

# Effect of Apical Preparation Size and Preparation Taper on Irrigant Volume Delivered by Using Negative Pressure Irrigation System

Matthew Brunson, DDS, MsD,\* Carlos Heilborn, DDS,\*<sup>†</sup> D. James Johnson, DDS, MS,\* and Nestor Cohenca, DDS\*

## Abstract

**Introduction:** The purpose of this investigation was to determine the effect that apical preparation size and preparation taper had on the volume of irrigant delivered to the working length of a root canal preparation in a clinically relevant amount of time. **Methods:** Forty intact human single-rooted teeth were randomly distributed into 2 separate phases. The first phase aimed to determine the smaller apical size that will allow more volume of irrigant at working length. All samples had the same taper and were sequentially instrumented to sizes of 30.06, 35.06, 40.06, and 45.06. The second phase aimed to determine the taper that will allow more volume of irrigant at working length. Teeth were sequentially instrumented to 40.02, 40.04, 40.06, and 40.08. All samples were irrigated by using the micro-cannula, and the volume of sodium hypochlorite suctioned at working length under negative pressure was measured during a period of 30 seconds by using a custom recovery device. **Results:** An increase in size from ISO #35 to ISO #40 resulted in a percentage gain of approximately 44% in mean irrigant volume, whereas an increase in size from ISO #40 to ISO #45 resulted in a percentage gain of approximately 4%. An increase in taper from 0.02 through 0.08 resulted in percentage gains of approximately 74%, 5.4%, and 2.4% increase, respectively. **Conclusions:** The data demonstrated that an increase in apical preparation size and taper resulted in a statistically significant increase in the volume of irrigant. In addition, an apical enlargement to ISO #40 with a 0.04 taper will allow for tooth structure preservation and maximum volume of irrigation at the apical third when using the apical negative pressure irrigation system. (*J Endod* 2010; **■**:1–4)

## Key Words

Apical negative pressure irrigation, apical preparation, taper, volume

The role of microorganisms in the pathogenesis of endodontic infections has been well-established (1). These microorganisms and the by-products they produce cause inflammation and bone resorption (2), and there is a clear correlation between periradicular healing and presence of bacteria in the root canal system before filling (3–5). Mechanical instrumentation alone is ineffective at completely removing residual bacteria and necrotic debris (6). Therefore, thorough cleaning and disinfection of the root canal system are essential for the success of nonsurgical root canal therapy.

Historically, irrigation has been achieved by using a positive pressure technique whereby irrigant is expressed under positive pressure into the root canal system. However, the effectiveness and safety in delivering the irrigant have been questioned (7–9). Recently, the use of negative pressure irrigation techniques has been reported (9) to be superior to positive pressure irrigation. Negative pressure irrigation systems have been shown to deliver irrigant to the apical portions of the root canal system in a safe and effective manner (9–11). It has also been suggested that negative pressure irrigation achieves better microbial control than traditional irrigation delivery systems, regardless of the amount of preparation taper (12).

EndoVac (Discus Dental, Culver City, CA) is a commercially available negative pressure irrigation system that combines a master delivery tip that delivers irrigant to the access cavity while drawing irrigant into the canal space by using macro- and micro-cannulas to clean and disinfect the canal system.

Whereas the volume of irrigant has been shown to be directly related to effectiveness of disinfection and root canal cleanliness when using traditional irrigation techniques (13), there is little evidence demonstrating the real volume of irrigant that can be delivered when using both positive and negative pressure. Even though the irrigant expressed through a positive pressure irrigation syringe system reaches the tip of the irrigation needle, it is difficult to measure the volume of irrigant being expressed because the rate/pressure of expression varies among practitioners. Moreover, it is difficult to determine whether that irrigant is actually reaching the apical third of the prepared canal (10). Nielsen and Baumgartner (9) reported the volume of irrigant delivered by the master delivery tip of the negative pressure irrigation system, but they did not measure the volume being suctioned back by the cannula within the canal. It is clinically important to know the volume of irrigant reaching the working length and the effect that preparation size and taper have on these volumes. The purpose of this investigation was to determine the effect that apical preparation size and preparation taper have on the volume of irrigant delivered to the working length of a root canal preparation by using negative pressure irrigation technique.

From the \*Department of Endodontics, School of Dentistry, University of Washington, Seattle, Washington; and <sup>†</sup>Department of Endodontics, University of Pacifico, Asunción, Paraguay.

Address requests for reprints to Dr Nestor Cohenca, Department of Endodontics, University of Washington, POB 357448, Seattle, WA 98195-7448. E-mail address: [cohenca@u.washington.edu](mailto:cohenca@u.washington.edu).

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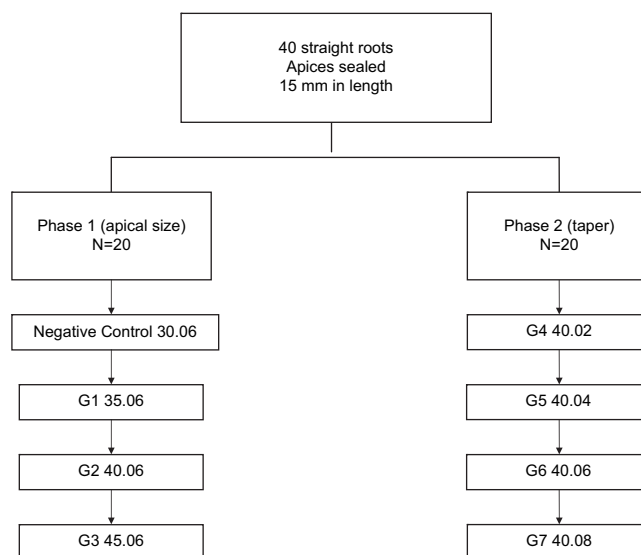
## Materials and Methods

Forty intact human single-rooted teeth (incisors and canines) were collected and stored in sterile saline before the investigation. Inclusion criteria consisted of single-rooted teeth with no root curvature and a single canal system with an apical constriction smaller than ISO size #30. The teeth were decoronated, leaving root segments of 15 mm in length. Patency with an ISO size #8 and #10 stainless steel K-file was achieved, and the working length was set at 1 mm back from the total root length. To determine the size of the apical constriction, 0.00 taper LSX nickel-titanium (NiTi) rotary instruments were rotated by hand to apically gauge the experimental teeth so that a maximum size 30.00 LSX NiTi rotary file would bind no less than 1 mm from the working length. Apical gauging was determined by using 0.00 taper instruments, assuming that when tapered instruments are used to gauge the apical constriction, the first file to bind does not always accurately determine the true apical diameter of the constriction (14). Root ends of all teeth were dried and sealed with glue to simulate *in vivo* conditions. The teeth were then randomly separated into 2 experimental phases, as described in the methodology flow chart (Fig. 1).

Phase I ( $n = 20$ ) was aimed to determine the smallest apical enlargement that would significantly increase the volume of irrigant at working length. All samples treated and measured had the same taper of 0.06. Accordingly, 20 experimental teeth were instrumented sequentially to preparation sizes of 30.06, 35.06, 40.06, and 45.06 by using K3 (Sybron Dental, Orange, CA) NiTi rotary instruments in a crown-down technique to working length according to manufacturer's instructions. All teeth were irrigated under negative pressure by using the macro-cannula with 1 mL of 6% NaOCl between each instrument. In addition, a stainless steel hand K-file size #10-20 was used between instruments to maintain a glide path to working length and remove apical debris. After each sequential preparation and apical size increase, the canal was irrigated by using the micro-cannula, and the volume of sodium hypochlorite suctioned at working length under negative pressure was measured during a period of 30 seconds. The micro-cannula was left at working length for 30 seconds and not moved up and down every 6 seconds as recommended by the manufacturer. Only the irrigant recovered at working length during this period of time was collected and measured by using a custom recovery device that allowed for all irrigant passing through the micro-cannula to be collected and measured (Fig. 2).

Phase II ( $n = 20$ ) was aimed to determine the smaller taper preparation that will allow more volume of irrigant at working length. From the results of phase I, it was determined that an apical size of ISO size #40 resulted in the largest increase in volume of irrigant to working length (44%) as compared with all other apical preparation sizes. It was therefore determined that an apical size of ISO size #40 would be used as the constant apical size in phase II of the study to determine optimum taper for delivery of irrigant.

The experimental teeth in phase II ( $n = 20$ ) were instrumented sequentially to preparation sizes of 40.02, 40.04, 40.06, and 40.08. Different tapered preparations were shaped by using K3 (Sybron Dental) (40.02, 40.04, 40.06) or Profile GT (40.08) (Tulsa Dental, Tulsa, OK) NiTi rotary instruments in a crown-down technique to working length according to manufacturer's instructions. All teeth were irrigated under negative pressure by using the macro-cannula with 1 mL of 6% NaOCl between each instrument. In addition, a stainless steel hand K-file size #10-20 was used between instruments to maintain a glide path to working length and remove apical debris. After each sequential taper increase, the canal was irrigated by using the micro-cannula, and the volume of sodium hypochlorite suctioned at working



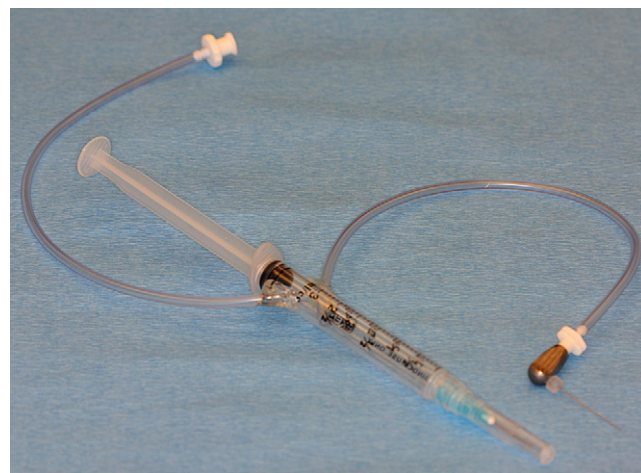
**Figure 1.** Flowchart of methodology.

length under negative pressure was measured during a period of 30 seconds by using the custom recovery device.

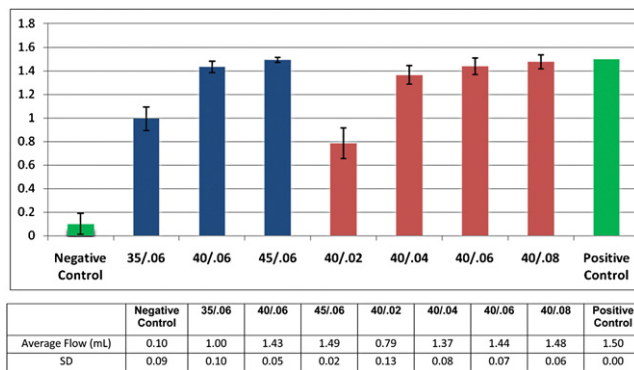
Positive controls for both phases consisted of measuring the maximum volume of 6% NaOCl capable of being suctioned by the EndoVac micro-cannula from a medicinal cup during a period of 30 seconds. Because the apical size of the micro-cannula is 0.32 mm, negative control for both phases was tested by the volume of irrigant aspirated with a preparation size of 30.06. With the micro-cannula wedged into the canal, the space between the cannula and the canal walls is eliminated, thus inhibiting the flow of irrigant to the micro holes. Negative pressure in the high volume suction line was measured to be a constant 7.5 inches/Hg during the period of the study.

## Results

The positive control demonstrated that the maximum volume capable of being aspirated by the EndoVac micro-cannula is 1.5 mL/30 seconds under 7.5 inches/Hg of negative pressure. Negative control



**Figure 2.** Custom recovery device for collection and measurement of volume of irrigant aspirated from the apical third of root canals.



**Figure 3.** Graph demonstrating the volume of irrigant recovered at the apical third by apical size (blue) and taper (red).

resulted in a volume of 0.10 mL/30 seconds, corresponding to 6.6% of the maximum volume aspirated with the positive control.

Results of phase I showed that as the apical preparation size increased from ISO #30.06 to #45.06 with a constant preparation taper of 0.06, the mean irrigant volume increased consistently to a value close to the one obtained with the positive control (Fig. 3). Following the manufacturer's recommendations, an ISO #35 was considered to be the smallest apical size to effectively allow irrigant to pass circumferentially around the 0.32 mm micro-cannula. An increase in size from ISO #35 to ISO #40 resulted in a percentage gain of approximately 44% in mean irrigant volume, whereas an increase in size from ISO #40 to ISO #45 resulted in a percentage gain of approximately 4%. Statistical analysis with the Wilcoxon signed rank test of matched pairs showed significant differences between all pairwise comparisons of the volumes of all apical sizes tested in phase I ( $P < .01$ ).

Results of phase 2 showed that as the preparation taper increased from 0.02 to 0.08 with a constant apical preparation size of ISO #40, the mean irrigant volume also consistently increased to a value near maximum volume of the EndoVac micro-cannula (Fig. 3). An increase in taper from 0.02 through 0.08 resulted in percentage gains of approximately 74%, 5.4%, and 2.4% increase, respectively. Statistical analysis with the Wilcoxon signed rank test showed significant differences between all pairwise comparisons of the volume rate of all tapers tested in phase II ( $P < .01$  for all pairwise comparisons, except  $P < .03$  comparing groups 6 and 7).

Overall, the results showed that as apical preparation size and preparation taper increased from ISO size #35 to #45 and from 0.02 to 0.08, respectively, there was a statistically significant increase in the volume of irrigant through the EndoVac micro-cannula at working length.

## Discussion

Although specific volumes of endodontic irrigant needed to effectively disinfect the root canal system have not been established, it has been shown that the volume of irrigant is directly related to effectiveness of disinfection and root canal cleanliness when using traditional irrigation techniques (13). Although the current study was not aimed to compare the apical volume of irrigant at the apical level between positive and negative pressure, both systems are directly related to the mechanical instrumentation, with larger preparation sizes and taper allowing for more effective irrigation (15, 16).

The results of this study showed that there was a statistically significant increase in irrigant volume when apical preparation size increased from ISO #35 to ISO #45. This increase was expected and might be attributed to the design of the EndoVac micro-cannula and the place-

ment of the 12 suction holes along the side of the last 0.07 mm of the micro-cannula. As the apical size increases, there is a decreased chance of these holes contacting the root canal wall and becoming blocked. The larger area surrounding the micro-cannula also allows for increased volume of irrigant to the micro-cannula tip and a resulting increase in volume.

Although an increase in apical preparation size resulted in a statistically significant increase in irrigant volume flow, clinically the increase associated with larger sizes might be insignificant and the associated additional instrumentation unnecessary. Increasing the apical preparation size from ISO #35 to ISO #40 resulted in an increase in mean irrigant volume of approximately 44%, whereas an increase in apical preparation size from ISO #40 to ISO #45 resulted in an increase in mean irrigant volume of approximately 4%. Although statistically this was a significant increase, clinically the smaller increase might not be warranted because this small increase in volume might become irrelevant during the period of time of patient's treatment. In addition, increasing the apical preparation size might be difficult or even unfeasible in thin and curved roots and lead to transportation of the canal system and possibly perforation of the root.

Similarly, an increase in preparation taper was expected to increase mean irrigant volume. Increasing the preparation taper sequentially from 0.02 through 0.08 resulted in volume percentage gains of approximately 74% from 40.02 to 40.04, 5.4% from 40.04 to 40.06, and 2.4% from 40.06 to 40.08. All groups were statistically significant from each other, although the percentage increase of 74% from the 40.02 to 40.04 taper provided 14 times more volume than the ones achieved with the subsequent increase to 40.06 and 40.08 (5.4% and 2.4%, respectively). This difference is clinically significant and demonstrates that larger preparation tapers might be unnecessary and could potentially lead to weakening of the tooth/root structure, especially at the cervical area (17).

Although no consensus exists regarding the minimum apical preparation size or taper, instrumentation to size ISO #35 or #40 results in clinically adequate irrigant volume amounts for both positive and negative pressure systems. Although larger preparation tapers did allow for increased volumes of irrigant to reach the micro-cannula at working length, 0.04 taper should be considered adequate for effective irrigant volume when using the EndoVac irrigation system. Our ultimate goal should be to preserve as much tooth structure as possible without compromising disinfection and eradication of bacteria from the root canal system. This means enlarging the canal to the smallest size and taper possible that will still allow for sufficient volume of irrigant. Under the conditions of this study, root canal preparation to ISO #40 with a 0.04 taper seems to maintain a good balance of tooth structure preservation and adequate volume of irrigation at the apical third when using the apical negative pressure irrigation system.

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