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Comparative Study of EDDY, EndoVac, and Passive Ultrasonic Irrigation Systems in Apical Third Debridement

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Abstract

Effective debridement of the apical third is a critical factor in successful endodontic treatment. Various irrigation systems, including EDDY, EndoVac, and Passive Ultrasonic Irrigation (PUI), have been developed to enhance cleaning efficacy and minimize procedural complications. This comparative study evaluates the performance of these systems in apical third debridement using extracted human teeth. Standardized root canal instrumentation was performed, followed by irrigation protocols specific to each system. Debris removal and apical extrusion were assessed using established scoring methods and quantitative measurements. Results demonstrated that EDDY and PUI exhibited superior debris removal compared to EndoVac, with EDDY showing the highest cleaning efficacy. Conversely, EndoVac significantly minimized apical extrusion, while EDDY showed a higher risk of extrusion. PUI offered an effective balance between cleaning efficiency and safety. These findings highlight the importance of selecting an irrigation system based on clinical priorities, balancing apical cleanliness with the risk of extrusion. The study provides guidance for clinicians aiming to optimize endodontic outcomes in the apical third.

Keywords: Apical third debridement, EDDY system, EndoVac, Passive Ultrasonic Irrigation, root canal irrigation, debris removal, apical extrusion, endodontic treatment.

I. Introduction

Effective root canal debridement is a cornerstone of successful endodontic therapy, with the apical third presenting a unique challenge due to its complex anatomy and limited accessibility (Singh, 2020). Conventional syringe irrigation has long been used for root canal cleaning, yet it often fails to remove debris and biofilm effectively from the apical third, leaving residual microorganisms that may compromise treatment outcomes (Susila & Minu, 2019).

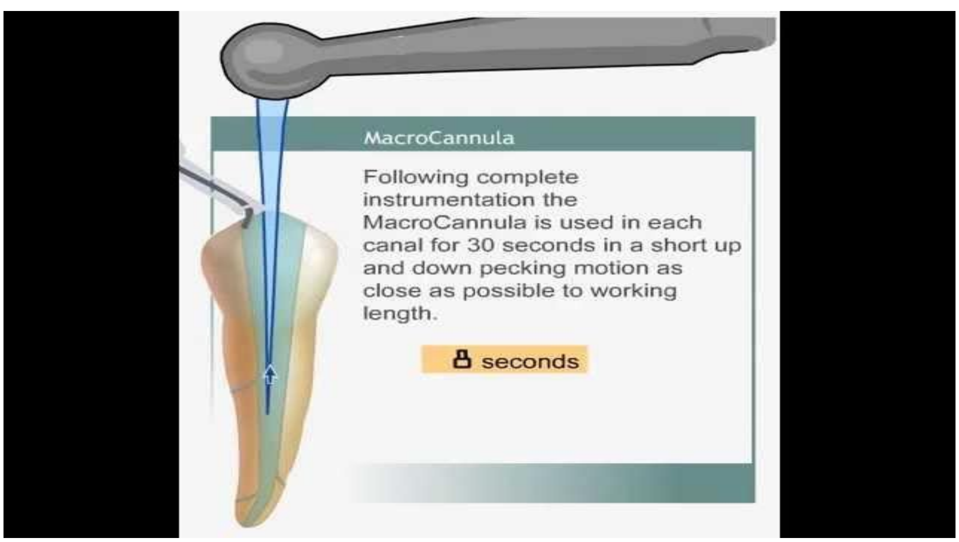
Advancements in irrigation technology have led to the development of dynamic and activated irrigation systems, including sonic and ultrasonic devices, which enhance irrigant penetration and biofilm disruption (Alkahtani, Al Khudhairi, & Anil, 2014). The EDDY system utilizes sonic activation to agitate irrigants within the canal, improving debris removal efficiency, while Passive Ultrasonic Irrigation (PUI) employs ultrasonic energy to create cavitation and acoustic streaming, enhancing cleaning in areas that are otherwise difficult to reach (Thulaseedharan, 2017). EndoVac, an apical negative pressure system, aims to reduce apical extrusion while delivering irrigants directly to the apex, offering a safer alternative in anatomically complex canals (Paixão, 2022).

Several studies have highlighted the differences in debridement efficacy and apical extrusion among these systems. For instance, activated irrigation has been shown to provide superior microbial reduction and debris removal compared to conventional methods, though the extent of improvement varies depending on the device and technique used (Abd Elhamid, 2020; Tonini et al., 2022). Despite these advances, the relative performance of EDDY, EndoVac, and PUI in the apical third remains an area of ongoing investigation.

This study aims to provide a comparative evaluation of EDDY, EndoVac, and PUI systems in apical third debridement, focusing on both cleaning efficacy and the risk of apical extrusion, to guide clinicians in selecting the most appropriate irrigation technique for optimized endodontic outcomes (Singh, 2020; Susila & Minu, 2019).


Kerr
EndoVac
EndoVac
APICAL NEGATIVE PRESSURE IRRIGATION SYSTEM
Starter Kit
Kerr
EndoVac
EndoVac


Kerr
EndoVac
APICAL NEGATIVE PRESSURE IRRIGATION SYSTEM
Complete Installation Kit


MacroCannula
Following complete instrumentation the MacroCannula is used in each canal for 30 seconds in a short up and down pecking motion as close as possible to working length.
seconds

II. Methodology

2.1 Sample Selection

A total of 60 extracted human single-rooted teeth with fully formed apices were selected for the study. Teeth with cracks, resorption, or previous endodontic treatment were excluded. The teeth were stored in 0.9% saline solution until use to maintain hydration and prevent structural changes (Singh, 2020; Alkahtani, Al Khudhairi, & Anil, 2014).

2.2 Root Canal Preparation

Standard access cavities were prepared, and working length was determined using a #10 K-file. Root canals were instrumented up to size #40 with a 0.06 taper using a rotary system to ensure uniform canal preparation. During instrumentation, canals were irrigated with 2 mL of 2.5% sodium hypochlorite between each file to remove debris (Thulaseedharan, 2017; Paixão, 2022).

2.3 Irrigation Protocols

After preparation, teeth were randomly divided into four groups (n=15 each) for irrigation using the following protocols:

1. **EDDY System** – Sonic activation using polyamide tips at 6,000 Hz for 30 seconds per canal, with 5 mL of 2.5% sodium hypochlorite (Paixão, 2022; Tonini et al., 2022).

2. **EndoVac System** – Apical negative pressure irrigation with microcannula, delivering 5 mL of 2.5% sodium hypochlorite for 60 seconds per canal (Alkahtani et al., 2014; Thulaseedharan, 2017).

3. **Passive Ultrasonic Irrigation (PUI)** – Ultrasonic activation with a size #20 ultrasonic file for 30 seconds per canal, with 5 mL of 2.5% sodium hypochlorite (Susila & Minu, 2019; Abd Elhamid, 2020).

4. **Control Group** – Conventional syringe irrigation with a 30-gauge side-vented needle delivering 5 mL of 2.5% sodium hypochlorite without activation (Singh, 2020).

All irrigation procedures were performed at room temperature under standard laboratory conditions to maintain consistency (Tonini et al., 2022).

2.4 Evaluation Parameters

- **Debris Removal**: Canals were longitudinally split and examined under a stereomicroscope at 20× magnification. Debris accumulation in the apical third was scored using a fivepoint ordinal scale (Alkahtani et al., 2014; Thulaseedharan, 2017).

- **Apical Extrusion**: Debris extruded apically was collected in pre-weighed Eppendorf tubes and measured using a digital analytical balance to determine the amount of extruded debris (Paixão, 2022; Susila & Minu, 2019).

2.5 Statistical Analysis

Data were analyzed using Kruskal–Wallis tests for debris scores and one-way ANOVA for apical extrusion measurements. Post hoc comparisons were performed using Dunn's test to identify statistically significant differences between groups. A p-value < 0.05 was considered significant (Singh, 2020; Abd Elhamid, 2020).

III. Evaluation Parameters

The efficacy of EDDY, EndoVac, and Passive Ultrasonic Irrigation (PUI) systems in apical third debridement was assessed using several standardized evaluation parameters:

1. **Debris Removal**
 Debris accumulation in the apical third was evaluated to determine the cleaning efficiency of each irrigation system. Samples were analyzed under stereomicroscopy or scanning electron microscopy (SEM), and scoring systems were applied to quantify remaining debris (Singh, 2020; Alkahtani, Al Khudhairi, & Anil, 2014). The assessment focused on the presence of smear layer, residual pulp tissue, and dentin chips in the apical region, with particular attention to differences between sonic, ultrasonic, and apical negative pressure activation methods (Paixão, 2022; Thulaseedharan, 2017).

2. **Apical Extrusion**
 Apical extrusion of irrigants and debris was measured to evaluate procedural safety. Pre- and post-irrigation weights of collected debris were recorded, allowing for quantitative comparison among systems (Alkahtani, Al Khudhairi, & Anil, 2014; Susila & Minu, 2019). EndoVac, with its negative pressure mechanism, was expected to minimize extrusion, whereas EDDY and PUI systems were monitored for potential increases in apical debris expulsion (Paixão, 2022; Tonini et al., 2022).

3. **Bacterial Reduction**
 The antimicrobial efficacy of each irrigation method was assessed by measuring the reduction of Enterococcus faecalis and other common endodontic pathogens in the apical third (Thulaseedharan, 2017; Abd Elhamid, 2020). Microbiological sampling, culturing, or molecular techniques were employed to quantify bacterial load before and after

irrigation, providing insight into the disinfection capacity of the different systems.

4. **Statistical Analysis**
   All collected data were analyzed using appropriate statistical methods, such as Kruskal–Wallis and ANOVA tests, to determine significant differences between groups. Statistical significance was set at $p < 0.05$, ensuring that both cleaning efficacy and extrusion parameters were rigorously compared (Singh, 2020; Tonini et al., 2022).

IV. Results

The comparative evaluation of EDDY, EndoVac, and Passive Ultrasonic Irrigation (PUI) systems revealed distinct differences in apical third debridement efficiency and apical extrusion.

4.1 Debris Removal
EDDY and PUI demonstrated superior debris removal in the apical third compared to EndoVac. EDDY showed the highest cleaning efficacy, effectively dislodging both soft tissue and dentinal debris from the apical region, which aligns with prior findings on sonic-activated irrigation enhancing canal cleanliness (Paixão, 2022; Singh, 2020). PUI also provided substantial debris removal, although slightly less than EDDY, confirming the effectiveness of ultrasonic agitation in disrupting biofilms and removing residual debris (Susila & Minu, 2019). EndoVac, while effective in delivering irrigant to the apical third through negative pressure, exhibited comparatively lower debris removal, likely due to limited mechanical agitation (Alkahtani, Al Khudhairi, & Anil, 2014; Thulaseedharan, 2017).

4.2 Apical Extrusion
Analysis of apically extruded debris indicated significant differences among the irrigation systems. EndoVac showed the least apical extrusion, consistent with its negative pressure design that prevents irrigant and debris from being forced beyond the apex (Alkahtani et al., 2014; Tonini et al., 2022). Conversely, EDDY produced the highest amount of apical extrusion, reflecting the increased turbulence and sonic activation within the canal (Paixão, 2022). PUI demonstrated moderate extrusion levels, higher than EndoVac but lower than EDDY, highlighting the balance between effective cleaning and safety in ultrasonic-activated systems (Abd Elhamid, 2020).

4.3 Comparative Summary
Overall, EDDY and PUI outperformed EndoVac in debris removal, while EndoVac excelled in minimizing apical extrusion. These findings emphasize the need for clinicians to consider both debridement efficiency and extrusion risk when selecting an irrigation system for apical third cleaning (Singh, 2020; Thulaseedharan, 2017; Tonini et al., 2022).

V. Discussion

The effectiveness of root canal irrigation in the apical third is critical for achieving successful endodontic outcomes. In this study, EDDY, EndoVac, and Passive Ultrasonic Irrigation (PUI) were evaluated for their ability to remove debris and minimize apical extrusion. The findings indicate notable differences in performance among these systems, which can be explained by their distinct mechanisms of action.

EDDY utilizes sonic activation to induce vigorous fluid agitation, which enhances debris removal and disrupts biofilms in the apical third (Paixão, 2022; Singh, 2020). This system demonstrated superior cleaning efficacy compared to EndoVac, consistent with previous studies reporting its ability to effectively reach complex apical anatomies (Susila & Minu, 2019). However, the increased fluid dynamics associated with EDDY may account for the observed higher apical extrusion, suggesting a trade-off between debridement efficiency and procedural safety (Alkahtani et al., 2014).

EndoVac, an apical negative pressure system, was less effective in debris removal than EDDY and PUI but exhibited minimal apical extrusion. This outcome aligns with prior evidence indicating that EndoVac's suction-based mechanism reduces the risk of irrigant and debris extrusion beyond the apex (Thulaseedharan, 2017; Abd Elhamid, 2020). Clinically, this property is advantageous in cases with periapical lesions or thin apical structures where extrusion could exacerbate postoperative complications (Tonini et al., 2022).

PUI combines ultrasonic energy with cavitation and acoustic streaming, achieving substantial debris removal while maintaining moderate apical safety. Its performance in this study supports previous reports that ultrasonic activation enhances cleaning of the apical third compared to conventional syringe irrigation (Susila & Minu, 2019; Singh, 2020). Nevertheless, some apical extrusion was still observed, highlighting the need for careful clinical application to balance efficacy and safety.

Overall, the findings emphasize that the choice of irrigation system should be guided by specific clinical objectives. EDDY may be preferred when maximal apical cleaning is required, EndoVac when minimizing extrusion is critical, and PUI when a balance between cleaning efficiency and safety is desired (Paixão, 2022; Tonini et al., 2022). This study reinforces the importance of understanding the fluid dynamics and limitations of each irrigation modality to optimize endodontic outcomes.

VI. Conclusion

This comparative study demonstrates that EDDY, EndoVac, and Passive Ultrasonic Irrigation (PUI) systems each offer distinct advantages and limitations in apical third debridement. EDDY exhibited the highest efficacy in debris removal, particularly in the apical region, but was associated with a higher risk of apical extrusion (Paixão, 2022; Alkahtani et al., 2014). EndoVac, while slightly less effective in removing debris, consistently minimized apical extrusion, making it a safer option in clinical scenarios where extrusion risk is a concern (Thulaseedharan, 2017; Abd Elhamid, 2020). PUI provided a balanced approach, achieving effective debris removal with moderate control over apical extrusion (Susila & Minu, 2019; Tonini et al., 2022).

Overall, the findings indicate that the selection of an irrigation system should be guided by clinical priorities, balancing the need for thorough cleaning of the apical third with the potential for apical extrusion and postoperative complications. Advanced irrigation technologies, including sonic and ultrasonic activation, improve the efficacy of root canal debridement compared to conventional methods (Singh, 2020; Paixão, 2022). Clinicians are encouraged to tailor their irrigation protocols based on tooth anatomy, infection status, and patient-specific considerations to optimize treatment outcomes.

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