

Effectiveness of the EndoActivator System in Removing the Smear Layer after Root Canal Instrumentation

David Uroz-Torres, BDS, Maria Paloma González-Rodríguez, DDS, PhD, and Carmen Maria Ferrer-Luque, DDS, MD, PhD

Abstract

Introduction: Elimination of the smear layer after root canal instrumentation requires the use of irrigating solutions. This cleaning can be completed with passive ultrasonic or sonic irrigation. The aim of this study was to evaluate the effectiveness of the EndoActivator System in removing the smear layer after rotary root canal instrumentation, with and without a final flush of 17% ethylenediaminetetraacetic acid (EDTA) solution, in coronal, middle, and apical thirds. **Methods:** Forty single-canal teeth were decoronated and randomly divided into 4 groups ($n = 10$). The groups were instrumented by using Mtwo System. EndoActivator was used with a final rinse of 1 mL of 17% EDTA or 4% NaOCl for 1 minute. The roots were longitudinally split and were grooved in the coronal, middle, and apical thirds. Scanning electron microscopy digital photomicrographs at $400\times$ were taken to evaluate the amount of smear layer in each third. **Results:** The NaOCl/EndoActivator group did not remove any smear layer of the root canal wall (100% in the coronal, middle, and apical thirds). In the groups that used 17% EDTA (with or without EndoActivator), the smear layer was eliminated completely (100%) in the coronal third, but the amount of removal was less in the other two thirds. The comparisons between NaOCl versus NaOCl/EndoActivator groups and EDTA/NaOCl versus EDTA/EndoActivator/NaOCl groups showed no significant differences in root canal thirds. **Conclusions:** The EndoActivator System did not enhance the removal of smear layer as compared with conventional Max-I-Probe irrigation with NaOCl and EDTA. (*J Endod* 2009; **35**:1–4)

Key Words

EDTA, EndoActivator System, scanning electron microscopy, smear layer, sodium hypochlorite

From the Department of Dental Pathology and Therapeutics, School of Dentistry, University of Granada, Granada, Spain.

Address requests for reprints to Professor Carmen María Ferrer-Luque, Department of Dental Pathology and Therapeutics, School of Dentistry, University of Granada, Campus de Cartuja, Colegio Maximo s/n. 18071, Granada, Spain. E-mail address: cferrer@ugr.es.

0099-2399/\$0 - see front matter

Copyright © 2009 American Association of Endodontists. All rights reserved

doi:10.1016/j.joen.2009.10.029

Hand and rotary instrumentation techniques produce an irregular, granular, and amorphous layer covering the dentin root canal. Subsequent smear layer removal requires the use of irrigating solutions that can dissolve both organic and inorganic components to eliminate microorganisms (1) and improve the hermetic sealing of the root canal system (2).

Different studies have shown that the use of 5.25%, 2.5%, or 1% sodium hypochlorite (NaOCl) with ethylenediaminetetraacetic acid (EDTA) solutions is effective in removing the smear layer during root canal instrumentation (3–5). It has also been seen that 1 mL of 17% EDTA for 1 minute was just as effective as 3 and 10 mL of this solution in smear layer removal with a 28-gauge Max-I-Probe (Dentsply Rinn, Elgin, IL) irrigating tip after rotary instrumentation (6). Less irrigation time (15 or 30 seconds) with 1 mL of 17% EDTA significantly decreased smear layer removal when compared with a 1-minute rinse (7), whereas a longer time of 2 minutes (10 mL 17% EDTA), followed by final irrigation with 10 mL of 5% NaOCl, caused intertubular and peritubular erosion (8).

After root canal shaping, cleaning might be completed with several irrigant agitation techniques (9) such as passive ultrasonic irrigation (PUI), sonic irrigation, or a final flush by syringe irrigation. It has been established that PUI in combination with NaOCl is more effective in removing dentin debris from the root canal (10–12), particularly in areas of complex root anatomy, as compared with the routine syringe delivery of the irrigant (13), in which the needle size and the depth of insertion of the needle can influence the effectiveness of irrigants (14).

Different results have been reported when comparing the effectiveness of PUI and sonic irrigation in the cleanliness of root canals (15–17). Studies of smear layer removal are inconclusive (9) and have been shown only with PUI (15, 18, 19). However, there is a gap in our knowledge of whether sonic agitation could reproduce the smear layer removal effect found with PUI.

Recently, the EndoActivator System (Dentsply Tulsa Dental Specialties, Tulsa, OK) was introduced to improve the irrigation phase. It is a sonically-driven canal irrigation system that comprises a portable handpiece and 3 types of disposable flexible polymer tips of different sizes that do not cut root dentin. Its design allows for the safe activation of various intracanal reagents and could produce vigorous intracanal fluid agitation (20). The EndoActivator System has been shown to better irrigate the simulated lateral canals at 4.5 and 2 mm from working length as compared with traditional needle irrigation alone (21), and it reportedly removed the smear layer used with demineralizing agents like EDTA and dislodged clumps of simulated biofilm within the curved canals of molar teeth (22).

The aim of this study was to evaluate the effectiveness of the EndoActivator System in removing the smear layer after rotary instrumentation, both with and without a final flush of 17% EDTA solution, in coronal, middle, and apical thirds.

Materials and Methods

Specimen Preparation

Forty single-canal maxillary human teeth extracted for periodontal reasons were stored in a 2% thymol solution until use. The specimens were decoronated to obtain a standardized root length of 15 mm by using a diamond disk in an Accutom 50 cutting

Basic Research—Technology

TABLE 1. Results of the 3 Categories of the Smear Layer in 4 Experimental Groups [n (%)]

	No smear layer	Smear layer in dentin tubules, clean dentin surface	Smear layer in dentin tubules and surface
4% NaClO			
Coronal third	0	0	10 (100)
Middle third	0	0	10 (100)
Apical third	0	0	10 (100)
4% NaClO + 17% EDTA			
Coronal third	10 (100)	0	0
Middle third	8 (80)	0	2 (20)
Apical third	2 (20)	3 (30)	5 (50)
4% NaClO + EndoActivator			
Coronal third	0	0	10 (100)
Middle third	0	0	10 (100)
Apical third	0	0	10 (100)
4% NaClO + 17% EDTA + EndoActivator			
Coronal third	10 (100)	0	0
Middle third	5 (50)	5 (50)	0
Apical third	1 (10)	4 (40)	5 (50)

EDTA, ethylenediaminetetraacetic acid.

machine (Struers, Ballerup, Denmark). The external surface of roots was sealed with nail polish to prevent the extrusion of irrigants through the apical foramen (23, 24).

Root Canal Instrumentation

The working length was determined by subtracting 1 mm from the length at which a #10 K-file (Dentsply/Maillefer, Ballaigues, Switzerland) tip extruded apically. Mtwo instruments (Sweden & Martina, Padova, Italy) were used to the full length in permanent rotation with a gentle in-and-out motion, with a 4:1 reduction handpiece (WD-66 EM; W & H, Buermoos, Austria) powered by a torque limited electric motor (Endo IT motor; VDW, Munich, Germany), according to the manufacturer's instructions. The instrumentation sequence was as follows: #10/04, #15/05, #20/06, #25/06, #30/05, #35/04, and #40/04.

The root canals were flushed with 1 mL of 4% NaOCl solution between files by using a plastic syringe with a closed-end needle (Hawe Max-I-probe; Dentsply Rinn) inserted as deep as possible into the root canal without binding. The teeth were randomly divided into 4 groups (n = 10). In NaOCl group, the canals were irrigated with a final flush of 3 mL of 4% NaOCl. In EDTA/NaOCl group, the canals were irrigated with a final flush of 1 mL of 17% EDTA for 60 seconds, followed by a final rinse of 3 mL of 4% NaOCl. In NaOCl/EndoActivator group, the canals were irrigated with a final flush of 3 mL of 4% NaOCl. The EndoActivator System was used to activate the 4% NaOCl for 60 seconds at 10,000 cycles per minute with a #15/02 polymer tip. In EDTA/EndoActivator/NaOCl group, the canals were irrigated with a final flush of 1 mL of 17% EDTA, after which the EndoActivator System was used for 60 seconds at 10,000 cycles per minute with a #15/02 polymer tip. Finally, a rinse of 3 mL of 4% NaOCl was applied.

Scanning Electron Microscopy Evaluation

The roots were longitudinally split in the buccolingual plane and were grooved to 3 levels at 4, 8, and 12 mm from the root apices by using a diamond bur to define the coronal, middle, and apical thirds. Canal halves were secured on metal stubs, desiccated, sputter-coated with gold, and viewed with scanning electron microscopy (LEO 1430 VP; Carl Zeiss NTS GmbH, Oberkochen, Germany).

Digital photomicrographs at 400 \times for smear layer evaluation were taken at the center of each third. The scoring procedure was carried out by 2 independent examiners who were trained in the punctuation procedure, resulting in a sufficient interobserver reproducibility, by using the criteria reported by Torabinejad et al (25), who measured the presence of smear layer as follows: Score 0 = no smear layer; absence of smear layer on the surface of the root canal; all tubules clean and open. Score 1 = moderate smear layer; no smear layer on the surface of the root canal, but tubules contain debris. Score 2 = heavy smear layer; smear layer covers the root canal surface and the tubules.

The final result of the smear layer analysis of each root canal specimen was obtained by calculating the percentage of each score on the images.

Statistical Analysis

The significant differences in the amount of smear layer removal by the irrigating solutions were analyzed by using the χ^2 Pearson test. The level of statistical significance was set at $P < .05$. All statistical analyses were performed by means of SPSS 15.0 software (SPSS Inc, Chicago, IL).

Results

The results of the 3 categories of smear layer amount in each of the 4 groups of irrigating solutions or combination of irrigating solutions and sonic system (EndoActivator) appear in Table 1 in the form of percentage distribution. Fig. 1 shows examples of smear layer removal in the coronal, middle, and apical thirds.

In both EDTA groups, the entire dentin wall of the coronal third was free of smear layer (100%), yet this percentage diminished to 80% of the dentin wall surface in the middle third and 20% in the apical third in EDTA/NaOCl group. In EDTA/EndoActivator/NaOCl group, the percentages of dentin wall free of smear layer were 50% and 10%, respectively, for the middle and apical thirds.

When comparing the amount of smear layer removal by all 4 groups in each root third, there were statistically significant differences in the results of the coronal third ($P < .05$), middle third ($P < .05$), and apical third ($P < .05$). Only NaOCl group versus NaOCl/EndoActivator group and EDTA/NaOCl group versus EDTA/EndoActivator/NaOCl group

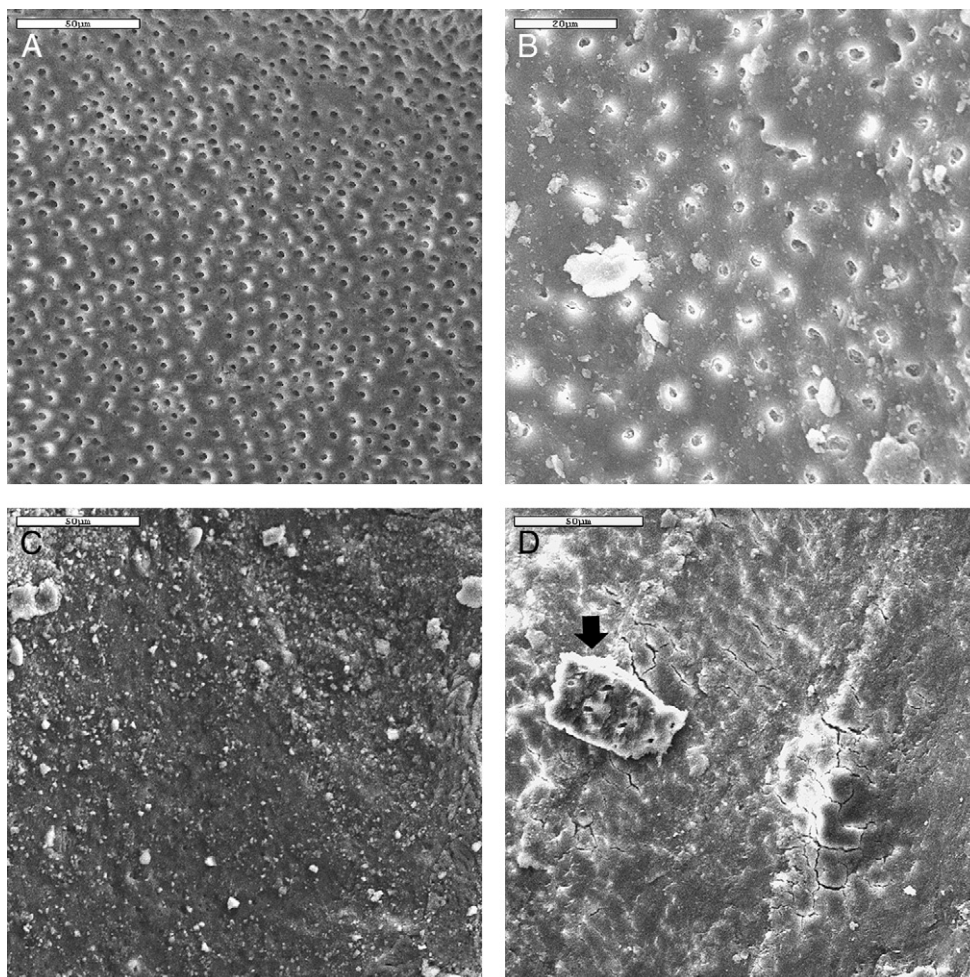


Figure 1. Representative scanning electron microscopy photomicrographs at $400\times$ of coronal, middle, and apical thirds in several specimens. (A) score 0 (coronal third), (B) score 1 (middle third), (C) score 2 (apical third), (D) score 2 (apical third), where a dentin chip (black arrow) with score 0 from a more coronal zone can be seen.

comparisons were not significantly different in the apical third, middle, or coronal third.

When comparing the results among the root thirds, NaOCl group and NaOCl/EndoActivator group showed no statistically significant differences, because the smear layer amount was equal in the three thirds (the entire surface was covered by smear layer). The other groups, EDTA/NaOCl and EDTA/EndoActivator/NaOCl, exhibited significant differences among thirds ($P < .05$). In the pairwise comparisons, EDTA/NaOCl group showed statistically significant differences in the comparisons of coronal third versus apical third ($P < .05$) and middle third versus apical third ($P < .05$). In EDTA/EndoActivator/NaOCl group, all 3 comparisons among thirds were significant (coronal versus middle, $P < .05$; coronal versus apical, $P < .05$; and middle versus apical, $P < .05$).

Discussion

In the present study focused on evaluating the effectiveness of a new sonically-driven system (EndoActivator) in removing the smear layer after rotary instrumentation of root canals, scanning electron microscopy was used.

Removal of the smear layer during or after root canal instrumentation (4, 26) requires the use of irrigants that can dissolve both organic

and inorganic components. The method recommended for this purpose involves a final rinse with 15% or 17% EDTA solutions followed by 1%–6% of NaOCl. However, there is no consensus with respect to the optimal volume (6, 27), time of application (5, 7), or the activation method of irrigating solutions (16, 28–31).

Ultrasonic devices have been used in the removal of smear layer in several studies, although their results are scarcely conclusive (9). Some authors have shown that the use of PUI for 3–5 minutes with NaOCl concentrations of 3% or 5% (15, 18) is sufficient for the complete removal of the smear layer in instrumented root canals. However, a time of application less than 1 minute did not allow for complete removal of the smear layer with 1% NaOCl (32). In this study, the use of a 4% NaOCl solution activated with EndoActivator for 1 minute did not achieve better elimination of smear layer than 4% NaOCl delivered by syringe irrigation. This result could be due to the fact that sonic frequency ranges are much lower than ultrasonic irrigation, and therefore the acoustic microstreaming would be lower, as would be the cleaning efficacy (16, 17).

The results of this study showed that the most effective smear layer elimination might be related to the use of a final flush with 17% EDTA solution. Without a final flush with 17% EDTA solution, the smear layer was seen to cover the root canal surface in the coronal, middle, and apical thirds, even when the EndoActivator System was used. These

results are in agreement with previous studies underlining the necessity of chelating or acid solutions to remove smear layer in root canal preparation (4, 29, 33, 34). Recently, a study showed the efficacy of a final rinse with 1 mL of 17% EDTA for 1 minute followed by a 3 mL rinse with 6% NaOCl for removing the smear layer after root canal instrumentation (7). Time exposures over 1 minute with EDTA might, however, produce an excess of chelating effect, which could affect the adhesion of endodontic sealers or adhesive cements and decrease the microhardness of the dentin walls (8, 35).

In the present study, a final rinse with 1 mL of 17% EDTA for 1 minute, with or without the use of EndoActivator, eliminated a greater amount of the smear layer in coronal and middle thirds than in the apical third, which showed the worst results. Meanwhile, de Gregorio et al (21), by using ultrasonic and sonic (EndoActivator) activation in simulated lateral canals, found better irrigation in the apical third (at 4.5 and 2 mm from working length) than with traditional needle irrigation alone, and the addition of EDTA did not result in better penetration of irrigants into the lateral canals. However, Mancini et al (34), in agreement with our results, showed that the smear layer was not removed completely in the apical third of the root canal by using 1 mL of BioPure MTAD (Dentsply Tulsa Dental) or 1 mL of 17% EDTA, followed by 3 mL of 5.25 NaOCl. This finding might be attributed to the lesser volume of final rinse used (1 mL 17% EDTA and 3 mL 4% NaOCl) and/or the major circulating volume of irrigant present in coronal and middle thirds as opposed to the apical third. In this sense, it was demonstrated that when the apical foramen was sealed, the apical thirds failed to become clear of smear layer (23, 24). A recent study indicated that a greater volume of 17% EDTA (5 mL) for 1 minute with ultrasonics followed by a greater volume of 1% NaOCl (5 mL) would prove efficient for smear and debris removal at the apical region of the instrumented root canal (30).

Chopra et al (31) irrigated root canals with a final flush of 10 mL 17% EDTA activated with a similar device, the F-file (PlasticEndo, Buffalo Grove, IL), for 30 seconds at 600 rpm in the electric slow speed rotary handpiece (Dentsply Tulsa Dental Specialties) followed by 10 mL 6% NaOCl; they concluded that the F-file was no more beneficial in removing smear layer, and that smear layer removal appeared to be mostly influenced by the introduction of an EDTA rinse.

Within the limitations of our study, the EndoActivator System did not enhance the removal of smear layer as compared with conventional Max-I-Probe irrigation with NaOCl and EDTA. A final irrigation with 1 mL of 17% EDTA solution was necessary to remove the smear layer after rotary instrumentation of root canal with or without the use of the EndoActivator System. The removal of smear layer was more complete in coronal and middle thirds than in the apical third. Further research entailing different solutions, volumes, and activation times of the irrigant would be necessary to fully evaluate the effectiveness of the EndoActivator System in smear layer removal after root canal instrumentation.

References

- Clark-Holke D, Drake D, Walton R, Rivera E, Guthmiller JM. Bacterial penetration through canals of endodontically treated teeth in the presence or absence of the smear layer. *J Dent* 2003;31:275–81.
- Shahravan A, Haghdoost AA, Adl A, Rahimi H, Shadifar F. Effect of smear layer on sealing ability of canal obturation: a systematic review and meta-analysis. *J Endod* 2007;33:96–105.
- Baumgartner JC, Mader CL. A scanning electron microscopic evaluation of four root canal irrigation regimens. *J Endod* 1987;13:147–57.
- Pérez-Heredia M, Ferrer-Luque CM, González-Rodríguez MP. The effectiveness of different acid irrigating solutions in root canal cleaning after hand and rotary instrumentation. *J Endod* 2006;32:993–7.
- Teixeira CS, Felipe MC, Felipe WT. The effect of application time of EDTA and NaOCl on intracanal smear layer removal: an SEM analysis. *Int Endod J* 2005;38:285–90.
- Crumpton BJ, Goodell GG, McClanahan SB. Effects on smear layer and debris removal with varying volumes of 17% REDTA after rotary instrumentation. *J Endod* 2005;31:536–8.
- Saito K, Webb TD, Imamura GM, Goodell GG. Effect of shortened irrigation times with 17% ethylene diamine tetra-acetic acid on smear layer removal after rotary canal instrumentation. *J Endod* 2008;34:1011–4.
- Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. *J Endod* 2002;28:17–9.
- Gu LS, Kim JR, Ling J, Choi KK, Pashley DH, Tay FR. Review of contemporary irrigant agitation techniques and devices. *J Endod* 2009;35:791–804.
- Goodman A, Reader A, Beck M, Melfi R, Meyers W. An in vitro comparison of the efficacy of the step-back technique versus a step-back/ultrasonic technique in human mandibular molars. *J Endod* 1985;11:249–56.
- Lee SJ, Wu MK, Lee SJ, Wu MK, Wesslink PR. The effectiveness of syringe irrigation and ultrasonics to remove debris from simulated irregularities within prepared root canal walls. *Int Endod J* 2004;37:672–8.
- Passarinho-Neto JG, Marchesan MA, Ferreira RB, Silva RG, Silva-Sousa YT, Sousa-Neto MD. In vitro evaluation of endodontic debris removal as obtained by rotary instrumentation coupled with ultrasonic irrigation. *Aust Endod J* 2006;32:123–8.
- Gutarts R, Nusstein J, Reader A, Beck M. In vivo debridement efficacy of ultrasonic irrigation following hand-rotary instrumentation in human mandibular molars. *J Endod* 2005;31:166–70.
- Chow TW. Mechanical effectiveness of root canal irrigation. *J Endod* 1983;9:475–9.
- Alacam T. Scanning electron microscope study comparing the efficacy of endodontic irrigating systems. *Int Endod J* 1987;20:287–94.
- Sabins RA, Johnson JD, Hellstein JW. A comparison of the cleaning efficacy of short-term sonic and ultrasonic passive irrigation after hand instrumentation in molar root canals. *J Endod* 2003;29:674–8.
- Stamos DE, Sadeghi EM, Haasch GC, Gerstein H. An in vitro comparison study to quantitate the debridement ability of hand, sonic, and ultrasonic instrumentation. *J Endod* 1987;13:434–40.
- Cameron JA. The use of ultrasonics in the removal of the smear layer: a scanning electron microscope study. *J Endod* 1983;9:289–92.
- Cameron JA. The synergistic relationship between ultrasound and sodium hypochlorite: a scanning electron microscope evaluation. *J Endod* 1987;13:541–5.
- Ruddle CJ. Endodontic disinfection: tsunami irrigation. *Endod Practice* 2008;11:7–15.
- de Gregorio C, Estevez R, Cisneros R, Heilborn C, Cohenca N. Effect of EDTA, sonic, and ultrasonic activation on the penetration of sodium hypochlorite into simulated lateral canals: an in vitro study. *J Endod* 2009;35:891–5.
- Caron G. Cleaning efficiency of the apical millimetres of curved canals using three different modalities of irrigant activation: a SEM study. Masters thesis, Paris VII University, Paris, France; 2007.
- Beruti E, Marini R, Angeretti A. Penetration ability of different irrigants into dental tubules. *J Endod* 1997;23:725–7.
- Albrecht LJ, Baumgartner JC, Marshall JG. Evaluation of apical debris removal using various sizes and tapers of ProFile GT files. *J Endod* 2004;30:425–8.
- Torbinejad M, Khademi AA, Babagoli J, et al. A new solution for the removal of the smear layer. *J Endod* 2003;29:170–5.
- da Silva LA, Sanguino AC, Rocha CT, Leonardo MR, Silva RA. Scanning electron microscopic preliminary study of the efficacy of SmearClear and EDTA for smear layer removal after root canal instrumentation in permanent teeth. *J Endod* 2008;34:1541–4.
- Yamada RS, Armas A, Goldman M, Lin PS. A scanning electron microscopic comparison of a high volume final flush with several irrigating solutions: part 3. *J Endod* 1983;9:137–42.
- Jensen SA, Walker TL, Hutter JW, Nicoli BK. Comparison of the cleaning efficacy of passive sonic activation and passive ultrasonic activation after hand instrumentation in molar root canals. *J Endod* 1999;25:735–8.
- Ferrer Luque CM, González López S, Navajas Rodríguez de Mondelo JM. Mechanical instrumentation of the root canals: a study using SEM and computerized image analysis. *Bull Group Int Rech Sci Stomatol Odontol* 1996;39:111–7.
- Kuah HG, Lui JN, Tseng PS, Chen NN. The effect of EDTA with and without ultrasonics on removal of the smear layer. *J Endod* 2009;35:393–6.
- Chopra S, Murray PE, Namerow KN. A scanning electron microscopic evaluation of the effectiveness of the F-file versus ultrasonic activation of a K-file to remove smear layer. *J Endod* 2008;34:1243–5.
- Cheung GSP, Stock CJR. In vitro cleaning ability of root canal irrigant with and without endosonics. *Int Endod J* 1993;26:334–43.
- Khedmat S, Shokouhinejad N. Comparison of the efficacy of three chelating agents in smear layer removal. *J Endod* 2008;34:599–602.
- Mancini M, Armellini E, Casaglia A, Cerroni L, Cianconi L. A comparative study of smear layer removal and erosion in apical intraradicular dentine with three irrigating solutions: a scanning electron microscopy evaluation. *J Endod* 2009;35:900–3.
- Cem Sayin T, Serper A, Cehreli ZC, Kalayci S. Calcium loss from root canal dentin following EDTA, EGTA, and tetracycline-HCl treatment with or without subsequent NaOCl irrigation. *J Endod* 2007;33:581–4.