Comparison of the Volume of Root Canal Irrigant Collected by 2 Negative Pressure Needles at Different Flow Rates of Delivery

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Abstract

Introduction: A greater irrigant volume improves the effectiveness of root canal irrigation. The purpose of this study was to compare 2 negative pressure systems regarding the volume of irrigant collected from the apical area in moderately curved canals at 3 different flow rates of delivery *in vitro*. **Methods:** The mesiobuccal canals of 30 molars with a curvature between 20° and 40° were prepared to size #40.04 taper. A closed system was created. The canals were irrigated at 3, 6, and 12 mL/min for 30 seconds using EndoVac (SybronEndo, Orange, CA) and the INP needle (Mixnus Fine Engineering Co Ltd, Nagano, Japan) (both independent variables). A recovery trap was used to collect the irrigant aspirated by the negative pressure needles. Irrigant volume (dependent variable) was measured in milliliters. Data were analyzed using mixed analysis of variance. **Results:** There was a statistically significant interaction between the negative pressure system and the irrigant volume collected ($P < .0005$). The mean irrigant volume collected by the different negative pressure systems was greater for INP at 3 ($P < .001$), 6 ($P < .001$), and 12 mL/min ($P < .001$) flow rate. Both negative pressure needles showed statistically significant differences ($P < .001$) between mean irrigant volume collected at different flow rates. **Conclusions:** A greater volume was collected by increasing the flow rate of irrigant delivery for both EndoVac and INP. The INP needle could collect a greater volume of irrigant from the apical third compared with EndoVac at all 3 different flow rates. *(J Endod 2018;■:1–4)*

Key Words

Irrigant replacement, negative pressure irrigation, root canal irrigation, volume

A thorough debridement of the root canal system cannot be achieved through instrumentation alone (1). Previous studies reported residual pulp tissue ranging from 3%–20% of the apical 3 mm of mandibular molars (2) and 4%–100% of untreated canal areas of maxillary molars (3). This reinforces the notion of using chemically active irrigation solutions as a necessary adjunct to mechanical preparation. When irrigating solutions are delivered to the most apical region of the root canal system, the ability to dissolve organic tissues, kill microbes, remove microbial by-products, and remove the smear layer is better achieved (4–6). Ideally, the solutions should come into contact with the biofilm/organic tissue/canal wall (7, 8). However, when this happens, a gradual weakening or inactivation of the irrigating solution occurs (4, 8–12). Therefore, frequent replenishment and a greater volume of the irrigating solution are recommended to improve the effectiveness of the irrigating solution (9, 13, 14).

Significance

By increasing the flow rate of delivery, a greater volume of sodium hypochlorite can be collected from the apical region when using negative pressure irrigation. This would allow replenishment with fresh irrigant at the working length and potentially cleaner canals.

The ability of the irrigant solution to reach the working length by using negative pressure irrigation with EndoVac (SybronEndo, Orange, CA) and, more recently, with the INP needle (Mixnus Fine Engineering Co Ltd, Nagano, Japan) has been shown previously (15–19). The negative pressure concept is relatively simple. When the negative pressure needle is placed within the canal during aspiration, the pressure generated in the apical region of the canal is lower in comparison with the atmospheric pressure. The pressure gradient created results in a net force directed toward the lower pressure area, which affects the irrigant solution deposited in the pulp chamber directing it toward the apical region from where it is collected by the aspirating tip (16). Minimal to no extrusion can be expected (20–22) because of the negative pressures developed within the root canal (23).

The volume of irrigating solutions reaching the apical third of the canal by negative pressure systems has been previously investigated using EndoVac (24–26) and both EndoVac and the INP needle (16). Influencing factors such as apical preparation size (25, 26), taper (25), root curvature (26), and type of needle (16) were identified. However, the influence of the flow rate of delivery has not been previously investigated. Therefore, the purpose of this study was to compare 2 negative pressure systems regarding the volume of irrigant collected from the apical area in moderately curved

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canals at 3 different flow rates of delivery *ex vivo*. The null hypothesis was that there is no difference in the volume of irrigant collected.

Methods

Sample size was calculated *a priori* with G*Power (version 3.1.9.2) (27). A minimum of 28 specimens would be required in a crossover design of 2 groups with 3 measurements each to detect an effect size of 0.25 by mixed analysis of variance (ANOVA) (repeated measures, within-between interaction) at 80% power and with a type I error probability of 5% (2-tailed). The mesiobuccal canals of 30 mandibular and maxillary molars were used in the present study. Teeth presenting cracks, resorption, immature apices, root caries, previous root canal treatment, and double curvatures were discarded according to the exclusion criteria. The presence of 2 separate canals in the mesial roots was confirmed radiographically. Upon access, a #10 K-file was introduced into the mesiobuccal canal, and the curvature was measured following the method proposed by Iqbal et al (28). Canals with curvatures between 20° and 40° and in which canal patency could be achieved were included in the study.

The lengths of the roots were standardized to 16 mm by decoronation perpendicular to the long axis of the tooth with a diamond disc (911HV.104.180; Komet Dental Gebr Brasseler Gmbh & Co KG, Lemgo, Germany). The canals were enlarged with nickel-titanium rotary files (MTwo; VDW, Munich, Germany) using the following sequence: #10.04, #15.05, #20.06, #25.06, #30.05, #35.04, and #40.04. During the instrumentation procedures, 1.5 mL 5.25% sodium hypochlorite (NaOCl) was delivered with a 27-G needle (Monoject 3 mL; Tyco HealthCare Group, Mansfield, MA). Then, a closed system was created by coating the apex with modeling wax.

Each tooth underwent all irrigation procedures in a randomized crossover design. The apical negative pressure systems used in the present study were the EndoVac microcannula and the INP40 needle (Fig. 1*A–C*). The EndoVac system was used according to the manufacturer's instructions. First, the macrocannula was used for 30 seconds to remove larger debris from the root canal. Then, the microcannula was used at the working length and 2 mm short of the working length in 6-second intervals for 30 seconds. The INP needle was also used according to the manufacturer's instructions and placed at 2 mm short of the working length, and the irrigant was delivered in the pulp chamber for 30 seconds.

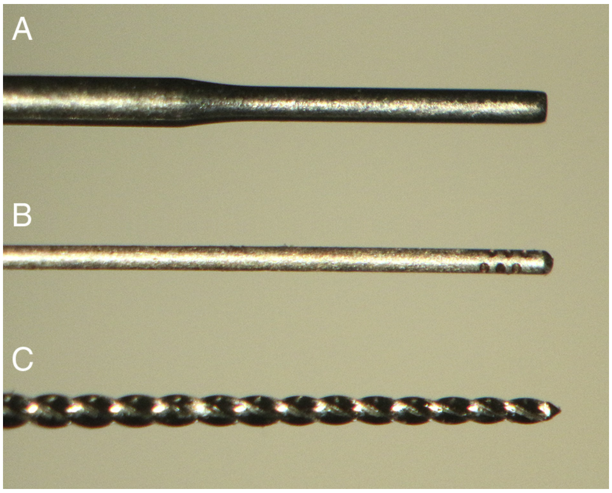

Figure 1. The tip design of the (*A*) INP and (*B*) EndoVac microcannula. (*C*) A #30.02 taper K-file for scale.

Root canal irrigant (NaOCl) was delivered at 3, 6, and 12 mL/min for 30 seconds using a syringe pump (NE-300 Just Infusion; New Era Pump Systems, Inc, Farmingdale, NY). A vacuometer (MVA6181; Mityvac, St Louis, MO) was used to measure the pressure of the suction line, which was calibrated at 4.42 mm Hg. The pressure was constantly recorded and maintained during all experimental procedures. A recovery device similar to the ones used in previous studies (16, 25, 26) was used. The irrigant delivered while using the microcannula (Fig. 1*B*) and the INP needle (Fig. 1*A*) was collected by the recovery device and measured afterward by a single blinded operator.

Statistical analysis was performed with an SPSS statistical package (version 15; SPSS Inc, Chicago, IL). The dependent variable was the irrigant volume collected (mL) treated as continuous data. The between-subjects factor was the negative pressure system (INP or EndoVac); the within-subjects factor was the delivery flow rate (3, 6 or 12 mL/min). Therefore, the 2-way mixed ANOVA test was used to detect any interaction between the negative pressure system used and the flow rate on the irrigant volume collected. If a statistically significant interaction was found, simple main effects for the flow rate and negative pressure system were further tested with 1-way ANOVA (univariate) with the Bonferroni post hoc test and the paired *t* test (repeated measures), respectively. The significance level was set at 0.05.

Results

The mean and standard deviation of the irrigant volume collected according to the negative pressure system and the flow rate are shown in Table 1. There was a statistically significant interaction between the negative pressure system and the irrigant volume collected ($P < .0005$, partial $\eta^2 = .974$). Furthermore, there was a statistically significant difference between the mean irrigant volume collected by the different negative pressure systems at 3 ($P < .001$), 6 ($P < .001$), and 12 mL/min ($P < .001$) flow rates (paired *t* test) (Table 1) (ie, the INP needle collected a statistically significantly greater mean irrigant volume at each flow rate tested compared with EndoVac). For both negative pressure systems, statistically significant differences ($P < .001$) in the mean irrigant volume collected were observed between all flow rates (Table 1); a significantly greater mean irrigant volume was collected with greater flow rates although the increments were not proportional.

Discussion

Laboratory studies have the advantage of easy control over variables and reproducibility. Additionally, crossover designs allow each tooth to serve as its own matched control, thus reducing error variance. The present study used moderately curved mesiobuccal canals of mandibular molars because of their relatively frequent occurrence in clinical practice. A final preparation size of #40.04 taper was used in order to accommodate the cannulas and to allow an adequate volume

TABLE 1. The Mean (Standard Deviation) of the Irrigant Volume Collected (in mL) at Different Flow Rates of Delivery According to the Negative Pressure System

Negative pressure system	Flow rate of irrigant delivery		
	3 mL/min	6 mL/min	12 mL/min
EndoVac	.71 (.09)^{Aa}	1.08 (.17)^{Ab}	1.24 (.12)^{Ac}
INP	1.35 (.06)^{Ba}	2.29 (.11)^{Bb}	4.23 (.19)^{Bc}

Different superscript lowercase letters indicate significant differences "within subjects" (between flow rates within the same negative pressure system) (1-way analysis of variance with the Bonferroni post hoc test). Different superscript uppercase letters indicate significant differences "between subjects" (between negative pressure systems at different flow rates (paired *t* test)).

of irrigation in the apical third when using negative pressure irrigation (25). However, although the volume of irrigant collected by a negative pressure device is proportional to the apical preparation size, one must take into consideration that it is also inversely proportional to canal curvature (26). Because of this, moderately curved canals were used in a crossover design.

The flow rates used in the present study were standardized using a syringe pump at 3, 6, and 12 mL/min for 30 seconds. Therefore, the volume delivered was 1.5, 3, and 6 mL for each flow rate. According to the results, by increasing the flow rate of delivery, the volume of irrigant collected increased significantly for both needles (Table 1). A recent study (23) exploring the periapical pressures developed during irrigation reported that when the irrigant was delivered at greater flow rates, the apical fluid pressures decreased (ie, the pressure gradient increased). Although this finding was not discussed in that study, it is in agreement with the findings of the present study. The increased pressure gradient would result in a greater net force affecting irrigant flow. Furthermore, the INP needle collected significantly more irrigant at each flow rate. Clinically, the flow rate of handheld syringe irrigation can vary significantly according to the sex of the operator (higher for males) and the needle gauge (mean flow rates of approximately 23.4, 17.4, and 13.2 mL/min for 25-G, 27-G and 30-G needles, respectively) (29) in an *ex vivo* setting. However, in an *in vivo* study (30), only needle gauge significantly influenced the flow rate, with lower flow rates reported than the previous study (ie, 16.2, 11.4, and 5.4 mL/min for 26-G, 27-G, and 30-G needles, respectively). Nevertheless, achieving high flow rates using small-diameter needles requires high pressures to be exerted on the plunger (29), which can be difficult to maintain for prolonged periods.

Moreover, during negative pressure irrigation, the clinician should ensure that the irrigant is present in the reservoir to maintain a constant flow. According to the negative pressure irrigation concept (16), the pressure gradient between the atmospheric pressure and the pressure generated at the apical third of the canal would influence the net force affecting irrigant flow. By altering the factors influencing the pressure gradient, a greater net force could be achieved, thus further increasing the volume of irrigant reaching the apical region of the root canal. This concept could be explored in future studies.

In the present study, the difference in irrigant volume collected could be explained by the design of the needles (Fig. 1). EndoVac consists of a microcannula with an internal and external diameter of 0.2 and 0.32 ($\approx$ 30 G) mm, respectively. The closed-ended tip of the microcannula of the EndoVac presents an array of twelve 0.1-mm-diameter holes, which would mean that the total area through which the irrigant must go through to enter the lumen is approximately 0.094 mm^2. Furthermore, some holes could easily get clogged with debris, thus reducing the total area and differential pressure achieved. On the other hand, the INP needle is 32-mm long with an external and internal diameter of 0.65 and 0.50 mm, respectively. The open tip of the INP needle has an internal and external diameter of 0.25 and 0.36 mm ($\approx$ 28 G), respectively. The inner diameter should allow a high volumetric flow rate and the outer diameter placement at 2 mm from the working length when the canal is enlarged to at least #40.04 taper. The tip of the INP needle has an area of approximately 0.053 mm^2 (0.21-mm internal diameter). However, more importantly, as reflected by the results, a greater pressure differential can be achieved by the INP needle, which could be explained by the needle lumen.

When placed at an appropriate position (16–18), negative pressure irrigation achieves irrigant penetration to the working length. This is clinically relevant because this would allow frequent replenishment of the irrigating solution at the most apical levels, which is recommended to improve the effectiveness of root canal irrigation (9, 13, 14). Replenishment of the irrigating solution has been shown to enhance the reaction rate of NaOCl (31) and increase canal cleanliness (13). However, no measurable turbulence and low shear wall stresses were observed using negative pressure irrigation (32). The additional use of ultrasonically assisted irrigation to clean areas such as isthmi and fins is recommended (19).

Comparison of the results with previous studies considering the same dependent variable (volume collected) is difficult because of the following differences in methodologies: the flow rate of delivery was 7 mL/min (24), 4 mL/min (16), or not reported (25, 26); the use of contrast solution with acrylic training replicas (16); single-canaled human teeth (24, 25) or replicas (16); and preparation sizes. To the authors' knowledge, the present study is the first to compare the influence of the flow rate of irrigant delivered on irrigant volume collected at the working length between different negative pressure devices.

Conclusion

An increase of the flow rate of irrigant delivery increases the volume of irrigant collection by negative pressure systems. The INP needle collected a greater volume of irrigant from the apical third regardless of the flow rate.

Acknowledgments

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

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