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THESIS APPROVAL PAGE FOR MASTER OF SCIENCE IN ORAL BIOLOGY

Title of Thesis: Apical Pressures Generated by the XP-3D Finisher and Irrigation Adjuncts

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THESIS/MANUSCRIPT APPROVED: DATE:

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Apical Pressures Generated by the XP-3D Finisher and Irrigation Adjuncts

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Abstract

Introduction: Irrigant extrusion outside of root canals can occur when the central venous pressure (CVP) of 5.88 mm Hg, is exceeded. Extrusion of the common irrigant, sodium hypochlorite, can cause severe pain, swelling, and nerve damage. The XP-3D Finisher (XP3D), a highly flexible adjunct to irrigation, can expand to contact canal walls while rotating at speeds of 1000 RPM. Currently no studies have reported the apical fluid pressure produced by the XP3D. **Methods:** Apical pressures were measured by manometer attached to a polycarbonate root canal model instrumented to an ISO #40 with 0.04 taper. Canals were flooded prior to activation of the following irrigation adjuncts: EndoActivator (EA), passive ultrasonic irrigation (PUI), and the XP3D. The EndoVac and side-vented needle irrigation (SNI) produce negative and positive apical pressures, respectively, and were used for comparison. **Results:** The XP3D created positive pressure (1.52 mm Hg) similar to EA and PUI but significantly lower than SNI (4.022 mm Hg), which did not surpass the CVP threshold. Pressure produced by the XP3D was the lowest of the adjuncts that produced positive pressure. The EndoVac was the only adjunct that produced negative pressure. **Conclusion:** The XP3D produced an apical pressure below CVP, reducing the chance of irrigant extrusion. No significant difference was observed when compared to the EA or PUI.

Introduction

The goal of chemomechanical cleansing of the root canal system is to eliminate or reduce bacteria to levels that permit healing in the periradicular tissues. Mechanical debridement removes layers of infected dentin, but not all dentin within the system can be contacted due to the complex nature of canal anatomy compared to file shape (1, 2). Elimination of bacteria, antigens, and tissue within the root canal system is accomplished through the combination of instrumentation and irrigation. An effective irrigant eliminates microorganisms and dissolves tissue. Irrigation is most often accomplished with the use of sodium hypochlorite (3,4). Often, an adjunct is utilized to improve the effectiveness of endodontic irrigants.

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). A study by Azim et al. (6) reports SNI had its best disinfection mid-root which may be from an increase in fluid velocity as the irrigant leaves the needle and flows coronally (5). As the velocity decreases near the coronal portion of the canal, the efficiency of dentinal tubule penetration also decreases.

Passive ultrasonic irrigation (PUI) can be an important adjunct for cleaning the root canal system because it has 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).

EndoActivator® (EA) (Dentsply, Johnson City, TN) is a handheld sonic activation system with disposable polymer activator tips that do not cut dentin (9). The EA is suggested for irrigant agitation after canals have been shaped and flushed with a manual syringe and an irrigation needle (10). The velocity produced by EA has been reported to be below the threshold required to create cavitation (11) which may be why a study by Keskin (12) showed no difference in calcium hydroxide removal when compared with SNI.

The EndoVac® (EV) (Kerr, Glendora, CA) produces negative apical pressure as was confirmed by Khan et al (13). The EV attaches to the high volume evacuator and uses a Master Delivery Tip that delivers and evacuates irrigant utilizing a macrocannula and a microcannula corresponding to a size 55 file and a 32 file, respectively (14).

The XP-3D Finisher® (XP3D) (Brasseler, Savannah, GA), also known as the XP-Endo Finisher, is a size 25 non-tapered instrument reported to enhance root canal cleaning and disinfection. 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. Shape change occurs in the last 10 mm and achieves a diameter of 3mm when rotating. The instrument expands and contracts within the canal as it moves. The XP3D scrapes canal walls and causes irrigant turbulence. The XP3D is recommended as the final step in the disinfection protocol (15). The XP3D has been shown to preserve root canal anatomy while cleaning irregularities because of its increased flexibility and ability to expand (16). While one study demonstrated cleaner canals with the XP3D compared to PUI and EA, the differences between XP3D and PUI were not statistically significant (17). 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, 18).

Although the effects of sodium hypochlorite are meant to be enhanced by irrigation adjuncts, its effects outside of the tooth, as in the case of periapical extrusion, can include severe pain, swelling, and nerve damage (19). The method of irrigation delivery and agitation can have an impact on safety and efficiency. Pressure within the canal exceeding the 5.88 mm Hg central venous pressure (CVP) may extrude fluid (20, 21). The potential for complications from irrigant extrusion increases when apical pressures created by irrigation of the root canal system exceed CVP. Currently, there are no studies reporting the apical fluid pressure produced by the XP3D. The purpose of this study was to ascertain the apical pressure produced by the XP3D compared to those generated by other irrigation adjuncts and to determine if these pressures exceed CVP.

Materials and Methods

A model for testing apical pressure previously described by Khan et al. was modified for this study (13). 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 was verified by placing a 40/.04 Vortex Blue® (Dentsply, Johnson City, TN) rotary file to length. The communication channel was threaded and a barbed tubing connector was attached for joining a digital manometer (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 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.

SNI, EA, PUI, EV, and the XP3D were tested by the same operator for all cycles. For the SNI and EV experimental groups, 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. For the other experimental groups, irrigant was placed in the canal prior to activation of the adjunct, and the level of irrigant in the canal was maintained at the appropriate level throughout the test cycle. 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:

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

Group II: 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 (23).

Group III: 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 (24).

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

Group V: EV with macrocannula was tested by activating the tip just short of its binding point within the canal.

Group VI: XP3D was tested using continuous, long (7-8 mm) push-pull strokes to working length at 1000 rpms and 1 Ncm torque (15).

Results

Apical pressures were recorded (Figure 2) and averaged to compare against the 5.88 mm Hg CVP pressure. None of the adjuncts averaged an apical pressure that exceeded CVP although SNI did have one trial in which pressure matched CVP. Of the tested groups, SNI produced the greatest average pressure (4.022 mm Hg). When compared to SNI by t-test statistical analysis, all adjuncts demonstrated significantly lower average pressures ($p<0.001$). Although there were no statistically significant differences among the apical pressures created by the positive pressure-producing adjuncts, the XP3D demonstrated a lower average pressure than EA and PUI. The EV was the only adjunct to produce negative pressure. The microcannula produced an average pressure of -3.874 mm Hg, while the macrocannula produced an average pressure of -175.161 mm Hg.

Discussion

There are many possible variables that could influence the incidence of apical extrusion of irrigants. Studies have shown that apical pressure is affected by irrigant flow rate (13, 25, 26). Although this study showed pressure produced by SNI to be less than or equal to CVP, it is possible to surpass this pressure if flow rates are increased over the 2 ml/min used in this study. According to Conard, apical pressure produced by a 30-G side-vented needle at a depth of 1 mm from the apex produced a mean pressure of 17.1 mm Hg and 26.9 mm Hg at flow rates of 1 and 3 ml/min, respectively. These values are 4-6 times higher than results in the current study. Differences in pressure may be due to the differing sizes of the canal models (45/.02 versus 40/.04) or the pressure-measuring devices (fiber optic transducer vs digital manometer) (25). In the study by Khan et al., SNI produced an average pressure of 11 mm Hg at a 2 mL/min flow rate. At a flow rate of 1 mL/min, they recorded a more comparable SNI pressure (2.6 mm Hg) to the current study (4 mm Hg) (13). Park et al. found that SNI produced an average apical pressure of 1 mm Hg at a 2 mL/min flow rate in a canal size of 35/.06 (26). Boutsioukis et al. took a clinical approach with clinicians using SNI at their regular clinical pressure. In these realistic conditions, an average pressure of 487 mm Hg was produced in size 45/.06 canals (27).

In this study, the apical pressures produced by the EA, PUI, and XP3D were similar to one another and almost four times less than that produced by SNI. In previous studies, PUI was shown to cause irrigant extrusion when placed at the apex or 1 mm from the working length (13, 25). A difference with these studies was the use of continuous irrigation flow between 0.5 and 1 mL/min while the current study had static irrigant within the canal prior to PUI activation.

Although the EndoActivator has been shown to cause extrusion of irrigant, the amount of extrusion was shown to be minimal compared to SNI and PUI (28). The current study found low apical pressure (1.6 mm Hg) produced by the EndoActivator, was not significantly different than pressure produced by PUI (1.8 mm Hg).

Apical fluid pressure of the EV has been shown to produce negative pressure of about -35 mm Hg at most irrigation flow rates (13). The current study found an average negative pressure of -3.9 mm Hg with the microcannula and -186.4 mm Hg with the macrocannula. The high value of the macrocannula may have been due to inadvertent binding of the cannula within the canal.

Irrigant movement produced by the XP-3D Finisher likely has rotational direction, but the positive apical pressure recorded in this study indicates that a defined vortex is not produced. 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 file rotation instead of drawing fluid coronally.

In our study, use of the XP3D resulted in significantly less apical pressure than SNI, which was also below CVP, implying that it is less likely to result in significant extrusion of irrigant beyond the apex of the tooth. Despite this finding, such extrusion may occur if the XP3D is utilized beyond the working length of the root canal. In conclusion, this study found that the apical pressure produced by the XP-3D Finisher will not overcome the body’s CVP, and with regards to apical pressure and potential irrigant extrusion, it has a similar safety profile as PUI and EA when used according to the manufacturer’s directions..

Acknowledgements: The views and opinions expressed are solely those of the authors and do not reflect the official policy or position of the US Army, the Uniformed Services University of the Health Sciences, the Department of Defense, US Government, or Dwight D. Eisenhower Army Medical Center. The authors deny any conflicts of interest related to this study.

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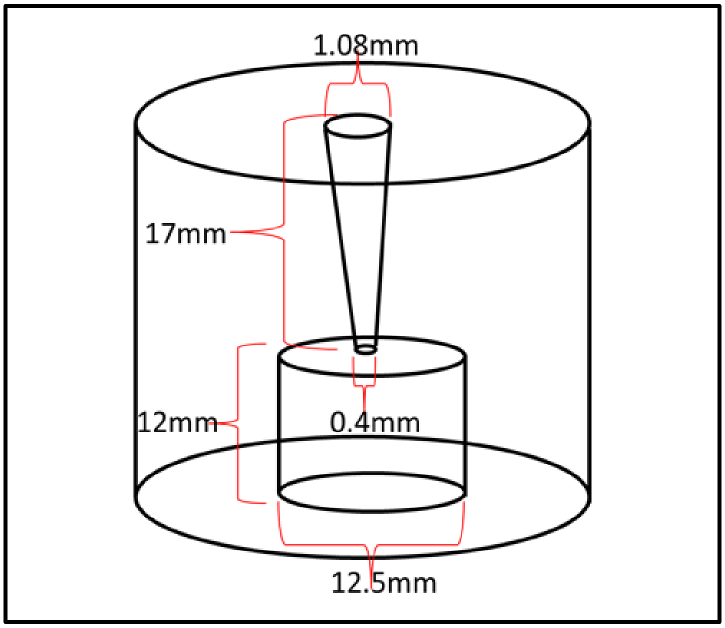

Figure 1. Canal Model Dimensions

Standard Needle Irrigation	4.022
Passive Ultrasonic Irrigation	1.766
EndoActivator	1.618
EndoVac (Microcannula)	-3.874
EndoVac (Macrocannula)	-186.391
XP-3D Finisher	1.52

Table 1. Average Apical Pressures (mm Hg)

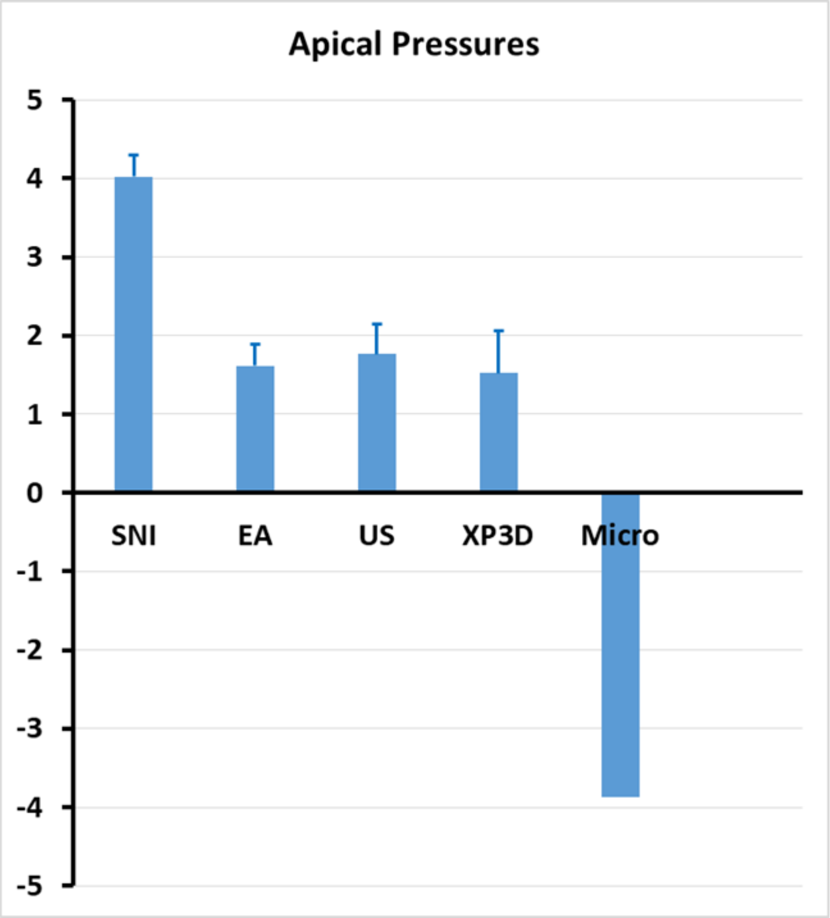

Figure 2. Comparison of Average Apical Pressures