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Evaluation of smear layer removal at the apical third of root canals using, fumaric acid, citric acid and EDTA: A scanning electron microscopic study

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Abstract

Introduction: During root canal preparation, a layer consisting of debris, necrotic tissues and microorganisms is formed called smear layer. This layer hinders the penetration of root canal medicaments, sealers and irrigants in to the dentinal tubules. Since there is no single irrigating solution which can completely eliminate smear layer, a combination of root canal irrigants along with root canal instrumentation is used.

Aim: To evaluate the efficacy of 0.7%Fumaric acid, 10%citric acid and 17%EDTA in smear layer removal from the apical third of root canal wall.

Materials and Methods: 50 single rooted mandibular premolars were collected and decoronated to a length of 13mm. Hand filing done up to No. 25 K file and prepared till F3 Pro Taper file. Intermittent use of 1ml of 3%NaOCl done for 1 min after each instrument change. They were randomly divided into4 groups[n=10]:

Group1:EDTA,Group2:citric acid,Group3:fumaric acid, and Group 4: normal saline. In all groups, 5ml of the respective irrigant was used for 1min.The final irrigation done with 5ml of 3%NaOCl for 1min to remove any precipitate formed during cleaning and shaping. Longitudinal grooves were prepared on the buccal and lingual surfaces of the samples with a silicon carbide disc without penetrating the root canals. Each tooth was then split in to 2 halves using chisel and mallet and subjected to scanning electron microscopic analysis to observe the extent of smear layer removal.

Statistical analysis: The scores obtained were statistically analyzed with Kruskal Wallis test followed by Mann Whitney Post hoc analysis to compare the mean smear layer removal scores between different Irrigants.

Result: At the apical third of root canal fumaric acid showed significant smear layer removal property than EDTA and citric acid

Conclusion: Fumaric acid can be tried as a new irrigating agent for smear layer removal in root canal therapy.

Introduction

Formation of smear layer during root-canal treatment is an inevitable process[1] .Whenever dentine is cut using hand or rotary instruments, the mineralized tissues are not shredded or cleaved but shattered to produce considerable quantities of debris. These are composed of very small particles of mineralized collagen matrix, is spread over the surface to form what is called the smear layer[2]. Although the exact components of this layer have not been determined yet, it is believed to contain thin particles of organic elements and inorganic materials such as odontoblastic processes, pulp tissue debris, blood cells, bacteria, etc[3]

The components of the smear layer can be forced into the dentinal tubules to varying distances during biomechanical preparation of root canal. This can occur as a result of the rotation and linear movement of root canal instruments. Also various studies have shown that, generation of capillary action between the dentinal tubules and the smear material will push the smear layer components further into the dentinal tubules[4].

Smear layer should be removed and dentinal tubules should have their patency to achieve fast disinfection with intra canal medicaments. Also, removal of the smear layer can result in better adaptation of the obturation materials to the canal walls.[5]

Irrigation is an essential part of root canal debridement which allows cleaning beyond what might be achieved by root canal instrumentation alone. It also helps by killing the microorganisms, flushing debris, and removing the smear layer from the root canal system[6]

Various chemical agents have been used to remove the smear layer. To date, no single irrigating solution is capable of removing both the organic and inorganic components of the smear layer. However, the most widely accepted protocol for smear layer removal is a sequential rinse using sodium hypochlorite (NaOCl) followed by ethylenediaminetetraacetic acid (EDTA)[7]. The use of 10 ml 17% EDTA followed by 1 ml 5% NaOCl for root canal irrigation was recommended by Yamada et al in order to remove both inorganic and organic components of smear layer[8].

It has been investigated that, citric acid concentrations ranging from 1% to 50% can also be used for effective smear layer removal[9]. Wayman et al[10] showed that the use of 10% citric acid and 2.5% NaOCl is a very effective approach for the smear layer removal. Di Lenarda et [11] reported no or a negligible difference in smear layer removal obtained by citric acid and EDTA.

Fumaric acid (Butene-1,4-dioic acid) which is a trans isomer of maleic acid is known for its excellent properties like anti-inflammatory, nontoxic, anti-carcinogenic, and growth modulatory potential[12].It is a well-known key intermediate product in citric acid cycle during glucose metabolism, and for the treatment of psoriasis and multiple sclerosis, the esters of fumaric acid have been used successfully[13]. Till date, only few studies have analyzed its performance in smear layer removal at apical third of root canal system. The purpose of this study was to evaluate the efficacy of 17% EDTA, 10% citric acid, and 0.7% fumaric acid followed by 3% NaOCl as final irrigant in smear layer removal at apical third of the root canal system by scanning electron microscope (SEM).

Materials and Methods

Forty intact human single-rooted permanent mandibular premolar teeth having a single canal and fully developed apices, were selected for the study. Radiographs were taken to confirm single canal and absence of any type of resorption, cracks, fractures, and calcifications The extracted teeth were scaled to remove debris, calculus, and rinsed with sodium hypochlorite to remove organic tissue and then stored in distilled water.

Preparation of the root canal

The teeth were decoronated to a standardized length of 13 mm by using a diamond disk (D and Z, Darmstadt, Germany).Subsequently, #10 K-file (Mani Inc., Japan) was inserted beyond the apex to confirm patency; 1 mm was subtracted from this length to establish the length to which the canals would be instrumented. Root canal instrumentation was performed along with 1 ml of 3% NaOCl (Vishal Dental Products, India) irrigating solution after each instrument change for 1 min. Nickel-titanium universal rotary pro taper file was used to shape the canal to an apical size of 25/0.08 (F2) (Dentsply Maillefer, Switzerland)

Irrigating solutions: 10% citric acid and 0.7% fumaric acid, were freshly prepared in Azyme biosciences research institute, Bengaluru, Karnataka.

Following root canal preparation the specimens were divided randomly into 4 groups (n=10).

Group 1 (n = 10): with 1 ml/min of 17% EDTA (Prime Dental Products, India),

Group 2 (n = 10): with 1 ml/min of 10% Citric acid

Group 3 (n = 10): with 1 ml/min of 0.7% Fumaric acid

Group 4 (n = 10): with 1 ml/min of normal saline (Infutec healthcare limited,Mumbai)

To ensure adequate and even distribution of the solutions, the roots were irrigated with 30-gauge side vented needle (Max-I-Probe™, Dentsply, New Delhi, India). with an apical-coronal motion to within 1 mm of working length. The final irrigation done with 5ml of 3%NaOCl for 1min to remove any precipitate formed during cleaning and shaping, and dried using sterile absorbent paper points (Diadent,Mumbai,India)

Diamond discs were used to cut deep grooves on the buccal and lingual surfaces of the roots, without perforating the root canals. The roots were then split with a chisel and mallet. One half of each tooth was selected and and stored in distilled water until use.

Scanning electron microscopic analysis

Samples were dehydrated and mounted on aluminum metal stubs, sputtered with gold, and analyzed under field emission SEM (Jeol, Tokyo, Japan) under ×2000 at the apical third of each root for the presence or absence of smear layer. The photomicrographs were evaluated by two independent evaluators who were unaware of the groups to which the samples belonged.

The amount of smear layer remained on the surface of the root canal or in the dentinal tubules was scored according to the criteria given by Torabinejad *et al*[14]

Score 1: No smear layer (no smear layer on the surface of the root canal: All tubules were clean and open)

Score 2: Moderate smear layer (no smear layer on the surface of the root canal, but tubules contained debris)

Score 3: Heavy smear layer (smear layer covered the root canal surface and the tubules)

The scores obtained were statistically analyzed with Kruskal Wallis test followed by Mann Whitney Post hoc analysis to compare the mean smear layer removal scores between different Irrigants.

Results

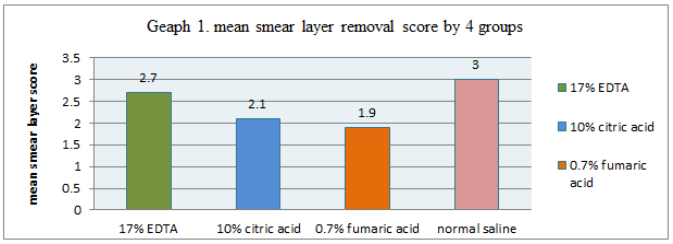
In this study, mean smear layer scores obtained among 4 groups shows statistically significant difference between the control group and the experimental groups except a non-significant difference obtained between the control and EDTA group. (Table 1)

Table 1: Mean Smear Scores (SD) and Statistical Comparison of the Remaining Smear Layer between 4 groups using Kruskal Wallis test

Groups	N	Mean	SD	Min.	Max.
17% EDTA	10	2.7	0.3	2	3
10%Citric acid	10	2.3	0.4	2	3
0.7% Fumaric acid	10	2.0	0.0	2	3
Normal saline	10	3	0.0	3	3

The level of significance was set at P<0.05.

Table 1 illustrates the comparison of mean Smear Layer Removal Scores between 4 groups. The test results demonstrate that the mean Smear Layer Removal Scores for 17% EDTA group was 2.7±0.3, for 10% citric acid group was 2.3 ±0.4, for 0.7% fumaric acid group was 2.0 ± 0.0 and for normal saline it was 3.0 ± 0.0.(Refer graph 1). There was a very highly significant difference between fumaric acid and EDTA group ($P < 0.0001$) whereas significant difference was noted between citric acid and EDTA group ($P < 0.05$).



SEM images of EDTA group shows few partially opened dentinal tubules with heavy smear layer. Whereas in fumaric acid and citric acid group more number of partially opened dentinal tubules can be seen with moderate smear layer. Normal saline the control group shows completely blocked dentinal tubules with heavy smear layer (Refer image 1-4). Citric acid and fumaric acid were equally effective in smear layer removal without any statistical difference. However the results showed fumaric acid was more effective in smear layer removal than citric acid and EDTA.

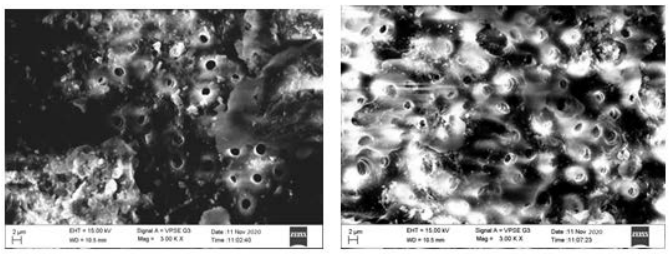


Fig.1 : SEM images of smear layer removal at the apical 3rd of root canal walls by 17% EDTA

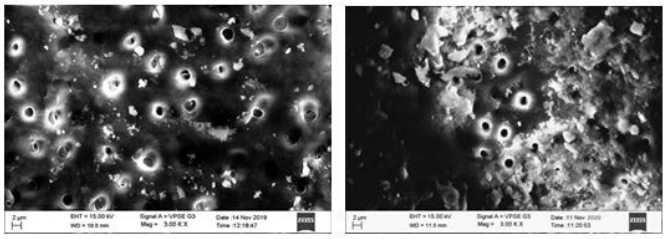


Fig.2: SEM images of smear layer removal at the apical 3rd of root canal walls by 10% citric acid

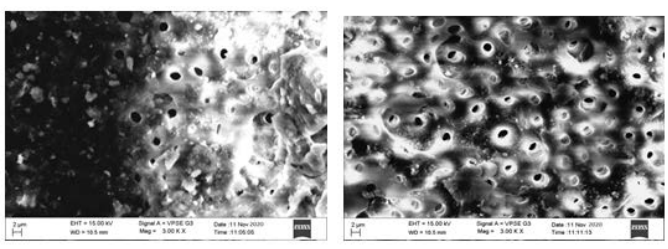


Fig.3: SEM images of smear layer removal at the apical 3rd of root canal walls by 0.7% fumaricacid

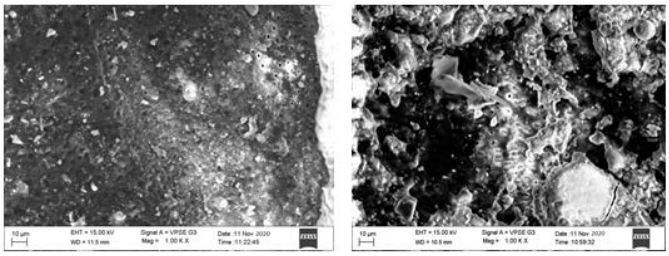


Fig.4 SEM images of smear layer removal at the apical 3rd of root canal walls by normal saline

Discussion

Success of an endodontic treatment is dependent on the elimination of micro-organism from the root canal system, which can be done by using various instrumentation techniques and use of effective irrigants during the biomechanical preparation of root canal[15]. Formation of smear layer is an inevitable process during root canal instrumentation. It is composed of a mixture of organic and inorganic materials, It prevents penetration of intra canal medicaments into the irregularities of the root canal system and also prevents complete adaptation of obturation materials to the prepared root canal walls[16].

Therefore, to eliminate smear layer from the root canal systems, endodontic irrigants must have additional properties, such as the ability to dissolve organic and inorganic materials, antibacterial effects, and biocompatibility with the tissues[17].

This present study has compared the action of 0.7% fumaric acid with well-established solutions, such as 17% EDTA and 10% citric acid at experimental periods of time in which these chemicals are known to be effective. As far as we are concerned, there is no study in the literature comparing EDTA, citric acid, and fumaric acid at the same concentrations as those used in the present study.

In group 1, canals were irrigated with 17% EDTA solution, showed significantly lower smear layer removal when compared to 0.7% fumaric acid and 10% citric acid. This result was in accordance with the study done by Maıra Prado et al[18]. who compared the efficacy of EDTA, citric acid and phosphoric acid in smear layer removal, and the result showed that, EDTA had the least smear layer removal property in the apical third of the root canal.

Kuruvilla et al[19]. compared the effectiveness of EDTA, etidronic acid, and maleic acid in smear layer removal apical root canal and found that, Final irrigation with 7% maleic acid is more efficient than 17% EDTA in the removal of smear layer from the apical third of root canal.

This can be due to the neutral pH of the EDTA, which is responsible for its self limiting property. During dentin demineralization, ca^{2+} exchange from dentin will occur by H^{+} ions which will reduce the pH so that the effect of EDTA decreases[20].

In group II, 10% citric acid were used to irrigate the canals. The result showed its increased ability to remove smear layer from apical root canal when compared to EDTA. It showed almost similar result with 0.7% fumaric acid. According to Goldman et al[21] smear layer removal effects obtained with citric acid were similar to those by EDTA. Whereas study report by Ando et al[22]. demonstrated a less cytotoxic irritable tissue response with citric acid than with EDTA. Dentin Decalcification property of citric acid was due to chelation of Ca^{2+} ions and acidity of the solution. Citric acid solutions were used in higher concentrations (25% and 50%), initially for endodontic use. Whereas recent studies and research data suggesting use of weaker solution of citric acid(6-19%) for better performance and that's the reason for considering 10% citric acid solution in this study.

In the present study, irrigating apical root canal with 10% citric acid found to be more efficient in smear layer removal than EDTA group but slightly lesser than fumaric acid group. SEM images after citric acid irrigation shows debris that are scattered over the dentinal tubules in few samples. Inability of the irrigants to penetrate deep into the apical part of the root canal might be because of its high surface tension. This is in accordance with the study done by hariharan et al[24]. Who evaluated the efficacy of various irrigants in removing the smear layer in primary teeth root canals after hand instrumentation and found that 6% citric acid was more effective than 5.25% NaOCl, 10% EDTA and 2% chlorehexidine. It is important to remember that Mariam et al[25] confirmed that root canal irrigation by both 10% citric acid and 17%EDTA were equally efficient in opening dentinal tubules. In this study, however, 17% EDTA had the least efficacy in terms of smear layer removal in comparison with 10% citric acid and 0.7% fumaric acid.

In group III, 0.7% Fumaric acid were used and the result demonstrating a statistically significant effect on smear layer removal over other group irrigants. This result is in accordance with Jaiswal et al. who evaluated the efficacy of 17% EDTA, 7% maleic acid and 0.7% fumaric acid in smear layer removal and found that both fumaric acid and maleic acid were equally effective in apical third of root canal without any significant difference between them but both showed significantly better results than EDTA.

This may be because, in fumaric acid two carboxylic groups are present which are opposite to each other in their three-dimensional orientation so it is able to bind with more number of Ca^{++}present in intra radicular dentin than the cis form of maleic acid in which the carboxylic group (-COOH) are always at the same side[26].

Fumaric acid is anti-inflammatory, non absorbable, nontoxic, anti carcinogenic and biocompatible solution having growth modulatory action. Therefore it can be used in the field of endodontics as a root canal irrigant to remove smear layer.

Conclusion

Within the limitation of this study it can be concluded that 0.7% of fumaric acid has better smear layer removal property at the apical third of root canal system than 10% citric acid and 17% EDTA.

Further in vivo and in vitro investigations are required to know more about the overall performance of fumaric acid and its effect on removing smear layer from root canal system.

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