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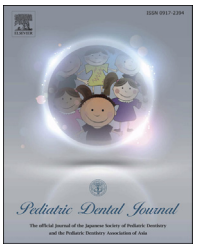

Research Paper

Removal of smear layer by various root canal irrigations in primary teeth

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ABSTRACT

Purpose: Proper root canal irrigation is essential for endodontic treatment. To evaluate the effectiveness of several root irrigation regimens, the extent of the removal of smear layer from the root canal in primary teeth was analyzed.

Methods: Fifteen extracted human primary teeth were divided into five groups and subjected to the following irrigation regimes: Group 1, needle irrigation with saline; Group 2, needle irrigation with 5% sodium hypochlorite (NaOCl); Group 3, ultrasonic irrigation with 5% NaOCl; Group 4, needle irrigation with 14% ethylene diamine tetraacetic acid (EDTA); Group 5, ultrasonic irrigation with 14% EDTA. The percentage of open dentinal tubules (POD) in the irrigated root canal was analyzed using a scanning electron microscope.

Results: POD for Groups 4 and 5 were significantly higher than Groups 1, 2, and 3 ($p < 0.01$, respectively). POD for Group 3 was significantly higher than Groups 1 and 2 ($p < 0.01$, respectively). By contrast, in Groups 4 and 5, erosive effects such as enlargement of orifices of dental tubules were observed. In Group 3, the smear layer was removed without erosion.

Conclusion: These results suggest that root canal irrigation with NaOCl using an ultrasonic effectively removed smear layer from the root canal in primary teeth.

1. Introduction

In clinical practice, primary teeth are subjected to endodontic treatment in cases such as pulpitis, apical periodontitis and trauma. Endodontic treatment of primary teeth is important for maintaining the primary dentition.

As in permanent teeth, endodontic treatment of primary teeth involves instrumentation, irrigation, and canal dressing. After instrumentation, a smear layer develops on the root canal wall and dentinal tubules are packed with debris, which can be observed by scanning electron microscope (SEM) [1]. The smear layer on root canals comprises dentin and necrotic and viable tissue, including remnants of odontoblastic processes, pulp tissue, and bacteria [1]. The smear layer penetrates dentinal tubules [2] and reduces the root dentin permeability [3]. Therefore, chemical substances and ultrasonic generator are used for root canal irrigation to remove the smear layer [4,5]. The SEM photograph after root canal irrigation showed that flushing with 17% ethylene diamine

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tetraacetic acid (EDTA) followed by 5.25% sodium hypochlorite (NaOCl) solution was the most effective in permanent teeth [4]. Ultrasonic irrigation with 17% EDTA for 1 min was significantly more effective than irrigation without ultrasonic generator in removing the smear layer from root canal of permanent teeth [5].

Previous studies examining the effectiveness of root irrigation in smear layer removal mostly focused on permanent teeth; few studies have reported findings in primary teeth. However, endodontic treatment of primary teeth is often necessary to retain the primary teeth until their permanent successors have erupted. The purpose of this study was to determine how root irrigation affects smear layer removal in primary teeth.

2. Materials and methods

This study was approved by the Ethics Committee for Research of the Hokkaido University Graduate School of Dental Medicine.

2.1. Tooth selection

Fifteen human primary teeth, which had been extracted for orthodontic reasons and not due to infection with more than two-thirds of the root length remaining, were collected from the Clinic for Dentistry for Children and Disabled Persons at Hokkaido University Hospital and several associated hospitals. As straight roots were preferred, single-rooted primary incisors and primary canines, and the palatal root of the second primary molars were selected in this study. Teeth were stored in 0.9% physiological saline solution at room temperature prior to the experiment.

2.2. Endodontic preparation of root canals

The roof of the pulp chamber was removed using a 1.4-mm diamond round bur attached to a turbine-powered handpiece under water. The root canal working length was determined by inserting a size No. 15 K-File (Dentsply, Maillefer, Tulsa, OK, USA) until the tip of the file was visible at the apical foramen. The root canals were enlarged sequentially using K-files from No. 15 to No. 40 and rinsed with 2.5 mL saline during each enlargement.

2.3. Conventional needle irrigation

The root canal was irrigated with chemical agents using a 23-gauge needle attached to a syringe (NIPRO, Osaka, Japan; Fig. 1A). The irrigants used in this experiment were 5% NaOCl (Neo Dental Chemical Products, Tokyo, Japan), 14% EDTA (Showa Yakuhin Kako, Tokyo, Japan), and 3% H_2O_2 (KENEI Pharmaceutical, Osaka, Japan).

2.4. Ultrasonic irrigation

The root canal was filled with 0.2 mL of 5% NaOCl or 14% EDTA and irrigated with the endodontic tip (ST49A-0.8tip; Osada, Tokyo, Japan; U-file size #15; Mokuda Dental, Hyogo, Japan; Fig. 1B) attached to an ultrasonic generator (ENAC10W; Osada; intensity Level 1), the end of which was located 2 mm above the apical foramen, for 15 s. These procedures were repeated three times. That is, the total time of ultrasonic irrigation was 45 s and the total volume of the irrigants was 0.5 mL.

2.5. Observation of the root canal after root irrigation

Fifteen teeth were divided into five groups with three teeth in each group subjected to the following irrigation regimes: Group 1, conventional needle irrigation with 0.6 mL of saline for 45 s followed by conventional needle irrigation with 5% NaOCl and 3% H_2O_2 in alternating combinations (= final irrigation); Group 2, conventional needle irrigation with 0.6 mL of 5% NaOCl for 45 s followed by final irrigation; Group 3, three times of ultrasonic irrigation with 0.2 mL of 5% NaOCl for 15 s followed by final irrigation; Group 4, conventional needle irrigation with 0.6 mL of 14% EDTA for 45 s followed by final irrigation; and Group 5, three times of ultrasonic irrigation with 0.2 mL of 14% EDTA for 15 s followed by final irrigation.

The irrigated roots were split into two halves along the longitudinal axis using a chisel and mallet. After dehydration with ethanol, the surfaces of specimens were sputter coated with gold-palladium, and then examined by SEM (S-4000; HITACHI, Tokyo, Japan). SEM photographs were taken at 10 sites in the middle region and four sites in the apical region per tooth. These sites were selected randomly so that each site was not repeated. The middle and apical regions of the canals were scanned to evaluate the amount of smear layer. The percentage of open dentinal tubules (POD) at the middle and apical regions of canals was calculated by using an SEM photograph taken at 1500× magnification. Each photograph was 120 mm × 150 mm. POD was defined as follows:

$$\text{POD}\ (\%) = [\text{area of root canal dentine with open dentinal tubules in an SEM photograph } (\text{cm}^2)/(12 \times 15)\ (\text{cm}^2)] \times 100$$

The open or partially open dentinal tubule without the smear layer such as in Groups 3, 4, and 5 in Fig. 3A was defined as the open dentinal tubule. By using a transparent cross-section paper with a millimeter scale superimposed on each SEM photograph, areas of all open dentinal tubules were calculated (Fig. 2).

2.6. Statistical analysis

POD was statistically analyzed using one-way factorial analysis of variance (ANOVA) followed by *posthoc* Bonferroni/Dunn test. A p value < 0.01 was considered statistically significant (SPSS; IBM, Tokyo, Japan).

3. Results

3.1. Observation of root canal wall (Fig. 3, Table 1)

3.1.1. Middle region of canals (Fig. 3A)

In Group 1, the smear layer was not removed and the dentinal tubules were not visible. In Group 2, a moderate smear layer

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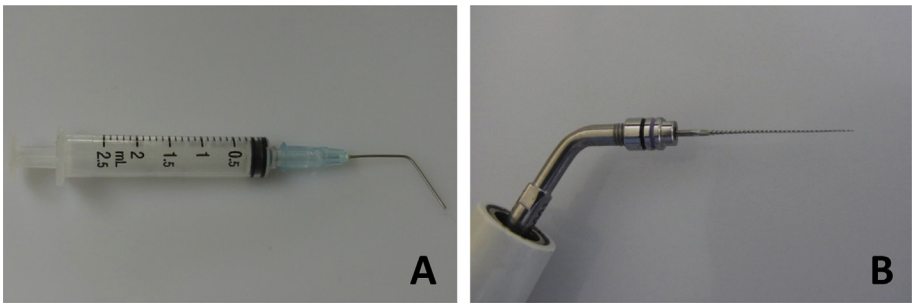

Fig. 1 – (A) A 23-gauge needle attached to syringe for conventional needle irrigation. (B) The endodontic tip attached to an ultrasonic generator for ultrasonic irrigation.

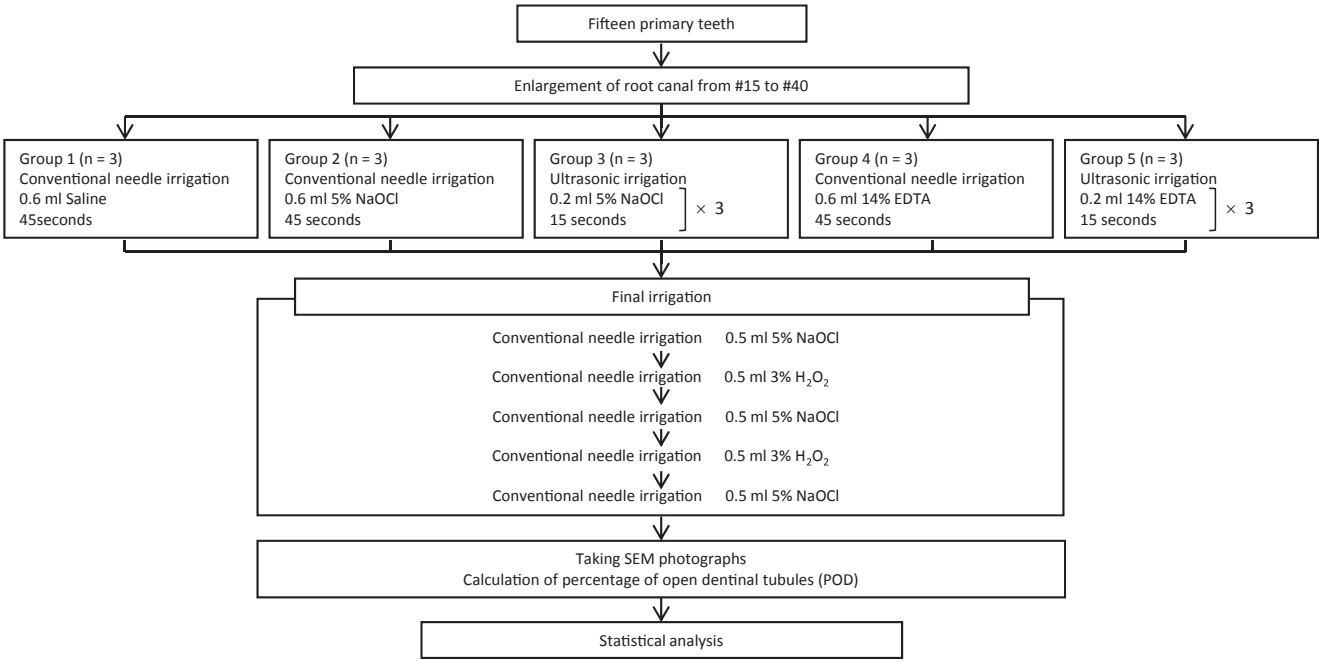

Fig. 2 – Experimental protocol.

was present and outlines of dentinal tubules were visible but not clear. In Group 3, the smear layer was removed and the dentinal tubules were open, but partially filled with debris. In Groups 4 and 5, the smear layer was removed and many dentinal tubules were clearly open, the orifices of dentinal tubules were enlarged. Severe erosion of the intertubular and peritubular dentin was also found, leading to widening of tubular diameters.

POD for Groups 4 and 5 was significantly higher than Groups 1, 2, and 3 ($p < 0.01$). There was no significant difference in POD between Group 4 and 5. POD for Group 3 was significantly higher than in Groups 1 and 2 ($p < 0.01$). There was no significant difference in POD between Group 1 and 2.

3.1.2. *Apical region of canals (Fig. 3B)*

In Groups 1 and 2, the smear layer had not been removed and the dentinal tubules were not visible. In Group 3, the smear layer was almost removed and the dentinal tubules were partly open. In Groups 4 and 5, the smear layer was almost removed and dentinal tubules were partially open.

POD for Group 5 was significantly higher than all other Groups ($p < 0.01$). There were no significant differences in POD among Groups 1, 2, 3, and 4.

4. Discussion

This *in vitro* study evaluated the effectiveness of root irrigation in removal of the smear layer for primary teeth. Our results suggest that root canal irrigation with NaOCl using an ultrasonic generator is effective in removing the smear layer without erosion. Erosion of the peritubular dentin is regarded as moderate erosion, and destruction of the intertubular dentin and conjugation of tubules is regarded as severe erosion [6].

In this study, single-rooted primary incisors and primary canines and a palatal root of the second primary molars with straight roots were used, because accurate root irrigation could be performed. Therefore, the effect of the difference in

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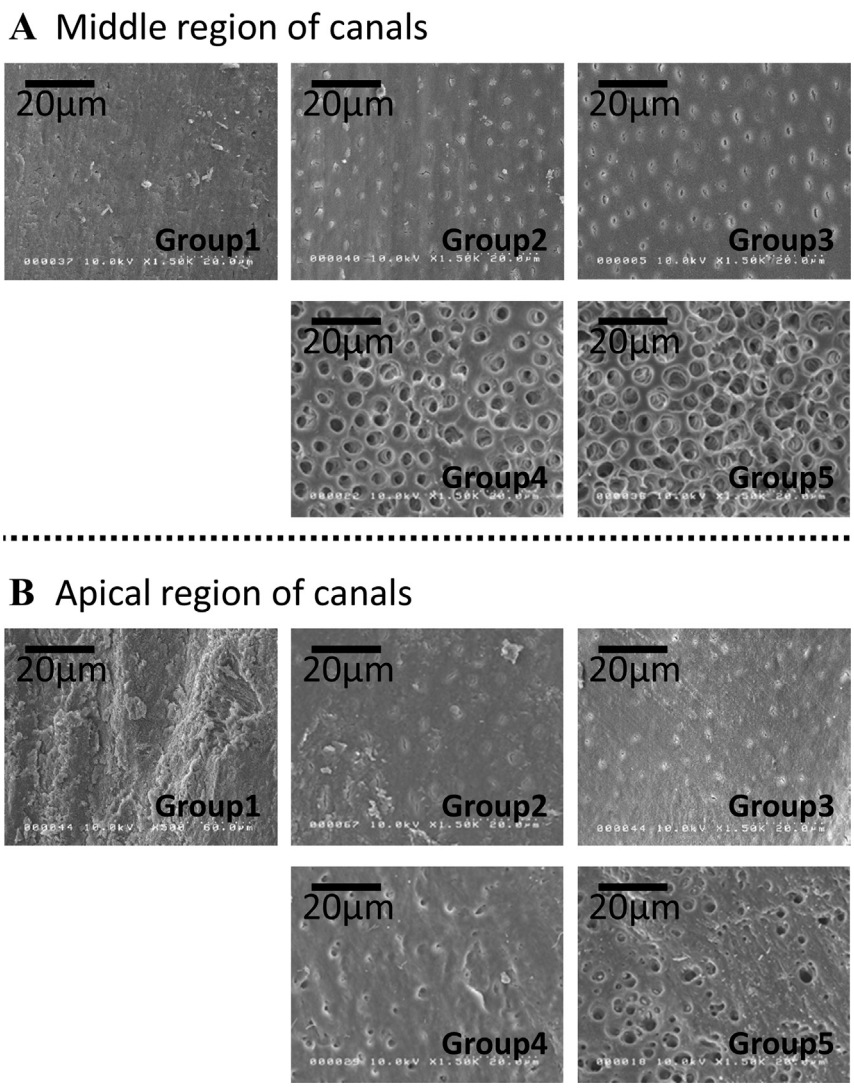

Fig. 3 – Typical images obtained from samples after root irrigation. Scanning electron microscope photographs are taken at 1500× magnification. Bar = 20 μm. (A) At the middle region of canals, in Group 1, the dentinal tubules were not visible. In Group 2, outlines of dentinal tubules were visible but not clear. In Group 3, the dentinal tubules were open, but partially filled with debris. In Groups 4 and 5, many dentinal tubules were wide open, and the orifices of dentinal tubules were enlarged. Excessive erosion of the intertubular and peritubular dentin was also found, leading to widening of tubular diameter. (B) At the apical region of canals, in Groups 1 and 2, the dentinal tubules were not visible. In Group 3, the dentinal tubules were partly open. In Groups 4 and 5, dentinal tubules were partially open.

the kind of selected teeth on the present results might be incomprehensible.

Most studies examining the effectiveness of root irrigation for smear layer removal focused on permanent teeth. Few studies using primary teeth have been reported. Therefore, the purpose of this study was to determine how root irrigation affected smear layer removal in primary teeth.

In permanent teeth, it is generally recommended to use EDTA and NaOCl sequentially for effective removal of both organic and inorganic components of the smear layer [7]. Furthermore, ultrasonic irrigation is more effective to remove the smear layer compared with conventional needle irrigation [8]. However, it has also been reported that the use of EDTA and NaOCl may lead to dentinal erosion in the root canal [9,10].

In the present study using primary teeth, conventional needle irrigation with saline and NaOCl could not remove the smear layer; however, ultrasonic irrigation with NaOCl could remove the smear layer effectively. Regardless of whether an ultrasonic generator was used, irrigation with EDTA removed the smear layer more effectively than with NaOCl, but erosive effects such as enlargement of the orifices of dentinal tubules were observed on root canal dentin (Group 5).

In permanent teeth, the smear layer consists of two separate layers: one superficial layer loosely attached to the underlying dentine and the other layer consisting of debris plugs in the openings of the dentinal tubules [11]. It was also reported that ultrasonic irrigation with NaOCl for 1 min removed the superficial smear layer but left the dentinal

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Table 1 – Observation of root canal wall after irrigations.

	Scanning electron microscope		POD (%)
	Amount of smear layer	Appearance of orifice of dentinal tubules	Mean ± SE
Middle region			
Group 1	Large	Not visible	1.20 ± 0.98**
Group 2	Moderate	Visible	10.80 ± 4.86**
Group 3	Small	Partially open	38.65 ± 6.91**
Group 4	None	Open and enlarged	96.20 ± 1.13**
Group 5	None	Open and enlarged	99.93 ± 0.07**
Apical region			
Group 1	Large	Not visible	0.09 ± 0.09**
Group 2	Large	Not visible	0.00 ± 0.00**
Group 3	Small	Visible	3.84 ± 2.68**
Group 4	Small	Partially open	13.98 ± 4.36**
Group 5	Very small	Partially open	51.48 ± 10.22**

**$p < 0.01$.
POD = percentage of open dentinal tubules; SE = standard error.

tubules sealed off [11]. In our study, ultrasonic irrigation with NaOCl for 45 s removed the superficial smear layer and part of the dentinal tubule plug layer. There are more organic substances and water in dentin in primary teeth than in permanent teeth, resulting in a low degree of hardness [12]. Furthermore, the density of the dentinal tubules in primary teeth is greater than that of permanent teeth [13]. Because of these structural differences, primary teeth dentin is more reactive to chemical substances [14]. These differences may be related to the findings that the smear layer in primary teeth is more easily removed than that of permanent teeth.

In permanent teeth, it was reported that ultrasonic irrigation with EDTA removed the smear layer better than conventional needle irrigation with EDTA [15]. Ultrasonic irrigation with EDTA for 1 min removed the smear layer effectively [15] but, by contrast, ultrasonic irrigation with EDTA for 1 min caused erosion [10]. In our study, irrigation with EDTA for 45 s widely opened the dentinal tubules and the orifices of dentinal tubules were enlarged. The erosive effect was increased by using an ultrasonic generator. Erosion has been shown to weaken root dentin in permanent teeth [9,10]. Therefore, caution is needed when using EDTA in primary teeth.

In the present study using primary teeth, removal of the smear layer at the apical region was not sufficient compared with that in the middle region. In permanent teeth, it is difficult to remove the smear layer at the apical region due to the complicated morphology of the root canal [16]. Furthermore, the histological features of root dentin in permanent teeth including the density and diameter of the dentinal tubules vary between the middle and apical regions [17]. These morphological and histological characteristics of the apical region may also account for inadequate smear layer removal in primary teeth. To improve smear layer removal, ultrasonic irrigation and accurate filing close to the apex and adequate enlargement of root canal are required, although further studies are needed to clarify the difference of the portion of the root canal related to smear layer removal.

In conclusion, this study suggested that root canal irrigation with NaOCl using an ultrasonic generator is effective for removal of smear layer in primary teeth.

Conflicts of interest

None of the authors has any conflicts of interest that should be declared.

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