# Efficacy of Flowable Gel-type EDTA at Removing the Smear Layer and Inorganic Debris under Manual Dynamic Activation

*Hee-Jin Kim, DDS, MSD,* Su-Jung Park, DDS, PhD,* Sang-Hyuk Park, DDS, PhD,[†‡] Yun-Chan Hwang, DDS, PhD,[§||] Mi-Kyung Yu, DDS, PhD,[¶] and Kyung-San Min, DDS, PhD[¶]*

## Abstract

**Introduction:** A flowable gel-type EDTA solution containing urea peroxide and polyacrylic acid was recently introduced into the endodontic market. However, its efficacy for removing the smear layer and inorganic debris remains unknown. This study was performed to investigate the relative efficacies of the flowable gel-type and liquid-type EDTA solutions for removal of the smear layer and inorganic debris. We also evaluated the effects of manual dynamic activation (MDA). **Methods:** Wettability was evaluated by measuring the contact angle. The incidence of accidental extrusion of irrigant was determined. The effervescent effect was evaluated by mixing the solutions with sodium hypochlorite. The efficacies of the EDTA solutions at removing the smear layer and inorganic debris were evaluated by scanning electron microscopic examination. **Results:** The contact angles of the 2 EDTA solutions did not differ significantly throughout the experiment ($P > .05$). Accidental extrusion occurred 4 times for the liquid-type EDTA but never for the gel-type EDTA. The gel-type but not the liquid-type EDTA showed an effervescent effect. The EDTA/MDA treatment combinations did not produce significantly different smear layer scores ($P > .05$). However, the debris scores for the coronal and middle parts were significantly lower for the gel-type EDTA with MDA than for the liquid-type EDTA without MDA ($P < .05$). **Conclusions:** Our results suggest that the newly introduced gel-type EDTA might be an acceptable irrigant for removing the smear layer and inorganic debris present on the root canal wall. *(J Endod 2013;39:910–914)*

From the *Department of Conservative Dentistry, Wonkwang University School of Dentistry, Iksan, Korea; †Department of Conservative Dentistry, Kyunghee University College of Dentistry, and ‡East-West Neo Medical Center, Seoul, Korea; §Department of Conservative Dentistry, School of Dentistry, and ||Dental Science Research Institute, Chonnam National University, Gwangju, Korea; and ¶Department of Conservative Dentistry, Chonbuk National University School of Dentistry, Jeonju, Korea.

Hee-Jin Kim and Su-Jung Park contributed equally as first authors.

Address requests for reprints to Dr Kyung-San Min, Department of Conservative Dentistry, Chonbuk National University School of Dentistry, 567 Baekje-daero, Deokjin-gu, Jeonju-si, Jeollabuk-do 561-756, Republic of Korea. E-mail address: endomin@gmail.com

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## Key Words

Debris, EDTA, effervescent, gel, manual dynamic activation, smear layer

Chelating agents were introduced into endodontics to facilitate the preparation of narrow and calcified root canals. Of these products, a liquid form of EDTA is the most widely used as a final irrigant for removing the smear layer and other inorganic substances (1). Although there is some controversy regarding the removal of the smear layer overlying dentinal tubules (2), previous studies have shown that the smear layer adversely affects disinfection and increases microleakage after canal obturation (3–5). Many liquid EDTA solutions have been introduced for endodontic use. However, most of them should be transferred to a syringe before use. In addition, liquid-type solutions as a factor of their lack of viscosity may be extruded unexpectedly if the clinician inadvertently depresses the piston of the syringe. A very low-viscosity, flowable gel-type EDTA (Endo-Prep EDTA Gel; Mediclus, Chungju, Korea) containing urea peroxide and polyacrylic acid, a so-called carbomer, was recently introduced. This gel-type EDTA is packaged in a preloaded syringe and can be used with various sizes of needles. Polyacrylic acid is added as a thickener to provide viscosity and a lubrication effect. Furthermore, the urea peroxide in this formulation is known to produce effervescence if it contacts sodium hypochlorite (NaOCl) (6). The effervescent reaction can push debris out of the root canal through the path of least resistance into the chamber (7). However, more viscous EDTA solutions may fail to reach the apical area of the root canal when used as irrigants. Therefore, most viscous chelators are used predominantly to aid the negotiation of calcified canals or decrease frictional stress during root canal preparation using rotary instruments, and the viscosity of any solution to be used as an irrigant for smear layer removal should be regulated carefully. However, there has been no study showing the efficacy of the flowable gel-type EDTA at removing the smear layer and inorganic debris.

An irrigant must directly contact the canal walls in order to be effective. However, it is often difficult to ensure that the irrigant reaches the apical portion of the canal because of the so-called vapor lock effect (8, 9). Research has shown that gently moving a well-fitting gutta-percha master cone up and down in short 2- to 3-mm strokes (manual dynamic activation [MDA]) within an instrumented canal can produce an effective hydrodynamic effect and significantly improve the displacement and exchange of any desired reagent (10, 11). Although MDA has been advocated as a method for canal irrigation because of its simplicity and cost-effectiveness, there is little information about its effects on the smear layer and inorganic debris when used with the gel-type EDTA. This study aimed to investigate the efficacy of the newly developed flowable gel-type EDTA versus that of the conventional 17% liquid-type EDTA solution at removing the smear layer and inorganic debris. We further explored whether MDA could improve the efficacy of smear layer and debris removal.

## Materials and Methods

### Dentin Specimen Fabrication

Freshly extracted human third molars without fractures or carious lesions were used. The teeth were embedded using autopolymerizing acrylic resin (Ortho-Jet; Lang Dental, Wheeling, IL). The specimens were then polished under distilled water with sandpaper to obtain flat dentin surfaces. All experimental procedures were approved by the Institutional Review Board of the Wonkwang University Dental Hospital, Iksan, Korea.

### Contact Angle Measurement

The contact angle of each experimental specimen was measured using a contact angle meter (Attension Theta Optical Tensiometer; KSV, Helsinki, Finland) based on the pendant drop method. One drop each of 17% liquid-type EDTA (Prevest Denpro, Jammu, India) and gel-type EDTA was deposited slowly on the prepared dentin surface, and images were captured using a high-resolution camera (Fig. 1*A–F*).

### Incidence of Accidental Extrusion of Irrigants

Access cavities were created in 2 freshly extracted mandibular premolars. Then, 20 fourth-year dental students who were unaware of the purpose of the experiment were instructed to fill both access cavities to the brim, 1 with gel-type EDTA and the other with liquid-type EDTA, using an irrigation syringe (B. Braun, Melsungen, Germany) and a 27-G needle (Ultradent, South Jordan, UT). To rule out the effect of practice, 10 students were asked to perform the irrigation with the liquid-type first and the remainder to use the gel-type first. The incidents of unexpected, accidental extrusion were recorded.

### Evaluation of the Effervescent Effect

Equal volumes of each EDTA solution (500 $\mu$L) were placed in separate Eppendorf tubes, and 10 $\mu$L red ink was added to each tube for visual enhancement. NaOCl (200 $\mu$L 2.5% solution) was added to the EDTA, and the tubes were photographed immediately.

### Root Canal Preparation

Caries-free, freshly extracted, single-rooted human teeth with 1 straight root canal ($N$ = 34) were used. The crown portions of the teeth were reduced to obtain a standardized root length of 19 mm. The working length was determined visually using a #10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) 0.5 mm short of the apical foramen. The root canals were prepared using ProTaper rotary instruments (Dentsply Maillefer) under copious irrigation with 2.5% NaOCl solution. The canals were finished until a size F3 reached the full working length.

### Experimental Groups

For final irrigation, these samples were then randomly divided into 4 experimental groups ($n$ = 8) and a control group ($n$ = 2) as follows:

1. Group 1 (L): liquid-type EDTA; final irrigation with 1 mL liquid-type EDTA (17%) was performed followed by 3 mL NaOCl (2.5%).
2. Group 2 (LM): liquid-type EDTA with MDA; after inserting 1 mL liquid-type EDTA into the canal, irrigant was agitated with the manual dynamic method. Briefly, for 1 minute, a well-fitting gutta-percha master cone was inserted into the canal and gently moved up and down in short 2- to 3-mm strokes for 100 times. Then, the canal was irrigated with 3 mL NaOCl (2.5%).
3. Group 3 (G): gel-type EDTA; final irrigation with 1 mL gel-type EDTA was performed followed by 3 mL NaOCl.
4. Group 4 (GM): gel-type EDTA with MDA; after inserting 1 mL gel-type EDTA into the canal, the same protocol as used in group 2 was applied.

For the control group (C), final irrigation was performed without agitation using only 4 mL NaOCl (2.5%) by using a syringe and a 27-G

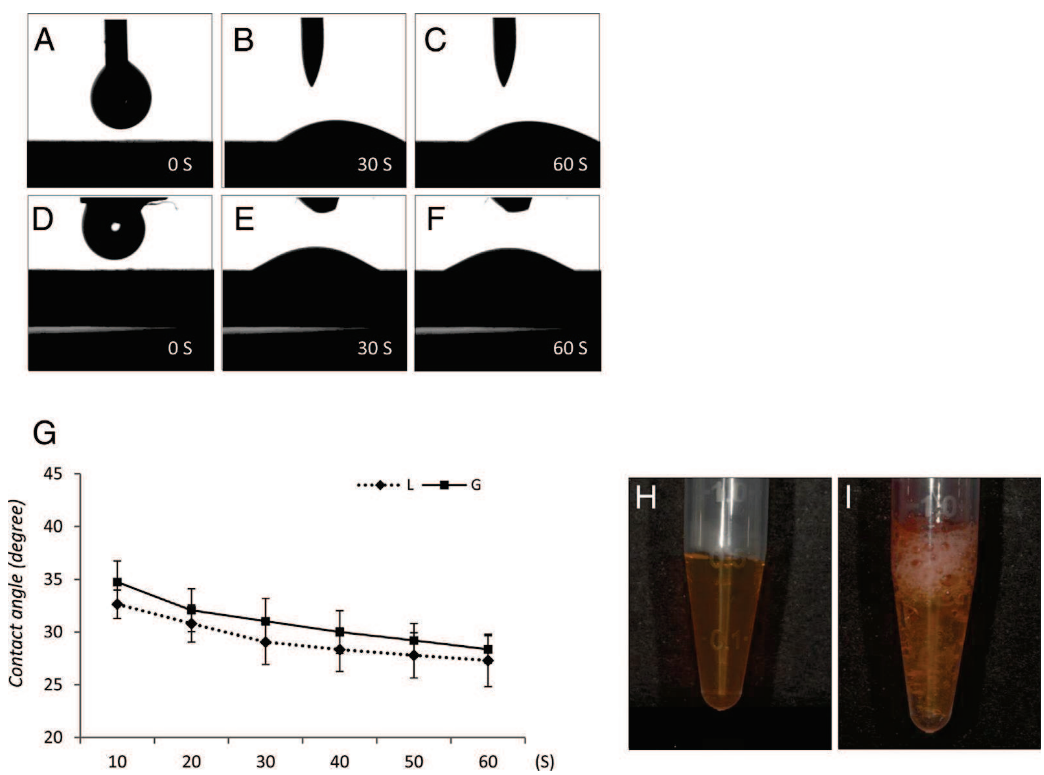


**Figure 1.** Representative photographs showing the measurement of the contact angles of (*A–C*) liquid-type EDTA and (*D–F*) gel-type EDTA solutions. (*G*) Contact angle values measured at different time points. Values are shown as the mean ± standard deviation. *A significant difference compared with the control was declared at $P$ < .05. The effervescent effects of (*H*) liquid-type and (*I*) gel-type EDTA solutions. The bubbles were produced immediately after mixing with 2.5% NaOCl. G, gel-type; L, liquid-type.

needle, which was placed 1 mm from the working length. For all groups, a final rinsing with 5 mL physiological saline solution finished instrumentation.

### Scanning Electron Microscopic Examination

Longitudinal grooves were made on the root surface in the buccolingual direction using a slow-speed carborundum disk. The root was then split with a chisel into 2 halves. The most representative hemisection of each tooth was selected for scanning electron microscopic examination. The root canals were dried using increasing concentrations of alcohol (10%, 25%, 50%, 75%, and 100%) and examined using a scanning electron microscope (S-2300; Hitachi, Tokyo, Japan) at ×1000, ×2000, and ×6000 magnification at an impressed voltage of 20 kV. Specimens with each magnification were observed at the 3- (apical), 6- (middle), and 9-mm (coronal) levels from the apex by 3 independent observers who were residents and were unaware of the specific treatment protocol of each specimen. The operator coded, blinded, and randomized the roots among all experimental groups using a numeric scale and 10 preselected squares of a grid as described by Hülsmann et al (12) (Tables 1 and 2).

### Statistical Analysis

The contact angle measurements were analyzed by 1-way analysis of variance followed by a multiple-comparison Tukey test. Nonparametric data (ie, the scores for the smear layer and inorganic debris) were analyzed using the Kruskal-Wallis test. The significance level for all statistical analyses was set at $\alpha = 0.05$. All statistical computations were performed with the SPSS version 12.0 program (SPSS GmbH, Munich, Germany).

## Results

### Contact Angle Measurement

We measured the contact angles of the EDTA solutions in order to investigate their degrees of wettability and flowability. Figure 1*G* shows the mean values of the contact angles observed for the different irrigants over 60 seconds. There was no significant difference between the 2 EDTA solutions over this time period ($P > .05$).

### Incidence of Accidental Extrusion of Irrigants

To determine how likely the liquid-type and gel-type EDTA solutions were to be expressed unexpectedly from the syringe during irrigation, we investigated the incidence of accidental extrusion. Of the 20 students instructed to fill cavities using both solutions, 4 students experienced accidental extrusion of the liquid-type EDTA, whereas no student experienced accidental extrusion of the gel-type EDTA.

**TABLE 1.** Scoring System for the Smear Layer

| Score | Description |
|---|---|
| 1 | No smear layer, orifice of dentinal tubules patent |
| 2 | Small amount of smear layer, some open dentinal tubule |
| 3 | Homogenous smear layer along almost the entire canal wall, only very few open dentinal tubules |
| 4 | The entire root canal wall covered with a homogenous smear layer, no open dentinal tubules |
| 5 | A thick, homogenous smear layer covering the entire root canal wall |

**TABLE 2.** Scoring System for Inorganic Debris

| Score | Description |
|---|---|
| 1 | Clean canal wall, only very few debris particles |
| 2 | Few small conglomerations |
| 3 | Many conglomerations, less debris than 50% of the canal wall covered |
| 4 | More than 50% of the canal wall covered |
| 5 | Complete or nearly complete covering of the canal wall by debris |

### Effervescent Effects of Liquid-type and Gel-type EDTA Solutions

To verify that the gel-type EDTA has an effervescent effect, we observed the response when it was mixed with NaOCl. The gel-type EDTA produced bubbles immediately after mixing with NaOCl (Fig. 1*I*), whereas the liquid-type EDTA did not (Fig. 1*H*).

### Efficacies of Liquid-type and Gel-type EDTA Solutions at Removing the Smear Layer and Inorganic Debris

Figure 2*A* through *I* shows representative scanning electron micrographs taken from different parts of the cleaned and shaped canal walls. As shown in Figure 3*A* through *C*, the smear layer scores for the coronal, middle, and apical parts did not differ significantly among the treatment groups ($P > .05$). However, the debris scores for the coronal and middle parts were significantly lower in group 4 (GM) than in group 1 (L) ($P < .05$) (Fig. 3*D–F*). All specimens in the control group had smear layer and debris scores of 4 or 5.

## Discussion

In this study, we investigated whether the newly produced flowable gel-type EDTA solution removes the smear layer and inorganic debris more effectively than the conventional liquid-type EDTA. The manufacturer states that this gel-type EDTA contains polyacrylic acid (carbomer) and urea peroxide. The addition of polyacrylic acid provides viscosity and a lubrication effect. The gel-type EDTA can be obtained in a preloaded syringe, and an appropriate amount is then expressed into a small-sized (eg, 27- or 30-G) needle. Unlike previously marketed viscous chelators, this EDTA solution showed similar wettability as the liquid type (Fig. 1*G*, $P > .05$) and is therefore flowable enough to be inserted into the apical area of a prepared root canal without any supplementary instrumentation. However, flat coronal dentin surfaces were used in this study instead of the inner surface of the root canal. It was reported that tubule density and orientation influence the wettability (13). In this respect, further experiments should be conducted by using the inner surface of the canal.

The viscosity prevents accidental extrusion from the irrigation needle and allows the clinician to control the volume extruded easily. Unexpected, accidental extrusion of EDTA fails to confine the irrigant to the access cavity and may contaminate the operating field and patient. Thus, the ease of controlling the volume dispensed is an advantageous property of an EDTA solution used as an irrigant. In our study, the number of accidental extrusions was 0 of 20 for the gel-type EDTA but 4 of 20 for the liquid-type EDTA. The viscosity and lubrication properties conferred by the polyacrylic acid might inhibit irregular movement of the piston of the syringe and consequently prevent uncontrolled expression from the needle. Moreover, the evaluation was performed by dental students who had been practicing endodontic treatment in the laboratory and the clinic for approximately 1 year. Among them, 4 students had difficulty in obtaining constant pressure-controlled extrusion when they intended to fill the access cavity with the liquid-type EDTA and experienced

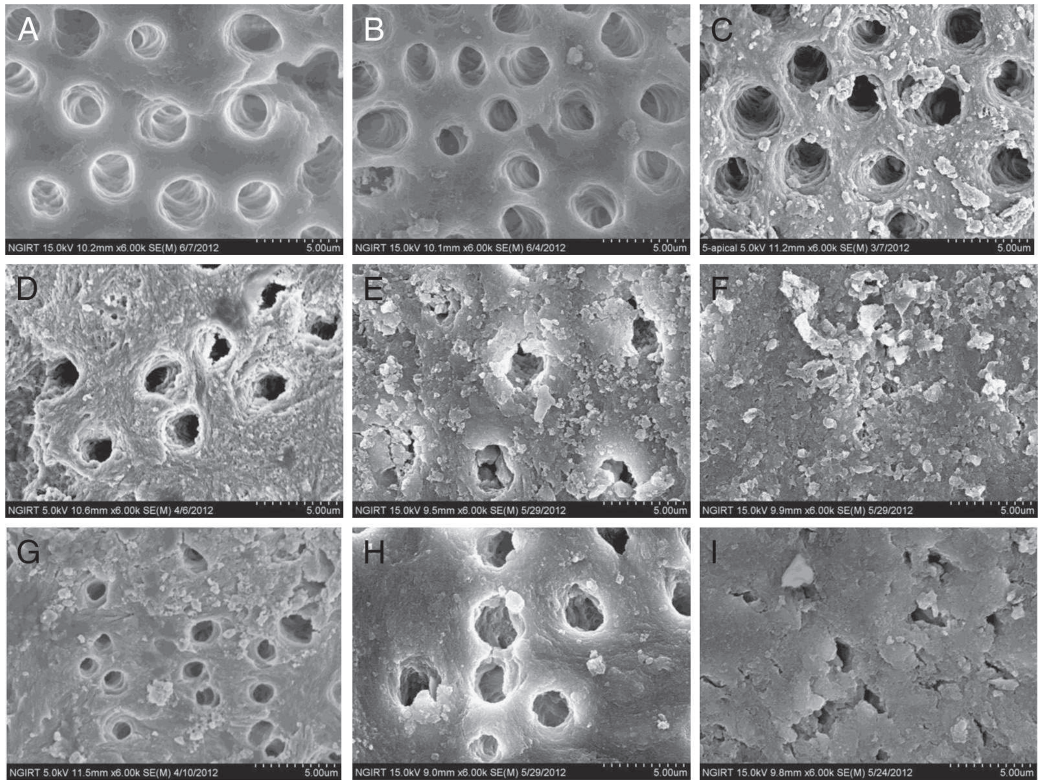


**Figure 2.** Representative scanning electron micrographs taken from different parts of the cleaned and shaped root canal walls (×6000). (*A*) SL1, D1 (group 4, coronal), (*B*) SL1, D2 (group 3, coronal), (*C*) SL1, D3 (group 2, apical), (*D*) SL2, D4 (group 2, middle), (*E*) SL3, D4 (group 2, apical), (*F*) SL4, D5 (group 2, apical), (*G*) SL2, D3 (group 3, apical), (*H*) SL2, D2 (group 2, apical), and (*I*) SL3, D5 (group 1, apical). SL, smear layer score; D, debris score.

unexpected extrusion. We postulated that this unexpected extrusion was caused by the lack of viscosity in the liquid-type EDTA. Therefore, the results indicate that the viscosity of the gel-type solution is advantageous for controlling the volume of irrigant even when used by beginners.

In the present study, we evaluated the efficacies of 2 types of EDTA solution for the removal of the smear layer. Our results showed that the degree of smear layer removal did not differ significantly between the solutions. Crumpton et al (14) reported that the use of 1 mL 17% liquid EDTA

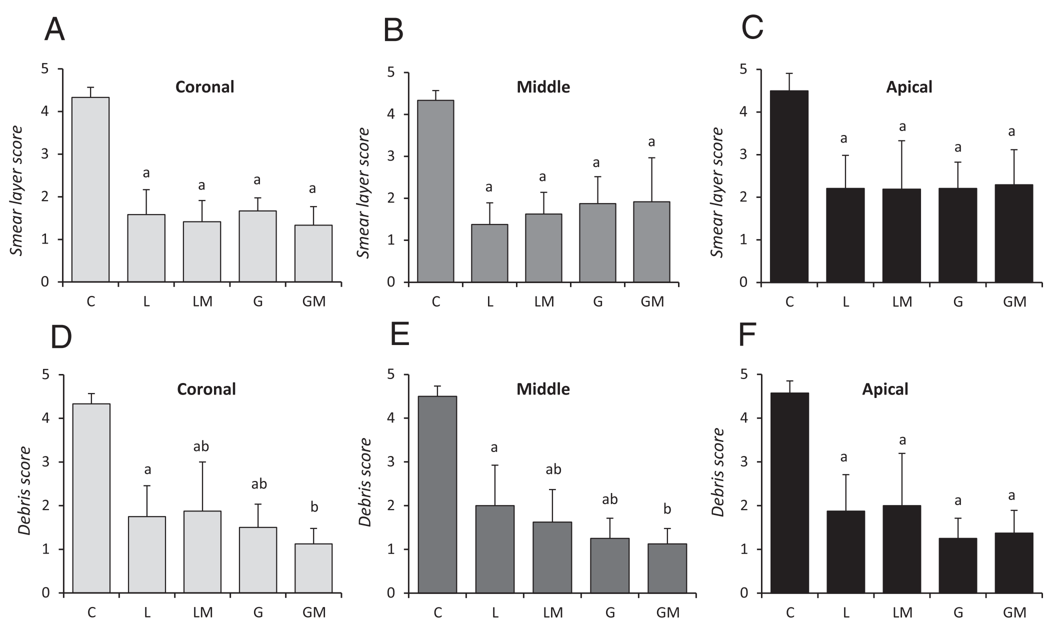


**Figure 3.** Efficacies of the liquid-type and gel-type EDTA solutions at removing (*A–C*) the smear layer and (*D–F*) inorganic debris. Values are shown as the mean ± standard deviation. Groups identified by the same symbol are not significantly different ($P > .05$). L (group 1), liquid-type EDTA; LM (group 2), liquid-type EDTA with MDA; G (group 3), gel-type EDTA; GM (group 4), gel-type EDTA with MDA; C, control.

for 1 minute efficiently removed the smear layer. The gel-type EDTA used in this study contains not only 17% EDTA but also polyacrylic acid to provide viscosity. Traditionally, viscous chelators have been used to promote the emulsification of organic tissue and facilitate the negotiation of the canal. Viscous chelators such as RC-Prep (Premier Dental Product, Norristown, PA) cannot be infiltrated into the apical area of the root canal without instrumentation. In contrast, the flowable gel-type EDTA used in this study was much less viscous and showed similar wettability as the liquid-type EDTA (Fig. 1*G*, $P > .05$). This property allows the gel-type EDTA to flow into the apical portion of the root canal. Therefore, it was as effective as the conventional liquid-type EDTA for removing the smear layer.

In the current study, the use of the gel-type EDTA with MDA facilitated the removal of inorganic debris but not the smear layer better than passive irrigation (Fig. 3, $P < .05$). Inorganic debris, which is derived from dentin chips, is more loosely attached than the smear layer, which is produced and adhered onto the wall by instrumentation. MDA itself might produce a sufficient hydrodynamic force for the irrigant to detach the debris from the canal wall. Furthermore, the gel-type EDTA produced gaseous bubbles when it contacted NaOCl (Fig. 1*I*). Currently, a combination of EDTA and NaOCl is the irrigant system most widely used by clinicians to remove the smear layer from root canals (15, 16). The gel-type EDTA used in this study contains urea peroxide. Urea peroxide and NaOCl produce significant effervescence, creating an elevator action to help evacuate debris (6). This effervescent effect might have enhanced the removal of inorganic debris in our experiments. Furthermore, the combination of urea peroxide with NaOCl causes a nascent release of oxygen that kills anaerobic bacteria (17). However, the gaseous bubbles thus formed, if not completely eliminated, may produce pressure after sealing and cause postoperative pain. Clinicians should use normal saline or NaOCl as the final irrigant in order to neutralize any remaining peroxide (18).

Overall, there was no significant difference between the gel-type EDTA and the liquid-type EDTA in removal of the smear layer and inorganic debris although the gel-type EDTA solution used with MDA removed debris from the coronal and middle parts more effectively than did the conventional liquid-type EDTA used without MDA. Our results suggest that the newly introduced gel-type EDTA might be an acceptable irrigant for removing the smear layer and inorganic debris present on the root canal wall.

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*The authors deny any conflicts of interest related to this study.*

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