Original Article

Experimental Study of Smear Layer and Debris Remaining Following the Use of Four Root Canal Preparation Systems Using Scanning Electron Microscopy

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Abstract

Background and Aim: Since the use of rotary nickel titanium instruments is an essential part of endodontic treatment, itis important to compare the root canal cleaning ability of these instruments. The aim of this study was to compare the amount of smear layer and debris remaining following the use of four rotary instruments: MTwo, Pro Taper, Race and BioRaCe.

Materials and Methods: A total of120 mesiobuccal canals of extracted human first molars with apical root curvature of 10° to 20°were selected. Working length of all roots was 19 mm. The roots were randomly divided into four groups of 30 specimens. After the preparation of access cavity, the roots were instrumented using rotary instruments according to the manufacturer's instructions. After each file, the root canal was irrigated with 2.5%sodium hypochlorite. Then the roots were studied under scanning electron microscope. The smear layer and debris scoreswere evaluated by 2 endodontistsusingSchafer and Schlingemannclassification. Kruskal -Wallis and Dunn tests were used for statistical analysis of results.

Results: The amount of smear layer produced by MTwo was lower than the other instrumentation techniques and it was significantly lower than that in BioRaCe system ($p<0.05$). The amount of debris was also lower in the mentioned group but the difference in this respect between groups was not significant. BioRaCe system had the highest level of remained smear layer while Pro Taper had the highest amount of remained debris.

Conclusion: Within the limitations of this study, it was revealed that MTwo instruments had greater capability of removing smear layer and debris than the BioRaCe system.

Key Words: Root canal preparation/instrumentation , Smear layer , SEM

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Introduction

Debris and smear layer removal before root canal obturation is among the important goals of root canal therapy. In all root canal cleaning and shaping techniques, formation of dentinal debris and smear layer is inevitabledue to the effect of instrumentation on root canal walls.

Smear layer has a protective role against the penetration of intracanal bacteria [1-2] but its impact on the outcome of endodontic treatment has not been well identified. However, due to its adverse effects such as contamination and obstruction of dentinal tubules, accumulation of microorganisms, limiting the penetration of antibacterial irrigating solutions into the dentinal tubules and reducing the seal between the restoration and dentinal walls, elimination or reduction of smear layer is recommended [3-12].

Considering the growing use of nickel-titanium (NiTi) rotary instruments in endodontic treatments and introduction of new files with various capabilities into the market, assessment of the ability of these instruments in production of smear layer and debris (amount, thickness and type) seems necessary. NiTiinstruments have greater capability for cleaning the coronal and middle parts of the root canal system rather than the apical segment [13-15]. Several studies have compared the smear layer and debris production by different rotary files.

Schafer et al. evaluated the shaping ability and cleaning efficacy of three rotary systems of Mtwo, K3 and RaCe during instrumentation of curved canals of human extracted teeth and showed that Mtwo offered superior results in terms of debris and smear layer removal compared to K3 and RaCe [13]. Burklein et al, in their study showed that Mtwo and Reciproc yielded better results in debris removal from the apical one-third of the canal compared to WaveOne and ProTaper; whereas, no significant difference was detected in residual smear layer between the 4 systems [16]. In a study by Foschi et al, ProTaper and Mtwo rotary systems were used for preparation of single-rooted canals and the coronal, middle and apical segments were evaluated. They reported that both instruments were able to achieve clean debris-free surfaces in coronal and middle thirds but failed to create dentinal surfaces free from smear layer and debris [17].

In a study by Paque et al, canal cleanliness in two systems of RaCe and ProTaper was compared by determining the amount of smear layer and debris. The two systems were not significantly different in terms of debris but it was demonstrated that RaCe was more efficient in cleaning the apical region [18]. In a study by Schafer and Vlassis, debris removal was better in RaCe system than in ProTaper ($P<0.001$) but the two systems had no significant difference in terms of smear layer [19]. In a study by Shahi, the ability of FlexMaster, RaCe and NiTiFlex K file instruments in root canal preparation was compared and the amount of debris and smear layer was evaluated using the Holseman method. Overall, FlexMaster produced less smear layer and debris than RaCe and NiTiFlex K file. NiTiFlex K file resulted in greater amount of smear layer in the apical third of the canal compared to FlexMaster [20]. Instrumentation with none of these systems resulted incompletely cleaned root canals [1,13, 19, 20]. Removal of smear layer, pulp residues and dentin chips and creating bacteria-free canal walls have been the objectives of many studies. Only a few electron microscopic studies have been conducted in this regard and in the majority of them only two systems have been compared. In the present study, the efficacy of 4 different rotary systems of BioRaCe, RaCe, Mtwo and ProTaper in debris and smear layer removal was compared using electron microscopy to obtain a good knowledge about the characteristics of NiTi rotary instruments.

Materials and Methods

In this experimental study, 120 extracted human mandibular first molar teeth with closed and completely formed apices were selected. The teeth were free from extensive coronal caries. After removal of tissue appendages, the teeth were immersed in 2.5% sodium hypochlorite solution for 2 hours. After this phase, the specimens were immersed in 0.9% normal saline solution until the completion of canal preparation. Periapical radiographs were obtained of the teeth using RVG system (Cygnus Technologies LLC, Cygnus Ray MPS, USA). After ensuring the absence of calcification, resorption or fracture in teeth, occlusal access cavity was prepared. To determine the apical curvature of the canals the long-axis technique (LAT) described by Hankins andElDeebwas used. A total of 120 mesiobuccal canals with 10-20° apical curvature and widening (radius) equal to a #10 or 15 file were selected.

Teeth crowns were cut using a diamond disc (D+Z, Diamond, Germany) yielding a working length of 19 mm in all samples. Next, the teeth were divided into 4 experimental groups of 30 each. Root canal preparation in the 4 groups was performed using one of the BoRaCe, RaCe, Mtwo or ProTaper systems according to the manufacturer’s instructions. Each instrument was used for 4 canals and after each instrument, the root canalwas flushed with 2 ml of 2.5% sodium hypochlorite solution.

A.Canal preparation with RaCe system (FKG Dentaire, Switzerland) using the crown-down technique: Started with #40 file with 10% taper and continued with #35 file with 8% taper followed by #30 with 6% taper, #25 with 4% taper and #20 with 2% taper until complete preparation of the canal.

B.Canal preparation with Mtwo system (VDW, Switzerland) using the single length technique: After ensuring canal patency using #10 hand K file, Mtwo instruments of #10 with 4% taper, #15 with 5% taper, #25 with 6% taper and #25 with 6% taper were used were used to the working length.

C.Canal preparation with BioRaCe system (FKG Dentaire, Switzerland)

D.Canal preparation with ProTaper files (Dentsply Maillefer, Switzerland): S1 was used until resistance was met. SX was used until resistance was met. Canal patency was ensured and working length was determined. S1, S2 to F1 were used.

After canal preparation, specimens were stored in 100% humidity to be used in the next step. For preparation of specimens for evaluation under electron microscopy, a small notch was created on the buccal and lingual surfaces of the roots using a rotary disc and the roots were split in half longitudinally using a chisel and a hammer. The specimens were then dehydrated, dried in a desiccator and transferred to electron microscopy lab with moist absorbent materials. The apical thirds of the roots were selected, coronal and middle thirds were covered with aluminum foils and the apical region was gold coated (10 nm) in a vacuum device.

In the next step, cross sections of dentinal tubules inside the canal under an electron microscope (Philips, Germany) at 750X magnification were photographed using a computer (Figure 1).

Obtained micrographs along with the prepared forms and classifications were handed to two endodontists (Table 1). Considering the non-normal distribution of data, Kruskal Wallis and Dunn test were used for statistical analysis of data.

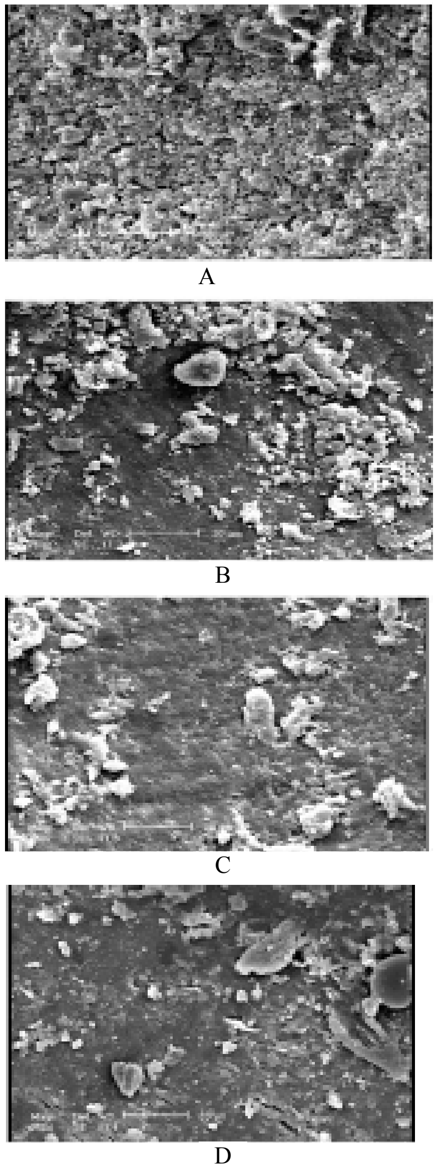

Figure 1: Smear layer and debris (750X magnification)

A. BioRaCe, B. Mtwo, C. ProTaper, D. RaCe

Results

The frequency distribution of the amount of smear layer and debris in the 4 understudy groups is demonstrated in Tables 2 and 3. The Kruskal Wallis test revealed significant differences between the 4 groups in terms of the amount of smear layer (P=0.006). However, the 4 systems were not significantly different in terms of the amount of debris (P>0.05). The lowest amount of smear layer and debris belonged to Mtwo system. Pairwise comparison of groups with Dunn's test with the consideration of an adjusted level of significance at P value=0.0083 using Bonferroni test yielded the following results:

Mtwo system caused less smear layer than BioRaCe ((P=0.229), but the amount of debris pro

Table 1: Classification of the amount of smear layer and debris according to Schafer and Schlingemann

Smear amount	Definition
1	No smear layer, open dentinal tubules in cross-sectional view
2	Small amount of smear layer, several open dentinal tubules in cross-sectional view
3	A uniform smear layer on the canal surface, only a small number of dentinal tubules are open in cross-sectional view
4	The entire canal surface is covered with a uniform smear layer and all tubules are obstructed
5	A uniform thick smear layer covering the entire canal surface
Debris amount	**Definition**
1	The canal wall is clean, very few particles are observed
2	Small debris accumulations
3	Large debris accumulations in a way that less than half the canal is covered with debris
4	More than 50% of the canal is covered with debris
5	Complete or relatively complete coverage of canal walls with debris

Table 2: Frequency distribution of smear layer in the 4 understudy techniques

Technique		Amount of smear layer					Total
		1	2	3	4	5	
Biorace	Number				4	24	28
	Percentage				14/3	85/7	100
Mtwo	Number				18	12	30
	Percentage				60	40	100
ProTaper	Number				7	19	26
	Percentage				26/9	73/1	100
RaCe	Number			1	7	20	28
	Percentage			0/9	32/1	67	100

Table 3: Frequency distribution of debris in the 4 understudy techniques

Technique		Amount of debris					Total
		1	2	3	4	5	
Biorace	Number	2	8	7	6	5	28
	Percentage	7/1	28/6	25	21/4	17/9	100
Mtwo	Number	3	13	5	8	1	30
	Percentage	10	43/3	16/7	26/7	3/3	100
ProTaper	Number	0	6	7	13	0	26
	Percentage	0	23/1	26/9	50	0	100
RaCe	Number	2	9	3	7	7	28
	Percentage	7/1	32/1	10/7	25	25	100

duced by BioRaCe was smaller (P=0.001); and the difference was not statistically significant.
ProTaper resulted in smaller amount of smear layer than BioRaCe (P=0.328) but in terms of debris, BioRaCe produced smaller amount of debris (P=0.520). However, these differences were not

statistically significant.
RaCe resulted in less amount of debris (P=0.495) and smear layer (P=0.223) than BioRaCe but the difference was not statistically meaningful.
Debris (P=0.061) and smear layer (P=0.019) formation in the Mtwo system was less than in ProTaper but the difference between the two systems was not significant either.
Comparison of Mtwo and RaCe showed that smear layer formation and debris in Mtwo was less than in RaCe. This difference for smear layer (P=0.062) and debris (P=0.031) was not significant.
Comparison of RaCe and ProTaper showed that smear layer (P=0.828) and debris (P=0.959) formation in the two systems were not significantly different.

Discussion

Controversy still exists regarding the advantages and disadvantages of smear layer but the majority of researchers believe that smear layer has to be reduced or removed before root canal filling because the organic debris present in the smear layer may act as substrate for bacterial growth. In addition, smear layer prevents the contact of sealer with canal walls and leads to microleakage in long-term [21-25].
Smear layer may interfere with the adhesion or penetration of sealer in the root canal system and prevent the penetration of gutta percha in thermoplastic techniques or compromise the bonding of composite resins to dentin. Smear layer removal increases the adhesion of sealer to dentin and enhances its tubular penetration. After smear layer removal, root canal filling materials can better adapt to the canal walls [26-32].
Application of NiTi alloy in endodontic instruments and rotary files caused a great revolution in root canal therapy. Considering the growing popularity of NiTi rotary instruments in endodontic treatments and introduction of new files into the market, assessment of the performance and efficacy of these systems for root canal preparation seems necessary. In this study, the cleanliness of canal and smear layer production were evaluated in 4 rotary systems by evaluation of the apical third under electron microscopy. Selection of the apical part for this assessment was due to the higher chance of accumulation of smear layer and debris in this region compared to middle or coronal thirds of the root [34].
In this study, mesial canals of the mandibular first molars were used because the effect of rotary file movements on dentinal walls is more evident in these canals due to their relatively small diameter and presence of curvature in their apical third. Also, greater amount of smear layer and debris are produced in them [13]. In electron microscopic images, the amount of smear layer and debris is usually very high; thus, in studies evaluating the effect of rotary files on smear layer and debris formation, 600-1000X magnification is usually used to assess higher number of dentinal tubules. In our study, 750X magnification was used.
Based on our obtained results, Mtwo system resulted in formation of less amount of smear layer and debris compared to other systems. It seems that this ability is due to the special design of Mtwo files. These files have a S-shaped cross-section and deep flutes and the distance between the cutting blades increases from the tip of the file towards the shank. This design helps reduce the risk of obstruction of the pathway and minimizes the accumulation of smear and dentinal chips. Also, rake angle of the file is positive in this system increasing its cutting ability and producing less smear layer. On the other hand, due to the large space between the cutting blades, a greater volume of debris is eliminated from the root canal system; which is in accord with the results of Schafer [13].
After Mtwo, RaCe ranked second in terms of yielding better results than BioRaCe and ProTaper which is in agreement with the findings of Paque [18]. Higher amount of smear layer and debris formation in RaCe and BioRaCe compared to Mtwo can be attributed to the design of instruments in the mentioned two systems because in these files the cutting blade has been converted into an arrow-shaped cutting surface and these changes are responsible for the reduced cutting ability and increased smear layer and debris formation by these files [19]. Our obtained results are in accord with those of Schafer et al, assessing debris formation by three systems of Mtwo, K3 and RaCe. Schafer showed that debris removal was significantly better by Mtwo than the other two systems [13]. Also, our study results confirmed the findings of Paratti and Paque [19]. The poorest

results belonged to ProTaper and BioRaCe. Higher amount of smear layer and debris produced in ProTaper compared to Mtwo and RaCe may be attributed to its cross-section design. Small distance between the cutting blades in the ProTaper system and progressive taper of these files may be the reason for higher amount of smear and debris production in this system [19]. On the other hand, reduction in number of files may also be responsible for increased formation of smear and debris in this group. Alapati et al. stated that production of dentinal debrisis the most important cause of fracture of ProTaper files sincedebris is caught between the canal wall and instrument flute of ProTaper files [19]. Furthermore, based on the results of Schafer and Vlassis, RaCe system offered better results than ProTaper; which is in concord with our findings [19]. In comparison between the 4 understudy systems, the least optimal results belonged to BioRaCe. Considering the similarity of the cross-section designs of BioRaCe and RaCe systems, it is assumed that smear layer and debris removal in the BioRaCe system should be similar to that of RaCe; but due to the smaller number of files in the BioRace system and also its greater degree of taper, it seems to have a decreased cleaning ability compared to RaCe producing greater amount of smear layer and debris [18]. However, BioRaCe files have recently been introduced to the market and no study has evaluated smear layer and debris production by them. Thus, comparison of our obtained results is not feasible.

Conclusion

Based on the results, it may be concluded that among the 4 rotary systems of Mtwo, ProTaper, RaCe and BioRaCe, the Mtwo system caused relatively less amount of smear layer and debris while the BioRaCe system resulted in greater amount of smear layer and debris formation.

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