Original Research

Comparative evaluation of canal cleanliness at apical third using Self-Adjusting File and Wave One File with different irrigants: an *in vitro* scanning electron microscopic study

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Abstract

Aim. To evaluate the cleaning ability of two single-file rotary systems- Self-Adjusting File (SAF) and Wave one (WO) systems in removing the smear layer using sodium hypochlorite (NaOCl) + ethylene diamine tetraacetic acid (EDTA) and NaOCl + Qmix as irrigants at apical one-third of the root canal.

Methods. Forty extracted human mandibular premolars were selected and working length was determined. The canal was manually instrumented up to a number 25 size K-file. The roots were divided into the following groups with 10 samples each – Group 1 using SAF: Group 1a- 3% NaOCl + 17% EDTA, Group 1b- 3% NaOCl + Qmix. Group2 using WO: Group 2a- 3% NaOCl + 17% EDTA, Group 2b- 3% NaOCl + Qmix. In the SAF group, the irrigation was performed continuously using the special irrigation apparatus. In the WO group, syringe irrigation was done followed by final irrigant activation using passive ultrasonic irrigation (PUI). The roots were sectioned longitudinally and subjected to scanning electron microscopic (SEM) examination. The amount of smear layer was evaluated using a five score index at the apical third level. Statistical analysis was performed using the Chi-square test.

Results. Group 1 (SAF) showed better canal cleanliness at apical third compared to Group 2 (WO) with both irrigant combinations and the results were statistically significant ($p<0.05$). 3% NaOCl + Qmix was equally as effective as 3% NaOCl + 17% EDTA in removing the smear layer with no significant difference between them.

Conclusion. Within the limitation of this study, SAF in combination with 3% NaOCl + Qmix or 3% NaOCl + 17% EDTA should be used for removing smear layer in critical areas of the root canal.

Keywords: ethylene diamine tetraacetic acid, Qmix, scanning electron microscope, self-adjusting file, smear layer, sodium hypochlorite, wave one file

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Introduction

The success of root canal therapy is mainly dependent on the elimination of microorganisms from the root canal [1]. This can be achieved by thorough cleaning and shaping of the root canal followed by three-dimensional obturation of the root canal system. The biomechanical preparation done either by manual or mechanized techniques results in the formation of an amorphous irregular layer known as the "smear layer" on the root canal walls [2]. The smear layer is made up of inorganic and organic substances such as odontoblastic process fragments, microorganisms, necrotic debris, and dentin minerals [3].

Retention or removal of the smear layer remains a controversy. Diamond et al. [4] and Michelich et al. [5] suggested that the retention of the smear layer reduces dentinal permeability, thereby preventing bacterial exchange. On the other hand, the presence of a smear layer was found to harbor and protect bacteria within the dentinal tubules, thereby preventing the canal from being disinfected [6]. It also acts as a barrier against the penetration and

adhesion of obturation materials on root canal walls [7].

The removal of the smear layer helps eliminate the microorganisms by allowing deeper penetration of irrigants and intracanal medicaments. It also helps achieve a good seal with the obturating materials by allowing deep penetration of the root canal sealers and by intimate adaptation of the obturating material [8]. Effective mechanical instrumentation followed by thorough chemical irrigation is necessary to achieve proper disinfection of the root canal. Recent advances in rotary instruments have led to the development of single-file systems such as Self- Adjusting Files (SAF) and Wave One Files (WO).

SAF introduced by ReDent-Nova is a three-dimensional canal adaptation system with a hollow lattice that allows for simultaneous irrigation and uniform removal of the dentin layer when used in a trans line motion [9]. The WO files (Dentsply Maillefer Ballaigues, Switzerland) are reciprocating single-file systems, manufactured with M-Wire technology. This thermal-treatment process has provided the added advantage of increased flexibility and improved resistance to cyclic fatigue to this file system [10].

To maximize the disinfection of the root canal, the shaping and mechanical enlargement of the root canal must be accompanied by copious irrigation. Current irrigation methods involve the use of sodium hypochlorite (NaOCl) for its tissue dissolving ability and antimicrobial activity, followed by the use of a chelating agent like ethylene diamine tetraacetic acid (EDTA) to remove the inorganic portion of the smear layer [11,12]. But EDTA lacks antimicrobial properties [13].

Recent research suggests that Qmix (Dentsply Tulsa Dental, USA), a mixture of a bis biguanide antimicrobial agent, a polyamino carboxylic acid calcium-chelating agent, and a surfactant, might be as effective as EDTA in removing smear layers when used after an initial rinse with NaOCl [14]. In a systematic review, it has been reported that Qmix had better smear layer removal capacity when compared to MTAD, NaOCl, Tubulicid Plus, and phytic acid, but there was no conclusive result between Qmix and 17% EDTA [15]. Moreover, Qmix was found to have a superior antibacterial effect on E. *faecalis* when compared to the usage of single irrigation solutions like 2% CHX, MTAD, 17% EDTA, 0.2% Cetrimide and low concentration NaOCl [16]. The present study aims to evaluate the cleaning ability of two single-file systems, that is WO and SAF, in terms of removal of the smear layer using NaOCl + EDTA and NaOCl + Qmix at the apical one-third of the root canal.

Methods

Forty intact non-carious mandibular premolars with a single canal were selected, disinfected with thymol, cleaned of debris, and stored in normal saline. The teeth having a straight root canal with less than 5-degree curvature as determined by Schneider's method were included in this study. Teeth with caries, calcifications, and curved root canals were not included. All teeth were decoronated using a diamond disc at low speed with water coolant, and root length was standardized to 13 mm. The root canals were negotiated with K file # 15 and the working length was determined 1 mm short of the apex. All canals were enlarged to a 25-size K file by manual instrumentation and saline irrigation. The apical foramen of all teeth were sealed with casting wax, numbered, labeled, and randomly divided into four equal experimental groups of ten samples each.

Group 1: Self-Adjusting File (SAF)

SAF was used according to the manufacturer's instructions. The irrigant flow rate of 5 ml/min was set in the VATEA irrigation device and the file was gently inserted into the root canal and operated by in-and-out vibrations. The following irrigation protocol was followed:

Group1a: 3% NaOCl for 3 minutes and saline for 1 minute, followed by 17% EDTA for 1 minute;

Group1b: 3% NaOCl for 3 minutes and saline for 1 minute, followed by Qmix for 1 minute;

Group 2: Wave One (WO).

The WO file was used according to the manufacturer's instructions. The X-Smart plus endo motor was used in "Wave One" mode. A large WO file (#0.40/.08) was used for cleaning and shaping. The file was operated by inward pecking motion with short 2-3 mm amplitude strokes passively up to the determined working length. Irrigation was performed as mentioned below.

Group 2a: Syringe irrigation with 3% NaOCl (10 ml) and saline (3 ml) followed by 17% EDTA (3 ml). Final irrigant activation with PUI of 3% NaOCl (5 ml) for 1 minute, saline (2 ml) for 1 minute, and 17% EDTA (2 ml) for 1 minute;

Group 2b: Syringe irrigation with 3% NaOCl (10 ml) and saline (3 ml) followed by 17% EDTA (3 ml). PUI of 3% NaOCl (5 ml) for 1 minute, saline (2 ml) for 1 minute and Qmix (2 ml) for 1 minute.

Syringe irrigation was done using a 30-gauge closed-end needle 1 mm short of its working length. PUI was performed by the intermittent flush technique wherein the irrigants were delivered by syringe irrigation and activated using an ultrasonic tip size 20 (Irrisafe, Aceton) passively inserted into the canal 1mm short of its working length, driven by an ultrasonic device (Satellac, Aceton) with power set at 5. A fresh solution of each irrigant was replenished after every 20-second cycle. A total of 3 cycles of PUI were performed for 1 minute. In both groups 1 and 2, the total volume of the irrigants was kept at 15 ml for 3% NaOCl and 5 ml for saline, EDTA, and Qmix.

All the root canals were then irrigated with 5 ml of saline as the final rinse. The specimens were dried with absorbent paper points and allowed to dry at room temperature for 24 hours. Deep grooves were cut using a diamond disc on each root on the buccal and lingual surfaces. To avoid further contamination with artificial debris, the disc was not allowed to advance into the root canal space. The roots were longitudinally split into two halves along the groove with a chisel. One-half of each tooth with the most visible

part of the apical third was selected and prepared for SEM examination (Hitachi E 1010). After assembly on coded stubs, the specimens were placed in a vacuum chamber and sputter-coated with a 300 A° gold layer and subjected to SEM analysis. The smear layer was evaluated from images at x3000 magnification.

Scoring Criteria

Hulsmann scores were used for the evaluation of the smear layer [17].

Smear layer score:

- Score 1: No smear layer and all dentinal tubules were open;
- Score 2: A small amount of smear layer and some dentinal tubules were open;
- Score 3: Homogeneous smear layer covering the root canal wall and only a few dentinal tubules open;
- Score 4: Complete root canal wall covered by a homogeneous smear layer and no open dentinal tubules were observed;
- Score 5: Heavy, homogeneous smear layer covering the complete root canal wall.

Scores 1 and 2 represent "clean canal wall". Scores 3, 4, and 5 represent the "presence of smear layer". Results were statistically analyzed by Chi-square Test.

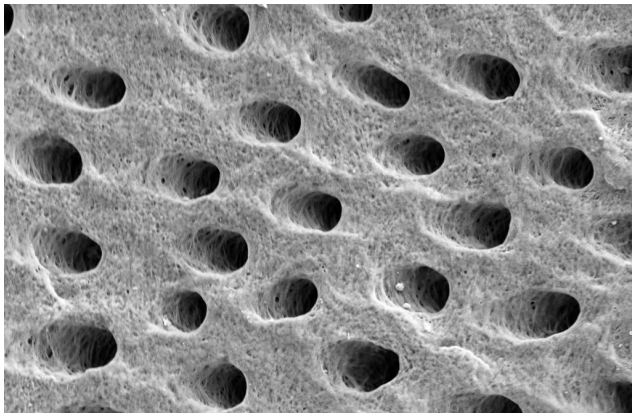

Figure1. Smear layer free open dentinal tubules at the apical level at x3000 on using SAF and 3% NaOCl + 17% EDTA as irrigant.

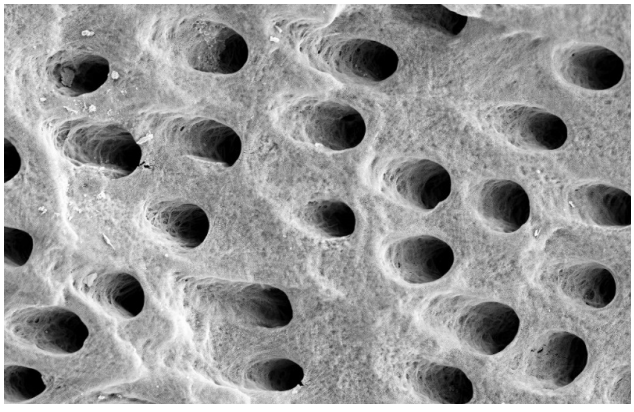

Figure 2. Smear layer free open dentinal tubules at the apical level at x3000 on using SAF and 3% NaOCl + Qmix as irrigant.

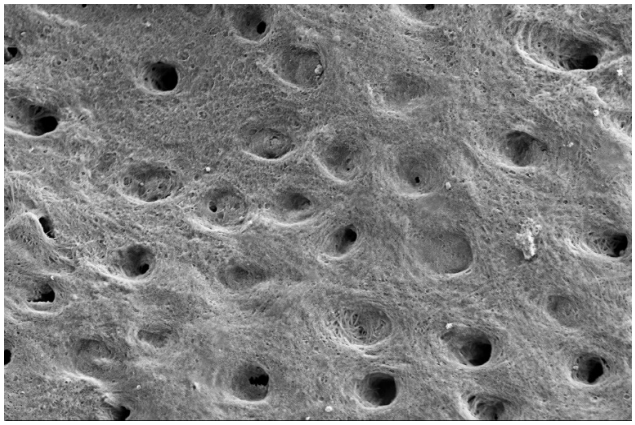

Figure 3. Smear layer blocked dentinal tubules at the apical level at x3000 on using WO and 3% NaOCl + 17% EDTA as irrigant.

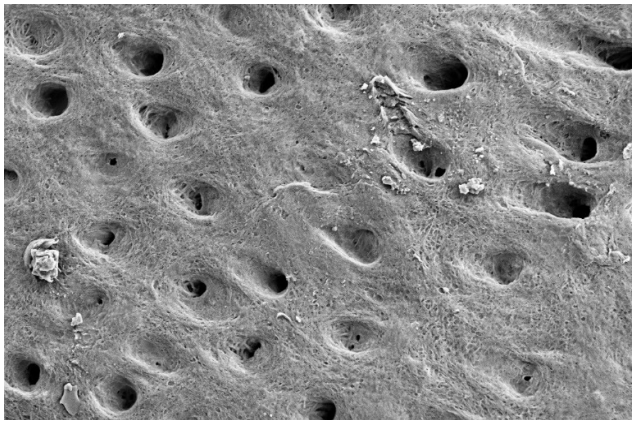

Figure 4. Smear layer blocked dentinal tubules at the apical level at x3000 on using WO and 3% NaOCl + Qmix as irrigant.

Results

Table I shows the comparison of smear scores for each group at the apical thirds. On comparing the smear layer scores, SAF resulted in 70% of canals being free of smear layer (Figures 1, 2), but WO was not effective in eliminating the smear layer (Figures 3, 4). Statistical analysis using the Chi-square test revealed a significant difference between the two systems when used in combination with NaOCl + EDTA and as well as with NaOCl + Qmix ($p<0.05$) (Table II). Both the irrigant combinations performed equally well, yielding 70% clean canals with SAF and only 10% clean canals with WO. There was no significant difference between NaOCl + EDTA and NaOCl + Qmix when used with different instrument systems (Table III).

Table I. Comparison of smear scores for each group.

Score	Group 1a	Group 1b	Group 2a	Group 2b	Pearson Chi-square value	*p-value*
1 Count Percentage within the group	2 20%	1 10%			18.925	0.0258
2 Count Percentage within the group	5 50%	6 60%	1 10%	1 10%		
3 Count Percentage within the group	3 30%	3 30%	5 50%	6 60%		
4 Count Percentage within the group			4 40%	3 30%		
Total Count Percentage within the group	10 100%	10 100%	10 100%	10 100%		

Table II. Comparison of SAF and WO in each irrigating agent.

Irrigant	Instrument		Fischer's exact Chi-square value for 20 cases	*p-value*
	SAF	WO		
NaOCl + EDTA Scores % within the instrument				
1	2 20%			
2	5 50%	1 10%	9.167	0.0271
3	3 30%	5 50%		
4		4 40%		
Total count	10 100%	10 100%		
NaOCl + Qmix Scores % within the instrument				
1	1 10%			
2	6 60%	1 10%	8.571	0.0355
3	3 30%	6 60%		
4		3 30%		
Total count	10 100%	10 100%		

Table III. Comparison of the irrigating agents in each instrument group.

Instrument	Irrigant		Fischer's exact Chi-square value for 20 cases	*p-value*
	NaOCl + EDTA	NaOCl + Qmix		
SAF Scores % within the irrigant				
1	2 20%	1 10%		
2	5 50%	6 60%	0.424	0.808
3	3 30%	3 30%		
4				
Total count	10 100%	10 100%		
WO Scores % within the irrigant				
1				
2	1 10%	1 10%		
3	5 50%	6 60%	0.234	0.971
4	4 40%	3 30%		
Total count	10 100%	10 100%		

Discussion

Chemo-mechanical preparation plays a vital role in the elimination of microorganisms in the root canal [18]. Recent years have witnessed a revolution in the development of novel rotary instrumentation systems to maximize debridement and reduce procedural errors. However, the predictable achievement of canal cleanliness, especially in the apical third, remains a challenge [19].

The results indicate that Group 1a (SAF with NaOCl + EDTA) and Group 1b (SAF with NaOCl + Qmix) produced clean canals in 70% of the samples. Group 2a (WO with NaOCl + EDTA) and Group 2b (WO with NaOCl + Qmix) resulted in only 10% of samples being free of the smear layer. This significant difference between the two groups can be due to the following reasons. SAF has gentle abrasive action producing less debris and the hollow lattice design allows for continuous flow of fresh and fully active irrigant throughout the procedure [20,21]. Moreover, SAF has a mild vibrating motion on the delicate mesh of the file within the continuously replenished irrigant, resulting in activation of the irrigant [22,23]. De-Deus et al. [24] and de Melo Ribeiro et al. [25] used SAF in oval-shaped root canals and reported that SAF was efficient in debriding oval canals because of its ability to adapt itself to the cross-section of the canal. Singla et al. [26] have suggested that in severely curved canals, SAF resulted in minimal dentin removal with more centered preparation and least canal transportation. On the contrary, Paranjpe et al. [27] reported inadequate apical preparation and irrigation using the SAF system, which might be due to differences in samples and testing methods.

In an earlier study, Bakthavatchalam et al. reported that the cleaning effect of SAF was better than WO files with 3% NaOCl and 17% EDTA delivered using a 30-gauge irrigation needle [28]. However, Jimna et al. [29] reported that WO files were equally good as SAF with irrigants delivered using a conventional syringe irrigating system and suggested that increased taper could be the probable reason for the better performance of WO files. The conventional closed-end needle irrigation system creates a vapor lock effect and precludes optimal delivery of irrigant to the apical area of the root canal. Studies have suggested that increasing the flow of the irrigant or inducing acoustic streaming in it improved the cleaning action of the irrigant [30,31,32]. So PUI was used to activate the irrigant in the WO group.

PUI is the most widespread non-cutting irrigation method performed with ultrasonically activated files. In PUI, the energy is transmitted from the file to the irrigant by ultrasonic waves, which produce streaming and cavitation of the irrigant, thereby disrupting the vapour-lock effect [33]. PUI generates a micro-acoustic current that causes hydrodynamic agitation of the irrigant and also promotes the cavitation effect by producing bubbles that rupture close to the dentin walls and aid in cleaning [34]. In this study, despite using PUI, the smear layer in the apical third of the root canal was not effectively removed by WO files. Similar results were reported by Khalap et al. [35]. The poor performance of WO files can be explained by the tendency of WO files to produce greater debris accumulation and thereby creating a burnishing effect when used in reciprocating motion [36,37]. But SAF has only a mild abrasive action and generates less smear layer [21,38]. Moreover, it has the advantage of mechanical scrubbing action with a continuous flow of fresh active irrigant, resulting in effective removal of the smear layer from the apical third of the root canal [22]. As an irrigant activation system, SAF was found to have better canal cleaning ability when compared to EndoVac, PUI, and syringe and needle irrigation [39].

The irrigant combinations of NaOCl + EDTA and NaOCl + Qmix were equally effective in removing the smear layer with no significant difference between them. The effective smear layer removal using Qmix could be attributed to the combined effect of its ingredients, that is, EDTA and Cetrimide. EDTA chelates and dissolves the inorganic content of the root canal by reacting with calcium ions, and cetrimide acts as a surface-active agent which enables better penetration of an irrigant into the root canal [40]. Similar results supporting the present study were reported by Dai et al. [14] and Stojicic et al. [41]. Venghat et al. reported that EDTA performed better in removing the smear layer than Qmix, though the results were not significantly different [42]. This difference in the results could be attributed to the difference in the scoring system used in the study. Arslan et al. suggested that the use of endoactivator and Er: YAG laser enhanced the smear layer removal ability of QMix in the apical thirds of the canals [43]. In a recent study, it was reported that the combined use of PUI with Qmix increased the canal cleanliness, especially in the apical third of the root canals [44].

SAF with an irrigation regimen using NaOCl + EDTA and NaOCl + Qmix was effective in removing the smear layer in hard-to-reach apical areas of the root canal when compared to WO files. The aggressiveness of the irrigant and the manner in which the irrigant is delivered determine the efficacy of an irrigant to remove the smear layer from the root canal walls [45]. The better performance of SAF shall be further validated by conducting clinical trials.

Conclusion

Within the limitations of this in vitro study, it can be concluded that

- SAF was very effective in cleaning the apical third of the root canal when compared to WO files using NaOCl + EDTA and NaOCl + Qmix as irrigants.
- The irrigant combination of 3% NaOCl and 17% EDTA were equally effective as 3% NaOCl and Qmix in removing the smear layer.
- Further clinical trials are required to validate the cleaning efficacy of SAF in teeth with complex anatomy harboring mixed biofilms.

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