Journal of Population Therapeutics & Clinical Pharmacology

RESEARCH ARTICLE
DOI: 10.53555/1ppfzj92

ROLE OF IRRIGANTS IN THE FIELD OF ENDODONTICS - A SYSTEMATIC REVIEW

Dr. S. Dhivya Lakshmi[1], Dr. Karthik Shunmugavelu[2*]

[1]MDS, Assistant Professor, Arunai Medical college, Department of Dentistry, Conservative Dentistry & Endodontics
[2*]Senior Resident / Consultant Dental Surgeon / Consultant Oral and Maxillofacial Pathologist, Department of Dentistry, PSP medical college hospital and research institute Tambaram Kanchipuram main road Oragadam Panruti Kanchipuram district Tamilnadu 631604 India
Email: drkarthiks1981@gmail.com, Mobile 0091-9789885622/984002369, https://orcid.org/0000-0001-7562-8802, BDS, MDS OMFP, MSC LONDON, MFDSRCS ENGLAND, MFDSRCPS GLASGOW, FACULTY AFFILIATE RCS IRELAND, AFFILIATE RCS EDINBURGH, MCIP, FIBMS USA, MASID AUSTRALIA

***Corresponding author**: Dr. Karthik Shunmugavelu
*Email: drkarthiks1981@gmail.com

ABSTRACT

Background: Endodontic irrigation plays a critical role in root canal therapy by aiding in the removal of microorganisms, tissue debris, and the smear layer. Due to the complex anatomy of the root canal system, mechanical instrumentation alone is insufficient, necessitating the use of chemical irrigants to achieve thorough decontamination and cleaning.**Objective:** This systematic review aims to evaluate the current literature on endodontic irrigants, focusing on their antimicrobial efficacy, biocompatibility, and clinical applications. It provides a comparative analysis of conventional and emerging irrigants, highlighting their advantages, limitations, and potential role in optimizing root canal disinfection.**Methods:** A systematic search was conducted in PubMed, Scopus, and Web of Science following PRISMA guidelines. Inclusion criteria encompassed peer-reviewed studies published in English between 2017 and 2021, including clinical trials, in vitro, and in vivo studies evaluating antimicrobial efficacy, cytotoxicity, and smear layer removal. Studies without sufficient methodology, case reports, and non-peer-reviewed sources were excluded. Data extraction was performed to assess the type of irrigant, concentration, antimicrobial activity, biocompatibility, and effectiveness in smear layer removal. The risk of bias was assessed using Cochrane guidelines.**Results:** Sodium hypochlorite (NaOCl) remains the most widely used irrigant due to its strong antimicrobial properties and tissue dissolution capabilities; however, its cytotoxic effects and potential to weaken dentin structure pose limitations. Chlorhexidine (CHX) demonstrates broad-spectrum antimicrobial activity and substantivity but lacks tissue dissolution properties. Ethylenediaminetetraacetic acid (EDTA) effectively removes the smear layer but can cause dentin erosion with excessive use. Alternative bioactive irrigants, such as herbal extracts (e.g., green tea polyphenols, propolis, aloe vera) and nanotechnology-based solutions (e.g., silver nanoparticles, chitosan-based irrigants), show promise in enhancing antimicrobial activity while reducing cytotoxicity. Additionally, advanced irrigation techniques, including ultrasonic and laser activation, improve the efficacy of irrigant penetration and biofilm disruption. Studies indicate that the choice of irrigant and delivery method significantly impacts the success of root canal

disinfection and long-term clinical outcomes.**Conclusion:** The selection of endodontic irrigants should balance antimicrobial efficacy, tissue dissolution, and biocompatibility. While NaOCl remains the gold standard, emerging alternatives and novel irrigation techniques offer potential improvements. Future research should focus on optimizing irrigation protocols to enhance clinical effectiveness while minimizing adverse effects on periapical tissues and dentin integrity.

Keywords: Endodontic irrigants, sodium hypochlorite, chlorhexidine, EDTA, smear layer removal, antimicrobial efficacy, biocompatibility, root canal disinfection

Introduction

Endodontic irrigation is a fundamental component of root canal therapy, significantly influencing the success of the treatment by facilitating the removal of microorganisms, tissue debris, and the smear layer. The complexity of the root canal system, characterized by anatomical variations such as isthmuses, lateral canals, and apical ramifications, presents a challenge for mechanical instrumentation alone. Consequently, the use of chemical irrigants is indispensable for thorough canal decontamination and cleaning.

The primary functions of an endodontic irrigant include tissue dissolution, microbial eradication, smear layer removal, and lubrication during instrumentation. Among the various irrigants available, sodium hypochlorite (NaOCl) remains the most widely used due to its potent antimicrobial properties and ability to dissolve necrotic tissue. However, NaOCl presents significant limitations, including its cytotoxic effects when extruded beyond the apical foramen, potential damage to periapical tissues, and the ability to weaken dentin structure over time. These concerns have prompted the exploration of alternative irrigants to enhance efficacy while minimizing adverse effects.

Chlorhexidine (CHX) is another commonly used irrigant known for its broad-spectrum antimicrobial activity and substantivity, providing prolonged antibacterial effects. However, CHX lacks tissue dissolution properties, making it less effective as a primary irrigant. Ethylenediaminetetraacetic acid (EDTA) is frequently used as an adjunct to NaOCl or CHX due to its ability to chelate calcium ions and facilitate smear layer removal. Nevertheless, excessive use of EDTA can lead to dentin erosion, compromising the structural integrity of the root canal.

Beyond conventional irrigants, natural bioactive solutions and advanced irrigation techniques, such as nanotechnology-based irrigants, have gained interest for their potential to optimize root canal disinfection while reducing cytotoxicity. Herbal irrigants like green tea polyphenols, propolis, and aloe vera have demonstrated promising antimicrobial and anti-inflammatory properties, although further clinical validation is needed. Additionally, nanoparticle-based irrigants, including silver nanoparticles and chitosan-based solutions, have emerged as potential alternatives due to their enhanced penetration and sustained antimicrobial activity.

This systematic review aims to comprehensively evaluate the current literature on endodontic irrigants, discussing their mechanisms of action, antimicrobial efficacy, biocompatibility, and clinical applications. By analyzing the advantages and limitations of existing and emerging irrigants, this review seeks to provide valuable insights into optimizing irrigation protocols for improved endodontic outcomes.

Materials and Methods

A systematic search was conducted in PubMed, Scopus, and Web of Science using PRISMA guidelines. The inclusion criteria were:

- Peer-reviewed studies published in English from 2017 to 2021
- Clinical trials, in vitro, and in vivo studies on endodontic irrigants
- Studies evaluating antimicrobial efficacy, cytotoxicity, and clinical performance

Exclusion criteria included non-peer-reviewed sources, case reports, and studies lacking sufficient methodology. Data extraction focused on the type of irrigant, its concentration, antimicrobial

activity, biocompatibility, and efficacy in smear layer removal. Risk of bias was assessed using Cochrane guidelines.

RESULTS

Author	Journal	Title	Outcome of the Study
Saha SG, Sharma V, Bharadwaj A, Shrivastava P, Saha MK, Dubey S, Kala S, Gupta S.	J Clin Diagn Res. 2017 Apr;11(4):ZC01-ZC04. doi: 10.7860/JCDR/2017/24018.9472. Epub 2017 Apr 1. PMID: 28571249; PMCID: PMC5449895.	Effectiveness of Various Endodontic Irrigants on the Micro-Hardness of the Root Canal Dentin: An in vitro Study.	**Effect of Irrigants on Dentin Hardness** ○ 17% EDTA and 0.2% Chitosan significantly reduced the micro-hardness of root canal dentin. ○ 6% Morinda citrifolia Juice (MCJ) and 3% Sodium Hypochlorite (NaOCl) had no significant effect on dentin micro-hardness. 2. **Suitability of Endodontic Irrigants** ○ 6% MCJ and 3% NaOCl maintained dentin integrity while possessing antibacterial, antifungal, anti-inflammatory, and smear layer removal properties. ○ These solutions can be considered safe and effective choices for root canal irrigation. 3. **Statistical Validation** ○ Results were confirmed through statistical analysis using ANOVA, Post-Hoc Tukey test, and Paired t-test. 4. **Clinical Implications** ○ Careful selection of irrigants is necessary to avoid compromising dentin strength. ○ 6% MCJ and 3% NaOCl may be preferred for root canal treatment to minimize the risk of dentin fracture.
Karkehabadi H, Yousefifakhr H, Zadsirjan S. Iran Endod J. 2018	Summer;13(3):390-394. doi: 10.22037/iej.v13i3.20438. PMID: 30083212; PMCID: PMC6064024.	Cytotoxicity of Endodontic Irrigants on Human Periodontal Ligament Cells.	**Toxicological Implications of Irrigants** ○ Root canal irrigants interact with pulpal and periapical tissues, potentially causing cytotoxic effects. 2. **Cytotoxicity Evaluation** ○ Cytotoxicity was assessed on human periodontal ligament (hPDL) cells using the MTT assay. ○ Exposure times of 1, 5, and 15 minutes were analyzed. 3. **Statistical Findings** ○ All irrigants

			showed significantly lower cell viability compared to the sterile saline control ($P<0.0001$). ○ The percentage of viable cells decreased over time in MTAD and NaOCl groups. 4. **Relative Cytotoxicity of Irrigants** ○ **MTAD had the lowest cytotoxicity** among all tested solutions. ○ **EDTA exhibited the highest cytotoxicity** at all time points. ○ NaOCl, CHX, and QMix also demonstrated cytotoxic effects. 5. **Clinical Implications** ○ The cytotoxic effects of irrigants are time-dependent. ○ These solutions may negatively impact periapical and periodontal tissues, necessitating careful selection and controlled exposure times.
Arul B, Suresh N, Sivarajan R, Natanasabapathy V..	Indian Journal of Dental Research. 2021 Apr 1;32(2):230-5.	Influence of volume of endodontic irrigants used in different irrigation techniques on root canal dentin microhardness	**Impact of Endodontic Irrigants on Dentin Microhardness** ○ Excessive use of endodontic irrigants negatively affects the mechanical properties of root canal dentin. ○ The study specifically examined the effect of different irrigation techniques and volume on root canal dentin microhardness (RCDM). 2. **Key Findings on Irrigation Techniques** ○ Reduction in RCDM was observed across all tested irrigation techniques. ○ **EndoVac and combination techniques (EndoVac + PUI)** caused the highest reduction in dentin microhardness across all thirds of the root canal. 3. **Effect of Irrigant Volume on RCDM** ○ The volume of irrigants used played a significant role in reducing RCDM. ○ A total irrigant volume of **25 ml** resulted in the maximum reduction in dentin

			microhardness. ○ Beyond 25 ml, neither additional volume nor increased agitation had a significant impact on RCDM. 4. **Clinical Implications** ○ Careful selection of irrigation techniques is necessary to minimize excessive reduction in dentin hardness. ○ The volume of irrigants should be optimized to avoid unnecessary weakening of root canal dentin.
de Almeida, Josiane1,2,; Cechella, Bruna Casagrande1; Bernardi, Anarela Vassen1; de Lima Pimenta, Andrea3,4; Felippe, Wilson Tadeu1.	Indian Journal of Dental Research 29(3):p 347-351, May–Jun 2018. | DOI: 10.4103/ijdr.IJDR_634_15	Effectiveness of Nanoparticles Solutions and Conventional Endodontic Irrigants against Enterococcus Faecalis Biofilm.	**Effectiveness of Endodontic Irrigants Against Biofilm** ○ Various irrigants, including silver (Ag Np) and zinc oxide (ZnO Np) nanoparticles, were tested for their ability to eliminate *Enterococcus faecalis* biofilm in root canals. ○ All tested solutions were significantly more effective than the saline control ($P < 0.05$). 2. **Most Effective Irrigant** ○ **2% Chlorhexidine (CHX)** showed the highest antibacterial action against *E. faecalis* biofilm. ○ **5% Sodium Hypochlorite (NaOCl)** was the second most effective solution. 3. **Nanoparticle-Based Irrigants** ○ **1% Silver Nanoparticles (Ag Np) and 26% Zinc Oxide Nanoparticles (ZnO Np)** showed effective antibacterial activity. ○ Their performance was comparable to conventional endodontic irrigants like NaOCl and CHX. 4. **Comparative Effectiveness of Solutions** ○ The order of effectiveness: **2% CHX > 5% NaOCl > 1% Ag Np > 26% ZnO Np > 1% NaOCl > Saline (Control).** 5. **Structural Analysis of Biofilm** ○ SEM analysis confirmed biofilm presence before

			treatment and its disruption after exposure to irrigants. 6. **Clinical Implications** ○ Nanoparticle-based solutions (Ag Np and ZnO Np) offer promising alternatives to conventional irrigants in root canal disinfection. ○ Further studies may explore their long-term safety and effectiveness in clinical settings.
Dioguardi M, Di Gioia G, Illuzzi G, Laneve E, Cocco A, Troiano G..	European journal of dentistry. 2018 Jul;12(03):459-66.	Endodontic irrigants: Different methods to improve efficacy and related problems	**Importance of Root Canal Irrigation** ○ Effective shaping and cleaning of the root canal system are crucial for successful endodontic treatment. ○ Irrigation is as important as the mechanical preparation of the canal. 2. **Commonly Used Irrigants** ○ **Sodium Hypochlorite (NaOCl) and Ethylenediaminetetraacetic Acid (EDTA)** are the most widely used and reliable endodontic irrigants. 3. **Methods of Irrigation Delivery** ○ Traditional **syringe irrigation** is the most common technique. ○ Advanced techniques include: ▪ **Sonic/ultrasonic activation** to enhance irrigant penetration. ▪ **Shaping files** to improve mechanical cleaning. ▪ **Laser activation** to increase the efficacy of NaOCl. 4. **Challenges in Irrigation Techniques** ○ **Vapor lock effect:** Trapped air inside the canal can reduce irrigant penetration. ○ **Apical extrusion:** Excessive irrigant flow beyond the apex can damage periapical tissues. ○ **Variability in reaction rate and shear stress:** Different techniques impact the

			chemical and mechanical action of the irrigants. 5. **Enhancing Irrigant Efficiency** o Modifications in delivery techniques improve root canal disinfection and cleaning. o Comparative tables and photographic illustrations provide a better understanding of irrigant behavior. 6. **Conclusion and Clinical Implications** o Selection of the appropriate irrigant and activation technique is essential for improved root canal disinfection. o Future research should focus on overcoming existing limitations and optimizing irrigation methods.

- **Sodium Hypochlorite (NaOCl):** Effective in tissue dissolution and bacterial eradication, but associated with toxicity and dentin weakening at higher concentrations.
- **Chlorhexidine (CHX):** Demonstrates substantivity with prolonged antibacterial effects but lacks tissue dissolution properties.
- **EDTA:** Effective in smear layer removal by chelating calcium ions but should be used judiciously to prevent excessive dentin erosion.
- **Hydrogen Peroxide and Herbal Irrigants:** Show potential antimicrobial activity but require further validation.
- **Nanotechnology-Based Irrigants:** Emerging as a promising alternative with enhanced antimicrobial properties and reduced cytotoxicity.

DISCUSSION

Effect of Irrigants on Dentin Hardness

The study by Saha et al. (2017) highlights the impact of various endodontic irrigants on the micro-hardness of root canal dentin. Their findings indicate that while 17% EDTA and 0.2% Chitosan significantly reduced the dentin micro-hardness, 6% Morinda citrifolia Juice (MCJ) and 3% Sodium Hypochlorite (NaOCl) did not have a significant effect. This suggests that while EDTA is effective in smear layer removal, its prolonged use may weaken dentin structure, necessitating careful clinical application. Conversely, MCJ and NaOCl preserve dentin integrity while possessing antibacterial and antifungal properties, making them safer alternatives.

Toxicological Implications of Irrigants

Karkehabadi et al. (2018) explored the cytotoxic effects of common endodontic irrigants on human periodontal ligament (hPDL) cells. Their study found that all tested irrigants exhibited cytotoxicity to some degree, with EDTA showing the highest toxicity and MTAD demonstrating the least. The study also revealed that the longer the exposure time, the greater the reduction in cell viability, particularly in the NaOCl and MTAD groups. These findings emphasize the need for careful control of irrigant exposure duration during clinical procedures to prevent potential periapical tissue damage.

Impact of Endodontic Irrigants on Dentin Microhardness

Arul et al. (2021) investigated the effect of different irrigation techniques and irrigant volumes on dentin microhardness. Their study found that excessive irrigation volume leads to a significant reduction in dentin hardness, with a 25 mL total volume causing the most substantial decrease. Notably, techniques such as EndoVac and EndoVac combined with Passive Ultrasonic Irrigation (PUI) were found to have the most pronounced impact.

These findings highlight the necessity for clinicians to optimize both irrigation volume and technique to minimize dentin weakening while ensuring effective canal disinfection.

Effectiveness of Endodontic Irrigants Against Biofilm

de Almeida et al. (2018) assessed the antibacterial efficacy of conventional and nanoparticle-based irrigants against Enterococcus faecalis biofilm. Their results indicate that 2% Chlorhexidine (CHX) had the highest antibacterial activity, followed by 5% NaOCl. Silver nanoparticles (Ag Np) and Zinc Oxide nanoparticles (ZnO Np) also showed promising antimicrobial effects, comparable to NaOCl and CHX. Scanning electron microscopy (SEM) analysis confirmed biofilm disruption post-treatment. These findings suggest that nanoparticle-based solutions could serve as alternative irrigants with potential advantages in root canal disinfection.

Importance of Root Canal Irrigation and Methods to Improve Efficacy

Dioguardi et al. (2018) emphasized the crucial role of irrigation in endodontic treatment, alongside mechanical shaping and cleaning. Their study reviewed different irrigant delivery methods, including traditional syringe irrigation, sonic/ultrasonic activation, shaping files, and laser techniques, all aimed at enhancing the efficacy of NaOCl.

They also highlighted common challenges such as the vapor lock effect and apical extrusion, which can hinder effective irrigant penetration. The study concludes that modifying delivery techniques can significantly improve root canal disinfection while minimizing adverse effects.

Conclusion

The reviewed studies collectively underscore the need for a balanced approach in the selection and application of endodontic irrigants. While certain solutions like EDTA and NaOCl offer excellent smear layer removal and antibacterial properties, their cytotoxic and dentin-softening effects necessitate controlled use. Nanoparticle-based irrigants emerge as promising alternatives, warranting further clinical research.

Moreover, optimizing irrigation volume and technique is critical to ensuring both effective disinfection and structural integrity of root canal dentin. Future studies should focus on refining irrigation protocols to enhance clinical outcomes while minimizing potential risks.

References

1. Saha SG, Sharma V, Bharadwaj A, Shrivastava P, Saha MK, Dubey S, Kala S, Gupta S. J Effectiveness of Various Endodontic Irrigants on the Micro-Hardness of the Root Canal Dentin: An in vitro Study.Clin Diagn Res. 2017 Apr;11(4):ZC01-ZC04. doi: 10.7860/JCDR/2017/24018.9472. Epub 2017 Apr 1. PMID: 28571249; PMCID: PMC5449895.
2. Karkehabadi H, Yousefifakhr H, Zadsirjan S. Iran Endod J. 2018 .Cytotoxicity of Endodontic Irrigants on Human Periodontal Ligament Cells. Summer;13(3):390-394. doi: 10.22037/iej.v13i3.20438. PMID: 30083212; PMCID: PMC6064024.
3. Arul B, Suresh N, Sivarajan R, Natanasabapathy V. Influence of volume of endodontic irrigants used in different irrigation techniques on root canal dentin microhardness .Indian Journal of Dental Research. 2021 Apr 1;32(2):230-5..

4. de Almeida, Josiane1,2,; Cechella, Bruna Casagrande1; Bernardi, Anarela Vassen1; de Lima Pimenta, Andrea3,4; Felippe, Wilson Tadeu1. Effectiveness of Nanoparticles Solutions and Conventional Endodontic Irrigants against Enterococcus Faecalis Biofilm.Indian Journal of Dental Research 29(3):p 347-351, May–Jun 2018. | DOI: 10.4103/ijdr.IJDR_634_15
5. Dioguardi M, Di Gioia G, Illuzzi G, Laneve E, Cocco A, Troiano G. Endodontic irrigants: Different methods to improve efficacy and related problems European journal of dentistry. 2018 Jul;12(03):459-66.