The Effectiveness of using Sonic and Manual Dynamic Irrigation Techniques to Remove the Smear Layer on the Apical Third of a Root Canal Wall

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Abstract

A smear layer can inhibit root canal sterilization and adaptation of root canal filling material on the apical third of a root canal wall. To eliminate this problemt, proper irrigation materials and techniques are needed. This study aimed to obtain more information about cleaning the smear layer on the apical third of a root canal wall that is irrigated using sonic and manual dynamic irrigation techniques. Thirty-two whole-extracted mandibular second premolars were divided into two groups. The teeth in Group 1 were irrigated using manual dynamic techniques, while the teeth in Group 2 were irrigated using sonic techniques. A scanning electron microscope (SEM) was used to inspect the cleanliness of the smear layer in the teeth in both groups. Then, a scoring method was used to determine the percentage of examination area in which the smear layer had been removed. The Kolmogorov-Smirnov test was used to analyze the data. There was no significant difference between Group 1 and Group 2 ($p = 0.56$); thus, no statistically significant difference was observed between both types of irrigation techniques. However, the sonic irrigation technique was better at cleaning the smear layer on the apical third of a root canal wall than the manual dynamic irrigation technique.

Experimental article (J Int Dent Med Res 2017;10(Special Issue): pp.744-750)

Keywords: Cleaning the apical third of a root canal wall, sonic irrigation technique, manual dynamic irrigation technique.

Received date: 17 August 2017 **Accept date:** 19 September 2017

Introduction

The aim of a root canal treatment is to eliminate the micro organisms left in the root canal and prevent their regrowth. The use of a root canal treatment technique increases the success of the treatment by 98%.[1] To obtain that outcome, the endodontic triad, which consists of preparing the access cavity, cleaning and shaping the root canal, and obturation, were introduced.[1] It is difficult to eliminate the infected vital pulp remnants, necrotic tissue, and bacteria in the complex root canal system using manual or rotary instruments because they can produce a smear layer.[1-5] A smear layer is a coating that consists of dentin, odontoblast process (also known as Tomes' fibers), pulp tissue, and bacteria, which can clog the dentinal tubules, the lateral portion of the root canal, the isthmus, and the main root canal.[4,6,7] The size of the particle that can clog the connection between the main root canal and the dentinal tubules, the lateral canal, and the isthmus, especially on the apical third of the root canal, ranges between 0.5µm and 15µm. This particle impedes the penetration of the medication used to sterilize the root canal and also inhibits the adaptation of the obturation material.[8]

It has been reported that the apical third portion of a root canal is more difficult to clean than the coronal and middle third portions.[8] This is due to the complexity of the apical third of a root canal, for example: the fins, cul-de-sacs, accessory canal, isthmus, the amount of dentinal tubules, and the formation of thevapor lock.[8] The vapor lock is a gas column trapped in the apical of a narrow close-ended canal; it is formed as a result of the hydrolysis process of NaOCl that releases ammonia and carbon dioxide.[3, 8, 9]

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Irrigation is intended to remove the smear layer. The type of material and the technique used for the irrigation impact its effectiveness. Although there are different kinds of irrigation materials, NaOCl is often preferred. However, when used alone NaOCl can not eliminate inorganic debris from a root canal, so it is often combined with ethylene diaminetetra acetic acid (EDTA) that has been proven to be effective in dissolving in organic debris.[6,10-13]

There are several types of irrigation techniques; these are generally classified as manual and machine-assisted irrigation. Passive-manual, brushes, and manual dynamic irrigation methods are classified as manual techniques. Machine-assisted irrigation techniques include rotary-brushes, sonic irrigation, and ultrasonic irrigation.[3,9] The passive-manual technique is commonly used in a root canal treatment. The irrigating solution is streamed along the root canal using a 27-G needle. However, this technique can only extract the irrigating solution 1mm beyond the needle tip.[14] This is problematic because the needle tip can usually only go no further than the coronal third. It can only reach the middle third, so it is not an effective way to clean the apical third.[3,8] Debridement using EDTA and NaOCl with a 27-G monojet is only effective in the coronal and middle third of the canal; it is not as effective in the apical third.[8]

To cleanse the apical third of the canal, a special irrigation technique is needed that can increase the circulation and reach the penetration depth of the liquid in the tubular dentin. Thus, it is important to use a technique that can enable the irrigating solution to generate a safe hydro dynamic effect in the root canal terminal by vibrating the dentinal debris and the smear layer in the apical third after the preparation is complete, until it is pushed out to the coronal without any side effects. This can be accomplished using manualdynamic, sonic, and ultrasonic techniques.[8]

The manual dynamic irrigation technique relies on the irrigating solution's chemical properties along with hydro dynamic activity that is activated manually using gutta-percha until the working length is reached. This method is effective because the gutta-percha can be activated to reach the apical third in order to optimize the penetration of the irrigating solution.[3,4,8,15] Sonic irrigating techniques have been reported to be able to enhance the penetrating action and debridement mechanism of the root canal by using vibrations that produce hydro dynamic effects.[16-19] Previous studies have shown that the sonic vibration irrigation technique is better at cleaning dentinal debris and removing the smear layer than the passive-manual irrigation technique.[3,8,16-21]

In both the manual dynamic technique and the sonic technique, the irrigating solution delivers a hydro dynamic effect into the root canal, so the smear layer is expected to be more effectively and efficiently removed.[3,8,16] The manual dynamic technique and the sonic technique produce a more effective result than the passive manual technique and other techniques, although it has been reported that a smear layer still remains after using those techniques.[8] However, a comparison of the ability of these two techniques to remove the smear layer has never been conducted. Therefore, it is important to investigate the difference between using manual dynamic and sonic techniques to cleanse and remove the smear layer on the root canal wall on the apical third.

Methods

This experimental laboratory study was conducted at the Conservation Dentistry Clinic of the Faculty of Dentistry at the University of Indonesia and the Biomedical Technology Laboratory of the Interdisciplinary Post Graduate Program at the University of Indonesia. The study's independent variables are: sonic and manual dynamic irrigation techniques. Its dependent variable is apical third cleanliness. Its confounding variable is root canal preparation.

The study's samples included medical waste, which consisted of 32 extracted human mandibular premolar teeth (medical research ethics) that met the following inclusion criteria:
Mandibular premolar teeth with an average length of 20± 2mm;
Single-rooted teeth with a straight root canal;
An apical closure and no defect on the root canal surface.

The exclusion criteria were:
Dilacerated teeth;
Multi-rooted teeth;
Teeth with no apical closure and a defect on the

root canal.

The mesial-distal aspect of each single-rooted mandibular premolar tooth with apical closure that has no defect on its root surface was then examined using radiography to observe the root canal anatomy. Each tooth was then cleaned and soaked in saline solution while waiting for the research process to begin. The apical patency was established with a #15 K-File until the end of the file was seen. Then, the working length was measured until it was 0.5 mm shorter than the working length of the #15 K-Filein this position. The samples were prepared using NiTi rotary instruments with ProTaper X-Smart (Dentsply®, Tulsar), using crown down techniques andsix files (Sx—F3). Two longitudinal grooves were made on the lingual and buccal surface of each root using a disc diamond bur and a low speed hand piece with a water cooler to facilitate the vertical cutting by using a chisel after the instrumentation and irrigation were completed. Then, each tooth was randomly numbered and randomly allocated into two groups, with the same number of samples in each group.

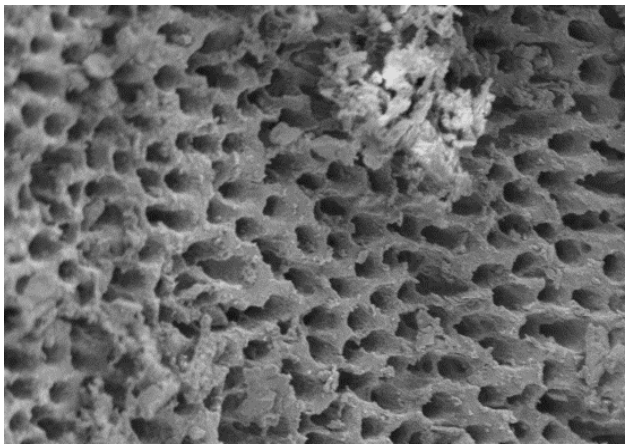
The root canal irrigation solutions were prepared by using 2.5ml NaOCl 2.625% in between instrumentation. The final irrigation solution was 2.5ml NaOCl 2.625%, 2.5ml EDTA 17%, and 2.5ml NaOCl 2.625%.

Group 1 (n=16): The root canals in this group were irrigated using the manual dynamic technique with a 27-G irrigation needle. The solution was administered into the canal with light pressure, then gutta-percha was inserted into the canal and activated in and out for 30 seconds.

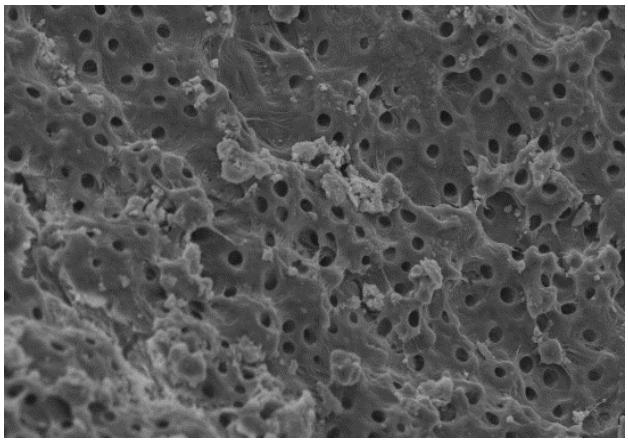
Group 2 (n=16): The root canals in this group were irrigated using the sonic technique with special tips, and then they were activated with vibration for one minute.

The root canals were dried using paper points, and the orifice was closed using temporary restorations. Immediately after drying, a stainless steel chisel was used to divide each sample vertically into two equal parts, according to the groove that was made at the beginning of the experiment. One part of the tooth was randomly chosen to be examined using SEM (Figure 1).

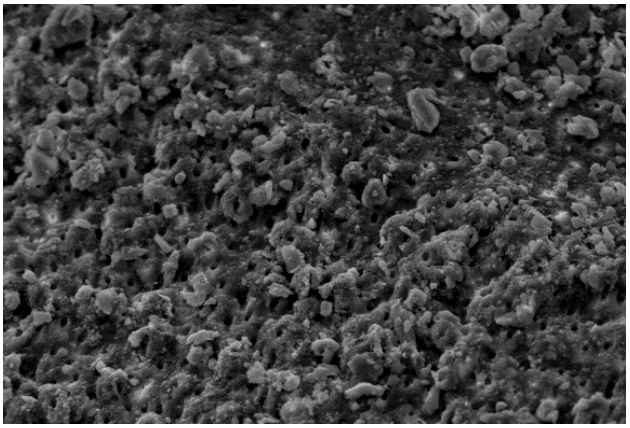
Figure 1. Examination of the apical third area of a tooth section



2A



2B



2C

Figure 2. SEM Photomicrographs;
Figure 2a. SEM photomicrograph scored as 0;
Figure 2b.SEM photomicrograph scored as 1;
Figure 2c. SEM photomicrograph scored as 2

An SEM photomicrograph was taken with 1000x standard magnification on three different points of the apical third of the root canal. Then,each image was digitally saved and scored using a double blind procedure.[5] The following scoring method was used to evaluate the cleanliness of the smear layer on the apical third of the root canal:
Score of 0: >75% of the apical third is free from the smear layer (Figure 2a).
Score of 1: 50–75% of the apical third is free from the smear layer (Figure 2b).
Score of 2: <50% of the apical third is free from the smear layer (Figure 2c).

Statistical analysis
Two groups of categorical data were tested using a non-paired parametric test. A chi-squared test was used to evaluate the extent to which the smear layer was removed from the apical third of the root canal wall. The significance level was set at P <0.05.

Result

Of the 32 samples, five (15.6%) had a score of 0,five (15.6%) had a score of 1, and 22 (68.8%) had a score of 2. In the sonic irrigation group, four (25%) of the samples had a score of 0, three (18.8%) had a score of 1, and nine (56.3%) had a score of 2. In the manual dynamic irrigation group, one(6.3%) sample had a score of 0, two (12.5%) had a score of 1, and 13 (81.3%) had a score of 2.

The data was statistically tested using the Kolmogorov-Smirnov test for two groups because the data did not qualify for the chi-square test; the mean value (p) between the sonic irrigation group and the manual dynamic irrigation group was 0.699 (p> 0.05). These results demonstrate that the significance value is more than the probability value (p), so there is no statistically significant difference between the sonic irrigation technique and the manual dynamic irrigation technique in terms of their ability to effectively clean the apical third of the root canal wall.

Groups	Smear layer cleanliness score on the apical third of a root canal wall						Total	
	0		1		2			
	n	%	n	%	n	%		
Sonic Irrigation	4	25	3	18.8	9	56.3	16	*P=0.699
ManualDynamic Irrigation	1	6,3	2	12.5	13	81.3	16	
Total	5	15.6	5	15.6	22	68.8	32	

Table 1. Smear Layer Score Distribution after Irrigation with Sonic and Manual Dynamic Techniques.
*Using the Kolmogorov-Smirnov Statistical Test

As seen in Table 1, the percentage of sonic irrigation technique (25%) samples that received a score of 0 was higher than the percentage of samples that underwent the manual dynamic irrigation technique (6.3%), and the percentage of sonic irrigation technique (18.8%) samples that received a score of 1 was higher than the percentage of samples that underwent the manual dynamic irrigation technique (12.5%), and the percentage of sonic irradiation technique (56.3%) samples that received a score of 2 was less than the

percentage of samples that underwent the manual dynamic irrigation technique (81.3%). This suggests that the sonic irrigation technique is more effective in cleaning the apical third of the root canal wall than the manual dynamic irrigation technique, although the differences between the two techniques were not statistically significant.

Discussion

In the present study, irrigation materials using both NaOCl and EDTA were applied in the root canal for 30 seconds. It has been reported that the use of NaOCl for 30 seconds reduces the number of micro organisms in root canals.[22] In addition, using EDTA for less than 30 seconds has been found to be effective in cleaning the smear layer, although it took longer to achieve optimal effectiveness.[23,24] The use of a combination of irrigation solutions and appropriate irrigation techniques not only effectively dissolves the organic and inorganic components of the dental pulp, it also eliminates bacterial contamination, cleans the smear layer, and reaches areas of the anatomy that can not be prepared properly due tothe anatomic variations of root canals.[3,4]

The present study used a modified, simpler version of the scoring method used by Ring.[22] The result showed that the statistical significance (p) between the sonic irrigation technique group and the manual dynamic irrigation technique group was 0.699 ($p > 0.05$). Thus, there was no statistically significant difference in the level of hygiene in the root canal wall in the apical third area between the sonic irrigation technique group (Endo Activator®, Dentsply®, Tulsar) and the manual dynamic irrigation technique group. In a study by Jiang et.al. that compared the sonic irrigation technique and conventional irrigation techniques, the sonic irrigation technique was more effective at cleaning the dentine debris than conventional techniques.

This finding is similar to the result reported by Al-Obaida in a study that evaluated the clearance of dentine and smear layer debris, suggesting that sonic irrigation techniques are more effective than conventional techniques that use irrigated syringe needles.[17-19] However, a study conducted by Torres et.al. comparing smear-layer cleaning of instrumented root canals reported that sonic irrigation techniques did not improve the smear-layer cleaning in the apical third of a root canal in comparison to conventional irrigation techniques using NaOCl and EDTA irrigation materials.[18]

In a study comparing the use of active irrigation techniques (manual dynamic) and passive irrigation (manual) Bronnec et al. found that active irrigation techniques were more effective in penetrating the root canal and exchanging irrigation fluids than passive irrigation techniques.[15] Some studies have found that both sonic and manual dynamic irrigation techniques are better, both for their ability to clean the smear layer and facilitate irrigation fluid exchange in comparison to passive irrigation techniques using irrigation needles; however, no previous studies have directly compared the two irrigation techniques.[8, 18]

The activation of sonic vibration (Endo Activator®. Dentsply®, Tulsar) and manual dynamics produces vibrations of 1–6 kHz and 3.3 Hz, respectively, which can have a hydrodynamic effect that contributes to physical displacement and liquid breakdown.[3,8] This may be the reason why no significant difference was found between the ability of these two techniques to clean the root canal walls in the apical third. In addition, in the present study, both the sonic irrigation technique and the manual dynamic irrigation technique were only activated for 30 seconds. This can cause hydro dynamic effects and irrigation material displacement, making each technique less effective in cleaning the smear layer, resulting in no significant difference between them in terms of their hygiene capabilities. Other studies have compared irrigation techniques using a longer application time of up to 3 minutes; they have reported that dentine debris disposal might be impacted by a shorter application time.[3,8]

Uroz-Torres et.al. compared the use of sonic irrigation techniques and manual irrigation techniques; they reported that there was no difference between them in terms of cleaning the smear layer; more over, they found that these techniques only clean the third and middle area of the corona in comparison to the third area of apex, which still had a smear layer.[18] However, in the present study, the percentage of samples with a score of 0, which shows that the root canal wall was cleaner than the smear

layer, was greater than 75%; and four (25%) of the sonic irrigation technique samples had a score of 0 while only one (3.1%) of the manual dynamic irrigation technique samples had that score.

This could be due to the fact the vibrational frequency of the sonic irrigation technique (Endo Activator®. Dentsply®, Tulsar), which has a range of 1–6 kHz, is higher than the vibrational frequency of the manual dynamic irrigation technique, which is only 3.3 Hz. Thus, it can be assumed that the acoustic vibrational speed and frequency in the sonic irrigation technique is more efficient.[18] Additionally, the vibration of the tip on a sonic irrigation technique, combined with the short distance of the up and down motions, can reach up to 10,000 cycles per minute (cpm), optimally, synergistically resulting in strong hydro dynamic phenomena, destruction, and smear layer and biofilm debridement.[3,8,9]

In the samples that received a score of 1, it appears that the sonic irrigation technique was slightly better (18.8%) in cleaning 50–75% of the surface wall from the smear layer than the manual dynamic irrigation technique (12.5%). In the sonic irrigation technique samples that received a score of 2 (56.3%), <50% of the surface was clean and free of a smear layer in comparison to the manual dynamic irrigation technique samples (81.3%) that also received a score of 2.

The results show that the manual dynamic irrigation technique is less effective at cleaning the smear layer than the sonic irrigation technique. This may be due to the fact that manual dynamic technique increases the hydro dynamics of the irrigation fluid by using gutta-percha, which corresponds to the final result of preparation, and the irrigation was moved up and down 2–3mm throughout the working length, only acting in the vertical direction.

In contrast, a sonic irrigation technique can produce an oscillation amplitude as a back-and-forth movement with a combination of up and down movements to act in both the vertical direction and the horizontal direction. This can lead to more optimal hydro dynamics for the irrigation fluid. In addition, in the manual dynamic technique the hydro dynamic irrigation fluid is produced by hand, which can result in operatorfatigue in a clinical setting; thus, it can be assumed that the expected 3.3Hz vibrational frequency is not achieved optimally.[4,9]

The overall score results demonstrate that the sonic irrigation technique is slightly better than the manual dynamic irrigation technique, but the statistical results show insignificant differences between the two techniques.

Conclusion

From the study's results it can be concluded there is no statistically significant difference between the sonic irrigation technique and the manual dynamic irrigation technique in terms of their ability to remove the smear layer in the apical third of a root canal. However, the percentage scores demonstrated that the sonic irrigation technique is better than the manual dynamic irrigation technique in removing the smear layer in the apical third of a root canal.

Acknowledgement

The publication of this manuscript is supported by Universitas Indonesia.

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