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Evaluation of debridement efficacy of root canal irrigants using different irrigation needles: An *in vitro* scanning electron microscopic study

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Abstract
Objective: The aim of the study was to evaluate the efficacy of debridement of root canal irrigants using three irrigation needles, analyzed with Scanning Electron Microscope (SEM)
Materials and Methods: Thirty single rooted teeth freshly extracted human mandibular premolars with fully formed apices were divided into three groups (n=10). Root canal instrumentation was done on all teeth using rotary files. Each group was irrigated using 3 different irrigation needles (Group I: 27 gauge side vented needle, Group II: 30 gauge side vented needle, Group III: 30 gauge flexible needle). During root canal preparation, 5.25% sodium hypochlorite and EDTA were used as irrigants. The teeth were sectioned and coronal, middle and apical third were evaluated for debris by Scanning Electron Microscope. The data was analyzed using One-way ANOVA Test followed by Kruskal Wallis Test followed by Dunn's post hoc test at a 5% significance level.
Results: Group III demonstrated the highest debris removal efficacy across all root canal regions, as indicated by the lowest mean scores. Significant differences were observed between Group III and both Groups I and II in all regions, while no significant differences were found between Groups I and II. The differences were most pronounced in the apical region, where Group III showed superior performance.
Conclusion: The findings highlight the importance of irrigation needle selection for effective canal debridement, particularly in the apical region.

Keywords: Canal irrigation, cleanliness, disinfection, endodontics, root canal irrigants

1. Introduction
Successful root canal disinfection necessitates the complete eradication of infective elements, including diseased pulp, microbes, and their endotoxins, as well as the dentin chips produced during the instrumentation process [1, 2]. Cleaning and shaping is a critical part of root canal treatment (RCT) which constitutes majorly of debridement of infected pulp, disinfection and exclusion of microbes from within the canals and the dentinal walls, to the best possible extent[3]. It becomes even more challenging in retreatment cases where it is required to remove metallic and non metallic materials as well [4]. The primary aim is to prepare the root canal space to ensure effective disinfection through the use of irrigating solutions and medicaments [5]. A variety of irrigation techniques are accessible, with the most common method is via syringes and irrigation tips. Manual dyanamic agitation with files or gutta percha, endoactivators etc are alternative methods of irrigant activation [6, 7]. Literature suggests the use of 27 to 30 gauge side vented needles for effective endodontic irrigation [8]. Irriflex (Produits Dentaires SA, Vevey, Switzerland) is a polypropylene irrigation tip with a soft body that effectively reaches the working length without encountering penetration issues in the prepared root canal. Its design allows it to adapt to the root's shape, facilitating the delivery of a high volume of irrigant to the apex [9].
Many case reports have recorded complications in the periapical tissues that are linked to irrigation procedures [10]. The extrusion of debris and irrigation solutions is likely the main factor contributing to the worsening of inflammation. This can lead to intense pain, swelling, periapical inflammation, and delayed healing in cases of apical periodontitis [11]. Therefore, the aim of the study was to evaluate the efficacy of debridement of root canal irrigants using three

irrigation needles, analyzed with Scanning Electron Microscope (SEM).

Methodology

Thirty mandibular premolars with fully formed apices were collected(n=30). Tooth specimens with fractures, resorption, or atypical root morphology were eliminated. A single canal was confirmed using radiographs taken from different orientations. The debris and soft tissue residues were cleared, and the teeth were immersed in physiological saline. Each tooth was cut at the cementoenamel junction with a diamond disc. To ensure consistent tooth lengths, all teeth were measured with a vernier calliper and standardized to 17 ± 3 mm. The access cavity was prepared in each tooth, followed by which working length was established using a size 10 K file, confirmed via loupes (3.5x). The working length was then adjusted by subtracting 1 mm from this measurement, and apical patency was verified with a 10 K file.

The samples were classified into three groups

- **Group 1:** 27-gauge side-vented needle (HMD, Unolock)
- **Group 2:** 30-gauge side-vented needle (Endorinse, SuperEndo)
- **Group 3:** 30-gauge flexible needle (Irriflex, Produits Dentaires, Switzerland)

In each group, the teeth were irrigated with 2 ml of 3% sodium hypochlorite (NaOCl) before being instrumented using NeoEndo Rotary files up to a size of 30/0.06. Following this, the canals were rinsed with 2 ml of 3% NaOCl, which was left undisturbed for 60 seconds. The final irrigation was done with 2 ml of 5.25% NaOCl, followed by 2 ml of 17% ethylenediaminetetraacetic acid (EDTA) and saline [3].

Following the instrumentation procedure, the teeth were divided by making a vertical groove in a buccolingual direction using carborundum discs at a low speed, with consistent water irrigation. The teeth were then split longitudinally with slight pressure applied using an enamel chisel. The most demonstrative halves of each tooth were selected for analysis, sputter-coated, and examined with SEM(2000x). Photographs were taken of each specimen at the apical, middle, and cervical thirds to assess the amount of debris left in the walls.

Scoring Criteria

The scores were assigned to respective SEM images based on the scoring criteria by Hulsmann *et al* [12].

Score 1: Only a few small remains in root canal walls.
Score 2: Few small collection of debris.
Score 3: Collections of debris covering <50% of the root canal walls.
Score 4: >50% of the canal walls covered by debris.
Score 5: Nearly entire root canal walls covered by remains

Statistical analysis

A one-way ANOVA test, followed by the Kruskal-Wallis test and then Dunn's post hoc test, was employed to assess the debridement efficacy among three groups, depending on the data distribution. The significance level was established at $p<0.05$.

Results

A comparative analysis of mean scores for debris removal efficacy across three groups yielded the following findings (Table 1). In the Coronal region, Group I registered a mean score of 1.70 (SD = 0.48), followed by Group II with a mean score of 1.80 (SD = 0.79). Group III recorded the lowest mean score of 1.10 (SD = 0.32). Statistical analysis revealed a significant difference (p = 0.02). Dunn's post hoc test indicated substantial differences between Group I and Group III (p = 0.008) and between Group II and Group III (p = 0.02), while no significant change was observed between Group I and Group II (p = 0.87).

In the Middle region, Groups I and II both achieved a mean score of 2.50, with standard deviations of 0.71 and 0.53, respectively. Group III had a lower mean score of 1.60 (SD = 0.52). The analysis demonstrated a significant difference (p = 0.004), with Dunn's post hoc test indicating significant differences between Group I and Group III (p = 0.006) and between Group II and Group III (p = 0.003). No significant difference was identified between Groups I and II (p = 0.83).

Table 1: Comparison of mean Score of debris removal efficacy between 3 groups in different regions using Kruskal Wallis Test followed by Dunn's Post hoc Test

Regions	Groups	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
Coronal	Group I	10	1.70	0.48	1	2	0.02*	I vs II	0.87
	Group II	10	1.80	0.79	1	3		I vs III	0.008*
	Group III	10	1.10	0.32	1	2		II vs III	0.02*
Middle	Group I	10	2.50	0.71	2	4	0.004*	I vs II	0.83
	Group II	10	2.50	0.53	2	3		I vs III	0.006*
	Group III	10	1.60	0.52	1	2		II vs III	0.003*
Apical	Group I	10	3.20	0.92	2	5	<0.001*	I vs II	0.13
	Group II	10	2.60	0.84	2	4		I vs III	<0.001*
	Group III	10	1.20	0.42	1	2		II vs III	<0.001*

* - Statistically Significant
Note: a. Kruskal Wallis Test & b. Dunn's Post hoc Test

Table 2: Comparison of mean Score of debris removal efficacy across 3 groups using Kruskal Wallis Test followed by Dunn's Post hoc Test

Groups	Regions	N	Mean	SD	Min	Max	p-value [a]	Sig. Diff	p-value [b]
Group I	Coronal	10	1.70	0.48	1	2	<0.001*	C vs M	0.02*
	Middle	10	2.50	0.71	2	4		C vs A	0.007*
	Apical	10	3.20	0.92	2	5		M vs A	0.02*
Group II	Coronal	10	1.80	0.79	1	3	0.04*	C vs M	0.04*
	Middle	10	2.50	0.53	2	3		C vs A	0.04*
	Apical	10	2.60	0.84	2	4		M vs A	0.71
Group III	Coronal	10	1.10	0.32	1	2	0.03*	C vs M	0.03*
	Middle	10	1.60	0.52	1	2		C vs A	0.56
	Apical	10	1.20	0.42	1	2		M vs A	0.04*

* - Statistically Significant
Note: a. Kruskal Wallis Test & b. Dunn's Post hoc Test

In the Apical region, Group I achieved the highest mean score of 3.20 (SD = 0.92), followed by Group II with a mean score of 2.60 (SD = 0.84) and Group III with the lowest mean score of 1.20 (SD = 0.42). The results indicated a highly significant difference ($p<0.001$). Dunn's post hoc test revealed significant differences between Group I and Group III ($p<0.001$) and between Group II and Group III ($p<0.001$), with no significant difference between Groups I and II (p = 0.13).

In brief, Group III consistently demonstrates the highest efficacy in debris removal across all regions, as evidenced by the lowest mean scores. Significant differences are observed between Group I and Group III, and Group II and Group III, highlighting that Group I and Group II generally have lower efficacy compared to Group III. This trend is particularly pronounced in the Apical region, where the differences in efficacy are most significant.

Discussion

Conventional syringes are commonly used by clinicians to deliver irrigants. Despite the numerous irrigant activation devices available in the market, introducing irrigants into the canals still requires needles that have suitable sizes and designs, with safety as a primary consideration [13]. Numerous studies have advocated the use of side-vented needles instead of open-ended ones to reduce the risk of periapical extrusion and to minimize postoperative pain [14-16].

All three needle designs selected for the study were side-vented. This aligns with the findings of a study conducted by Ghivari *et al* in 2011, which demonstrated that side-vented needles facilitate better debris removal in the middle and apical thirds of the root canal compared to single-beveled needles [17]. Samples were instrumented up to 30/0.06 as literature suggests better apical debridement in canals prepared to 6% taper [8].

The samples were sectioned for SEM analysis by longitudinally scoring the teeth buccally and lingually with diamond disk, then chisel and mallet were used to split. This minimizes the introduction of debris from the disk into the canal space. Khalap *et al* recommended this method because it produces lesser debris in inner dentinal walls [18].

Scanning electron microscopy (SEM) is one among the various techniques available for the evaluation of smear layer and dentinal tubules after canal preparation. Previous studies have emphasized the challenges posed by varying magnifications in SEM, as these differences can influence the outcomes of scoring systems. There are multiple systems available for assessing residual debris and smear layers. In this study, we employed the Hulsman five-point numerical scoring system [19, 20].

In the present study, the debridement efficiency of three distinct needles was evaluated. The internal anatomy of the canal, which influences the size, density, and viscosity of the irrigant, as well as the irrigant flow rate are some of the factors influencing the ability of an irrigant to access the apical root canal [21, 22]. The smaller 30-gauge needle showed intermediate levels of cleaning efficacy and extrusion, likely because its narrower diameter restricts the volume of irrigant flow while increasing the delivery pressure slightly. The 27-gauge needle, while larger in diameter and thus potentially allowing more flow, does not create the same high-velocity irrigant dynamics as the Irriflex needle [23]. Its larger tip size restricts penetration into narrower canals, reducing the effectiveness of debris removal, especially in the apical third of the canal, where deeper penetration is essential for efficient debridement. The 27-gauge needle was found to produce the least cleaning efficacy. This supports previous research showing that larger, stiffer needles often struggle to reach critical areas in curved or narrow canals, and that conventional needle systems are ineffective at eradicating the smear layer in the apical third. While 27-gauge needles may offer improved flow rates in the root canal, their larger external diameter could hinder how deeply they can enter the root canal, especially beyond curvatures [15, 21].

Irriflex needle is known for its high efficacy in cleaning and features such as soft and flexible silicone body with multiple lateral openings. This design enhances the flow and adaptability of the irrigant, improving pressure distribution and debris removal from the canal walls, which is evident from the SEM images (Fig. 1). Its flexibility allows for easier navigation of curved canals compared to traditional metal needles, increasing cleaning efficiency as described by Provoost *et al* in a similar study [9]. Studies conducted by Habeeb *et al*. and Paula *et al*. demonstrated that the use of the IrriFlex flexible needle resulted in a significantly reduced weight of debris extrusion in comparison to the Max-I-Probe and NaviTip Fx needles [24]. Needle irrigation effectively facilitates the disinfection of the main canal; however, more intricate anatomical regions, such as isthmic branches, deltas, and accessory canals—often characterized as contaminated niches would greatly benefit from the application of high flow rates of irrigants [24]. This enhancement can be achieved through irrigant activation utilizing various devices, including ultrasonics and lasers [9, 25].

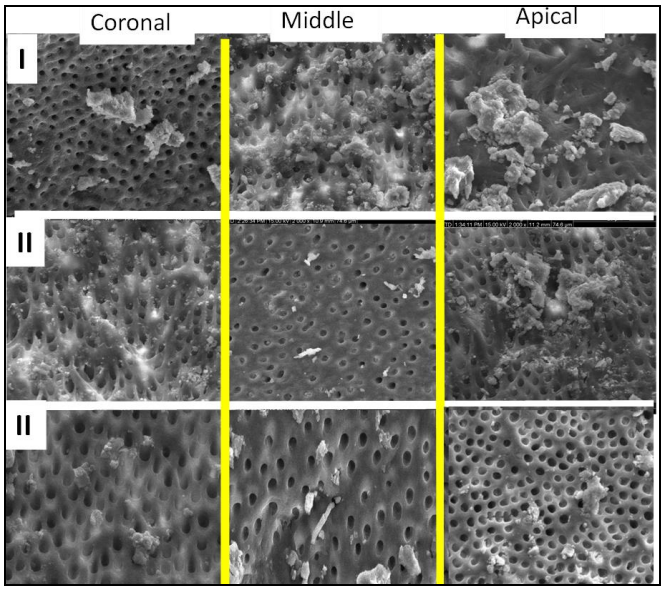

Fig 1: SEM images of comparison of debridement efficacy of 3 groups in coronal, middle and apical region under 2000x magnification

Conclusion

Overall, the study illustrates that smaller, more flexible needles like the Irriflex are associated with superior cleaning efficacy due to enhanced flow dynamics and adaptability. The study highlights the benefits of needle design and gauge for improved cleaning efficacy. The needle choice should be carefully balanced according to clinical needs, as increased extrusion can lead to postoperative complications, especially in vital or sensitive periapical tissues.

Conflict of Interest

Not available

Financial Support

Not available

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