Apical Extrusion of Sodium Hypochlorite Using Different Root Canal Irrigation Systems

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Abstract

Introduction: Root canal irrigation carries a risk of extrusion of irrigant into the periapical tissues. The objective of this study was to compare different irrigation systems in matched pairs of teeth prepared to an apical size of 35.06 and 50.06 by measuring the frequency and extent of apical extrusion of sodium hypochlorite (NaOCl) into a simulated periapical environment. The null hypothesis was tested that there is no difference between systems. **Methods:** Bilaterally matched pairs (n = 10) of single-canal extracted human anterior teeth were instrumented to an apical size of either 35.06 or 50.06. Teeth were embedded in a gel containing the pH-sensitive dye M-cresol purple that changes from yellow at pH 7.4 to purple at pH 9. Root canals were irrigated with 6% NaOCl (pH 11) by using EndoActivator (EA), EndoVac (EV), RispiSonic/MicroMega 1500 (MM), passive ultrasonic irrigation (PUI), and syringe irrigation with a slot-tipped needle (SN), so that each tooth underwent all irrigation procedures in a randomized crossover design. Apical extrusion was evaluated by image analyses. **Results:** The frequency of extrusion was less in teeth with apical preparation size 35.06 (36%) compared with 50.06 (60%) ($P = .014$) and was dependent on the irrigation system in 35.06 ($P = .039$) but not 50.06 groups. In the 35.06 group the frequency of extrusion was less for EV than for MM and SN (both $P = .029$). The extent of extrusion was less for MM compared with PUI ($P = .024$) and SN ($P = .046$) in the 35.06 group and greater for SN compared with all other systems in the 50.06 group ($P < .05$). The null hypothesis was rejected. **Conclusions:** The frequency of apical extrusion of NaOCl was dependent on the type of root canal irrigation system and apical preparation size. The extent of extrusion depended on the irrigation system, with syringe and slotted-needle irrigation resulting in the greatest extent of extrusion. *(J Endod 2011;37:1677–1681)*

Key Words

Apical extrusion, EndoActivator, EndoVac, Irrisafe, passive ultrasonic irrigation, root canal irrigation, sodium hypochlorite, Sonic Air MicroMega

Irrigation of the root canal system includes a risk of extrusion of the irrigant into the periapical region; in the case of irrigation with sodium hypochlorite (NaOCl), this can be associated with pain, swelling, and tissue damage (1–4). Commercially available irrigation devices have been developed with the aim of improving the delivery of irrigant throughout the root canal by using ultrasonic or sonic energy and apical negative pressure (5). The available data on extrusion of irrigant when using these devices appear to be limited to *in vitro* studies (6, 7). Apical extrusion of water was significantly reduced when using sonic or apical negative pressure devices compared with syringe and side-port needle or passive ultrasonic irrigation (PUI) with continuous irrigant flow (6). Similarly, there was significantly less apical extrusion of NaOCl by using apical negative pressure compared with syringe irrigation with a slotted needle (7).

Various methods have been used to evaluate apical extrusion of irrigants. In 1977 Salzgeber and Brilliant (8) observed apical extrusion of irrigants in patients with necrotic pulps by using a radiopaque solution. More recently, the apical extrusion of irrigant from various irrigation devices was evaluated *in vitro* by measuring the volume of the extruded liquid collected during irrigation (6); however, the experimental model did not provide resistance to apical flow by the surrounding structure, which would be expected clinically. Recently, an *in vitro* model was developed that measures extrusion of irrigants from the root canals of instrumented extracted teeth into a simulated periapical environment (7). The root of each tooth was embedded in a gel mixed with a pH-sensitive dye; after root canal irrigation with 6% NaOCl (pH 11), observations of color change in the gel beyond the root apex indicated extrusion of NaOCl into the gel (7).

The objective of the present *in vitro* investigation was to compare different irrigation systems in matched pairs of teeth prepared to an apical size of 35.06 and 50.06 by measuring the frequency and extent of apical extrusion of 6% NaOCl into a simulated periapical environment. The null hypothesis was tested that there is no difference between systems. The experimental model was based on that of Mitchell et al (7), with modifications to include quantification of the extent of extrusion.

Materials and Methods

Tooth Selection and Preparation

Ten pairs of single-canal bilaterally matched extracted human anterior teeth were used. Details on selection criteria and working length (WL) have been previously

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doi:10.1016/j.joen.2011.09.004

described (7). One tooth from each pair was instrumented to an apical size of ISO 35.06 and the other to 50.06 by using a crown-down technique and rotary files (Vortex; Dentsply Tulsa Dental, Johnson City, TN). Apical patency was maintained by passing a #15 file to WL after each rotary instrument. All teeth were irrigated with 1 mL 6% NaOCl between files and flushed with 5 mL 5% sodium thiosulfate and 5 mL of sterile saline after the last file used.

Embedding Teeth

Each tooth was rigidly fixed and secured with composite resin in a flat-sided clear plastic container with dimensions of 4.5 × 4 × 4 cm (SKS Industries, Watervliet, NY), which was then filled with a gel as previously described (7). A plastic master apical file size verifier (Dentsply) was placed at WL in each canal to block gel from entering the canal via the apical foramen. The container was filled to the cervical level of the tooth with 0.2% agarose gel (Difco Laboratories, Sparks, MD) (pH 7.3–7.4) containing 0.0013% v/v M-cresol purple (Sigma-Aldrich, St Louis, MO). M-cresol purple undergoes a pH-sensitive color change from yellow at pH 7.4 to purple at pH 9. Thus a color change in the gel to purple indicates the presence of NaOCl (pH 11).

Irrigation Procedures

The irrigation systems included in the study were EndoActivator (EA) (Dentsply), Rispi-Sonic file attached to a MicroMega 1500 (MM) (Medidenta International Inc, Woodside, NY), PUI (Irrisafe K15; Satelec, Merignac, France), EndoVac (EV) (Discus Dental, Culver City, CA), and syringe and 27-gauge slot-tipped needle (SN) (Monoject Tyco Healthcare, Mansfield, MA).

Each matched pair was randomly assigned to an irrigation system according to the protocol indicated in the experimental flowchart (Fig. 1) by using a 2-tiered randomization crossover design, so that each tooth cycled through all irrigation systems. SN, EV, and EA were in the first tier of irrigation systems. MM and PUI were assigned to the second tier because they were considered to have the potential to alter the canal wall. After completion of each cycle the gel was removed from the tooth, the root canal and root end were rinsed with 5 mL 5% sodium thiosulfate and 5 mL sterile saline, and a new gel was poured and allowed to set.

Immediately before irrigation the operator placed a dental dam on the tooth to prevent observation of the gel, and root canals were dried with paper points. NaOCl (6%) was used as the irrigant. The duration of irrigation was kept constant at 30 seconds for all irrigation systems. The total volume of irrigant used for EV and SN was 2 mL. For EA, MM, and PUI the root canal and pulp chamber space were filled with NaOCl with no further irrigant added. For the activated systems the tip of the device was placed into the root canal in accordance with the manufacturers' instructions, which corresponded to 2 mm from WL for EA, MM, and EV and 1 mm from WL for PUI. Irrigation devices were placed passively, with attempts to minimize contact with the walls of the canal during use. Immediately on completion of each cycle, remaining irrigant was aspirated from the canal by using a syringe with a 27-gauge slot-tipped needle, and the canal was dried with paper points.

The irrigation systems were used as follows.

With the EA, the appropriate-sized activator tip (25.04 for the 35.06 group and 35.04 for the 50.06 group) was placed loosely at 2 mm from WL and activated at 10,000 cycles/minute. A motion of 2- to 3-mm vertical strokes was used to agitate the irrigant.

With the MM, a #15 Rispi-Sonic file was placed 2 mm from WL and activated at 1500 Hz and 0.5-mm oscillations. The file was moved in 2- to 3-mm amplitude strokes.

With PUI, an IrriSafe ultrasonically activated file (#15/25) on a Satelec P5 booster ultrasonic unit (Satelec) with power setting 5 was placed 1 mm from WL and activated.

With EV, the microcannula was placed at WL. Irrigant was delivered to the canal via the master delivery tip at a rate of 2 mL/30 seconds. After every 6 seconds the microcannula was withdrawn 2 mm for 6 seconds and then placed back to WL.

With SN, the tip of the needle was placed short of binding and no closer than 2 mm from WL. The irrigant was delivered at a rate of 2 mL/30 seconds, moving in 2- to 3-mm amplitudes.

The purpose of the positive controls (POS) was to confirm that extrusion could occur in each sample. One hundred fifty microliters of irrigant was delivered to the apical foramen by an open-ended 30-gauge hypodermic needle positioned at WL.

Assessment of Extrusion

The tooth/gel set-up was positioned in front of a light-box for transillumination and digitally photographed (Canon, Lake Success, NY) in buccal/lingual (BL) and mesial/distal (MD) directions by using a camera positioned at a fixed distance (29.5 cm). Each sample was photographed before the first irrigation cycle (negative control [NEG]), visually inspected before subsequent irrigation cycles, and then photographed exactly 10 minutes after the start of irrigation for assessment of extrusion of NaOCl into the gel. Images were analyzed by using Adobe Photoshop 7 (Adobe, San Jose, CA) to determine the area of the gel color change expressed in pixels on BL and MD views as previously described (7). To quantify the extent of color change in the gel, the formula used was as follows:

$$\text{Extent of extrusion} = \text{Volume}_{\text{gel color change}} - \text{Volume}_{\text{root}},$$
$$\text{or } 4/3\ \pi\ r^3 - 1/3\ \pi\ R^2H$$

where r = radius of color change (averaged pixels from BL and MD views), R = radius of the root at its most coronal level of gel color change (averaged pixels from BL and MD views), and H = height of the root measured from the most coronal level of gel color change to the apex (averaged pixels from BL and MD views). Final values were expressed as arbitrary volume units.

Statistical Analysis

Kolmogorov-Smirnov tests showed the data were not normally distributed; therefore, nonparametric tests were used to compare groups.

For frequency of extrusion, each sample was categorized as either positive or negative for extrusion. Groups were compared by using the Cochrane-Q test for matched groups with repeated measurements and Fisher test. The effect of apical preparation size was evaluated by using McNemar test for matched pairs.

For extent of extrusion, groups required at least 3 positive samples to allow statistical analyses. The extent of extrusion was compared by using Mann-Whitney tests (for 2 groups) and Kruskal-Wallis tests (for 3 or more groups).

Results

All positive and negative controls performed as expected.

Frequency of Extrusion

Extrusion occurred less frequently in teeth with apical preparation size 35.06 (overall 36%) compared with size 50.06 (overall 60%) (P = .014) (Table 1). The frequency of extrusion was significantly influenced by the irrigation system in teeth with an apical

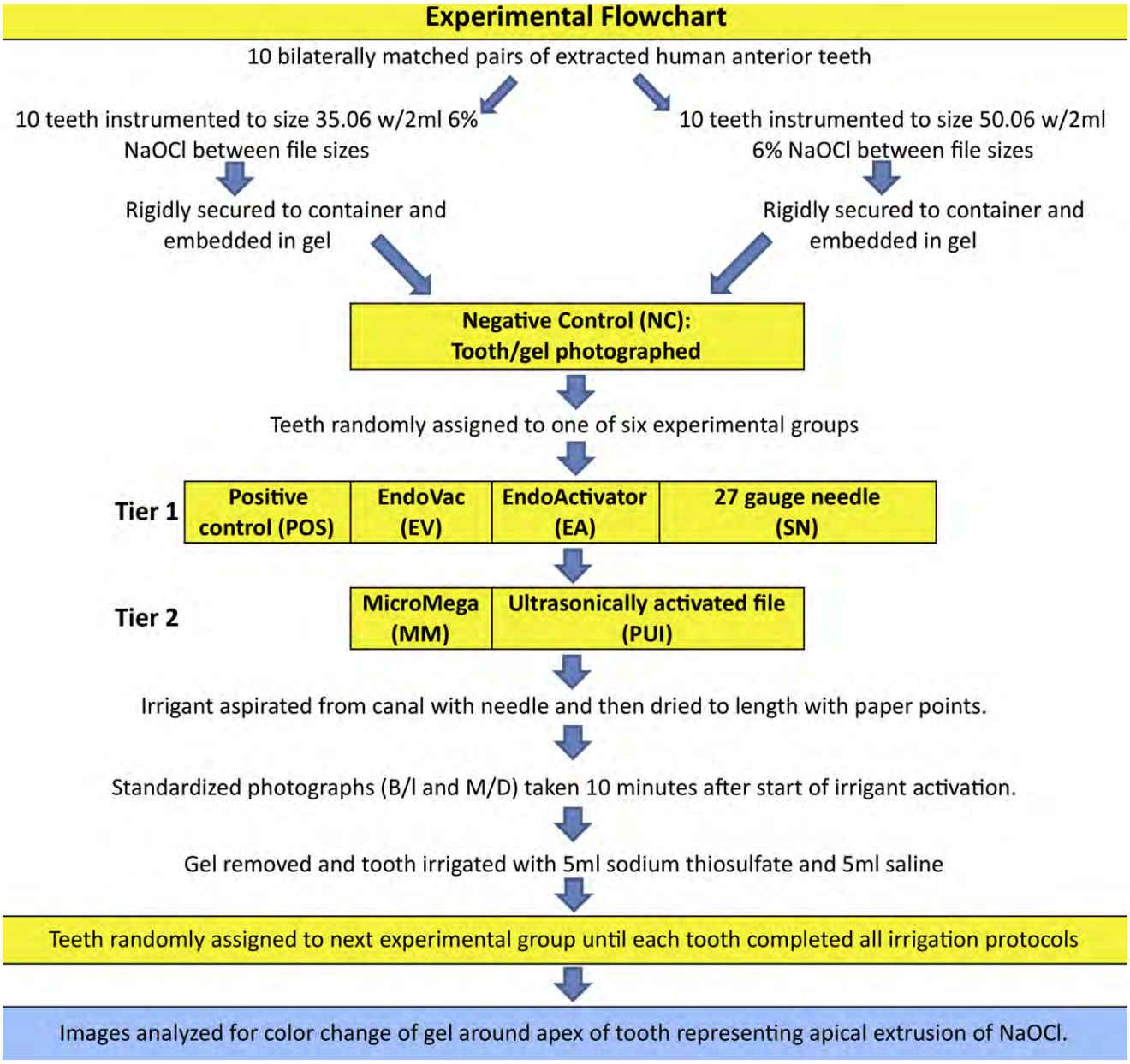

Figure 1. Experimental flowchart.

preparation size 35.06 (P = .039) but not 50.06. In the 35.06 group the frequency of extrusion for EV was significantly less than for MM and SN (both P = .029).

Extent of Extrusion

The extent of extrusion in positive samples is shown in Figure 2. Apical preparation size did not influence the extent of extrusion for groups MM, PUI, SN, and POS (the only groups for which sufficient positive samples were available for analysis). In size 35.06 groups, extrusion was less for MM compared with PUI (P = .024) and SN (P = .046); there were too few EA and EV positive samples to be included in the analysis. In size 50.06 groups, extrusion was greater for SN compared with EV, EA, and MM (all P < .006) and PUI (P < .05), with no other significant intragroup associations.

Discussion

The results of this *in vitro* study demonstrate that both apical preparation size and the method of activation and delivery of NaOCl into the apical one-third play a role in the amount of extrusion into the apical tissues. The null hypothesis was rejected. The lowest frequency of extrusion occurred with the EV system at an apical preparation size of 35.06. Although an advantage of needle irrigation is that it provides easy control of needle depth in the canal as well as the volume of irrigant delivered (9), this study found that syringe and needle irrigation resulted in greater frequency and extent of extrusion than activated devices. However, it should be noted that extrusion of irrigant is greater from open-ended needles, as used in this study, compared with those needles with a closed-ended needle design (10).

A large body of literature is available on debridement and antibacterial efficacy of various irrigant delivery systems (5). PIU, where the ultrasonically activated instrument is not intended to touch the canal

TABLE 1. Frequency of Extrusion of 6% NaOCl in Bilaterally Matched Pairs (n = 10) of Teeth Undergoing Different Root Canal Irrigation Procedures

	Irrigation systems						Controls	
Apical size	EA	EV	MM	PUI	SN	Overall*	POS	NEG
35.06[†]	2/10	1/10[‡]	6/10[‡]	3/10	6/10[‡]	18/50	10/10	0/10
50.06	6/10	4/10	5/10	6/10	9/10	30/50	10/10	0/10
Combined[§]	8/20	5/20	11/20	9/20	15/20		20/20	0/20

Values refer to samples positive for extrusion.

*P = .014, McNemar test.

[†]P = .039, Cochrane Q.

[‡]P = .029, Fisher test.

[§]P < .01, Cochrane Q.

walls (11), has been shown to result in significantly greater reduction in smear layer, bacteria, pulp tissue, and debris than needle irrigation or sonic activation (9, 12, 13). This has been attributed to acoustic streaming and cavitations produced by the ultrasonically activated file (14–16). Irrigant delivery options for PUI include continuous or intermittent flush. Both approaches have been shown to be effective in dentin debris removal (17), but an advantage of the latter is that the volume of irrigant delivered can be controlled. In the only previous study that evaluated extrusion of irrigant by using sonic or ultrasonic irrigation methods (6), there were similar volumes of extruded irrigant with syringe and side-ported needle, and PUI with continuous irrigant flow. However, continuous flow irrigation with PUI was used in the previous study (6), compared with this study in which irrigant was not replenished. It is noted that in accordance with the accompanying manufacturer's instructions, the IrriSafe tip placement was positioned 1 mm from the WL, compared with 2 mm for the other groups. Therefore, it is feasible that under the present experimental conditions PUI with continuous irrigation would have elicited greater frequency and extent of extrusion.

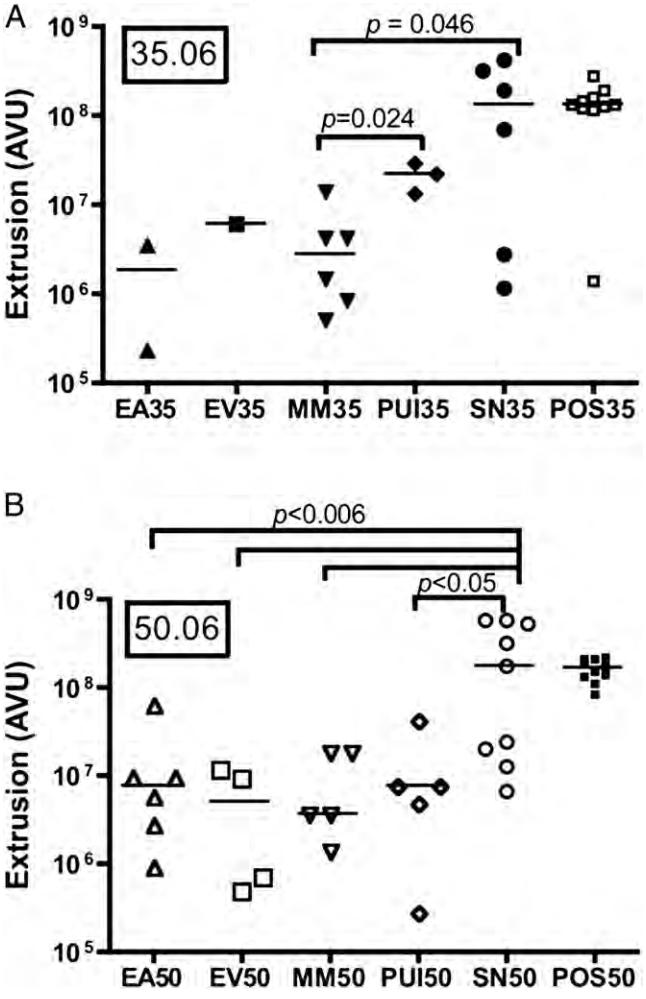

Figure 2. Extent of extrusion of 6% NaOCl in positive samples in 10 matched pairs of teeth prepared to apical size 30.06 (*A*) and 50.06 (*B*). Symbols represent the values for each of the positive samples in Table 1. Bars represent medians. AVU, arbitrary volume units.

Although it is less powerful than ultrasonic, sonic irrigation produces higher amplitude and tip movement. If constrained in the canal, longitudinal file oscillation can facilitate debridement (18). The Sonic Air Micro-Mega handpiece with a Rispi-Sonic file was originally developed for shaping of the root canals. When used as an adjunct to irrigation, it was shown to remove debris more efficiently than needle irrigation but was no better than PUI (19, 20). The EA has been shown to decrease smear layer (21, 22), but others have reported limited benefit of EA over needle irrigation (23) and less efficacy than ultrasonic agitation (24). In the present study both sonically activated devices, EA and MM, performed significantly better than SN with regard to extent of extrusion in teeth prepared to size 50.06 and better than both PUI and SN in the matched pairs prepared to 35.06 (Fig. 2). (It should be noted that in teeth prepared to size 35.06 there were too few samples from EA (n = 2) and EV (n = 1) groups that demonstrated extrusion to be included in analyses of extent of extrusion.)

The EV is a negative pressure irrigation device that has been shown to result in greater debris removal *in vitro* (25) and *in vivo* (26), with less extrusion of irrigant (6, 7) compared with needle irrigation. *In vitro* investigations on antimicrobial efficacy have been divergent; a reduction in colony-forming units was reported with the use of EV (27), in contrast with other studies that did not show a significant microbial reduction over needle irrigation (28, 29). A recent clinical trial concluded that postoperative pain was significantly less with EV compared with conventional needle irrigation (30). The authors hypothesized that this difference was attributable to EV preventing or lessening the amount of NaOCl extruded into the periapical tissues (30), which is supported by the findings of previous investigations (6, 7) and this study.

The present investigation adopted a protocol developed by Mitchell et al (7), with modifications to adapt to the inherent differences between irrigation systems studied. Previously, teeth were instrumented and irrigated after being embedded in the gel, and only SN and EV were compared (7). In the present investigation, teeth were instrumented before being embedded in the gel to allow for direct comparison of the final irrigation cycle only, eliminating the variable of instrumentation. Because of this change, photographs were taken 10 minutes after

initiating irrigation rather than 20 minutes from the start of instrumentation as previously (7). In addition, in this study apical sizes 35.06 and 50.06 were compared instead of 40.06 and 60.96 as previously (7). The smaller apical preparation size was selected to ensure that EV (size 32 at tip) could reach WL. Brunson et al (31) reported that the maximum irrigant exchange with EV was reached at 40.06, with a modest but insignificant increase in irrigant exchange at larger tapers and apical preparation sizes (up to 45.06). The increased frequency of extrusion with needle irrigation seen in the current study (60% for 35.06 and 90% for 50.06) when compared with the previous study (50% for size 40.04 and 58% for 60.04) (7) can be explained by differences in the experimental protocols. In the current study, all debris was removed from the root canal system before final irrigation. In the previous study, the tooth was instrumented and irrigated concurrently, which could have created debris that limited extrusion of irrigant (7).

Although the time of exposure to the irrigant was controlled to 30 seconds, the volume of irrigant differed. Samples in EV and SN groups had 2 mL of irrigant delivered, whereas those in EA, MM, and PUI groups did not have additional irrigant added. Frequency of extrusion for EV was less than for SN in agreement with previous results (6, 7). Despite the increased irrigant volume used with EV, in 35.06 groups the frequency of extrusion was significantly less than with MM (Table 1). In the present study there were insufficient positive samples for EA and EV to evaluate the extent of extrusion in size 35 groups. A larger sample size might have provided more samples with extrusion. However, in the 50.06 group all of the activated irrigation systems (EA, EV, MM, and PUI) had less extrusion than SN (Fig. 2), which, with the exception of PUI discussed above, supports Desai and Himel (6), who reported that EA and EV had significantly less extruded irrigant compared with needle and syringe irrigation in teeth prepared to 50.04.

The experimental model was designed to imitate conditions *in vivo* by simulating periapical tissues. However, caution should be exercised before extrapolating these results to the clinical situation, because the density of the gel has not been correlated with an intact periodontal ligament or an apical lesion. Furthermore, the porous nature of the gel allows for diffusion of the irrigants and an expansion of the affected area with time as long as the pH remains above 9. To overcome these limitations, all irrigants were aspirated from the canal, and the canal was dried with paper points immediately after completion of each cycle. In addition, photographs were taken exactly 10 minutes after the initiation of irrigation to standardize the amount of diffusion.

In conclusion, the frequency of apical extrusion of NaOCl was dependent on the type of root canal irrigation system and apical preparation size. The extent of extrusion depended on the irrigation system, with syringe and slotted-needle irrigation resulting in the greatest extent of extrusion.

Acknowledgments

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

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