ORIGINAL ARTICLE

Turk Endod J 2024;9(3):143–148
doi: 10.14744/TEJ.2024.47450

Effect of different irrigation systems and gravity on the amount of apically extruded debris

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Purpose: This study evaluated the impact of different irrigation systems and gravity on debris extrusion during endodontic procedures.

Methods: Sixty extracted human maxillary and mandibular canines meeting specific criteria were divided into groups: Group 1 comprised maxillary canines (n = 30), and Group 2 included mandibular canines (n = 30). Within each group, teeth were further subgrouped based on selected irrigation systems: a) Conventional Needle Irrigation (CNI) (n = 15), and b) Sonic Irrigation (SI) with EDDY (n = 15). Debris extrusion was measured. A two-way ANOVA was performed to assess the effect of irrigation systems and gravity on the amount of extruded debris.

Results: The results indicated measurable apical extrusions of debris. Although the mandibular position caused more debris extrusion compared to the maxillary position, there was no significant difference related to the effect of gravity. Furthermore, within each group, SI with EDDY exhibited slightly more debris extrusion than CNI, but this difference was not statistically significant.

Conclusion: These findings indicate that both the position (mandible and maxilla) and activation effects, either independently or interactively, do not create a statistically significant difference in debris extrusion.

Keywords: Conventional needle irrigation, Debris extrusion, EDDY, Gravity.

Introduction

Chemical debridement is a significant step for thoroughly cleansing and disinfecting the intricate root canal system, which is crucial for successful root canal treatment (RCT) (1,2). The root canal system's complex anatomy, which includes fins, isthmuses, lateral canals, accessory canals, and anastomoses, poses challenges during mechanical instrumentation. These irregularities often result in missed areas that can harbor bacteria and other microorganisms (3). Additionally, the presence of bacterial biofilms, viruses, yeasts, archaea, and the smear layer generated during instrumentation exacerbates the complexity of the chemical debridement process, presenting a significant barrier to achieving thorough disinfection of the root canal system (4). Therefore, the success of chemical debridement hinges greatly on employing suitable delivery systems and activation techniques (5).

While numerous techniques and devices have been intro-

Cite this article as: Harorlı H, Ercan E, Değermenci M, Pektaş ŞN, Er K. Effect of different irrigation systems and gravity on the amount of apically extruded debris. Turk Endod J 2024;9:143-148.

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Submitted: August 26, 2024 Revised: September 26, 2024 Accepted: October 00, 2024 Published: January 07, 2025

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duced to the dental market for this purpose, not all have proven effective in achieving the desired outcome. The syringe and needle are the predominant choices for delivering irrigation in endodontic procedures. Conventional needle irrigation (CNI), which involves using different types of needles attached to a plastic syringe, is often associated with apical positive pressure, and the type of needle (open or closed-ended) and level of tip placement determine its safety and efficacy (6). A sonic-powered irrigation device, EDDY (VDW, Munich, Germany), is propelled by an air scaler operating at approximately 6000 Hz. It incorporates a non-cutting disposable polyamide tip designed to safeguard against the cutting of root canal dentin and produces 3D movement, enabling cavitation and acoustic flow during irrigation (7). Both systems are linked to apical extrusion and can lead to postoperative discomfort between appointments (8).

Gravity influences all objects in the universe. However, most in vitro extrusion studies (9–11) have been conducted using a mandibular position. In endodontic procedures, due to patients being positioned supinely, the influence of gravity on irrigant extrusion towards the apex may be minimal (12). However, the movement of irrigant is controlled by external factors like pressure variations, buoyancy, and gravity, making it impossible to overlook the role of gravity in periapical extrusion.

This study seeks to assess the influence of different irrigation systems and gravity on the amount of extruded debris. The null hypotheses proposed that there would be no significant differences in the amount of debris extruded among the different irrigation systems and that gravity would have no effect on the amount of extruded debris.

Materials and Methods

The manuscript of this laboratory study has been written according to the Preferred Reporting Items for Laboratory Studies in Endodontology (PRILE) 2021 guidelines (13) (Fig. 1).

This study was approved The Clinical Research Ethics Committee of Akdeniz University Faculty of Medicine (TBAEK 147). The sample size calculation was conducted using the G*Power (version 3.1) package program. The minimum number of samples for each group in the 2×2 two-way ANOVA design was 13, with 80% power, 0.40 effect size, and 0.05 alpha value.

Sixty freshly extracted human maxillary and mandibular canines, which had no prior RCTs, immature apex, fractures, root decay, signs of internal/external resorption, or canal calcifications, were checked using visual and x-ray methods. From these, 30 teeth were chosen from each category: Group 1: maxillary canines (n = 30) and Group 2: mandibular canines (n = 30). Following randomization, teeth were subgrouped based on the selected irrigation systems: (a) CNI (n = 15), and (b) Sonic irrigation (SI) (EDDY) (n = 15).

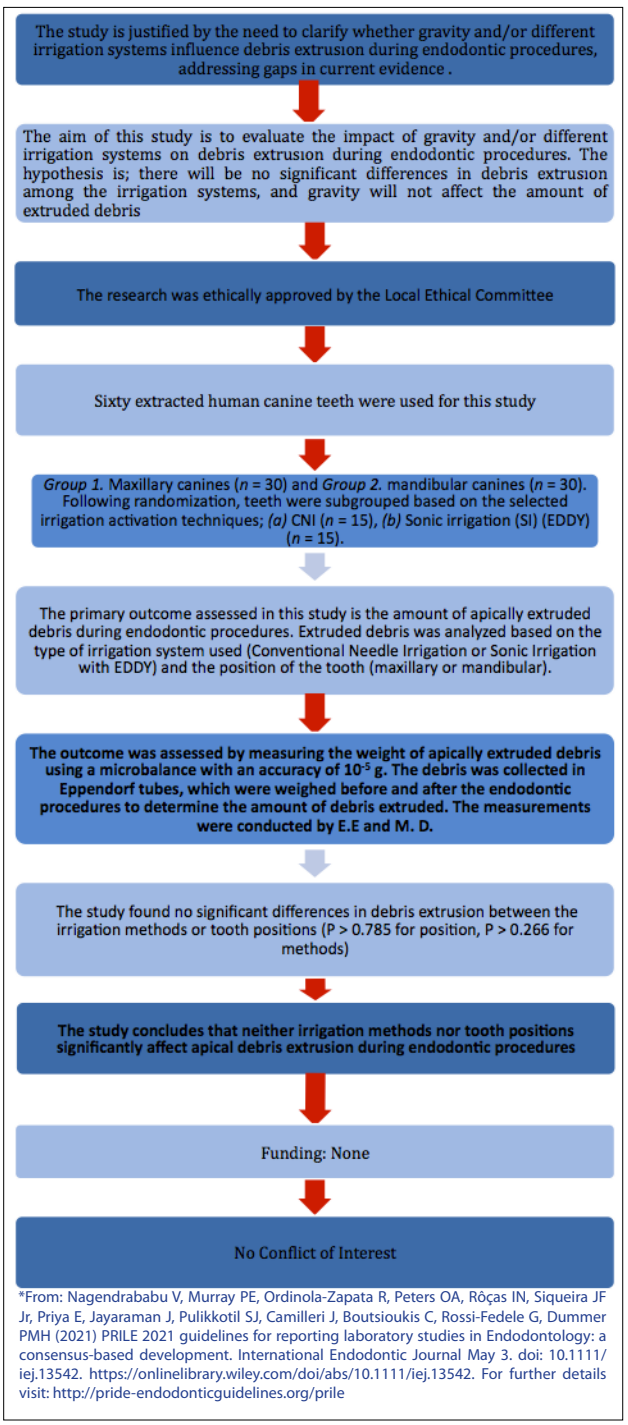


Fig.1. PRILE 2021 flowchart: A visual representation of the study design.



Fig. 2. Maxillary and mandibular positioning of the tooth at the experimental setup.

Crowns were partially removed using a high-speed bur, with all teeth standardized at 24 ± 1 mm, and access cavities were prepared. Working length (WL) was calculated by inserting a 10-K file into the canal until visible at the foramen, subtracting 1 mm. The teeth in which the 15-K file fitted snugly at the WL were selected for the study.

Experimental Model

The Myers and Montgomery method was employed to collect extruded debris using Eppendorf tubes (14). Prior to the irrigation process, three successive measurements were conducted for each tube using a microbalance with an accuracy of 10^-5 g (Shimadzu AP225WD, Kyoto, Japan), and the average values were documented. The teeth were attached to the tubes using Eppendorf stoppers, and a 27-gauge (G) needle was inserted through the stopper to balance the air pressure between the inside and outside of the tube.

An articulator was used to simulate the mandible and maxilla, and sockets for Eppendorf tubes were created in hard plaster, which was then secured to the articulator. The Eppendorf tubes were placed into these sockets. To mimic clinical conditions and hinder the operator from observing debris extrusion during the preparation, rubber dams were individually placed around each tooth.

The mounting plate was positioned according to the patient's head position in the dental chair for the maxillary and mandibular simulation (Fig. 2).

Preparation Procedures and Debris Collection

For tooth preparation, a Dentsply X-Smart Plus endodontic motor (X-Smart Plus; Dentsply Maillefer, Ballaigues, Switzerland) was used with ProTaper Next (PTN; Dentsply Maillefer) X1 (17/0.04), X2 (25/0.06), and X3 (30/0.07) files.

For CNI, the canals were irrigated with 2.5 mL of distilled water after each file and 5 mL of distilled water for the final irrigation, resulting in a total of 10 mL of distilled water. For SI with EDDY, a 28 mm polymer tip was powered by an air scaler handpiece at 1 mm from the WL. Sonic activation was applied in three 20-second cycles between each file and at the end of preparation. A 28-G side-vented needle was used for irrigation in all groups, placed 2 mm short of the WL.

The debris on the surface of each tooth root was carefully washed away using 1 mL of distilled water and collected in Eppendorf tubes. Subsequently, these tubes were placed in an incubator set at 37 °C for 14 days to allow the distilled water to evaporate. After the incubation period, all tubes were weighed three times again, just as before, and the average values were recorded. The weight of the debris was determined by subtracting the preoperative tube weight from the postoperative weight.

The Shapiro-Wilk test did not find enough evidence against a normal distribution. The impact of gravity and different irrigation systems on the amount of debris extruded was tested using two-way ANOVA at a significance level of 0.05, with the analysis done in Jamovi software (Version 2.3.28.0).

Results

Table 1 presents the mean values for the weight of extruded debris for each group. The results indicated that all groups tested caused measurable apical extrusions of debris. Although the mandibular position caused more debris extrusion compared to the maxillary position, there was no significant difference related to the effect of gravity ($P = 0.785$). Furthermore, within each group, SI with EDDY exhibited a greater extrusion of debris when compared to CNI. Nevertheless, it is essential to emphasize that these differences did not attain statistical significance ($P = 0.266$).

Discussion

Several factors influence the extrusion of debris and irrigant during RCTs, including the anatomy of the root canal, the type of files used, the method of preparation, the size of the apical enlargement, the choice of the irrigation solution and technique (15-17). Yusufoğlu et al. (18) stud-

Table 1. The mean and standard deviation (SD) values for the weight of extruded debris (g) for each group.

	df	F	p
Irrigation	1	1.263	0.266
Location	1	0.074	0.785
Irrigation X Location	1	0.011	0.916
		Irrigation Systems	
		(a) CNI	(b) SI
Maxillary location, (n: 30), Mean (SD)		0.00072 (0.00036)	0.00085 0(0.00025)
Mandibular location, (n: 30), Mean (SD)		0.00076 (0.00031)	0.00086 (0.00043)

Conventional needle irrigation (CNI), Sonic irrigation (SI).

ied how different methods of activating irrigation (passive ultrasonic irrigation (PUI), EDDY, photon-initiated photoacoustic streaming, and manual irrigation) affect the extrusion of debris from the root canals of mandibular molars with curved roots. They discovered that the EDDY system led to significantly more debris being pushed out compared to the other methods. Mitchell et al. (19) determined that CNI resulted in more debris extrusion from the apex compared to EndoVac, EndoActivator, Rispisonic, and PUI. Boutsioukis et al. (6) showed higher mean pressure at the apical foramen with open-ended needle irrigation, suggesting a heightened risk of apical extrusion. In this study CNI group, irrigation was performed only with a 28-G side-vented needle. However, in the EDDY group, the solution was first irrigated using the 28-G side-vented needle, followed by activation with the EDDY tip. This additional activation might have led to more extrusion, though the effect was insufficient to create a significant difference in outcomes. This may suggest that the acoustic flow generated by EDDY during activation does not statistically significantly affect debris extrusion.

Gravity can affect the accessibility of irrigation solutions to the apex and their extrusion from the apex [18]. In the present study, like previous studies (20,21), irrigation solution was extruded apically when CNI and EDDY were used in the maxillary position, despite the effect of gravity. Kaşıkçı et al. (22) evaluated the effect of gravity on the amount of debris extrusion after retreatment using 4 different techniques in curved canals and determined that gravity did not affect the amount of extruded debris. Similarly, although more debris was extruded in the mandibular position compared to the maxillary position, no significant difference between the two positions was observed in this study. However, Uzunoğlu et al. (12) conducted an in vitro study to evaluate the impact of gravity on irrigant extrusion from the apex using CNI, RinsEndo (RE), and PUI techniques. Contrary to the current study, they found that gravity significantly influenced debris extrusion irrespective of the irrigation technique employed. In the study, after preparing the distobuccal roots of maxillary molars, the roots were sealed with floral foam, and the total amount of extruded material during the final irrigation was measured. No specific efforts were made to distinguish the amount of debris from the irrigant. The floral foam used in the experimental setup provided periapical resistance and was employed as a method to quantify the amount of extruded material. These differences in study designs may explain the variations in results between studies.

The study results determined that there were no significant differences in the amount of debris extruded between different irrigation systems and that gravity did not affect debris extrusion. Consequently, the null hypotheses were accepted.

In the present study, the use of different tooth groups could affect the amount of extruded debris due to varying root canal anatomies. However, to better reflect the clinical situation, single-rooted mandibular and maxillary canine teeth with similar anatomical features were selected.

The experimental arrangement, following the Myers and Montgomery model for extrusion testing, is commonly used and thus was chosen for this study. During instrumentation, the total volume of irrigant used was 10 mL, and 28G side-vented needles were utilized for irrigation instead of open-ended needles to minimize apical pressure (6). Additionally, distilled water was preferred over NaOCl to reduce the chance of crystal deposition. One significant drawback of in vitro studies is their inability to faithfully recreate the periapical environment. Some studies (12,23,24) have employed floral foam to mimic the resistance of periapical tissues. However, the absorption of fluid by the foam can lead to an underestimation of extrusion. Therefore, the apical barrier was not used in present study. However, the outcomes might differ in an in vivo setting due to the existence of periapical tissues, which serve as a natural barrier hindering the extrusion of irrigants and debris. Future research could explore fur-

ther refinements in experimental setups to better simulate clinical conditions and evaluate the efficacy of irrigation systems in vivo.

Conclusion

In conclusion, our study investigated the impact of irrigation systems and gravity on apical extrusion during RCT. We found no significant differences in the amount of extruded debris among irrigation systems and in terms of gravity. SI with EDDY showed slightly more debris extrusion than CNI, but this difference was not statistically significant. Present findings provide valuable insights for clinical practice and underscore the need for further in vivo research to validate our results.

Authorship Contributions: Concept: K.E.; Design: H.H., K.E.; Supervision: K.E.; Data: H.H., K.E., E.E., M.D., Ş.N.P.; Analysis: H.H., K.E., E.E., M.D., Ş.N.P; Literature search: H.H., K.E., E.E., M.D., Ş.N.P; Writing: H.H., K.E., E.E.; Critical revision: K.E.

Use of AI for Writing Assistance: Not declared

Source of Funding: None declared.

Conflict of Interest: None declared.

Ethical Approval: The study protocol was approved by the Akdeniz University Faculty of Medicine Ethics Commitee (protocol no: TBAEK 147).

Informed consent: Written informed consent was obtained from patients who participated in this study.

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