



Review Article

Natural Products Used as Disinfectants in Prosthodontics and Oral Implantology: A Narrative Review



Manar Hamed Almehyawi¹, Diyala Mohammed Basyoni¹, Rima Basil Alsibaie¹, Khadijah Hashim Alhussini¹, Renad Mohammed Lashkar¹, Rama Krishna Alla^{2*} , Mohammed Shammass³ and Ghaida Meshari Alotaibi¹

¹Ibn Sina National College for Medical Studies, Jeddah, Makkah, Saudi Arabia; ²Division of Dental Materials, Vishnu Dental College, Bhimavaram, West Godavari, Andhra Pradesh, India; ³Department of Oral and Maxillofacial Rehabilitation, Division of Prosthodontics, Ibn Sina National College for Medical Studies, Jeddah, Makkah, Saudi Arabia

Received: March 26, 2025 | Revised: May 08, 2025 | Accepted: July 09, 2025 | Published online: July 31, 2025

Abstract

Infection control is essential for the success of prosthodontic and oral implant procedures, as microbial contamination can lead to serious complications such as denture stomatitis and peri-implantitis. While synthetic disinfectants like chlorhexidine are commonly used, they may cause side effects including irritation, toxicity, and the development of microbial resistance over time. Natural products derived from plants, animals, and minerals are currently being explored as safer alternatives. Compounds such as epigallocatechin gallate from green tea; eugenol from clove oil; quercetin, thymol, cinnamaldehyde, and flavonoids from propolis; and terpinen-4-ol from tea tree oil have shown strong antimicrobial and anti-biofilm properties. These natural agents are not only effective against harmful oral bacteria but also promote healing, are more biocompatible, environmentally friendly, and are often preferred by patients. However, challenges remain regarding their routine clinical use. The strength and composition of natural agents can vary, and there is a lack of consistent product standards, clinical trials, and comprehensive safety data. Currently, these products are not approved by the U.S. Food and Drug Administration for dental use and are only available as over-the-counter remedies. Production costs and scalability must also be evaluated in comparison with synthetic alternatives. Emerging technologies, such as nanocarriers and targeted delivery systems, are being developed to enhance the effectiveness of natural agents in dental applications. Further clinical research and the establishment of clear regulatory guidelines are necessary to support their integration into clinical practice. Natural disinfectants hold significant potential to become valuable, safe, and sustainable tools for maintaining hygiene in prosthodontics and oral implantology.

Introduction

Prosthodontics and oral implantology have transformed dental care by restoring the function and aesthetics of patients with missing or damaged teeth. In the United States, over five million dental implants are placed annually to replace missing teeth.¹ These fields utilize various materials, including metals, ceramics, and polymers.² Despite their durability, these materials are susceptible to microbial contamination, posing significant challenges to

infection control. Nosocomial infections, often originating in clinical settings, are primarily associated with biofilm formation due to the high pathogenicity of biofilm-producing microorganisms.³ Bacterial adhesion to implant surfaces initiates biofilm development, emphasizing the critical role of implant surface properties in influencing host responses.⁴ Effective infection control, including the strategic use of disinfectants, is essential for preserving oral health and ensuring the long-term success of dental prostheses and implants.

Disinfectants play a vital role in reducing microbial load on dental instruments and surfaces, ensuring aseptic conditions during procedures, and minimizing infection risk.⁵ They help prevent bacterial colonization around implants, thereby aiding in the control of peri-implantitis by reducing inflammation and protecting surrounding tissues.⁶ Although disinfectants may not replace established decontamination protocols, their contribution to maintaining asepsis remains crucial for successful implant therapy.⁷ However, the long-term use of synthetic disinfectants raises concerns due to their adverse effects. Despite their proven antimicrobial efficacy,

Keywords: Antimicrobial agents; Biofilms; Dental implants; Herbal medicine; Nanotechnology; Phytotherapy.

*Correspondence to: Rama Krishna Alla, Division of Dental Materials, Vishnu Dental College, Bhimavaram, West Godavari, Andhra Pradesh 534202, India. ORCID: <https://orcid.org/0000-0002-0668-4605>. Tel: +91-9502507299, E-mail: rkdenalbio-materials@gmail.com; ramakrishna.a@vdc.edu.in

How to cite this article: Almehyawi MH, Basyoni DM, Alsibaie RB, Alhussini KH, Lashkar RM, Alla RK, et al. Natural Products Used as Disinfectants in Prosthodontics and Oral Implantology: A Narrative Review. *J Explor Res Pharmacol* 2025;000(000):000–000. doi: 10.14218/JERP.2025.00016.

agents such as chlorhexidine can cause mucosal irritation, tissue cytotoxicity, allergic reactions, and may contribute to the development of antimicrobial resistance. These health and environmental risks have spurred interest in safer and more sustainable alternatives, particularly natural disinfectants for routine dental use. Historically, synthetic disinfectants have been the primary agents used to combat microbial contamination in dental practices. Nonetheless, growing concerns about their toxicity, ecological impact, and role in promoting antimicrobial resistance have led to increased interest in natural alternatives. Limitations of synthetic disinfectants, including cytotoxicity, promotion of antimicrobial resistance, allergic responses, ecological damage, high production or disposal costs, have called their long-term viability into question. Their harmful effects on oral tissues and potential to disrupt microbial homeostasis further compromise their clinical sustainability. By contrast, natural alternatives offer several advantages that support their integration into dental disinfection protocols. These agents are generally more biocompatible, exhibit lower toxicity, and are less likely to induce microbial resistance. Derived from renewable sources, they impose a reduced ecological burden. Additionally, their milder sensory profiles and cultural familiarity enhance patient acceptability. These benefits position natural disinfectants as promising substitutes in prosthodontics and implantology, aligning with goals of efficacy, safety, and sustainability.

Natural products, including plant-based extracts, animal-derived substances, and mineral compounds, exhibit potent antimicrobial properties with fewer side effects, making them attractive candidates for dental applications.⁸ Furthermore, they offer a viable means of preventing biofilm formation.⁹ Although natural disinfectants are not new, their applications in prosthodontics and oral implantology remain underexplored. Plant-derived agents such as clove, neem, and tea tree oil, along with animal-based products like honey and propolis, have demonstrated strong antimicrobial and anti-inflammatory effects.¹⁰ Natural substances including propolis, Aloe vera, and green tea have shown notable antimicrobial, antioxidant, and anti-inflammatory activities, making them effective for cavity disinfection.¹¹ These alternatives are often less toxic, more cost-effective, environmentally friendly, and generally better accepted by patients.⁹ Despite these advantages, the literature lacks comprehensive reviews specifically addressing the use of natural disinfectants for prosthetic materials and dental implant surfaces. This gap highlights the need for a focused evaluation of their efficacy, safety, and clinical potential in prosthodontics and oral implantology. Accordingly, this review aims to bridge that gap by critically analyzing natural disinfectants, comparing their mechanisms of action and efficacy with those of synthetic agents, and assessing their potential for integration into clinical dental protocols.

Methodology

This narrative review was designed to explore and critically appraise the use of natural disinfectants in prosthodontics and oral implantology. A comprehensive electronic literature search was conducted from December 1, 2024, to March 30, 2025, across five major databases: PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and Google Scholar.

Search strategy

The search strategy was developed using a combination of Medical Subject Headings and free-text keywords combined with Boolean operators (“AND,” “OR”) to maximize sensitivity and specificity

across databases. Keywords included “natural disinfectants,” “prosthodontics,” “phytotherapeutic agents,” “dental materials,” “herbal products,” “implantology,” “natural antimicrobials,” “denture disinfection,” “essential oils,” “peri-implantitis,” and “plant-based antimicrobials in oral care.” A representative PubMed search string was: (“natural disinfectants” OR “herbal products”) AND (“prosthodontics” OR “dental materials”) AND (“implantology” OR “peri-implantitis”). Searches were performed across PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and Google Scholar to ensure comprehensive literature coverage. PubMed/MEDLINE was used for peer-reviewed biomedical articles, Scopus and Web of Science for multidisciplinary scientific publications, Cochrane Library for relevant reviews and clinical trials, and Google Scholar to identify additional gray literature. Reference lists of selected articles were also manually screened to identify any missed studies.

Selection criteria

Inclusion criteria comprised original research articles, systematic reviews, or clinical trials evaluating natural products with antimicrobial or disinfectant properties in prosthodontics and/or implantology; studies published in English; *in vitro*, *in vivo*, or clinical studies addressing oral biofilm control, denture disinfection, peri-implant mucositis, or related implant-associated infections; and studies reporting outcomes on antimicrobial efficacy, biocompatibility, or clinical performance. Exclusion criteria included studies not directly related to prosthodontics or implantology; articles focusing solely on synthetic disinfectants or conventional chemical agents; editorials, commentaries, letters, or abstracts lacking methodological detail; duplicate publications or papers with incomplete data; and articles published in languages other than English.

Study selection and data extraction

Study selection followed a three-phase process: initial screening of titles, followed by abstract review, and finally full-text evaluation for eligibility. Two independent reviewers, MS and RK, conducted all screening and selection phases. Discrepancies were resolved through mutual discussion. Data extraction utilized a standardized format focusing on study type, source of the natural agent, active phytochemical components, mechanisms of action, mode of application, antimicrobial efficacy, advantages, limitations, and clinical relevance to prosthodontic and implant care.

Classification of natural products used as disinfectants

Plant-based products

The antimicrobial properties of plant-based products and their lower incidence of side effects compared to chemical agents have increased their popularity as natural substitutes for oral hygiene.¹⁰ Clove, miswak, tea tree oil, neem, and Aloe vera are herbs and essential oils that have demonstrated effectiveness in supporting dental and oral health. After ginger-garlic paste, neem and tea tree oil, clove oil exhibits the strongest antimicrobial activity against microorganisms responsible for dental caries.¹² Caries disinfectants such as tea tree oil and Aloe vera gel are effective; however, 2% chlorhexidine has demonstrated superior results.¹³ The potent antibacterial, antifungal, and antiviral compounds found in miswak, eucalyptus oil, thyme oil, and cinnamon oil make them excellent for maintaining oral health and prosthetic surfaces by dissolving and disrupting biofilms.¹⁴

Animal-based products

Animal-based disinfectant products, particularly bee-derived substances such as propolis and honey, have gained attention in dentistry for their antimicrobial properties. Propolis, a resinous substance produced by bees, has garnered significant interest due to its diverse therapeutic effects. It exhibits potent antibacterial, antifungal, antiviral, and anti-inflammatory activities, making it valuable for dental applications.¹⁵ Its efficacy in inhibiting oral pathogens such as *Streptococcus mutans* (*S. mutans*) and *Candida albicans* (*C. albicans*) supports its use in preventing dental caries and oral infections.¹⁶ Propolis has also been investigated for treating recurrent aphthous stomatitis, oral mucositis, and cavity disinfection following caries removal.¹⁷

Mineral and microbial products

Natural mineral and microbial products are promising alternatives to synthetic disinfectants for dental implants, offering antimicrobial properties and promoting biocompatibility with minimal side effects. Clay minerals have demonstrated antibacterial properties against various pathogens, including antibiotic-resistant strains. Antimicrobial coatings on prosthetic surfaces may inhibit colonization by *Candida* species-containing polymicrobial biofilms in dental implantology. These coatings include antibiotics, sanitizing agents, nanoparticles, and antimicrobial peptides.¹⁸ Bacteriocins produced by lactic acid bacteria are promising bioactive peptides with antimicrobial activity against oral pathogens.^{18,19} All natural disinfectants, their active compounds, mechanisms, applications, advantages, and limitations in prosthodontics and implantology are summarized in Table 1.^{20–38}

Mechanisms of action of natural disinfectants

Antimicrobial properties

Direct anti-microbial action

Natural compounds act through multiple mechanisms in oral health: inhibiting bacterial growth and adhesion, exhibiting bacteriostatic and bactericidal effects, suppressing glucan production and amylases, disrupting biofilms and co-aggregation, altering signal transduction, reducing acid and lactic acid production, lowering bacterial hydrophobicity, and downregulating key metabolic genes such as those involved in glycolysis.³⁹ Cubebin derivatives have shown bacteriostatic and fungicidal activities against gram-positive oral bacteria and *C. albicans*. Essential oils and plant extracts exert bactericidal effects by damaging bacterial membranes or intracellular structures. Targeting DNA gyrase, a key enzyme involved in bacterial DNA replication, is another effective mechanism. Quercetin, a natural flavonoid found in propolis, binds to DNA gyrase, thereby inhibiting bacterial proliferation by disrupting DNA synthesis.⁴⁰ Moreover, quercetin affects quorum sensing pathways, plasma membranes, bacterial adhesion, efflux pump inhibition, nucleic acid synthesis blockage, and membrane modification or destruction.⁴¹ Propolis inhibits DNA-dependent RNA polymerase, disrupting bacterial protein synthesis, and reduces bacterial DNA, RNA, and protein levels, hindering bacterial growth. *S. mutans* utilizes quorum sensing to regulate bacteriocin production, which influences microbial competition and biofilm formation, playing a key role in dental caries pathogenesis.⁴² These bacteriocins, also called mutacins, inhibit the growth of competing oral bacteria. However, some oral streptococci, such as *Streptococcus gordonii*, can interfere with *S. mutans* bacteriocin

production through the *challisin* gene (*sgc*), potentially disrupting its virulence.⁴³ The mechanisms of action of key natural disinfectants are illustrated in Figure 1.

Biofilm disruption

Bacterial biofilms are structured microbial communities encased in a self-produced extracellular matrix.⁴⁴ Natural agents, such as cranberry extracts and propolis, inhibit biofilm formation by blocking bacterial adhesion and disrupting signaling pathways. They also target fungi by impairing adenosine triphosphate synthesis, altering ion flux, and inducing reactive oxygen species-mediated membrane and mitochondrial damage. Essential oils such as cinnamon and clove exhibit antibacterial and antiplaque effects by enhancing surface wettability and reducing bacterial adhesion on implant materials.⁴⁵ Epigallocatechin gallate (EGCG) inhibits planktonic growth and biofilm formation of *S. mutans* in a dose-dependent manner by reducing exopolysaccharide production, suppressing *gff* gene expression, lowering DNA content, and binding the glucan sucrose enzyme to block its activity.⁴⁶ The natural antibacterial totarol shows bactericidal effects against oral bacteria and inhibits biofilm growth on implant surfaces, while clove oil suppresses biofilm formation by downregulating virulence genes and quorum sensing, thereby reducing extracellular polymeric substance secretion.⁴⁷

Anti-inflammatory and healing properties

Natural agents such as curcumin (from turmeric) and chamomile extracts effectively reduce inflammation by inhibiting the production of pro-inflammatory cytokines and enzymes like cyclooxygenase-2. This modulation of inflammatory responses minimizes tissue damage and promotes healing around implants. Periodontitis, an inflammatory dental disease caused by specific microorganisms, leads to tissue destruction. Key pathogens include *Porphyromonas gingivalis* (*P. gingivalis*), *Actinobacillus actinomycetemcomitans*, and *Tannerella forsythia*.⁴⁸ Herbal and natural disinfectants such as tulsi, neem, guava, propolis, and sanguinarine have shown efficacy in controlling these pathogens.⁴⁹ Natural disinfectants reduce bacterial load, enhance the longevity of dental restorations, and may improve resin-dentin bond strength.

Mechanisms specific to oral microorganisms

Natural disinfectants show promise against oral pathogens involved in peri-implantitis and diseases caused by ill-fitting prostheses, notably targeting *P. gingivalis* and *S. mutans*. Green tea polyphenols combat bacteria, fungi, and viruses by disrupting cell membranes, inhibiting vital enzymes, and damaging DNA. Similarly, clove oil penetrates bacterial cell walls, effectively killing *S. mutans*, a major contributor to dental caries.⁵⁰ Various oral pathogens, their associated diseases, and effective antimicrobial natural products are highlighted in Table 2 and Figure 2.^{51–56}

Applications in prosthodontics

Disinfection of prosthetic appliances

Prosthetic appliances such as dentures, crowns, bridges, and veneers are prone to microbial contamination, increasing the risk of infection. Citrus extracts effectively target *C. albicans*, a common denture pathogen. Natural agents, such as soda, vinegar, thymol, and salt, have demonstrated efficacy comparable to commercial denture cleaners. Phytotherapeutic herbs rich in polyphenols, flavonoids, and tannins offer antimicrobial, antifungal, and anti-

Table 1. Overview of various natural disinfectants and their roles in prosthodontics and implantology

Example	Source	Active compound	Mechanism of action	Application in prosthodontics/implantology	Advantage	Limitation	Reference
Bioactive compound	Plant (<i>Podocarpus totara</i>)	Totarol	Contact killing, biofilm inhibition	Coatings on the surfaces or abutments of titanium implants and silicon wafers	Strong anti-microbial and anti-coating on dental surface	Delayed anti-adhesion and inhibition effect on biofilm development	20
Clove	Plant (<i>Syzygium aromaticum</i>)	Eugenol	Disrupts microbial cell membranes, inhibits biofilms	Denture disinfectant, anti-inflammatory, used in oral rinses	Strong antimicrobial activity, anti-inflammatory	Potential irritation, taste issues	21
Tea tree oil	Plant (<i>Melaleuca alternifolia</i>)	Terpinen-4-ol	Antimicrobial, disrupts cell membranes	Used in mouthwashes, peri-implantitis treatment	Antifungal, anti-bacterial	Allergic reactions in some individuals	22
Neem	Plant (<i>Azadirachta indica</i>)	Azadirachtin, nimbidin	Inhibits bacterial growth, anti-inflammatory	Used in denture cleaning, oral rinses	Wide antimicrobial spectrum	Bitter taste, inconsistent strength	23
Aloe vera	Plant (<i>Aloe barbadensis</i>)	Aloin, Aloe-emodin, anthraquinones	Anti-inflammatory, antimicrobial	Used in peri-implant healing gels, oral hygiene products	Healing properties, soothing effect	Requires high concentration for efficacy	24
Miswak	Plant (<i>Salvadora persica</i>)	Salvadorine	Antibacterial, biofilm disruption	Used for cleaning teeth and prosthetic surfaces	Natural toothbrush, potent antimicrobial	It may not fully replace modern methods	25
Eucalyptus oil	Plant (<i>Eucalyptus globulus</i>)	1,8-cineole	Antibacterial, antifungal, antiviral	Oral rinses for infection control	Broad antimicrobial action	May irritate in large doses	26
Thyme oil	Plant (<i>Thymus vulgaris</i>)	Thymol	Antimicrobial inhibits microbial enzyme systems	Oral rinses, prosthetic surface disinfection	Effective against a wide range of bacteria	Potential irritant at high concentrations	27
Cinnamon oil	Plant (<i>Cinnamomum verum</i> / <i>Cinnamomum cassia</i>)	Cinnamaldehyde	Antibacterial, disrupts bacterial cell walls and surface charge, inhibits quorum sensing	Surface disinfectant for dental tools and prostheses	Strong antifungal and antibacterial	High doses may cause irritation	28
Green tea extract	Plant (<i>Camellia sinensis</i>)	Epigallocatechin gallate (EGCG)	Inhibits bacterial enzymes, biofilm reduction, reduced plaque index, gingival index	Used in oral gels, toothpaste, adjunct to peri-implant treatments	Antioxidant, anti-inflammatory	Effectiveness varies depending on the concentration	29

(continued)

Table 1. (continued)

Example	Source	Active compound	Mechanism of action	Application in prosthodontics/implantology	Advantage	Limitation	Reference
Propolis	Animal (bee product)	Flavonoids, phenolic acids	Inhibits microbial growth, has antioxidant properties, antifungal, antiviral	Used in mouthwashes, topical application for implant sites	Strong antimicrobial and healing effects	Inconsistent composition, potential allergies	30
Honey	Animal (bee product)	Hydrogen peroxide, flavonoids	Antimicrobial, inhibits biofilm formation, wound healing	Used for wound healing in implantology, peri-implantitis management	Promotes healing, anti-inflammatory	Sticky texture, limited availability	31
Shark liver oil	Animal (marine animal)	Alkylglycerols	Antimicrobial, promotes wound healing	Used in implant sites for anti-inflammatory effects	Promotes tissue regeneration, anti-inflammatory	Limited availability, high cost	32
Bee venom	Animal (bee product)	Melittin, Phospholipase, Apitoxin	Antimicrobial, anti-inflammatory	Potentially used in topical applications for wound care	Strong anti-inflammatory effects	Risk of allergic reactions	33
Silk protein	Animal (silkworms)	Sericin	Antimicrobial, enhances cell proliferation	Used in dental biomaterials for improved biocompatibility, adhesives, wound healing, coating	Biocompatible, promotes tissue repair	Limited use, can be expensive	34
Clay	Natural (mineral)	Silica, Montmorillonite, Bentonite	Absorbs toxins, has antimicrobial properties	Used in surface cleaning of prostheses, denture disinfectants	Natural, mild antimicrobial effects	Variable efficacy requires proper application	35
Zeolite	Natural (mineral)	Aluminosilicates	Adsorbs toxins, antimicrobial effects	Used in water filtration, potential use in denture cleaning, dental liners	Effective in adsorbing impurities	Limited direct applications in dentistry	36
Bacteriocins	Natural (produced by microbes)	Nisin, Pediocin	Antimicrobial, disrupts microbial cell membranes	Potential use in oral gels, coatings for implants	Targeted antimicrobial activity	Limited availability, may be strain-specific	37
Lactic acid bacteria	Natural (fermented products)	Lactic acid	Antimicrobial, produces antimicrobial peptides	Used in probiotics for oral health, potential application in mouthwashes	Promotes oral health, inhibits pathogens	Limited effectiveness against all pathogens	38

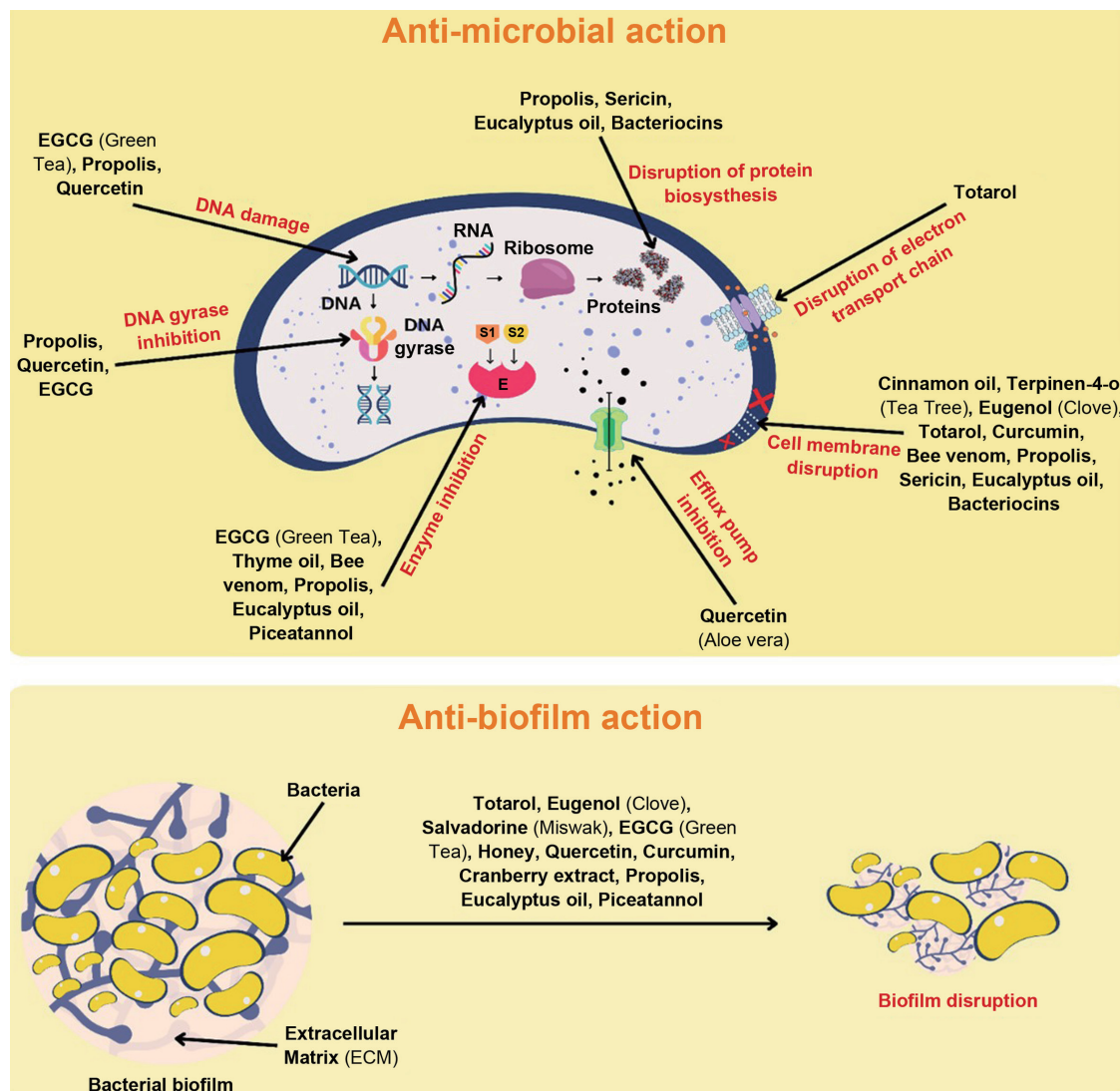


Fig. 1. Mechanism of action of natural disinfectants. EGCG, epigallocatechin gallate.

inflammatory benefits, supporting oral health and prosthodontic appliance maintenance.⁵⁷ Examples of natural disinfectants used in prosthodontics include:

- *Clove*: Its active compound eugenol disrupts microbial membranes and inhibits biofilm formation, making it effective for denture disinfection and oral rinses. It also has anti-inflammatory properties that reduce mucosal irritation associated with prosthetic appliances.²¹
- *Tea tree oil*: Terpinen-4-ol in tea tree oil exhibits potent antibacterial and antifungal activities by disrupting cell membranes. It is used in mouthwashes targeting peri-implant infections and denture-related biofilms.²²
- *Neem*: Neem extracts, rich in azadirachtin and nimbidin, have broad-spectrum antimicrobial and anti-inflammatory effects and are widely used in denture cleaning and oral rinses to reduce microbial colonization on prosthetic surfaces.²³
- *Thyme oil*: It effectively inhibits microbial enzyme systems and serves as an oral rinse and prosthetic surface disinfectant, demonstrating efficacy against diverse bacteria involved in pros-

thetic contamination.²⁷

- *Cinnamon oil*: Cinnamaldehyde disrupts bacterial cell walls and inhibits quorum sensing, making it a strong antifungal and antibacterial agent for disinfecting dental instruments and prostheses.²⁸
- *Green tea extract*: EGCG inhibits bacterial enzymes and reduces biofilm formation, useful in oral gels and toothpaste adjunctive to prosthetic hygiene, and helps reduce plaque and gingival inflammation.²⁹
- *Propolis*: It is rich in flavonoids and phenolic acids, and it inhibits microbial growth and promotes healing when applied topically or in mouthwashes for prosthetic-related infections.³⁰

Incorporation in dental materials

Integrating natural antimicrobial agents such as propolis, tea tree oil, or curcumin into dental materials, including titanium surfaces, makes them inhospitable to bacterial and fungal growth. Studies have demonstrated that adding phytoncide (a volatile organic compound produced by plants) to polymethyl methacrylate resins

Table 2. Oral pathogens, their associated diseases, and effective natural disinfectants

No	Oral pathogens	Disease	Natural disinfectant	Refs
1	<i>Porphyromonas gingivalis</i>	Chronic periodontitis, peri-implantitis	Green tea polyphenols (EGCG), trans-cinnamaldehyde, tulsii, neem, guava, propolis, honey, totarol, garlic extract, bacteriocins, sanguinarine	51
2	<i>Actinobacillus actinomycetemcomitans</i>	Periodontitis	Tulsii, neem, guava, propolis, garlic extract, sanguinarine	51
3	<i>Tannerella forsythia</i>	Chronic periodontitis, peri-implantitis	Tulsii, neem, guava, propolis, sanguinarine	51
4	<i>Streptococcus mutans</i>	Dental caries (tooth decay)	Clove oil, green tea, polyphenols EGCG, honey, sericin, garlic extract, bacteriocins	52
5	<i>Actinomyces israelii</i>	Actinomycosis, root surface caries, gingivitis	Cinnamon oil, clove oil, eucalyptus, EGCG	52
6	<i>Actinomyces naeslundii</i>	Root surface caries, gingivitis	EGCG, garlic extract	52
7	<i>Actinomyces oris</i>	Early plaque formation, gingivitis, root caries	EGCG	52
8	<i>Actinomyces odontolyticus</i>	Dental caries, root canal infections	EGCG	52
9	<i>Prevotella intermedia</i>	Gingivitis, periodontitis, peri-implantitis, acute necrotizing ulcerative gingivitis (ANUG), endodontic infections	Curcumin, EGCG, honey, totarol, garlic extract	52
10	<i>Fusobacterium nucleatum</i>	Necrotizing ulcerative gingivitis (NUG), root canal infection, periodontitis, peri-implantitis	Propolis, Aloe vera, EGCG, honey, totarol, garlic extract	52
11	<i>Treponema denticola</i>	Chronic periodontitis, necrotizing ulcerative gingivitis (NUG)	Propolis, EGCG	53
12	<i>Prevotella nigrescens</i>	Periodontitis, endodontic infections	Curcumin, totarol, garlic extract	54
13	<i>Campylobacter rectus</i>	Chronic periodontitis	Propolis, EGCG, Aloe vera, cranberry, honey	54
14	<i>Pseudomonas aeruginosa</i>	Periodontal disease, endodontic infections	EGCG, honey	54
15	<i>Eubacterium nodatum</i>	Periodontal disease	Honey	54
16	<i>Candida albicans</i> (yeast)	Oral candidiasis (thrush), denture stomatitis	EGCG, garlic extract, citrus extracts	54
17	<i>Selenomonas</i> spp.	Chronic periodontitis	Cinnamon bark oil, Aloe vera	55
18	Epstein-Barr virus (EBV)	Oral hairy leukoplakia, periodontal disease, Peri-implantitis	EGCG, cranberry extract, propolis	55
19	<i>Eikenellacorrodens</i>	Periodontal disease, endodontic infections	Garlic extract	56
20	<i>Dialisterpneumointes</i>	Periodontitis, endodontic infections, periradicular diseases	Propolis	56
21	<i>Treponema socranskii</i>	Chronic periodontitis, necrotizing periodontal diseases	EGCG	56
22	<i>Porphyromonas endodontalis</i>	Endodontic infections	Propolis	56
23	<i>Staphylococcus</i> spp.	Peri-implantitis, prosthetic infections	Tea tree oil, garlic extract, cinnamon oil, honey, Aloe vera	56
24	<i>Desulfobulbus</i> spp.	Periodontal disease	Garlic extract	56
25	<i>Lactobacillus</i> spp.	Dental caries, especially root caries	EGCG	56
26	<i>Actinomyces viscosus</i>	Root surface caries, gingivitis	EGCG	56
27	<i>Aggregatibacter actinomycetemcomitans</i>	Aggressive periodontitis, chronic periodontitis	EGCG, honey, totarol	56
28	<i>Veillonella parvula</i>	Periodontal disease, endodontic infections	EGCG	56
29	Herpes simplex virus type 1 (HSV-1)	Herpetic gingivostomatitis, cold sores, Peri-implantitis	Aloe vera, EGCG, propolis, licorice root extract	56
30	Human papilloma virus (HPV)	Oral warts, potentially associated with oral cancers, periodontitis	EGCG, curcumin, Aloe vera	56

EGCG, epigallocatechin gallate.

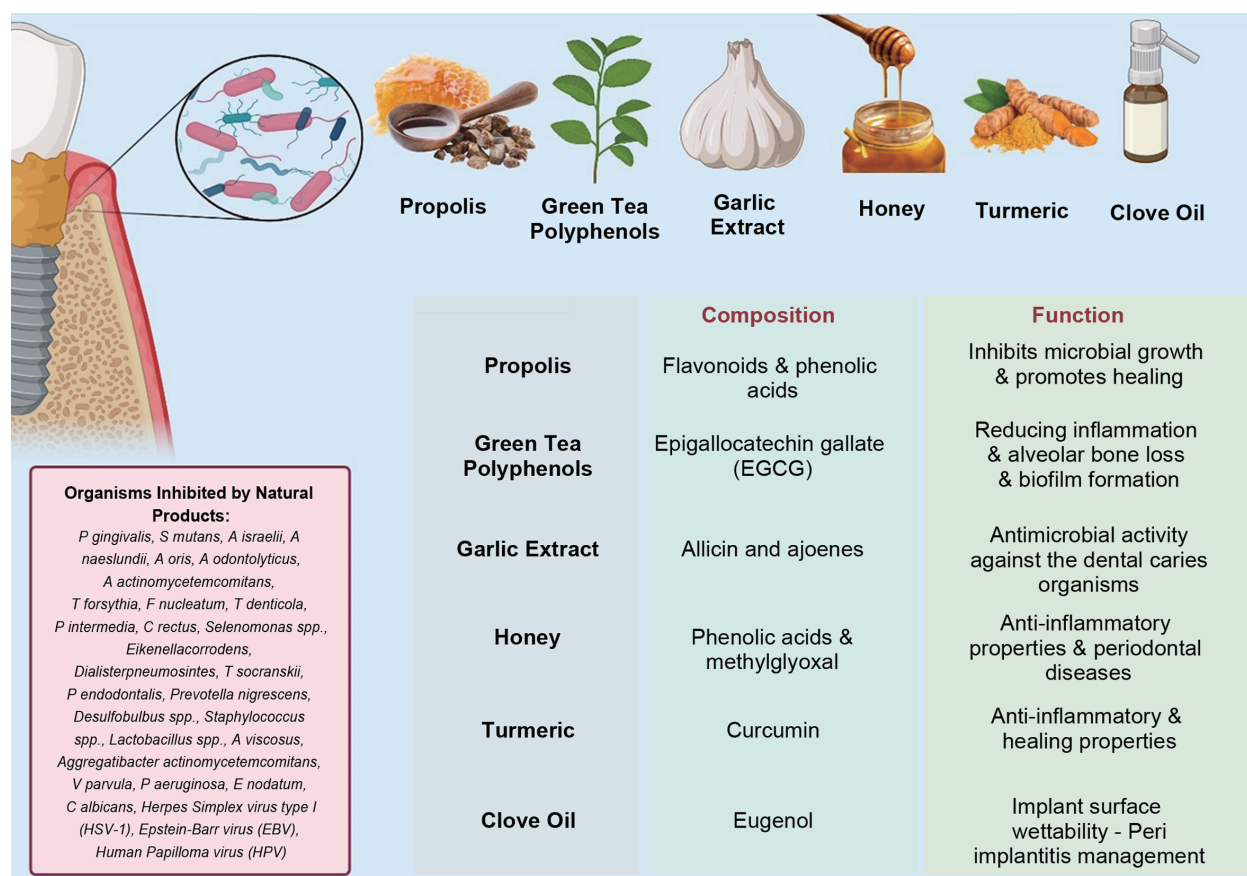


Fig. 2. Antimicrobial natural agents and their bioactive compounds with functional roles in oral and peri-implant health.

commonly used in denture bases significantly inhibits *C. albicans* growth.⁵⁸ Incorporating these natural agents into dental cements enhances antimicrobial properties without compromising mechanical strength or biocompatibility. However, a systematic review found inconclusive evidence regarding the effectiveness of incorporating antimicrobial agents into denture base resins.⁵⁸

Use in oral rinses and gels

The popularity of herbal mouthwashes and gels as adjuncts to traditional prosthetic care has increased. Caries-causing microorganisms such as *Streptococcus mitis*, *S. mutans*, *Staphylococcus aureus*, and *Lactobacillus* spp. can be significantly inhibited by clove oil, ginger-garlic paste, neem, cinnamon oil, eucalyptus oil, turmeric, and tea tree oil in mouthwashes and dentifrices. A herbal mouth rinse containing natural ingredients outperformed commercial products in inhibiting *S. mutans*, *Streptococcus sanguis*, and *Actinomyces viscosus*.⁵⁹ Herbal mixtures and cranberry mouth rinses demonstrated antimicrobial effects comparable to chlorhexidine against *S. mutans*, *Lactobacillus fermentum*, and *Lactobacillus casei*, suggesting their potential as effective natural alternatives.⁵⁹

Applications in oral implantology

Disinfection of implant surfaces

Presurgical sterilization of implant surfaces is critical to prevent

early implant failure caused by microbial contamination. Various sterilization techniques may affect titanium implant surfaces, altering their critical surface energy and bioadhesive properties. Essential oils, such as cinnamon and clove, have demonstrated significant antibacterial effects on various implant materials, increasing surface wettability and reducing bacterial adhesion over 48 hours. Citric acid and tetracycline effectively disinfect osseointegrated implant surfaces contaminated with *P. gingivalis*, although nanotite surfaces prove more challenging to disinfect.⁶⁰ Totarol, a natural antibacterial agent, has shown promising results as a coating on implant surfaces, providing long-term inhibition of bacterial adhesion and biofilm development.⁶⁰ Various natural products used as disinfectants in oral implantology are described below.

Totarol: This bioactive compound from *Podocarpus totara* has been successfully applied as a coating on titanium implant surfaces, significantly inhibiting bacterial adhesion and biofilm formation over prolonged periods.²⁰

Cinnamon and clove oils: Both essential oils exhibit antibacterial properties that enhance implant surface wettability, thereby reducing bacterial adhesion on implant materials during the critical early postsurgical period.^{21,28}

Management of peri-implant infections

Peri-implantitis is a common inflammatory condition characterized by destruction of peri-implant soft and hard tissues, often driven by bacterial biofilm formation. This can lead to bone loss and potential implant failure.⁶¹ Topical application of several natu-

ral agents has demonstrated efficacy in controlling peri-implantitis. Both propolis and Aloe vera tooth gels improved clinical and microbiological parameters in patients with chronic periodontitis, with propolis showing superior reduction of red complex microorganisms.⁶² EGCG is known for its antibacterial and anti-biofilm activity against a diverse bacterial population at implant sites, including *P. gingivalis*, *S. mutans*, *Fusobacterium nucleatum*, *Aggregatibacter actinomycetemcomitans*, and *C. albicans* (Table 2).^{51–56} A few natural agents used to treat peri-implantitis are described below.

- **Propolis and Aloe vera:** Both agents exhibit antimicrobial, anti-inflammatory, and wound-healing properties. Propolis demonstrated superior reduction of red complex bacteria in chronic periodontitis, while Aloe vera promoted peri-implant tissue healing.^{24,30}
- **Green tea extract:** This agent exerts antibacterial and anti-biofilm effects against key peri-implant pathogens such as *P. gingivalis*, *S. mutans*, and *C. albicans*, thereby enhancing implant site health.²⁹

Adjunctive use with mechanical debridement

Natural products, particularly those with antimicrobial properties, serve as useful adjuncts to mechanical therapy for periodontal diseases. Green tea extract has shown promise as adjuvant therapy by reducing inflammation, osteoclastic activity, and alveolar bone loss in experimental periodontitis.⁶³ The modified lipid-soluble form EGCG exhibits synergistic effects with antibiotics, inhibiting biofilm formation by up to 99% in various pathogenic bacteria. Combinations of natural agents such as propolis and EGCG have demonstrated enhanced anti-inflammatory and antimicrobial efficacy, suggesting potential synergy. These combinations may further improve clinical outcomes when used alongside conventional therapies. The combination of essential oils with mechanical debridement also shows promise in managing peri-implantitis, though further research, including *in vivo* studies and clinical trials, is needed to establish efficacy and optimal application methods.⁶⁴

- **Green tea extract:** Acts synergistically with conventional periodontal therapies, reducing inflammation and alveolar bone loss, demonstrating promising adjunctive benefits in managing peri-implantitis.⁶³
- **Lipid-soluble EGCG:** This shows enhanced biofilm inhibition (>99%) when combined with antibiotics, suggesting potential for improved clinical outcomes.⁶³
- **Combination of propolis and EGCG:** The combination enhances anti-inflammatory and antimicrobial effects, indicating potential synergy when used alongside mechanical debridement.^{29,30}
- **Essential oils:** Preliminary evidence suggests that essential oils can support mechanical therapy in peri-implantitis management, although further clinical studies are required to establish standardized protocols.⁶⁴

Regulatory and economic considerations

The translation of natural antimicrobial products into dental applications requires careful navigation of regulatory frameworks such as the U.S. Food and Drug Administration (hereinafter referred to as FDA) and European Medicines Agency pathways. Over-the-counter (OTC) limitations apply to many botanicals unless supported by substantial safety and efficacy data. Natural agents like propolis, tea tree oil, and neem are often classified as dietary supplements or traditional remedies, whereas synthetic compounds

undergo stricter clinical trials and approvals.^{17,23,62} Economically, natural products may offer cost advantages due to lower production and processing costs, but variability in standardization can increase long-term expenses. In contrast, synthetic alternatives offer consistency but incur higher regulatory and production costs.^{35,36}

Challenges and future directions

Standardizing natural disinfectants for dental implantology and periodontics remains challenging due to variability in extraction methods, plant sources, and formulations. Diverse protocols lead to inconsistent results,⁶⁵ complicating assessments of efficacy, safety, and toxicity across the literature. Unlike synthetic disinfectants, natural products lack uniform chemical composition (Fig. 3a–h), affecting antimicrobial potency, stability, and shelf life.⁶⁶ Moreover, natural compounds are often susceptible to degradation under extreme conditions, such as high temperature, variable pH, oxidation, and enzymatic activity, which are commonly encountered during dental procedures such as ultrasonic scaling, autoclaving, or surgical exposure. Such degradation can significantly compromise therapeutic efficacy unless stabilized through appropriate formulation strategies. Extraction and purification processes may also affect compound structure and functionality.⁶⁶

Clinical trials and evidence-based applications

Currently, no natural disinfectants are FDA-approved and are typically marketed under the OTC classification. Despite growing interest, the clinical translation of natural oral health products remains limited. Globally, research spans basic investigations, bio-prospecting, and bioactivity assessments, with regional variations in focus areas.⁶⁷ Clinical trials evaluating propolis-based gels, green tea polyphenols, cranberry extract rinses, and neem-based products have shown encouraging results in reducing microbial load and improving periodontal indices.^{66,67} For instance, propolis and Aloe vera gels have demonstrated improvements in probing depth and bleeding scores in periodontitis patients, while green tea mouth rinses have shown reductions in *S. mutans* levels and gingival inflammation.⁶⁶ Nonetheless, these trials are often constrained by small sample sizes, short durations, and a lack of standardization in product formulations, which limits their generalizability. Natural products offer a rich repertoire of bioactive compounds with anti-caries and anti-periodontal potential; however, their complex chemistry and poorly understood mechanisms of action remain barriers to widespread clinical adoption.^{66,67} Moreover, the lack of large-scale, multicenter, randomized controlled trials restricts the establishment of standardized guidelines for integrating these agents into routine dental protocols. Bridging this gap through methodologically sound, longitudinal randomized controlled trials is essential to validate their efficacy and safety, ultimately supporting regulatory approval and clinical implementation.⁶⁸

Innovation in delivery systems

Nanotechnology offers a promising approach for combating biofilm-associated oral diseases. These systems have shown potential in various dental applications, including caries prevention, tooth remineralization, and periodontal infection management.⁶⁸ This technology enables the encapsulation of natural antimicrobial agents, enhancing their stability, bioavailability, and controlled release at infection sites. Nanocarriers, such as liposomes and nanoparticles, can penetrate biofilms and sustainably release natural disinfectants, thereby improving therapeutic outcomes in dental

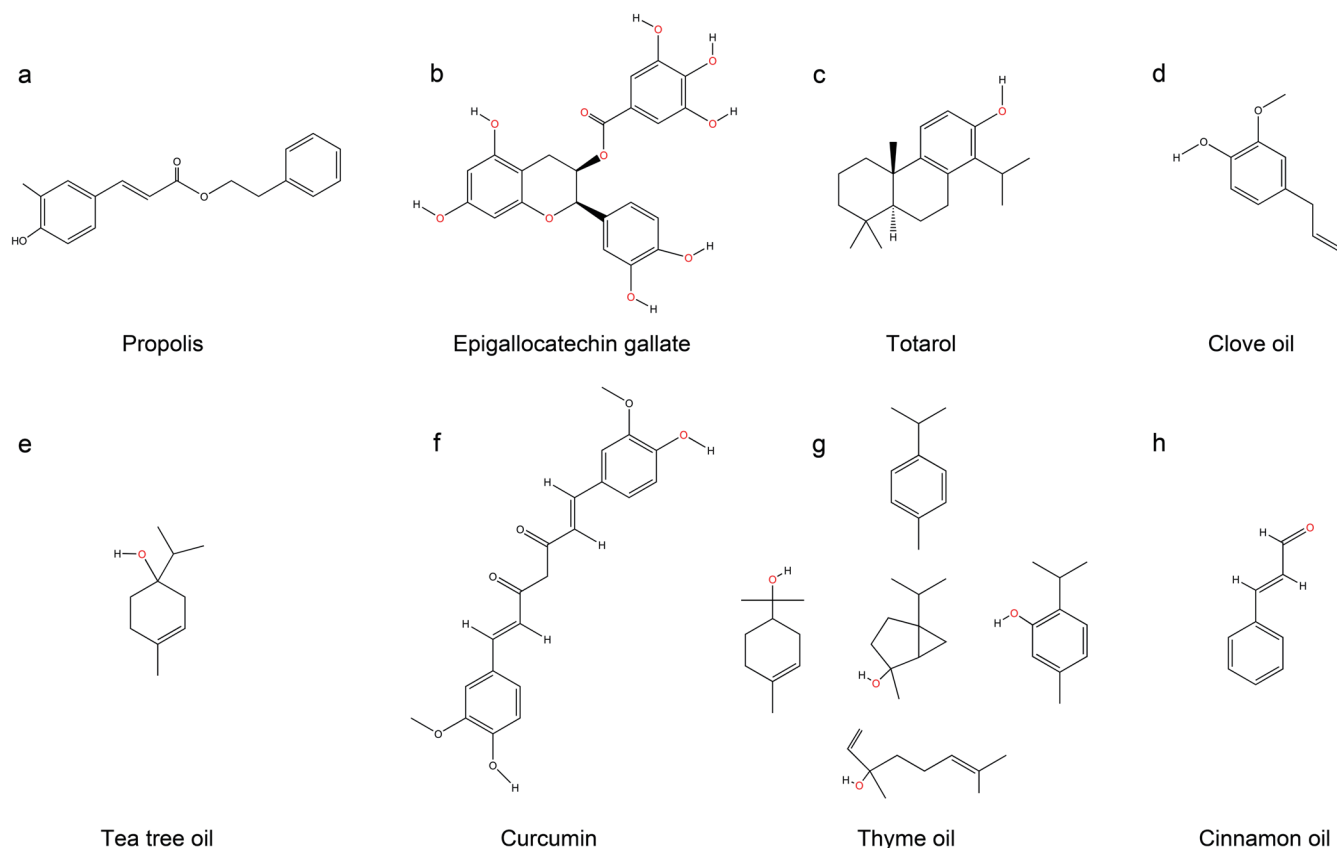


Fig. 3. Molecular structures of key plant-derived antimicrobial agents explored in prosthodontics and oral implantology (a) Propolis, (b) Epigallocatechin gallate, (c) Totarol, (d) Clove oil, (e) Tea tree oil, (f) Curcumin, (g) Thyme oil, and (h) Cinnamon oil.

implantology and periodontics.⁶⁹ However, the scarcity of comprehensive clinical evidence on the synergistic effects of nanotechnology and natural disinfectants has limited broader adoption in dental practice.

Integration into mainstream prosthodontics and implantology

Integrating natural disinfectants into mainstream prosthodontics and implantology presents promising opportunities due to their proven antimicrobial properties, high biocompatibility, and low risk of adverse reactions. Nevertheless, broader adoption in routine clinical settings faces several challenges.⁷⁰ Despite these obstacles, natural disinfectants hold significant potential to emerge as viable substitutes for synthetic agents, especially in response to the increasing demand from patients and healthcare providers for safer, more environmentally friendly products.

Limitations

This review has several limitations that should be acknowledged. Clinical evidence supporting the use of natural disinfectants in prosthodontics and oral implantology is still limited, making it difficult to draw firm conclusions regarding their long-term efficacy and safety. Additionally, variations in study design, sample size, and methodology across the existing literature complicate direct comparisons. Much of the current understanding is based on *in vitro* or preclinical studies, which may not accurately reflect clinical outcomes. Furthermore, the potential interactions between natural

and synthetic disinfectants have not been sufficiently explored. Finally, publication bias and language restrictions may have led to the exclusion of relevant studies, potentially affecting the comprehensiveness of this review.

Conclusions

Natural products such as propolis, EGCG, and clove oil show significant promise as effective disinfectants in prosthodontics and oral implantology due to their biocompatibility and reduced side effects compared to synthetic agents. To facilitate their clinical adoption, standardized protocols for compound extraction and formulation must be established. Rigorous Phase II and III clinical trials focusing on peri-implantitis management are essential to validate their efficacy and safety. Collaboration with regulatory agencies is crucial for enabling OTC approval. These targeted measures will support the integration of natural disinfectants into mainstream dental practice, offering safer and more environmentally sustainable alternatives for infection control.

Acknowledgments

We would like to express our sincere gratitude to Dr. Arpita Kabiraj, Associate Professor, Index Institute of Dental Sciences, Indore, India for her valuable guidance and support throughout the research. Her expertise and insights were invaluable in shaping our research and helping us overcome these challenges.

Funding

None.

Conflict of interest

The authors have no conflict of interest related to this publication.

Author contributions

Study concept and design (MS, RKA), acquisition of data (MHA, DMB, RBA), analysis and interpretation of data (MHA, DMB, RBA, KHA, RML), drafting of the manuscript (RKA, MS), critical revision of the manuscript for important intellectual content (RKA, KHA, RML), administrative, technical, or material support (MHA, DMB, GMA), and study supervision (RKA, MS, GMA). All authors have made significant contributions to this study and have approved the final manuscript.

References

- [1] Boyce RA. Prosthodontic Principles in Dental Implantology: Adjustments in a Coronavirus Disease-19 Pandemic-Battered Economy. *Dent Clin North Am* 2021;65(1):135–165. doi:10.1016/j.cden.2020.09.011, PMID:33213707.
- [2] Rutkūnas V, Gedrimienė A, Auškalnis L, Admakin O, Mangano F. Accuracy of Fixed Implant-Supported Dental Prostheses Additively Manufactured by Metal, Ceramic, or Polymer: A Systematic Review. *J Prosthodont* 2022;31(51):70–87. doi:10.1111/jopr.13449, PMID:35313029.
- [3] Narayana PSVVS, Srihari PSVV. Biofilm resistant surfaces and coatings on implants: A review. *Mater Today Proc* 2019;18(Part 7):4847–4853. doi:10.1016/j.matpr.2019.07.475.
- [4] Devanga Ragupathi NK, Veeraraghavan B, Karunakaran E, Monk PN. Editorial: Biofilm-mediated nosocomial infections and its association with antimicrobial resistance: Detection, prevention, and management. *Front Med (Lausanne)* 2022;9:987011. doi:10.3389/fmed.2022.987011, PMID:35979211.
- [5] Al-Makramani BMA. Infection Control in Dental Clinics: Prosthodontics Perspectives. *J Contemp Dent Pract* 2022;23(9):953–961. doi:10.5005/jp-journals-10024-3305, PMID:37283004.
- [6] Baima G, Citterio F, Romandini M, Romano F, Mariani GM, Buduneli N, *et al*. Surface decontamination protocols for surgical treatment of peri-implantitis: A systematic review with meta-analysis. *Clin Oral Implants Res* 2022;33(11):1069–1086. doi:10.1111/clr.13992, PMID:36017594.
- [7] Jervøe-Storm PM, Jepsen S, Marder M, Kraus D, Stoilov M, Enkling N. Prevention of internal bacterial colonization of dental implants: A comparative longitudinal observational study. *Clin Oral Implants Res* 2023;34(9):979–986. doi:10.1111/clr.14124, PMID:37394702.
- [8] Singer L, Bourauel C. Herbalism and glass-based materials in dentistry: review of the current state of the art. *J Mater Sci Mater Med* 2023;34(11):60. doi:10.1007/s10856-023-06764-w, PMID:37962680.
- [9] Dey S, Deshmukh S. Cavity Disinfection with Natural Agents and their Efficacy: A Review on Recent Literature. *Anti-Infective Agents* 2024;22(3):1–9. doi:10.2174/0122113525285948231215115207.
- [10] Saleem W, Sarfraz B, Mazhar S. Combined Effect of Honey, Neem (*Azadirachta indica*), and Turmeric against *Staphylococcus Aureus* and *E. Coli* Isolated from a Clinical Wound Sample. *BioSci Rev* 2022;4(4):21–44. doi:10.32350/BSR.44.01.
- [11] Fernandes A, Jobby R. Bacteriocins from lactic acid bacteria and their potential clinical applications. *Appl Biochem Biotechnol* 2022;194(10):4377–4399. doi:10.1007/s12010-022-03870-3, PMID:35290605.
- [12] Kanth MR, Prakash AR, Sreenath G, Reddy VS, Huldah S. Efficacy of Specific Plant Products on Microorganisms Causing Dental Caries. *J Clin Diagn Res* 2016;10(12):ZM01–ZM03. doi:10.7860/JCDR/2016/19772.9025, PMID:28209019.
- [13] Patri G, Sahu A. Role of Herbal Agents - Tea Tree Oil and Aloe vera as Cavity Disinfectant Adjuncts in Minimally Invasive Dentistry-An In vivo Comparative Study. *J Clin Diagn Res* 2017;11(7):DC05–DC09. doi:10.7860/JCDR/2017/27598.10147, PMID:28892888.
- [14] Aljarbou F, Almobarak A, Binrayes A, Alamri HM. *Salvadora persica*'s Biological Properties and Applications in Different Dental Specialties: A Narrative Review. *Evid Based Complement Alternat Med* 2022;2022:8667687. doi:10.1155/2022/8667687, PMID:35652125.
- [15] Handa A, Hegde N, Mahendra S, Mahesh CM, Ramesh PC, Soumya KM. Propolis and its potential in dentistry: a review. *Int J Health Sci Res* 2012;1(2):143–147.
- [16] Akca AE, Akca G, Topçu FT, Macit E, Pıkdöken L, Özgen İŞ. The Comparative Evaluation of the Antimicrobial Effect of Propolis with Chlorhexidine against Oral Pathogens: An In Vitro Study. *Biomed Res Int* 2016;2016:3627463. doi:10.1155/2016/3627463, PMID:26949701.
- [17] Alghutaimel H, Matoug-Elwerfelli M, Alhaji M, Albawardi F, Nagendrababu V, Dummer PMH. Propolis Use in Dentistry: A Narrative Review of Its Preventive and Therapeutic Applications. *Int Dent J* 2024;74(3):365–386. doi:10.1016/j.identj.2024.01.018, PMID:38378400.
- [18] Garaicoa JL, Bates AM, Avila-Ortiz G, Brogden KA. Antimicrobial Prosthetic Surfaces in the Oral Cavity-A Perspective on Creative Approaches. *Microorganisms* 2020;8(8):1247. doi:10.3390/microorganisms8081247, PMID:32824437.
- [19] Tang HW, Phapugrangkul P, Fauzi HM, Tan JS. Lactic acid bacteria bacteriocin, an antimicrobial peptide effective against multidrug resistance: a comprehensive review. *Int J Pept Res Ther* 2022;28:14. doi:10.1007/s10989-021-10317-6.
- [20] Xu Z, Krajewski S, Weindl T, Loeffler R, Li P, Han X, *et al*. Application of totarol as natural antibacterial coating on dental implants for prevention of peri-implantitis. *Mater Sci Eng C Mater Biol Appl* 2020;110:110701. doi:10.1016/j.msec.2020.110701, PMID:32204015.
- [21] Zhang Y, Wang Y, Zhu X, Cao P, Wei S, Lu Y. Antibacterial and anti-biofilm activities of eugenol from essential oil of *Syzygium aromaticum* (L.) Merr. & L. M. Perry (clove) leaf against periodontal pathogen *Porphyromonas gingivalis*. *Microb Pathog* 2017;113:396–402. doi:10.1016/j.micpath.2017.10.054, PMID:29101062.
- [22] Longbottom CJ, Carson CF, Hammer KA, Mee BJ, Riley TV. Tolerance of *Pseudomonas aeruginosa* to *Melaleuca alternifolia* (tea tree) oil is associated with the outer membrane and energy-dependent cellular processes. *J Antimicrob Chemother* 2004;54(2):386–392. doi:10.1093/jac/dkh359, PMID:15254026.
- [23] Wylie MR, Merrell DS. The Antimicrobial Potential of the Neem Tree *Azadirachta indica*. *Front Pharmacol* 2022;13:891535. doi:10.3389/fphar.2022.891535, PMID:35712721.
- [24] Farman H, Fayyaz S, Jabeen H, Muhammad N, Khan MA, Liaqat S. Aloe Vera in Dentistry: A Review. *Biomed Lett* 2021;7(2):178–186. doi:10.47262/BL/7.2.20211006.
- [25] Abhary M, Al-Hazmi AA. Antibacterial activity of Miswak (*Salvadora persica* L.) extracts on oral hygiene. *J Taibah Univ Sci* 2016;10(4):513–520. doi:10.1016/j.jtusci.2015.09.007.
- [26] Osman FA, Sarhan LA, Eladl NE, Desai V, Narayanan J, Thangavelu L, *et al*. Efficacy of a Eucalyptus oil-based dentifrice in reducing plaque and gingival bleeding scores - A randomized clinical crossover study. *J Adv Pharm Technol Res* 2024;15(1):25–28. doi:10.4103/JAPTR.JAPTR_103_23, PMID:38389967.
- [27] Salehi B, Mishra AP, Shukla I, Sharifi-Rad M, Contreras MDM, Segura-Carretero A, *et al*. Thymol, thyme, and other plant sources: Health and potential uses. *Phytother Res* 2018;32(9):1688–1706. doi:10.1002/ptr.6109, PMID:29785774.
- [28] Wijesinghe GK, Feiria SB, Maia FC, Oliveira TR, Joia F, Barbosa JP, *et al*. In-vitro Antibacterial and Antibiofilm Activity of *Cinnamomum verum* Leaf Oil against *Pseudomonas aeruginosa*, *Staphylococcus aureus* and *Klebsiella pneumoniae*. *An Acad Bras Cienc* 2021;93(1):e20201507. doi:10.1590/0001-376520210201507, PMID:33656062.
- [29] Furquim Dos Santos Cardoso V, Amaral Roppa RH, Antunes C, Silva Moraes AN, Santi L, Konrath EL. Efficacy of medicinal plant extracts as dental and periodontal antibiofilm agents: A systematic review of randomized clinical trials. *J Ethnopharmacol* 2021;281:114541.

- doi:10.1016/j.jep.2021.114541, PMID:34416298.
- [30] Yumnam R, Nandan N, Kumar NC, Raj S, Mannepalli A. Effect of propolis in oral health. *J Ayurveda Integr Med Sci* 2017;2(1):186–192. doi:10.21760/jaims.v2i1.7509.
 - [31] Yupanqui Miesles J, Vyas C, Aslan E, Humphreys G, Diver C, Bartolo P. Honey: An Advanced Antimicrobial and Wound Healing Biomaterial for Tissue Engineering Applications. *Pharmaceutics* 2022;14(8):1663. doi:10.3390/pharmaceutics14081663, PMID:36015289.
 - [32] Szostak WB, Szostak-Wegierek D. [Health properties of shark oil]. *Przegl Lek* 2006;63(4):223–226. PMID:17083160.
 - [33] Tiwari R, Tiwari G, Lahiri A, Ramachandran V, Rai A. Melittin: a natural peptide with expanded therapeutic applications. *Nat Prod J* 2022;12(2):13–29. doi:10.2174/2210315510999201210143035.
 - [34] Chithrashree GC, Kumar MS, Sharada AC. Sericin, a Versatile Protein from Silkworm-Biomedical Applications. *Shanlax Int J Arts Sci Humanit* 2021;8(S1):6–11. doi:10.34293/sijash.v8iS1-Feb.3924.
 - [35] Nomicisio C, Ruggeri M, Bianchi E, Vigani B, Valentino C, Aguzzi C, *et al*. Natural and Synthetic Clay Minerals in the Pharmaceutical and Biomedical Fields. *Pharmaceutics* 2023;15(5):1368. doi:10.3390/pharmaceutics15051368, PMID:37242610.
 - [36] Deshpande S, Kheur S, Kheur M, Eyüboğlu TF, Özcan M. A Review on Zeolites and Their Applications in Dentistry. *Curr Oral Health Rep* 2023;10:36–42. doi:10.1007/s40496-023-00330-7.
 - [37] Chan KT, Song X, Shen L, Liu N, Zhou X, Cheng L, Chen J. Nisin and its application in oral diseases. *J Funct Foods* 2023;105:105559. doi:10.1016/j.jff.2023.105559.
 - [38] Antonio LA, Alfonso PA, Tolentino EJC, Tabios CP, Sebastian PDS, Salamat GV, *et al*. A Review of Lactic Acid Bacteria and their Bacteriocins: Classification, Biosynthesis, and Mechanism against Oral Pathogens. *Asian J Biol Life Sci* 2021;10(2):291–299. doi:10.5530/ajbls.2021.10.41.
 - [39] Chinsebu KC. Plants and other natural products used in the management of oral infections and improvement of oral health. *Acta Trop* 2016;154:6–18. doi:10.1016/j.actatropica.2015.10.019, PMID:26522671.
 - [40] Nourbakhsh F, Lotfalizadeh M, Badpeyma M, Shakeri A, Soheili V. From plants to antimicrobials: Natural products against bacterial membranes. *Phytother Res* 2022;36(1):33–52. doi:10.1002/ptr.7275, PMID:34532918.
 - [41] Yang D, Wang T, Long M, Li P. Quercetin: Its Main Pharmacological Activity and Potential Application in Clinical Medicine. *Oxid Med Cell Longev* 2020;2020:8825387. doi:10.1155/2020/8825387, PMID:33488935.
 - [42] Matsumoto-Nakano M. Role of *Streptococcus mutans* surface proteins for biofilm formation. *Jpn Dent Sci Rev* 2018;54(1):22–29. doi:10.1016/j.jdsr.2017.08.002, PMID:29628998.
 - [43] Merritt J, Qi F. The mutacins of *Streptococcus mutans*: regulation and ecology. *Mol Oral Microbiol* 2012;27(2):57–69. doi:10.1111/j.2041-1014.2011.00634.x, PMID:22394465.
 - [44] Muhammad MH, Idris AL, Fan X, Guo Y, Yu Y, Jin X, *et al*. Beyond Risk: Bacterial Biofilms and Their Regulating Approaches. *Front Microbiol* 2020;11:928. doi:10.3389/fmicb.2020.00928, PMID:32508772.
 - [45] Al-Radha AS, Younes C, Diab BS, Jenkinson HF. Essential oils and zirconia dental implant materials. *Int J Oral Maxillofac Implants* 2013;28(6):1497–1505. doi:10.11607/jomi.3142, PMID:24278917.
 - [46] Hairul Islam MI, Arokiyaraj S, Kuralarasan M, Senthil Kumar V, Harikrishnan P, Saravanan S, *et al*. Inhibitory potential of EGCG on *Streptococcus mutans* biofilm: A new approach to prevent Caries. *Microb Pathog* 2020;143:104129. doi:10.1016/j.micpath.2020.104129, PMID:32169491.
 - [47] Rodríguez O, Sánchez R, Verde M, Núñez M, Ríos R, Chávez A. Obtaining the essential oil of *Syzygium aromaticum*, identification of eugenol and its effect on *Streptococcus mutans*. *J Oral Res* 2014;3(4):218–224. doi:10.17126/joralres.2014.051.
 - [48] Bui FQ, Almeida-da-Silva CLC, Huynh B, Trinh A, Liu J, Woodward J, *et al*. Association between periodontal pathogens and systemic disease. *Biomed J* 2019;42(1):27–35. doi:10.1016/j.bj.2018.12.001, PMID:30987702.
 - [49] Yuvashree M, Sushmi CB, Yogasri A, Sujitha VB, Hemalatha R. Role of antiseptics and disinfectants in the control of periodontitis: An overview. *Int J Appl Dent Sci* 2023;9(4):130–133. doi:10.22271/oral.2023.v9.i4c.1859.
 - [50] Bahjat SA. Evaluation of Antibacterial and Antibiofilm Activity of Cinamon, Clove, Eucalyptus, and Tea Tree Oils Against Oral Streptococci. *Rafidain J Sci* 2019;28(3):1–14. doi:10.33899/rjs.2019.163138.
 - [51] Carvalho ÉBS, Romandini M, Sadilina S, Sant'Ana ACP, Sanz M. Microbiota associated with peri-implantitis-A systematic review with meta-analyses. *Clin Oral Implants Res* 2023;34(11):1176–1187. doi:10.1111/clr.14153, PMID:37523470.
 - [52] Kong C, Zhang H, Li L, Liu Z. Effects of green tea extract epigallocatechin-3-gallate (EGCG) on oral disease-associated microbes: a review. *J Oral Microbiol* 2022;14(1):2131117. doi:10.1080/20002297.2022.2131117, PMID:36212989.
 - [53] Lombardo Bedran TB, Feghali K, Zhao L, Palomari Spolidorio DM, Grenier D. Green tea extract and its major constituent, epigallocatechin-3-gallate, induce epithelial beta-defensin secretion and prevent beta-defensin degradation by *Porphyromonas gingivalis*. *J Periodontol Res* 2014;49(5):615–623. doi:10.1111/jre.12142, PMID:24206194.
 - [54] Deglovic J, Majtanova N, Majtan J. Antibacterial and Antibiofilm Effect of Honey in the Prevention of Dental Caries: A Recent Perspective. *Foods* 2022;11(17):2670. doi:10.3390/foods11172670, PMID:36076855.
 - [55] Kucia M, Wietrak E, Szymczak M, Kowalczyk P. Effect of *Ligilactobacillus salivarius* and Other Natural Components against Anaerobic Periodontal Bacteria. *Molecules* 2020;25(19):4519. doi:10.3390/molecules25194519, PMID:33023121.
 - [56] Setiawan AS, Subarnas A, Djais A, Milanda T, Ichwan S. Antibacterial Effect of Green Tea Leaves and Pomegranate Arils Ethanol Extract towards *Streptococcus mutans* ATCC 25175 and *Veillonella parvula* ATCC 10790T. *Malaysian Journal of Medicine & Health Sciences* 2024;20:137–142.
 - [57] Shrestha S, Shrestha BR. Denture Cleansing the Natural Way: A Review. *J Nepal Prosthodont Soc* 2023;6(2):85–91. doi:10.3126/jnprossoc.v6i2.64708.
 - [58] An S, Evans JL, Hamlet S, Love RM. Incorporation of antimicrobial agents in denture base resin: A systematic review. *J Prosthet Dent* 2021;126(2):188–195. doi:10.1016/j.prosdent.2020.03.033, PMID:32800329.
 - [59] Abu-Obaid E, Salama F, Abu-Obaid A, Alanazi F, Salem M, Auda S, *et al*. A Comparative Evaluation of the Antimicrobial Effects of Different Mouthrinses against Oral Pathogens: An In Vitro Study(1). *J Contemp Dent Pract* 2020;21(5):500–508. PMID:32690831.
 - [60] Lubin J, Hernandez MA, Drukteinis SE, Parker WB, Murray PE. Effectiveness of disinfection therapies and promotion of osteoblast growth on osseointegration and nanotite implant surfaces. *Implant Dent* 2014;23(4):426–433. doi:10.1097/ID.0000000000000067, PMID:24776940.
 - [61] Lang NP, Mult HC, Tonetti MS. Peri-implantitis: etiology, pathogenesis, prevention, and therapy. *Dent Implant Complications*. In: Froum SJ (ed). *Dental Implant Complications: Etiology, Prevention, and Treatment*. 1st ed. New Jersey: John Wiley & Sons; 2015:170–186. doi:10.1002/9781119140474.ch9.
 - [62] Kumar A, Sunkara MS, Pantareddy I, Sudhakar S. Comparison of Plaque Inhibiting Efficacies of Aloe Vera and Propolis Tooth Gels: A Randomized PCR Study. *J Clin Diagn Res* 2015;9(9):ZC01–ZC03. doi:10.7860/JCDR/2015/13185.6413, PMID:26501001.
 - [63] de Almeida JM, Marques BM, Novaes VCN, de Oliveira FLP, Matheus HR, Fiorin LG, *et al*. Influence of adjuvant therapy with green tea extract in the treatment of experimental periodontitis. *Arch Oral Biol* 2019;102:65–73. doi:10.1016/j.archoralbio.2019.03.028, PMID:30974379.
 - [64] Almershed N, Adams R, Mort J, Farnell D, Thomas DW, Claydon N. The use of non-surgical interventions in patients with peri-implantitis: a systematic review and meta-analysis. *Oral Surg* 2021;14(2):178–190. doi:10.1111/ors.12548.
 - [65] Lima-Filho JV, de Aguiar Cordeiro R. In vitro and in vivo antibacterial and antifungal screening of natural plant products: prospective standardization of basic methods. In: Albuquerque U, Cruz da Cunha L, de Lucena R, Alves R (eds). *Methods and Techniques in Ethnobiology and Ethnecology*. Springer Protocols Handbooks. New York, NY: Humana Press; 2014. doi:10.1007/978-1-4614-8636-7_17.
 - [66] Ngwoke KG, Odimegwu DC, Esimone CO. Antimicrobial natural prod-

- ucts. Science against microbial pathogens: communicating current research and technological advances. In: Méndez-Vilas A (ed). FORMATEX Microbiology Series N° 3. Vol 3. Badajoz (Spain): Formatex Research Center; 2011:1011–1026.
- [67] Hashim NT, Babiker R, Rahman MM, Mohamed R, Priya SP, Chaitanya NC, *et al*. Natural Bioactive Compounds in the Management of Periodontal Diseases: A Comprehensive Review. *Molecules* 2024;29(13):3044. doi:10.3390/molecules29133044, PMID:38998994.
- [68] Xiao J, Liu Y, Klein MI, Nikikova A, Ren Y. Nanotechnology and Delivery System for Bioactive Antibiofilm Dental Materials. In: de Melo MAS (ed). *Designing Bioactive Polymeric Materials For Restorative Dentistry*. 1st ed. London: CRC Press, Taylor & Francis; 2020:165–197. doi:10.1201/9780429113284-7.
- [69] Mohanta YK, Chakrabartty I, Mishra AK, Chopra H, Mahanta S, Avula SK, *et al*. Nanotechnology in combating biofilm: A smart and promising therapeutic strategy. *Front Microbiol* 2022;13:1028086. doi:10.3389/fmicb.2022.1028086, PMID:36938129.
- [70] Mekhemar M, Geib M, Kumar M, Radha, Hassan Y, Dörfer C. *Salvadora persica*: Nature's Gift for Periodontal Health. *Antioxidants (Basel)* 2021;10(5):712. doi:10.3390/antiox10050712, PMID:33946353.