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RESEARCH ARTICLE

REMOVAL OF SMEAR LAYER IN THE ROOT CANAL USING ELECTROLYZED SALINE

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ABSTRACT

Background: Sodium hypochlorite has been vastly used as root canal irrigant but its toxicity and storage risks are of concern. There has been a constant search for the ideal root canal irrigant.
Objectives: The aim of this study is to evaluate electrolyzed saline, produced from a custom-made chair side apparatus for its smear layer removal efficiency on root canal walls and compare it with the commercially available agents- EDTA and MTAD.
Methods: A chair side apparatus has been designed to produce and dispense electrolytically activated solutions (Electrolyzed saline) for the purpose of root canal irrigation. Two different solutions, one, which is oxidizing in nature, consisting primarily of Chlorine derivatives and another, reducing in nature, consisting primarily of sodium hydroxide, are obtained. A combination of these two solutions was used for root canal irrigation in extracted teeth. The other test agents included 3% NaOCl, 3% NaOCl alternated with 17% EDTA, Electrolyzed saline alternated with 17%EDTA and MTAD. Root canals were split and the samples were subjected to Scanning electron microscopic evaluation.
Results: Under the conditions of this study, Electrolyzed saline significantly cleaned the root canal surfaces and the results were comparable to EDTA as well as MTAD. Alternating Electrolyzed saline with 17% EDTA irrigation showed similar smear layer removal efficacy. The cleaning efficacy of Electrolyzed saline was significantly better than 3% Sodium hypochlorite.
Conclusions: Under the conditions of this study, the smear layer removal efficacy of Electrolyzed saline was significantly better than 3% NaOCl. There was no significant difference for smear layer scores when compared with the remaining groups (Sodium hypochlorite (3%) +EDTA , Electrolyzed saline +EDTA and MTAD)

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INTRODUCTION

Thorough debridement of the root canal system is essential for the successful outcome of endodontic therapy. This is achieved by mechanical instrumentation in conjunction with irrigation. The ideal root canal irrigant has been described by Zehnder (2006) as being systemically nontoxic, non-caustic to periodontal tissues, having little potential to cause an anaphylactic reaction, possessing a broad antimicrobial spectrum, capable of dissolving necrotic pulp tissue, inactivating endotoxins, and either preventing the formation of a smear layer or dissolving it once it has formed. Although many kinds of endodontic irrigant have been investigated; none have been able to exhibit all the above-mentioned properties. Sodium hypochlorite (NaOCl) is the most widely used irrigant (Cheung and Stock, 1993; Gulabivala and Stock, 1995; Johnson and Noblett, 2009). It dissolves pulp tissue and is a potent anti-microbial agent. Its most important property of being an organic issue solvent makes it the most popular irrigant in use. Sodium hypochlorite itself does not remove the smear layer. Smear layer components include very small particles with a large surface: mass ratio, which makes them soluble in acids (Pashley *et al.,* 1985).The most common chelating solutions are based on EDTA, which reacts with the calcium ions in dentine and forms soluble calcium chelates. The combination of NaOCl and Ethylene diamine tetra acetic acid (EDTA) has been recommended for smear layer removal (Yamada *et al.,* 1983; Baumgartner *et al.,* 1987). NaOCl when extruded beyond the apex causes severe pain, swelling and necrosis of the periapical tissues (Cymbler and Ardakani,

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1994; Calişkan *et al.,* 1994). The use of concentrated NaOCl as a root canal irrigant might cause severe clinical problems when extruded into vital tissue (Gernhardt *et al.,* 2004). Because of toxicity, extrusion is to be avoided (Pashley *et al.,* 1985; Hulsmann and Hahn, 2000), thus contraindicating its use in teeth with open apices. It is purchased and stored. Any spillage during handling causes bleaching of the clothes. Its vapor can be an irritant to the eyes. It is corrosive in nature, thus root canal instruments become more prone to mechanical breakdown. The need remains for a treatment system that delivers an irrigation solution alternative to NaOCl having the same advantages of NaOCl but still overcoming its disadvantages of storage risks and toxicity caused when extruded through the tooth apex. The need further remains for the use of a more biologically acceptable root canal irrigant. Torabinejad *et al.* (2003) have reported the development of new irrigant for use in canal disinfection and smear layer removal, BioPure MTAD (Dentsply, Tulsa, OK). It is a mixture of a tetracycline isomer (doxycycline), an acid (citric acid), and a detergent (Tween 80). The antimicrobial action of MTAD comes from the presence of Doxycycline and its chelating ability from Citric acid. Tween 80, being a detergent reduces surface tension thus improving the wettability. Russian scientists have developed a process whereby Electro-chemically activated water ECA is produced with a unique anode–cathode system (Leonov, 1997). It utilizes a special Flow through electrolyte module (FEM) consisting of cylindrical titanium electrodes separated by a ceramic membrane. It has shown good cleaning efficacy when used as root canal irrigant (Marais, 2000). We have prepared a similar irrigating solution (Electrolyzed saline or New chair side ECA solution- NECA) by using a simpler technique by means of a compact indigenous chair side apparatus, which can prepare the irrigant in small quantities for immediate use (Kavita Dube and Pradeep Jain). The irrigant primarily consists of two solutions- 1. Solution collected at the anode (SOLUTION A) in which H+ Cl-, OH- are present. Chlorine is evident in this solution by its odour. These ions may react with each other forming OCl-, HOCl- and Cl2 etc. The exact composition cannot be known but these molecules are oxidizing in nature. Solution collected at the cathode (SOLUTION B) in which Na+, H+ and OH- are present. Na+ is unstable and will form NaOH by reacting with OH^-. Sodium hydroxide is beneficial as it has detergent properties. This will be useful in cleansing the root canal.

Aims and objectives

- To compare the cleaning efficacy of this root canal irrigant with a) Sodium hypochlorite (3%) (Parcan-Septodont), b) Sodium hypochlorite (3%) +EDTA (Smear clear-Sybron Endo) and MTAD (Dentsply, Tulsa Dental, Tulsa, OK)
- To study the effect of Combination of EDTA with Electrolyzed saline on cleansing of root canal wall.

MATERIALS AND METHODS

150 single-rooted permanent human teeth were collected immediately after extraction. After conventional access preparation for each tooth, a size 15 K file MANI was used to determine the working length. The file was introduced into the canal of each root until it just reached the apical foramen. Working length was set at 1.0 mm short of that position. Canal orifices were flared with Gates Glidden burs size. The specimens were divided into five groups of thirty teeth each.

Group A: Sodium hypochlorite: The root canals of group A were prepared using a series of K-type files sizes 15–60 manually in a serial technique by circumferential filing and by irrigating with a 3% solution of NaOCl. Irrigation was performed after every size file. Syringe irrigation was used. After the canal was prepared to size 60, a final flush of irrigation was carried out. A minimum of 30 ml of 3% NaOCl was used in the irrigation process for each tooth.

Group B: Electrolyzed saline: Root canals were prepared using the same files and the same manual technique as in group A. After the use of each size file, the canal was irrigated with Electrolyzed saline (alternatively solution A & solution B). 15 ml of solution A and 15ml of Solution B was used in the irrigation process of each tooth. Final flush of irrigation was carried out with solution B.

Group C: Sodium Hypochlorite with EDTA: The root canals of group D were prepared using a series of K-type files sizes 15–60 manually in a serial technique by circumferential filing and by irrigating with a 2.5% solution of NaOCl. Irrigation was performed after every size file. Syringe irrigation was used alternating with 17 % EDTA (Smear clear-Sybron Endo). 14 ml of NaOCl and 14 ml of 17 % EDTA was used. After the canal was prepared to size 60, final flush of irrigation was carried out with 5ml of 3 % NaOCl followed by 2 ml of 17 % EDTA (Smear clear- Sybron Endo).

Group D: Electrolyzed saline solution with EDTA: The root canals of group D were prepared using a series of K-type files sizes 15–60 manually in a serial technique by circumferential filing and by irrigating with a 2.5% solution of NaOCl. Irrigation was performed after every size file. Syringe irrigation was used alternating Solution A, followed by Solution B followed by irrigation with 17 % EDTA (Smear clear- Sybron Endo). 14ml of Electrolyzed saline (SOLUTION A &B) and 14ml 17 % EDTA was used. After the canal was prepared to size 60, final flush of irrigation was carried out with 2ml of Electrolyzed saline followed by 6 ml of 17 % EDTA (Smear clear- Sybron Endo).

Group E: Biopure MTAD: The MTAD solution was freshly prepared as per the manufacturer's instructions. The root canals of group F were prepared using a series of K-type files sizes 15–60 manually in a serial technique by circumferential filing and by irrigating with MTAD. Irrigation was performed after every size file. Syringe irrigation was used. 30 ml of MTAD was used.

Preparation for SEM examination

The canals were not dried following preparation so as to retain the existing condition of the walls. The specimens were stored in 70% ethanol in preparation for scanning electron microscopic (SEM) examination. Longitudinal grooves were cut on the buccal and lingual surfaces with a diamond disc so as not to penetrate the canal. Each root was split in two with cutting pliers and prepared for SEM observation. The specimens were dehydrated by graded concentrations of ethanol and freeze-dried with t-butyl alcohol.

Table 1. Comparison of smear layer scores between different root canal irrigants.

Irrigants	Smear layer scores				Total N (%)
	Score 0 N (%)	Score 1 N (%)	Score 2 N (%)	Score 3 N (%)	
Electrolyzed saline	26 (86.67)	03 (10.00)	01 (3.33)	00 (0.00)	30 (100.00)
Sodium hypochlorite	00 (0.00)	10 (33.33)	07 (23.33)	13 (43.34)	30 (100.00)
Sodium hypochlorite + edta	26 (86.67)	04 (13.33)	00 (0.00)	00 (0.00)	30 (100.00)
Electrolyzed saline +edta	26 (86.67)	04 (13.33)	00 (0.00)	00 (0.00)	30 (100.00)
Bio pure mtad	27 (90.00)	03 (10.00)	00 (0.00)	00 (0.00)	30 (100.00)
Total	134 (74.44)	25 (13.89)	08 (4.44)	13 (7.23)	180 (100.00)
Kruskal-wallis test	KW = 118.756, DF = 5, P = 0.000 (<0.001), VERY HIGH SIGNIFICANT				
Mann-whitney u test	Sodium hypochlorite > electrolyzed saline= sodium hypochlorite + edta = edta + electrolyzed saline = bio pure mtad				

They were then mounted on aluminum stubs, coated with 20-nm gold using an Ion Sputter and stored in a desiccating cabinet to maintain dryness until SEM observation. A scanning electron microscope (Carl Zeiss, Supra 5-Germany) operated at 20 kV was used to view the specimens. Photomicrographs were taken of the middle and apical thirds of all specimens at a magnification of 1000. The photomicrographs were evaluated using the rating system developed by Gorman *et al.* (1995) by two evaluators who were blinded to the sample group. (Score 0- No Smear layer, all tubules open; Score 1- Little smear , >50 % of tubules open; Score 2- Moderate smear layer, < 50 % of tubules open ; Score 3 –Heavy smear layer, outline of tubule indistinguishable).

RESULTS

Table 1 shows comparison of smear layer scores between different root canal irrigants. In Electrolyzed saline irrigant group, 26 (86.67%) samples were at score 0, 03 (10.00) at score 1 and01 (3.33) at score 2. In sodium hypochlorite group, 10 (33.33%) samples were at score 1, 07 (23.33%) at score 2 and 13 (43.34%) at score 3. In each of sodium hypochlorite + EDTA and EDTA + Electrolyzed saline groups, 26 (86.67%) samples were at score 0 and 04 (13.33%) at score 1. In Bio pure MTAD group, 27 (90.00%) samples were at score 0 and 03 (10.00%) at score 1. Kruskal-wallis test showed significant difference for smear layer scores between different irrigants (kw = 118.756, df = 5, p <0.001). After significant results of Kruskal-wallis test, Mann-whitney u test was applied for pairwise comparison, which showed that smear layer scores in sodium hypochlorite group were significantly higher than any other irrigant group. Also, there was no significant difference for smear layer scores between remaining groups.

DISCUSSION

The importance of root canal irrigation is well established. Complete debridement by mechanical instrumentation alone is not possible owing to the irregularities in root canal systems, presence of narrow isthmi and apical deltas. Irrigation serves the important purpose of both physical flush as well as chemical disinfection. The use of nickel titanium rotary instruments has allowed us to gain time during endodontic treatment. The time we gain is best compensated by an abundant irrigation for a better cleaning of the endodontic system that will directly contribute to the success of endodontic treatment. No single irrigant has been found to dissolve organic pulpal material and demineralize the inorganic calcified portion of the canal wall. The bactericidal potential of NaOCl is not in doubt (Siqueira *et al.,* 1998), but the fact that it is highly toxic to human tissues is of concern (Spangberg *et al.,* 1973; Thé *et al.,* 1983).

Electrolyzed saline could be considered as an active form of Sodium hypochlorite with the ionic components in a metastable state. The solutions A and B are used alternatively in the root canal while cleaning and shaping, with a final rinse with solution B. Since these solutions contain molecules in their active form, the reaction in the canal will be immediate and effective. Moreover, we speculate that even if the solutions enter the periapical tissues, the solutions would mix with each other forming saline again, thus making these solutions biologically acceptable. As the Electrolyzed saline solution is prepared chair side for immediate use, the problems associated with storage and handling are minimal. To remove or not to remove the smear layer has for long been a subject of controversy. Its advantages and disadvantages remain controversial. However, greater evidence supports its removal (Torabinejad *et al.,* 2002; Clarke-Holke *et al.,* 2003). The organic debris present in the smear layer might constitute substrate for bacterial growth; also it may slowly disintegrate (Delivanis *et al.,* 1983). Removal of smear layer allows better adaptation of sealers to the canal wall (Wennberg and Orstavik, 1990). Coronal and apical leakage is reported to be reduced after removal of smear layer (Leonard *et al.,* 2004).

The samples treated with 3 % Sodium hypochlorite showed significantly higher smear layer scores than any other irrigant group. (Figure 1) There was no significant difference for smear layer scores between remaining groups. Initially, the use of EDTA solution was proposed by Ostby (1957) to assist with the instrumentation of calcified, narrow or blocked canals because of its ability to foster the chelation of the calcium ions at a pH close to neutral. Its efficiency in removing inorganic dentin particles, preventing the formation of smear layer during instrumentation has been demonstrated. It is used at 15-17% and pH 7-8 (Gabriela *et al.,* 2015). It was observed that many samples treated with Bio pure MTAD, showed severe erosion with also three samples showing cracks in the electron microscopic images. (Figure 6). Similar observations were made by Tay *et al.* Large globular deposits were seen in many of the electron microscopic images of samples treated with MTAD. As speculated by Tay *et al,* we assume that they represent calcium salts of either doxycline hyclate or citric acid (Franklin *et al.,* 2006). In some specimens, these globules extensively covered the root canal dentin. Tay and Pashley investigated the structure of instrumented root dentin after irrigation. Both EDTA and MTAD created a zone of demineralized collagen matrices in eroded dentin and around the dentinal tubules, with the mildly acidic MTAD being more aggressive than EDTA (Tay *et al.,* 2006). For maximum effect during and after instrumentation, chelating agents should be combined with tissue solvents. Electrolyzed saline serves as a combination of tissue solvent as well as root canal cleanser. The pH of the solution A is about 6.17 (Figure10).

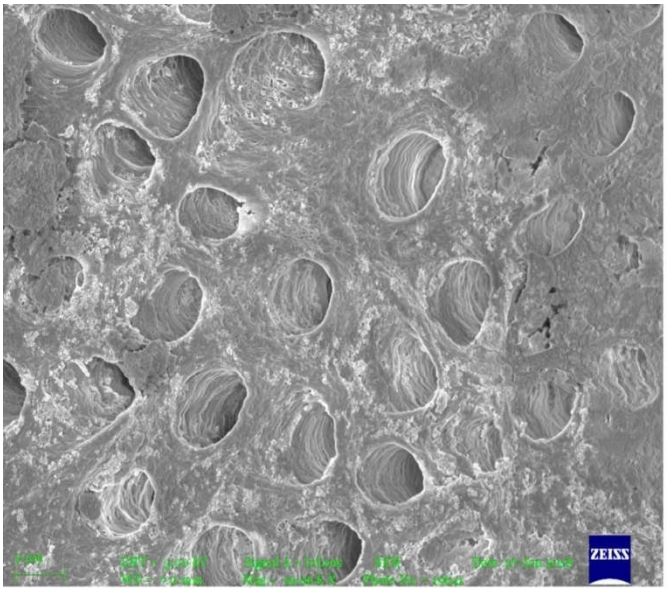

Figure 1. SEM Image of sample treated with Sodium Hypochlorite (10000X)

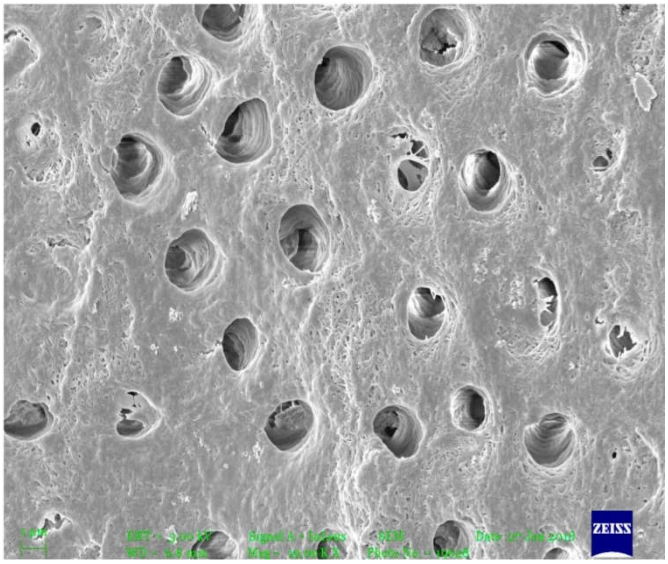

Figure 2. SEM Image of sample treated with Electrolyzed saline (10000X)

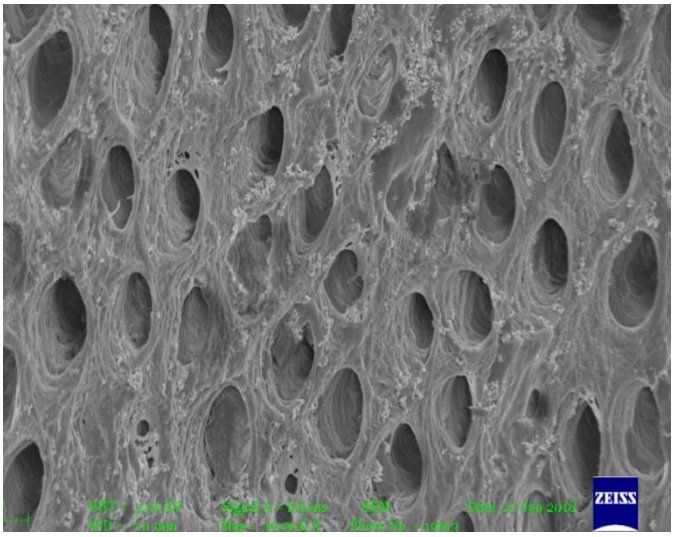

Figure 3. SEM Image of sample treated with Electrolyzed saline (10000X)

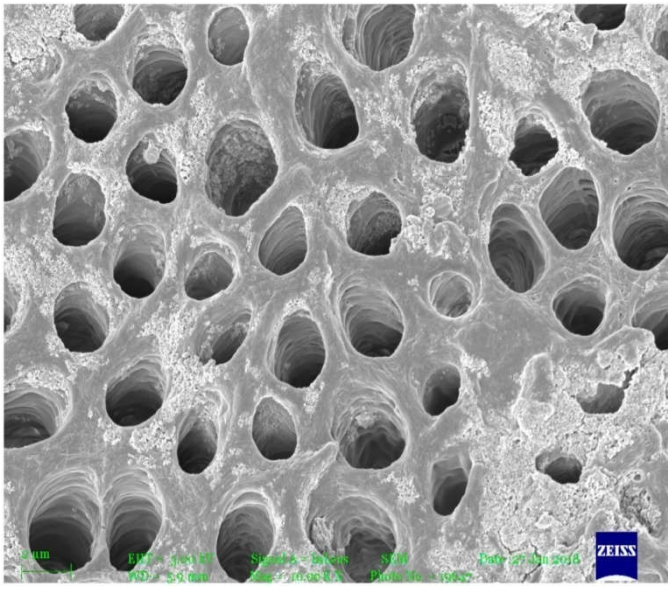

Figure 4. SEM Image of sample treated with Sodium Hypochlorite with EDTA (10000X)

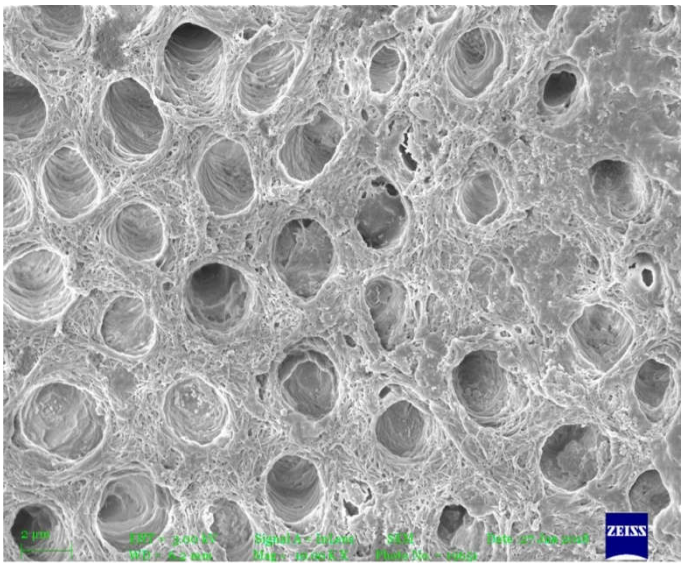

Figure 5. SEM Image of sample treated with Electrolyzed saline with EDTA (10000X)

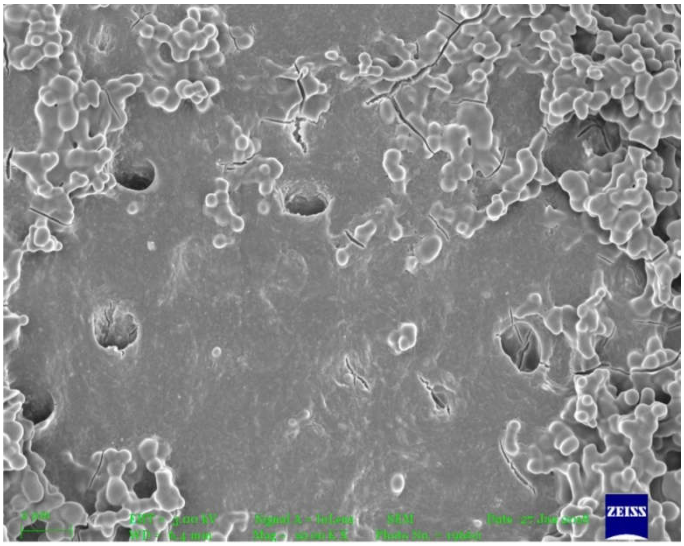

Figure 6. SEM Image of sample treated with MTAD (10000X)

means of syringe following instrumentation with 5% NaOCl showed a similar effect to that of 15% EDTA irrigation for removal of smear layer and debris (Hata *et al.,* 2008). Solovyeva and Dummer found ECA anolyte and catholyte to be effective in removing the smear layer and debris from the root canals[30]. All these findings are similar to the results of the current study. These results are significant because they demonstrate the efficacy of Electrolyzed saline as an irrigant to remove the smear layer. It cleaned the root canal wall surfaces in a remarkable way, removing the smear layer in large areas. It is produced from distilled water, salt and electricity by a simple electrolytic process and a compact chair side apparatus.

Conclusion

Under the conditions of this study, the smear layer removal efficacy of Electrolyzed saline was significantly better than 3% NaOCl. There was no significant difference for smear layer scores when compared with the remaining groups (Sodium hypochlorite (3%) +EDTA, Electrolyzed saline +EDTA and MTAD)

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