ORIGINAL PAPER

Comparison of Three Activating Methods of Irrigation on Smear Layer- and Debris-Removal Efficiency After WaveOne Gold® Single File

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ABSTRACT

Background: An endodontic treatment consists in cleaning, shaping and filling the root canal system. Irrigation is the chemical part of the process that ensures the total removal of debris. Activating the irrigation solution will improve and accelerate the process. **Objective:** The aim of the study is to evaluate the removal of debris and smear layer at 1, 3, and 5mm from the foramen after needle irrigation, EndoActivator® and Irrisafe®. Sixty single-rooted teeth were prepared using Primary WaveOne Gold®. **Methods**: Teeth were randomly assigned to 4 groups (n=15): needle irrigation - Group A, EndoActivator® for 1 min - Group B, Irrisafe® for 1 min - Group C, Irrisafe® for 30 sec - Group D. Root canals were observed under a scanning electron microscope. Data were analyzed by Friedman and Wilcoxon tests. **Results:** Debris was significantly higher with group A compared to B, C, and D. Irrisafe® was significantly more effective in removing the smear layer than the other groups. However, activation techniques showed less debris and smear layer than needle alone nevertheless. **Conclusion:** Irrisafe® showed the best results regardless of time.

Keywords: single file, debris, smear layer, Irrigation, SEM evaluation.

1. BACKGROUND

Cleaning and shaping of root canal system is an essential step to endodontic treatment success (1). However, during shaping procedure, an amorphous and irregular layer on dentinal walls is created by the effect of instrumentation. Debris and smear layer have been shown to be a physical barrier between the root canal filling material and canal walls, thus favoring the occurrence of marginal leakage (1, 2).

Metallurgical properties and files design showed to be more decisive than the number of instruments used and their kinematics on the cutting efficiency, debris production and thus the cleaning abilities of the files (3). In order to simplify the root canal treatment sequences, single files were lunched in the market. WaveOne Gold® single file, was shown to be almost three times faster than multiple rotary files in achieving the same final shape (4).

Cleaning efficiency of mechanical instrumentation is insufficient, and adequate irrigation protocol should be implemented to improve cleanliness (2). Although it is accepted that NaOCl is the universal irrigating solution to digest the canal content, disinfect, and remove the debris from the canal space, however, EDTA 17% solution as a final rinse is recognized that it is essential to suppress the mineral component of the smear layer (5). To ensure an effective action, irrigants should be in direct contact with canal walls mostly in the apical third (6).

Moreover, it is demonstrated that inside the canal, needle irrigation delivers irrigants no more than 0 to 1.1 mm beyond its tip (7). Furthermore, presence of vapor lock (entrapped air bubbles) in the apical third portion might also hinder the exchange of irrigants and reduce the debridement efficacy of irrigants (6). Multi-vented needle creates almost no flow apically to its tip (8). Therefore, the simple use of needle technique seems to be insufficient to completely clean the canal, mainly in the apical area. To overcome anatomical and technical problems, different activation systems such as sonic and ultrasonic devices have been suggested to improve the distribution of irrigating solutions and irrigants flow (5).

The sonic activation with EndoActivator® (Dentsply-Sirona, Ballaigues, Switzerland) using disposable flexible polymer tips produces intra-canal micro-streaming and fluid agitation (9). Passive ultrasonic irrigation (PUI) is a noncutting method, and can be used in intermittent or continuous flow of irrigant (10), which transmits acoustic energy from a small diameter stainless steel file or a smooth wire to the irrigation solution (1). Hydrodynamic cavitation was shown to occur during PUI within the confinement of a root canal (11). Both sonic EndoActivator® (Satelec Acteon, Merignac, France) and ultrasonically Irrisafe® (Satelec Acteon, Merignac, France) activated files can be used in static or dynamic protocol in the root canal (12).

2. OBJECTIVE

The aim of the present study is to compare cleanliness of the root apical third following canal preparation with WaveOne Gold , after needle and activated irrigation. Different agitation protocols in dynamic and continuous delivery mode of irrigants including sonic and ultrasonic waves at 60 seconds were used as well as one group at 30 seconds. The null hypothesis is that there would be no differences between the different methods of irrigation in terms of debris and smear layer, at 1, 3 and 5 mm from the apex using scanning electron microscopy (SEM).

3. MATERIAL AND METHODS

Root Canal Preparation

This study was revised and approved by the scientific and ethics committees of the Lebanese University (CUMEB/D131/192018). A total of sixty extracted single rooted teeth, with mature apical foramen (Class I Vertucci classification) were selected. Two radiographies of both, mesial and buccal sides of the teeth were taken to assess canal morphology. Only roots with single straight canals, and an angle curvature inferior to 10° (according to Schneider's method) were included (13). Canals with complex configuration and calcified were excluded. Immediately after extraction, teeth were cleaned and stored in a Hank's balanced salt solution (HBSS). Crowns were sectioned at 17mm from the root tips, perpendicularly to their long axis with a diamond disk (Axis, Sybron Endo, Sybron Dental, Anaheim, CA, USA). To create a four walls access, a thermoformed plastic tube was fixed on the coronal part of all roots and adjusted for a total length of 21mm. Working length (WL) was set when a manual #10 K-file, under visual control of a loupe of 3x magnification, reached the foramen, and then reduced of 1mm. A #15 K-file was introduced in all root canals; once resistance was felt, the sample was considered eligible for the study. Canals accepting wider diameters than #15 K-file were discarded. All canals were prepared using WaveOne Gold® Primary (25/100, 0.07) (DTDS and DENTSPLY Maillefer) as a single-file reciprocating system according to the manufacturer's instruction after a glide path with a #15 K-file (Flexofile, Dentsply Maillefer, Ballaigues, Switzerland) to WL. The X-Smart IQ™ motor (Dentsply-Sirona, Ballaigues, Switzerland) designed and programmed for the reciprocating file was used in this study. Each file was discarded after being used for a single canal. Root canals were initially irrigated with 2mL of a 5.25% NaOCl, then with 2mL of the same solution after each file withdrawal from the canal, during all mechanical sequences. The Max-i-Probe® irrigation needle, 30 ga. x1", blue (Dentsply-Sirona, Ballaigues, Switzerland) was inserted as deep as possible into the root canal without binding. A small amount of Carbowax® (Dow Chemical Co, Midland, MI) was placed on all root tips to create a closed irrigation system (14).

The specimens were randomly assigned into four experimental groups (n=15) according to the root canal irrigating method technique. For all groups except group D, a final irrigation protocol was performed by a continuous delivery of solution as follows: 5 mL of 17% EDTA solution (Acteon Pharma, Merignac, France) for 60 seconds followed by 5mL of 5.25% NaOCl for 60 seconds. For Group D, the same protocol of final irrigation was conducted for only 30 seconds. A 5mL of distilled water was used between the final irrigants and subsequently for all groups.

a) Control group A: A conventional syringe with a Max-i-Probe® irrigation needle, 30 ga. x1", blue (Dentsply-Sirona, Ballaigues, Switzerland) was inserted to a maximum of 1mm shorter than the WL with a dynamic motion of 2mm push-pull amplitude for 60 seconds.

b) Group B, sonic activation (PSI 1 min): Irrigating solutions were activated using the EndoActivator® system (Dentsply-Sirona, Ballaigues, Switzerland) with a 20/.04 ISO size tip (the EndoActivator has a single operating frequency) to a depth of 2mm from WL with a dynamic motion of 2mm push-pull amplitude for 60 seconds.

c) Group C, passive ultrasonic irrigation (PUI 1 min): Irrigating solutions were activated with an ultrasonic insert Satelec Irrisafe® Tip #20/21mm coupled to a P5 Newtron® XS ultrasonic device (Satelec Acteon, Merignac-Cedex, France), at a power setting of 6, to a depth of 2mm from the WL with a dynamic motion of 2mm push-pull amplitude for 60 seconds.

d) Group D, passive ultrasonic irrigation (PUI 30 sec): The procedure was similar to the group C with an activation time limited to 30 sec.

Specimen preparation for Scanning Electron Microscope (SEM)

The canal orifices were plugged with cotton pellets and Cavit® (3M ESPE, Seefeld, Germany) to prevent penetration of debris during sectioning. A longitudinal groove was performed with a diamond disk (Axis, Sybron Endo, Sybron Dental, Anaheim, CA, USA). Using a dental chisel, each root was separated into two halves, which were placed in suitable supports for SEM evaluation (17). The specimens were allowed to dry overnight in a desiccator at room temperature. Each specimen was then coated with a gold-palladium layer and observed under an emission field scanning electron microscopy (SEM; AIS-2100 780, Seron, South Korea)

Field Emission Scanning Electron Microscopic Evaluation

Root canals were screened, and three micrographs for each root were taken at -1, -3, and -5mm from the apex at two different magnifications (500x, and 1,000x). Micrographs were saved, coded then distributed randomly for evaluation. A blinded scoring was performed independently. For calibration purposes, two endodontists examined 20 specimens,

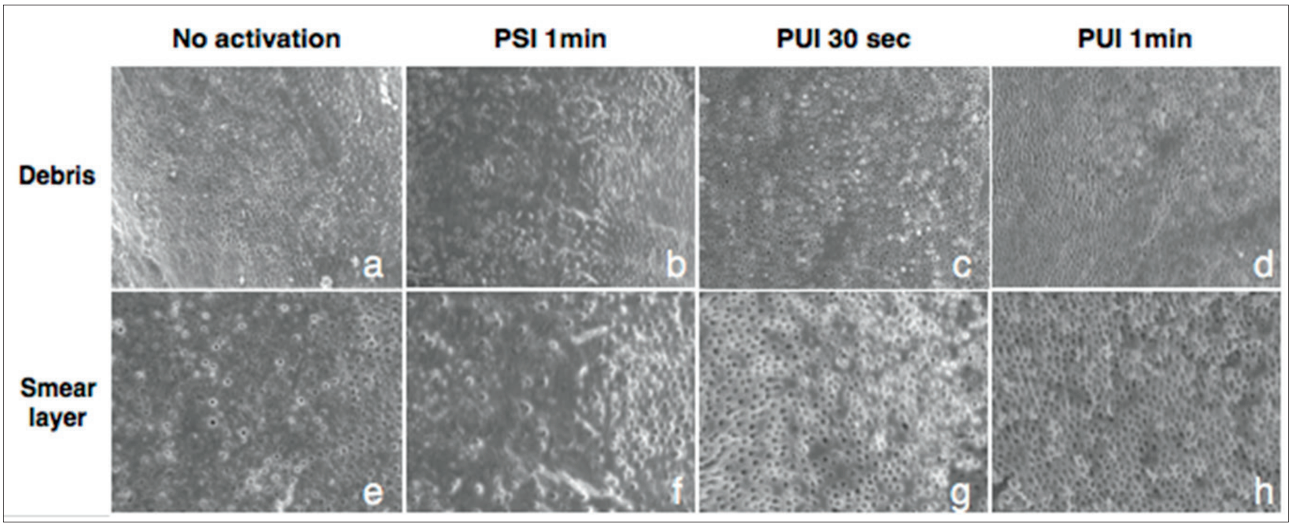

Figure 1. Representative samples of scanning electron micrographs after different modes of irrigation (magnification 500 x) showing debris (a, b, c, d) and smear layer (e, f, g, h) on dentin.

according to a 5-score index system codified by Hülsmann et al. This score index measures the presence of debris (dentine chips, pulp remnants and particles loosely attached to the canal wall): score 1 = clean canal wall, only very few debris particles, score 2 = few small conglomerations, score 3 = many conglomerations; less debris than 50 % of the canal wall covered, score 4 = more than 50% of the canal wall covered, score 5 = complete or nearly complete covering of the canal wall by debris. For smear layer (the presence, the quantity, and the distribution), the codified index system scores: 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 root canal wall (only a few dentinal tubules open), score 4 = complete root canal wall covered by a homogenous smear layer (no open dentinal tubules), and score 5 = heavy homogenous smear layer covering the complete root canal wall.

Cleanliness was then assessed at 500x for the presence of debris and at 1,000x for smear layer evaluation (16) (Figure 1).

Statistical analyses

Statistical analyses were performed using a software program (SPSS for Windows, Version 24.0, Chicago, IL). The level of significance was set at $\alpha = 0.05$. The outcome measurements of the study were the amount of debris and the amount of smear layer. Scoring debris and smear layer was performed by each evaluator separately. The Intraclass Correlation Coefficient (ICC) with 95% confidence interval was calculated to assess the reproducibility between measurements. The average value of the two evaluations was then obtained.

Kolmogorov-Smirnov tests were done to evaluate the normality distribution of variables. Since variables were not normally distributed, non-parametric tests were used. Friedman tests were conducted to compare the mean outcomes within distances and Wilcoxon tests were used to compare measurements between the four groups at 1mm, 3mm and 5 mm from the apex.

Kruskal-Wallis tests followed by multiple comparisons tests were performed to compare the total amount of debris and the total amount of smear layer in the apical third among groups.

4. RESULTS

Reproducibility of measurements

The intraclass correlation coefficient in each group was high indicating an excellent reproducibility of measurement of the amount of debris and smear layer between the evaluators (ICC>0.892). The average measurement of both evaluators was used for statistical analyses.

Comparison of the total amount of debris

In the third apical, the mean amount was significantly higher with group A (-p-value=0.034); no significant difference was found between groups B, C and D (-p-value=0.908) (Table 1).

	Groups	N	Mean	Std. Deviation
Debris at 1mm	A	15	1.210	.170
	B	15	1.227	.283
	C	15	1.157	.192
	D	15	1.220	.269
Debris at 3 mm	A	15	1.507	.326
	B	15	1.223	.377
	C	15	1.200	.275
	D	15	1.237	.339
Debris at 5 mm	A	15	1.420	.358
	B	15	1.287	.493
	C	15	1.193	.192
	D	15	1.193	.244
Debris Total	A	15	1.379	.201
	B	15	1.246	.276
	C	15	1.183	.126
	D	15	1.217	.242

Table 1. Mean amount of debris among groups

Comparison of the total amount of smear layer

In the apical third, the mean amount of smear layer was significantly higher with groups A and B, it was significantly lower with C and D (-p-value<0.05); no significant difference was found between groups A and B (-p-value=0.836) and between C and D (-p-value=0.663) (Table 2).

	Groups	N	Mean	Std. Deviation
Smear layer at 1mm	A	15	2.060	1.2403
	B	15	2.137	.6994
	C	15	1.653	.4510
	D	15	1.693	.7174
Smear layer at 3 mm	A	15	1.910	.9158
	B	15	1.870	.7068
	C	15	1.320	.3369
	D	15	1.357	.5806
Smear layer at 5 mm	A	15	2.017	1.0535
	B	15	1.270	.4784
	C	15	1.143	.1545
	D	15	1.053	.1060
Total smear layer	A	15	1.996	.815
	B	15	1.759	.381
	C	15	1.372	.199
	D	15	1.368	.268

Table 2. Mean amount of smear layer among groups

5. DISCUSSION

The disinfecting ability of mechanical instrumentation has been reported to be sketchy. The majority of published studies were limited mainly to continuous rotary files. Data, using reciprocating instruments, remains insufficient (4). A study by Feghali et al 2019 conducted on WaveOne Gold and Reciproc Blue in term of cleanliness of canal walls, using needle irrigation showed better results with WaveOne Gold rather than with Reciproc Blue. Despite the rigorous irrigating volume protocol, the reduced preparation time used by reciprocating single files, plays a negative role in removal of debris and smear layer (15, 17).

Studies have shown that more efficiency can be obtained, when irrigants get in direct contact with the entire canal walls. However, conventional irrigation alone, fails to clean properly the coronal, middle and apical thirds of the root canal, leading to an inadequate removal of smear layer (18). In the present study, WaveOne Gold® was chosen as a single file working with reciprocity motion to compare the amount of debris and smear layer left after different irrigation methods.

"In vitro" studies have several advantages, such as the aptitude to ensure uniformity and variables control. Thus, in this protocol and in order to simulate "in vivo" clinical conditions (access cavity of 4 walls); a thermoformed plastic tube was fixed on the coronal part of the roots creating a constant reservoir for irrigants. An "in vitro-closed" irrigation system was created with an apical plug wax to imitate the resistance in extruding irrigant solution through the foramen (19) and to investigate a more difficult situation with the presence of vapor lock at the apical third (6). Moreover, checking intra-examiner and inter-examiner was mandatory to control the results. Intraclass Correlation Coefficient (ICC) values showed high concordance in both intra and inter-examiner.

Studies on Max-i-Probe® irrigation needle (30G) recommended its use; smaller diameter provided better apical third cleaning of the root canals (20). However, conventional irrigation lacks to clean properly the coronal, middle and apical thirds of the root canal leading to an adequate removal of the smear layer (19). The present study revealed that the amount of debris and smear layer within distance in the needle group, are significantly different. They were also significantly higher when simple needle irrigation was used which is in concordance with Kuhn et al. (21).

Passive sonic irrigation (PSI) and passive ultrasonic irrigation (PUI) are noncutting irrigation protocols. Studies have shown the superiority of passive ultrasonic irrigation on sonic and needle irrigation in terms of cleanliness of root canals (14) which is in accordance with our results. In terms of debris elimination, both PSI and PUI showed to be efficient in the apical third. The main difference was found in the amount of smear layer between PSI and PUI. Group C and D showed better cleanliness compared to group B.

Ultrasonic activation of irrigants enhances its action due to a synergetic effect of streaming and cavitation, as well as to a rise of temperature (22). However, Macedo et al 2014, concluded that the increase in chemical effect by ultrasonic activation of the irrigant is not due to temperature elevation. Recommendation for activation time of PUI, varies from 20 seconds to 5 minutes (19, 20). Activation time for a maximum of one minute was demonstrated to be efficient in removing smear layer from the apical region (7, 17). To prevent any heating and damaging to surrounding structures, ultrasonic power transmitted to irrigants must be used in low intensity (11). Discrepancies in the interpretation of different data led us to use low intensity in ultrasonic activation. With the continuous flow of irrigant protocol, the external temperature is likely to drop from 37°C to 32°C (23). The current investigation used the continuous flow technique, in order to simulate clinical conditions. Heating the surrounded tissues (24, 25), and flooding the whole root canal system with irrigant could be more efficient in removing smear layer.

Regarding the ultrasonic mode used, most experiments were performed using static irrigation rather than dynamic irrigation (26). In the present study, irrigants were activated for 30 and 60 seconds in a dynamic mode at low intensity. The results showed that there was no difference in term of debris and smear layer at the apical third between both PUI for 30 and 60 seconds. The continuous flow mode of irrigation plays a major role in cleanliness of dentinal walls and compensates the reduced time of activation. This procedure distributes irrigants all over the dentinal walls, and is enhanced in the dynamic mode, even at low intensity of ultrasonic activation. This might explain the results obtained in both group C and D. More studies must be conducted in this field to clarify the phenomena and to set up a well-defined protocol.

PUI (passive ultrasonic irrigation) is considered unsuitable by some investigators since it is impossible to prevent the ultrasonically activated instrument from touching the canal walls. The increase of the temperature of the irrigation solution is higher with stiffer files (24). To avoid undesirable morphological changes or untimely increases of temperature (23), non-cutting threads ultrasonic tips with blunt working-end tip of #20 instruments were used at a low ultrasonic intensity.

NaOCl is the most widely used irrigant in endodontics. It showed bactericidal and organic tissue solvency properties (2). After shaping and cleaning of the canal, it is recommended to complete cleanliness with a final rinse using 15%

or 17% EDTA solution followed by 1%–6% of NaOCl (27). There is no consensus on which solution should be ultrasonically activated (11, 15, 26). In this study, both final irrigants EDTA and NaOCl were activated, while incorporating distilled water in between. Distilled water, is supposed to neutralize the effect of irrigants and helps preventing deposition of salt occluding dentinal tubules. Moreover, the reaction between EDTA and NaOCl is exothermic and mixing them together results in a rapid and dramatic decrease of free chlorine (28) and gas formation before neutralization (29).

A numerical evaluation scheme was used after SEM analysis to rate the cleaning efficacy of three different techniques (16). SEM studies might present some methodological limitations, as bias can occur, both from canal wall selection and scoring (30). Although this study might not be conclusive for evaluating cleanliness of canal walls, after reciprocating instruments, further studies should be conducted to assess the efficiency with other types of reciprocating instruments and compare results with the present investigation.

6. CONCLUSION

Within the limitations of this study, the results showed that in continuous flow of irrigant with a dynamic mode of activation, PUI was better than PSI and needle irrigation in term of cleanliness of the apical third. No significant difference was found between the Irrisafe® groups at 1 min and 30 seconds which could be more safe and suitable on dentinal walls with the same efficiency.

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