

REVIEW ARTICLE

ROLE OF HERBAL EXTRACTS IN ROOT CANAL DISINFECTION AND REMOVAL OF SMEAR LAYER: A REVIEW

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ABSTRACT

Background: The success of endodontic treatment depends on the complete debridement and disinfection of canal space. Various chemicals have been used for canal disinfection. However, to overcome the adverse effects, toxicity issues, and microbial resistance of most conventional canal disinfectants, alternative agents are needed. Many herbal products have been studied and recommended for canal disinfection. This article aimed to review the role of herbal extracts in canal disinfection as an irrigant, intracanal medicament, and their efficacy in smear layer removal.

Results: Studies were identified through search of the following electronic databases: PubMed, Science direct, Scopus and Google Scholar. The search was undertaken with keywords herbal agents/ products for root canal disinfection, *Enterococcus faecalis*, endodontics, smear layer, biofilm, herbal extracts and antimicrobial activity. The literature was reviewed for past 30 years (1990- till June 2020). The results showed that several in-vitro studies reported effective antimicrobial action of herbal extracts for canal disinfection, however, very less in-vivo or clinical studies have been reported to ascertain the use of these agents for endodontic therapy.

Conclusions: The study concludes that herbal agents can be effectively used for canal disinfection. However, long-term, invitro, clinical, biocompatibility studies clinical trials are further needed to confidently use these products in endodontics. Herbal extracts can be used as substitute to existing root canal disinfectants due to their unique properties. Therefore, improving the endodontic success rate by preventing root canal failures, persistent and reinfections.

INTRODUCTION

The prime motto of any endodontic procedure is to avert the occurrence of apical periodontitis or to make suitable environment for periodical healing in the presence of disease. Thus, the logic of root canal treatment is to eliminate the infection and to further prevent the microorganisms from infecting or reinfection of the root canal system.¹To accomplish complete eradication of the infection and to enhance periapical healing, "bio-mechanical preparation" of the root canal is done by mechanical instrumentation of the root canals along with simultaneous utilization of chemical agents.²

The complex root canal anatomy which harbors microbes and tissue debris in root canal ramifications poses difficulty in effective root canal disinfection.³The most challenging part of root canal disinfection are the presence of smear layer and the biofilm. There is smear layer formation on root canal walls subsequently post instrumentation. This film contains inorganic and organic dentin, necrotic and vital pulp tissue, tissue debris, microbes, and blood cells. It is shown that the smear layer inhibits the penetration of antimicrobial irrigants and intracanal medicaments (ICM's) into the dentinal tubules.^{4,5} Therefore,

for enhancing penetration of antimicrobial agents into dentinal tubules, for proper adhesion of obturating agents to the walls of the root canal and to lessen microleakage coronally and apically, the smear layer must be preferably cleaned. Thus, the elimination of the smear from the canal walls is highly desirable to obtain long-term endodontic success.⁶

Endodontic microbiota is diverse and exists in the form of biofilm. It is reported that the microbes in the biofilm pose the greatest resistance due to the protective extracellular polymeric matrix (EPM) of the biofilm. The root canal morphology, structure, and composition of the biofilm, characteristics of different microorganisms within biofilm affects thorough endodontic disinfection. Therefore, irrigants and intracanal medicaments (ICM) play an important role in root canal disinfection.⁷

The regularly employed endodontic irrigating agents are chlorhexidine (CHX), sodium hypochlorite (NaOCl), and ethylene-diamine-tetra-acetic acid (EDTA) solution.^{8,9} Despite the widespread use of these irrigants, they have certain limitations which is a great concern. The drawbacks of sodium hypochlorite are inadequate penetrability in the intricate root canal system, toxicity, the menace of emphysema, allergic

reaction, unpleasant odor and flavor, and also its failure to eliminate the smear layer.¹⁰ It is seen that, prolonged contact of dentin to high concentrations of sodium hypochlorite disturb the elasticity and flexural strength of root dentine so, making the tooth more susceptible to vertical fracture, which has forlorn outcomes.^{11, 12}

Chlorhexidine (CHX) is used efficiently as a substitute to sodium hypochlorite for root canal irrigation owing to its broad-spectrum antimicrobial activity and substantivity effect. However, the disadvantages include discoloration of the tooth, dryness and burning perception in oral mucosa, and brown precipitate if it interacts with NaOCl which is proved to be carcinogenic.¹³ Intracanal drugs such as Ca (OH)₂ cause collagen breakdown that weakens the root dentin. A triple antibiotic paste consisting of ciprofloxacin, minocycline, and metronidazole have latent adverse effects such as tooth discoloration and demineralization of dentin.⁸

Chelating agents such as 17% ethylene diamine tetra acetic acid (EDTA),¹⁴ 10% citric acid,¹⁵ tannin, and maleic acid are applied for removal of smear layer. Nevertheless, repeated irrigation using EDTA can demineralize the dentine and cause erosions in the root canal esp. in coronal third and middle third.¹⁶

Despite significant development in the field of dentistry, there is no ideal root canal irrigant and hence there is an ongoing search for alternative antimicrobial agents that are more biocompatible, dentin friendly, and combat the growing microbial resistance and can overcome the limitations of the conventional irrigants. Herbal extracts are attaining fame in all branches of medicine, because of their biocompatibility.¹⁷ Many plants and their extracts are used as Phytomedicines in dentistry. These herbal medicines are obtained from the roots, seeds, leaves, flowers, and stems of medicinal plants. The herbal extracts possess high anti-oxidant, anti-inflammatory, and antibiotic properties that have favored their application in Endodontics for root canal decontamination; such as intracanal medicament and irrigants to overcome the possible adverse effects of the conventional root canal disinfectants.¹⁸

Various researches and studies have been done for the valuation of herbal extracts as irrigant and/or intra-canal medicament and in removal of the smear layer. To date, several studies have shown the indications of herbal agents in root canal disinfection. This article reviews and discusses the role of several herbal extracts that are utilized for canal disinfection, antimicrobial efficacy to eliminate *E. faecalis* and smear layer removal.

METHODS

Search strategy

Studies were selected by a search on the below mentioned electronic databases like PubMed, Scopus, Google Scholar, and Science direct. The terms that were used as keywords were *Enterococcus faecalis*, endodontics, root canal failure, root

canal disinfectants, biofilm, smear layer, herbal extracts, and antimicrobial activity. The literature was reviewed for past 30 years (1990-June 2020).

Study selection

By the inclusion criteria, studies were mandatorily: (a) published in peer-reviewed journals in the English language (b) provided original data and (c) overtly report on antimicrobial effectiveness of herbal extracts on *E. faecalis* in root canals and removal of smear layer. Articles published as abstracts only and literature published in other languages were excluded.

Commonly used Herbal extracts in endodontics:

Propolis (*Beeswax*)

Pharmacologically vigorous constituents in propolis are flavonoids, phenolics, and aromatics. It displays certain biologic actions such as antimicrobial, anti-inflammatory, antioxidant, sedating, and cytotoxic properties. Propolis is commonly employed in root canal disinfection as intracanal medicament and irrigant. It can be effectually used alongside Ca (OH)₂ as dressing for eradication of endodontic pathogens mainly to counter *E. faecalis*.^{19,20}

Aloe Vera (Vera Aloe barbadensis miller)

Aloe Vera extract possesses potent antibacterial, antifungal, and anti-inflammatory activity.²¹ The aloin and aloe-emodin are the active constituents of the gel. Owing to its curative ability, *Aloe vera* has been used in Endodontics both as a medicament and irrigant.²²

Ginger (*Zingiber officinale*)

Ginger is known to have anti-inflammatory, analgesic, antipyretic, antimicrobial, and hypoglycemic properties.²³ Ginger exhibited the highest antibacterial efficacy against *E. faecalis* compared with chlorhexidine and garlic extract.²⁴

Liquorice (*Glycyrrhiza glabra*)

Liquorice is known for its anti-inflammatory, antiviral and anticarcinogenic activities²⁵. Glycyrrhizin, a triterpenoid compound, imparts the sugary flavor of licorice root. The antimicrobial activity of licorice against *E. faecalis* may be linked to the glycyrrhizin. The biocompatibility of liquorice was good with fibroblast cells when compared to calcium hydroxide, which was noxious to the cells²⁶.

Neem (*Azadirachta indica*)

It is commonly branded as the margosa tree or Indian neem.²⁷ Neem is counted on as one of the predominant medicinal herb in naturopathy. The antioxidant and antimicrobial properties of neem extract makes it a potent root canal irrigant alternative to sodium hypochlorite. Advantages of neem for root canal irrigation include its biocompatibility, act as an antioxidant and thus it's not expected to cause the

major injuries to patients that occur when NaOCl is used.²⁸

Indian mulberry (*Morinda citrifolia*)

Morinda citrifolia juice (MCJ) has an extensive range of therapeutic properties such as antibacterial, antiviral, antifungal as well as palliative effects.²⁹ MCJ seems to be one of the first liquid to be recognized as a potential substitute to the use of NaOCl as an intracanal irrigant. It has also been found to be an herbal irrigant that is effective in smear layer removal when used at a concentration of 6%.³⁰ The use of MCJ may potentially be advantageous as a root canal irrigant since it is biocompatible, antioxidant, and has no adverse effects. MCJ comprises milder acids which may be responsible for its reported smear layer removal action.³¹ MCJ at 6% concentration has a pH of 3.5.

Triphala

Triphala is a powder that is made up of alike portions of *Emblca officinalis*, *Terminalia chebula*, and *Terminalia bellerica*.³² It is a proven antioxidant, anti-inflammatory agent, and has radical scavenging activities.³³ Triphala has chelating action due to the presence of fruits rich in citric acid and thus may assist in the elimination of smear layer.³⁴

Miswak (*Salvadora persica* L)

Miswak is a chewing stick routinely used as a brush to clean the teeth and the oral cavity. It is prepared from the fragrant root of a bush called Arrak. The chewing sticks comprise of trimethyl amine, salvadorime chloride, and fluoride in high volumes.²⁸ Studies have shown the antimicrobial action of *S. Persica* and also found that 5 mg/ml solution of *S. persica* was as effective as 17% EDTA in removing the smear layer from the canal wall.^{35,36}

Wild sage (*Casearia sylvestris*)

It is a Brazilian herb in the Salicaceae family. Its popular name is "guacatonga." The *C. sylvestris* extract forms a rich source of phospholipase A2 inhibitors which reduces the acute stage of inflammation and extends the regenerative stage. A preliminary study reported that the natural medicaments Propolis and *Casearia sylvestris* may offer a good alternative as short-term intracanal medicaments.³⁷

Lime juice (*Citrus aurantifolia*)

Citrus aurantifolia (lime juice) extract as the final irrigant, since it comprises of citric acid alongside with an additional antimicrobial feature. Lime juice comprises 88% water, 6–8% citric acid, 2% potassium citrate, and other substances. Owing to the citric acid as a basic constituent in *C. aurantifolia*, researchers have evaluated it for its possible role in the endodontic smear layer removal and open the dentinal tubules.³⁸ Furthermore, the role of natural fruit juices including *C. aurantifolia* on the exposed root dentin surfaces in the elicitation of dentinal hypersensitivity has been confirmed

and is linked with the removal of existing smear layer on the exposed dentin.³⁹

Ritha (*Sapindusmukorossi*)

Sapindusmukorossi (Sapindaceae), widely called as "ritha," "aritha" otherwise "soapnut" is found all over India. The chief components of the fruit's pericarp are saponins (10–11.5%), sugars (10%), and mucilage. Higher content of saponins results in greater surfactant action.⁴⁰

A combination of *C. aurantifolia* and *S. mukorossi* in 2:1 concentration has been studied to be highly efficient in removal of smear layer. Emulsification activity of the bio-surfactants like *S. mukorossi* is one of the important properties that dissolve the water-insoluble substances/hydrocarbons. This property may be primarily responsible for the better smear layer removal effect when used in combination.⁴⁰

German chamomile (*Matricaria recutita*)

GCE is an extract of the dried flowers of the plant *Matricaria recutita*, commonly known as "German chamomile." It is one of the most commonly used herbs for medicinal purposes. It also contains acids like capric acid, o-coumaric acid, p-coumaric acid, dihydroxybenzoic acid, and caprylic acid, with a pH of 7.6 and effectively removes the smear layer.⁴¹ This extract has antimicrobial activity, anti-inflammatory effect and antioxidant property.⁴²

Role of herbal extracts as root canal irrigant, intracanal medicament and removal of smear layer

From the safety and side effects point of view, continual upsurge in antibiotics insensitivity and futility of conventional drug formulation, researchers are fascinated by herbal substitutes that are widely used in medical preparations subsequently from numerous years owing to their biocompatibility, great anti-inflammatory, antimicrobial, and antioxidant properties, minimum toxicity and antimicrobial resistance.^{18, 43} The most commonly studied plant extracts as endodontic irrigants, intracanal medicaments, and smear layer removal have been summarized in Table 1.

Role of Herbal Extracts against *Enterococcus faecalis*.

Enterococcus faecalis (*E. faecalis*) is a gram-positive facultative microorganism commonly associated with endodontic diseases. Its elimination from root canal is of paramount importance, as it is the most resistant microbe usually associated with failure of root canal treatment.⁶⁰ *E. faecalis* possess virulence factors such as cytolysin, lytic enzymes, aggregation substance, pheromones, and lipoteichoic acid. It can invade dentinal tubules and cementum. It produces the collagen-binding proteins such as Adhesin, Ace, and serine protease which help in adhesion to the collagen present in dentin and cementum.⁶¹ It can survive even after meticulous root canal instrumentation

and root canal disinfection. *E. faecalis* forms a biofilm in the root canal and is more resistant to available antibacterial agents. It can survive even in the presence of intracanal medication.⁶² It penetrates root dentin, cementum and survive longer period

seven in nutrient-depleted conditions such as an obturated canal and lead to persistent or reinfections.⁶³ Studies show herbal extracts exhibit effective antimicrobial activity against this resistant microbe due to their unique properties.^{64,65}

Table 1: Table 1: Herbal extracts and their role in root canal disinfection

Scientific name	Common name	Pharmacological active components	Endodontic purpose	References
<i>Propolis</i>	Beeswax, Blue glue	Flavonoids, Aromatic acids, Esters present in Resins, Galangin, Pinocembrin	Irrigant	Al-Qathami H et al ¹⁴⁴ Kandaswamy et al ¹⁴⁵
			ICM	Oncag O et al ¹²⁰ Banskota et al ¹¹⁹
<i>Aloe vera</i>	Star cactus, Barbados	Latex, Glucomannan, mannose derivatives, hemicellulose, calcium oxalate	ICM	Bazvand et al ¹⁴⁶
			Irrigant	Sahebi et al ¹⁴⁷ Bharadwaj et al ¹⁴⁸
<i>Allium sativum</i>	Garlic	Allicin	ICM	Eswar et al ¹⁴⁹
<i>Zingiber officinale</i>	Ginger	flavonoids	ICM	Maekawa et al ¹⁵⁰
<i>Glycyrrhiza glabra</i>	Liquorice	glycyrrhizin	ICM	Badr et al ¹²⁶ Kumar D et al ¹⁵¹
<i>Azadirachta indica</i>	Neem	Azadirachtin, Nimbin, gallic acid, catechin	Irrigant	Nayak et al ¹⁵² Vinoth Kumar et al ¹⁵³
<i>Salvadora persica L</i>	Miswak	trimethyl amine, salvadorime chloride and fluoride	ICM	Al Sabawi et al ¹⁵⁴ Al Obaida et al ¹⁵⁵
			Smear layer removal	Balto et al ¹³⁶
<i>Passiflora edulis</i>	Passion Fruit	flavonoids, alkaloids, cyanogenic compounds	Irrigant	Jayahari et al ¹⁵⁵
			Smear layer removal	Rees et al ¹⁵⁶
<i>Morinda citrifolia</i>	Indian mulberry, Painkiller bush, Cheese fruit	L-asperuloside, Acubin, Alizarin kaempferol, Octanoic acid, Ascorbic acid, Ricinoleic acid	Smear layer removal	Murray et al ¹³⁰ Prabhakar et al ¹³⁴
Triphala		Citric acid	Smear layer removal	Pujar et al ¹⁵⁷ Prabhakar et al ¹³⁴
<i>Marticaria recutita</i>	German chamomile	(capric acid, caprylic acid, chlorogenic acid, o-caumaric acid, p-caumaric acid, dihydroxybenzoic acid	Smear layer removal	Sadr et al ¹⁵⁸ Shah S G et al ¹⁴¹ Ganguly S et al ¹²⁷
<i>Casearia sylvestris</i>	Wild Sage	phospholipase A2 inhibitors	ICM	Da Silva et al ¹³⁷
<i>Melaleuca alternifolia L</i>	Tea extract, fruit teas, Tea tree oil	Terpinen-4-ol	Smear layer removal	Sadr et al ¹⁵ Jeremy S et al ¹⁵⁹

The role of various herbal agents against *Enterococcus faecalis* is summarized in table 2.

Table 2: Herbal extracts against endodontic pathogen *Enterococcus faecalis*

Reference	Herbal agent/ s studied	Type of study	Method of evaluation	Conclusion
Kandaswamy D et al ¹⁴⁵	<i>Propolis</i> and <i>Morinda citrifolia</i> (MJC)	Invitro study	CFU/mL was determined.	<i>Propolis</i> and MJC were effective against <i>E. faecalis</i> .
Kamath U et al ¹⁶⁶	<i>Melaleuca alternifolia L</i> (Tea tree oil)		Agar well diffusion method	<i>Melaleuca alternifolia L</i> is effective against <i>E. faecalis</i> .

Chandrappa PM et al ⁶⁷	<i>Azadirachta indica</i> (Neem) and Tulsi (<i>Ocimum sanctum</i>)	Invitro study	Agar diffusion method	neem extract is effective against <i>E. faecalis</i> . followed by Tulsi.
MahendraM et al ⁶⁵	<i>Azadirachta indica</i> (Neem) and Tulsi (<i>Ocimum sanctum</i>)		CFU/mL was determined	Neem and Propolis showed less growth of <i>E. faecalis</i> .
Neelakantan P et al ⁶⁴	Curcumin		colony-forming units (CFU/mL) was counted using biofilm model of <i>E faecalis</i>	Curcumin is effective against <i>E. faecalis</i> .
Kumar D et al ⁵¹	<i>Azadirachta indica</i> (Neem) <i>Glycyrrhiza glabra</i> (Liquorice), cinnamum, <i>zeylanicum</i> , <i>Syzygium aromaticum</i> (Clove) and <i>Accacianilotica</i> (Babool)		Antimicrobial zone of inhibitions against <i>E. faecalis</i> and <i>Streptococcus mutans</i> .	Babool and clove extracts are effective against <i>E. faecalis</i> .
Awooda E M and Abdelkarim et al ⁶⁸	Ginger and cinnamon	<i>Ex vivo study</i>	The colony-forming units (CFU/mL) and the minimum inhibitory concentration	Ginger was found more effective against <i>E faecalis</i>
Karkare SR et al ⁶⁹	Aloe vera and Garlic	<i>Invitro study</i>	Agar diffusion method	<i>A. vera</i> exhibited antibacterial efficiency against <i>E. faecalis</i>
Prabhakar J et al ³⁴	Triphala and Green Tea Polyphenols(GTP)		Biofilm model of <i>E faecalis</i> and CFU/ml was determined	Herbal agents can be alternatively used as root canal irrigants.
Saxena D et al ⁷⁰	Propolis, <i>Azadirachta indica</i> (AI), Triphala, <i>Curcuma longa</i> , and <i>Morinda citrifolia</i> (MC)		Disk diffusion method	Propolis and AI have important antimicrobial activity against <i>E. faecalis</i> .
Kalaiselvam R et al ⁷¹	<i>Piper nigrum</i> (<i>Piperaceae</i>), <i>Piper longum</i> (<i>Piperaceae</i>) and <i>Zingiber officinale</i> Roscoe (<i>Zingiberaceae</i>)		Real-time PCR	2% chlorhexidine has greater antibacterial efficacy against <i>E. faecalis</i> followed by <i>Zingiberofficinale</i> Roscoe (<i>Zingiberaceae</i>) extract
Podar R et al ⁷²	<i>Morinda itrifolia</i> (MC), <i>Azadirachta indica</i> (AI)	<i>In vivo study</i>	CFU/mL was counted at baseline and after irrigation (posttreatment)	No change in the antimicrobial efficiency of 6% <i>M. citrifolia</i> , <i>A. indica</i> , and 3% NaOCl as root canal irrigants.

DISCUSSION

The good prognosis of endodontic treatment over the years, rests on the complete cleaning and disinfection of pulpal space.²The main reason for endodontic failure is incomplete cleaning canal system. The intricate root canal structure makes elimination of micro-organisms problematic.³Many chemical substances have been suggested in various studies for root canal disinfection.² However, due to the adverse effects, toxicity issues, inability to completely remove the smear layer, growing microbial resistance to the routinely used conventional root canal disinfectants and inability to eliminate the microbes such as *Enterococcus faecalis* which flourish in periapical abscesses and granulomas, causing catastrophe of the endodontic treatment lead to development of alternative modalities.⁶ Many herbal products with biological and antimicrobial properties have been studied and recommended for root canal disinfection. The major advantages of using herbal extracts as alternative antimicrobial agents for root canal disinfection are ease of availability of these extracts, cost efficiency, augmented shelf life, low toxicity, and absence of microbial resistance.¹⁷

The findings of our review show that herbal agents are widely used for root canal disinfection. They are effectively studied as an ICM, irrigant, and for elimination of the smear

layer.^{36,52,54} Most of the studies are pertinent to the evaluation of antibacterial activity against *E faecalis*; as it is responsible for root canal failure and persistent infections.⁶⁴⁻⁶⁹ The results of our search are summarized in tables 1 and 2 which clearly show that different herbal agents were studied for endodontic disinfection.

Extracts of *Azadirachta indica*, *Ocimum sanctum*, *Syzygium aromaticum*, *Cinnamomum zeylanicum*, and *Citrus aurantifolia* have been explored as possible endodontic irrigating agent.⁷³ However most of the literature suggests that *Propolis* and *Azadirachta indica* (AI) are effective for root canal irrigation.^{45, 65} Studies have shown promising results of propolis against *E. faecalis* biofilms in contrast to other natural irrigants and NaOCl.^{45,70}

Aloe vera has been reported to exhibit active antimicrobial activity against *E faecalis*.^{48, 74} Kurian B *et al.*, showed MIC (Minimal Inhibitory Concentration) of Aloe vera was higher than calcium hydroxide in removing *E. faecalis* and its antibacterial property augmented with time.⁷⁵ On the contrary, Sahebiet al., assessed the antibacterial efficiency of *Aloe vera* as an irrigant compared to 2.5% Sodium hypochlorite and stated that Aloe vera was inefficient in combating *E. faecalis* and thus was not mentioned as irrigating solution.⁴⁷ Bharadwaj et al., also stated that even after ultrasonic activation,

aloe vera was not efficient against *E. faecalis* biofilms.⁴⁸

Vinoth Kumar et al., assessed the antimicrobial efficiency of *Curcuma longa*, *Aloe barbadensis*, *Azadirachta indica*, *Myristica fragrans* and *Terminalia chebula* as endodontic irrigants against *E. faecalis* and *C. albicans*. The study concluded that neem was extremely effectual in comparison to other natural irrigants against both the organisms.⁵³ Dutta and Kundabala in their study evaluated the decrease in bacterial count using anaerobic culture technique in infested root canals and found that the combination of NaOCl and neem irrigant led to the maximum decrease in bacterial counts.⁷⁶

Most studies show that *Propolis*, *Morinda citrifolia*, *Triphala*, *German chamomile* and *Tea tree extracts* possess the ability to remove the smear layer.^{26,41,51} *Morinda citrifolia* (MC) 6% shows effective antimicrobial activity when used as ICM and for smear layer removal.³⁰ Shah SG et al compared 6% German chamomile extract (GCE) and 6% *Morinda citrifolia* juice (MCJ) for smear layer removal and concluded that GCE 6% was effective in the removal of smear layer, when used with either continuous or syringe and needle irrigation systems and does not cause demineralization of dentin whereas EDTA does.⁴¹ Bolhari B et al. concluded that both of the alcoholic and completed combinations of citrus aurantifolia excerpts were not able to efficiently eliminate smear layer in comparison with 17% EDTA in the course of root canal treatment.⁷³

In an *in-vivo* study, comparing the antimicrobial activity of *S. persica*, propolis, NaOCl, and saline as root canal irrigants in primary teeth, it was concluded saying that 12.5% alcoholic extract of *S. persica* could be a good natural substitute to 3% sodium hypochlorite.³⁵ Shakouie et. al. compared the antimicrobial efficiency of triphala with various concentrations of NaOCl against *E. faecalis* and stated that triphala displayed superior antimicrobial activity against *E. faecalis* when compared to 0.5 and 1% NaOCl.⁷⁷

The studies show that most of the herbal agents exhibit effective antimicrobial activity against *E. faecalis*, however,

a majority of studies recommend *Azadirachta indica*(AI) to be most effective against *E faecalis* followed by propolis and *Morinda citrifolia* (MC).^{45,65,67,70} Aloe vera has mixed opinions regarding its antimicrobial effect on *E. faecalis*.^{47,48,74} The literature search shows that most of the studies conducted on *E faecalis* are invitro antimicrobial studies however, relatively few clinical/*in-vivo* studies have been conducted (Table 2).

It was found that most of the studies undertaken exhibit effective antimicrobial activity, effectively remove smear layer recommending herbal extracts for root canal disinfection. However, the search shows that there is a lack of cytotoxicity studies of these herbal extracts. Determination of cytotoxicity of these agents is important for effective clinical use. However, further studies including standardization protocols for using herbal agents, in vivo studies, in vitro studies evaluating the antimicrobial efficacy using nonculture methods, cytotoxicity studies, clinical trials, and long-term studies are to be undertaken, so that herbal extracts can be effectively and confidently employed for root canal disinfection.

CONCLUSION

Application of Herbal extracts for root canal disinfection has revolutionized the traditional concepts. The in vitro observations of herbal products appear promising, however clinical studies, longitudinal studies, preclinical and clinical experiments are needed to assess the biocompatibility and safe margins of these agents is needed before they can irrefutably be suggested for root canal disinfection. Herbal extracts are usually harmless if used with appropriate knowledge, but they can be detrimental if misused. Many herbal medicines bare possible risk, side effects, and prescription exchanges that may disturb our safe practice of dentistry. Hence forward, herbal agents should only be used for treatment procedures that have been proven to be operational, and with negligible risk involved.

Herbal extracts pave a new horizon in root canal disinfection as root canal irrigants, intra-canal medicaments and as agents for removal of smear layer.

REFERENCES:

1. Hargreaves KM, Cohen S. Pathways of Pulp. 10th ed. Ch 15.; 2011. p. 559.
2. Siqueira JF Jr, Rôças IN, Riche FN, Provenzano JC. Clinical outcome of the endodontic treatment of teeth with apical periodontitis using an antimicrobial protocol. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2008 Nov;106(5):757-62. [DOI]
3. Siqueira JF Jr., Rocas IN, Ricucci D. Biofilm in endodontic infection. Endod Top 2010;22:33-49. [DOI]
4. Orstavik D, Haapasalo M. Disinfection by endodontic irrigants and dressings of experimentally infected dentinal tubules. Endod Dent Traumatol. 1990 Aug;6(4):142-9. [DOI]
5. Bystrom A, Sundqvist G. The antibacterial action of sodium hypochlorite and EDTA in 60 cases of endodontic therapy. Int Endod J. 1985 Jan;18(1):35-40. [DOI]
6. Cergneux M, Ciucchi B, Dietschi JM, Holz J. The influence of the smear layer on the sealing ability of canal obturation. Int Endod J. 1987 Sep;20(5):228-32. [DOI]
7. Halkai KR, Mudda JA, Shivanna V, Rathod V, Halkai R. Antibacterial Efficacy of Biosynthesized Silver Nanoparticles against Enterococcus faecalis Biofilm: An in vitro Study. Contemp Clin Dent. 2018 Apr-Jun;9(2):237-41. [DOI]
8. Ballal NV, Kandian S, Mala K, Bhat KS, Acharya S. Comparison of the efficacy of maleic acid and ethylenediaminetetraacetic acid in smear layer removal from instrumented human root canal: a scanning electron microscopic study. J Endod. 2009 Nov;35(11):1573-6. [DOI]
9. Goldman M, Goldman LB, Cavaleri R, Bogis J, Lin PS. The efficacy of several endodontic irrigating solutions: a scanning electron microscopic study: Part 2. J Endod. 1982 Nov;8(11):487-92. [DOI]
10. Siqueira JF Jr, Rôças IN, Favieri A, Lima KC. Chemomechanical reduction of the bacterial population in the root canal after instrumentation and irrigation with 1%, 2.5%, and 5.25% sodium hypochlorite. J Endod. 2000 Jun; 26 (6):331-4. [DOI]

11. Giardino L, Ambu E, Savoldi E, Rimondini R, Cassanelli C, Debbia EA, et al. Comparative evaluation of antimicrobial efficacy of sodium hypochlorite, MTAD, and tetraclean against *Enterococcus faecalis* biofilm. *J Endod* 2007;33: 852-5. [\[DOI\]](#)
12. Zehnder M. Root canal irrigants. *J Endod*. 2006 May;32(5):389-98. [\[DOI\]](#)
13. Basrani BR, Manek S, Sodhi RN, Fillery E, Manzur A. Interaction between sodium hypochlorite and chlorhexidine gluconate. *J Endod*. 2007 Aug;33(8):966-9. [\[DOI\]](#)
14. Lui JN, Kuah HG, Chen NN. Effect of EDTA with and without surfactants or ultrasonics on removal of smear layer. *J Endod*. 2007 Apr;33(4):472-5. [\[DOI\]](#)
15. Götze Gda R, Cunha CB, Primo LS, Maia LC. Effect of the sodium hypochlorite and citric acid association on smear layer removal of primary molars. *Braz Oral Res*. 2005 Oct-Dec;19(4):261-6. [\[DOI\]](#)
16. Calt S, Serper A. Time-dependent effects of EDTA on dentin structures. *J Endod*. 2002 Jan;28(1):17-9. [\[DOI\]](#)
17. Li L, Zhou X, Li N, Sun M, Lv J, Xu Z. Herbal drugs against cardiovascular disease: traditional medicine and modern development. *Drug Discov Today*. 2015 Sep;20(9):1074-86. [\[DOI\]](#)
18. Ravishankar P, Lakshmi T, Kumar SA. Ethno-Botanical approach for root canal treatment- an update. *J Pharm Sci & Res* 2011; 3: 1511-9.
19. Banskota AH, Tezuka Y, Kadota S. Recent progress in pharmacological research of propolis. *Phytother Res*. 2001 Nov;15(7):561-71. [\[DOI\]](#)
20. Oncag O, Cogulu D, Uzel A, Sorkun K. Efficacy of propolis as an intracanal medicament against *Enterococcus faecalis*. *Gen Dent*. 2006 Sep-Oct;54(5):319-22. [\[PMID\]](#)
21. George D, Bhat SS, Antony B. Comparative evaluation of the antimicrobial efficacy of aloe vera tooth gel and two popular commercial toothpastes: an in vitro study. *Gen Dent*. 2009 May-Jun;57(3):238-41. [\[PMID\]](#)
22. Neena IE, Ganesh E, Poornima P, Korishettar R. An ancient herb aloe Vera in dentistry: A review. *J Oral Res Rev*. 2015; 7:25-30. [\[DOI\]](#)
23. Mascolo N, Jain R, Jain SC, Capasso F. Ethnopharmacologic investigation of ginger (*Zingiber officinale*). *J Ethnopharmacol*. 1989 Nov;27(1-2):129-40. [\[DOI\]](#)
24. Gulve M.N, Gulve N.D. Comparison of Antimicrobial Efficacy of Ginger Extract and 2% Sodium Hypochlorite against *Enterococcus faecalis* using agar diffusion method. *J. Ind Dent Assoc*. 2010; 4:347-349.
25. Shibata S. A drug over the millennia: pharmacognosy, chemistry, and pharmacology of licorice. *Yakugaku Zasshi*. 2000 Oct;120(10):849-62. [\[DOI\]](#)
26. Badr AE, Omar N, Badria FA. A laboratory evaluation of the antibacterial and cytotoxic effect of Liquorice when used as root canal medicament. *Int Endod J*. 2011 Jan;44(1):51-8. [\[DOI\]](#)
27. Ganguli S. Neem: A therapeutic for all seasons. *Curr Sci* 2002; 82: 1304.
28. Almas K. The antimicrobial effects of extracts of *Azadirachta indica* (Neem) and *Salvadora persica* (Arak) chewing sticks. *Indian J Dent Res*. 1999 Jan-Mar;10(1):23-6. [\[PMID\]](#)
29. Younos C, Rolland A, Fleurentin J, Lanhers MC, Misslin R, Mortier F. Analgesic and behavioural effects of *Morinda citrifolia*. *Planta Med*. 1990 Oct;56(5):430-4. [\[DOI\]](#)
30. Murray PE, Farber RM, Namerow KN, Kuttler S, Garcia-Godoy F. Evaluation of *Morinda citrifolia* as an endodontic irrigant. *J Endod*. 2008 Jan;34(1):66-70. [\[DOI\]](#)
31. Saghiri MA, Godoy FG, Asgar K, Lotfid M. The effect of *Morindacitrifolia* juice as an endodontic irrigant on smear layer and microhardness of root canal dentin. *Oral Sci Int* 2013; 10:53-7. [\[DOI\]](#)
32. Prakash S, Shelke AU. Role of Triphala in dentistry. *J Indian Soc Periodontol*. 2014 Mar;18(2):132-5. [\[DOI\]](#)
33. Jagetia GC, Baliga MS, Malagi KJ, Sethukumar Kamath M. The evaluation of the radioprotective effect of Triphala (an ayurvedic rejuvenating drug) in the mice exposed to gamma-radiation. *Phytomedicine*. 2002 Mar;9(2):99-108. [\[DOI\]](#)
34. Prabhakar J, Senthilkumar M, Priya MS, Mahalakshmi K, Sehgal PK, Sukumaran VG. Evaluation of antimicrobial efficacy of herbal alternatives (Triphala and green tea polyphenols), MTAD, and 5% sodium hypochlorite against *Enterococcus faecalis* biofilm formed on tooth substrate: an in vitro study. *J Endod*. 2010 Jan;36(1):83-6. [\[DOI\]](#)
35. Al-Obaida MI, Al-Essa MA, Asiri AA, Al-Rahla AA. Effectiveness of a 20% Miswak extract against a mixture of *Candida albicans* and *Enterococcus faecalis*. *Saudi Med J*. 2010 Jun;31(6):640-3. [\[PMID\]](#)
36. Balto H, Ghandourah B, Al-Sulaiman H. The efficacy of *Salvadora persica* extract in the elimination of the intracanal smear layer: A SEM study. *Saudi Dent J*. 2012 Apr;24(2):71-7. [\[DOI\]](#)
37. Silva FB, Almeida JM, Sousa SM. Natural medicaments in endodontics -- a comparative study of the anti-inflammatory action. *Braz Oral Res*. 2004 Apr-Jun;18(2):174-9. [\[DOI\]](#)
38. Sharifian MR, Shokouhinejad N, Monsef Esfahani HR, Aligholi M, Amjadi M. Antimicrobial effect of *Citrus aurantifolia* extract on *Enterococcus faecalis* within the dentinal tubules in the presence of smear layer. *Journal of Dental Medicine*. 2011 Sep 1;24(2).
39. Corrêa FO, Sampaio JE, Rossa Júnior C, Orrico SR. Influence of natural fruit juices in removing the smear layer from root surfaces--an in vitro study. *J Can Dent Assoc*. 2004 Nov;70(10):697-702. [\[PMID\]](#)
40. Chhabra N, Gyanani H, Kamatagi L. Smear layer removal efficacy of combination of herbal extracts in two different ratios either alone or supplemented with sonic agitation: An in vitro scanning electron microscope study. *J Conserv Dent*. 2015 Sep-Oct;18(5):374-8. [\[DOI\]](#)
41. Saha SG, Singh R, Bhardwaj A, Vijaywargiya P, Billore J, Saxena D. Efficacy of smear layer removal by two Ayurvedic herbal irrigants, using continuous vs. syringe and needle irrigation. *Endodontology* 2019; 31:72-7. [\[DOI\]](#)
42. Martins HM, Martins ML, Dias MI, Bernardo F. Evaluation of microbiological quality of medicinal plants used in natural infusions. *Int J Food Microbiol*. 2001 Aug 15;68(1-2):149-53. [\[DOI\]](#)
43. Groppo FC, Bergamaschi Cde C, Cogo K, Franz-Montan M, Motta RH, de Andrade ED. Use of phytotherapy in dentistry. *Phytother Res*. 2008 Aug;22(8):993-8. [\[DOI\]](#)
44. Al-Qathami H, Al-Madi E. Comparison of sodium hypochlorite, propolis and saline as root canal irrigants: A pilot study. *Saudi Dent J*. 2003 May;15(2):100-103.
45. Kandaswamy D, Venkateshbabu N, Gogulnath D, Kindo AJ. Dentinal tubule disinfection with 2% chlorhexidine gel, propolis, morinda citrifolia juice, 2% povidone iodine, and calcium hydroxide. *Int Endod J*. 2010 May;43(5):419-23. [\[DOI\]](#)
46. Bazvand L, Aminozarbian MG, Farhad A, Noormohammadi H, Hasheminia SM, Mobasherizadeh S. Antibacterial effect of triantibiotic mixture, chlorhexidine gel, and two natural materials Propolis and Aloe vera against *Enterococcus faecalis*: An ex vivo study. *Dent Res J (Isfahan)*. 2014 Jul;11(4):469-74. [\[PMID\]](#)
47. Sahebi S, Khosravifar N, Sedighshamsi M, Motamedifar M. Comparison of the antibacterial effect of sodium hypochlorite and aloe vera solutions as root canal irrigants in human extracted teeth contaminated with *enterococcus faecalis*. *J Dent (Shiraz)*. 2014 Mar;15(1):39-43. [\[PMID\]](#)
48. Bhardwaj A, Velmurugan N; Sumitha, Ballal S. Efficacy of passive ultrasonic irrigation with natural irrigants (*Morinda citrifolia* juice, Aloe Vera and Propolis) in comparison with 1% sodium hypochlorite for

- removal of *E. faecalis* biofilm: an in vitro study. *Indian J Dent Res.* 2013 Jan-Feb;24(1):35-41. [\[DOI\]](#)
49. Eswar K, Venkateshbabu N, Rajeswari K, Kandaswamy D. Dentinal tubule disinfection with 2% chlorhexidine, garlic extract, and calcium hydroxide against *Enterococcus faecalis* by using real-time polymerase chain reaction: In vitro study. *J Conserv Dent.* 2013 May;16(3):194-8. [\[DOI\]](#)
 50. Maekawa LE, Valera MC, Oliveira LD, Carvalho CA, Camargo CH, Jorge AO. Effect of *Zingiber officinale* and propolis on microorganisms and endotoxins in root canals. *J Appl Oral Sci.* 2013 Jan-Feb;21(1):25-31. [\[DOI\]](#)
 51. Kumar N, Sidhu P. The antimicrobial activity of *Azadirachta indica*, *Glycyrrhiza glabra*, *Cinnamum zeylanicum*, *Syzygium aromaticum*, *Acacia nilotica* on *Streptococcus mutans* and *Enterococcus faecalis* - An in vitro study. *Endodontology* 2011; 23:18-25.
 52. Nayak A, Ranganathan N, Sowmya GB, Kishore B, Kudalkar M. Evaluation of antibacterial and anticandidal efficacy of aqueous and alcoholic effect of neem (*Azadirachta Indica*): An in vitro study. *International Journal of Research in Ayurveda & Pharmacy.* 2011; 2: 230-235.
 53. Vinothkumar TS, Rubin MI, Balaji L, Kandaswamy D. In vitro evaluation of five different herbal extracts as an antimicrobial endodontic irrigant using real time quantitative polymerase chain reaction. *J Conserv Dent* 2013;16:167-70. [\[DOI\]](#)
 54. Al Sabawi NAK, Al Sheikh Abdal AK-K, Taha MYM. The antibacterial activity of *Salvadora persica* solution (miswak-siwak) as root canal irrigant. *J Pure Appl Sci* 2007; 4 :69-91.
 55. Jayahari NK, Niranjana NT, Kanaparthi A. The efficacy of passion fruit juice as an endodontic irrigant compared with sodium hypochlorite solution: an in vitro study. *J Investig Clin Dent.* 2014 May;5(2):154-60. doi: 10.1111/jicd.12023. Epub 2013 Jan 25. [\[DOI\]](#)
 56. Rees JS, Loyn T, Rowe W, Kunst Q, McAndrew R. The ability of fruit teas to remove the smear layer: an in vitro study of tubule patency. *J Dent.* 2006 Jan;34(1):67-76. [\[DOI\]](#)
 57. Pujar M, Patil C, Kadam A. Comparison of antimicrobial efficacy of Triphala, (GTP) Green tea polyphenols and 3% of Sodium hypochlorite on *Enterococcus faecalis* biofilms formed on tooth substrate: In Vitro. *J Int Oral Health;* 2011; 3(2): 23-28.
 58. Sadr Lahijani MS, Raouf Kateb HR, Heady R, Yazdani D. The effect of German chamomile (*Marticaria recutita* L.) extract and tea tree (*Melaleuca alternifolia* L.) oil used as irrigants on removal of smear layer: a scanning electron microscopy study. *Int Endod J.* 2006 Mar; 39(3):190-5. [\[DOI\]](#)
 59. Rees J, loyn T, Rowe W, Kunst Q, McAndrew R. The ability of fruit teas to remove the smear layer: an in vitro study of tubule patency. *Journal of Dentistry* 2006; 34: 67-76. [\[DOI\]](#)
 60. Hancock HH 3rd, Sigurdsson A, Trope M, Moiseiwitsch J. Bacteria isolated after unsuccessful endodontic treatment in a North American population. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod.* 2001 May;91(5):579-86. [\[DOI\]](#)
 61. Halkai RS, Hegde MN, Halkai KR. Evaluation of *Enterococcus faecalis* adhesion, penetration, and method to prevent the penetration of *Enterococcus faecalis* into root cementum: Confocal laser scanning microscope and scanning electron microscope analysis. *J Conserv Dent.* 2016 Nov-Dec;19(6):541-548. [\[DOI\]](#)
 62. Halkai R, Hegde M N, Halkai K. *Enterococcus faecalis* can survive extreme challenges Overview. *NUJHS* 2012;2(3):49-53 ISSN 2249-7110. [\[DOI\]](#)
 63. Halkai R, Hegde MN, Halkai K. Evaluation of the presence of *Enterococcus faecalis* in root cementum: A confocal laser scanning microscope analysis. *J Conserv Dent.* 2014 Mar;17(2):119-23. [\[DOI\]](#)
 64. Neelakantan P, Subbarao C, Sharma S, Subbarao CV, Garcia-Godoy F, Gutmann JL. Effectiveness of curcumin against *Enterococcus faecalis* biofilm. *Acta Odontol Scand.* 2013 Nov;71(6):1453-7. [\[DOI\]](#)
 65. Mahendra M, Agrawal N, Munaga S, Tyagi S. Antimicrobial activity of different biological extracts as intracanal medicament against *Enterococcus faecalis*: An in vitro study. *Endodontology* 2016;28:166-70. [\[DOI\]](#)
 66. Sheth H, Kamath U, Ramesh S, Singla K. Comparison of the Antibacterial Efficacy of Tea Tree Oil with 3% Sodium Hypochlorite and 2% Chlorhexidine against *E. faecalis*: An in vitro Study. *J Contemp Dent* 2013; 3 (3):117-20. [\[DOI\]](#)
 67. Chandrappa PM, Dupper A, Tripathi P, Arrojo R, Sharma P, Sulochana K. Antimicrobial activity of herbal medicines (tulsi extract, neem extract) and chlorhexidine against *Enterococcus faecalis* in Endodontics: An in vitro study. *J Int Soc Prev Community Dent.* 2015 Dec;5(Suppl 2):S89-92. [\[DOI\]](#)
 68. Awooda, Abdel karim. The Effect of Herbal Medicine against *Enterococcus faecalis* on Infected Root Canal Substrate: An Ex-vivo Study. *European Journal of Medicinal Plants,* 2016; 17(2): 1-10. [\[DOI\]](#)
 69. Karkare SR, Ahire NP, Khedkar SU. Comparative evaluation of the antimicrobial activity of hydro alcoholic extract of Aloe Vera, garlic, and 5% sodium hypochlorite as root canal irrigants against *Enterococcus faecalis*: An in vitro study. *Journal of the Indian Society of Pedodontics and Preventive Dentistry.* 2015; 33: 274-8. [\[DOI\]](#)
 70. Saxena D, Saha SG, Saha MK, Dubey S, Khatri M. An in vitro evaluation of antimicrobial activity of five herbal extracts and comparison of their activity with 2.5% sodium hypochlorite against *Enterococcus faecalis*. *Indian J Dent Res [serial online]* 2015 [cited 2021 Sep 8];26:524-7. [\[DOI\]](#)
 71. Kalaiselvam R, Soundararajan K, Rajan R M, et al. (July 24, 2019) Comparative Evaluation of the Anti-bacterial Efficacy of Herbal Medicaments and Synthetic Medicaments Against *Enterococcus faecalis* using Real-time Polymerase Chain Reaction. *Cureus* 11(7): e5228. [\[DOI\]](#)
 72. Podar R, Kulkarni GP, Dadu SS, Singh S, Singh SH. In vivo antimicrobial efficacy of 6% *Morinda citrifolia*, *Azadirachta indica*, and 3% sodium hypochlorite as root canal irrigants. *Eur J Dent.* 2015 Oct-Dec;9(4):529-534. [\[DOI\]](#)
 73. Bolhari B, Sharifian MR, Aminsobhani M, Monsef Esfehiani HR, Tavakolian P. Assessing the efficacy of citrus aurantifolia extract on smear layer removal with scanning electron microscope. *Iran Endod J.* 2012 Spring;7(2):88-97. Epub 2012 Jun 1. [\[PMID\]](#)
 74. Maguire H., Torabinejad M., Kettering J. The use of aloe vera gel as an intracanal medicament. *J. Endod.* 1996; 22: 193. [\[DOI\]](#)
 75. Kurian B, Swapna D.V, Nadig R.R, Ranjini M.A, Rashmi K, Bolar S.R. Efficacy of calcium hydroxide, mushroom, and Aloe vera as an intracanal medicament against *Enterococcus faecalis*: An in vitro. *Endodontology.* 2016; 28:137-42. [\[DOI\]](#)
 76. Dutta A, Kundabala M. Comparative anti-microbial efficacy of *Azadirachta indica* irrigant with standard endodontic irrigants: A preliminary study. *J Conserv Dent [serial online]* 2014 [cited 2021 Sep 8];17:133-7. [\[DOI\]](#)
 77. Shakouie S, Eskandarinezhad M, Gasemi N, Milani AS, Samiei M, Golizadeh S. An in vitro comparison of the antibacterial efficacy of triphala with different concentrations of sodium hypochlorite. *Iran Endod J.* 2014 Fall;9(4):287-9. Epub 2014 Oct 7. [\[PMID\]](#)