Submitted: 08 September, 2022 Accepted: 20 October, 2022 Published: 03 January, 2023 DOI:10.22514/jocpd.2022.016

Journal of Clinical Pediatric Dentistry

ORIGINAL RESEARCH

Smear layer removal efficacy of irrigating solutions applied distinct needle designs: a scanning electron microscopy study

Akif Demirel[1,*], Nur Sena Önder[1], Merve Alkış[2], Şaziye Sarı[1]

[1]Department of Pediatric Dentistry, Faculty of Dentistry, Ankara University, 06560, Ankara, Turkey
[2]Department of Pediatric Dentistry, Faculty of Dentistry, Uşak University, 64000, Uşak, Turkey

***Correspondence**
akifdemirel@ankara.edu.tr
(Akif Demirel)

Abstract

This research aimed to assess the efficacy of different irrigants applied with different types of needle tips on smear layer removal (SLR) in primary incisors. This study was carried out with 35 freshly extracted upper primary incisors. The samples were randomly distributed to five study groups (n = 7) (1 to 4: experimental, 5: control). These included Group 1: 5% Ethylenediaminetetraacetic Acid (EDTA) + 1% Sodium Hypochlorite (NaOCl) applied with open-ended needle (OEN), Group 2: 6% Citric Acid (CA) + 1% NaOCl applied with OEN, Group 3: 5% EDTA + 1% NaOCl applied with double side-vented needle (DSVN), Group 4: 6% CA + 1% NaOCl applied with DSVN and Group 5: 1% NaOCl applied with OEN. Accordingly, the inner root surfaces were examined using scanning electron microscopy (SEM). The differences between the groups were analyzed using Kruskal-Wallis, Friedman and Siegel-Castellan tests ($p < 0.05$). In the coronal third, all the experimental groups (groups 1, 2, 3 and 4) were superior to the control group ($p = 0.002$, $p = 0.002$, $p < 0.001$ and $p < 0.001$, respectively). Groups 2, 3 and 4 showed superior SLR to the control group ($p = 0.024$, $p = 0.001$ and $p = 0.004$, respectively) in the middle third. DSVN groups of EDTA and CA showed superior SLR efficacy than the control ($p < 0.001$ and $p = 0.002$, respectively) in the apical third. The SLR efficacy was higher in the coronal third compared to the apical third in the experimental groups (groups 1, 2, 3 and 4) ($p = 0.015$, $p = 0.048$, $p = 0.048$ and $p = 0.048$, respectively). In addition, 3 samples of EDTA showed erosion (2 in the coronal with OEN, 1 in the middle with DSVN). It was possible to conclude that the SLR efficacy of DSVNs and OENs was similar. CA could be recommended since it did not cause erosive damage compared to EDTA in primary incisors.

Keywords

Citric acid; EDTA; Irrigation; Primary teeth; Pulpectomy; Side-vented needle

1. Introduction

The success of pulpectomy is closely associated with the effective elimination of infectious microorganisms in primary teeth [1–3]. The smear layer (SL) consisting of inorganic and organic components occurs as a result of the mechanical effect of root canal instruments on root canal surfaces. This layer, which is formed by the fragmentation of mineralized dental hard tissues, is defined as an amorphous structure containing coagulated proteins, odontoblast residues, blood cells, necrotic pulp tissue remnants, saliva, various microbes and dentinal particles [3–5]. The SL obturates the dentin tubules and prevents irrigants and canal filling materials from reaching the dentinal tubules. For this reason, it is strongly recommended to remove the SL to achieve more successful effective results in root canal treatment [5, 6].

Various irrigation solutions such as sodium hypochlorite (NaOCl), citric acid (CA), physiological saline (PS), and ethylenediaminetetraacetic acid (EDTA) are used in pulpectomy procedures of primary teeth for chemo-mechanical debridement. NaOCl is often preferred due to its higher antimicrobial effect and ability to remove organic contents, even at 0.5% concentration [3, 7, 8]. However, it has been stated in many studies that NaOCl cannot effectively remove the SL due to its low efficacy in dissolving inorganic tissues [7, 9]. EDTA is a chelating agent and it removes especially the inorganic contents of SL. It has been reported in dental literature that EDTA has erosive effects on dentinal surfaces. CA, an organic acid, has been emphasized to effectively remove SL without causing erosive damages in inter- and peritubular dentin [3, 10].

In primary teeth, root canals include anatomical variations such as accessory canals, lateral branches, and morphological differences. In addition, the mechanical instrumentation us unable reach the apical third which means that it is important to use more effective irrigation methods that provide antimicrobial efficacy [8, 11]. On the other hand, even irrigation methods cannot access all the surfaces in root canal —especially in the apical— due to the complex anatomical morphology of primary teeth. The position of the apical opening moves coronally with physiological root resorption and the width of the apical foramina enlarges in primary teeth in time. For this reason, there is a risk of an increase in the overflow/extrusion of irrigants and debris into the periapical area [3, 8, 12–14]. This can jeopardize the safety of both the periapical region and the permanent tooth germ. Therefore, there is a need for a safer irrigation protocol and method. Due to anatomical variations, irrigation materials cannot effect the hard-to-reach areas, which means the SL cannot be completely removed from these areas, especially in the apical third. Therefore, the irrigation solutions/systems to be used are expected to be more effective in the apical region [3, 4, 8, 14]. Side-vented needles (SVNs) have been developed to deliver the irrigation solutions laterally. Since these needles are designed with closed-ends, the possibility of irrigation solutions to overflow to the periapical region is also reduced [15]. The irrigation process applied with SVNs is expected to provide more efficacy compared to open-ended needles (OENs) [15–17].

Based on the abovementioned preliminary information, the aim of this research was to assess the effects of various irrigation regimens and needle tips used in root canal treatment procedures on smear layer removal (SLR) in primary teeth.

2. Materials and Methods

2.1 Power Calculation and Sample Inclusion/Exclusion Criteria

The power calculation (effect size (f) = 0.65) revealed that a minimum of 35 samples were sufficient for the study protocol (power: 80%, type I error: 5%). Therefore, 35 freshly extracted upper primary incisor teeth obtained from 30 pediatric dental patients (aged 3–5 years) were used in this study. Incisor teeth that already required extraction were used for the study protocol and the main reasons for extraction were dento-alveolar traumatic injuries and incurable severe dental caries associated with periapical abscess, fistula or advanced support bone loss. The patients included in this study were followed-up under the scope of space maintenance and management. Where necessary, a space maintainer or a removable denture appliance was applied. Also, the other inclusion criteria of the samples in this study are as follows; teeth (i) with a single root, (ii) with a restorable crown structure, (iii) without any root anomalies, (iv) with a physiological root resorption grade not more than 1/3 of the root length, and (v) with the dimension of the apical foramen not higher than #50 K-file diameter.

The fracture of the roots, dentinal cracks, intracanal calcifications (partial or total), resorption lacunas on internal/external root surfaces or canal obliteration were analyzed using a stereomicroscope and the samples that included these pathologies were excluded [3, 14].

2.2 Study Procedures

The organic tissue remnants and periodontal ligament residues on the external root surfaces were cleaned with 2.5% NaOCl solution and a sharp periodontal hand instrument. The samples were than immersed in 0.9% PS until the initiation of the procedures of the study.

The samples included were embedded in dental modelling wax blocks (Polywax, Bilkim, İzmir, Turkey) leaving the crowns out to mimic the apical irrigation pressure like that of the mouth. Endodontic access cavity was prepared by diamond round burs (Meisinger, 801G-coarse, Hager & Meisinger GmbH, Neuss, Germany). Coronal pulp tissue, pulp residues and dentin debris were removed with a sharp excavator and gently irrigated with saline solution. Radicular pulp tissues were removed using a barbed broach (#30, DiaDent Group International Inc, Burnaby, BC, Canada). Next, the endodontic working length (WL) was measured to be 1–2 mm shorter than the root apex on periapical radiographs. The root canals were mechanically instrumented with #15-45 K-files (Ready Steel® Instruments, Dentsply Sirona, Ballaigues, Switzerland). During the mechanical instrumentation procedures, the root canals were irrigated with 10 mL of 1% NaOCl between each endodontic file by using different types of needles (Double side-vented needles (DSVNs, Fig. 1a and 1c) (30 gauge, Fanta Dental, İstanbul, Turkey) or OENs (Fig. 1b and 1d) (27 gauge, Genject Corp., Ankara, Turkey)) for each study group. Subsequently, the final irrigation was performed using EDTA or CA irrigation solutions applied with DSVNs or OENs. In all irrigation procedures, the needle tip was inserted into the root canal 2 mm shorter than the root apex, and irrigation of 10 mL solution was completed in a time period of 1 minute. Subsequently, the excess irrigant in the root canal was removed using an aspirator.

2.3 Study Groups

The samples included in this study were randomly distributed into five study groups consisting of 7 samples. The chemo-mechanical root canal instrumentation procedures for each group were described in detail below.

2.3.1 Experimental Groups

Group 1 (5% EDTA + OEN): The root canals were irrigated with 10 mL of 1% NaOCl by using an OEN between each instrumentation for 1 min. The final irrigation procedure was performed using 10 mL of 5% EDTA and an OEN.

Group 2 (6% CA + OEN): The root canals were irrigated with 10 mL of 1% NaOCl by using an OEN between each instrumentation for 1 min. The final irrigation procedure was performed using 10 mL of 6% CA and an OEN.

Group 3 (5% EDTA + DSVN): The root canals were irrigated with 10 mL of 1% NaOCl by using a DSVN between each instrumentation for 1 min. The final irrigation procedure was performed using 10 mL of 5% EDTA and a DSVN.

Group 4 (6% CA + DSVN): The root canals were irrigated with 10 mL of 1% NaOCl by using a DSVN between each instrumentation for 1 min. The final irrigation procedure was performed using 10 mL of 6% CA and a DSVN.

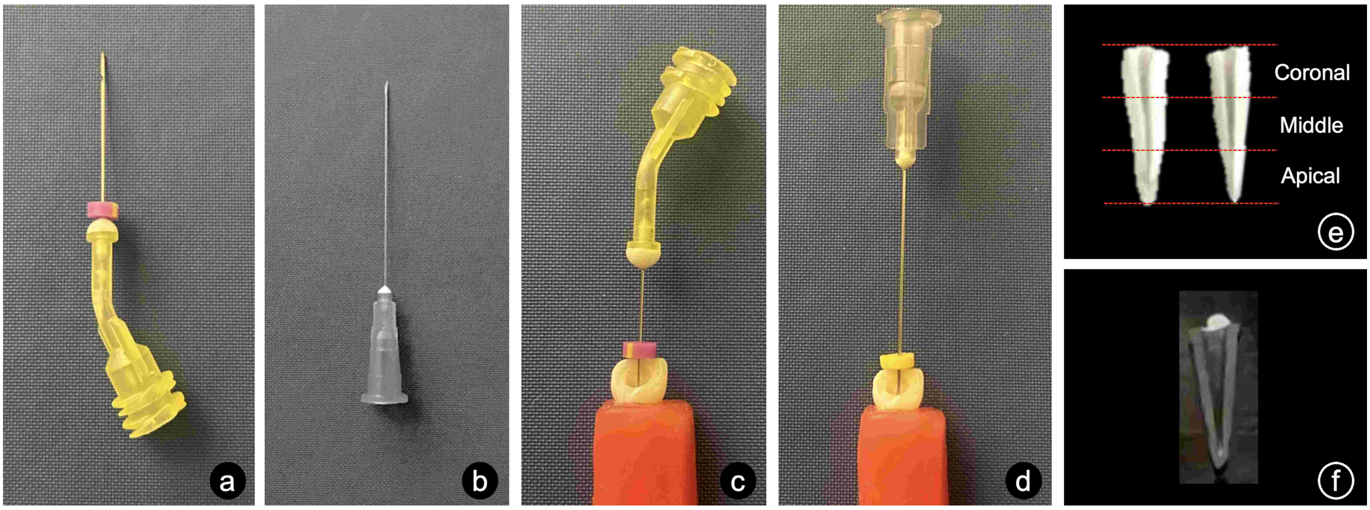

FIGURE 1. Needles, irrigation and SEM preparation stages. Double side-vented needle (a), open-ended needle (b), irrigation with double side-vented needle (c), irrigation with open-ended needle (d), tooth halves for the preparation for SEM analysis and root thirds (e) and sputter-coated tooth halves for SEM analysis.

2.3.2 Control Group

Group 5 (1% NaOCl + OEN): The root canals were irrigated with 10 mL of 1% NaOCl by using an OEN between each instrumentation for 1 min. The final irrigation procedure was performed using 10 mL of 1% NaOCl and an OEN.

Subsequently, the root canal systems were dried with the paper points (Pearl Endo, Pearl Dent Co., Ltd., Ho Chi Minh, Vietnam) and the endodontic access cavities were sealed with glass hybrid restorative system until SEM analysis (Equia Forte® HT, GC America Inc.).

2.4 SEM Evaluation

The SLR was assessed with a SEM device (Zeiss GeminiSEM 500-71-08, Carl Zeiss, Germany). Initially, the roots of the teeth were removed from the dental wax blocks. The roots were split longitudinally into two halves using sharp diamond disks under water cooling (Fig. 1e) (Micracut 201, Metkon, Bursa, Turkey). Subsequently, the roots were dried by vacuum, mounted on aluminum stubs and then sputter-coated with 135 Å Au-Pd particles (Fig. 1f) (80% for Au, 20% for Pd) (Polaron SC7620 Sputter Coater, Quorum Tech., UK) for SEM analysis. The inner root surface of each sample was evaluated in three equal regions to be coronal, middle, and apical (Fig. 1e). While the SEM assessment, in order to reflect the own characteristics of the scored thirds (coronal, middle and apical), approximately central regions of root thirds were examined instead of the adjacent areas of each root thirds. During the SEM assessment, all images were taken at × 3500 magnification. The SEM photographs were blindly scored at one-week intervals by the same investigator (A.D). The scoring investigator was blinded to the sample origin. Intra-examiner reliability was analyzed by Kappa statistics and the reliability value was 0.9, demonstrating good reliability. The level of SLR was determined using the following evaluation criteria, which were previously stated in dental literature [3, 10, 14].

Score 0: Most of the dentin tubules were open and no SL was observed.

Score 1: Most of the dentin tubules were partially obliterated or partially visible and moderate SL was observed.

Score 2: Most of the dentin tubules were completely obliterated and SL was observed in abundance.

2.5 Statistical Analyses

The data obtained was analyzed using the Kruskal-Wallis test. The statistical difference between the parts of the roots was analyzed using the Friedman test. Binary comparisons between the study groups were analyzed using the Siegel Castellan test. The level of statistical significance was taken as 5%.

3. Results

In the coronal third, all the experimental groups (groups 1, 2, 3 and 4) showed superior the SLR results when compared with the control group (Group 5) with statistical significance (p = 0.002, p = 0.002, $p < 0.001$ and $p < 0.001$, respectively). However, there is no statistical difference between the groups of 5% EDTA and 6% CA solutions applied with both OENs and DSVNs ($p > 0.05$) (Table 1; Figs. 2 and 3).

In the middle third, 6% CA with OEN, 5% EDTA with DSVN and 6% CA with DSVN achieved effective the SL removal with a statistically significant margin over the control group (p = 0.024, p = 0.001 and p = 0.004, respectively) (Table 1; Figs. 2 and 3).

In the apical third, DSVN groups (5% EDTA with DSVN and 6% CA with DSVN) achieved effective the SL removal with a statistically significant margin over the control group ($p < 0.001$ and p = 0.002, respectively) (Table 1; Figs. 2 and 3).

In addition, the SLR was statistically higher in the coronal third compared to the apical in all experimental groups (groups 1, 2, 3 and 4) (p = 0.015, p = 0.048, p = 0.048 and p = 0.048, respectively) (Table 1; Figs. 2 and 3).

Erosive changes, excessive removal of inter- and peritubular dentin tissues was found in 3 samples (2 in the coronal third with OEN, 1 in the middle third with DSVN) in the use of EDTA solutions. Moreover, these defects were found in the

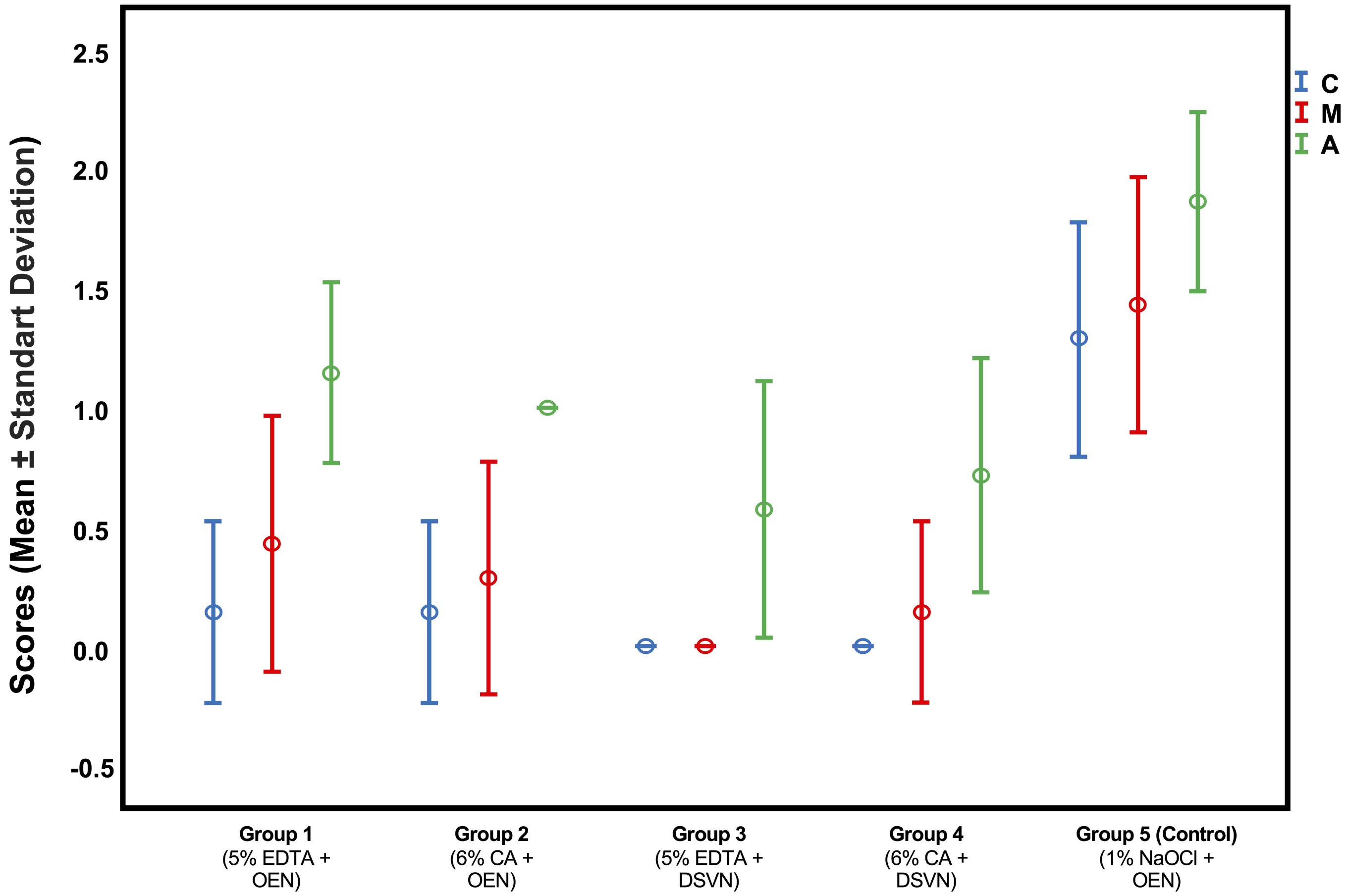

FIGURE 2. The distribution of SEM scores of the study groups in coronal, middle and apical thirds. C: coronal; M: Middle; A: Apical; EDTA: Ethylenediaminetetraacetic Acid; OEN: open-ended needle; CA: Citric Acid; DSVN: double side-vented needle; NaOCl: Sodium Hypochlorite.

coronal and middle parts. However, these defects were not detected in the apical part (Fig. 3).

4. Discussion

The present research compared the effects of two different irrigation protocols applied using two different needle designs on the SLR in primary teeth. Chemo-mechanical debridement and root canal irrigation are considered to be essential parts of pulpectomy procedures in primary teeth [3]. For the optimal efficacy of irrigation, irrigation solutions should provide their effects on all the surface of the root canals [18]. The irrigation needles are designed differently to increase the efficacy of irrigation procedures as well as to protect the periapical tissues [17]. OENs produce higher apical pressure and cause more irrigation solution to access the periapical tissues. Also, although irrigation procedures using OEN are typically the preferred technique in root canal treatments, the replenishment of the solution is restricted, especially in the apical third [2, 19]. However, SVN tips allow irrigants to contact to the root canal walls rather than the periapical area. The use of SVNs prevents the extrusion of irrigation solutions and debris into the periapical area. Thus, the efficacy of irrigation procedures in the apical region increases with the use of SVNs [16, 17]. The design of the needle tip effects the pattern of the flow, the speed of the irrigation solution and the pressure to the apical area, which are all the important criteria regarding irrigation safety and efficacy [17, 20]. On the other hand, the increase in the width of the apical foramen of primary roots with physiological root resorption process and the underlying permanent tooth germ also suggest that apical irrigation should be performed in safety limits [3, 8]. Little information is available in the literature regarding the use of SVNs on primary teeth and there is still no consensus on this issue. Based on abovementioned pre-information, this study investigated the effects of DSVNs in the SLR—especially in the apical area.

NaOCl is a frequently used irrigation agent in pulpectomy procedures of primary dentition due to its high antibacterial activity. However, noteworthy disadvantage is that NaOCl is not an inorganic tissue solvent and cannot effectively remove the SL. For this reason, irrigants such as EDTA and CA which act on inorganic tissues and remove the SL more effectively are preferred. These solutions are mostly used in combination with NaOCl due to antibacterial activity. However, the concentrations of EDTA and CA used in primary teeth differ from those in permanent teeth [3, 14]. Unlike permanent teeth, the hard dental structures of the primary teeth contain more organic material and water. This affects the hardness of dental tissues. Therefore, primary tooth dentin tissue responds more reactively to irrigation agents [4, 21]. This indicates that

TABLE 1. Statistical comparisons between the study groups, and comparisons between the root thirds.

Irrigation Groups	SLR Scores of Coronal Third Median (Min–Max)	SLR Scores of Middle Third Median (Min–Max)	SLR Scores of Apical Third Median (Min–Max)	*p* value (for the comparison of root thirds)	*p* values (for binary comparisons)
Group 1: 5% EDTA applied with OEN	0 (0–1)	0 (0–1)	1 (1–2)	$p = 0.004$*	Coronal-Middle: $p = 1.000$ Coronal-Apical: $p = 0.015$* Middle-Apical: $p = 0.135$
Group 2: 6% CA applied with OEN	0 (0–1)	0 (0–1)	1 (1–1)	$p = 0.012$*	Coronal-Middle: $p = 1.000$ Coronal-Apical: $p = 0.048$* Middle-Apical: $p = 0.135$
Group 3: 5% EDTA applied with DSVN	0 (0–0)	0 (0–0)	1 (0–1)	$p = 0.018$*	Coronal-Middle: $p = 1.000$ Coronal-Apical: $p = 0.048$* Middle-Apical: $p = 0.326$
Group 4: 6% CA applied with DSVN	0 (0–0)	0 (0–1)	1 (0–1)	$p = 0.015$*	Coronal-Middle: $p = 1.000$ Coronal-Apical: $p = 0.048$* Middle-Apical: $p = 0.260$
Group 5: 1% NaOCl applied with OEN (Control)	1 (1–2)	1 (1–2)	2 (1–2)	$p = 0.115$	-
p value (for the comparison of irrigants)	$p < 0.001$*	$p = 0.001$*	$p < 0.001$*		
p values (for binary comparisons)	Group 1 and 2: $p = 1.000$ Group 1 and 3: $p = 1.000$ Group 1 and 4: $p = 1.000$ Group 1 and 5: $p = 0.002$* Group 2 and 3: $p = 1.000$ Group 2 and 4: $p = 1.000$ Group 2 and 5: $p = 0.002$* Group 3 and 4: $p = 1.000$ Group 3 and 5: $p < 0.001$* Group 4 and 5: $p < 0.001$*	Group 1 and 2: $p = 1.000$ Group 1 and 3: $p = 1.000$ Group 1 and 4: $p = 1.000$ Group 1 and 5: $p = 0.107$ Group 2 and 3: $p = 1.000$ Group 2 and 4: $p = 1.000$ Group 2 and 5: $p = 0.024$* Group 3 and 4: $p = 1.000$ Group 3 and 5: $p = 0.001$* Group 4 and 5: $p = 0.004$*	Group 1 and 2: $p = 1.000$ Group 1 and 3: $p = 0.768$ Group 1 and 4: $p = 1.000$ Group 1 and 5: $p = 0.119$ Group 2 and 3: $p = 1.000$ Group 2 and 4: $p = 1.000$ Group 2 and 5: $p = 0.052$ Group 3 and 4: $p = 1.000$ Group 3 and 5: $p < 0.001$* Group 4 and 5: $p = 0.002$*		

*p values with * symbol indicate the statistical significance. Min: Minimum; Max: Maximum; SLR: smear layer removal; EDTA: Ethylenediaminetetraacetic Acid; DSVN: open-ended needle; CA: Citric Acid; DSVN: double side-vented needle; NaOCl: Sodium Hypochlorite.*

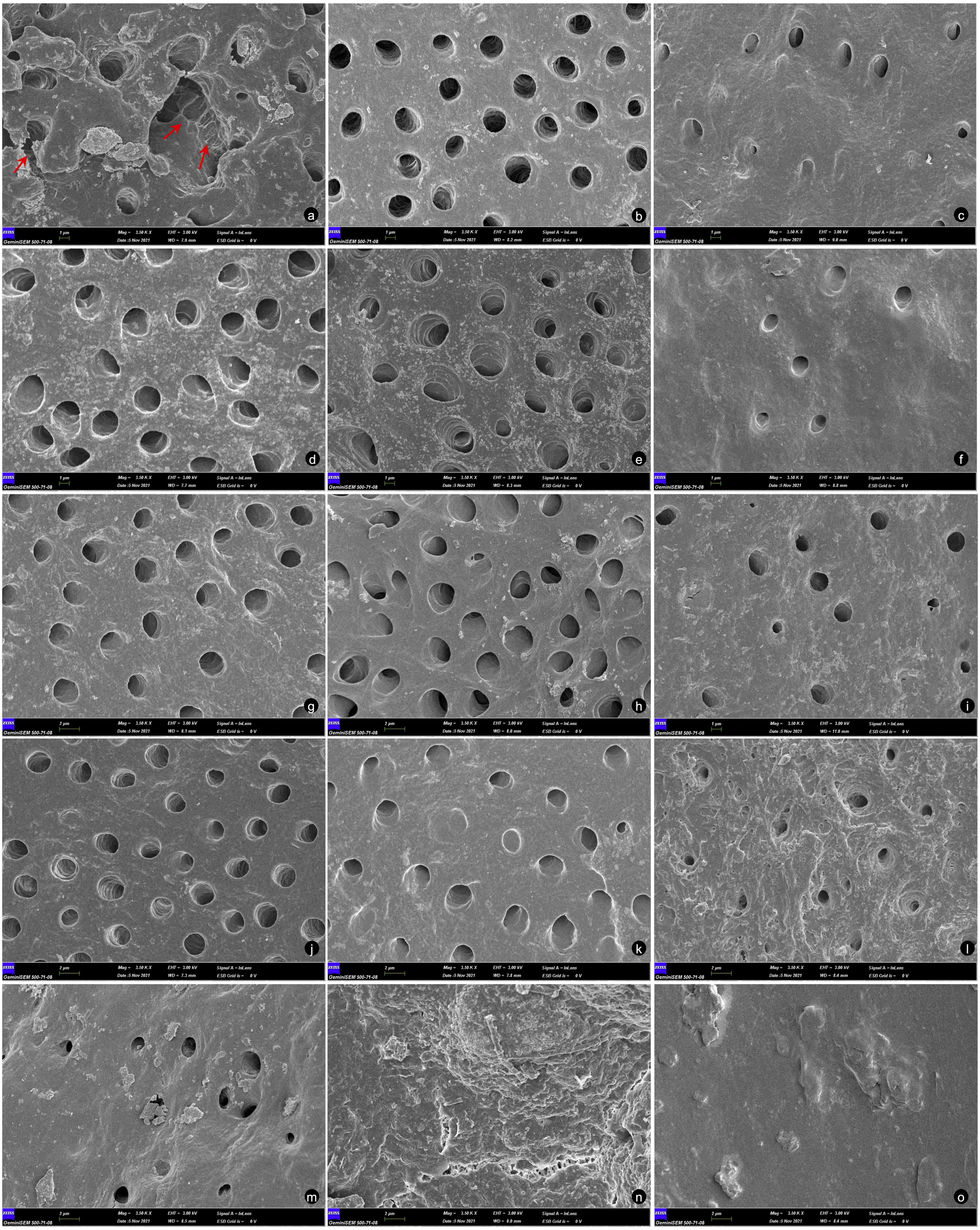

FIGURE 3. Representative SEM images for all the study groups. Representative SEM images for EDTA solution applied with OEN (a–c). Coronal third (a, score 0), middle third (b, score 0) and apical third (c, score 1) in Group 1. Note the erosive defects in intra- and peritubular dentin in coronal third in Group 1 (a) (indicated with red arrows). Representative SEM images for CA solution applied with OEN (d–f). Coronal third (d, score 0), middle third (e, score 0) and apical third (f, score 1) in Group 2. Representative SEM images for EDTA solution applied with DSVN (g–i). Coronal third (g, score 0), middle third (h, score 0) and apical third (i, score 1) in Group 3. Representative SEM images for CA solution applied with DSVN (j–l). Coronal third (j, score 0), middle third (k, score 1) and apical third (l, score 1) in Group 4. Representative SEM images for NaOCl solution applied with OEN (m–o). Coronal third (m, score 1), middle third (n, score 2) and apical third (o, score 2) in Group 5.

SL could be removed more readily in primary teeth than in permanent ones. In this case, it is possible to say that the use of irrigation agents that remove the SL in primary teeth at concentrations in permanent teeth will cause erosive changes on dentin. Therefore, it is critical that the irrigants used in primary teeth are in a dilution that will both effectively remove the SL and not cause harmful erosive changes on the dentin surface [3, 14]. Demirel *et al.* [3] stated that the SL removal capability of 6% CA + 1% NaOCl was similar to that of 10% EDTA + 1% NaOCl without causing erosive changes. On the other hand, Demirel [14] recommended the use of 5% EDTA + 1% NaOCl due to its SLR efficacy—which is similar to EDTA solutions—and because of its low erosive potential. Based on these findings, 5% EDTA and 6% CA solutions were preferred as irrigation agents in this study.

The root canal system shows a large number of branches, ramifications, accessory, and lateral canals, especially in primary molars [13, 22]. Therefore, upper primary incisors with single roots were included in this study so that the specified variables do not affect the objectivity of the findings and results. On the other hand, with the physiological root resorption process, the enlargement of the apical foramen diameter and inability of the instruments to reach the apical region is observed in primary teeth [3, 4, 9]. These conditions may cause the SLR in the apical region to be less than in other parts of the root. Therefore, as in previous studies [1, 3, 7, 9, 23], the inner root surfaces were assessed in three regions as the coronal, middle and apical in this study. Additionally, SEM imaging was used for the assessment of the SLR scores as in the previous studies [2–4, 7, 9]. A ×3500 magnification level was used to allow a detailed imaging of root canal surfaces and orifices of dentin tubules for making accurate examination.

In this study, the SLR efficacy of all the experimental groups (Group 1 to 4) was statistically higher than the control group in the coronal third (1% NaOCl). This finding conformed to previous studies. Hariharan *et al.* [9] found that the irrigation of 10% EDTA + 5.25% NaOCl showed superior SLR than 5.25% NaOCl alone in the coronal third. Also, Demirel *et al.* [3] noted that SLR efficacy of 10% EDTA + 1% NaOCl solution was statistically higher than 1% NaOCl. In addition, similar findings were in line with the previous studies for CA solution. Hariharan *et al.* [9] and Demirel *et al.* [3] stated that 6% CA and 6% CA + 1% NaOCl, respectively, provided superior SL removal than 5.25% and 1% NaOCl, respectively. On the other hand, no statistically significant difference was found between 5% EDTA and 6% CA solutions applied with both OEN and DSVNs in this study. On the other hand, the use of 5% EDTA + 1% NaOCl solution showed the erosive damage to the peritubular dentin in 2 samples in the coronal third. Therefore, in the coronal third, regardless of the needle type, 6% CA + 1% NaOCl solution may be recommended as it showed similar SLR efficacy with 5% EDTA + 1% NaOCl but caused no erosive changes. When the dental literature was evaluated, limited information was available concerning the effects of SVNs in primary teeth regarding the SLR. However, similarly, Ferreira *et al.* [24] reported no statistical significance between OEN and SVNs in SLR in the coronal third of the canals of permanent incisors.

In the middle third, 6% CA + 1% NaOCl solution applied with both OEN and DSVN needle (Group 2 and 4, respectively) and 5% EDTA + 1% NaOCl solution applied with DSVN (Group 3) showed significantly superior SLR results than the control group. Moreover, there was found to be no statistical difference between 6% CA + 1% NaOCl and 5% EDTA + 1% NaOCl protocols applied with both OENs and DSVNs similar to the coronal third. This finding was in agreement with a study conducted by Ferreira *et al.* [24] who evaluated the use of different types of needle tips in SLR efficacy in permanent root canals. They reported no statistical difference between conventional (OENs) and SVN tips regarding SLR in the middle third. The absence of statistically significant difference was attributed to the fact that the factors in the needle type affected the flushing action, flow rate of the irrigant and fluid dynamics in the apical rather than the middle third. In addition, EDTA showed more erosive changes than CA, which was in agreement with other studies [3, 4, 9]. In this context, in the 5% EDTA + 1% NaOCl solution applied with DSVN caused minimal erosive damages around the peritubular dentin in the middle third of one sample. Moreover, erosive changes were not detected as severely as in previous studies since the lesser (5%) EDTA concentration was used in this study. Although minimal erosion was seen in EDTA irrigation, all precautions should be taken when using EDTA in primary root canals, or rather, CA—which is safer in this respect—is a preferable alternative.

In the apical third, irrigation with EDTA and CA solutions using DSVN was statistically superior than the control group. However, a statistical difference between the experimental groups (groups 1 to 4) was not observed. Similarly, Ferreira *et al.* [24] reported that there was no statistical difference between OENs and SVNs in the apical third of the permanent incisors. Guerreiro-Tanomaru *et al.* [25] also determined that the diameter was more important than the needle design (apical opening and side opening) in the cleaning of the apical third of the mandibular incisors and the authors emphasized that the needles with smaller diameter were more efficient. However, even if there is no statistical difference between the use of OENs and DSVNs, the use of DSVNs may be recommended since they offered statistically superior SLR results compared to the control group. In addition, there was evidence that DSVNs reduce extrusion of apical debris in dental literature. Silva *et al.* [17] emphasized that DSVNs may be safely used during endodontic treatment procedures.

There were similar studies regarding the use of OENs and SVNs in the root canals by computational fluid dynamics models [16, 26]. Boutsioukis *et al.* [16] reported that the flow of the irrigation agent was better directed to the root canal surfaces in the apical in the use of SVNs. Their study emphasized that the flow dynamics of OENs differed from SVNs resulting in more irrigation solution replacement in front of OENs but also higher apical pressure. Accordingly, it was reported that irrigant could better reach the apical third in the use of OENs [16]. Similar to this finding, in this study, the absence of statistically superior efficacy of the SLR of SVNs compared to OENs in the apical third may be based on the needle tip placement, which was 2 mm shorter than the root apex, resulting in the insufficient reach of the irrigation solution. In this context, increasing the insertion depth of the needle tip when using

SVNs may be recommended. However, this recommendation needs to be confirmed by further experimental investigations.

Another result of this study was that the removal level of the SL was significantly lower in the apical third in comparison to the coronal third in all the experimental groups (groups 1 to 4). This finding complied with previous studies [3, 4, 7, 9]. The inability to effectively remove the SL in the apical third was attributed to the insufficient access of irrigation equipment and the solution amount to this region [3, 14]. As mentioned above, to overcome this inaccessibility, the insertion depth of the needle tip was critical [26] and ultrasonic irrigation devices were recommended [4]. In this respect, it has been reported that the use of ultrasonic generators offers better results than the traditional irrigation needles [4]. Bearing this in mind, Toyota *et al*. [4] stated that the use of 14% EDTA solution with ultrasonic devices provided significantly superior results for the SLR in the apical third. However, the authors also emphasized that the erosive changes in root canal dentin were increased by the use of ultrasonic equipment due to more interaction between the irrigants and root dentin. In addition, no statistical difference was determined between all the root thirds regarding the SLR efficacy in the control group. This has been attributed to the inability of NaOCl to remove the SL even if it reaches the root surface. Besides, this finding was in-line with previous studies [3, 14].

The present study had some strengths and limitations. Further studies are needed to provide evidence-based protocols for the removal of the smear layer after the use of side-vented needles in primary teeth. For this reason, it was thought that the present work would contribute to the dental literature. On the other hand, as a limitation of this study, as this study was conducted under *in-vitro* conditions, the irrigation procedures especially in the apical third could not be simulated like *in-vivo* environment. As another study limitation, needle diameters in this study could not be standardized due to the lack of commercial availability.

In primary dentition, the roots are exposed to physiological root resorption, unlike permanent teeth. As a result, the apical opening is displaced coronally and the width of the apical foramina increases over time [27]. Therefore, extreme care should be taken against the overflow of debris and the extrusion of various irrigants—many of which are toxic—to the periapical area. The permanent tooth germ located between or around the roots of the primary teeth may be negatively affected by the extrusion of irrigants. However, the SL in the apical third—which is the most difficult area of the primary root canals to reach—should be removed effectively for ideal chemo-mechanical cleaning [3, 8]. This is achieved by the effective contact of irrigants with the dentinal surfaces. For this reason, the irrigation efficacy in the apical third must be of a quality that will provide adequate debridement and it must be safe for the periapical area [3, 4, 8, 14]. On the other hand, irrigation efficacy in the apical third depends on various factors such as the length of needle placement to the root canal, the pressure of irrigation, the total duration of the irrigation, the morphology of the root canals, the position and diameter of the apical opening, and the taper of root canal after the mechanical preparation [16, 26]. In this context, there is need for further studies on the use and efficacy of SVNs, evaluating different factors and offering suggestions to clinicians.

5. Conclusions

Within the limitations of the present study, regardless of irrigation materials, it was concluded that the smear layer removal efficacy of double side-vented and open-ended needle types was similar. On the other hand, although there was no statistical difference between EDTA and citric acid in terms of smear layer removal efficacy, the use of citric acid, which was found to not cause erosive damage, could be recommended.

AUTHOR CONTRIBUTIONS

AD, NSÖ, MA and ŞS—designed the study protocol. AD, NSÖ and MA—performed the *in-vitro* experiments. AD, NSÖ, MA and ŞS—analyzed the data. AD, NSÖ, MA and ŞS—wrote all the manuscript text.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

The research protocol was approved by the Institutional Ethical Board of Ankara University, Faculty of Dentistry (Approval ID: 18/04). The written consent forms were obtained from children and their parents. This research has followed CRIS guidelines for *in-vitro* researches and the Declaration of Helsinki.

ACKNOWLEDGMENT

Not applicable.

FUNDING

This research received no external funding.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

[1] Gupta S, Kenchappa M, Gupta P, Chaurasiya S, Sharma P, Satyarth S. Smear layer removal in primary teeth using a novel irrigant, QMix: an *in vitro* study. Journal of Cranio-Maxillary Diseases. 2015; 4: 137-143.

[2] Buldur B, Kapdan A. Comparison of the EndoVac system and conventional needle irrigation on removal of the smear layer in primary molar root canals. Nigerian Journal of Clinical Practice. 2017; 20: 1168-1174.

[3] Demirel A, Yüksel BN, Ziya M, Gümüş H, Doğan S, Sari Ş. The effect of different irrigation protocols on smear layer removal in root canals of primary teeth: a SEM study. Acta Odontologica Scandinavica. 2019; 77: 380–385.

[4] Toyota Y, Yoshihara T, Hisada A, Yawaka Y. Removal of smear layer by various root canal irrigations in primary teeth. Pediatric Dental Journal. 2017; 27: 8–13.

[5] Mali S, Singla S, Tyagi P, Sharma A, Talreja N, Gautam A. Comparative evaluation of the efficacy of different herbal irrigants on the removal of smear layer of primary teeth: a scanning electron microscopy study. Journal of the Indian Society of Pedodontics and Preventive Dentistry. 2020; 38: 374–380.

[6] Barcelos R, Tannure PN, Gleıser R, Luız RR, Prımo LG. The influence of smear layer removal on primary tooth pulpectomy outcome: a 24-month, double-blind, randomized, and controlled clinical trial evaluation. International Journal of Paediatric Dentistry. 2012; 22: 369–381.
[7] Ximenes M, Triches TC, Beltrame AP, Hilgert LA, Cardoso M. Effect of endodontic irrigation with 1% sodium hypochlorite and 17% EDTA on primary teeth: a scanning electron microscope analysis. General Dentistry. 2013; 61: 24–27.
[8] Kaur R, Singh R, Sethi K, Garg S, Miglani S, Vats S. Irrigating solutions in pediatric dentistry: literature review and update. Journal of Advanced Medical and Dental Sciences Research. 2014; 2: 104–115.
[9] Hariharan V, Nandlal B, Srilatha K. Efficacy of various root canal irrigants on removal of smear layer in the primary root canals after hand instrumentation: a scanning electron microscopy study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2010; 28: 271-277.
[10] Pitoni CM, Figueiredo MC, Araújo FB, Souza MA. Ethylenediaminetetraacetic acid and citric acid solutions for smear layer removal in primary tooth root canals. Journal of Dentistry for Children. 2011; 78: 131–137.
[11] Tannure PN, Azevedo CP, Barcelos R, Gleiser R, Primo LG. Long-term outcomes of primary tooth pulpectomy with and without smear layer removal: a randomized split-mouth clinical trial. Pediatric Dentistry. 2011; 33: 316–20.
[12] Fumes AC, Sousa-Neto MD, Leoni GB, Versiani MA, da Silva LAB, da Silva RAB, *et al*. Root canal morphology of primary molars: a micro-computed tomography study. European Archives of Paediatric Dentistry. 2014; 15: 317–326.
[13] Ozcan G, Sekerci AE, Cantekin K, Aydinbelge M, Dogan S. Evaluation of root canal morphology of human primary molars by using CBCT and comprehensive review of the literature. Acta Odontologica Scandinavica. 2016; 74: 250–258.
[14] Demirel A. The smear layer removal efficiency of different concentrations of EDTA in primary teeth: a SEM study. Cumhuriyet Dental Journal. 2021; 24: 57–65.
[15] Provoost C, Rocca GT, Thibault A, Machtou P, Bouilllaguet S. Influence of needle design and irrigant flow rate on the removal of *enterococcus faecalis* biofilms *in vitro*. Dentistry Journal. 2022; 10: 59.
[16] Boutsioukis C, Verhaagen B, Versluis M, Kastrinakis E, Wesselink PR, van der Sluis LWM. Evaluation of irrigant flow in the root canal using different needle types by an unsteady computational fluid dynamics model. Journal of Endodontics. 2010; 36: 875–879.
[17] Silva PB, Krolow AM, Pilownic KJ, Casarin RP, Lima RKP, Leonardo RDT, *et al*. Apical extrusion of debris and irrigants using different ırrigation needles. Brazilian Dental Journal. 2016; 27: 192–195.
[18] Zehnder M. Root Canal Irrigants. Journal of Endodontics. 2006; 32: 389–398.
[19] Wu MK, van der Sluis LWM, Wesselink PR. The capability of two hand instrumentation techniques to remove the inner layer of dentine in oval canals. International Endodontic Journal. 2003; 36: 218–224.
[20] Shen Y, Gao Y, Qian W, Ruse ND, Zhou X, Wu H, *et al*. Three-dimensional numeric simulation of root canal irrigant flow with different ırrigation needles. Journal of Endodontics. 2010; 36: 884–889.
[21] Dadresanfar B, Khalilak Z, Delvarani A, Mehrvarzfar P, Vatanpour M, Pourassadollah M. Effect of ultrasonication with EDTA or MTAD on smear layer, debris and erosion scores. Journal of Oral Science. 2011; 53: 31–36.
[22] Katge F, Wakpanjar M. Root canal morphology of primary molars by clearing technique: an i*n vitro* study. Journal of Indian Society of Pedodontics and Preventive Dentistry. 2018; 36: 151-157.
[23] Vallabhaneni K, Kakarla P, Avula SSJ, Reddy NVG, Gowd MP, Vardhan KR. Comparative analyses of smear layer removal using four different irrigant solutions in the primary root canals—a scanning electron microscopic study. Journal of Clinical and Diagnostic Research. 2017; 11: ZC64–ZC67.
[24] Ferreira NS, Camargo CH, Palo RM, Martinho FC, Gomes AP. Comparison of the effectiveness of 3 irrigation devices for the cleaning of root canal walls instrumented with oscillatory and rotary techniques. General Dentistry. 2015; 63: 71–74.
[25] Guerreiro-Tanomaru JM, Loiola LE, Morgental RD, Leonardo RDT, Tanomaru-Filho M. Efficacy of four irrigation needles in cleaning the apical third of root canals. Brazilian Dental Journal. 2013; 24: 21–24.
[26] Boutsioukis C, Lambrianidis T, Verhaagen B, Versluis M, Kastrinakis E, Wesselink PR, *et al*. The effect of needle-insertion depth on the irrigant flow in the root canal: evaluation using an unsteady computational fluid dynamics model. Journal of Endodontics. 2010; 36: 1664–1668.
[27] Özer S, Tunç E Ş, Kalyoncuoğlu E, Gülcan B. Evaluation of different root canal filling methods in primary teeth. Meandros Medical and Dental Journal. 2018; 19: 132–137.

How to cite this article: Akif Demirel, Nur Sena Önder, Merve Alkış, Şaziye Sarı. Smear layer removal efficacy of irrigating solutions applied distinct needle designs: a scanning electron microscopy study. Journal of Clinical Pediatric Dentistry. 2023; 47(1): 58-66. doi: 10.22514/jocpd.2022.016.