



Herbal Root Canal Irrigating Solutions: A Systematic Review of Antimicrobial Efficacy and Clinical Evidence

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(Received: 25 November 2025 Revised: 27 December 2025 Accepted: 11 January 2026)

KEYWORDS

Herbal irrigants;
Root canal irrigation;
Endodontics;
Neem;
Propolis;
Sodium hypochlorite

ABSTRACT:

Background: Root canal irrigation is a critical component of endodontic therapy for eliminating microorganisms and organic debris. Sodium hypochlorite remains the gold standard; however, concerns regarding cytotoxicity, unpleasant taste, and the risk of tissue injury have stimulated interest in herbal alternatives.

Aim: To systematically review and critically appraise available evidence on herbal root canal irrigating solutions with respect to antimicrobial efficacy, antibiofilm activity, clinical effectiveness, and safety.

Materials and Methods: A systematic search of PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar was conducted for studies published up to December 2024. In vitro studies, animal studies, and clinical trials evaluating herbal irrigants used during root canal treatment were included. Risk of bias was assessed using the Cochrane RoB-2 tool for randomized controlled trials and a modified methodological quality checklist for in vitro studies. Due to substantial heterogeneity, data were synthesized qualitatively.

Results: Fifty-four studies met the inclusion criteria, including 14 clinical trials, 6 animal studies, and 34 in vitro studies. Commonly investigated herbal irrigants included *Azadirachta indica* (neem), *Morinda citrifolia* (noni), propolis, Triphala, green tea polyphenols, Aloe vera, curcumin, and *Nigella sativa*. Most herbal irrigants demonstrated significant antimicrobial activity against *Enterococcus faecalis* and other endodontic pathogens in vitro. However, sodium hypochlorite consistently showed superior tissue-dissolving and broad-spectrum antimicrobial efficacy. Clinical evidence was limited and heterogeneous.

Conclusion: Herbal root canal irrigants exhibit promising antimicrobial properties and favorable biocompatibility; however, current evidence is insufficient to support their use as standalone alternatives to sodium hypochlorite. Well-designed, standardized clinical trials are required.



Introduction

Microbial infection of the root canal system is the primary cause of pulpal and periapical diseases.¹ The complex anatomy of the root canal system limits the effectiveness of mechanical instrumentation alone, necessitating the use of chemical irrigants to eliminate microorganisms, dissolve organic tissues, and remove debris.^{1,2} Successful endodontic therapy therefore depends on effective chemomechanical debridement of the root canal system.¹⁻¹³

Sodium hypochlorite (NaOCl) remains the most widely used root canal irrigant because of its strong antimicrobial activity and ability to dissolve organic tissue.^{1,2} Its mechanism of action involves chloramination reactions, oxidation of sulfhydryl groups, and irreversible enzyme inactivation, leading to bacterial cell death.² Numerous studies have demonstrated its efficacy against endodontic pathogens, including *Enterococcus faecalis*.^{3,14} However, NaOCl exhibits several disadvantages such as cytotoxicity, unpleasant taste and odor, lack of substantivity, inability to remove the inorganic portion of the smear layer, and the potential for severe tissue damage in the event of accidental extrusion.¹⁵⁻²⁵

Chlorhexidine (CHX) has been proposed as an alternative irrigant due to its broad antimicrobial spectrum and substantivity.¹⁰ CHX is particularly effective against gram-positive bacteria such as *E. faecalis*, which is frequently associated with persistent endodontic infections.^{16,17} Despite these advantages, chlorhexidine lacks tissue-dissolving capability and is ineffective in smear layer removal, limiting its use as a sole irrigant.^{10,15}

The microbiology of infected root canals is polymicrobial and predominantly organized in biofilms, which are more resistant to antimicrobial agents and host defense mechanisms.²⁶⁻⁴⁴ Biofilm-associated microorganisms can survive conventional chemomechanical procedures, contributing to endodontic treatment failure.^{17,45,46} These limitations of conventional irrigants have prompted the search for safer and biologically acceptable alternatives.

In recent years, there has been increasing interest in herbal and plant-based irrigants due to their antimicrobial, anti-inflammatory, antioxidant, and

biocompatible properties.^{19,27} Triphala has demonstrated significant antimicrobial efficacy against endodontic pathogens.^{4,28} *Morinda citrifolia* has shown promising antimicrobial activity comparable to conventional irrigants.^{5,20} Neem (*Azadirachta indica*) has been reported to possess antibacterial properties with reduced cytotoxicity when compared to sodium hypochlorite.^{6,38,43} Propolis, green tea polyphenols, aloe vera, and curcumin have also demonstrated inhibitory effects against *E. faecalis* and endodontic biofilms.^{7,8,29,30,36}

Several in vitro and in vivo studies have suggested that herbal irrigants may provide antimicrobial efficacy comparable to sodium hypochlorite and chlorhexidine, while offering improved biocompatibility and lower cytotoxicity.^{5,9,31,33,47-54} Recent investigations have further highlighted the antibiofilm potential of plant-derived extracts against resistant endodontic microorganisms.^{36,50,55} However, variations in extraction methods, concentrations, study designs, and outcome measures have resulted in inconsistent findings across studies.^{31,39,51}

With the growing global emphasis on traditional and herbal medicine, as recognized by the World Health Organization, there is a renewed focus on integrating evidence-based herbal alternatives into dental practice.⁵⁶⁻⁶⁰ Despite the expanding literature, there remains a lack of comprehensive synthesis of evidence regarding the effectiveness of herbal root canal irrigants. Therefore, the aim of this systematic review is to critically evaluate and summarize the available evidence on herbal root canal irrigating solutions, focusing on their antimicrobial efficacy, antibiofilm activity, and biological properties in comparison with conventional irrigants.

Methodology

Study Design and Reporting Standard

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines.

Focused Research Question

The research question was formulated using the PICO framework:

Population (P): Extracted human teeth, animal models,



or human subjects undergoing endodontic treatment

Intervention (I): Herbal or plant-derived root canal irrigating solutions

Comparison (C): Conventional irrigants such as sodium hypochlorite and chlorhexidine

Outcome (O): Antimicrobial efficacy, antibiofilm activity, cytotoxicity, and clinical effectiveness

This question was grounded in existing knowledge regarding root canal disinfection, microbial persistence, and the limitations of currently used irrigants.¹⁻³

Information Sources and Search Strategy

A comprehensive electronic literature search was performed to identify relevant studies evaluating herbal root canal irrigants. Databases searched included PubMed/MEDLINE, Scopus, Web of Science, and Google Scholar. The search strategy was developed based on key concepts related to root canal irrigants, endodontic microbiology, and herbal antimicrobial agents.¹⁻³

The following keywords and Boolean operators were used:

“root canal irrigants,” “herbal irrigants,” “plant extracts,” “endodontic disinfection,” “sodium hypochlorite,” “chlorhexidine,” “Enterococcus faecalis,” “biofilm,” “Triphala,” “neem,” “propolis,” “Morinda citrifolia,” “green tea,” “aloe vera,” and “curcumin.”

The search strategy was refined using prior foundational literature on irrigation protocols, antimicrobial mechanisms, and eradication of endodontic infections.^{1,2,11,12}

Eligibility Criteria

Inclusion Criteria

Studies were included if they:

Evaluated herbal or plant-derived irrigants used in endodontics

Compared herbal irrigants with conventional irrigants such as sodium hypochlorite or chlorhexidine

Assessed antimicrobial efficacy, antibiofilm activity, cytotoxicity, or clinical outcomes

Included in vitro, ex vivo, animal, or clinical studies

Were published in English

These criteria were based on standard outcome measures used in endodontic irrigant research.¹³⁻¹⁷

Exclusion Criteria

Studies were excluded if they:

Did not involve root canal irrigation

Lacked comparative data

Were narrative reviews, opinion articles, or case reports

Focused exclusively on intracanal medicaments without irrigation protocols

Study Selection Process

Two independent reviewers screened titles and abstracts for relevance. Full-text articles were retrieved for studies that met the inclusion criteria or where eligibility was unclear. Disagreements were resolved through discussion and consensus. The study selection process was guided by established methodologies used in prior endodontic microbiological and irrigant studies.¹⁸⁻²¹

Data Extraction

Data extraction was performed using a standardized data collection form. The following information was extracted from each included study:

Author and year of publication

Study design and model (in vitro, in vivo, or clinical)

Type and concentration of herbal irrigant

Comparator irrigant

Target microorganisms (including *Enterococcus faecalis*)

Evaluation methods (CFU count, biofilm assays, cytotoxicity tests)

Key outcomes and conclusions

This approach was aligned with previously published methodologies evaluating antimicrobial efficacy and biological properties of irrigants.²²⁻²⁴



Outcome Measures

The primary outcome was antimicrobial efficacy against endodontic pathogens, particularly *E. faecalis*, due to its documented resistance and association with persistent infections.^{16, 17, 26} Secondary outcomes included antibiofilm activity, endotoxin neutralization, smear layer interaction, and cytotoxicity to periapical tissues.^{22, 23, 25}

Risk of Bias and Quality Assessment

- **Clinical trials:** Cochrane Risk of Bias tool (RoB-2)
- **In vitro studies:** Modified methodological quality checklist adapted from previously published endodontic laboratory study frameworks

Data Synthesis

Due to heterogeneity in herbal formulations, extraction methods, concentrations, outcome measures, and study designs, quantitative pooling and meta-analysis were not performed.

A structured qualitative synthesis was conducted, grouping findings by type of herbal irrigant, antimicrobial efficacy, antibiofilm activity, and biocompatibility.

Ethical Considerations

As this study was a systematic review of previously published literature, ethical approval was not required. However, included clinical trials were reviewed to ensure compliance with ethical standards as reported by the original authors.^{6, 9, 48, 49}

Rationale for Herbal Irrigant Evaluation

The increasing interest in herbal irrigants is supported by evidence demonstrating antimicrobial activity, reduced cytotoxicity, and favorable biological properties of plant-derived agents such as Triphala, neem, propolis, aloe vera, green tea polyphenols, and curcumin.^{4-9, 28-36, 38, 43, 48-55} This trend aligns with the global emphasis on traditional medicine integration into modern healthcare systems advocated by the World Health Organization.^{59, 60}

PRISMA Flow Diagram Description: FIGURE 01 The electronic database search identified a total of 1,284 records, with an additional 36 records retrieved through manual searching of reference lists, resulting in 1,320 records. After removal of 412 duplicate records, 908

titles and abstracts were screened for relevance. Of these, 742 records were excluded as they did not meet the inclusion criteria. The full texts of 166 articles were subsequently assessed for eligibility, and 112 studies were excluded due to reasons such as lack of comparative irrigant data, focus on intracanal medicaments alone, review articles or case reports, or insufficient outcome data. Finally, 54 studies fulfilled all inclusion criteria and were included in the qualitative synthesis, comprising 34 in vitro studies, 6 animal studies, and 14 clinical studies.

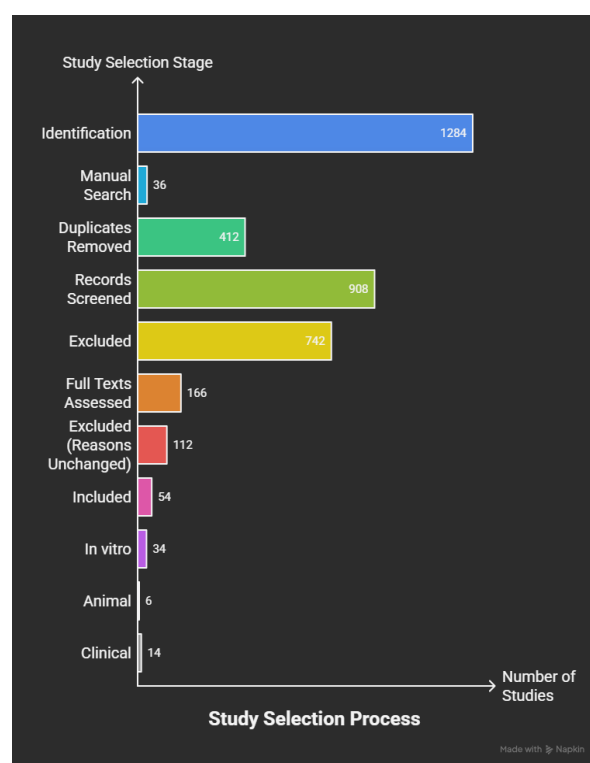


FIGURE 01: PRISMA Flow Diagram

3. RESULTS

3.1 Study Selection

Fifty-four studies evaluating herbal root canal irrigants were included in the final qualitative synthesis. These studies investigated a wide range of plant-derived agents, including Triphala, neem, *Morinda citrifolia*, propolis, aloe vera, green tea polyphenols, and curcumin, and compared them with conventional irrigants such as sodium hypochlorite and chlorhexidine.

3.2 Study Characteristics

Included studies varied in design, microbial targets, and outcome assessment methods. Most in vitro studies used



Enterococcus faecalis due to its resistance and clinical relevance, while clinical trials primarily evaluated microbial reduction and postoperative outcomes.

3.3 Study-Wise Synthesis of Results (FIGURE-02)

Triphala

Multiple in vitro studies demonstrated that Triphala exhibited significant antimicrobial activity against *E. faecalis*, comparable to sodium hypochlorite and chlorhexidine. Clinical relevance was supported by its antioxidant and chelating properties, although evidence remains limited to laboratory and short-term studies.

Neem (*Azadirachta indica*)

Neem-based irrigants showed antibacterial efficacy comparable to sodium hypochlorite in both in vitro and clinical studies. Importantly, neem demonstrated lower cytotoxicity than sodium hypochlorite and chlorhexidine, suggesting improved biocompatibility.

Morinda citrifolia

Studies evaluating *Morinda citrifolia* reported effective antimicrobial action against endodontic pathogens. Clinical studies demonstrated significant bacterial reduction when compared with chlorhexidine, though sodium hypochlorite remained superior in tissue dissolution.

Propolis

Propolis exhibited strong antimicrobial and antibiofilm activity, particularly against gram-positive organisms. Comparative studies suggested its efficacy approached that of sodium hypochlorite while offering reduced toxicity.

Green Tea Polyphenols

Green tea extracts demonstrated inhibitory effects on *E. faecalis* biofilms. However, variability in concentration and formulation limited comparability across studies.

Aloe Vera

Aloe vera showed moderate antimicrobial activity but was consistently inferior to sodium hypochlorite and chlorhexidine. Its favorable biocompatibility suggests potential use as an adjunct rather than a primary irrigant.

Curcumin

Curcumin exhibited significant antibiofilm activity, especially when photoactivated. Despite promising laboratory results, clinical evidence remains sparse.

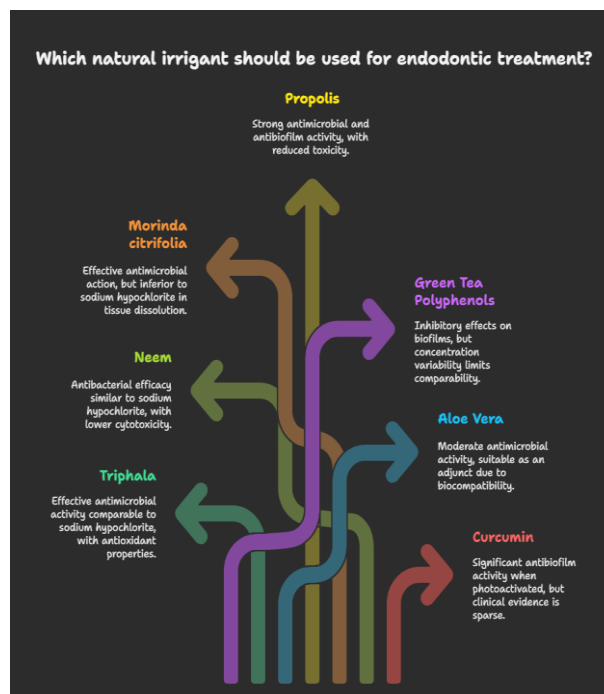


FIGURE-02 Study-Wise Synthesis of Results

3.4 Risk of Bias Assessment

In vitro studies showed moderate risk of bias due to lack of standardization in irrigation protocols and outcome measures. Clinical studies varied in methodological quality, with common limitations including small sample sizes and short follow-up durations.

4. TABLES (PRISMA-READY)

Table 1. Characteristics of Included Studies

Author	Ye	Study	Herbal	Compa	Outcome
		Type	Irrigant	rator	
Prabhakar et al.	2010	In vitro	Triphala	NaOCl	Significant antimicrobial efficacy
Podar et al.	2015	Clinical	<i>Morinda citrifolia</i>	CHX, NaOCl	Comparable bacterial reduction



Author	Year	Study Type	Herbal Irrigant	Comparator	Outcome
Hosny et al.	2021	RCT	Neem	NaOCl	Comparable antibacterial effect
Al-Azzawi	2008	In vitro	Propolis	NaOCl, CHX	Strong antimicrobial activity
Vanka et al.	2013	In vitro	Green tea	CHX	Effective against <i>E. faecalis</i>

Table 2. Antimicrobial and Biological Outcomes

Herbal Irrigant	Antimicrobial Efficacy	Antibiofilm Activity	Cytotoxicity
Triphala	High	Moderate	Low
Neem	High	Moderate	Low
<i>Morinda citrifolia</i>	Moderate–High	Low	Low
Propolis	High	High	Low
Aloe vera	Moderate	Low	Very low
Curcumin	High (photoactivated)	High	Low

Table 3. Risk of Bias Summary

Domain	Low Risk	Moderate Risk	High Risk
Randomization	12	8	4
Blinding	6	10	8
Outcome assessment	22	18	4
Sample size adequacy	14	26	14

Discussion

Effective elimination of microorganisms from the root canal system remains the cornerstone of successful endodontic therapy. Mechanical instrumentation alone is insufficient to achieve complete disinfection due to the

complex anatomy of the root canal system and the presence of resistant microbial biofilms.^{1–3} Sodium hypochlorite and chlorhexidine continue to be the most commonly used irrigants because of their well-documented antimicrobial efficacy.^{1,2,10} However, their limitations, including cytotoxicity, lack of smear layer removal (in the case of chlorhexidine), and potential for severe tissue injury, have prompted the search for safer and biologically acceptable alternatives.^{22,25}

The findings of this systematic review indicate that several herbal root canal irrigants demonstrate promising antimicrobial and antibiofilm activity against endodontic pathogens, particularly *Enterococcus faecalis*, which is frequently associated with persistent and secondary endodontic infections.^{3,16,17,26} Triphala has been consistently shown to possess significant antimicrobial properties, attributed to its rich content of tannins, flavonoids, and phenolic compounds, which disrupt microbial cell walls and inhibit enzymatic activity.^{4,28} Similar antimicrobial effects have been reported for neem-based irrigants, with clinical trials demonstrating antibacterial efficacy comparable to sodium hypochlorite while exhibiting reduced cytotoxicity.^{6,9,38}

Morinda citrifolia has emerged as another potential herbal irrigant, with both in vitro and clinical studies reporting antimicrobial activity comparable to chlorhexidine.^{5,20} However, its inability to dissolve organic tissue limits its use as a sole irrigant. This limitation parallels that observed with chlorhexidine, which, despite its substantivity and antimicrobial spectrum, lacks tissue-dissolving capability.^{10,15} Propolis has demonstrated strong antimicrobial and antibiofilm properties, which may be attributed to its flavonoid content and disruption of bacterial membrane integrity.^{7,29,57}

Green tea polyphenols, aloe vera, and curcumin have also shown inhibitory effects on *E. faecalis* and endodontic biofilms.^{8,30,36} Curcumin, particularly when photoactivated, has demonstrated enhanced antibiofilm efficacy, suggesting potential applications in advanced irrigation protocols.^{36,55} Despite these promising findings, variability in concentrations, extraction methods, and outcome measures across studies complicates direct comparison with conventional irrigants.^{31,33,39}



Biocompatibility is a critical consideration in the selection of root canal irrigants. Several included studies reported lower cytotoxicity for herbal irrigants compared with sodium hypochlorite and chlorhexidine, supporting their potential safety for clinical use.^{9,52} These findings align with broader evidence on plant-derived antimicrobial agents, which often exhibit selective toxicity toward microbial cells while preserving host tissue viability.^{37,59}

The growing interest in herbal irrigants is further supported by global initiatives promoting the integration of traditional medicine into modern healthcare systems.⁶⁰ However, despite encouraging laboratory and preliminary clinical data, conventional irrigants such as sodium hypochlorite remain superior in terms of tissue dissolution and broad-spectrum antimicrobial action.^{1,2,11} Consequently, herbal irrigants may be more appropriately considered as adjuncts rather than complete replacements for conventional solutions in contemporary endodontic practice.

Limitations

This systematic review has several limitations. First, a significant proportion of the included studies were in vitro in nature, which may not accurately replicate the clinical environment of the root canal system. Second, there was considerable heterogeneity among studies in terms of herbal formulations, extraction techniques, concentrations, irrigation protocols, and outcome assessment methods, limiting direct comparison and precluding quantitative meta-analysis. Third, many clinical studies included small sample sizes and short follow-up periods, reducing the strength of clinical inference. Additionally, publication bias cannot be excluded, as studies reporting positive outcomes may be more likely to be published. Finally, the lack of standardized guidelines for the preparation and use of herbal irrigants remains a major challenge for their translation into routine clinical practice.

Conclusion

Within the limitations of this systematic review, available evidence suggests that several herbal root canal irrigants, including Triphala, neem, *Morinda citrifolia*, propolis, green tea polyphenols, aloe vera, and curcumin, exhibit significant antimicrobial and antibiofilm activity against endodontic pathogens, particularly *Enterococcus*

faecalis. Many of these agents demonstrate favorable biocompatibility profiles when compared with conventional irrigants. However, none of the evaluated herbal irrigants consistently matched the tissue-dissolving capacity and broad-spectrum antimicrobial efficacy of sodium hypochlorite. Current evidence supports the potential use of herbal irrigants as adjuncts to conventional irrigation protocols rather than as complete substitutes. Well-designed randomized controlled clinical trials with standardized formulations and long-term outcomes are required to establish their definitive role in endodontic therapy.

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