0%	100.0%		
II	1	11	8	20		
	5.0%	55.0%	40.0%	100.0%		
III	15	5		20		
	75.0%	25.0%		100.0%		
IV	9	11		20		
	45.0%	55.0%		100.0%		
Total	41	29	10	80		
	51.3%	36.3%	12.5%	100.0%		

*Statistically significant

were observed in 35 and 60% samples in group I, 20 and 70% samples in group II, 20 and 75% samples in group III, and 5 and 80% samples in group IV respectively. Table 2 shows the proportion of samples scored for debris at the coronal third level. Scores 1 and 2 were observed in 30 and 65% samples in group I, 15 and 60% samples in group II, 15 and 70% samples in group III, and 5 and 85% samples in group IV respectively. Table 3 shows the proportion of samples scored for smear layer at the middle third level. Scores 2 and 3 were observed in 45 and 50% samples in group I, 65 and 30% samples in group II, 65 and 30% samples in group III, and 45 and 50% samples in group IV respectively. In group IV, 5% of samples scored as 5. Table 4 shows the proportion of samples scored for debris at the middle third level. Scores 2 and 3 were observed in 20 and 70% samples in group I, 25 and 70% samples in group II, 30 and 70% samples in group III, and 20 and 75% samples in group IV respectively. The scores for the debris and smear layer at the coronal and middle third levels between the groups were not statistically significant

Table 7: Comparison of scores for smear layer and debris at coronal, middle, and apical level

Groups		*Coronal smear layer score*	*Coronal debris score*	*Middle smear layer score*	*Middle debris score*	*Apical smear layer score*	*Apical debris score*
I	Mean	1.70	1.75	2.45	2.90	3.15	3.30
	Std. deviation	0.57	0.55	0.60	0.55	0.37	0.66
II	Mean	1.90	2.10	2.40	2.80	4.05	4.35
	Std. deviation	0.55	0.64	0.60	0.52	0.69	0.59
III	Mean	1.85	2.00	2.25	2.70	3.10	3.25
	Std. deviation	0.49	0.56	0.55	0.47	0.45	0.44
IV	Mean	2.10	2.05	2.45	2.90	3.30	3.55
	Std. deviation	0.45	0.39	0.60	0.64	0.47	0.51
	Chi-square	6.001	4.794	1.902	1.548	30.844	31.381
	p-value	0.112	0.188	0.593	0.671	0.000*	0.000*

*Statistically significant

(p-value > 0.05) (Table 7). Table 5 showed the proportion of samples scored for smear layer at the apical third level. Score 3 was observed in 85% samples in group I, 20% samples in group II, 95% samples in group III, and 70% samples in group IV. Scores of 4 and 5 were observed in 55 and 25% samples in group II. Table 6 shows the proportion of samples scored for debris at the apical third level. Scores 3 and 4 were observed in 80 and 10% samples in group I, 5 and 55% samples in group II, 75 and 25% samples in group III, and 45 and 55% samples in group IV respectively. Score of 5 was observed in 40% samples in group II.

A statistically significant difference ($p < 0.05$) was observed between the groups with regard to the amount of debris and smear layer at the apical level. The samples in groups I (Fig. 1) and III (Fig. 3) showed lesser smear layer and debris score followed by group IV (Fig. 4) and group II (Fig. 2). Group II (ProTaper group) performed worst in the apical third of the root canal with regards to cleaning ability of the root canal.

DISCUSSION

One of the most important objectives during root canal instrumentation is the removal of vital and necrotic pulp tissue, dentin debris, and infected dentin, in order to eradicate most of the microorganisms from the root canal system.[8,9]

In the present study, a combination of rotary ProTaper system and hand K-Flexofiles used to instrument the canal walls was evaluated for cleaning efficiency. No statistically significant differences were observed between the groups with regards to removal of debris and smear layer in the coronal and middle third levels of the root canal. The root canal walls in the coronal and the middle thirds were comparatively cleaner than the apical third for all the instrumentation techniques. The cleaning efficiency of the instruments in coronal and middle third was better because of the use of irrigants, such as, sodium hypochlorite and EDTA; larger preparation in the coronal portion allowed larger volume of irrigants to be in contact with the canal walls; and positive rake angle of ProTaper instruments, which works like a curette, may help to eliminate dentinal shavings during instrumentation.

Failure of irrigants to reach the apical third results in the inefficient removal of smear layer and debris in the apical third irrespective of the instrumentation technique. Other authors have found that cleaning action is reduced toward the apex and, therefore, chelating agents are more efficient in the coronal and middle third of the root.[3,10-16] Regardless of the instrumentation technique employed, partially uninstrumented areas with residual debris were found in all the sections of canal. This finding has also been described by other authors.[2,17-20]

Statistically significant differences were observed between the groups in cleaning the apical third of the root canals. Group II performed the worst, while groups I and III were better in cleaning the apical third of the root canal compared to groups IV and II.

Apical extrusion of the material was found during instrumentation, which is consistent with earlier studies.[21-23] However, this trouble was not assessed, taking into account the less occurrence of exacerbation at the time of clinical endodontic work; this *in vitro* surveillance may not be pertinent in the clinical state of affairs.

Ability to efficiently clean the endodontic space is reliant on both irrigation and instrumentation.[24] The use of torque-control handpiece may reduce the cutting efficiency of the instrument, and the progression of the file into the apical third becomes difficult.[25] The mechanical endodontic devices induce more widespread dental filing than manual instrumentation and thus the quantity of dentinal shavings created is higher.[6] This explains that rotary ProTaper instrumentation was less effective in cleaning the root canal walls in the apical third. Thus, final instrumentation with hand K-flexofiles in group III was able to produce cleaner canal walls compared to group II.

The mechanical and chemical effectiveness of any kind of irrigation regime depends on its ability to reach every portion of the canal system. Canal curvature, size of apical enlargement, mode of distribution of the irrigant and its volume, and wetting properties are some of the factors that can affect the efficiency of the irrigation regimes.[3] The decline of efficiency along the apical part could be attributed to limited distribution of the irrigant, the obstacle being attributed to the optimal apical flooding of the irrigants. The alternate use of EDTA and NaOCl (group III) as irrigants performed better than EDTA used with normal saline (group IV). This finding has also been described by other authors.[3,14-16]

The scale defined by Hulsmann et al[7] was used to score each sample and was based on different numerical estimation scheme for smear layer and debris. However, the measurements of debris and smear layer were arbitrary and at best ordinal in nature and considered as one of the limitation in the assessment of micrograph. Also, the depth of debris and smear layer cannot be determined precisely under SEM. Preparation of specimen also induced artifacts.

Based on the results of this study, it can be recommended to use both hand and rotary instruments together for better debridement of the root canal. The clinical relevance of the present study indicated that none of the instrumentation techniques could produce completely clean canals, but the hand instrumentation and combination of hand and rotary ProTaper instrumentation demonstrated better results than the rotary ProTaper technique. Also, the use of EDTA and NaOCl alternately was better than EDTA and normal saline in cleaning the root canals.

CONCLUSION

Instrumentation of the canals with hand files after automated rotary preparation could result in cleaner canal walls. The use of EDTA and NaOCl alternately was more effective in removing debris and smear layer compared to EDTA used without NaOCl. Thus, instrumentation of the canals with hand files after automated rotary preparation and alternate irrigation with EDTA and NaOCl could result in cleaner canal walls.

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