Effectiveness of Rotary Endodontic Instruments on Smear Layer Removal in Root Canals of Primary Teeth: A Scanning Electron Microscopy Study

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Aim : *The present SEM study was undertaken to evaluate the effect of root canal instrumentation using both manual and rotary files in the root canals of primary anterior teeth.* ***Study design:*** *Thirty freshly extracted primary maxillary incisors were divided into 3 groups of 10 teeth each. In Group I, root canals were instrumented with rotary NiTi files; in Group II, the root canals were instrumented using manual NiTi K files and; in Group III, manual instrumentation was done with stainless steel K files. Longitudinal sections were prepared and processed for observation under SEM at the coronal, middle and apical thirds. Scoring of smear layer was done according to Hulsmann and the data obtained was subjected to statistical analysis.* ***Results****: Rotary files cleaned the coronal and middle thirds of root canals more effectively. Statistically there was no significant difference between the groups. Lowest score of 2.6 in the apical third of root canals was seen with hand NiTi files.* ***Conclusion:*** *Rotary instrumentation was as effective as manual instrumentation in removal of smear layer in the root canals of primary anterior teeth.*

Key words: *rotary instruments, SEM, files, smear layer, apical third*

INTRODUCTION

Over the years a variety of instruments and techniques have been proposed for root canal preparation. Nickel titanium alloys were first developed in 1962 and the alloy was named Nitinol, an acronym for the elements from which the material was composed; *ni* for nickel, *ti* for titanium and *nol* from the Naval Ordnance Laboratory. In 1988, Walia introduced the use of nickel titanium alloy for the manufacture of root canal files. [1] These alloys consist of 55% (w/w) nickel and 45% (w/w) titanium. Nickel titanium files have a 2-3 times higher elastic flexibility in bending and torsion as well as superior resistance to corrosion compared with stainless steel files.[2]

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During the recent decades several rotary nickel-titanium (NiTi) endodontic systems have been introduced into the market. Individual designs and features affect the performance of the rotary instruments. [2] Hero Shaper is a relatively new system developed in 2001 (Micro-Mega, France) Hero is an acronym for 'High Elasticity in Rotation.' Hero Shaper supplements the existing Hero 642. Compared with other rotary NiTi systems, Hero files have no radial lands but have a triple helix cross-section and a positive rake angle. The Hero Shaper files are supplied in ISO sizes of 20, 25 and 30, and in 0.4 and 0.6 tapers.[3].

During root canal preparation a smear layer is produced on the canal walls. The smear layer is a combination of inorganic and organic particles; including bacteria and tissue remnants. The removal of debris and smear layer from the root canal system prior to obturation is one of the primary aims of endodontic treatment.[4] The presence of an infected smear layer may prevent antimicrobial agents from gaining access to the infected dentinal tubules. [5,6]

The use of rotary files in primary teeth was first reported by Barr et al in 1999.[7] Most of the studies on the use of rotary files in primary teeth have primarily evaluated instrumentation time, shape of the prepared canals and cleaning capacity. [8-16] However, there are conflicting reports regarding the cleaning ability of rotary instruments in comparison to manual methods.[9,17-19]

Hence, the present SEM study was undertaken to evaluate the effectiveness of root canal instrumentation using both manual and rotary files in the root canals of primary anterior teeth.

MATERIALS AND METHOD

Approval to carry out all experimental procedures in this in vitro study was taken from the institutional review board and ethical committee. Thirty freshly extracted primary maxillary incisors with at least two-thirds of intact roots and without internal/external resorption were selected for the study. These incisors were extracted from healthy children as they were retained beyond the normal time of exfoliation. All teeth were radiographically evaluated and those teeth with evidence of internal resorption, calcification and defects were excluded. Teeth which showed excessively large root canal (initial file size ≥ #40) were not included for the study. The teeth were then washed with water and stored in normal saline for 1 week. The crowns were sectioned with a diamond disc and the remainder of the pulp tissue was removed with a broach. The patency of the canal was established using a #15 file. They were then randomly assigned to 3 experimental groups of 10 teeth each, according to the type of instrumentation used to clean and shape the canals. In Group I, root canals were instrumented with rotary NiTi files (Hero Shaper ,Micro-Mega, Besancon, France) using anthogyr hand piece (Dentsply, Switzerland); in Group II, the root canals were instrumented using manual NiTi K files(Dentsply, Switzerland) and; in Group III, manual instrumentation was done with stainless steel K files. (Mani inc., Japan)

All root canals were prepared by a single operator. The working length was kept 1mm short of the apex. Initially a guiding path was created with a #15 hand stainless steel file to the working length.

In Group I, initially the Endoflare was introduced 3 mm into the canal to eliminate the coronal interference as recommended by the manufacturer. All the instruments were used with an "in-and-out" (pecking) motion with light apical pressure [20] until resistance was felt. Initially the smaller instrument in the series was used, and then the sequence was repeated. Not all the instruments were required to complete the preparation.[20] Each instrument was used only thrice and then replaced with a new one.

In groups II and III, manual instrumentation of the canals was done using NiTi and stainless steel files, respectively. The canals were prepared according to procedure described by Grossman.[21] All canals were enlarged to three sizes larger than the initial file that was used. In all three groups, during instrumentation, the canals were irrigated intermittently with 5 ml of normal saline, since it does not alter the smear layer.

Following canal preparation, all the canals were flushed with normal saline and dried with absorbent paper points. Two longitudinal grooves were prepared on the palatal/lingual and buccal surfaces of each root with a diamond disk used with a high-speed water-cooled handpiece to facilitate vertical splitting of the 2 halves. The grooves were not deep enough to enter the canals. A plastic hand instrument was used to separate the 2 halves and the section with the most visible part of the apex was conserved, processed and gold sputtered .(Sputter Coater; SPI, Toronto, Canada) [22,23] The sections were examined under Scanning Electron Microscope (SEM) (JEOL 5200; JEOL,Tokyo, Japan) at the coronal, middle and apical thirds at 1000X magnification. The geometric centre of each third was observed. Scoring of smear layer was done according to Hulsmann [24] (Table 1) by a second operator who was blind to the groups and was trained prior to recording. Individual scores for the 3 groups were recorded. Scoring was repeated twice in order to remove any bias and the kappa value for intra-examiner reproducibility was k=0.94. Data obtained was subjected to statistical analysis using Chi square test, Kruskwal Wallis ANOVA for inter-group comparison and Mann Whitney test for intra-group comparison.

Table 1: Scoring of smear layer according to Hulsmann

Score 1	No smear layer, orifice of dentinal tubules patent
Score 2	Small amount of smear layer, some open dentinal tubules
Score 3	Homogeneous smear layer along almost the entire canal wall, only a very few open dentinal tubules
Score 4	The entire root canal wall covered with a homogeneous smear layer, no open dentinal tubules
Score 5	A thick homogeneous smear layer covering the entire root canal wall

RESULTS

The frequency of scores for smear layer observed in each group are given in Table 2. A thick homogeneous smear layer covering the entire canal wall (score 5) was more frequently observed only in the apical third of root canals in group I. (Fig.1) Minimal or no smear layer (scores 1,2) was observed more frequently in the coronal and middle thirds of root canals in all 3 groups.

Table 3 shows the mean scores observed in all groups. Lower mean scores for coronal and middle thirds of root canals were seen in group I whereas; for apical third of root canals a lowest mean score of 2.6 was seen in group II. (Fig. 2)

Intra-group comparison showed that in group I, a significantly lower mean score of 1.2 was observed in coronal third of root canals, in comparison to middle and apical thirds. ($p \leq 0.05$) In group III, there was a significant difference between coronal and apical thirds of root canals. ($p \leq 0.05$) (Table 4)

Root canals prepared using hand stainless steel files, showed smear layer with very few open dentinal tubules. (Fig. 3) With rotary instrumentation, smear layer was not present in the coronal and middle thirds. The dentinal tubules were clearly visible and free from smear plugs. (Fig. 4)

DISCUSSION

Root canal treatment of primary teeth can be both challenging as well as time consuming in children, especially during preparation of the canals. Considering that rotary files are more convenient to use and can facilitate root canal treatment, their application may be more appropriate to use in children. Canal preparation is one of the most important phases of primary root canal treatment and is mainly aimed at the debridement of the canals.[6]

The principles of mechanical cleaning and shaping of root canals are similar for both primary and permanent teeth. Curvatures and irregularities of the root canal walls of primary teeth can be cleaned efficiently with Ni-Ti instruments using clock-wise rotation resulting in removal of pulp tissue, dentin and necrotic residues from the canals, similar to manual filing.[8] However care should be exercised with the narrow and fine canals of primary teeth. Since the canals of primary molars are tortuous and ribbon-shaped, a crown down technique is not always required as more of the softer dentin may be removed [8] In this study primary anterior teeth with relatively straight canal morphology were selected.

Table 2: Frequency of scores obtained in three groups

Area	Scores	Group I		Group II		Group III		Total		Chi square value	P value
		n	%	n	%	n	%	n	%		
Apical third	2	2	20.0	5	50.0	4	40.0	11	36.7	6.823	0.338
	3	3	30.0	4	40.0	1	10.0	8	26.7		
	4	2	20.0	1	10.0	3	30.0	6	20.0		
	5	3	30.0	0	0	2	20.0	5	16.7		
Middle third	1	4	40.0	3	30.0	3	30.0	10	33.3	3.843	0.698
	2	5	50.0	3	30.0	4	40.0	12	40.0		
	3	1	10.0	3	30.0	3	30.0	7	23.3		
	4	0	0	1	10.0	0	0	1	3.3		
Coronal third	1	8	80.0	4	40.0	5	50.0	17	56.7	5.779	0.448
	2	2	20.0	3	30.0	3	30.0	8	26.7		
	3	0	0	2	20.0	2	20.0	4	13.3		
	4	0	0	1	10.0	0	0	1	3.3		

Table 3: Mean scores for smear layer at coronal, middle and apical third in all three groups

Area	Groups	Number	Mean± SD	KW ANOVA
Apical third	I	10	3.60±1.17	0.140
	II	10	2.60±0.70	
	III	10	3.30±1.25	
Middle third	I	10	1.70±0.67	0.486
	II	10	2.20±1.03	
	III	10	2.00±0.82	
Coronal third	I	10	1.20±0.42	0.120
	II	10	2.00±1.05	
	III	10	1.70±0.82	

Table 4: Comparison of mean scores within each group

Groups		Apical	Middle	Coronal
Group I	Apical	-	0.001*	0.000*
	Middle	Significant	-	0.066
	Coronal	Significant	Not Significant	-
Group II	Apical	-	0.337	0.131
	Middle	Not Significant	-	0.636
	Coronal	Not Significant	Not Significant	-
Group III	Apical	-	0.025	0.006*
	Middle	Significant	-	0.397
	Coronal	Significant	Not Significant	-

*p≤0.05 is significant

Fig.1: Presence of smear layer in apical third of root canals prepared using rotary NiTi files

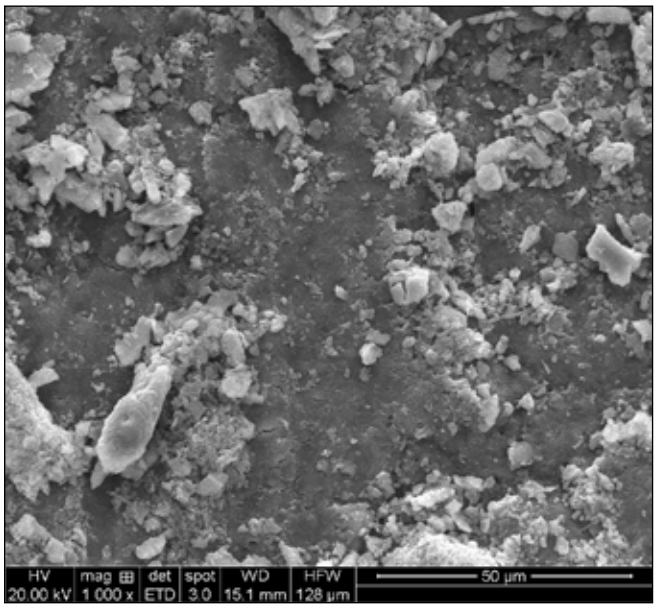


Fig.2: Apical third showing small amount of smear layer and some open dentinal tubules in root canals prepared using hand NiTi files

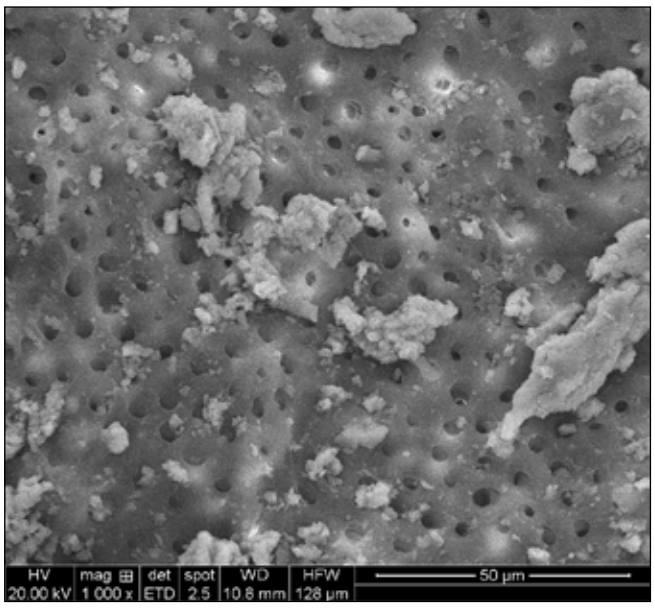


Fig.3: Smear layer with very few open dentinal tubules in root canals prepared using hand stainless steel files

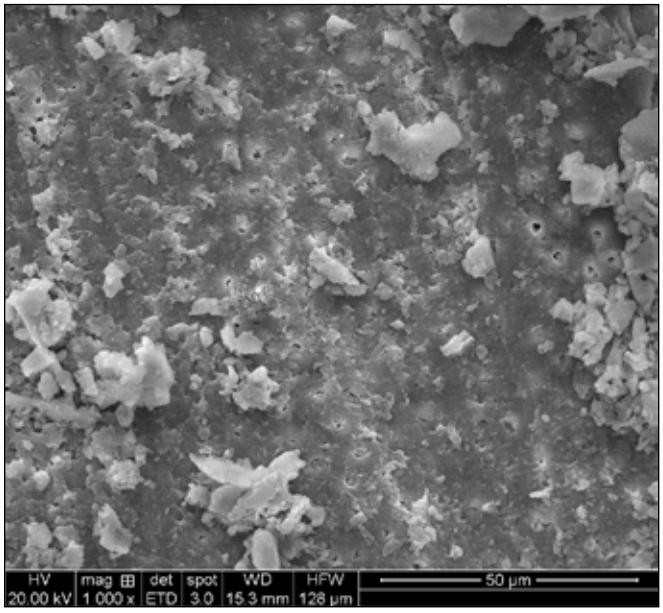
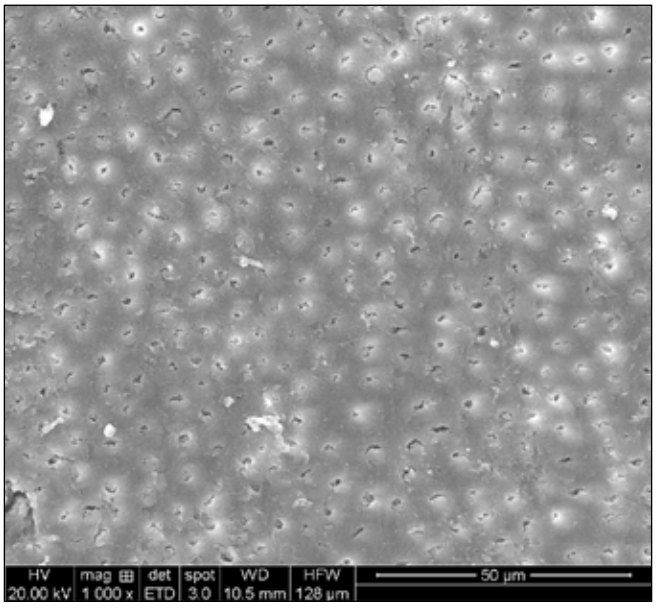


Fig.4: Presence of open dentinal tubules in coronal third of root canal prepared using rotary files



Hand instruments have been in use since more than 100 years and are still an integral part of endodontic cleaning and shaping procedures. Stainless steel instruments have been routinely used in root canal preparations. To counter the difficulties faced with the use of stainless steel instruments, NiTi instruments are being used for their flexibility and superior resistance to fracture. Hence, in our study, hand instruments made of stainless steel and NiTi weres compared with that of rotary NiTi files.

The use of the anthogyr hand piece is suitable in children due to its small head which gives better access and maximum visibility in posterior areas. It also has an auto stop feature and torque adjustment facility for each file. The use of such motors offers the advantage of reducing breakage and increasing working safety.

The Hero Shaper files also have a shorter metallic shaft, with a non-cutting tip, making it more appropriate for use in primary teeth. Its helix angle increases from tip to shank and so there is no screwing action of the file into the dentin.[25] Since there are no radial lands nor U-shaped blades there is no clogging of the flutes. The concept of the adapted pitch used for Hero Shaper files involves varying the length of the pitch or the cutting portion as a function of taper, thus making the instruments very flexible. The triple helix design of 3 equally spaced cutting edges offers lower and more uniformly distributed stresses.When a positive blade rake angle is present, the cutting action is enhanced[26] and the torsional load of the instruments is decreased.[27] The instruments with increased taper have advantages because they shape the canal in its final conical outline more easily than the cylindrical instruments. The instrument also has an 'anti breakage control feature' that allows the instrument to "unwind" so as to prevent the risk of fracture. It is, however, very important that the rotation speed remains constant and regular.

The Endoflare is a separate #25file with a short blade length of 15mm and a working length of 10mm that is suitable for shorter canal lengths in primary teeth. Its 0.12 taper and positive cutting angle allow for better cutting and excellent debridement. Its non cutting tip makes it safer for use in primary teeth. It is used only to flare the coronal third at the beginning of shaping. Coronal flaring can be done to remove any cervical interferences from the root canal entrances, which represent an obstacle to free access of endodontic instruments to the apical portion of the root canal. [28-30] This is particularly suitable in primary molars where there is an abrupt cervical constriction and dentinal shelf covering the canal orifice. [31]

Smear layer, which is mainly inorganic, is produced when a canal is instrumented [32] and no smear layer is found on areas that are not instrumented. [33] The advantages and disadvantages of the presence of smear layer, and whether it should be removed or not from the instrumented root canals, are still controversial. Under the scanning electron microscopy (SEM), the smear layer is viewed as a uniform, dense layer of an amorphous structure that completely obliterates the entrance to the dentin tubules and drastically reduces the permeability of the dentin. [34] The removal of smear layer significantly improves the tightness of the sealing in the coronal area, [35] and reduces the apical microleakage of the root canal.[36]

Studies regarding smear layer removal in primary teeth are less. The root canal system of the primary teeth should be cleaned, decontaminated, shaped, and enlarged, since the canal has to be filled with non-setting pastes. These pastes should penetrate the tubules in order to minimize bacterial contamination and not allow reinfection of the root canal system. [37]

SEM allows evaluation of root canal wall along their entire length. However, only the surface can be examined, and the depth of debris cannot be determined precisely. Different grading system for scoring the root canal surface is possible when a scoring system is used. In fact, magnification is a compromise between the need to observe large areas of the root internal surface, yet still maintaining the possibility of identifying specific structures.

SEM studies have shown that in comparison to the coronal and middle thirds, rotary files produced greater smear layer in the apical third of root canals. [38, 39] Clockwise motion of the rotary files pulls pulp tissue and dentin out of the canal. Rotary files were more effective possibly due to the triple cutting edges of

the files rotating at 7 turns per second. By using a crown-down technique together with the Endoflare when beginning the shaping procedure, more dentine was removed from the coronal and the mid-root portions. During manual instrumentation, although a step-back technique was used for root canal preparation, the files when used in a circumferential motion were not totally effective in cleaning the root canal walls at the different thirds. Another reason for the reduced efficiency of manual instruments in smear layer removal is the less taper of these files.

Our findings were in contrast to an earlier study, where-in hand stainless steel K files were more effective in cleaning the coronal third of root canals in primary molars.[13]The investigators felt that it may be due to the operators' tendency to place hand instruments further coronally; while the rotary preparation path is not affected by the operator.[13] Also they did not find a difference in cleanliness efficacy at the apical and middle thirds, between rotary files and hand stainless steel K files.[13] In the present study, manual instrumentation with NiTi files was found to be more efficient in cleaning apical thirds of the root canals. (Fig. 2) This was in accordance with an earlier study. [14] Studies that used dye penetration method [9,10] observed no significant differences in the cleaning capacity between manual and rotary instrumentation techniques in all three thirds of root canals of primary teeth.

An important fact that needs to be emphasized is that efficient cleaning does not necessarily depend only on the type of instrumentation technique used. In order to dissolve debris and smear layer, chemical irrigation solutions are recommended along with mechanical instrumentation. [24.35,40]

Irrigants comprising of chelating agents are often fortified with detergents to enhance their effectiveness. While Ethylene diamine tetra acetic acid dismantles smear layer by chelating calcium ions from remnant dentin fragments, citric acid dissolves the dentin fragments *via* a combination of chelation and acidic dissolution due to its low pH. Both irrigants may continue to dissolve calcium ions present in the canal walls below the smear layer, potentially weakening the underlying dentin.[4] Since saline does not influence smear layer removal [41] irrigation was carried out with saline in our study

In an SEM study on primary teeth, irrigation with 10%EDTA + 5.25% sodium hypochlorite showed conjugation of dentinal tubules, erosion of peritubular dentin, and break down in the intertubular dentin in almost all the three root thirds (cervical, middle, apical). [41] Sodium hypochlorite promoted the formation of a smear layer during shaping, and EDTA and citric acid facilitated smear layer removal in root canals of primary maxillary anterior teeth.[42]

Further SEM studies should be carried out using different instrumentation techniques together with chemical irrigants on root canals of primary teeth. Knowledge and experience of rotary system is essential in addition to the skill of the operator. Care should be taken not to over-extend apically and not to perforate the thin dentinal walls. A decreased working time can help maintain patient cooperation by diminishing the potential for tiredness. The use of appropriate rotary instrumentation systems appears to be a promising technique in the preparation of root canals of primary teeth.

CONCLUSIONS

1. Rotary files were as effective as manual files in the instrumentation of root canals of primary anterior teeth.
2. Rotary instrumentation resulted in more smear layer in the apical third than in the coronal and middle third of root canals.
3. Hand NiTi instruments were more effective in the apical third of root canals.

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