



Smear Layer Removal by 1% Phytic Acid after Root Canal Preparation with Three Different Rotary Systems

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Abstract

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AIM: This study compared the removal of the smear layer using 1% phytic acid or 17% ethylenediaminetetraacetic acid (EDTA) after root canal instrumentation with SmartTrack X3, Endo*star E, and ProTaper Gold rotary systems using an environmental scanning electron microscope (ESEM).

METHODS: Sixty single-rooted unidentified extracted human maxillary anterior teeth were selected. The length of all the roots used was adjusted to 16 mm from the apex. Modified access cavities were done. Roots were equally and randomly allocated to three main groups (n = 20) corresponding to the rotary systems: group A1, SmartTrack X3; group A2, Endo*star E3; and group A3, ProTaper Gold. Each group was divided into two equal subgroups (n = 10), corresponding to the chelating agents applied as a final rinse: subgroup B1, 1% phytic acid, and subgroup B2, 17% EDTA. Roots were split in a buccolingual direction into two equal halves and examined under ESEM in the presence or absence of a smear layer at the cervical, middle, and apical segments.

RESULTS: 1% Phytic acid and 17% EDTA recorded no statistically significant for removing the smear layer. For all subgroups, there was a significant difference in smear layer removal and more open dentinal tubules in the cervical segment versus the apical segment.

CONCLUSION: In smear layer removal from root canals, 1% phytic acid was effective as 17% EDTA in smear layer removal from root canals after SmartTrack X3, Endo*star E3, or ProTaper Gold rotary systems instrumentation.

Introduction

Effective root canal treatment was achieved with proper root canal preparation and 3-dimensional fluid-tight seal obturation. Root canal preparation forms an amorphous, granular, and irregular layer called "smear layer." This layer is composed of inorganic and organic materials, pulp tissue, collagen, blood cells, necrotic debris, nerve fibers, tissue fluid, and microorganisms [1].

It is challenging to completely clean and shape the root canal due to its varying anatomy [2], [3]. In simple, narrow, straight root canals with round cross-sections, most currently used rotary instruments will adequately clean and shape the canal, with favorable results. However, in oval, flat, or curved root canals, rotary files often fail to adequately clean and shape the canal, leaving fins that may not have been touched [4]. These parts might hide microbes and/or debris that would develop periradicular inflammation and inhibit sealing of the obturation material [5].

Root canal cleaning cannot be achieved using instrumentation alone. Therefore, irrigation is a critical component in canal debridement [6], [7]. After root canal instrumentation, the dentin debris and smear layer cover the canal lumen [8]. The smear layer weakens the seal of the canal filling by blocking the dentinal tubules and preventing penetration of sealers and disinfectants [9], [10].

Sodium hypochlorite (NaOCl) is the highly used irrigant for root canal cleaning due to its ability to dissolve pulp tissue and its strong antimicrobial action [11]. Although, it has some harmful properties, such as allergic potential and tissue toxicity at high concentrations [12], [13].

Ethylenediaminetetraacetic acid (EDTA) is frequently used as a chelating agent. The action of the chelating agent depends on the pH, solution concentration, and time of application [14], [15], [16].

The smear layer was successfully removed by coupling NaOCl with EDTA [17]. However, it has been reported that more than 1 min application of a chelating agent might cause changes in the root canal dentin [18], [19]. This could reduce the microhardness of dentin, weaken the tooth structure, and influence the clinical performance of teeth after endodontic treatment [20], [21]. In addition, EDTA has a detrimental effect on the periapical tissue [22].

Phytic acid (IP6, inositol hexakisphosphate) is an organic acid obtained from rice bran. It contains six phosphate groups bonded to the carbon atoms of the carbohydrate ring [23]. Phytic acid is recommended as a chelating agent for the removal of the smear layer due to its capacity to chelate multivalent cations such as calcium, iron, and magnesium [24].

This study aimed to compare 1% phytic acid and 17% EDTA for the smear layer removal after root canal preparation using SmartTrack X3, Endo*star E, or ProTaper Gold rotary systems using environmental scanning electron microscope (ESEM). The null hypothesis suggested that there was no difference between 1% phytic acid and 17% EDTA in removal of smear layer from the root canals after instrumentation using the three different rotary systems.

Materials and Methods

Collection of samples

This study was granted by the Research Ethics Committee (no. 217/2019) of the Faculty of Dentistry, Suez Canal University.

Sixty unidentified human maxillary anterior teeth were selected from a large number of teeth. The selected teeth had type I root canals, with completely formed apices. Teeth with calcified root canals, external or internal root resorption, previous endodontic manipulation, or cracks were excluded from the study.

This study was double-blinded by the operator and the observers. The allocator divided the collected teeth into groups and subgroups with coded numbers, and each group placed in an opaque envelope. The operator was aware of the file type at the time of canal preparation for coded grouped teeth. A random sequence was created using computer software (<http://www.random.org/>) [25].

Preparation of samples

Selected teeth were stored in saline solution for 2 weeks before use. Each tooth was scaled using an ultrasonic scaler (Woodpecker, China) to be completely free from external fragments or calculus.

The length of all the teeth used was adjusted to 16 mm from the apex by decoronation using a tapered stone under copious amounts of water. Modified access cavities were created using round burs, and all the apices were sealed with epoxy resin.

To prepare a 1% phytic acid solution, 1 g of 50% phytic acid was added to 100 mL distilled water. The solution was stirred for 2 h using a magnetic stirrer (Spectrum MS300HS, Phasi Charoen District, Bangkok, China). A 1% phytic acid solution has no harmful effects and decreases the erosive potential of radicular dentine [22].

Grouping of samples

Roots were equally and randomly distributed into three main groups (n = 20), corresponding to the rotary system used in root canal instrumentation, as follows:

Group A1: SmartTrack X3 (Nikini Dental B.V.) Netherlands) was operated on in the following sequence: N1 (17/0.06) to cervical two-segments. This was followed by N2 (17/0.04), C1 (20/0.06), C2 (25/0.06), C3 (30/0.06), and C4 (40/06) to the full working length (WL) at 300 rpm and 300 g/cm³ N/cm torque [26].

Group A2: Endo*star E3 (Poldent Co., Warsaw, Poland) started with file 1 (30/08) to prepare the root canal for approximately half of the WL. File 2 (25/06) was prepared for the root canal to achieve full WL, followed by files 3 (30/04), 4 (35/04), and 5 (40/04) at 150–300 rpm and 3 N/cm torque [27].

Group A3: ProTaper Gold (Dentsply Maillefer, Ballaigues, Switzerland) was started with the SX (19/04) file for cervical preparation, followed by S1 (18/02), S2 (20/04), F1 (20/07), F2 (25/08), F3 (30/09), and F4 (40/06) to full WL at 300 rpm and 2 Ncm torque [28].

Each group was subdivided into two equal subgroups (B1 and B2; n = 10) corresponding to the chelating agents used in the final rinse: 5 mL of 1% phytic acid (Sigma) for subgroup B1 and 5 mL of 17% EDTA (FEI Company, Netherlands) for subgroup B2. A 30-gauge needle (Ultradent, UT, USA) with a syringe was used to deliver the solutions and was inserted 2–3 mm less than the WL without binding for 1 min.

Regimen of preparation

All procedures were performed using dental loupes (Univet, Italy) by 1 operator. The instruments for all groups were discarded after three uses. The endodontic motor (X-smart, Dentsply Maillefer) was adjusted for each file corresponding to the instructions of manufacturer in crown-down order, which progressed with light apical pressure in a slow-in and slow-out motion [29]. After each file, the canals were irrigated with 2 mL 2.5% NaOCl for 1 min. Apical patency was checked using #10 K, and paper points were used to obtain dryness [30].

Examination of samples

All roots were split into two equal halves in a buccolingual direction as described by Parente *et al.* [31]. Every one half of each root canal lumen was examined under ×1000 magnification using ESEM (FEI Company, Netherlands) at the cervical, middle, and apical segments. Photomicrographs were achieved at three randomly selected places in each segment. The absence or presence of the smear layer was examined through 270 photographs by three blinded observers according to Saber and Hashem [32] scores: (1) The smear layer was completely absent; most of the tubules were opened and debris-free; (2) the smear layer covered <25% of the canal wall and dentinal tubules; (3) the smear layer was evident in

25–50% of the canal surface and tubules; (4) the smear layer was evident in 50–75% of the canal surface and tubules; and (5) the smear layer covered 75–100% of the canal surface and tubules.

Statistical analysis

The acquired data were organized and statistically analyzed. Three-way analysis of variance was tested the interactions between different variables, and non-parametric data were subjected to the Friedman test for comparisons between more than two groups in related samples. The Wilcoxon test was used for comparison of two groups for related samples. However, the Mann–Whitney U-test was used for comparison of two groups in unrelated samples. The significance level was adjusted at $p \leq 0.05$. Statistical analyses were done using IBM SPSS Statistics version 20 for Windows.

Results

Comparison of smear layer scores at the three root canal segments

Intragroup comparisons shown that the lowest scores were recorded in the cervical segment, followed by the middle and apical segments (Table 1). Statistically significant differences were recorded between all segments for each subgroup, except for the SmartTrack X3 rotary system with 17% EDTA (A_1B_2 subgroup) ($p < 0.05$). In the SmartTrack X3 rotary system plus 1% phytic acid (A_1B_1 subgroup), a statistically significant difference was detected when the apical segment was compared with the cervical and middle segments, and no statistically significant difference was recorded between the cervical and middle segments (Figure 1).

In the Endo*star E3 rotary system with both chelating agents, a statistically significant difference was recorded between the cervical and apical segments, and no statistically significant difference was recorded between any other pairs (Figure 2).

In the ProTaper Gold rotary system with both chelating agents, a statistically significant difference was shown when the apical segment was compared to the cervical and middle segments, and no statistically

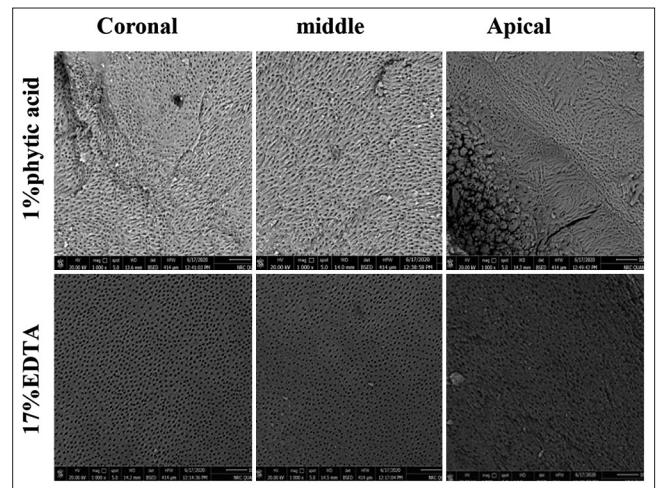


Figure 1: Representative ESEM microphotographs showing selected samples from the cervical, middle, and apical segments representing root canal lumen prepared by SmartTrack X3 + 1% phytic acid (A_1B_1) or 17% EDTA (A_1B_2)

significant difference was recorded between the middle and cervical segments (Figure 3).

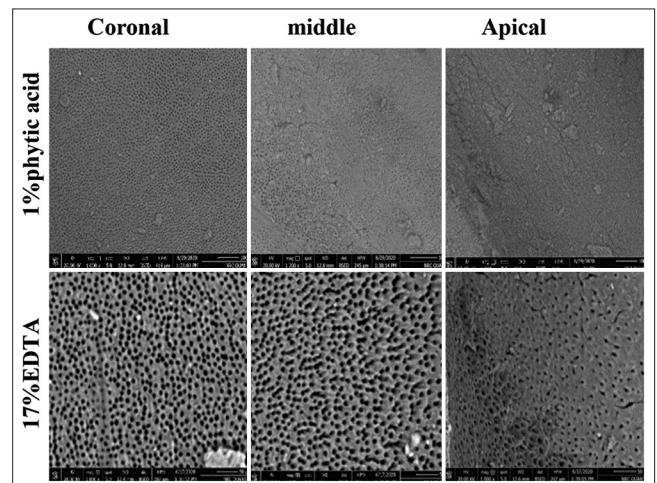


Figure 2: Representative ESEM microphotographs showing selected samples from the cervical, middle, and apical segments representing root canal lumen prepared by Endo*star E3 + 1% phytic acid (A_2B_1) or 17% EDTA (A_2B_2)

Comparison between the smear layer scores of chelating agents in the three root canal segments

Removal of the smear layer in the cervical, middle, and apical segments of the root canal using 1% phytic acid as the final rinse (B_2) was not statistically significant among the three rotary systems used (Table 2).

Table 1: Mean and standard deviation values of smear layer scores at the three root canal segments with each chelating agent after using three different rotary systems

Root canal segments	SmartTrack X3 A_1		17% EDTA B_2		Endo*star E3 A_2		17% EDTA B_2		ProTaper Gold A_3		17% EDTA B_2	
	1% phytic acid B_1		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Cervical	0.2 ^a	0.447	0.2 ^a	0.447	0.0 ^b	0.000	0.0 ^b	0.0	0.2 ^a	0.447	0.0 ^b	0.000
Middle	0.2 ^a	0.447	0.2 ^a	0.447	0.8 ^{a,b}	0.837	0.8 ^{a,b}	0.837	0.6 ^b	0.548	0.2 ^a	0.447
Apical	2.0 ^a	0.000	0.6 ^a	0.548	1.6 ^a	0.548	1.8 ^a	0.447	2.0 ^a	0.000	1.8 ^a	0.447
P	0.012*		0.368 (NS)		0.018*		0.014*		0.010*		0.009*	

*Significant ($p < 0.05$), NS ($p > 0.05$). Means with different superscript letters are statistically significantly different according to Friedman test. NS: Non-significant, SD: Standard deviation, EDTA: Ethylenediaminetetraacetic acid.

In contrast, among the three rotary systems used, smear layer removal with 17%EDTA as the final rinse (B_2) was statistically insignificant at the cervical and middle segments of the root canal and statistically significant at the apical segment of the root canal. Lower smear layer removal scores recorded for SmartTrack X3 rotary system plus 1% 17%EDTA (A_1B_2) subgroup, with significant differences compared with the other two segments.

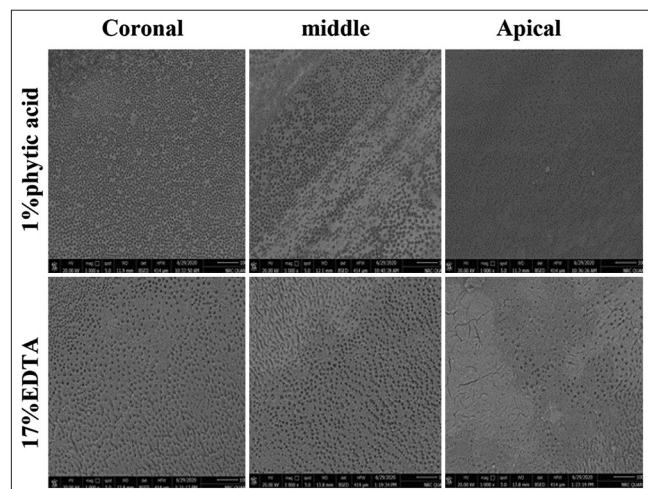


Figure 3: Representative ESEM microphotographs showing selected samples from the cervical, middle, and apical segments representing root canal lumen prepared by ProTaper Gold + 1% phytic acid (A_3B_1) or 17% EDTA (A_3B_2)

Discussion

At present, several available techniques may improve final irrigation before obturation [33]. This study compared the smear layer removal by 1% phytic acid and 17% EDTA after root canal instrumentation with (SmartTrack X3, Endo*star E3, and ProTaper Gold rotary systems) using ESEM.

The study was performed under strict and standardized conditions to minimize bias and confounding factors. The selected maxillary teeth have bulky roots that make splitting and microscopic evaluation easier [34]. The teeth length was adjusted to 16 mm to obtain a constant working length. Moreover, the sealed root apices simulate clinical situations, in which the foramen of the tooth and the outer surface are close to the periodontal ligament, where gases may be entrapped inside the root canal [35].

Whenever the root canal lumen was prepared using rotary or hand instruments, the hard tissues were not cleaved or ragged, but crushed to form a smear layer. Many studies have defined the smear layer as a non-adherent structure retained on the root canal walls, because it can entomb bacteria and counteract leakage [36], [37], [38], [39]. Others considered that the smear layer could close the dentinal tubules and permit bacterial growth [40], [41]. Nevertheless, the choice of irrigants and chelating agents can be based on smear layer removal capability [35].

In endodontic treatment, NaOCl is commonly used as an irrigant for dissolving the pulp tissue and the organic portion of the smear layer. However, the inorganic portion of the smear layer cannot be removed [37], [38].

Contact time and concentration are the main factors affecting irrigant action. However, 17% EDTA is the gold standard for eliminating the smear layer within 1–3 min, as shown in the present study, as it causes erosion of the inter- and peritubular dentin when used for a longer time [39]. Ionized EDTA had the facility to chelate the inorganic part of the smear layer. However, EDTA has certain drawbacks, such as cytotoxicity, lack of antimicrobial activity, and inhibition of macrophage function [40], that alter the inflammatory response in the periapical region [41].

1% phytic acid was a biocompatible material reported to replace EDTA for removal of smear layer, based on its advantages of a negative charged molecule that has the capability to chelate the multivalent cations such as magnesium, iron, and calcium. The smear layer was successfully removed with a 1% phytic acid, revealing a cross-linked collagen network, thereby enhancing the bond strength to the dentin [24].

The results of this study revealed the highest amount of smear layer in the apical segment of the canal, followed by the middle segment, which can be described by the lower number of dentinal tubules and the narrow canal lumen at the apical segment. Furthermore, the apices of the samples were sealed to avoid debris extrusion through the apex and debris that could not exit the canal persisted in the apical region [42]. In addition, this might be due to the nature of the sclerosed dentin at the apical segment, as reported by Paque *et al.* [43]

SmartTrack X3 files recorded satisfactory results with both final chelating agents, because these files used heat-treated Ni-Ti, which offers more

Table 2: Mean and standard deviation values of smear layer scores at each segment with each rotary system after using two chelating agents

Root canal segments	1% phytic acid B_1						17% EDTA B_2					
	Cervical		Middle		Apical		Cervical		Middle		Apical	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
SmartTrack X3 A_1	0.2 ^a	0.447	0.2 ^a	0.447	2.0 ^a	0.000	0.2 ^a	0.447	0.2 ^a	0.447	0.6 ^b	0.548
Endo*star E3 A_2	0.0 ^a	0.000	0.8 ^b	0.837	1.6 ^b	0.548	0.0 ^a	0.000	0.8 ^b	0.837	1.8 ^b	0.447
ProTaper gold A_3	0.2 ^a	0.447	0.6 ^b	0.548	2.0 ^a	0.000	0.0 ^a	0.000	0.2 ^a	0.447	1.8 ^b	0.447
p	0.584 (NS)		0.337 (NS)		0.11 (NS)		0.368 (NS)		0.267 (NS)		0.011*	

*Significant ($p < 0.05$), NS ($p > 0.05$). Means with different superscript letters are statistically significantly different according to Kruskal–Wallis. NS: Non-significant, SD: Standard deviation, EDTA: Ethylenediaminetetraacetic acid.

flexibility to bend extreme curves, thereby decreasing the risks of ledging, instrument separation, and canal transportation [26]. These factors explain the lower smear layer removal scores, with significant differences compared with the other two files tested.

Endo*star E3 rotary system with both chelating agents showed no statistically significant difference among the three root canal segments. This might be due to Endo*star E3 manufacturing from the highest-quality Ni-Ti alloy, which provides durability and flexibility. The modified S-shaped cross-section with two 90° cutting edges that ensure efficient cutting provided transport of debris up the canal [27]. In the present study, the root canals were instrumented through the crown-down technique with Endo*star E3 (40/04). This was proven by Schäfer *et al.* [44], who reported that the flexibility of Ni-Ti instruments decreased with increasing file taper and files with a taper equal to or <0.04 was recommended.

In the case of the ProTaper Gold rotary system with both chelating agents, a statistically significant difference was shown when the apical segment was compared with the cervical and middle segments. ProTaper Gold is a rotary NiTi file system manufactured as a modified version of the famous ProTaper Universal, and developed using proprietary advanced metallurgy through heat treatment. It has a progressive taper, non-cutting tip, and a convex triangular cross-sectional design [45]. The greater taper of the ProTaper Gold F3(30/09) might be the reason for the increased smear layer formation score, especially in the apical segment, which was confirmed by Reddy *et al.* [46] Elnaghy and Elsaka [47].

Nassar *et al.* [24] and Podili *et al.* [48] observed better removal of the smear layer with 1%phytic acid than 17% EDTA. In contrast, Afshan *et al.* [22] reported that 17%EDTA was more effective than 1%phytic acid on the smear layer. This disagreement may be due to differences in application time. In the present study, 1% phytic acid and 17% EDTA were equally effective and did not differ in their ability to remove the smear layer.

Conclusion

Within the limitations of this study, we accepted the null hypothesis and concluded that final irrigation with 1% phytic acid was as effective as and not different from 17% EDTA in the ability for removal of smear layer from the root canals after instrumentation using three different rotary systems. However, further studies with larger sample sizes are essential to determine the biocompatibility and efficacy of phytic acid in clinical settings.

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