*Journal of Exploratory Research in Pharmacology* **2025** vol. 10(2) | 49–61
DOI: 10.14218/JERP.2025.00016

Review Article

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

Manar Hamed Almehyawi[1], Diyala Mohammed Basyoni[1], Rima Basil Alsibaie[1], Khadijah Hashim Alhussini[1], Renad Mohammed Lashkar[1], Rama Krishna Alla[2*], Mohammed Shammas[3] and Ghaida Meshari Alotaibi[1]

[1]*Ibn Sina National College for Medical Studies, Jeddah, Makkah, Saudi Arabia;* [2]*Division of Dental Materials, Vishnu Dental College, Bhimavaram, West Godavari, Andhra Pradesh, India;* [3]*Department 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:** June 09, 2025 | **Published online:** June 25, 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: rkdentalbiomaterials@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; 10(2):49–61. 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 *gtf* gene expression, lowering DNA content, and binding the glucan sucrase 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 *(Podocarpus totara)* | 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 *(Syzygium aromaticum)* | 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 *(Melaleuca alternifolia)* | Terpinen-4-ol | Antimicrobial, disrupts cell membranes | Used in mouthwashes, peri-implantitis treatment | Antifungal, anti-bacterial | Allergic reactions in some individuals | 22 |
| Neem | Plant *(Azadirachta indica)* | Azadirachtin, nimbidin | Inhibits bacterial growth, anti-inflammatory | Used in denture cleaning, oral rinses | Wide antimicrobial spectrum | Bitter taste, inconsistent strength | 23 |
| Aloe vera | Plant *(Aloe barbadensis)* | 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 *(Salvadora persica)* | 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 *(Eucalyptus globulus)* | 1,8-cineole | Antibacterial, antifungal, antiviral | Oral rinses for infection control | Broad antimicrobial action | May irritate in large doses | 26 |
| Thyme oil | Plant *(Thymus vulgaris)* | 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 *(Cinnamomum verum/ Cinnamomum cassia)* | 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 *(Camellia sinensis)* | 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 |

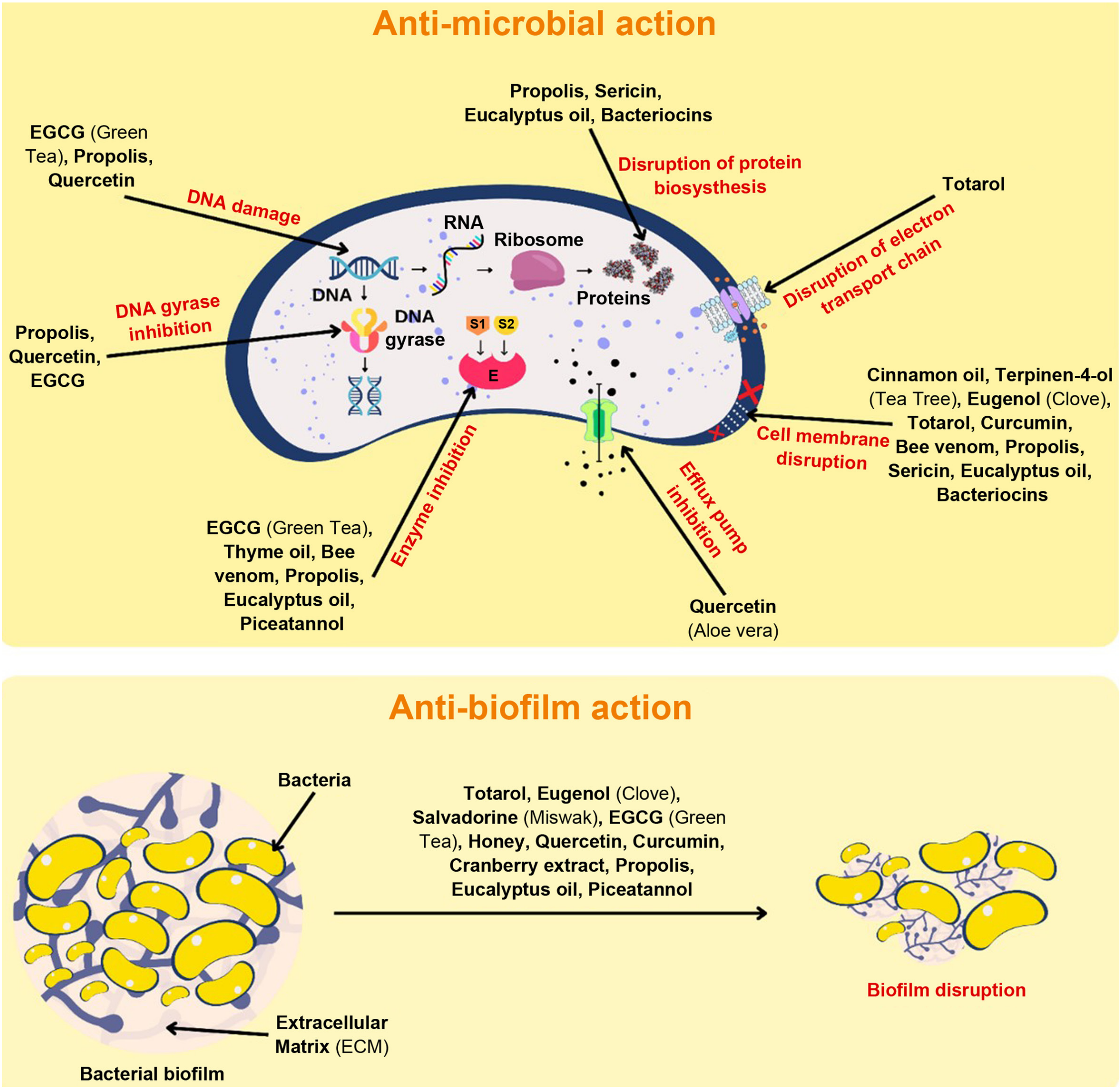


**Fig. 1. Mechanism of action of natural disinfectants.** EGCG, epigallocatechin gallate.

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 prosthetic 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 | Porphyromonas gingivalis | Chronic periodontitis, peri-implantitis | Green tea polyphenols (EGCG), trans-cinnamaldehyde, tulsi, neem, guava, propolis, honey, totarol, garlic extract, bacteriocins, sanguinarine | 51 |
| 2 | Actinobacillus actinomycetemcomitans | Periodontitis | Tulsi, neem, guava, propolis, garlic extract, sanguinarine | 51 |
| 3 | Tannerella forsythia | Chronic periodontitis, peri-implantitis | Tulsi, neem, guava, propolis, sanguinarine | 51 |
| 4 | Streptococcus mutans | Dental caries (tooth decay) | Clove oil, green tea, polyphenols EGCG, honey, sericin, garlic extract, bacteriocins | 52 |
| 5 | Actinomyces israelii | Actinomycosis, root surface caries, gingivitis | Cinnamon oil, clove oil, eucalyptus, EGCG | 52 |
| 6 | Actinomyces naeslundii | Root surface caries, gingivitis | EGCG, garlic extract | 52 |
| 7 | Actinomyces oris | Early plaque formation, gingivitis, root caries | EGCG | 52 |
| 8 | Actinomyces odontolyticus | Dental caries, root canal infections | EGCG | 52 |
| 9 | Prevotella intermedia | Gingivitis, periodontitis, peri-implantitis, acute necrotizing ulcerative gingivitis (ANUG), endodontic infections | Curcumin, EGCG, honey, totarol, garlic extract | 52 |
| 10 | Fusobacterium nucleatum | Necrotizing ulcerative gingivitis (NUG), root canal infection, periodontitis, peri-implantitis | Propolis, Aloe vera, EGCG, honey, totarol, garlic extract | 52 |
| 11 | Treponema denticola | Chronic periodontitis, necrotizing ulcerative gingivitis (NUG) | Propolis, EGCG | 53 |
| 12 | Prevotella nigrescens | Periodontitis, endodontic infections | Curcumin, totarol, garlic extract | 54 |
| 13 | Campylobacter rectus | Chronic periodontitis | Propolis, EGCG, Aloe vera, cranberry, honey | 54 |
| 14 | Pseudomonas aeruginosa | Periodontal disease, endodontic infections | EGCG, honey | 54 |
| 15 | Eubacterium nodatum | Periodontal disease | Honey | 54 |
| 16 | Candida albicans (yeast) | Oral candidiasis (thrush), denture stomatitis | EGCG, garlic extract, citrus extracts | 54 |
| 17 | Selenomonas 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 | Eikenellacorrodens | Periodontal disease, endodontic infections | Garlic extract | 56 |
| 20 | Dialisterpneumosintes | Periodontitis, endodontic infections, periradicular diseases | Propolis | 56 |
| 21 | Treponema socranskii | Chronic periodontitis, necrotizing periodontal diseases | EGCG | 56 |
| 22 | Porphyromonas endodontalis | Endodontic infections | Propolis | 56 |
| 23 | Staphylococcus spp. | Peri-implantitis, prosthetic infections | Tea tree oil, garlic extract, cinnamon oil, honey, Aloe vera | 56 |
| 24 | Desulfobulbus spp. | Periodontal disease | Garlic extract | 56 |
| 25 | Lactobacillus spp. | Dental caries, especially root caries | EGCG | 56 |
| 26 | Actinomyces viscosus | Root surface caries, gingivitis | EGCG | 56 |
| 27 | Aggregatibacter actinomycetemcomitans | Aggressive periodontitis, chronic periodontitis | EGCG, honey, totarol | 56 |
| 28 | Veillonella parvula | Periodontal disease, endodontic infections | EGCG | 56 |
| 29 | Herpes simplex virus type I (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.

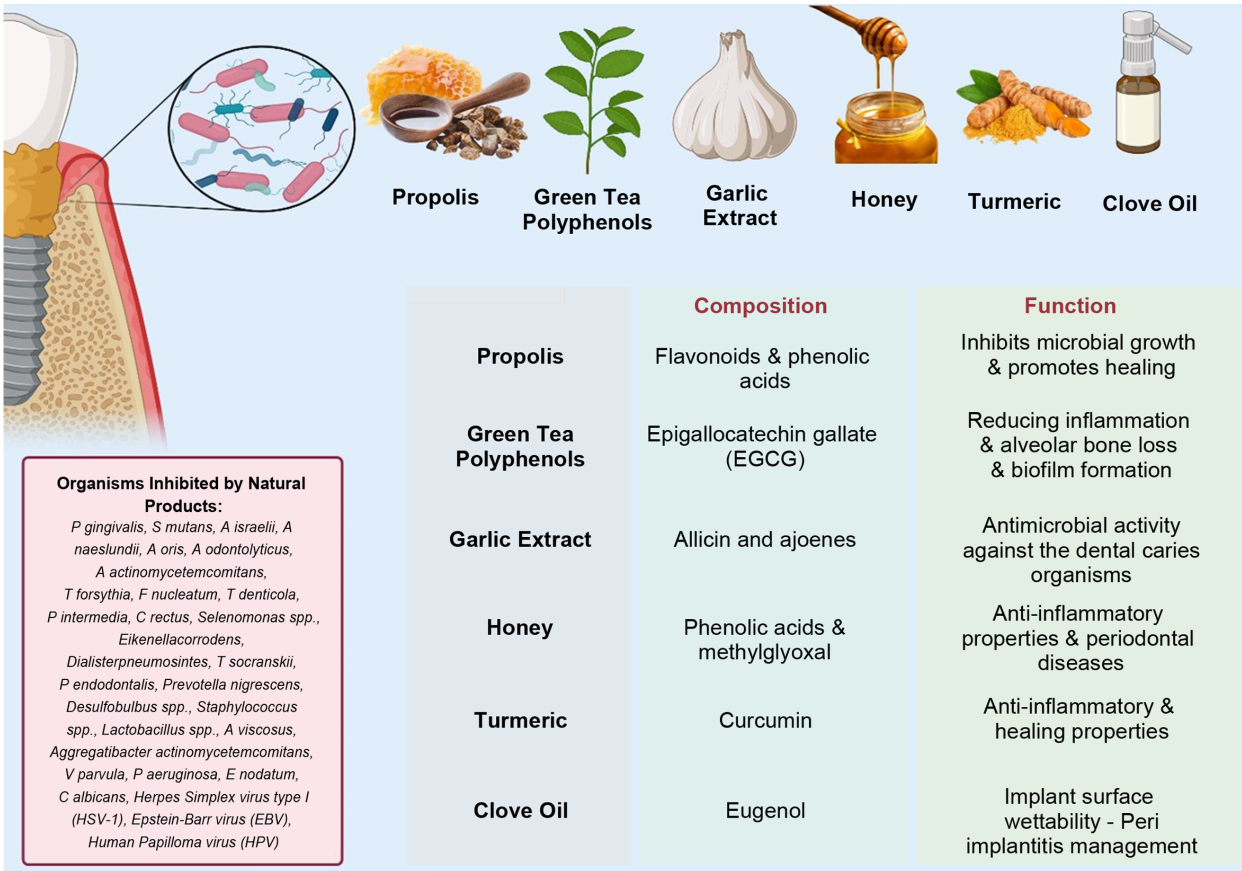


**Fig. 2. Antimicrobial natural agents and their bioactive compounds with functional roles in oral and peri-implant health.**

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 osseotite 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 natural 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, bioprospecting, 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

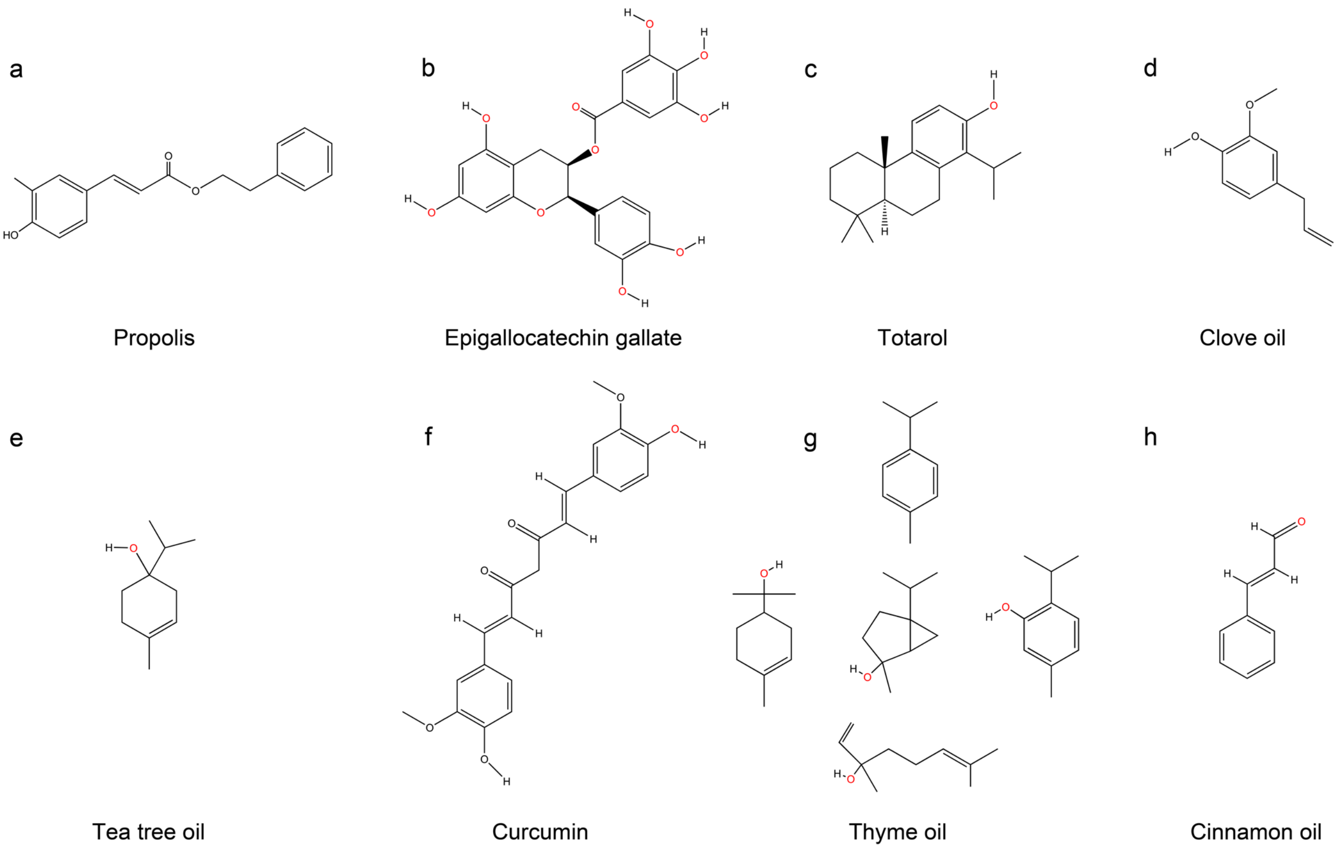


**Fig. 3. Molecular structures of key plant-derived antimicrobial agents explored in prosthodontics and oral implantology (a) Propolis, (b) Epigallocatechin gallate, (c) Totarol, (d) Clove oil, (e) Tea tree oil, (f) Curcumin, (g) Thyme oil, and (h) Cinnamon oil.**

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.

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