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Apical Pressure and Extrusion Generated by Various Endodontic Irrigation Delivery Systems

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Abstract

Irrigant extrusion outside of root canals may occur when excessive apical fluid pressures are produced. Currently, no studies have reported the apical pressure produced by the TruNatomy irrigation needle (TNI). The aim of this study was to investigate the relative apical pressure and extrusion produced by the TNI and other irrigation delivery method and adjuncts. A polycarbonate root canal model was instrumented to an ISO #40 with 0.04 taper. Irrigant was delivered at a rate of 2mL/min for 1 minute with side-vented needle irrigation (SNI), TNI, and the EndoVac master delivery tip (MDT). The following irrigation adjuncts were activated while delivering irrigant into the model: EndoActivator (EA), passive ultrasonic irrigation (PUI), EndoVac micro-cannula (EV), and the XP-3D Finisher (XPF). Apical pressure was measured by a manometer attached to the model, and the amount of apical irrigant extrusion was measured as a function of mass. The TNI demonstrated a significantly higher mean pressure (15.8 mm Hg) and extrusion compared to other irrigation delivery methods and adjuncts, ($p < 0.05$). SNI produced significantly higher pressure (8.47 mm Hg) and extrusion compared to all other irrigation delivery systems and adjuncts other than TNI, ($p < 0.05$). There was no statistically significant difference among MDT, EA, PUI, XP3D and EV. The TNI produced a greater amount of apical pressure and extruded more amount irrigant than SNI, MDT, EA, PUI, XP3D, and EV.

Introduction

Irrigation is an integral part of endodontic treatment and has been widely used in conjunction with mechanical instrumentation. The goal of instrumentation and irrigation is to remove and eradicate microorganisms and to remove all organic tissue from the root canal system. Mechanical instrumentation alone cannot achieve this goal because instruments cannot contact all surfaces in the root canal system (1,2). Irrigant, on the other hand, can flow into the isthmus and ramification of root canal system to enhance cleaning and disinfection. Maximum elimination of bacteria, antigens, and tissue within the root canal system is accomplished through the combination of instrumentation and irrigation. An effective irrigation protocol eliminates microorganisms and dissolves tissue. Irrigation is most often performed with the use of sodium hypochlorite, and many endodontists will utilize an irrigation adjunct during their treatment (3).

The various magnitude of apical pressure are employeed when the irrigants are delivered to the root canal system. Irrigants is an effective antimicrobial when they are in contact with bacteria, and it would be ideal for irrigants to be delivered to all root canals surfaces, including apical constrictions, to prevent blockage of dental debris. It is also vital to not extrude irrigants into the soft tissues periapically. High apical pressure may increase the risk of extruding irrigants, but it is not known at what magnitude of positive pressure hypochlorite accidents amy occur. One author recommended that the apical pressure above the central venous pressure of 5.88 mm Hg may increase the chance of extruding irrigants into the surrounding tissues (4).

Irrigation solution may be administered via manual side-vented needle irrigation (SNI) delivery which can transport irrigant up to 1mm beyond the needle tip (5). SNI has been found to be most effective in disinfecting the mid-root region of the canal, possibly due to an increase in fluid velocity as the irrigant leaves the needle and flows coronally (6). As the velocity decreases near the coronal portion of the canal, the efficiency of dentinal tubule penetration also decreases.

TruNatomy™ irrigation needle (TIN) (Dentsply, Johnson City, TN) is a size 30 gauge non-metallic side-vented needle irrigation delivery system. The TIN is made with polypropylene to curve and flex easily to follow the root canal anatomy. It has been recently released in the market and is part of the TruNatomy root canal system, including glide path and shaping files, absorbent points, and conform fit gutta-percha obturation points.

Passive ultrasonic irrigation (PUI) can be an essential adjunct for cleaning the root canal system, having been shown to remove more organic tissue and debris from the canal than SNI alone (7). After mechanical preparation, the canal is filled with an irrigant solution, and a tip is inserted and activated with ultrasonic energy. PUI generates acoustic streaming and/or cavitation within the irrigant (8).

The EndoActivator® (EA) (Dentsply, Johnson City, TN) is a handheld sonic activation system with disposable polymer activator tips that do not cut dentin (9) . The velocity produced by EA has been reported to be below the threshold required to create cavitation ((10)Jiang *et al.* 2010), which may be why one study showed no difference in calcium hydroxide removal when compared with SNI (11).

The EndoVac® (EV) (Kerr, Glendora, CA) produces negative apical pressure during irrigation within the canal (4). The EV attaches to the high volume evacuator and is used in conjunction with a Master Delivery Tip (MDT) that delivers and evacuates irrigant utilizing a macrocannula and a microcannula corresponding to a size 55 file and a 32 file, respectively.

The XP-3D Finisher® (XP3D) (Brasseler, Savannah, GA), also known as the XP-Endo Finisher, is a size 25 or 30 non-tapered instrument reported to enhance root canal cleaning and disinfection. Unlike the similarly-named XP-3D Shaper® (Brasseler, Savannah, GA), which is used to shape the canal throughout the procedure, the XP3D is recommended by the manufacturer as the final step in the disinfection protocol to enhance irrigation and debride the canal without affecting the canal shape similar to other irrigation adjuncts. The XP3D is made with a NiTi MaxWire® alloy that is straight in its martensitic phase at a temperature below 30°C while assuming a spoon shape in the austenitic phase at body temperature. The shape change of the instrument occurs in the last 10 mm, and it can achieve a diameter of three mm when rotating. The instrument expands and contracts within the canal as it moves. The XP3D creates irrigant turbulence and scrapes canal walls. While one study demonstrated cleaner canals with the XP3D compared to PUI and EA, the differences between XP3D and PUI were not statistically significant (12). In another study, canal disinfection with the XP3D was shown to be more efficient than other irrigation systems (SNI, EA, and Photon-Induced Photoacoustic Streaming) in eliminating bacteria from the main root canal space up to 50 µm deep into dentinal tubules (6,13).

Although the effects of sodium hypochlorite are meant to be enhanced by irrigation adjuncts, its impact outside of the tooth, as in the case of periapical extrusion, can include severe pain, swelling, and nerve damage (14). The method of irrigation delivery and agitation can have an impact on safety and efficacy. The potential for complications from irrigant extrusion increases as the apical pressures produced by the different irrigation adjuncts and protocols increase. Currently, there are no studies reporting the apical fluid pressure created by the TIN. The purpose of this study was to ascertain the safety of the TIN and other various irrigation systems by measuring the apical pressure and the apical extrusion of the irrigant.

Materials and Methods

A previously described model for testing apical pressure and apical extrusion was modified for this study (4,15). In order to standardize all tested groups, a simulated 17-mm polycarbonate root canal model representing a size 40/.04 preparation was fabricated with a communication channel opposite the canal (Figure 1). The length and taper were verified by placing a 40/.04 Vortex Blue® (Dentsply, Johnson City, TN) rotary file to length. The irrigation flow rate was controlled with a syringe pump set to 2 mL/min in order to reproduce a consistent delivery and evacuation of the irrigant.

TNI, SNI, EA, PUI, EV, and the XP3D were performed by the same operator using water for all cycles. For the TNI and SNI experimental groups, irrigant was directly delivered to the root canal model. For the other experimental groups, irrigant was delivered by EndoVac Master Delivery Tips (MDT) ((Kerr, Glendora, CA). Test cycles were 60 seconds, and each irrigation adjunct was tested for 15 cycles. The following protocols, utilizing manufacturer's instructions when applicable, were followed:

TNI Group: SNI was tested using continuous, short (1-3 mm) push-pull strokes 1 mm from working length.

SNI Group: SNI was tested using continuous, short (1-3 mm) push-pull strokes 1 mm from working length with a 30-gauge side-vented needle (Max-I-Probe®, Dentsply, Johnson City, TN).

EA Group: EA was tested using continuous, short (1-3 mm) push-pull strokes 1 mm from working length with a size 25/0.04 polymer tip activated at 10,000 cycles per minute.

PUI Group: PUI was tested by placing the size 25/0.02 non-cutting ultrasonic tip (IrriSafe™, Satelec, Merignac, France) 1 mm from working length at a frequency of 35 kHz.

Micro EV Group: EV with microcannula was tested by activating the tip at working length.

XP3D Group: XP3D was tested using continuous, long (7-8 mm) push-pull strokes to working length at 1000 rpm and 1 Ncm torque.

For the first part of the study, the communication channel was threaded, and a barbed tubing connector was attached for joining a digital manometer (Figure 2-3) (HHP91, Omega, Norwalk, CT) to the canal model. The manometer measured the pressure change apical to the canal. To ensure accurate pressure readings, prior to each test, the tubing between the manometer and the model was disconnected on the manometer. Air was propelled through the tubing to clear the line of the residual irrigant. The tubing was then reattached to the manometer. After reattachment, the manometer was calibrated to 0 mm Hg and set to record pressure.

For the second part of the study, a root canal model was mounted in the mating lid of a removable 120-ml collection vial (Figure 2-5). The mating lid was open to the atmosphere to equalize the pressure. The collection vile was emptied and weighed on a digital scale (Figure 2-6) (Fisher Science Education, Hanover Park, IL) and then securely screwed into the model/lid assembly. Extruded amount of irrigant was collected in a plastic container (Figure 2-5), and the weight of irrigant was measured and converted to volume.

Apical pressure and extruded irrigant volumes were analyzed by ANOVA, followed by Tukey's multiple comparisons test. A P value of < 0.01 was considered statistically significant in multiple comparisons.

Results

Average apical pressures in each group with SEM are shown in figure 2. Of the tested groups, TIN produced the greatest average pressure (15.800 mm Hg). SNI produced the second greatest average pressure (8.466 mm Hg) followed by PUI, EA, XP3D and MDT. The Micro EV was the only adjunct to produce negative pressure (-3.784 mm Hg). Post-hoc analysis revealed that all group comparisons for apical pressure are statistically significant ($P < 0.01$), with the exception of one comparison. Apical pressures in EA and XP3D groups are not significantly different ($P > 0.99$).

The average amount of extruded irrigants with SEM are shown in figure 3. Of the test groups, TIN extruded the greatest amount (84.54%), whileSNI extruded the second greatest amount (64.53%). Extruded amounts of these two groups are significantly different from each other and from all other groups ($P < 0.01$). There was no statistically significant difference among the amount of extruded irrigants produced by EA, PUI, XP3D, and EV ($P > 0.90$).

Discussion

While an apical pressure has not been definitively established as the threshold above which sodium hypochlorite accidents occur, it has been suggested that pressure within the canal exceeding central venous pressure (CVP) may extrude fluid (16). TIN and SNI produced an average apical pressure that exceeded CVP(17). There are many possible variables that could influence the incidence of apical extrusion of irrigants. In our pilot study, the length of the tubing (Figure 2-2) from the root canal model and monometer affected the pressure. We selected 130 cm because it was the shortest tubing length to set the manometer flat on a hard surface. Studies have shown that apical pressure is affected by the flow rate of irrigant delivery (4,18). The final preparation size of the canal can also affect the apical pressure produced during irrigation. Park *et al.* found that SNI had an average apical pressure of 1 mm Hg at a 2 mL/min flow rate in a canal size of 35/.06 (18). Since this study utilized a simulated canal model, it is unknown what effect the canal surface may have on apical pressures. It is also important to note that in a clinical scenario, the irrigation adjuncts in this study are utilized after cleaning and shaping the canal, which usually includes a component of SNI.

The second part of the study correlated with studies by Desai & Himel (15). The percentage of the extruded amount of irrigant is more than likely much higher than the extrusion during root canal treatment. The root canal model did not have minor apical constrictions and was open to atmospheric pressure. This setting was attempted to mimic cases where the root apex is communicating with the maxillary sinus. Once the surface tension was lost and due to the cohesion, extrusion of water was accelerated once it started to flow outside of the tooth.

The EV has been shown to produce a negative apical pressure of about -35 mm Hg at most irrigation flow rates (4). The current study found an average negative pressure of -3.0 mm Hg with the microcannula. This difference in pressures may be a result of different methods of canal preparation and irrigant delivery.

Irrigant movement produced by the XP3D likely has a rotational direction, but the positive apical pressure recorded in this study indicates that a defined vortex is not created. This finding could be due to the long up and down strokes of the file, which may keep the fluid primarily in the area of instrument rotation rather than drawing the fluid in a coronal direction.

Both part one and part two of the study show similar trends (Figure 3 and 4) where TIN produced the highest apical pressure and extrusion followed by SNI. It is challenging to conclude that the higher apical pressure and extrusion created by TIN is clinically significant. More studies should be conducted to compare safety and effectiveness of TIN compared to SNI and other various adjuncts. Also, it is essential to note that TIN produced relatively higher pressure and extrusion compared to SNI and other various adjuncts in our study under the same conditions.

Conclusions

In our study, the use of the TIN resulted in significantly higher apical pressure and higher amounts of extrusion than other irrigant delivery systems, implying that it is more likely to result in significant extrusion of irrigant beyond the apex of the tooth. In conclusion, regarding apical pressure and potential irrigant extrusion, this study found that the apical pressure produced by the TIN has a lower safety profile and should be used with caution.

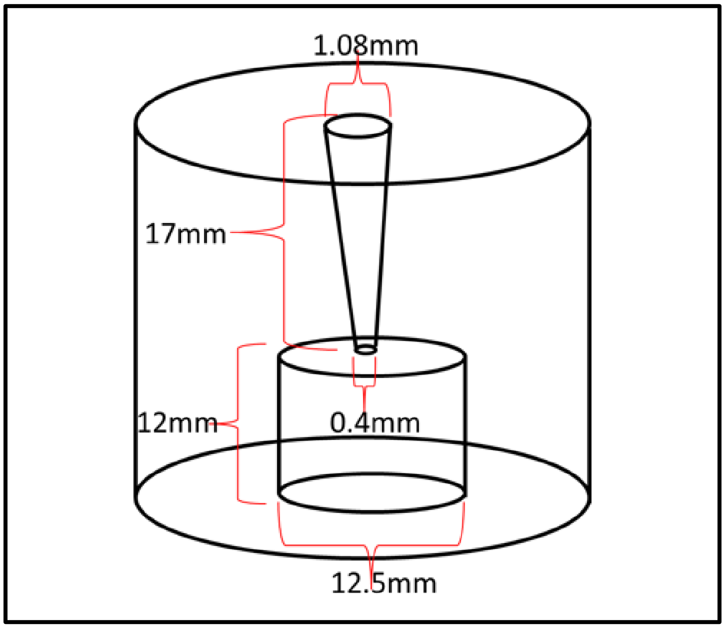


Figure 1

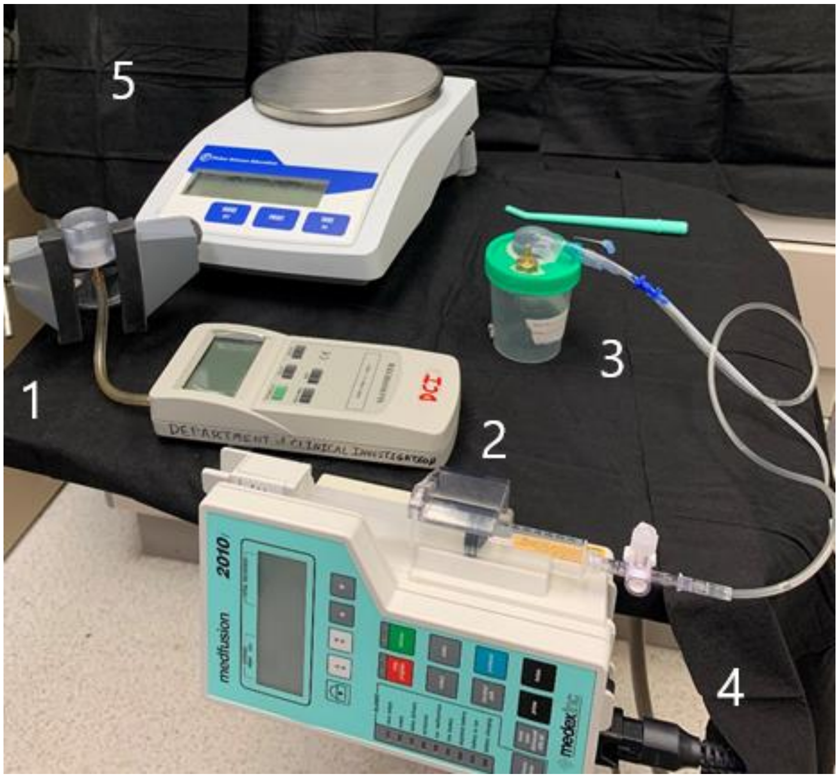


Figure 2

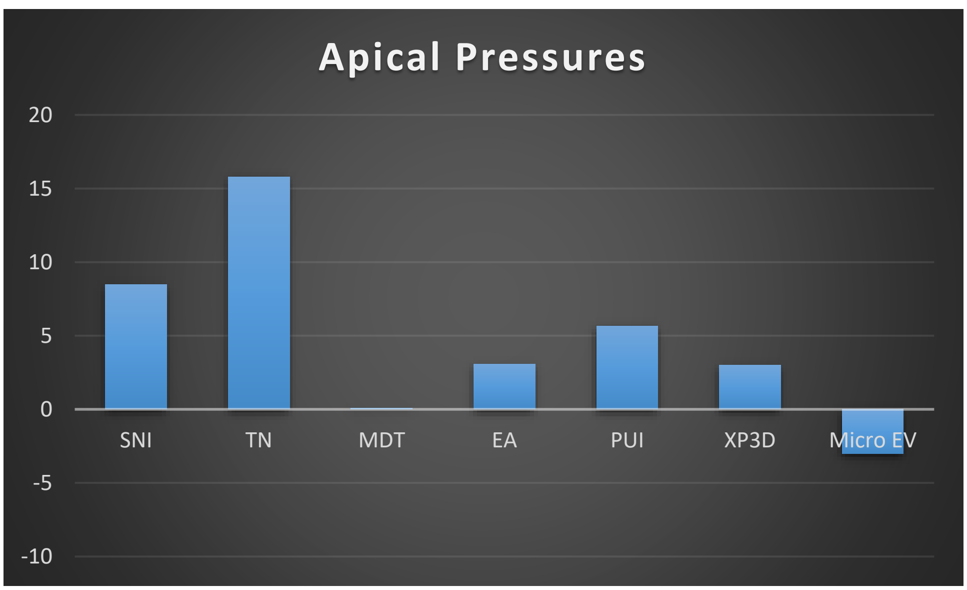
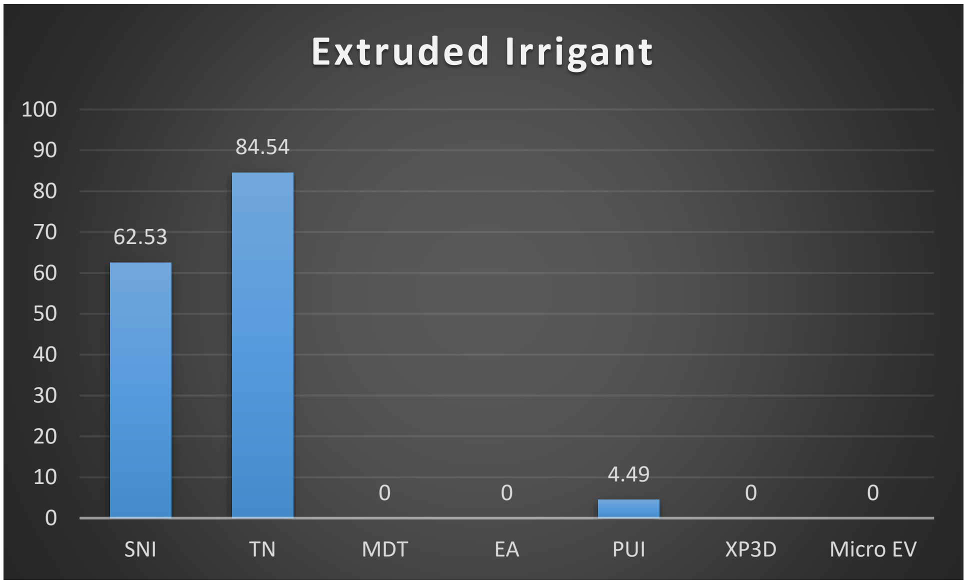


Figure 3



Extruded Irrigant
100
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60
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30
20
10
0
62.53
84.54
0
0
4.49
0
0
SNI
TN
MDT
EA
PUI
XP3D
Micro EV

Figure 4

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