

## Effect of Gravity on Periapical Extrusion of Irrigating Solution With Different Irrigation Protocols in Immature Anterior Teeth

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### ABSTRACT

**Objective:** Periapical extrusion is frequently observed during endodontic therapy. It can lead to acute injury of periapical tissues, resulting in interappointment pain or swelling. The effect is pronounced in teeth with immature teeth which are more susceptible to the extrusion of irrigant. The aim of this study was to evaluate the effect of gravity on apical extrusion of irrigating solution with different irrigation protocols in immature anterior teeth.

**Methods:** An extracted maxillary central incisor was modified to simulate an open apex with an apical diameter of 1.3 mm and parallel canal walls. The tooth was subjected to a cone-beam computed tomographic scan, and the image data set was utilized to prepare 30 resin tooth models with a 3D printer. These resin teeth were used to form an open-ended Myers and Montgomery extrusion models. These were then randomly divided into two groups to simulate their orientation in the jaw during endodontic therapy, i.e., group I (maxillary arch, n=15) models fixed at 45° inclined plane and group II (mandibular arch, n=15) models placed at a plane parallel to the floor. Five models from each group (n=5) were tested by three different irrigation protocols: positive pressure (PP) Irrigation, passive ultrasonic irrigation (PUI), and negative pressure (NP) irrigation. The extruded irrigating solution was collected in glass vials, and the volume was measured.

**Results:** The volume of extruded irrigating solution in groups I and II was compared using Mann–Whitney U-test. The median values for PP, PUI, and NP irrigation protocols were 0.6, 1, and 0 ml and 10, 10, and 0.5 ml for groups I and II, respectively. PP and PUI protocols were associated with significantly less extrusion in group I when compared to group II (P=0.004). There was no statistically significant difference in the volume of irrigating solution extruded in groups I and II (P=0.007) for NP irrigation protocol.

**Conclusion:** Gravitation force has an influence on periapical extrusion of irrigant in immature permanent teeth irrespective of the irrigant system used. NP performed better when compared to PP or PUI irrigation protocol irrespective of the tooth orientation.

**Keywords:** Gravity, immature teeth, irrigant extrusion, negative pressure irrigation, passive ultra sonic irrigation

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### HIGHLIGHTS

- This study evaluated the effect of gravity on periapical extrusion of irrigant in immature teeth.
- All irrigation protocols lead to high amount extrusion of irrigant in the mandibular model compared to the maxillary model
- Negative pressure irrigation is the best irrigation protocol in immature permanent teeth

### INTRODUCTION

The pulp necrosis can occur after traumatic dental injury or bacterial contamination through morphological alteration (palatogingival groove and dens invaginatus and evaginatus) in the tooth structure (1). The stage of root development at the time of pulp necrosis can result in cessation of development of root thickness and length of the root (2). There is no consensus in the literature regarding the mini-

imum apical root end diameter to be classified as open apex with various authors recommending the use of #40–#100 ISO size file to gauge the apex (3). The American Association of Endodontics (AAE) classified the teeth with apical diameter >1.5 mm as cases with high level of difficulty based on case difficulty assessment index, and their management requires specialized endodontic skills (4). Irrespective of the etiology, an immature tooth with wide open apex and thin, fragile dentinal walls obscures the use of conventional root canal techniques. With recommendations of minimal

instrumentation in such teeth, disinfection relies on the action of irrigant and intracanal medicament (5).

Chemical debridement efficacy of an irrigation protocol depends on the root canal anatomy, presence of biofilm and necrotic tissue, type of irrigating solution and method of its delivery inside the root canal. Syringe and needle are the most commonly used irrigation delivery device in endodontics. The type of needle (open or closed-ended) and level of tip placement determines its safety and efficacy (6). Passive ultrasonic irrigation (PUI) has been recommended for the removal of necrotic debris and intracanal medicament to achieve clean disinfected root canals (7). Both these systems are associated with periapical extrusion and can result in postoperative pain or interappointment flare-ups. Furthermore, the damage to stem cells in the periapical region by extruded sodium hypochlorite can have a detrimental effect on regenerative procedures (8). Endovac is a negative pressure irrigation system developed to minimize extrusion. This simultaneous delivery and evacuation system contravenes the vapor-lock effect and facilitates the delivery of solution in the apical third (9).

Extrusion during endodontic irrigation has been studied with both in vitro and in vivo models using various delivery devices and techniques. A majority of in vitro studies are performed on the mandibular model to investigate the extrusion from the root apex. Gravity is a force that influences every object in the universe. Since the chair/patient position differs during endodontic treatment on the maxillary or mandibular teeth, it can be acknowledged that the gravitational force will have different influences on the flow and velocity of irrigant in both the jaws (10). The influence of gravity has not been elucidated on apical extrusion of irrigant in the case of immature permanent teeth. Thus, the aim of the study was to investigate the effect of gravity on apical extrusion of irrigant in the case of immature permanent anterior teeth.

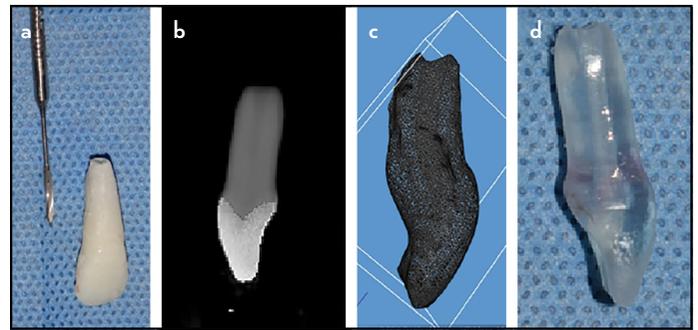
## MATERIALS AND METHODS

### Preparation of resin tooth model

An extracted maxillary central incisor was used for the study. The apical 3 mm of the root was resected. Conventional access opening was made, and Peeso Reamers (size 1–4) were used to prepare a parallel-walled canal space with a constant 1.3 mm diameter to simulate an immature open apex (11). The tooth was mounted on a wax block and subjected to the cone-beam computed tomography (CBCT) scan (i-CAT Imaging Sciences International, Hatfield, PA, USA). The DICOM file of the segmented tooth image was transformed and stored into a stereolithography (STL) format using 3D Slicer software version 4.10.2 (6). This STL file was used to obtain resin tooth replicas using a 3D printer (Fig. 1). A total of 30 resin tooth models with simulated open apex were used in the study.

### Preparation of extrusion model

An open-ended extrusion model was prepared by following the Myers and Montgomery model (12). A glass vial with the rubber lid was taken. A heated instrument was used to make a hole in the rubber lid. The resin tooth model was then inserted in the hole and sealed with the help of modeling wax. A mea-



**Figure 1.** Preparation of resin tooth model. (a) model of immature tooth, (b) CBCT image, (c) STL image, (d) resin tooth model

sured 2-ml Eppendorf tube was used as an irrigant collecting container which was tightly fitted and sealed with the help of modeling wax in the apical portion of resin tooth model. The whole assembly was then inserted into the glass vial. A 23-G needle was inserted into the rubber lid to equalize the pressure inside the vial to atmospheric pressure.

### Preparation of a model for the simulation of maxillary and mandibular arch

For simulating the tooth position in both the arches extra-orally, a custom-made model with a base and arm fixed at 45° inclined plane was made by wooden sticks (Fig. 2). The hole was drilled into the wooden sticks of base and inclined arm to receive the tooth model assembly and simulate the tooth position in mandibular and maxillary arch, respectively.

The samples were then divided randomly into two groups of 15 teeth each based on arch being simulated (Group I: Maxillary Group and Group II: Mandibular Group). The endodontist was asked to perform the irrigation with 10 ml of distilled water in a manner similar to while performing a clinical case using the following three irrigation protocols.

### Positive pressure (PP) Irrigation (n=5)

5-ml syringe with a 27-gauge side-vented needle (SS White, Lakewood, New Jersey, USA) was used. The needle was placed



**Figure 2.** Custom made device to simulate maxillary and mandibular arch

2 mm short of the root end. The canal was irrigated with 10 ml of distilled water with up and down motion of the needle, keeping the maximum needle penetration depth 2 mm short of the root apex with estimated flow rate of 0.062 ml/s.

#### Passive ultrasonic irrigation (PUI) (n=5)

Ultrasonic irrigation was performed with a piezoelectric unit (Satelec Acteon, Merignac, France). The intermittent flush technique was selected due to better control of irrigant flowing in the apical third. The root canal was intermittently flushed with 2 ml of distilled water for 30 seconds with 27-gauge needle placed at 2 mm short of working length. The irrigating solution was activated ultrasonically for 20 seconds using an ISO #20 stainless-steel K-file kept centered and 2 mm short of the root end. The irrigation and activation procedure was repeated, and the tooth received five ultrasonic activations for a total activation time of 100 seconds. A total of 10 ml of distilled water was used for root canal irrigation with the estimated flow rate of 0.066 ml/s.

#### Negative pressure (NP) irrigation (n=5)

Irrigation was performed with EndoVac (Discus Dental, Culver City, CA, USA) delivery/evacuation tip placed above the access opening to deliver 10 ml of distilled water over a period of 2 minutes with an estimated flow rate of 0.083 ml/s. The macro-cannula was placed till the root end and moved up and down within apical 2 mm of root canal space during negative pressure irrigation.

These three irrigation protocols were performed in five resin tooth models each for both groups I and II, and the irrigant extruded periapically was collected. The volume of extruded irrigant was measured by using a calibrated collection vial in milliliters.

## RESULTS

The data were analyzed using SPSS software version 17 (IBM corporation, New York, USA). The median values in groups I (maxillary arch) and II (mandibular arch) were subjected to Mann-Whitney U-test. A significance level was set at a P value < 0.005. The results are illustrated in Table 1. Group II was associated with more irrigant extrusion than group I for all three irrigation protocols. PP and PUI protocols were associated with significantly less extrusion in group I when compared to group II where entire volume (10 ml) of irrigating solution was extruded (P=0.004). For negative pressure irrigation protocol, there was no statistically significant difference in the volume of irrigating solution extruded in groups I and

II (P=0.007). NP performed better than PP and PUI protocols irrespective of the group I or II (Table 1).

## DISCUSSION

Periapical extrusion has been extensively studied and reported in literature in terms of irrigating solution, bacteria, and debris (13). The majority of the studies on extrusion have used permanent teeth with mature apex with limited experiments performed on immature or open apex teeth. Since the flow of irrigant is governed by external forces such as pressure difference, buoyancy, and gravity, the influence of later on the periapical extrusion cannot be ruled out. Currently, limited studies have examined the effects of gravity on extrusion in the tooth with mature apex (10, 14, 15). However, this is the first study to demonstrate the effect of gravity on periapical extrusion of irrigating solution in immature anterior teeth.

Varieties of irrigation and agitation systems have been developed to improve the disinfection. Nevertheless, some periapical extrusion may be observed regardless of the irrigation system or technique used, when the root canal is prepared up to apical constriction, and apical patency is preserved (16). The absence of apical constriction provides the irrigating solution and unhindered access to periapical tissues in mature teeth. The risk of extrusion further increases in immature teeth with divergent or parallel root canals with the absence of apical constriction and wide apical foramen.

A negative pressure irrigation technique is recommended in such teeth to minimize periapical extrusion (9). Results of a recent in vivo study suggest that Er, Cr: YSGG laser-activated or passive ultrasonic irrigation is safe to use in teeth with open apex (17). Since it is difficult to clinically assess and quantify debris or solution extruded, the majority of data is based on ex vivo studies. Different methods have been reported in the literature to quantify the periapical extrusion using linear measurement, volume, weight, and electrolyte concentration (18). The inability to replicate the periapical environment is the biggest limitation of in vitro studies. The floral foam (a dense, porous, sponge like material) has been used in few experiments to simulate the resistance by periapical tissues. However, absorption of fluid by foam repeatedly results in underestimation of extrusion (19). The experimental setup based on Myers and Montgomery model for testing extrusion is widely reported and hence was adopted for the present study. The use of Eppendorf tube allows for better quantification of the extruded material as compared to foam. The effect of closed Vs open system in-vitro models on the efficiency of root canal

**TABLE 1.** Median value of extruded irrigant in different experimental groups

Irrigation protocol	Median (min-max) Groups		P value (Significance level P<0.005)
	I (Maxilla)	II (Mandible)	
Positive pressure Irrigation	0.6 (0.5-1.05) ml	10 (10-10) ml	0.004*
Passive ultrasonic irrigation (PUI)	1 (0.5-1.50) ml	10 (10-10) ml	0.004*
Negative pressure irrigation	0 (0-0.2) ml	0.5 (0.5-1.5) ml	0.007

The level of significance was predetermined as 0.005

irrigation was studied by Tay et al. It was demonstrated that development of vapour-lock in the closed system leads to retention of debris in the apical part of root canal space. In contrast, the open system model allowed fluid exchange and resulted in better cleaning efficacy. This type of model also represents teeth with periapical pathology where bony defects provide space for extrusion (20).

The study based on the computational fluid dynamics (CFD) model revealed that an irrigant extruded from open-ended needle exerts greater mean pressure at root apex as compared to side-vent needle, inserted at the same depth (21). Thus, side-vented needles were used in this study. The depth of needle penetration is an important variable in root canal irrigation. Placement of needle close to the root apex is associated with more extrusion in mature teeth. However, a study investigating the effect of two-needle insertion depth for irrigation extrusion in immature teeth did not find any significant difference between 2 and 4 mm when apical diameter was 1.70 mm (22). It has also been reported that the action of irrigant is limited to 2 mm from the tip of the needle during positive pressure irrigation (23). Therefore, in the present study, the needle was inserted within 2 mm of the working length so as to simulate the clinical scenario. The EndoVac irrigation involves the use of macrocannula in the coronal part followed by microcannula in the narrow apical pulp canal space in teeth with mature apices. However, clogging of side vents is a common problem with microcannula and can hamper its efficacy (24). Insertion of macrocannula up to the root apex is possible in immature teeth and results in lesser extrusion of irrigating solution than microcannula (25). Hence, a modified negative pressure irrigation protocol for immature teeth with the use of macro cannula was utilized for the experiment.

In the present study, NP protocols performed better than PUI and PP, and there was no significant difference between the last two protocols. These results are consistent with the previous studies where EndoVac resulted in less debris or solution extrusion when compared to various manual, sonic, or ultrasonic irrigating or agitation systems (26). Although statistically insignificant, PUI resulted in more extrusion than PP irrigation which is in contrast to other studies that have reported less extrusion with PUI, where no attempt was made to replenish the solution inside canal (27, 28). However, in a clinical scenario, the root canal is irrigated with 2 ml of sodium hypochlorite solution using syringe and needle before ultrasonic activation (24). More extrusion with PUI in this study is in concurrence with the findings of Kartas et al. (29) and can be attributed to flushing of canal with irrigant after each ultrasonic activation cycle.

The volume of irrigating solution extruded in the simulated mandibular jaw was more as compared to maxilla. These are in agreement with a previous study conducted on teeth with mature apices (10, 14). The result revealed the effect of gravity on periapical extrusion of irrigant in open apex tooth model. The negative pressure irrigation protocol was not influenced by the position of teeth in either maxillary or mandibular jaw. This could be due to the placement of macrocannula at the root end and delivery of irrigant from the coronal part. The effect of gravity was more pronounced in positive pressure or

passive ultrasonic irrigation protocols, where a significant reduction of irrigant extrusion was seen in teeth with simulated maxillary jaw position. The interesting finding of the present study is the beneficial effect of gravity on the reduction of periapical extrusion when these irrigation protocols are used in teeth with simulated maxillary jaw positions. CFD-based future studies can be planned to further establish the findings of this study and also to understand irrigation dynamics in immature teeth.

## CONCLUSION

- Negative pressure irrigation resulted in the least extrusion among all the irrigation protocols studied.
- Positive pressure or passive ultrasonic irrigation protocols resulted in less extrusion in immature tooth model oriented to simulate position in maxillary arch as compared to mandibular arch.

## Disclosures

**Conflict of interest:** The authors deny any conflict of interest.

**Ethics Committee Approval:** The ethics committee approval was not needed for the study.

**Peer-review:** Externally peer-reviewed.

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