Effect of Different Irrigation Devices on Removal of Smear Layer - A Systematic Review

Sagar Borse¹, Anita Sanap¹, Vini Mehta², Nikhil Borse¹, Swapnil Bhosale¹, Piyush Oswal¹

ABSTRACT

Introduction: Various irrigation activation methods have been developed in order to provide effective delivery of irrigant. Effective irrigant delivery and agitation are prerequisites to promote root canal disinfection and debris removal from inaccessible areas and improve successful endodontic treatment. Objective: The aim of present review is to compare the effectiveness of different irrigation devices in removal of smear layer in an in vitro study design.

Material and methods: MEDLINE, the Cochrane library, Google Scholar and major journals were searched for studies from January 2005 to December 2015 to identify appropriate articles. A comprehensive search was designed, and the articles were independently screened for eligibility by two reviewers. In vitro studies done on human extracted teeth evaluating removal of smear layer using different irradiating devices and using Scanning Electron Microscope (SEM) were included

Results: Total 142 articles were searched out of which 66 articles were selected after reading title and abstract. As a second step, full text papers were obtained. Finally a total of 16 articles were included after reading and evaluating full text papers, out of which 5 articles were excluded on basis of insufficient data and 11 articles were selected for final synthesis. Most of the articles supported machine assisted irradiation devices for removal of smear layer which can improve root canal therapy.

Conclusion: Machine assisted irrigation devices performed well in removal of smear layer.

Keywords: Irrigation Devices, Smear Layer Removal, SEM

INTRODUCTION

The micro-organisms play important role in the pathogenesis of pulp and periapical diseases.¹ The success of endodontic therapy depends on disinfection of the entire root canal system, which requires elimination of microorganisms and their byproducts and prevention of its re-infection. The disinfection of root canal is achieved by mechanical preparation along with the irrigating solutions.²

All instrumentation systems as well as rotary systems are ineffective in cleaning and shaping of all surfaces and irregularities within the canal system.³ As they only clean central body of the canal, rest of the canal structures like lateral and accessory canals, canal fins, isthmi, and cul-de-sacs are untouched after completion of the preparation.⁴ Additionally; instrumentation produces a 1 to 5µm-thick smear layer that can block dentinal tubules from irrigant and sealer penetration.⁵

Mechanical instrumentation that leads to the formation of tissue debris and smear layer formation gives favorable environment for microorganisms to grow and disrupt the seal between the material and canal walls. Direct contact of irrigating solution with the entire canal wall surfaces is necessary for effective action particularly for the apical portions of small root canals⁶ and it was stated that enhancement of the flushing action is necessary to improve root canal cleanliness.⁷

Various irrigation activation methods have been developed in order to provide effective delivery of irrigant. Effective irrigant delivery and agitation are prerequisites to promote root canal disinfection and debris removal from inaccessible areas and improve successful endodontic treatment Irritant volume and fluid flow dynamics are important factors that affect canal debridement.

So to achieve goal of irrigation various irrigation activation based on different working principles like positive pressure agitation, Negative pressure agitation, sonic and ultrasonic agitation has been introduced in recent years.

The evaluation of endodontic therapy protocols in terms of smear layer removal during chemico-mechanical disinfection is essential to establish evidence-based guidelines to improve clinical outcomes in endodontics. Previous studies have pointed out the smear layer removal effectiveness of different irrigation devices during root canal treatment. However, no systematic review comparing the effectiveness of these irrigation activation devices during endodontic treatment has been conducted. The aim of this systematic review is to compare effectiveness of different irrigation devices in smear layer removal in an in-vitro study design.

MATERIALS AND METHODOLOGY

The methodology used in this systematic review includes

1 a literature search strategy,
2 selection criteria,
3 screening and data extraction.

The PRISMA (preferred reporting items for systematic reviews and meta-analyses) was followed in this systematic review.⁸

PICO

P - Participants: Extracted human teeth.
I - Intervention: Irrigation devices
C – Comparison: In between different irrigation devices
O – Outcomes: Removal of Smear layer

Literature search strategy

The search strategy covered electronic databases and the reference

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lists of such articles identified and published from January 2005 to December 2015. The electronic databases searched were the following: PubMed (MEDLINE), Cochrane library and Google Scholar. The following combination of key words were used: Irrigation devices AND smear layer removal AND scanning electron microscopy (SEM).

**Inclusion criteria**
1. Articles in English or those having detailed summary in English
2. In-vitro studies done on human extracted teeth.

**Exclusion criteria:**
Reviews, case reports, abstracts, letters to editors, editorials were excluded.

**Screening and data extraction**
Initially, potential relevant publications involving endodontic irrigants were retrieved independently by two reviewers (SB and AS). All articles were screened for eligibility criteria. Any disagreements were resolved by consensus after discussion with a third reviewer (VM). The extraction of information from studies were conducted by the same reviewers.

**RESULTS**
The results of the search strategy are presented in table 1. Figure 1 represent flow chart of systematic review process. Preliminary screening consisted total 142 articles out of which 66 articles were selected. For full-text screening, the following criteria were taken into consideration: In-vitro studies done on human extracted teeth in which smear layer removal evaluation was done using scanning electron microscopy (SEM) by using different irrigation devices. Finally a total of sixteen articles were included out of which eleven articles was finally synthesized in this systematic review.

**DISCUSSION**
The success of endodontic therapy depends on the substantial removal of vital and necrotic tissues, microorganisms, and their products from the root canal system. Chemo-mechanical debridement combining mechanical instrumentation with chemical irrigants can promote an adequate disinfection of the root canal systems during the endodontic treatment. This is probably because of the significant reduction of intra canal microorganisms and necrotic tissues. As a limitation of all instrumentation technique to clean only main central canal, the un-instrumented areas like lateral canal, accessory canals, fins, apical deltas and ramifications remains infected, the disinfection in these areas can be achieved through chemical irrigation solution, but its accesses is affected by many factors like presence of smear layer, vapour lock effect, narrower diameter of the apical portion of canal. Traditional techniques of syringe irrigation fails to achieve the goal of disinfection. So to increase efficacy of irrigation solution various irrigation activation devices has been introduced recently. They increases the efficacy, contact area and contact time of irrigating solution with root canal wall promoting it into inaccessible areas and achieving disinfection.

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Search strategy</th>
<th>Number of articles</th>
<th>Number of selected articles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Irrigation devices AND smear layer removal AND SEM</td>
<td>46</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Irrigation devices AND debris removal AND SEM</td>
<td>23</td>
<td>12</td>
</tr>
<tr>
<td>3</td>
<td>Irrigation system AND smear layer removal AND SEM</td>
<td>13</td>
<td>12</td>
</tr>
<tr>
<td>4</td>
<td>Irrigation system AND debris removal AND SEM</td>
<td>16</td>
<td>9</td>
</tr>
<tr>
<td>5</td>
<td>Irrigation activation system AND smear layer removal AND SEM</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>Irrigation activation system AND debris layer removal AND SEM</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>Irrigation activation devices AND root canal debridement OR root canal cleansing AND SEM</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>8</td>
<td>Irrigation activation devices AND root canal debridement OR root canal cleansing AND SEM</td>
<td>12</td>
<td>6</td>
</tr>
<tr>
<td>9</td>
<td>Irrigation activation techniques AND smear layer removal AND SEM</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>142</td>
<td>66</td>
</tr>
</tbody>
</table>

Table-1: Detailed Search Strategy and Keywords

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Figure 1: Flowchart summarizing the article selection process
<table>
<thead>
<tr>
<th>Author and Year</th>
<th>Sample size</th>
<th>No. of Groups</th>
<th>Irrigation devices</th>
<th>Groups</th>
<th>Irrigants Used</th>
<th>SEM Magnification</th>
<th>SEM Results</th>
<th>Results</th>
</tr>
</thead>
</table>
| Ghivari S. Kubasad G. and 2011 | 30          | 3             | Syringe            | i. Navitip FX, ii. Side vented needle, iii. single beveled needle     | 1 ml of 5.25% NaOCl in between instrumentation and 1 ml of 5.25% NaOCl as final wash | 30X and 200X      | 1. Apical 3.60±0.16 Middle: 2.04±0.16 Coronal 1.40±0.16  
ii. Apical 3.60±0.16 Middle: 1.70±0.15 Coronal 2.50±0.16  
iii. Apical 3.70±0.15 Middle: 2.30±0.26 Apical 2.60±0.26 | The brush covered needle: coronal third, side vented needle: middle third and single beveled needle failed to remove from any part |
| Bolhari B and 2014    | 60          | 3             | Lasers             | 1. NaOCl + EDTA  
2. Er,Cr:YSGG laser 1.5 W  
3. Er,Cr:YSGG laser 2.5W  
4. Positive Control Group |  
2. Coronal-15 middle-15 apical-15  
3. Coronal-15 middle-15 apical-15  
4. Coronal-0 middle-0 apical-0. | Treatment with Er,Cr:YSGG laser showed a similar degree of effectiveness in smear layer removal to that of conventional EDTA and NaOCl |
| Zhu X. and 2013       | 48          | 5             | PIPS               | 1. Normal Saline  
2. NaOCl  
3. NaOCL + EDTA  
4. EDTA |  
300X  
5000X | Coronal 3.75±0.46 Middle 4.00±0.54 Apical 4.38±0.52 Overall 4.04±0.55  
Coronal 2.75±0.46 Middle 3.25±0.46 Apical 3.88±0.83 Overall 3.29±0.75  
Coronal 1.75±0.46 Middle 2.13±0.35 Apical 3.63±0.52 Overall 2.50±0.93  
Coronal 2.63±0.52 Middle 3.25±0.46 Apical 3.63±0.52 Overall 3.17±0.64 | PIPS-aided irrigation and syringe irrigation with NaOCl + EDTA can remove smear layer in coronal and middle thirds of single-rooted teeth, but cannot remove smear layer in the apical third |

Table-2: Overview of Included Studies
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size</th>
<th>Irrigation Method</th>
<th>Control</th>
<th>Concentration</th>
<th>Magnification</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agarwal V. and 2011</td>
<td>36</td>
<td>Syringe and Ultrasonic</td>
<td>Hypodermic needle (control)</td>
<td>Normal saline 1% NaOCl 2.5% NaOCl</td>
<td>2000X</td>
<td>Apical 2.44</td>
</tr>
<tr>
<td>Gade V. and 2013</td>
<td>20</td>
<td>Syringe and negative pressure</td>
<td>Side Vented needle</td>
<td>2.5%NaOCl 17% EDTA</td>
<td>2000X</td>
<td>Apical 1.89</td>
</tr>
<tr>
<td>Salman M.I. and 2010</td>
<td>50</td>
<td>Syringe and sonicare brush</td>
<td>Syringe 2.Syringe 3.Syringe 4.Syringe 5.Sonicare</td>
<td>1.2mL of sterile water 2.2mL of 2.5% NaOCL 3.2mL of 2.5% NaOCL and final rinse with 17% EDTA for 60 sec. 4.2mL of 2.5% NaOCL and final rinse with 17% EDTA for 90 sec. 5.2mL of 2.5% NaOCL and final rinse with 17% EDTA for 90 sec. 200X and 1000X</td>
<td>4</td>
<td>30 s of passive agitation of 17% EDTA + Sonicare CanalBrush resulted in debris removal and smear layer reduction</td>
</tr>
</tbody>
</table>

Table-2: Overview of Included Studies
**Table 2: Overview of Included Studies**

<table>
<thead>
<tr>
<th>Study</th>
<th>Equipment</th>
<th>Protocol</th>
<th>Concentration</th>
<th>Magnification</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vivan R.R. and 2010</td>
<td>RinseEndo system</td>
<td>Saline</td>
<td></td>
<td>1000X and 2000X</td>
<td>Comparison between RinseEndo system and irrigation in the cleaning ability of root canal walls.</td>
</tr>
<tr>
<td>Garip Y. and 2010</td>
<td>Canal brush and Endovac</td>
<td>1% NaOCl and 17% EDTA</td>
<td></td>
<td>35X and 1000X</td>
<td>Irrigation with brushing tended to produce cleaner canal walls.</td>
</tr>
<tr>
<td>Silva D.H.D and 2015</td>
<td>Max I probe and Endovac</td>
<td>NaOCl + EDTA</td>
<td></td>
<td></td>
<td>Machine-assisted irrigation devices and activation of irrigant resulted in better irrigation at the apical third level in both quantity and quality.</td>
</tr>
</tbody>
</table>

*PUI= Passive ultrasonic irrigation, SEM = Scanning electron microscope, NaOCl= Sodium hypochlorite, CHX= Chlorhexidine, PIPS= Photon induced photoacoustic, EDTA= Ethylenediaminetetraacetic acid.*
Irrigation activation devices based on various principles like positive pressure, apical negative pressure, sonic and ultrasonic and lasers are reported in literature. The 11 studies included in this review have compared irrigation devices based on various principles with conventional needle. Out of 11 articles included in this study only 1 article has compared different irrigating needles, other article compared Rinse-Endo system and rest 10 articles have compared irrigation activation devices with conventional needle irrigation. 10 articles have compared efficacy of different irrigation activation devices with conventional needle additionally they have used different concentrations of sodium hypochlorite and the ethylene diamide tetraacitic acid as irrigating solution. The sodium hypochlorite and EDTA helps in removal of smear layer are better than normal saline and showing better result compared with saline.

Out of 11 articles selected for this systematic review 3 articles compared EndoVac irrigation system with side vented needle in one study and used 2.5% NaOCL and 17% EDTA as irrigating solution and concluded that EndoVac system is better in all the aspect when compared to conventional needle irrigation, in another study using Endovac compared with canal brush and conventional syringe as control group and used 1% NaOCL and 17% EDTA as irrigating solution and they also concluded that Endovac is better as compared to canal brush and conventional needle irrigation, one more study included Endovac and compared it with Max-I probe, Endoactivator and conventional needle as control group and using NaOCL and EDTA and they concluded that EndoVac and Endoactivator performed much better than conventional needle and Max-I probe. So machine assisted irrigation systems performed much better than conventional needle.

EndoVac showed better result as compared to other irrigating devices because of negative pressure it creates in the canal, which takes the irrigant to the full Working Length. As irrigant comes in direct contact with the entire dentinal walls, the results are in support of the literature and research showing the maximum efficacy of EndoVac.

Passive ultrasonic irrigation was mentioned in 1 article out of 11 articles selected for this study and they compared passive ultrasonic irrigation with conventional syringe irrigation using different concentrations (1% and 2.5%) of NaOCL. The mechanisms of acoustic streaming and cavitation was the rapid movement of particles of fluid in a vortex-like motion around a vibrating object. The fluid transportation from the apical to the coronal end, at a rate of a few centimetres per second, results in hydrodynamic shear stresses around the file and disrupts most biological material is the main reason for effectiveness of passive ultrasonic devices. So study concluded From the outcome of the present study it can be suggested that PUI with 1% NaOCl is more effective in removal of debris from the root canal system than syringe irrigation with a higher concentration of 2.5% NaOCL. Hence 1% NaOCl, which is more biocompatible.

Sonic irrigation activation was used in one study and they compared EndoActivator and Max-I-Probe with endovac and conventional needle irrigation and used NaOCL and EDTA as irrigating solution and they concluded that endoactivator and endovac are more effective in cleaning the canal compared to max I probe and conventional needle.

Lasers were compared in 2 articles out of which one article compared PIPS irrigation activation which uses Er:YAG laser with conventional needle irrigation using different irrigating solutions combination using NaOCL, EDTA, NaOCL+EDTA and CHX and concluded that no significant difference was found between PIPS and conventional needle irrigation. Another study compared Er, Cr:YSGG laser different power output with conventional needle irrigation also they used NaOCL+EDTA for conventional group and saline for laser group and they concluded that conventional needle irrigation was better than Er, Cr: YSGG laser at any output used. One last study compared Er:YAG laser with different time interval (20sec and 40 sec) and 17% EDTA and they concluded that Er:YAG laser was better than conventional needle irrigation.

Other than these devises used 3 articles compared canal brush devices, out of which 2 articles compared canal brush with conventional needle irrigation and they both concluded that canal brush was more effective than conventional needle irrigation. And 19 article compared canal brush with EndoVac and conventional needle in which they concluded that canal brush and conventional needle was not effective.

Out of 11 articles selected for this review only 1 article compared different types of irrigation needles like brush covered needle and side vented needle with conventional needle and they concluded that brush covered and side vented needle were effective as compared to conventional needle.

**Limitations**

Studies included in this systematic review evaluated smear layer removal using different irrigating devices should have followed same scoring criteria for SEM scores evaluation to give conclusive evidence.

**Implication for future research**

Further in vitro study required with larger sample size for better comparisons. The scoring criteria’s used for evaluation of smear layer removal for scanning electron microscopy should be standardized.

**CONCLUSION**

Effective irrigant delivery and agitation leading to effective cleanliness are prerequisites for successful endodontic treatment. This systematic review presents an overview of the irrigant agitation methods currently available and their debridement efficacy. So on the basis of data available in this systematic review it can be concluded that machine assisted irrigation devices are more effective in removal of smear layer and can improve success of root canal therapy.

**REFERENCES**

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