Effect of Needle Insertion Depth and Root Canal Curvature on Irrigant Extrusion *Ex Vivo*

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Abstract

Introduction: The aim of this study was to evaluate the effect of needle type and insertion depth, apical preparation size, and root canal curvature on irrigant extrusion by using a recently introduced method. **Methods:** Sixteen human teeth with a straight root canal (group A) and 16 with a moderately curved root canal (group B) were sequentially prepared to sizes 25 or 35, .06 taper and mounted on a plastic vial filled with distilled water to simulate a periapical lesion. The vial was either closed or open to the environment. A point-conductivity probe was used to determine the volume of extruded irrigant into the vial. NaOCl was delivered by an open-ended or a closed-ended needle at 1, 3, or 5 mm short of working length. Results were analyzed by two 4-way mixed-design analyses of variance. The level of significance was set to $P < .05$. **Results:** The open-ended needle extruded significantly more irrigant than the closed-ended. Irrigant extrusion decreased as needles moved away from working length or when the apical size was increased. Needle wedging increased extrusion, especially when an open-ended needle was used. Root canal curvature did not have a statistically significant effect on irrigant extrusion. **Conclusions:** Needle type, needle insertion depth, and apical preparation size had a significant effect on irrigant extrusion. *(J Endod 2013;39:521–524)*

Key Words

Apical extrusion, curvature, endodontic treatment, insertion depth, irrigation, needle, preparation size, sodium hypochlorite

Inadvertent irrigant extrusion toward the periapical tissues has been described in a number of case reports (1–4). Sequelae such as severe pain, burning sensation, inflammation, and possible delayed healing may develop, depending on the type of irrigant used (5). Currently, NaOCl is widely considered as the primary irrigant of choice (6, 7), but in case of extrusion it also exerts a caustic effect on vital tissue (8). A recent survey indicated that 42% of the endodontists in the United States had experienced at least 1 NaOCl accident during their career (9).

Several *ex vivo* studies have investigated the parameters affecting irrigant extrusion (10–15). However, methodological limitations such as absence of periapical tissue simulation hinder comparisons and extrapolation of the conclusions to clinical practice (16). In addition, factors that have been frequently associated with irrigant extrusion in case reports, such as needle wedging, have not been investigated *ex vivo* (16). Recently, a new method for real-time quantification of irrigant extrusion by a conductivity probe was introduced (17). The aim of the present study was to evaluate the effect of needle type and insertion depth, apical preparation size, and root canal curvature on irrigant extrusion by using this new method.

Materials and Methods

All procedures were approved by the Ethics Committee of the institution. A repeated-measures experimental design was used. The protocol has been described in detail in a previous study (17). Sample size estimation was conducted *a priori* by G*Power 3.1.2 (18). Thirty-two teeth with a single root canal were included in the present study and were divided into 2 groups: A and B (n = 16). The teeth were collected from a pool of extracted teeth shortly after extraction. Root canal curvature was either <10° (group A, straight root canals) or 20°–30° (group B, curved root canals) according to Weine (19) and was limited to the apical third of the root canal. The working length (WL) was standardized at 19 mm, 0.5 mm short of the apical foramen.

A single operator instrumented all specimens by a crown-down technique using rotary nickel-titanium instruments (K^3; SybronEndo, Orange, CA) initially to size 25 and later to size 35, both with .06 taper. Each root canal was irrigated with 2 mL 2.5% NaOCl between successive instruments by using a 30-gauge open-ended needle (NaviTip; Ultradent Products Inc, South Jordan, UT) placed at 3 mm short of WL. At the end of instrumentation the root canal was irrigated with 5 mL 2.5% NaOCl and 10 mL distilled water and dried with paper points. No attempts were made to remove the smear layer. Each specimen was mounted into the mating lid of a 10-mL plastic

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vial with self-curing acrylic resin and further coated with cyanoacrylate (Pattex; Henkel, Düsseldorf, Germany) to ensure a fluid-tight seal between the specimen and the lid. The apical 5 mm of the root, which was not embedded in acrylic resin, was also covered with cyanoacrylate while a size 10 K-file (Dentsply Maillefer, Ballaigues, Switzerland) protruded 2.5 mm from the surface to create a standardized artificial constriction of 0.15 mm. All specimens were stored at 100% relative humidity between experiments.

A testing apparatus (Fig. 1) was fabricated for the experiments (17). Briefly, a 10-mL opaque plastic vial filled with distilled water was used to simulate a periapical lesion and accommodate the extruded irrigant. The vial was mounted on a custom-made translation stage. Each specimen was consecutively fitted on the vial. Two types of 30-gauge needles, an open-ended (NaviTip) and a closed-ended (KerrHawe Irrigation Probe; KerrHawe SA, Bioggio, Switzerland), were used for root canal irrigation. The needle insertion depth was standardized at 1, 3, or 5 mm short of WL by the translation stage. NaOCl 2.5% was supplied by a custom-made syringe pump at a clinically realistic flow rate of 0.26 mL/s (20). A point-conductivity probe (21) was used to assess the volume of extruded irrigant in real time by determining electrolyte concentration in the vial. A 21-gauge open-ended needle (Penta; PentaFerte, Campi, TE, Italy) was also inserted in the vial and was connected to a plastic Luer-Lock valve. During the experiments, the valve was either completely closed or completely open to simulate a low-compliance (water-closed, WC) or a high-compliance (water-open, WO) condition within the vial (17, 22). The liquid in the vial was continuously stirred by a custom-made magnetic stirrer.

The sequence of the experiments was randomized to prevent a possible carryover effect. The vial and the probe were flushed with distilled water between successive experiments. Electrolyte concentration measurements and syringe-pump on/off timings were interfaced to a personal computer. The conductivity of reference NaOCl solutions (0.0001%–2.5%, as determined by iodometric titration and ion chromatography) was measured *in situ* by the probe to create a calibration curve. Conductivity measurements were converted to volumes of extruded irrigant, which were further divided by the volume of delivered irrigant (2 mL) to obtain the percentage of delivered irrigant that was extruded in each case. Data were automatically analyzed in Excel 2003 (Microsoft Corp, Redmond, WA).

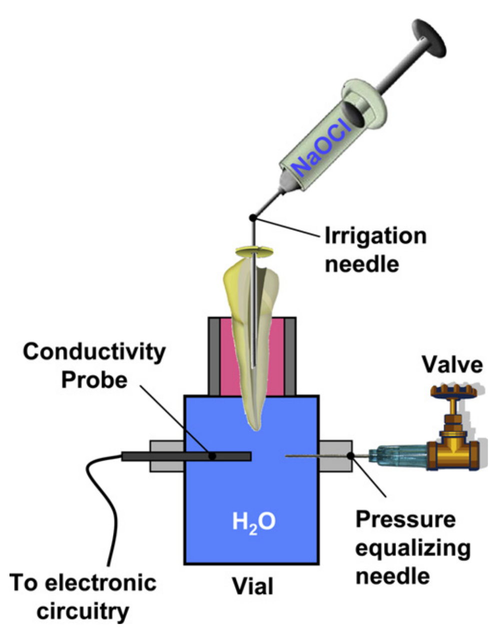

Figure 1. Schematic diagram of the apparatus used for irrigant extrusion measurements. The vial was filled with distilled water. During the experiments, the valve was either completely closed or completely open to simulate a low-compliance condition (WC) or a high-compliance condition (WO), respectively.

The effects of needle type, needle insertion depth, apical preparation size, and root canal curvature on the percentage of the delivered irrigant that was extruded were analyzed separately for low-compliance (WC) and high-compliance (WO) conditions by two 4-way mixed-design analyses of variance. Normality of the data was verified by the Shapiro-Wilk test, and sphericity was evaluated by the Mauchly test. The null hypothesis was that the 4 factors have no significant effect on the amount of extruded irrigant. The Tukey least significant difference post hoc test was used for pair-wise comparisons. The level of significance was set to $P < .05$. The Bonferroni correction was applied when appropriate. Statistical analysis was performed by using SPSS 15.0 (SPSS Inc, Chicago, IL).

Results

Descriptive statistics are presented in Figure 2. In the low-compliance condition (WC), the interaction of needle type by needle insertion depth by apical size was statistically significant ($P < .001$). In the high-compliance condition (WO), the interactions of needle type by apical size and of needle type by needle insertion depth were statistically significant ($P < .001$ and $P = .020$, respectively). A simple-effects analysis was performed for these factors, and the main effect of root canal curvature was interpreted for both conditions. Confidence intervals (CI) are reported as absolute differences in the percentage of delivered irrigant that was extruded at 95% probability.

Within the low-compliance condition (WC), the open-ended needle extruded significantly more irrigant than the closed-ended needle when positioned at 1 or 5 mm in a size 25 root canal ($P < .001$, CI 2.7%–5% [1 mm]; $P = .009$, CI 0.09%–0.73% [5 mm]) and at all positions in a size 35 root canal ($P < .001$, CI 0.28%–0.46%). Irrigant extrusion decreased as needles moved away from WL. The difference between 1 and 3 mm was significant for both needles in size 25 ($P < .001$, CI 1.33%–2.73% [closed-ended], CI 4.18%–6.76% [open-ended]) and size 35 root canals ($P < .001$, CI 0.28%–0.46%). However, the difference between 3 and 5 mm was only significant for the closed-ended needle ($P < .001$, CI 0.28%–0.88% [size 25]; $P < .001$, CI 0.07%–0.21% [size 35]) but not for the open-ended needle ($P > .051$). The volume of extruded irrigant was significantly lower in size 35 root canals compared with size 25 for both needle types and all insertion depths (closed-ended: $P < .001$, CI 1.77%–2.93% [1 mm], 0.67%–1.13% [3 mm], and 0.31%–0.61% [5 mm]; open-ended: $P < .001$, CI 4.57%–6.87% [1 mm], 0.50%–1.48% [3 mm], and 0.30%–0.82% [5 mm]).

In the high-compliance condition (WO), the open-ended needle extruded significantly more irrigant than the closed-ended needle at all insertion depths ($P < .001$, CI 12.80%–20.22% [1 mm], 8.23%–15.39% [3 mm], and 8.89%–15.03% [5 mm]) and for both apical sizes ($P < .001$, CI 16.07%–21.83% [size 25] and 5.63%–10.19% [size 35]). The volume of extruded irrigant was significantly lower in size 35 root canals compared with size 25 for both needle types ($P = .001$, CI 1.82%–7.50% [closed-ended]; $P < .001$, CI 12.69%–18.71% [open-ended]). Irrigant extrusion also decreased as needles moved away from WL. A significantly higher volume of irrigant was extruded when the needle was positioned at 1 mm compared with 3 mm ($P < .001$, CI 3.24%–10.66% [closed-ended] and 7.96%–15.34% [open-ended]) and at 3 mm compared with 5 mm