Original Article

Comparison of the EndoVac System and Conventional Needle Irrigation on Removal of the Smear Layer in Primary Molar Root Canals

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ABSTRACT

Objective: This study aimed to compare the EndoVac system and conventional needle irrigation in removing smear layer (SR) from primary molar root canals. **Materials and Methods:** Fifty extracted human primary second molar roots were instrumented up to an apical size of 0.04/35 and randomly divided into two main groups; Group 1: EndoVac system (n = 25) and Group 2: Conventional needle irrigation (n = 25) and three subgroups (a) NaOCl + ethylenediaminetetraacetic acid (EDTA) (n = 20) (b) ozonated water (OW) + EDTA (n = 20) and (c) saline (control, n = 10). After a standardized final irrigation protocol performed for all teeth, scanning electron microscope images were taken at ×1000 magnification for each thirds of each root canal. Data were analyzed by the weighted kappa, Kruskal–Wallis, and Wilcoxon signed rank tests. **Results:** EndoVac was more effective than conventional needle in the removal of SR from the apical third of the root canal system ($P < 0.05$). The OW + EDTA regimen provided similar SR removal compared with NaOCl + EDTA. **Conclusions:** EndoVac has better performance than conventional needle irrigation in the removal of the SR in the apical thirds of the primary molar root canals. As a final irrigation regimen, the OW + EDTA regimen is as effective as the NaOCl + EDTA regimen.

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INTRODUCTION

Early loss of primary teeth (PT) causes functional, esthetical, and developmental problems. Root canal treatment is indicated for PT having irreversible pulpitis symptoms or necrosis.[1] Pulpectomy procedures of PT involve mechanical instrumentation with hand or rotary files, irrigation with various irrigants, and obturation of root canal with a resorbable filling.[2] Clinical success of PT pulpectomy has been shown in many studies.[3-5]

PT root canals are rarely straight and almost have lateral canals, apical deltas, fins, and anastomoses in their morphology. Severely divergent, curved primary molar roots and anatomical variations due to radicular resorption, and dentin apposition on the root canal limit the chemomechanical debridement efficacy of instrumentation and irrigation.[6,7]

Smear layer (SR) is an amorphous, irregular surface of organic and inorganic debris retained on the dentin and other surfaces after instrumentation.[8] This irregular layer needs to be removed since it limits the penetration of irrigation solutions, and it acts as a substrate for bacteria and a barrier between fillings and root canal wall.[9] The hermetical sealing of resorbable fillings to the dentinal tubules and canal walls of PT is very important for clinical success.[3] Barcelos *et al.*[4] found that SR removal improved root canal treatment successfully in PT in a 24-month period in an *in vivo* study.

Mechanical instrumentation cannot clean the canal entirely. Therefore, chemical debridement with an irrigation solution is necessary to eliminate bacteria,

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flush debris, and remove the SR from root canal system.[10] Many types of irrigation solutions were used such as NaOCl, chlorhexidine, hydrogen peroxide, and saline, yet there is no consensus on which irrigant and concentration should be used for primary root canal treatment. NaOCl is the most commonly used irrigant in endodontics since its great antimicrobial efficacy, the property to dissolve vital and necrotic tissues, low cost, and availability.[11] Exactly, 2.5% NaOCl is most widely used for PT root canals.[2] Ethylenediaminetetraacetic acid (EDTA) is a chelating agent that is needed as a final rinse for the removal of a SR, and 17% concentration is widely used.[12] A NaOCl following EDTA regimen is the most commonly used final irrigation regimen in endodontic treatment.[13] However, alternative irrigant regimens have been investigated, since the extrusion of NaOCl on vital tissues and periapical areas causes several complications and also special care is needed for the upcoming permanent successor in pediatric endodontic treatment. In addition, Niu *et al*.[14] reported that more debris is removed by irrigation with EDTA followed by NaOCl than with EDTA alone, but also, final irrigation with NaOCl following EDTA causes more dentinal erosion.

Ozone (O_3) is a powerful oxidizing agent that has great antimicrobial effects and higher biocompatibility.[15] O_3 can be used in dentistry either in gaseous, aqueous, or oiled forms. Ozonated water (OW) is an alternative to NaOCl for eliminating cytotoxic effects on vital tissues.[16] Many studies[17-19] have investigated the antimicrobial efficacy of OW, but to our knowledge, no study has examined the SR removal effect of an OW and EDTA combination as a final irrigation regimen.

Although conventional needle irrigation is the most used technique in endodontics, the replenishment and exchange of the irrigant is limited at the apical part, lateral canal, and isthmus.[20] Furthermore, positive pressure with the risk of extruding irrigants to periradicular tissues can lead to postoperative pain as well as tissue and permanent teeth bud damage.[21,22] A conventional needle is not successful for delivering safely and effectively high volumes of irrigation solution to the entire root canal and untouchable parts.[23] Therefore, new irrigation systems and devices have been introduced to increase the effectiveness of root canal debridement.

EndoVac (Discus Dental, Culver City, CA, USA) is an apical negative pressure system that delivers irrigants safely to apical areas and unreachable parts in the root canal system.[24] The superiority of EndoVac system to conventional needle irrigation regarding debridement efficacy, SR removal, and antimicrobial efficacy on permanent teeth has been reported.[25,26] In addition, EndoVac system extrudes less irrigant to the periapical area and decreases the risk of NaOCl accidents.[21]

The rationale of the study was that the dental literature shows a lack of importance of irrigation in primary root canal treatment. The effect of different irrigation solutions and delivery systems in primary root canal treatment has not been well-elucidated. To our knowledge, no study was conducted on the SR removal of both OW and the EndoVac system on PT.

The aim of this *in vitro* study was to compare the SR removal of two final irrigation regimens using the EndoVac system and conventional needle irrigation method with different irrigation solutions in primary molar root canals. The null hypotheses of the present study were (a) there is no difference between EndoVac and conventional needle irrigation systems regarding removing the SR from primary molar root canals (b) there is no difference between OW + EDTA and NaOCl + EDTA final irrigation regimens regarding removing the SR from primary molar root canals.

Materials and Methods

Teeth selection

Ethical approval was obtained from the Health Ethics Committee of the University of Cumhuriyet University, Sivas, Turkey (ID: 2012-04/04). The study was conducted on the largest palatinal or distal roots of, respectively, human primary maxillary or mandibular second molars. Freshly extracted primary molar teeth were collected, and each tooth was radiographed digitally to determine curvature <30° and the root resorption scale degree as "res_i or $res_{1/4}$," described by Fanning.[27] Teeth with fractured, calcified, or previous root canal treatment were excluded. The sample consisted of 50 primary molars, and the sample size was calculated as $\alpha = 0.01$, $\beta = 0.10$, $1-\beta = 0.90$, and $P = 0.91234$.[28] Only one root of each tooth was used; nonused roots were removed by diamond blazer. All teeth were stored at +4°C in a physiological saline supplemented with 0.02% sodium azide.

Specimen preparation

Each tooth was decoronated and the root length standardized to 11 mm. The working length (WL) was determined by inserting a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) into each root canal until visible apically under a magnifying loupe ×20 and by subtracting 1 mm from this point.[29] Thereafter, each root apical foramina was closed with soft modeling wax (Cera Reus, SA, Reus, Spain) to create a closed system.[29] Horizontal grooves were placed for mechanical retention in the experimental setup. Root cementum was coated with two layers of nail varnish to prevent bacterial retention.[29] Each root was inserted into polyvinylsiloxane impression material and adapted to the previously prepared experimental setup.[25] Each root canal was instrumented crown down with a nickel–titanium rotary Profile. 04 ISO (Dentsply Tulsa, Tulsa, OK) up to an apical 0.04/35 file by using 1 mL 2.5% NaOCl at each file change with a 27-gauge needle in accordance with the manufacturer's recommendations.[30]

Experimental materials

An experimental setup was prepared based on the fixture previously designed[29] to facilitate consistent irrigation protocols performed by one single operator. A separate fluid collection trap was not used to measure irrigant volume suctioned by the EndoVac system [Figure 1].

2.5% NaOCl, 17% EDTA (Werax, Izmir, Turkey), 0.9% sterile saline and 4 parts per million (ppm) OW were used as irrigation solutions in the study. The ozonation of water was performed by bubbling O_3 through sterile distilled water at 4 mg/L using the O_3 generator digitally (TeknO_3zone, Izmir, Turkey).

Experimental groups and final irrigation

Fifty extracted human primary second molar roots were randomly divided into 2 groups; Group 1. EndoVac (n = 25), Group 2 conventional needle (n = 25) and three subgroups (two experimental subgroups; (a) NaOCl + EDTA (n = 20), (b) OW + EDTA (n = 20), and control group (c) saline (n = 10).

Each tooth had the same total final irrigation time of 6 min with average rate was 5 mL/min, and the total irrigant volume delivered was 30 mL for each canal. Final irrigation procedure was carried out as:

Group 1 (EndoVac group)

- Subgroup 1a (NaOCl + EDTA) (n = 20): Experimental group consisted of a 30 s period of irrigation with 2.5% NaOCl using the macrocanula, followed by leaving the canal full of irrigant for 30 s. Three irrigation cycles were performed by using the microcanula placed, respectively, at WL for 6 s, 2 mm shorter WL for 6 s, and WL for 6 s. The first cycle was 30 s of 2.5% NaOCl, followed by 30 s of soaking; the second cycle was 1 min %17 EDTA, followed by 1 min of soaking; and the third cycle was 1 min of 2.5% NaOCl, followed by 1 min of soaking
- Subgroup 1b (OW + EDTA) (n = 20): Same procedure as group NaOCl + EDTA. Differently, 4 ppm OW was used instead of 2.5% NaOCl
- Subgroup 1c (saline) (n = 10): 0.9% sterile saline was used as the only irrigant.

Group 2 (conventional needle irrigation group)

- Subgroup 2a (NaOCl + EDTA) (n = 20): 27 gauge needle was inserted into the canal 2 mm shorter WL, and 2.5% NaOCl was delivered into the canal for 1 min active and followed by 1 min of soaking. 17% EDTA was delivered for 1 min active and soaked for 1 min. Finally, 2.5% NaOCl was delivered into the canal for 1 min active, followed by 1 min of soaking
- Subgroup 2b (OW + EDTA) (n = 20): Same procedure as group NaOCl + EDTA. Differently, 4 ppm OW was used instead of 2.5% NaOCl
- Subgroup 2C (saline) (n = 10): 0.9% sterile saline was used as the only irrigant.

After the final irrigation procedure, all experimental canals were rinsed with sterile saline and dried with sterile paper points, and a sterile cotton pellet was placed into the access cavity and sealed with Cavit G (3M ESPE, Seefeld, Germany). Each tooth was removed from polyvinylsiloxane and stored in bottles containing physiological saline supplemented with 0.02% sodium azide.

Scanning electron microscope

Two opposing longitudinal grooves were prepared on both the buccal and lingual external root surfaces using a diamond disc without penetrating into the canal. Root surfaces were rinsed with compressed water and air to avoid contamination with external debris. Roots were then split open by inserting a chisel into the grooves and twisting. The most visible and intact half part of each root was used for the study. Each specimen was dehydrated in graded ethanol series 25%, 50%, 75%, 90% for 25 min and finally in 100% ethanol for 1 h. The specimens were critically point-dried, mounted on aluminum stubs, sputter-coated with gold/palladium and examined with a scanning electron microscope (SEM) (Leo 440 CCD, Leica, Bensheim, Germany). Coronal (8–10 mm from apex), middle (5–7 mm from apex) and apical (1–3 mm from apex) thirds of each specimen were examined, and photographs were taken at ×1000 magnification and labeled by an independent SEM technician. Two independent examiners who were unaware of which specimens belonged to which groups blindly analyzed and scored for the degree of SR removal. Each examiner scored all photographs twice at a 2-week interval.

A 5-level scoring system described by Hülsmann *et al*.[31] was used for the degree of SR removal: 1 = no SR, dentinal tubules open [Figure 2a]; 2 = small amount of SR, some dentinal tubules open [Figure 2b]; 3 = homogenous SR covering the root canal wall, only a few dentinal tubules open [Figure 2c]; 4 = complete root canal wall covered by a homogenous SR, no open dentinal tubules [Figure 2d]; 5 = heavy, nonhomogeneous SR, no open dentinal tubules [Figure 2e].

Statistical analysis

All data were processed by SPSS 15.0 software (SPSS Inc., Chicago, IL, USA). Intra- and inter-examiner reliability for SEM assessment was verified by a weighted coefficient kappa (Kw) test. The scores of SEM evaluation were analyzed by the Kruskal-Wallis and Wilcoxon signed rank tests at 0.05 significance level.

Results

The kappa test showed good inter- and intra-examiner agreement, with values at 0.90 or above. Table 1 shows the results of the SEM evaluation of remaining SR for EndoVac and conventional needle groups regarding final irrigation regimen and root canal part. EndoVac showed better results than did the conventional needle at each root canal part, but only statistical significance was found at the apical third ($P < 0.05$). Regarding the final irrigation regimen, saline was the least effective group ($P < 0.05$). There was no statistically significant difference between other irrigation regimens ($P > 0.05$).

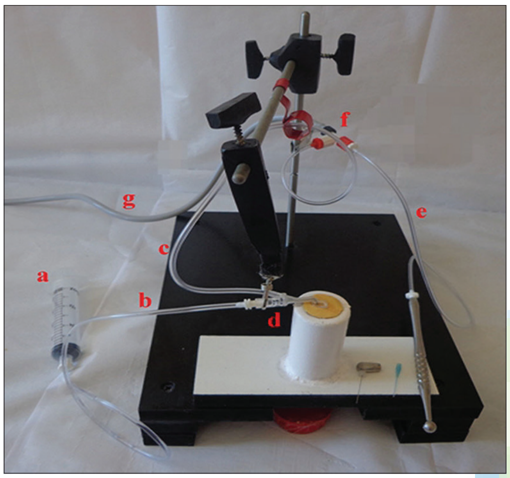

Figure 1: An experimental setup to perform irrigation by single operator. (a) 20 mL syringe, (b) connector between 20 mL syringe and the master suction tip, (c) connector between the master suction tip and high vacuum line, (d) the master suction tip, (e) connector between the high vacuum line and EndoVac hand piece, (f) high vacuum line, (g) connector to dental unit

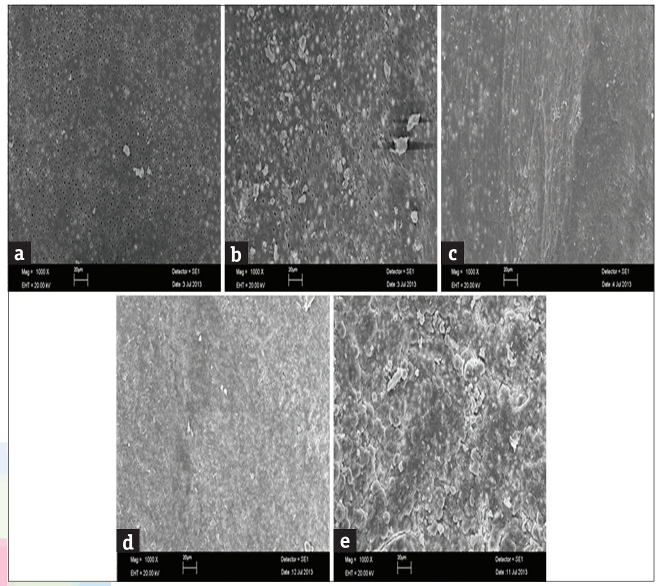

Figure 2: Examples of scanning electron microscope images of a 5-level scoring system at × 1000 magnification. (a) Score 1 = no smear layer, dentinal tubules open, (b) score 2 = small amount of smear layer, some dentinal tubules open; (c) score 3 = homogenous smear layer covering the root canal wall, only a few dentinal tubules open; (d) score 4 = complete root canal wall covered by a homogenous smear layer, no open dentinal tubules; (e) score 5 = heavy, nonhomogeneous smear layer, no open dentinal tubules

Table 1: Scores of scanning electron microscope evaluation of remaining smear layer for EndoVac and conventional needle groups regarding final irrigation regimens and root canal parts

Groups	Total scores	Score 1 (%)	Score 2 (%)	Score 3 (%)	Score 4 (%)	Score 5 (%)
EndoVac						
NaOCl + EDTA	30	23 (30.67)	7 (9.33)	0 (0.00)	0 (0.00)	0 (0.00)
OW+EDTA	30	24 (32.00)	6 (8.00)	0 (0.00)	0 (0.00)	0 (0.00)
Saline	15	0 (0.00)	0 (0.00)	0 (0.00)	5 (6.67)	10 (13.33)
Conventional needle						
NaOCl + EDTA	30	16 (21.33)	4 (5.33)	6 (8.00)	3 (4.00)	1 (1.33)
OW + EDTA	30	17 (22.67)	3 (4.00)	5 (6.67)	4 (5.33)	1 (1.33)
Saline	15	0 (0.00)	0 (0.00)	0 (0.00)	3 (4.00)	12 (16.00)
EndoVac						
Coronal	25	20 (26.67)	0 (0.00)	0 (0.00)	3 (4.00)	2 (2.67)
Middle	25	19 (25.33)	1 (1.33)	0 (0.00)	2 (2.67)	3 (4.00)
Apical	25	8 (10.67)	12 (16.00)	11 (14.67)	7 (9.33)	12 (16.00)
Conventional needle						
Coronal	25	17 (22.67)	3 (4.00)	0 (0.00)	2 (2.67)	3 (4.00)
Middle	25	16 (21.33)	4 (5.33)	0 (0.00)	1 (1.33)	4 (5.33)
Apical	25	0 (0.00)	0 (0.00)	11 (14.67)	7 (9.33)	7 (9.33)

EDTA=Ethylenediaminetetraacetic acid; NaOCl=Sodium hypochlorite; OW=Ozonated water

Regarding the root canal part, the apical third had a statistically significant difference when compared to the coronal and middle thirds ($P < 0.05$). Scores of SEM evaluation of the apical third were higher than those of the coronal and middle thirds for each EndoVac and conventional needle group. At the coronal and middle thirds, the SR could be totally eliminated but could not at the apical thirds of both EndoVac and conventional groups. Examples of the 5-level scoring systemat ×1000 magnification SEM images obtained from the samples of the present study was shown in Figure 2.

Discussion

The success rate of PT pulpectomies has been presented by many studies.[3-5] These studies have generally focused on the efficacy of root canal fillings, but the effect of new irrigation solutions and delivery systems has not been well-examined in PT.

SR removal increases the penetration of irrigants and fillings to deeper dentinal tubules and untouchable parts of the entire root canal system. Studies[3,4] investigating the effect of SR removal on PT pulpectomies have focused on the irrigation solutions and concentration. Barcelos *et al*.[4] reported that pulpectomy outcome was improved by SR removal in PT. Present study was designed to assess the effect of both irrigant activation techniques and two final irrigation regimens to remove SR removal in primary molar root canals.

Within the limitation that this was the first study that evaluates the irrigation activation techniques in PT pulpectomy, the present study showed similar results with the previous studies performed in permanent teeth.[28,29,32,33] The results of this study showed that in the middle and coronal thirds, no difference existed between EndoVac and needle groups, and the SR was totally removed. However, EndoVac was significantly superior to needle irrigation in the apical third of the root canal. Although the total contact time and the volume of EDTA and other irrigants were the same for both groups, this difference may be due to the activation of delivery systems. With similar to previous study by Abarajithan *et al*.,[28] the turbulence effect of negative pressure with EndoVac and delivering irrigants to the entire WL made the difference in the apical third of PT root canals. Also, with a larger apical size, microcanula can be placed at the full WL, and the holes in the microcanula can contact entirely root canal wall.[34]

Another reason for the similarity may be that the distal and palatinal roots of primary second molars were chosen for the study since its single canals and the relatively round, tapering apical anatomy. Relatively straight and round single canals would seemingly allow for consistent mechanical instrumentation and optimal sectioning through more direct comparison of irrigation techniques. On the other hand, this strict selection limits the clinical validity of this study, as PT roots show various anatomical modifications and irregularities.[6]

In this study, an *ex vivo* closed-end canal model was used to simulate the *in vivo* scenario, in which a tooth root is clinically enclosed with periodontal ligament and alveolar bone. This results in gas entrapment at the apical part and is called a "vapor lock effect," which prevents the irrigant from reaching WL.[30] This experimental model helps to provide a more direct comparison of irrigation delivery systems. With similar to Parente *et al*.,[29] in this study EndoVac was found as an effective method to overcome the fluid dynamics challenges inherent in closed canal systems.

In the present study, the canals were instrumented with Profile 0.4 ISO instruments to a final apical size 0.04/35 taper, based on the manufacturers' recommendations regarding the size of EndoVac's microcanula. Canoglu *et al*.[2] reported that Profile 0.04 ISO reduces preparation time and can be an alternative to manual instruments in primary molars. Also, Brunson *et al*.[34] stated that the volume of the irrigant being delivered into the apical areas by using microcanula increases with a larger apical preparation size. Larger preparation in PT is controversial to achieve the increasing effect of irrigants and filling materials, root canal walls must be prepared with care to not weaken the root canal walls or make root perforations. However, some PT may not clinically accommodate preparations of a larger apical size and coronal flare.

The increased volume of irrigant delivered facilitates debridement efficacy. We performed a final irrigation procedure that was standardized as total irrigation time: 6 min, rate 5 mL/min and a total volume of 30 mL. Irrigation and total treatment time are critical factors when treating child patients. The protocol used in our study seems to be clinically optimal.

An ideal endodontic irrigant should be systemically nontoxic and noncaustic to vital tissues. In addition, used irrigants in pediatric pulpectomy must not cause defects to permanent successor teeth. An ideal irrigation regimen should have an antimicrobial effect, tissue solving, SR removal and biocompatibility. The NaOCl following EDTA regimen is the most commonly used final irrigation method clinically.[35] However, this combination cannot provide all of one's needs. It is certain that NaOCl is the main irrigant in endodontics but it has too many disadvantages, especially for pediatric patients. Sitotoxic effects on the vital tissues and permanent teeth buds and also bad taste can lead a child patient to give up on the treatment. OW with higher biocompatibility has been evaluated as an alternative to NaOCl. The antimicrobial efficacy of OW combined with EDTA as a final irrigation regimen has been investigated previously, but to date, no study has evaluated the SR removal effectiveness of this combination in PT.

Our results showed that as a final irrigation regimen, no difference exists between the OW + EDTA and NaOCl + EDTA regimens for SR removal. Further *in vivo* and *in vitro* studies must be focused on both antimicrobial efficacy and SR removal as the final irrigation regimen.

The results of this study showed that in the middle and coronal thirds, no difference existed between EndoVac and needle groups, and the SR was totally removed. However, EndoVac was significantly superior to needle irrigation in the apical third of the root canal. Although the total contact time and the volume of EDTA and other irrigants were the same for both groups, this difference may be due to the activation of delivery systems. The turbulence effect of negative pressure with EndoVac and delivering irrigants to the entire WL makes the difference. Also, with a larger apical size, microcanula can be placed at the full WL, and the holes in the microcanula can contact entirely root canal wall.

Conclusions

Within the limitations of the present study, EndoVac showed significantly better performance than did conventional needle irrigation in the removal of the SR in the apical third of the root canal system of primary molars. As a final irrigation regimen, the OW + EDTA regimen was as effective as the NaOCl + EDTA regimen was. Further *in vivo* and *in vitro* studies are needed to investigate the effectiveness of irrigation delivery systems and irrigation regimens in PT using curved roots with isthmus and anatomical irregularities.

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Conflicts of interest

There are no conflicts of interest.

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