

# Evaluation of Smear Layer Removal using Different Irrigant Activation Methods (Passive Ultrasonic Irrigation and Conventional Syringe Irrigation) - A Systematic Review

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## ABSTRACT

**Background and Aim:** Removal of smear layer and reduction in bacterial load from the root canal systems is an essential part in the success of endodontic therapy. Mechanical instrumentation alone may not be sufficient to remove this biofilm from the root canal, owing to the canal anatomy and other challenges. Adjunctive use of irrigants with conventional or passive ultrasonic irrigation system is a method to overcome this aspect. Thus, the aim of this systematic review was to compare the effect of conventional irrigation with that of passive ultrasonically activated irrigation (PUI) on the reduction of microorganisms and removal of smear layer during root canal disinfection.

**Materials and Methods:** The research question was created based on the PICO strategy. Two reviewers independently performed a comprehensive literature search in electronic databases. Following application of inclusion and exclusion criteria to the selected articles, a systematic data extraction sheet was constructed. Based on the area of interest the articles were included in the study.

**Results:** A total of 13 articles were included for the systematic review. The included studies were heterogeneous in study design; hence, meta-analysis was not performed. There was superior reduction of microbial reduction which resulted in better disinfection with passive ultrasonic irrigation system was seen compare to the conventional system.

**Conclusion:** The use of PUI has shown to be having superior microbial reduction and better smear layer removal than the conventional irrigation in the root canal disinfection was seen.

**Clinical relevance:** The study report will help in better utilisation of passive ultrasonic irrigation system along with the mechanical instrumentation for the better success of root canal therapy.

**Keywords:** Conventional irrigation, Endodontic irrigation, Ultrasonic irrigation.

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## Introduction

Disinfection of root canal is the prime importance in the success of the root canal treatment. To overcome this problem much research is continuously happening to improve the existing method of disinfection. However, the challenge is not completely resolved. Various irrigant are being tried and modified their mode of application. In last decade entry of many new gadgets with the advances in helped to resolve this major issue. However, there are still lack of studies which can give the evidence based in at the hierarchy which can guide the endodontist to use that particular method of intervention.<sup>1</sup>

Though the success rate of endodontic treatment ranges from 83 to 98% and for teeth with periapical lesion is 49%, which is very low rate of success. Many reasons are being discussed and presented. One among them is the inflammation in the periapical areas due to periapical injuries. This inflammation which is initiated by the bacterial infection and root canal may act as a continuous source of this inflammation.<sup>2</sup> In addition, anatomical variation seen in the root canal and other anatomical deformities can aggravate the condition and acts as a nidus for this inhabitant bacteria, which is difficult to remove from this niche. Biomechanical preparation also becomes incomplete, that leaves huge void in achieving the success of root canal treatment.<sup>3</sup> It is not only the anatomical variation but iatrogenically induced errors during the canal's shaping can lead to the formation of grooves and concave areas in its walls, which makes many surfaces as being non-instrumented throughout the length of the root canal, which again acts as a source of infection and effectively decreases the success of the root canal treatment.

With the consideration of these challenges, the clinicians have come out with the different strategies to handle this. One of the major changes happened more than two decades ago is the use of various types of irrigating solution. Irrigating solution as an adjunct to the mechanical preparation can enhance the effect of mechanical preparation and complete the cleaning process. This was the earnest attempt to reduce the microbial load, since irrigants can get it in to the area where the instrumentation was not possible and reduce the number of microorganisms and fastens the process of healing.<sup>4</sup> At that point of time, this was very successful and various irrigants were tried. These root canal irrigations played an important role in the success of endodontic treatment. It acted as an adjunct to instrumentation by lubrication, remove debris, microorganisms, smear layer and prevent apical debris packing. Thus it not only exerted their effects, by mechanical, but also by its chemical and biological actions.<sup>4</sup>

Mechanically, forces exerted during forcing the irrigants helped in creating the mechanical effect. At the same time, chemical effect of the active components released responsible for the specific actions on the organic and inorganic debris, which also shown the antimicrobial action on the organisms. Thus, all together it created a better environment for the root canal. Since the root canals are considered as "closed systems", the "irrigation dynamics"<sup>5</sup> works well within this root canal system and exerts desired effect. They are mainly agents such as ethylenediaminetetraacetic acid (EDTA) and sodium hypochlorite (NaOCl). These two agents were more commonly used since they have been helpful in removing organic and inorganic components of the smear layer.<sup>5</sup> However, addition to these various anti-infective agents is also being used, especially chlorohexidine (CHX).

Naturally, these agents are used with the syringes. Different type of syringes, with the end pores or side pores or with different gauge of needle are being used, where it was compared to the mechanical instrumentation alone has shown better results in reducing the bacterial load and also removal of smear layer, in terms of clinical parameters, assessment of pain being one of the criteria also shown favourable results. There is modification in the delivery of this agents, with one of the methods where there is pre-heated NaOCl is being used with better results.<sup>6</sup>

As the method of evaluation improved and availability of equipment being improved, addition of other armamentarium to the standard procedure of irrigation with a syringe has begun. Use of the sonic and the ultrasonic techniques and mechanisms are being tested. These methods not only helped in delivery of the irrigant to the areas not accessible from the mechanical instrumentation, but also created additional effect of acoustic flow with the forces that cause physical rupture of bacterial biofilm.<sup>7</sup> With this concept, many devices with different modality of delivery of the agents has come to the commercial market with different results. Though these devices have shown better result or equal result as when the syringe is used, there is still conflict or difference of results in studies.<sup>8-10</sup>

With the clinical superiority of some device over the other, it is required to have clarity on these systems and their uses, so that, one can utilise them in the clinical practice with given guidelines. Thus, this systematic review was undertaken to evaluate the effect of of smear layer removal using different irrigant activation methods (passive ultrasonic irrigation and conventional syringe irrigation).

**Materials and Methods**

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta Analyses Guide (PRISMA)<sup>11</sup> and the PICO strategy (Population, Intervention/Exposure, Comparison, and Outcome). The PICO question was: Is conventional syringe irrigation effect in smear layer removal better than different irrigant activation methods (passive ultrasonic irrigation)?

*The PICO strategy for research*

Acronym	Descriptors
P	Patients submitted to endodontic treatment, with no specific age.
I	They manage the failure of endodontic treatment.
C	To evaluate the effectiveness of PUI and compare it with conventional syringe irrigation.
O	Review the effectiveness of PUI and conventional syringe irrigation to remove the smear layer.

**The search strategy**

The search strategy consisted of a search in the electronic databases, PubMed, Web of Science, and Google Scholar. The list of references of each article included and published by December 2020. A combination of key words used for the search: (Ultrasonic irrigation OR ultrasound OR conventional irrigation), (Ultrasonic irrigation OR ultrasound OR endodontic irrigation), (Ultrasonic irrigation OR ultrasound OR endodontic irrigation OR passive endodontic device), (Ultrasonic irrigation OR ultrasound OR endodontic irrigation OR passive ultrasonic irrigation), (End activator OR PUI OR sonic and ultrasonic activation and conventional), with all this word smear layer was added. (Figure 1)

**Data Collection methods:**

**Inclusion Criteria:**

All the articles included where the randomised clinical trials that evaluated the use of passive ultrasonic irrigation technique compared with the conventional irrigation technique, restricted for English language and from 2010 until 2020.

**Exclusion Criteria:**

The other criteria were the assessment of smear layer removal. The literature reviews, letters to the editor, editorials, case reports or case series, in vitro studies, animal studies, not written by English language and study that included from 2009 and before were excluded.

**Screening and data extraction**

The electronic search identified a total of 5517 articles. All the references were transferred to Endnote Program (EndNote, Thomson Reuters, version x7) and the duplicates were removed. The articles were selected based on their titles and abstracts by two independent reviewers. Any disagreement was resolved by consensus with a third reviewer. The data was collected as per the information required and tabulated.

**Results**

Out of the 5517 articles selected, 3513 articles were removed which were duplicate. Out of 2004 studies, 1972 articles were excluded based on the exclusion and inclusion criteria. Remaining 32 articles were studied one by one by, title analysis and/or the abstracts by two reviewers. From which 21 studies selected for a full reading of the text, out of which 13 were included in the present systematic review. (Table 1)

All the 13 studies included in which there was comparison of conventional vs. passive ultrasonic irrigation system was used. Studies included were assessed either antibacterial efficacy or/smear layer removal efficacy. The results of the systematic review have shown that, passive ultrasonic irrigation in system was better than the conventional system. In terms of reduction in specific microorganism, assessed by checker board and PCR showed more reduction with the Endovac and Endo activator system.<sup>12</sup> Chemo-mechanical preparation significantly reduced LPS and LTA level. The smear level removal was shown better with the passive ultrasonic irrigation system compared to that of conventional. It was also shown that, at different depth of root canal smear layer removal is different. Up to 3 mm in to the root canal, conventional and PUI showed the same results. However, above 3 mm, especially above 5 mm, the PUI like Endovac and Endo activator showed the better results in smear layer removal.

**Figure 1 - Flow chart representing the number of articles screened and evaluated**

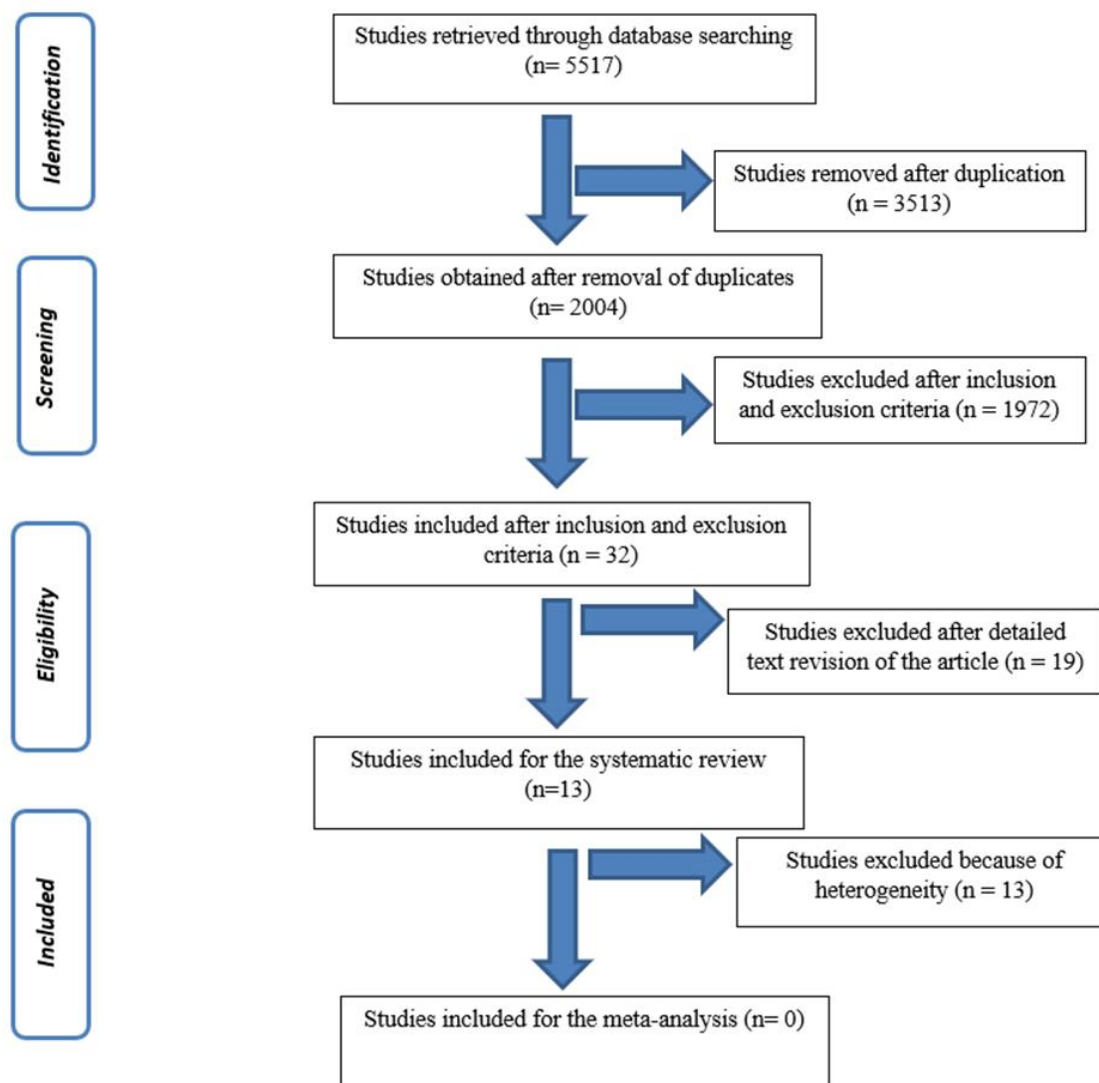


Table 1 Characteristics of the included studies

#	Author (s)	Sample	Device Used	Control	Irrigant used	Method of Evaluation	Results
1	Huffaker et al. (2010)	84	Endo Activator	Syringe 27 gauge needle		Anaerobic tube turbidity test	S: 52%; EA: 60%
2	Siu et al. (2010)	47	EndoVac	Syringe debridement		Histological sections - debris	EV: 0.05%; S: 0.12%
3	Munoz et al. (2012)	30	EndoVac; PUI	Irrsafe syringe	IOHEXOL (radiopaque length solution)	Delivery of irrigating solution	M: 1.51 +- 0.43 mm EV: 0.42 +-0.30 mm PUI: 0.21+-0.25 mm immediate
4	Pawar et al.(2012)	52	EndoVac	Syringe with antibacterial 27 gauge needle		Antibacterial efficacy	EV: 17.4%; S: 9.1 %-immediate
5	Palva et al. (2012)		PUI	Navitip syringe	2% CHX	Antibacterial - PCR	CHX Syringe -14% +ve ; PUI-23% +ve; PCR- CHX Syringe-43% +ve ; PUI-54% +ve
6	Mancini et al. (2018)	80	EndoActivator, EndVac, PUI, and LAI (n=15)	Control (n=10)	Irrigated with 5.25% NaOCl at 37 °C	Smear layer	None of the activation/delivery systems completely removed the smear layer from the root canal walls; EV and EA showed better results at 1, 3, 5, and 8 mm and 3, 5, and 8 mm from the apex
7	Aviero et al. (2020)	24	Reciprocating activation group using Easy Clean tip (EC, n = 8) ultrasonic activation group using Irrisonic insert	Control group without activation (WA, n = 8),	6% NaOCl	Culture technique and microbiota composition was analysed using the Checker board technique. The levels of LPS and LTA were quantified using limulus amoebocyte lysate (LAL) and enzyme-linked immunosorbent assay (ELISA)	Chemo-mechanical canal preparation significantly decreased the levels of LPS and LTA (p < 0.05), but no significant difference were found between the groups (p > 0.05). A significant reduction Occurred in Group US,

							followed by Groups EC and WA
8	Generali et al. (2018)	34	Manual dynamic agitation and passive ultrasonic irrigation		5.25% NaOCl solution	Penetration into different level	No significant differences in penetration
9	Jamleh et al. (2018)	40	Syringe irrigation (SI), EndoVac (EV), and CUI, with NaCOI and EDTA	CUI with saline	NaCOI and EDTA	Smear layer by SEM	CUI was comparable to EV at 1 and 3 mm but different to SI at 1 mm
10	Bueno et al. (2019)	45	Rotary NiTi system CUI	Syringe		Smear layer removal	CUI better than syringe
11	Betancourt et al. (2020)	40	Er, Cr: YSGG laser activated system and PUI		2.5% NaOCl		Radiopaque contrast medium was absent from the periapical tissues in all cases
12	Haupt et al. 2020	90	Sonic PUI Sonic activation Eddy EndoActivator	Syringe	3% NaCOI	Smear layer	EA and ED superior than syringe No activation tech able to remove from root canal
13	Iandolo et al. 2020	40	Ultrasonic activation UAI with intracanal heated NaCOI		3% NaCOI	Flow rate	UAI with intracanal heated NaCOI - better and less debris

### Discussion

The smear layer removal in endodontic therapy is the major requirement for the success. Removal of the smear layer is usually done by using irrigating by a combination of mechanical and chemical process. However off late, various irrigant solutions are used with the intention of removing the complete smear layer and to have a root canal free of bacteria. Most commonly recommended solutions which are capable of dissolving both organic (NaOCl) and inorganic components (EDTA).<sup>13</sup> As per various research results, recommended combination is a final rinse of 15% or 17% EDTA solution followed by 1–6% of NaOCl.<sup>5</sup> Though it is being commonly used and followed, there is no universal acceptance on different parameters involved with this, such as, amount or volume to be used<sup>14</sup> and duration of application or utilisation of various availed activation method of irrigating solutions.<sup>15</sup> Conventional system of using syringe with various modification in terms gauge of the needle, design of the needle (end pore or side pores) is being used for the irrigation. This is commonly being used as a standard method of irrigation. In last decade, availability of various systems to deliver or activate this irrigation system has changed the scenario of the endodontic therapy and boasted with the better success with these systems.<sup>6</sup>

In the present systematic review, most of the studies used NaOCl in different concentration. There was no standard concentration used (2.5%, 3%, 5.25%, and 6%).<sup>16-20</sup> Along with it few authors utilised the EDTA along with NaOCl.<sup>20</sup> Whatever the system being used for the delivery, the agents being used is same with the conventional or activator system. Thus, it appears that NaOCl in various concentrations are most sought after irrigant solution for the debridement. However, which concentration NaOCl is to be used for the better results cannot be ascertained, because the number of studies available was less and the favourable results were obtained by all the studies.

Conventional vs. different irrigant activation methods (passive ultrasonic irrigation systems) were always first line of the research once the various systems made available in the markets. Studies included used conventional syringes for the irrigation as a control method. Though there is variation in the type of the needle being used, most common gauge is used were 27 with the end opening. Other types of irrigation needle used were Irri-Safe Tip<sup>21</sup> and NaviTip syringe.<sup>22</sup> Comparison of among these various types of conventional irrigation was not possible because, lesser number of (1 each) studies are being used. However, despite of changes in the conventional system, antibacterial efficacy or smear layer was seen with all the conventional system less than that of the of passive ultrasonic activation systems.<sup>17,20,23-25</sup>

There is variety of devices being used in this study. Endo Activator, EndoVac, PUI, LAI, reciprocating activation group using Easy Clean tip, ultrasonic activation group using Irrisonic insert, Rotary NiTi system, Er, Cr: YSGG laser activated system, Sonic PUI, Sonic activation. The number of studies utilised the Endo Activator and Endo Vac system were 3 each among the selected studies. These two systems are latest being used and probably the reason for the increased utilisation in the study. mechanism of action of all these devices are different, though the common mechanism behind all the device is that, activated irrigation which agitate and improve the flow of irrigants to the intricacies of root canal system by mechanical or other energy. All the studies which compared the convention vs. passive irrigation system in terms of smear layer and antibacterial efficacy showed better results with the passive irrigation system. These results are achieved with no surprise because, these activated irrigant delivery systems claim improved irrigant transfer, debridement, minimal periapical extrusion and removal of smear layer or biofilm.<sup>17,20,23-25</sup> Smear layer often is obstinate for removal offering a niche for microbes to thrive post-treatment. Though the aim of the study was to assess the system which is useful in removal of smear layer, we have also included the studies which measures the indirect way of removal of smear layer that is the antibacterial efficacy. All the studies in this review showed better antibacterial efficacy and smear layer removal than that of the conventional irrigation methods. Antibacterial efficacy is assessed in the present studies are of different nature. Anaerobic tube turbidity test, PCR, culture technique, assessment of microbiota composition by the checkerboard technique. LPS and LTA quantification by limulus amoebocyte lysate (LAL) and enzyme-linked immunosorbent assay (ELISA).<sup>12,26</sup> Though the tests done varied, the results were equivalent in comparison to that of the conventional techniques. some of the studies showed the better efficacy immediately and up to few days and at 6 week or more there was no difference in the results were seen.<sup>12,26</sup> One of the studies assessed the microbial composition showed the decrease in the specific micro-organisms.<sup>12</sup> All the studies assessed the smear layer efficacy, were done by SEM.<sup>17,20,23-25</sup> All the studies have shown better efficacy in smear layer removal than that of the conventional. However, it is to be noted that, none of the system were efficient in removal of smear layer completely. It is also noted that, most of the conventional were equal efficient to that of the activation systems at 1 and 3 mm and at maximum 5 mm, however 5 and above at 8 mm activation systems like Endo Vac and Endo Activator found to be useful than that of the conventional. Agitation of the fluid and forceful flow of the fluid can better penetrate the surface close to the apex and remove the smear layer.<sup>6</sup>

With the antibacterial efficacy and smear layer removal, the extrusion of irrigant beyond the root canal is considered to be one of the unwanted effects of these systems. It is essential to know the extrusion of the irrigant out of the root canal as not an expected effect, despite the system may show better result with the smear layer removal or antibacterial efficacy. Though it was not in the aim of the study, these effects were noted in the selected study. In general, it has been found that curved canals extrude less irrigant while canals with resorption extrude more. Syringe

and slotted needles extrude the maximum amount of irrigant, may be due multi-slotted and not a regulated flow.<sup>27</sup> Endo Vac generally has been shown to extrude the least and prevent vapour lock.<sup>28</sup> Sonic system extrudes less than syringe with side port needle or PUI with continuous flow.<sup>29,30</sup> Endo Vac and Endo Activator were comparable in irrigant extrusion and were significantly lower than conventional.<sup>31</sup> With all the above findings, it was found that ultrasonic was found to be the best in efficiency and safety. Thus, it is clear that with the above result, both Endo Vac and Endo Activator extrude less amount of irrigant out of the root canal and also efficient in smear layer removal and its antibacterial efficiency.

In the present study, we have included one study Er, Cr: YSGG laser activated system. It was shown that, Er, Cr: YSGG LAI improves the antimicrobial efficacy of 0.5% NaOCl against 10-day-old *E. faecalis* biofilms. Though this is only one study included in this systematic review, it was shown that, Er, Cr: YSGG laser was better than of the PUI system in terms of antibacterial efficacy.<sup>18</sup>

There are several limitations in the present study, though they have used NaOCl as an irrigant, different concentration of solution was used. Thus, the actual effect of device used along with them may not be comparable. Activation time used in the studies varied from 30 seconds to 1 minute or more. Thus, lack of standardisation of this timing may have impact on the studies. Thirdly, the time scheduled for the smear layer removal was varied from studies. This also may have impact on the results of the study.

**Conclusion**

Within the limitation of the systematic review study, it can be concluded that passive ultrasonic irrigation system is better than the conventional irrigation system in terms of antibacterial efficacy and smear layer removal. However, as more studies available in future with more standardised parameters, outcome of review will be more meaningful and valid.

<i>Abbreviations</i>	
PUI	Passive ultrasonic irrigation
EDTA	Ethylenediaminetetraacetic acid
NaOCl	Sodium hypochlorite
CHX	Chlorohexidine
PCR	Polymerase chain reduction
CSI	Conventional syringe irrigation
LPS	Lipopolysaccharides
LTA	Lipoteichoic acid
LAI	Laser activation irrigation
LAL	Limulus amoebocyte lysate
ELISA	Enzyme-linked immunosorbent assay
EC	Easy clean tip
SI	Syringe irrigation
CUI	Continuous ultrasonic irrigation
UAI	Ultrasonically activated irrigation
SEM	Scanning electron microscopy
WA	without activation
EA	EndoActivator
ED	EDDY

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