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The efficacy of ultrasonic activation device in smear layer elimination for different irrigation solutions: An in vitro research

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Abstract

Aim: This study aims to compare and evaluate the efficacy of four different irrigating solutions like sodium hypochlorite, ethylenediaminetetraacetic (EDTA), Oxum, and ozonated water with ultrasonic agitation in removing the smear layer in the apical third of root canals using Scanning Electron Microscopy (SEM).

Materials and methods: 50 newly extracted human mandibular premolars with a single, fully formed root and no curvatures were used in the investigation. The samples were equipped with a ProTaper Gold rotary file system after the teeth were decoronated to a uniform working length of 15 mm. The samples were then divided in half, submitted to SEM examination, dried with paper points, and flushed with distilled water. SEM pictures of the root samples' apical third zone were captured at 5000X resolution and graded from 1 to 4 on a scale.

Results: One-way ANOVA and the Tukey's post hoc test were used in the statistical analysis, which was carried out using SPSS software version 17.0. When compared to other groups, the 17% EDTA group had the lowest smear layer scores, according to the data, which were statistically significant. The Oxum group and the 5% NaOCl group came in second and third, respectively, whereas the saline control group and the ozone water group had the highest smear layer ratings.

Conclusion: The present investigation shows that EDTA is the best irrigant for removing the smear layer during root canal therapy.

Keywords: EDTA, Passive Ultrasonic Activation, Scanning Electron Microscope, Smear Layer

Introduction

The odontoblastic process, pulp tissue debris, bacteria, and blood cells are observed to be present in the smear layer, which is incarnated by the instrumentation procedure [1]. When dentin is cut with either rotary or manual tools [2,3], the mineralized tissues become weakened and release an important quantity of debris. This debris is composed of a mineralized collagen matrix that spreads over the dentin's surface to create a smear layer. Proper biomechanical preparation, irrigation, disinfection, and obturation are essential for an effective root canal procedure [4]. Along with this, it is imperative to prepare the root canal in such a way that the filling materials are placed adequately for a competent apical seal. The presence of the smear layer was found to have a nocent effect, as it prevents the penetration of the irrigants and intracanal medicaments into dentinal tubules [5].

Although the impact of eliminating the smear layer on a successful root canal procedure is still up for debate, it seems that doing so is better than leaving it in place. Acids or chelating agents are required for the elimination of the inorganic components of the smear layer in addition to organic component solvents [6]. The elimination of the smear layer is still unclear despite the presence of numerous irrigants and irrigating equipment. It becomes necessary to combine irrigants as it is difficult to remove both organic and inorganic particles with a single irrigant. In addition to acting against a wide range of germs, sodium hypochlorite (NaOCl) also dissolves both healthy and necrotic tissue. NaOCl's primary drawback is its cytotoxicity when injected into periradicular tissue. Despite being a more effective irrigant, NaOCl is unable to dissolve the inorganic component of the smear layer, which allows the smear layer to be retained during instrumentation [1]. A chelating chemical called ethylenediaminetetraacetic acid (EDTA) aids in the separation of biofilms that have adhered to the root canal wall. The combination of NaOCl and EDTA has been suggested in numerous research because it effectively eliminates both organic and inorganic waste.

However, prolonged treatment may unintentionally cause intertubular and peritubular dentin erosion [7], and it has been demonstrated that the smear layer may be removed efficiently only in the coronal and middle thirds of the tooth, with less success in the apical third. Therefore, in this work, fresh irrigating chemicals including Oxum and ozonated water have been investigated as final irrigants for effective smear layer removal in addition to EDTA.

The aim of the present study is to compare the smear layer removal efficacy of four different irrigating solutions EDTA, NaOCl, Oxum, and ozonated water with ultrasonic agitation in the apical third of root canals.

Methodology

Sample selection

The study was conducted at Department of Conservative Dentistry and Endodontics, Mgv K.B.H Dental College Panchavati, Nashik. After obtaining ethical approval from the Mgv K.B.H Dental College Panchavati, 50 freshly extracted human mandibular premolars that were extracted for orthodontic and periodontal reasons were taken for the study.

Inclusion and exclusion criteria

Included were healthy teeth with closed apices and well-developed roots that were free of cavities, fissures, and fractures. Vertucci's type I teeth all have a single root and a single canal. The study excluded teeth having dilacerated roots, multiple roots, numerous canals, and fused canals.

Teeth preparation-Utilising diamond discs, decoronation was used on all of the samples to obtain a uniform working length of 15 mm. By advancing the # 15 K file (Mani Inc., Delhi, India) until it approached the apex, the canal's integrity was determined. The working length was determined to be 1 mm shorter than that length when the file tip was visible at the apex under magnifying loupes. The canals were cleaned and shaped up to F2 size using the ProTaper Gold rotary at the prescribed speed and torque per the manufacturer. During each file of instrumentation, the canals were irrigated with 1 ml of 3% NaOCl, whereas normal saline was the only irrigant in the control group.

Group allocation and Irrigation- Ten tooth samples were randomly assigned to each of five groups, with five groups total. Group I contains normal saline (0.9%w/w), Group II 17% EDTA, Group III 5% NaOCl, Group IV Oxum-Super Oxidised Solution (Alkem Laboratories Ltd., Mumbai, India), and Group V is ozonated water that has just been made employing a UNO5 oxygen concentrator by injecting oxygen present into 1 L of sterile distilled water at a pressure of 7gh-1.

Then, 5 ml of each irrigant were applied to each sample for 1 minute. The irrigants were injected into the root canal using a double vented 30-gauge endodontic irrigation needle in accordance with the respective groups. Then, for 1 minute, a size 20 file was passively held inside the root canal in all samples to perform ultrasonic agitation. To remove any precipitation, 5 cc of distilled water was used to irrigate each root canal. The canals were blot dried using sterile paper points from META BioMed in Chungcheongbuk-do, Korea. Deep grooves were carved into the root's buccal and lingual surfaces without penetrating them with diamond discs. Chisel and mallet were used to chisel off the roots. Each tooth's half is chosen to be cleaned for SEM examination.

SEM analysis- Ethyl alcohol (30%–100%) was used in escalating quantities to dry and dehydrate the specimens. The samples were then mounted on metallic stubs after drying in the air, and a gold sputter coater was used to apply the coating. The smear layer's presence or absence was checked on these samples using a scanning electron microscope. At the apical third of each specimen, root canal walls were photographed at 5000X magnification.

Scoring criteria

The scoring system described by Prado et al. in 2011 was used to evaluate the degree of smear layer removal [8].

Score 1: no smear layer and all tubules are clean and open.

Score 2: a few areas covered by smear layer, with most tubules cleaned and opened.

Score 3: smear layer covering almost all the surface, with a few tubules, opened and

Score 4: smear layer covering all the surfaces.

Results

The SEM images taken of all the experimental groups at the apical third of the tooth samples are shown in Figure 1 and 2.

Figure 1

SEM images of experimental groups at 5000X resolution.

Group A - EDTA (Ethylenediaminetetraacetic acid) 17%,

Group B - NaOCl (Sodium hypochlorite) 5%,

Group C - Oxum (Superoxidised solution)

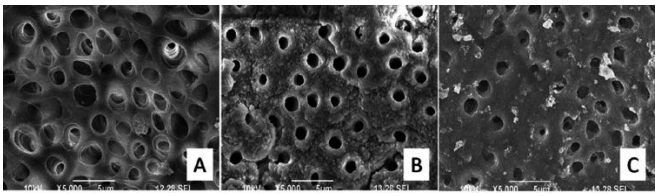
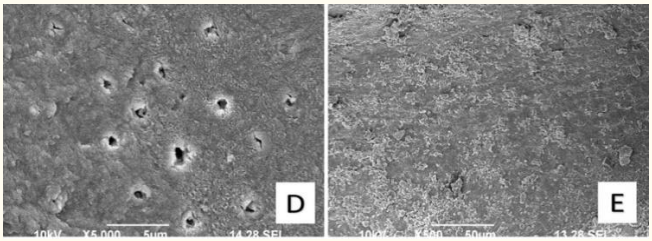


Figure 2



SEM images of experimental groups at 5000X resolution.

Group D – Ozonated water (Freshly prepared)

Group E – Normal saline (Control group)

Data were collected and statistically analyzed using one-way ANOVA followed by Tukey's post hoc test using software version SPSS 17.0 version (SPSS Inc., Chicago). The significance level is set at a p-value <0.05. Table 1 depicts the smear layer removal scores of various groups at the apical third of root canals with p values.

Table 1: Descriptive statistics and intergroup comparison by one-way ANOVA

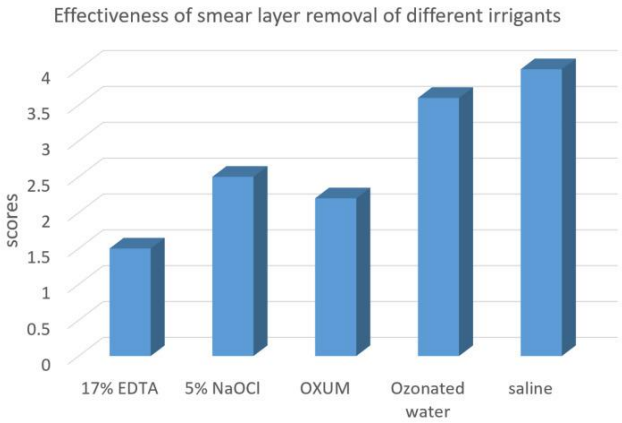
Intergroup comparison by one-way ANOVA shows a highly significant difference ($p<0.001$) in the smear layer removal between all the experimental irrigation groups.

Group	Mean	SD	95% Confidence Interval for Mean		F	p-value
			Lower Bound	Upper Bound	37.2	0.001*
Saline	4.0000	.0000	4.0000	4.0000		
EDTA	1.5556	.5270	1.1504	1.9607		
NaOCl	2.5556	.5270	2.1504	2.9607		
Oxum	2.2222	.6666	1.7098	2.7347		
Ozone	3.6667	.5000	3.2823	4.0510		

EDTA: Ethylenediaminetetraacetic acid; NaOCl: Sodium hypochlorite; Oxum: Superoxidised solution

The in-vitro research's findings demonstrate a substantial variation in the smear layer removal by the various irrigation systems employed. Amongst the five irrigants utilised, Group II (EDTA) was shown to be the most effective with statistically significant smear layer reduction, according to the data. The Oxum group and the 5% NaOCl group came in second and third, respectively, whereas the saline control group and the ozone water group had the highest smear layer ratings. All of the irrigants were effective for removing smear layers in the following groups: group II, group IV, group III, group V, and group I. (Figure 3).

Figure 3



EDTA: Ethylenediaminetetraacetic acid; NaOCl: Sodium hypochlorite; Oxum: Superoxidised solution

Mean score values of SEM images.

All of the experimental irrigant groups' smear layer removal efficiency was ranked (from lowest score to highest score) as follows: group II; group IV; group III; group V; and group I.

The many pairwise comparisons by the Tukey post hoc test are shown in Table 2. There was a considerable difference between distinct groups when the intragroup comparison was carried out. There was no discernible difference in the data between saline and ozone, EDTA

and Oxum, or NaOCl and Oxum when a pair-wise comparison was performed.

Table 2: Intragroup comparison by Post hoc Tukey's test

Pairwise comparison by Post hoc Tukey's test shows no significant difference in the values between saline and Ozone, EDTA and Oxum, NaOCl and Oxum.

EDTA: Ethylenediaminetetraacetic acid; NaOCl: Sodium hypochlorite; Oxum: Superoxidised solution

(I) Group	(J) Group	Mean Difference (I-J)	P value
Saline	EDTA	2.44444*	.000*
	NaOCl	1.44444*	.000*
	Oxum	1.77778*	.000*
	Ozone	.33333	.622
EDTA	Saline	-2.44444*	.000*
	NaOCl	-1.00000*	.001*
	Oxum	-.66667	.053
	Ozone	-2.11111 *	.000*
NaOCl	Saline	-1.44444*	.000*
	EDTA	1.00000*	.001*
	Oxum	.33333	.622
	Ozone	-1.11111 *	.000*
Oxum	Saline	-1.77778*	.000*
	EDTA	.66667	.053
	NaOCl	-.33333	.622
	Ozone	-1.44444*	.000*
Ozone	Saline	-.33333	.622
	EDTA	2.11111 *	.000*
	NaOCl	1.11111 *	.000*
	Oxum	1.44444*	.000*
* Significance value (P<0.05)			

Discussion

It is prudent to get rid of the smear layer from teeth with infected root canals in order to clean the entire root canal system, regardless of the debate. Despite the broad variety of irrigants on the market today, finding the best root canal irrigant remains a challenge because of a number of difficult-to-remove elements such dentine substrate, root canal bacteria, and smear layer. No one irrigant has been discovered to be efficient in removing both organic and inorganic material to yet because there are so many factors that can affect how it acts. As a result, removing the smear layer necessitates combining the effectiveness of numerous irrigants because no one irrigating solution can yet satisfy all ideal requirements [9].

The most popular technique to date has been the chemical approach, which involves using chelating agents to remove the smear layer, with ethylenediaminetetraacetic acid (EDTA) being the most used agent [1]. For efficient smear layer removal, sodium hypochlorite (NaOCl) and EDTA should be used alternatively [10]. The intraradicular dentin may unintentionally deteriorate as a result of this combination watering routine, while [11] this is a worry. In this investigation, the smear layer was removed using ultrasonic agitation and four different irrigating solutions, including 17% EDTA, Oxum, ozonated water, and 5% sodium hypochlorite. The present investigation aimed to evaluate and compare how well these irrigants removed the smear layer from the apical section of the root canal.

All of the current irrigants were found to have less success entering the apical third of the root canal when compared to the coronal and middle thirds, which is because the apical third has a stagnation plane for leftover fluid [12].

Traditional irrigation systems frequently fail to deliver to the apical third due to gas-particle entrapment and complex morphology. Thus, using ultrasonic activation and/or the addition of a detergent that reduces surface tension will allow for the proper access to the apical third. Air bubbles that prevent penetration are removed

by mechanical stimulation, which effectively lowers the smear layer in the apical third [13].

The present research used 30 gauge double-sided vented irrigation needles, which can enter the apical third due to their small bore size, as well as to increase the effectiveness of the irrigant's contact with the canal wall for the elimination of the smear layer and to block the vigorous passage of irrigant through the apical foramen [14].

According to the research's findings, 17% EDTA was shown to be the most efficient, followed by Oxum, in the removal of organic and inorganic components of the smear layer when compared to NaOCl, Oxum, and ozone. The results of the intragroup comparison showed that the values between saline and ozone, EDTA and Oxum, and NaOCl and Oxum did not differ significantly.

In this work, the smear layer was completely eradicated when EDTA was employed alone with ultrasonic agitation to irrigate the canal, demonstrating that ultrasonic agitation also enhances the clearance of organic material in addition to its natural ability to remove the smear layer by EDTA [14,15]. This is consistent with Wu et al.'s findings that 17% EDTA was more successful in eliminating the smear layer than other irrigants such as 20 percent citric acid and Biopure MTAD [16].

The bulk of these studies opposed the use of NaOCl alone to remove the smear layer, despite the fact that a sizable body of data supported the use of 17% EDTA in combination with NaOCl to do so. In the present investigation, smear layer removal using passive ultrasonic irrigation and 5% NaOCl was comparable to that using EDTA and oxum. According to Cameron et al. in 1983, ultrasonic activation of NaOCl for one minute removed the surface smear layer above it but left the dentinal tubules shut off [17]. NaOCl, which has a good antibacterial effect when coupled with ultrasonic activation, also increases the debris/smear layer removal by producing shear stress in the smear layer's inorganic particles by acoustic streaming, making it easier to remove [18,19].

In the current study, EDTA 17% showed more damaged dentinal tubules and intertubular dentin. The organic part was removed using 5% NaOCl, while the inorganic half of the smear layer was left intact. Both organic and inorganic smear layers were efficiently removed by Oxum without altering the appearance of the dentinal surface.

Oxum is a highly reactive oxygen species-rich pure solution that has undergone electrochemical processing to become a superoxidized aqueous solution. Super oxidised water is an FDA-approved stable irrigant used for wound care therapy because of its neutral pH and long half-life. The main ingredients in oxum, a hypotonic solution, are sodium hypochlorite, hypochlorous acid, ozone, and hydrogen peroxide. It is a well-known bactericide, fungal killer, virucidal, and sporicidal agent that, upon electrolysis, generates free radicals that swiftly react and denature proteins in the bacterial cell wall [20]. Oxum performed better than EDTA in the current investigation at removing smear layers [21]. Large sections of the smear layer were eliminated, leaving the collagen fibres visible and in tact with less degradation. This is in line with research by Mensudar et al. from 2016, who discovered that the coronal third saw the largest smear layer loss relative to the middle and apical thirds, and that the smear layer was destroyed in bigger sections with less erosion [22].

Oxum also has the benefit of being biocompatible with the host tissues. Because multicellular organisms are not harmed by the irrigant's osmolarity variations, the

irrigant solely damages the cell membrane of single-cell organisms and denatures bacterial proteins.

Recent investigations have shown the benefits of employing ozone for root canal disinfection. Ozonated water has been found to have a high efficacy and higher bactericidal action when compared to other ozonated goods. Ozonated water has been shown to have comparable antibacterial efficacy to NaOCl as a root canal irrigant. They are also very biocompatible with tissues and don't seem to alter the properties of the enamel or dentin [23]. The possibility of using ozone to facilitate restorative treatments in dentinal tubules has also been raised [24]. Thus, in this study, ozone was utilised in combination with ultrasonic activation to remove the smear layer, and the results show that ozone water has an insignificant smear layer removal ability when compared to the other irrigants examined. In the future, a synergistic action of enhanced antimicrobial properties and smear layer elimination might be attempted by combining ozone with other irrigants having smear layer removal properties, such as mild acids [25,26].

Within the constraints of this investigation, EDTA and Oxum are equally effective at removing the smear layer. This work requires further validation in vivo because the presence of blood, tissue remnants, and a heap variable may impact the effectiveness of irrigants in the root canal system. Additionally, it is more challenging and confusing to remove the smear layer in curved canals. To validate these results and evaluate their consistency with regard to treatment outcomes, additional study into lengthy clinical investigations is necessary.

Conclusion

According to the study's limitations, 17% EDTA is shown to be the best irrigant for removing the smear layer during root canal therapy. The inorganic portion of the smear layer was left alone while the organic material was removed with 5% NaOCl. In place of EDTA, more recent irrigants like Oxum can be utilised to remove smear layers while still being biocompatible with dentin. In the future, smear layer removal and increased antibacterial properties of ozone can be achieved by combining it with additional irrigants.

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