Original Article

Evaluating the influence of different irrigation needles on the apical cleaning efficacy of endodontic irrigation – An *in vitro* study

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Abstract

Context: Irrigation is an essential part of a successful root canal treatment.

Aim: This study evaluates and compares the influence of three different double-sided vented irrigation needle gauges (G) (27G, 30G, and 31G) on the apical cleaning effectiveness of endodontic irrigation using radiovisiography.

Settings and Design: A thorough protocol describing the objectives and methodologies of the study was submitted to the Institutional Ethics Committee, Vivekanandha Dental College for Women. Ethical clearance no. VDCW/IEC/340/2023.

Subjects and Methods: Forty-five human mandibular premolars were extracted, filled with a radiopaque medium, and subjected to irrigation with three varying sizes of double-sided vented irrigation needles. Preirrigation and postirrigation radiographic images were digitally subtracted to assess the cleaned areas.

Statistical Analysis Used: Statistical analysis was carried out with SPSS version 27. For the purpose of intergroup comparisons, one-way analysis of variance was implemented, followed by the execution of the Tukey honestly significant difference *post hoc* test. Throughout the comparisons, $P < 0.05$ was deemed statistically significant.

Results: Maximum cleaning was observed in 31G double-sided vented irrigation needles, followed by 30G and 27G double-sided vented irrigation needles.

Conclusions: The 31G double-sided vented irrigation needles exhibit a higher level of effectiveness in the cleansing of the apical third of the root canal system in comparison to the other two irrigation needle variants.

Keywords: Apical cleaning efficacy; digital subtraction; double-sided vented irrigation needles; radio opaque medium

INTRODUCTION

To ensure the highest success rates in root canal treatment, the irrigation of root canals is essential for the thorough removal of debris, bacteria, and pulp tissue during the chemo-mechanical preparation process.[1] Disinfection and debridement are greatly contingent upon the irrigation protocols utilized, and they have been traditionally recognized as important supplementary measures to instrumentation.[2] Due to the intricate anatomy of root canals, around one-third of the wall surface remains uninstrumented, contributing to insufficient debridement.[3]

According to Cohen, irrigation is defined as "to wash out a body cavity or wound with water or a medicated fluid."[4] The objective of irrigation is to ensure that the irrigant

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thoroughly penetrates the whole root canal system, a process that is significantly affected by the design of the irrigation needle.[5] Conventional syringe irrigation is recognized as the predominant technique employed in endodontics, wherein the irrigating solution is introduced into the root canal through a syringe and needle, utilizing either a passive delivery method or one that incorporates agitation.[6]

Evidence from the existing literature highlights that a variety of factors, such as the size and shape of the needle, the depth at which the needle tip is inserted, the positioning of the needle port, and the anastomosis of the canal, significantly affect the efficiency of root canal cleansing and the eradication of bacterial biofilms.[7] Moreover, the size of the needle significantly impacts the success of apical cleaning during the endodontic irrigation procedure.[8]

Irrigation solutions are specifically formulated to be contained within the root canal system; nevertheless, there are occasions when these solutions are unintentionally forced out through the apical foramina as a result of irrigation. The apical extrusion of these solutions presents a considerable risk and may result in severe complications associated with root canal treatment.[9] To address this possible danger, researchers have created side-vented irrigation needles designed to administer the solution from the side.[10] In contemporary practice, integrating irrigant delivery and aspiration through pressure alternation devices also serves as a feasible resolution to this problem.[11] However, negative pressure irrigation does not enjoy the same level of popularity as syringe irrigation, likely due to the latter's ease of use, cost-effectiveness, and broad availability.

The present study aimed to evaluate and compare the influence of three different double-sided vented irrigation needles (27G, 30G, and 31G) on the apical cleaning effectiveness of endodontic irrigation by using radiovisiography (RVG) from the root canals of mandibular premolars.

SUBJECTS AND METHODS

Approval for this study was obtained from the Institutional Ethics Committee (VDCW/IEC/340/2023) after a thorough review. Forty-five human permanent mandibular premolars with single canals and closed apices were extracted and collected for the study. The rationale for selecting mandibular premolars in this research stems from their regular extraction for orthodontic reasons, which provides a readily available and ethically sound source for the study. The preference for single canals is based on their ease of visualization and analysis, particularly with the aid of image processing, which enhances the assessment of cleaning efficacy.

Access opening was performed using an Endo Access bur (21 mm, size 2, Dentsply Maillefer, Switzerland). The patency of the canal was assessed using #10 K files (Mani, Utsunomiya, Tochigi, Japan). Subsequently, the working length of each canal was determined with #15 K files (Mani, Utsunomiya, Tochigi, Japan) by reducing 1 mm from the total length and verified using RVG.

The root canals were then instrumented using the Wave One NiTi rotary file system, with instrumentation extended to size 25 and a 0.07 taper at the working length. After the biomechanical preparation, the 45 premolars were randomly distributed into three different experimental groups, with 15 teeth designated for each group.

- Group I: Utilized double-sided vented irrigation needles with a gauge of 27G
- Group II: Utilized double-sided vented irrigation needles with a gauge of 30G
- Group III: Utilized double-sided vented irrigation needles with a gauge of 31G.

Upon completion of biomechanical preparation, the apical foramen of each specimen was sealed with sticky wax and held in silicone impression material (Flexceed-Vinyl polysiloxane impression material, GC, India) that was uniformly filled with Iohexol radiopaque contrast medium (Eurasia Health Care LLP, Mumbai). For every group, 2 ml of distilled water was irrigated using a disposable plastic syringe (HMD, Faridabad, Haryana) along with the designated irrigation needles [Figure 1a-c].

A single operator inserts each irrigation needle passively to a depth of 1 mm below the canal binding. Prior to and following the irrigation procedure, each specimen positioned on the assembly [Figure 1d] underwent radiographic imaging in both buccolingual and mesiodistal orientations utilizing a Woodpecker RVG i-sensor H1/H2 digital system (Guilin Woodpecker Medical Instrument Co., Ltd., China). These images served as the foundation for evaluating the apical cleaning effectiveness of irrigation needles [Figure 1e].

Digital image processing was conducted with Adobe Photoshop (Adobe Systems Inc., San Jose, CA, USA) to carry out image subtraction. For standardisation uniform software settings are followed in image processing such as grid size, resolution, and transparency across all datasets. The preirrigation images [Figures 3 and 4], (GI-BL [a], GI-MD [a] GII-BL [a] GII-MD [a] GIII-BL [a] and GIII-MD [a]) which contained a radiopaque contrast medium (Iohexol), were meticulously analyzed. Subsequently, regions where the contrast medium had been displaced or removed due to irrigation i.e. post irrigation images [Figures 3 and 4]

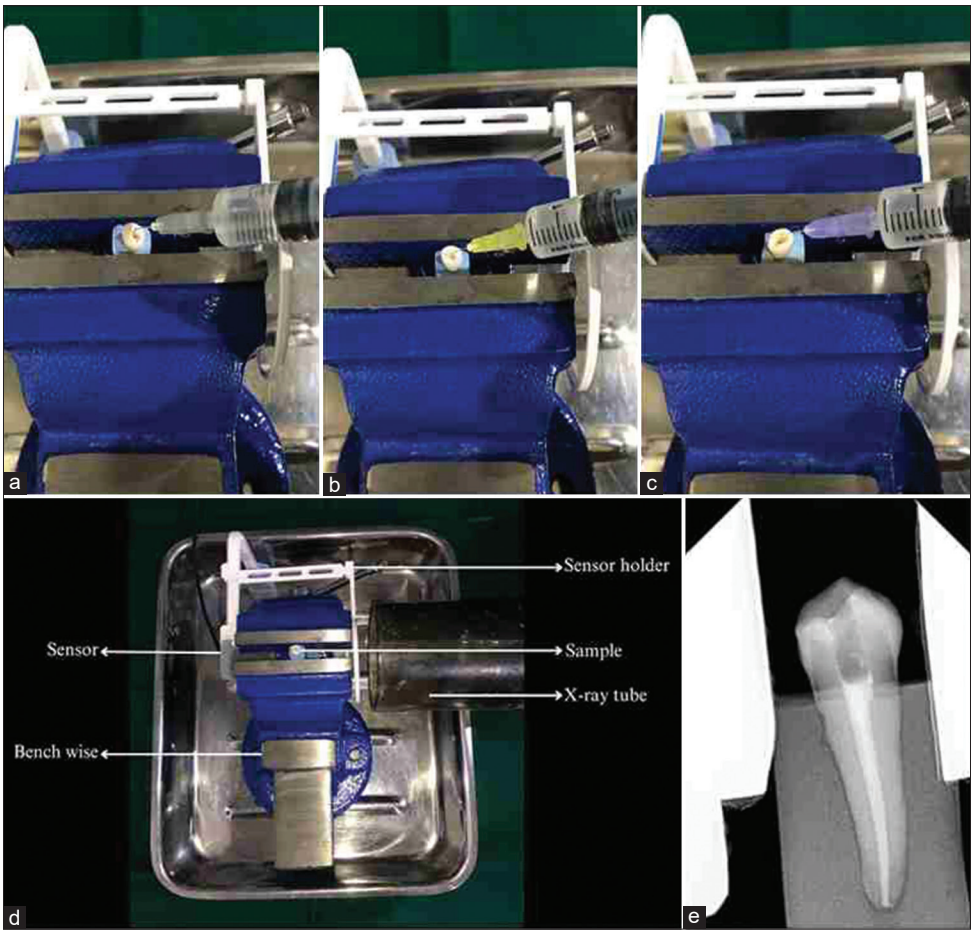


Figure 1: (a-c) Irrigation with 27G, 30G and 31 G double-sided vented irrigation needle gauges (d) Positioning assembly (e) Image before digital image processing (The image was captured while the sample was secured in the positioning assembly)

(GI-BL [b], GI-MD [b] GII-BL [b] GII-MD [b] GIII-BL [b] and GIII-MD [b]) were subtracted from the pre-irrigation images. Following this, we derived subtracted images [Figures 3 and 4] (GI-BL [c], GI-MD [c] GII-BL [c] GII-MD [c] GIII-BL [c] and GIII-MD [c]).

The delineated areas of interest in both preirrigation and subtracted images were measured in square millimeters (mm^2) using the calibration tools within Image Tool 3 software.[8] The ratios between the preirrigation and subtracted areas [Figures 3 and 4] (GI-BL [d], GI-MD [d] GII-BL [d] GII-MD [d] GIII-BL [d] and GIII-MD [d]) were expressed as a percentage to quantitatively assess the cleaning efficacy achieved by each irrigation needle (varied needle gauges). The final values were obtained as an average of the buccolingual and mesiodistal measurements.

Statistical analysis

Data analysis was executed through the use of SPSS, version 27 (Statistical Package for the Social Sciences, IBM Corp., Armonk, USA). The average values for the bucco-lingual and mesio-distal areas prior to irrigation, as well as the area obtained after subtraction, were calculated. The mean subtracted area was divided by the mean preirrigation area, with the results expressed as percentages indicative of apical cleaning for each irrigation needle. Descriptive statistics, including mean and standard deviation, were used to summarize the apical cleaning percentages for each irrigation needle group.

To assess the assumptions for parametric testing, the Shapiro–Wilk test was conducted to evaluate the normality of residuals, and Bartlett's test was used to examine the homogeneity of variances across groups. As both assumptions were met, one-way analysis of variance (ANOVA) was employed to compare the mean apical cleaning percentages among groups. In cases where ANOVA detected significant differences, Tukey's honestly significant difference *post hoc* test was performed to determine the specific intergroup differences while adjusting for multiple comparisons. A significance level of $P < 0.05$ was set for all statistical analyses.

RESULTS

The descriptive statistics for the evaluated study variable

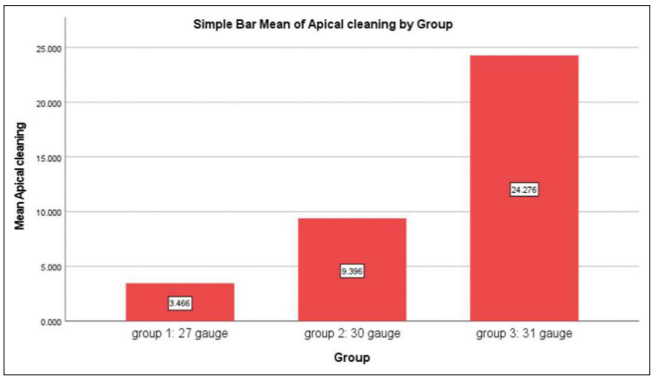


Figure 2: Bar graph for apical cleaning with different irrigation needles

Table 1: Mean (%) and standard deviations of apical cleaning achieved with the various double-sided vented irrigation needles

Needle gauge	*n*	Mean±SD
27G irrigation needle	15	3.47 ± 0.06^{A}
30G irrigation needle	15	9.40 ± 0.53^{B}
31G irrigation needle	15	24.28 ± 3.37^{C}

^{A,B,C}Distinct uppercase letters within the same column signify statistical significance. SD: Standard deviation

"apical cleaning" in each irrigation needle group are presented as the mean and standard deviation in Table 1. It also [Table 1] illustrates a statistically significant difference among the irrigation needles assessed for apical cleaning. 31G irrigation needle showed a greater ability to remove radiopaque contrast medium during irrigation (24.28 ± 3.37) [Table 1].

The mean values for apical cleaning in different irrigation needles were illustrated using a bar graph, as shown in Figure 2.

DISCUSSION

The fundamental aim of endodontic procedures is to eradicate inflamed or necrotic pulp and pathogenic microbes from the root canal area before the implementation of three-dimensional obturation.[12] According to Louis Grossman, it is essential to perform irrigation of the canal after instrumentation to remove remnants of pulp tissue and dentinal debris.[13] The research focused on assessing how effective apical cleaning is when performed through endodontic irrigation using various tested needle designs.

chow *et al*[14] explored the efficacy of root canal irrigation utilizing 23G and 25G hypodermic needles. Their results revealed that smaller needles were superior in effectiveness to their larger counterparts. Guerreiro-Tanomaru *et al*.[8] performed a study to evaluate the effectiveness of different irrigation needle gauges (23G, 22G, and 30G) in cleansing

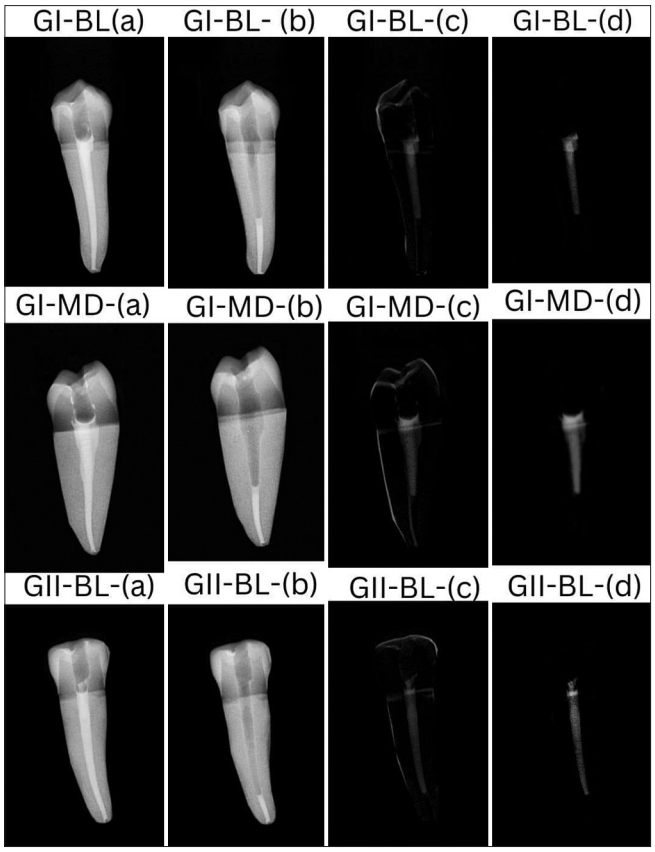


Figure 3: GI-BL – (a) Group I-Pre irrigation image in buccolingual direction (sample filled with radio-opaque liquid) GI-BL – (b) Group I-Post irrigation image in buccolingual direction (contrast medium had been displaced or removed due to irrigation). GI-BL – (c) Group I-Digital subtracted image in buccolingual direction (post irrigation image subtracted from pre irrigation image). GI-BL – (d) Group I-Subtracted area in buccolingual direction. GI-MD – (a) Group I- Pre irrigation image in mesiodistal direction (sample filled with radio-opaque liquid). GI-MD – (b) Group I-Post irrigation image in mesiodistal direction (contrast medium had been displaced or removed due to irrigation). GI-MD – (c) Group I-Digital subtracted image in mesiodistal direction (post irrigation image subtracted from pre irrigation image). GI-MD – (d) Group I-Subtracted area in mesiodistal direction. GII-BL – (a) Group II- Pre irrigation image in buccolingual direction (sample filled with radio-opaque liquid). GII-BL – (b) Group II-Post irrigation image in buccolingual direction (contrast medium had been displaced or removed due to irrigation). GII-BL – (c) Group II-Digital subtracted image in buccolingual direction (post irrigation image subtracted from pre irrigation image). GII-BL – (d) Group II-Subtracted area in buccolingual direction

the apical third of the root. The results showed that 30G needles are the most effective in debriding the apical portion of the root canal. The current study's findings provide further credence to this assertion.

Utilizing fine irrigation needles appears to be a prudent approach, given their superior efficacy in removing

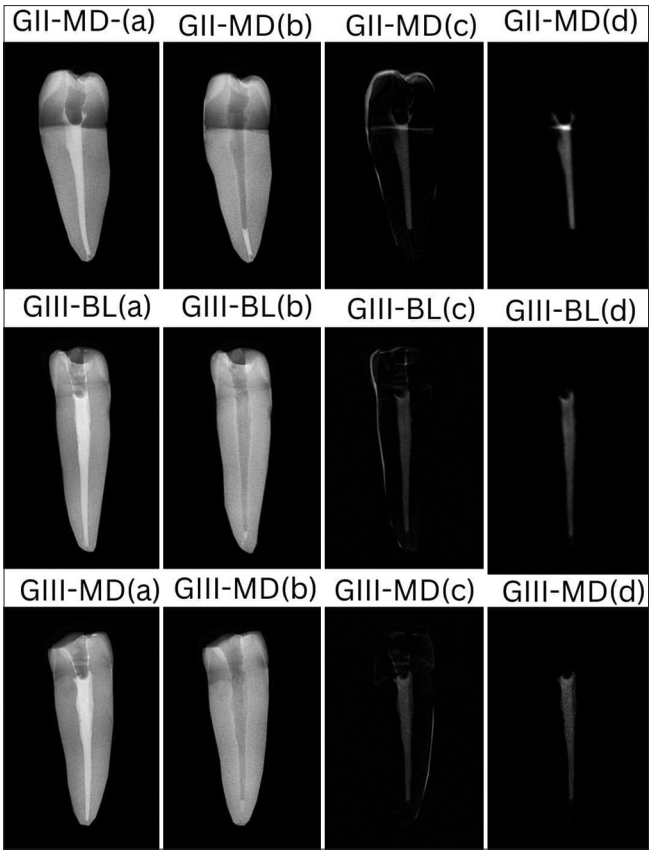


Figure 4: GII-MD – (a) Group II- Pre irrigation image in mesiodistal direction (sample filled with radio-opaque liquid). GII-MD – (b) Group II-Post irrigation image in mesiodistal direction (contrast medium had been displaced or removed due to irrigation). GII-MD – (c) Group II-Digital subtracted image in mesiodistal direction (post irrigation image subtracted from pre irrigation image). GII-MD – (d) Group II-Subtracted area in mesiodistal direction. GIII-BL – (a) Group III-Pre irrigation image in buccolingual direction (sample filled with radio opaque liquid). GIII-BL – (b) Group III-Post irrigation image in buccolingual direction (contrast medium had been displaced or removed due to irrigation). GIII-BL – (c) Group III-Digital subtracted image in buccolingual direction (post irrigation subtracted from pre irrigation image). GIII-BL – (d) Group III-Subtracted area in buccolingual direction. GIII-MD – (a) Group III- Pre irrigation image in mesiodistal direction (sample filled with radio-opaque liquid). GIII-MD – (b) Group III-Post irrigation image in mesiodistal direction (contrast medium had been displaced or removed due to irrigation). GIII-MD – (c) Group III-Digital subtracted image in mesiodistal direction (post irrigation image subtracted from pre irrigation image). GIII-MD – (d) Group III-Subtracted area in mesiodistal direction

particles from the apex, which is of paramount importance. Based on a review of the existing literature, our research incorporates 27G, 30G, and 31G double-sided-vented irrigation needles, which are predominantly used for root canal irrigation. The selection of these needle sizes is justified by their ability to effectively deliver solutions to the apical third of the root canals due to their reduced size.

A study by Silva *et al*.[10] focused on the apical expulsion of debris and irrigants through the use of various needles (a flat open-end needle, a side-vented needle, and a double-sided-vented needle). The research concluded that the type of needle plays a crucial role in analyzing the volume of extruded irrigant and debris, with double-sided vented needles resulting in less material being extruded. A computational analysis by Bulgu *et al*.[5] assessed the effects of various root canal needle designs on the effectiveness of irrigation. The study revealed that the use of double-sided-vented, closed-ended needles results in considerably reduced apical pressure when contrasted with open-ended needles. Consequently, the present study opted for the use of double sided-vented, closed-ended irrigation needles.

The depth of penetration of an irrigant into a canal is significantly influenced by the irrigation tip gauge. Specifically, a 27G tip can reach the apex of an ISO 45-sized canal, while a 30G tip can access a size 35 canal, and a 31G tip can reach the apex of a size 30 canal.[15] According to Khademi *et al*.,[16] a size 30 file is the smallest required for ensuring that irrigants effectively reach the apical third of the root canal. However, the authors do not address the potential complications associated with this size, which could increase the possibility of perforation, ledge formation, and canal transportation, particularly in cases involving curved and narrow root canals.

The findings of the current investigation unequivocally demonstrate that canals that are prepared to a minimum diameter of size 25 at the apex can be reliably irrigated, provided that the preparation exhibits an adequate taper to facilitate the positioning of the irrigation needle tip within the apical third of the canal. In the current analysis, we used 27G, 30G and 31G, which has 0.42 mm, 0.32 mm and 0.28 mm diameters with apical preparation of 25 size, 07 taper, which has 0.25 mm apical width, which allows the placement of needles in the apical third.

Naoum *et al*.[17] reported that the implementation of contrast media and radiopaque solutions in digital radiography effectively enhances the understanding of root canal anatomy. In this research, Iohexol (Omnipaque) was used to evaluate the effectiveness of endodontic irrigation. This ensured consistency and reproducibility in the evaluation of irrigation efficacy.

The choice of iohexol (Omnipaque) as a contrast medium for the assessment of irrigation in this study is justified by its low osmolarity, nonionic nature, and water solubility. In addition, it has a viscosity and density akin to that of 5.25% Naocl.[18]

It is essential to acquire the images that share the same projection geometry, as this is required for subtraction

radiography. Bronnec *et al*.[19] employed a bench vice to assemble the teeth held in impression material, charge-coupled device sensor, and X-ray tube. In the present study, we created a similar configuration specifically for our experimental purposes. The assembly was dismantled only after the experiment was finished.

Carvalho *et al*.[20] concluded that the radiographic changes can be evaluated using digital subtraction radiography by using Adobe Photoshop image-analysis software. In this study, digital image processing was conducted using Adobe Photoshop to implement image subtraction. This technique facilitates precise measurement of the areas that were cleaned through irrigation, thereby providing reliable data regarding the effectiveness of various gauge irrigation needles.

In recent years, advancements in irrigation systems, including RinsEndo and EndoVac, have emerged to optimize apical cleaning. The research conducted by Vivan *et al*.[21] indicates that RinsEndo demonstrates a cleaning effectiveness that is not significantly different from that of conventional irrigation techniques using syringes and 30G needles. Furthermore, Rajamanickam *et al*.[22] observed that there was no significant difference between automated irrigation and manual syringe needle irrigation in terms of debris and smear layer removal.

Kapetanović Petričević *et al*.[23] conducted a comparative analysis of the efficacy of shock wave enhanced emission photoacoustic streaming (SWEEPS), ultrasonically activated irrigation, and conventional syringe-needle irrigation utilizing a 31G needle. The authors concluded that the SWEEPS technique demonstrates significant potential for use in retreatment procedures. The research conducted by Mathevanan *et al*.[24] focused on the incidence of postoperative pain associated with passive ultrasonic irrigation (PUI) and laser-activated irrigation (LAI) in contrast to conventional needle irrigation (CNI) with a 31G needle. Their results revealed that PUI resulted in the lowest pain levels when compared to LAI and CNI. Prior studies have demonstrated mixed outcomes concerning the effectiveness of conventional syringe irrigation when compared to other irrigation methods. Hence, it is logical to deliberate on the unification of multiple irrigation approaches to ensure a harmonious balance of cost, effectiveness, and efficiency.

Clinical implications

It is essential for the clinicians to select irrigation needles that correspond to the size and taper of the apical preparation, ensuring that they are compared with the needle's external diameter. Such needles are only appropriate for straight and mildly curved canals, as they are unsuitable for severely curved configurations. In instances where root canals demonstrate complex anatomical configurations, such as accessory canals and isthmuses, it is beneficial to consider integrating various techniques as previously described.

Numerous factors that impact treatment outcomes are under the operator's control, such as the choice of syringe needle type and design, the selection of various volume barrels for irrigation, and the positioning of the needle according to the estimated working length. Clinicians should consider the adoption of smaller gauge irrigation needles to enhance the treatment outcomes. The significance of these findings is considerable and highlights the importance of optimizing the size of irrigation needles to improve the efficacy of root canal therapy.[25]

Limitations

This study, while yielding encouraging results, does have certain limitations that need to be recognized. The present study was conducted *in vitro* and clinical conditions may present additional challenges that were not accounted for in this controlled environment. Future research should focus on evaluating the performance of different irrigation needles with agitation in various apical sizes to confirm their effectiveness. Furthermore, exploring the combination of different irrigation solutions with these needles could provide insights into optimizing the irrigation protocols for maximum efficacy.

CONCLUSIONS

This study concludes that, within its constraints, the 31G double-sided vented irrigation needle demonstrated superior performance in apical cleaning compared to the 27G and 30G needles during root canal treatment. The findings suggest that a smaller gauge needle can enhance the penetration and distribution of the irrigation solution in the apical third, resulting in more effective cleaning.

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Conflicts of interest

There are no conflicts of interest.

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