# Efficacy of Active Irrigation Techniques in Smear Layer Removal after Reciprocating Instrumentation

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## ABSTRACT

This study evaluated the effectiveness of three irrigation techniques—Passive Ultrasonic Irrigation (PUI), Endoactivator, and non-activated irrigation—in removing the smear layer from mandibular premolars. Forty-two teeth were instrumented and randomly assigned to the three groups, and smear layer removal was assessed using SEM. PUI demonstrated the highest effectiveness, particularly in the coronal third of the root canal. The Endoactivator system showed moderate results, while non-activated irrigation was the least effective, especially in the apical third. Overall, PUI was the most efficient method for smear layer removal compared to the other techniques.

***Keywords:*** *Non activated irrigation, Passive ultrasonic irrigation, Reciprocating instrumentation, Smear layer removal*

**How to Cite:** Vishnu Valsan, Saleem Azhar, Abhinay Agarwal, Atul Jain, Lairikyengbam Sujata Devi, Anshika Singhai, (2025) Efficacy of Active Irrigation Techniques in Smear Layer Removal after Reciprocating Instrumentation, *Journal of Carcinogenesis, Vol.24, No.3s*, 179-185.

## 1. INTRODUCTION

The goal of endodontic treatment is to thoroughly clean and debride the root canal system to eliminate bacteria, necrotic tissue, and debris that could impede healing or result in reinfection. Given the intricate anatomy of the root canal system, where tools cannot always reach, irrigation becomes essential for effective cleaning and sanitization [1]. Conventional endodontic tools cannot access isthmi or other complex regions of the root canal system, making irrigation a crucial component of the procedure [2].

Sodium hypochlorite (NaOCl) has been the gold standard for root canal irrigation due to its antimicrobial properties and ability to dissolve organic tissues. However, it is less effective at removing the smear layer, a layer of debris that forms during the preparation of the canal [3]. This layer consists of a mixture of inorganic and organic materials, including bacteria, necrotic tissue, and dentinal fragments [4]. Despite the significant role irrigation plays in removing debris and cleaning the root canal system, it cannot eliminate the smear layer on its own. The presence of the smear layer can adversely affect the success of root canal therapy by preventing effective sealing and hindering the penetration of intracanal medicaments into the dentinal tubules [5].

Efficient irrigation is crucial for improving the cleaning and debridement of the root canal system, especially when addressing the smear layer. Studies have shown that, during root canal preparation, the smear layer can block the dentinal tubules, harbor bacteria, and reduce the effectiveness of endodontic sealers and obturation materials[6]. To overcome this issue, active irrigation techniques, such as sonic and ultrasonic devices, have been developed to improve the effectiveness of traditional irrigation methods[7]. These methods improve the mechanical cleaning action of the irrigants and aid in the effective removal of the smear layer.

Manual and positive pressure irrigation methods were once used to administer irrigants; however, these techniques proved inadequate in providing sufficient agitation and penetration, especially in complex canal systems. Traditional side-vented needle irrigation also tends to be inefficient in achieving optimal cleaning effects, particularly in hard-to-reach areas within the root canal system [8]. Consequently, newer methods such as sonic, ultrasonic, and negative pressure irrigation have gained traction due to their superior ability to enhance the flow and penetration of irrigants into the canal system.

Sonic irrigation, first introduced by Tronstad et al. in 1985, offered an alternative to traditional ultrasonic irrigation. Sonic devices operate at lower frequencies (1–6 kHz), producing larger amplitude oscillations with lower shear forces, in contrast to ultrasonic systems that function at higher frequencies (25–30 kHz) and generate smaller amplitude oscillations with higher shear forces. Passive ultrasonic irrigation (PUI) employs ultrasonic energy to agitate the irrigant, improving its ability to reach all areas of the root canal system and break down debris [9, 10].

The removal of the smear layer has long been a challenge in endodontics, with research indicating that conventional irrigation methods are often insufficient for its removal. Consequently, irrigant delivery methods have evolved to incorporate activated irrigation techniques, which utilize mechanical energy to improve the penetration and cleaning effectiveness of irrigation solutions. Techniques like sonic and ultrasonic irrigation, which promote cavitation and acoustic streaming, have been developed to enhance smear layer removal and overall canal cleaning [11].Despite these advancements, concerns about the potential damage to dentinal structure during the use of activated irrigation systems remain, and further research is needed to balance efficacy with safety [12].

In recent years, the introduction of reciprocating instruments has provided another significant advancement in root canal therapy. These instruments, which alternate between clockwise and counterclockwise rotations, offer superior control during canal preparation, especially in curved canals. Compared to traditional rotary instruments, reciprocating systems reduce torsional stress and lower the risk of instrument separation. Additionally, reciprocating systems tend to produce less debris and smear layer, further enhancing the cleaning and debridement process [13, 14].

Therefore, this study is important to determine the most effective irrigation techniques for smear layer removal following reciprocating instrumentation in endodontic treatment.

## 2. METHODOLOGY

This in vitro study was conducted to assess and compare the efficacy of smear layer removal using two active irrigation techniques following reciprocating instrumentation. The research took place at the Department of Conservative Dentistry and Endodontics, Teerthanker Mahaveer Dental College and Research Centre, Moradabad, Uttar Pradesh, and was approved by the Institutional Review Board of the Faculty of the same institution. Ethical approval for the study procedures was obtained.

A total of 42 non-carious mandibular premolar teeth were selected from a pool of freshly extracted teeth. These teeth were indicated for extraction and were cleaned to remove soft tissue debris and calculus using an ultrasonic scaler with an attached surface scaler tip. They were then stored at a controlled temperature of around 4°C until they were ready for use in the experiment. The teeth were carefully examined for cracks and defects, and any teeth showing such issues were excluded from the study. Infection control procedures were followed in accordance with Occupational Safety Health and Health Administration (OSHA) and Centers for Disease Control and Prevention (CDC) guidelines.

The teeth were sectioned using a diamond disc, employing a high-speed motor (KaVo Dental), and stored in zip-lock covers and stainless steel trays. Prior to scanning electron microscopy (SEM) analysis, the teeth were prepared using ascending concentrations of Isopropyl alcohol. Sterile self-sealing coded sterilization pouches, UV light chambers, silica gel, and fused calcium hydroxide were utilized during preparation. The samples were mounted on custom sample blocks with distance markings for accurate SEM analysis.

The SEM analysis was performed using a JSM IT 500LA SEM, with samples coated with a gold palladium sputter coating machine and carbon tape applied to ensure conductivity. The armamentarium used for the study included Dentsply Endo-Z Tungsten Carbide bur, Airotor, reciprocating files (Neo Endo), Endoactivator system (Glin), ultrasonic device with Irrisafe tip no. 25, diamond disk, endodontic motor, and reciprocating handpiece. Irrigating solutions included 17% EDTA, 5.25% NaOCl, and regular saline.

The study sample was prepared for group allocation by storing teeth in saline before beginning the experiment. A diamond disc was used to section the roots 2 mm below the cementoenamel junction (CEJ), and the sectioned samples were mounted onto acrylic resin substrates using a 2 × 2 × 2 cm putty mold. The teeth were then randomly allocated into three groups using a computer-generated random number method, each group being identified by a unique code: Group 1 (PUI), Group 2 (Endoactivator system), and Group 3 (Non-activated irrigation), with 14 samples in each group.

The irrigation procedures were carried out as follows: Group 1 (PUI) was treated with 17% EDTA (3 mL) followed by 5.25% NaOCl (6 mL) in three 20-second cycles using a size 25.01 Irrisafe tip with ultrasonic energy at power setting 10. Group 2 (Endoactivator system) followed a similar protocol, with the Endoactivator system set at 10,000 cpm. Group 3 (Non-activated irrigation) used 17% EDTA (3 mL) for one minute followed by 5.25% NaOCl (6 mL).

For sample preparation for SEM imaging, longitudinal grooves were made on the buccal and lingual sides of the roots using a diamond disk. Specimens were marked with graphite lead at 8 mm, 5 mm, and 2 mm from the apical foramen, with the middle and apical thirds also marked for accurate SEM analysis. The samples were then coated with a Quorum sputter coating machine, and high-resolution imaging was performed using the advanced field emission scanning electron microscope (FE-SEM) at X2000 magnification.

To assess the smear layer, each sample was assigned a code, and two independent researchers evaluated the smear layer and debris using high-resolution monitors. The scoring criteria for the smear layer were as follows: Score 1 for no smear layer with dentinal tubules visible, Score 2 for few scattered smear layers with open dentinal tubules, Score 3 for partially open dentinal tubules with a thin smear layer, Score 4 for a thick smear layer partly covering dentinal tubules, and Score 5 for complete covering with a thick smear layer.

The results of smear layer removal were statistically analyzed, and comparisons between groups were made using appropriate statistical tests. The smear layer removal scores were averaged using median, mean, and standard deviation. Significant differences in smear layer removal between groups were found, especially in the apical third of the root canal, where the activated irrigation methods showed superior effectiveness.

This methodology ensured rigorous control over experimental conditions, allowing for a comprehensive comparison of the effectiveness of different irrigation techniques in smear layer removal following reciprocating instrumentation.

## 3. RESULT

The study aimed to assess and compare the effectiveness of three irrigation techniques: PUI, Endoactivator, and Non-activated irrigation, in removing the smear layer at different root canal depths. The results were evaluated through statistical analyses, including mean, standard deviation, median, and Kruskal-Wallis tests.

Table 1& graph 1 presents the mean and standard deviation for smear layer removal at various parts of the root canal (coronal, middle, and apical) for each irrigation technique. PUI demonstrated the most effective smear layer removal, with the lowest mean scores across all regions. Specifically, in the coronal part, PUI achieved a mean score of 3.00 (±1.33), followed by Endoactivator at 3.83 (±0.38) and Non-activated irrigation at 3.89 (±0.32). The middle and apical parts showed similar trends, where PUI again performed better than the other two methods.

The median scores for smear layer removal, as shown in table 2& graph 2, further supported the findings from the mean values. PUI had the highest median score, particularly in the coronal part of the root canal, with a median score of 6.00 (IQR 1.00) ($P < 0.01$). The Endoactivator system, though effective, showed a median score of3.00 (IQR 0) in the coronal region, and 2.00 (IQR 1.00) in the middle and apical parts. Non-activated irrigation, on the other hand, showed the least effectiveness, with a median score of 2.00 (IQR 1.00) across all regions.

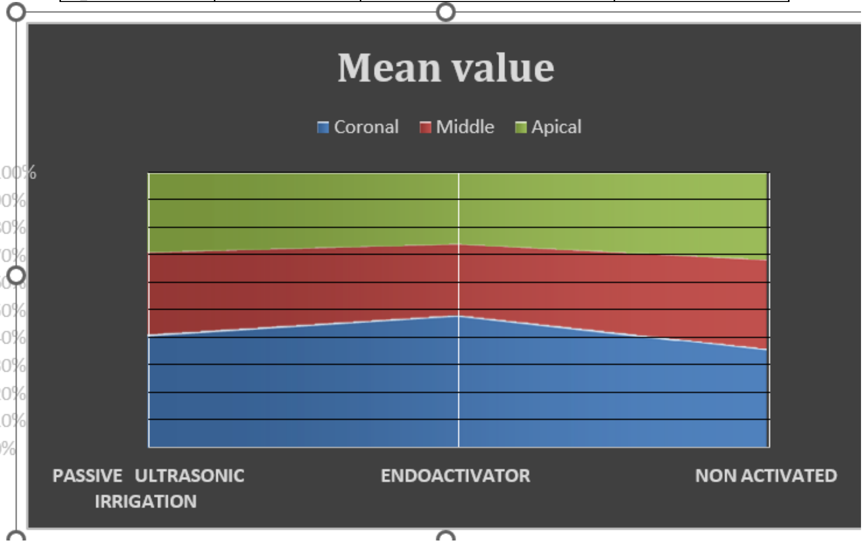
A comparison of the irrigation techniques using the Mann-Whitney U test (table 3) indicated no significant difference between the Endoactivator and Non-activated groups ($P = 0.276$), suggesting that these two methods were similarly ineffective at removing the smear layer. However, PUI demonstrated better performance, though statistical significance was not observed in direct comparison across all groups.

The Kruskal-Wallis test results, as summarized in table 4, showed significant differences in smear layer removal for PUI in the coronal part of the root canal ($P < 0.01$). The Endoactivator also demonstrated statistically significant effectiveness in the coronal region ($P = 0.03$). In contrast, Non-activated irrigation exhibited no significant difference across the different regions ($P = 0.99$), reinforcing its limited efficacy in smear layer removal.

Finally, SEM imaging (Figure 3) provided visual evidence of the smear layer removal at different root canal depths. The SEM images confirmed that PUI was the most effective method, with clear dentinal tubules visible in the coronal and middle parts of the canal. In contrast, the Endoactivator and Non-activated irrigation groups showed significant smear layer presence, particularly in the apical third of the root canal.

**Table 1: The mean and standard deviation of non-activated irrigation, endoactivator, and PUI methods**

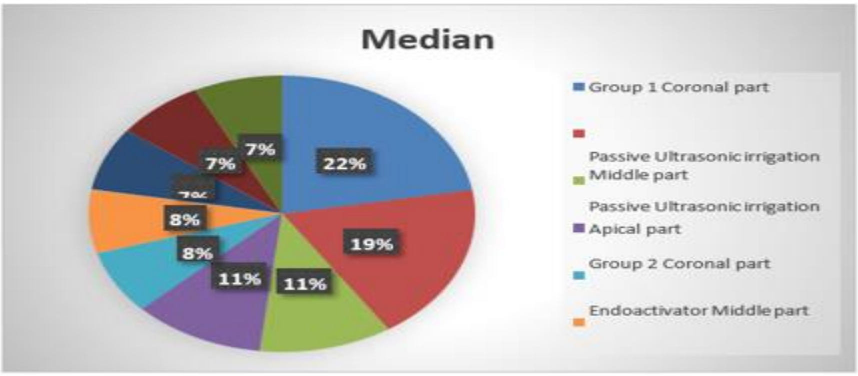
| | PUI | Endoactivator | Non activated |
|---|---|---|---|
| **Coronal** | 3(1.33) | 3.83(0.38) | 3.89(0.32) |
| **Middle** | 1.61(1.42) | 2.78(1.40) | 3.50(1.04) |
| **Apical** | 1.50(1.15) | 2.67(1.46) | 3.39(0.70) |




**Graph 1:Mean valueof threegroupsincoronal,apicalandmiddle part**

**Table2:The median score represents the smear layer removal of the groups at various root canal depths.**

| Irrigation techniques | | Median | IQR | Pvalue |
|---|---|---|---|---|
| **Group 1 PUI** | Coronalpart | 6.00 | 1.00 | **0.01*** (Significant) |
| | Middlepart | 5.00 | 2.00 | |
| | Apicalpart | 3.00 | 1.00 | |
| **Group 2 Endoactivator** | Coronalpart | 3.00 | 0 | **0.03*** (Significant) |
| | Middlepart | 2.00 | 1.00 | |
| | Apicalpart | 2.00 | 0 | |
| **Group3 Non-activated** | Coronalpart | 2.00 | 1.00 | 0.87 (Insignificant) |
| | Middlepart | 2.00 | 1.00 | |
| | Apicalpart | 2.00 | 1.00 | |




**Graph 02: Median value of three group in coronal, apical and middle part**

**Table3: Comparison between the passive ultrasonic, endoactivator and non activated**

| Irrigation techniques | N | Mean ranks | Sum of ranks | Test statistics | |
|---|---|---|---|---|---|
| **PUI** | 14 | 34.95 | 1118.5 | Mann whitney U | 433.5 |
| **Endoactivator** | 14 | 30.05 | 961.5 | Z | -1.09 |
| **Non activated** | 14 | 32.45 | 945.2 | Pvalue | 0.276 |

**Table4: Kruskal–Walli's test forsmearlayer**

| Irrigationtechniques | | N | Mean ranks | Chi square | p value |
|---|---|---|---|---|---|
| **PUI** | **Coronal** | 14 | 51.09 | 1.115 | **0.01*** (Significant) |
| | **Middle** | | | | |
| | **Apical** | | | | |
| **Endoactivator** | **Coronal** | 14 | 49.59 | 0.021 | **0.03*** (Significant) |
| | **Middle** | | | | |
| | **Apical** | | | | |
| **Non activated** | **Coronal** | 14 | 44.81 | 0.034 | 0.99 (Insignificant) |
| | **Middle** | | | | |
| | **Apical** | | | | |

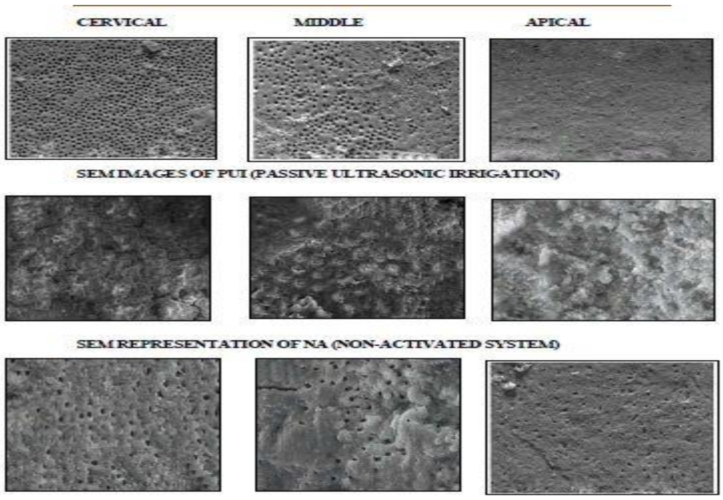



**Figure 3: SEM Images**

## 4. DISCUSSION

The process of smear layer formation during root canal instrumentation, caused by the capillary action between debris and dentinal tubules, plays a significant role in the obstruction of dentinal tubules and impedes proper disinfection. This accumulation of debris, consisting of microorganisms and their byproducts, can adversely affect the long-term success of root canal treatment if not properly addressed [15]. Bacteria and their byproducts present in the root canal system contribute significantly to pathological processes in both the pulp and periapical areas. Appropriate activation mechanisms enhance the effectiveness of irrigants in removing bacteria and their byproducts, promoting better treatment outcomes [16].

Recent studies have focused on the various aspects of root canal irrigation, such as the technique employed, syringe methods, needle type, and the depth and placement of the irrigation needle. Among the most challenging tasks faced by endodontists are the removal of the smear layer and cleaning of areas that are missed during biomechanical preparation. The apical third of the canal, with its complex ramifications and fins, is particularly difficult to clean, often retaining bacteria despite the most careful efforts [17]. These challenges highlight the need for more effective irrigation techniques to ensure thorough debridement, especially in the apical areas where smear layer removal remains problematic.

PUI is widely regarded as the gold standard in endodontic irrigation. The PUI technique uses ultrasonic frequencies between 25 to 30 kHz, which, when propagated through the root canal, create a pattern of nodes and antinodes, enhancing the agitation of the irrigant. However, a potential limitation of PUI is the dampening effect that may occur when the canal is only moderately expanded and the tip comes in contact with the root canal walls. This limitation was mitigated in this study by enlarging the canals to #30/9%, which restored the efficacy of PUI for smear layer removal [18].

Another common technique is the EndoActivator sonic irrigation system, known for its user-friendly nature. Sonic irrigation operates at a lower frequency range (1000–6000 Hz), resulting in lower streaming velocities for the irrigant compared to PUI. The tip's movement creates longitudinal vibrations in restricted areas, which may explain its suboptimal performance in smear layer removal [19]. In this study, the EndoActivator system was employed with a #20/4% tip to maintain consistency with the PUI group.

In line with previous studies, the current investigation found that while the EndoActivator group demonstrated moderate smear layer removal, it was less effective than PUI. Specifically, in terms of smear layer removal efficiency, the PUI group outperformed all other methods, with the best results observed in the coronal third of the root canal. This outcome is consistent with studies that have demonstrated the superior effectiveness of PUI in cleaning and debridement [20].

The use of SEM was pivotal in evaluating the effectiveness of smear layer removal in this study. SEM provides high-resolution images that offer detailed insights into the topography and morphology of dentinal surfaces, making it a valuable tool for assessing smear layer removal. The choice of SEM over other modern imaging methods was driven by its accessibility, cost-effectiveness, and ability to generate high-quality data [21].

Reciprocation allows for more thorough cleaning, especially in complex or curved canals, as it provides both cutting and cleaning action in multiple directions. This back-and-forth motion helps remove debris, clean the canal walls, and improve overall preparation, particularly in difficult-to-reach areas like the apical third of the canal where bacteria often persist. Additionally, reciprocation reduces the risk of instrument fracture by exerting less stress on the file, which decreases the likelihood of fatigue and failure [22]. This feature is especially important in intricate or severely curved canals. Furthermore, reciprocation enhances the effectiveness of irrigation techniques, such as PUI and sonic irrigation systems, by promoting better irrigant flow and penetration into the canal, aiding in smear layer removal. Previous studies support the use of reciprocation, showing improved cleaning efficacy and greater control over shaping, particularly in challenging root canal anatomies, making it an ideal technique for achieving optimal results in endodontic treatments [23].

One limitation of this study is that it was conducted using straight-canal teeth with a single root, which may not fully replicate the challenges encountered in clinical practice with more complex root canal systems. Additionally, the disc-based sample sectioning method may lead to debris accumulation in the canal area, potentially influencing the results. Furthermore, while the study evaluated the lateral penetration of irrigants, 3D analysis of irrigation techniques could provide more comprehensive insights, an area that warrants further exploration.

## 5. CONCLUSION

This study demonstrates that non-activated irrigation is ineffective in removing the smear layer, particularly in the apical third. PUI showed superior efficacy, especially in the coronal third, outperforming the Endo Activator system. Further refinement of ultrasonic techniques could enhance smear layer removal across all sections of the root canal.

**Conflicts of Interest:** Nil

**Financial Support:** Nil

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