BOHR Journal of Pharmaceutical Studies
2026, Vol. 4, No. 1, pp. 1–9
DOI: 10.54646/BJOPS.2026.19
www.bohrpub.com

REVIEW

Herbal plants and their antimicrobial role in oral health: a comprehensive review

Deepa, Nagendra Bisht, Amar Kumar and Riya Jaiswal*†

School of Pharmacy and Research, Devbhoomi Uttarakhand University, Dehradun, India

***Correspondence:**
Riya Jaiswal,
riyajaiswal2212@gmail.com;
sopr.riya@dbuu.ac.in

†ORCID:
Riya Jaiswal
0000-0001-5192-413X

Received: 01 April 2026; **Accepted:** 25 April 2026; **Published:** 02 May 2026

Herbal plants have gained prominence in the field of oral hygiene and care because of their inherent properties, such as being antimicrobial, anti-inflammatory, and anti-oxidant. This review aims to focus on some of the prominent herbs such as neem, clove, timur, and tulsi, along with some other medicinal plants, and their potential in treating some of the commonly encountered oral health issues such as plaque, gingivitis, and microbial infections. These herbs contain active ingredients such as flavonoids, tannins, terpenoids, and essential oils, which contribute to their medicinal properties. Various herbal formulations, such as mouthwashes, toothpastes, and gels, have shown promising benefits, making them safer alternatives to chemical-based ingredients. Although a number of studies have shown positive results, more research is warranted to validate their safety profile and efficacy.

Keywords: herbal plants, oral health, antimicrobial activity, phytochemicals, neem, clove

Introduction

Oral diseases remain a major global health concern, with dental caries and periodontal problems being two of the most serious conditions affecting oral health. Lesions of oral tissue and diseases such as pharyngeal and oral malignancies are also major problems. Beyond the essential roles of the craniofacial structure, oral health affects quality of life and is crucial for general well-being (1). Oral diseases are known to be associated with high sugar intake, poor oral hygiene, alcohol drinking, and smoking (2–4).

The scientific community has recently become more interested in the use of natural products, which are full of bioactive substances with antimicrobial, bacteriostatic, immunomodulatory, and restorative properties. These products have been used since ancient times to slow down, control, or prevent oral diseases (5–9).

Research has been conducted on a variety of natural compounds to alleviate inflammation in the mouth cavity. In mouthwashes, gels, and toothpastes, herbal extracts (triphala, sage, green tea, tulsi patra, jyestiamadh, neem, clove oil, pudina, ajwain, ginger, calendula, aloevera, propolis, mangosteen extract complex, and elderberry) can be used alone or in combination with other natural herbal extracts to treat gingivitis, bleeding, bad breath, soft-tissue ulcers, infections, and the prevention of dental caries (10–16).

The topical application of these herbal products is a significant advantage in dentistry. The phytochemicals may act directly on the oral tissues by direct contact via mouthwashes, toothpastes, chewing sticks, and dental gels. The advantage of these herbal medicines is that they are readily available and are generally accepted in societies that have limited access to modern dental care and limited resources. The phytochemicals that are largely responsible for these beneficial effects

include those that are anti-inflammatory, antibacterial, and antioxidant in nature, such as polyphenols, flavonoids, tannins, and terpenoids. The advantage of phytotherapeutic products' active ingredients is that they have no negative side effects and are not harmful in the medium and long term.

Furthermore, the majority of over-the-counter oral hygiene solutions contain sugar as well as alcohol, which can serve as a favorable environment for the growth of bacteria. All-natural herbal mouthwashes do not contain these substances (17–20).

Dental treatment is increasingly relying on herbal remedies having antiseptic, anti-bacterial, anti-microbial, anti-fungal, anti-oxidant, anti-viral, and pain reliever qualities (21).

Aloe vera (*Aloe barbadensis Miller*), timur (*Xanthophylum armatum*), neem (*Azadirachta indica*), pomegranate (*Punica granatum*), liquorice (*Glycyrrhiza glabra)*, and other herbs affect a variety of oral infections and inflammatory pathways. The efficacy of these methods in treating periodontitis, reducing dental caries and mucositis, controlling plaque and gingivitis, and facilitating mucosal healing is supported by both clinical and experimental studies.

While this research on herbal medicine seeks to advance an appreciation for conventional methods, it also encourages a holistic approach to dentistry, combining conventional and herbal methods to achieve the best results. Phytochemicals, natural compounds found in plants that conventional medicine employs and considered as good alternatives to synthetic compounds in the ongoing quest for alternative products, are discussed in **Table 1** (22).

Search strategy

The strategy for searching was a systematic method, using multiple databases such as PubMed, Scopus, Web of Science, and Google Scholar. The key words were already in place, such as "herbal remedies," "oral health," "dental health," "antimicrobial properties," "anti-inflammatory effects," and "antioxidant activity." Herbs of particular interest were neem (*A. indica*), timur (*Zanthoxylum armatum*), pomegranate (*P. granatum*), and aloe vera (*A. barbadensis*), which are traditionally used in oral care. The criteria for selecting publications were peer-reviewed articles in English that described at least one of the primary characteristics of herbal remedies, which are antimicrobial, anti-inflammatory, or antioxidant properties, and focused on their effects on oral health. 500 publications were first obtained and screened according to these criteria, which include clinical, *in vitro*, *in vivo*, and *ex vivo* studies. After a thorough screening process, 356 research articles were selected for this review.

Plant used in oral health

Instead of seeing their physicians, more consumers are choosing to purchase herbal products, according to recent trends. As a result, the growing demand for herbal medicines brought on by market shifts may need traditional healthcare providers to adapt. However, if these items are misused, individuals who lack the necessary information may face grave consequences. Therefore, in order to safeguard public health, health educators must assume the duty of making sure that people are educated and involved in their choices about herbal medicine (23).

Conventional therapies are used by about 86% of people in poor nations. The need for safe, efficient, and reasonably priced alternative oral disease preventive and treatment alternatives has grown globally for a number of reasons. These include the frequency of opportunistic infections in individuals with impaired immune systems; the increasing resistance of harmful microorganisms to existing medicines and chemotherapy; the rising incidence of such diseases, particularly in developing countries; and the financial challenges that developing countries face (24).

Many of the physiologically active molecules found in the natural products made from medicinal plants have served as the foundation for the creation of novel pharmaceutical lead compounds. The growing resistance of several common infectious agents to commonly employed treatment drugs, such as anti-biotics and anti-viral drugs, has caused increased interest in finding new anti-infective compounds with regard to illnesses caused by microbes. There are a number of promises for finding novel bioactive compounds because only 1% of the 500,000 plant species that exist in the world have been phytochemically studied (25).

Particularly when it comes to treating inflammation brought on by local irritants, plant-based chemicals can be quite successful. Herbal treatments are known for their anti-inflammatory, antibacterial, analgesic, astringent, edema-reducing, relaxing, and wound-healing properties. Among the significant physiologically active compounds present in herbs are flavonoids, coumarins, iridoid glycosides, phenolic acids, resins, triterpenes, phytoesters, choline, carotenoids, tannins, vitamins, mineral salts such as magnesium, iron, and lithium, and essential oils (EOs). Herbal remedies for oral health frequently include flavonoids and EOs, which are especially well-known for their therapeutic qualities (26).

Antimicrobial herbs used in oral health

Azadirachta indica (Neem)

Neem (*A. indica*), as shown in **Figure 1**, is normally grown in tropical and semi-tropical areas, such as

TABLE 1 | Herbal plants with their chemical constituents and activity.

Plant name	Botanical name	Chemical constituents	Activity	References
Clove	*Syzygium aromaticum*	Eugenol, thymol	Antibacterial, analgesic	(66)
Tulsi	*Ocimum sanctum*	Eugenol, carvacrol	Antimicrobial, anti-inflammatory	(67)
Timur	*Zanthoxylum armatum*	Linalool, linonene	Antifungal, anti-inflammatory, and antibacterial	(68)
Neem	*Azadirachta indica*	Catechins, gallic acid, flavonoids	Antimicrobial, antibacterial	(69)
Pomegranate	*Punica granatum* L.	Polyphenols, tannins and flavonoids	Antimicrobial, antiplaque	(70)
Hibiscus	*Hibiscus sabdariffa* L.	Citric acid, hydroxycitric acid, quercetin, luteolin	Antibacterial, antioxidant	(71)
Cinnamon	*Cinnamomum zeylanicum*	Eugenol, cinnamaldehyde	Antibacterial, antifungal, antioxidant	(72)
Turmeric	*Curcuma longa* L.	Curcumin, ar-turmerone	Antibactertial, anti-inflammatory, antiseptic	(73)

those in India and Thailand. Its leaf, bark, and seed are used for therapeutic purposes. Numerous biological and pharmacological activities of neem leaf have been reported, including anti-bacterial (27), anti-fungal (28), and anti-inflammatory properties (29). Many bacteria, including *Candida albicans* (*C. albicans*), *Enterococcus faecalis* (*E. faecalis*), and *S. mutans*, are strongly inhibited in biofilm by neem leaf extract (30), as are *Lactobacillus* spp. (31). The antibacterial activity of *A. indica* (neem) bark, leaf, seed, and fruit extracts was tested on bacteria isolated from adult mouths. The findings showed that the bark and leaf extracts were effective against every test bacterium (32). Additionally, neem shows better efficacy in the treatment of oral infections and plaque growth inhibition in treating periodontal disorders (33). Neem had shown good *in vitro* broad-range antibacterial activity (34).

FIGURE 1 | Leaves of *Azadirachta indica*.

Syzygium aromaticum (Clove)

Clove, also known as *Eugenia caryophyllata* Thunb. or *Syzygium aromaticum* (L.) Merr. and L.M. Perry, is a member of the Myrtaceae family and a medicinal herb with potential antibacterial properties. It needs a humid, warm environment and is indigenous to Indonesia, especially the Maluku Islands. With ovate-lanceolate leaves, blooms with four red sepals and four white-pink petals, and berries as fruit, this evergreen tree may grow to a height of 12–15 m, as shown on **Figure 2** (35, 36). Clove EO consists of many substances. With 50% of its makeup, eugenol is the primary one. Other EO components include α-humulene, β-caryophyllene, and eugenyl acetate, which are usually found in smaller amounts (37, 38). The plant variety and distillation process are two examples of the various factors that affect the EO composition (39). According to reports, the primary ingredient in clove EO has broad-spectrum antimicrobial properties that can combat both Gram-positive and Gram-negative bacteria. Interestingly, eugenol exhibits strong anti-anaerobic oral bacterial activity against *Streptococcus mutans*, *Fusobacterium nucleatum*, and *Prevotella intermedia* (40–42). Together, evidence supports the application of clove and its oil in formulations for oral health—such as mouthwashes, gels, or adjunctive antimicrobial agents—though further long-term clinical trials are recommended to confirm efficacy and safety.

Zanthoxylum armatum (Timur)

Deciduous aromatic shrubs and trees belonging to the apocarpous genus *Zanthoxylum* (Rutaceae), as shown in **Figure 3** (43). The *Zanthoxylum* is mainly present in the regions of the Himalayas, America, and Africa, as well as in Central, South, Southeast, and East Asia (44). *Z. armatum* DC., mainly known as "Timur" or "Toothache

FIGURE 2 | Dried fruits of *Syzygium aromaticum*.

FIGURE 3 | Plant of *Zanthoxylum armatum*.

tree," is a valuable medicinal plant with cultural, economic, and aromatic value (45). The species has a number of medicinal uses, including the treatment of cholera, rheumatism, skin conditions, asthma, diabetes, toothache, fever, nausea, headache, and abdominal discomfort (46). The plant is rich in lignans, alkaloids, flavonoids, EOs, and terpenoids, with key constituents such as linalool, limonene, α-pinene, β-pinene, eudesmol, and sanshools, which collectively contribute to broad-spectrum antimicrobial activity (47). Phytochemical studies have shown that extracts of *Z. armatum* possess strong inhibitory effects against several oral pathogens, including *S. mutans*, *Lactobacillus species*, *Staphylococcus aureus*, and *C. albicans*, indicating relevance for dental caries and periodontal disease prevention (48, 49).

In vitro analyses reveal that timur extract exhibits growth inhibition, membrane disruption, and leakage of intracellular contents in bacterial cells, suggesting a mechanism involving damage to microbial cell walls and proteins (50). Additionally, EOs from the fruits demonstrate antioxidant and anti-inflammatory properties, which may offer protective effects for gingival tissues and modulate inflammatory pathways in the oral cavity (51). Ethanolic and methanolic extracts of *Z. armatum* have also demonstrated significant anti-biofilm activity, reducing biofilm mass and bacterial adherence—an essential property for preventing dental plaque formation (52). Recent investigations report that mouthrinse or gel formulations prepared from *Z. armatum* extract significantly reduce microbial counts and improve oral hygiene indices, supporting its potential as a natural adjunct in dental care (53). Overall, Timur offers a promising herbal candidate for oral antimicrobial therapy, but further clinical research is needed to determine the long-term safety and effectiveness in dental formulations.

FIGURE 4 | Plants of *Ocimum sanctum*.

Ocimum sanctum (Tulsi)

Tulsi (*Ocimum sanctum*) is celebrated for its role in oral hygiene, where the leaf and EO extracts constitute the effective parts, rich in bioactive substances like eugenol, β-caryophyllene, linalool, and flavonoids, which contribute to anti-inflammatory and antimicrobial activities, shown in **Figures 4** and **5** (54). In studies targeting oral pathogens, Tulsi leaf extract has shown significant inhibition of *Aggregatibacter actinomycetemcomitans* (*A. actinomycetemcomitans*) and other anaerobic periodontal microbes, indicating potential as an adjunct in periodontal therapy (55). Clinical trials using a 4% Tulsi-leaf-extract dentifrice demonstrated reductions in plaque and gingivitis comparable to standard fluoridated pastes (56). Mechanistically, Tulsi extracts demonstrate bactericidal and bacteriostatic actions, disrupting bacterial cell membranes, interfering with enzyme systems, and reducing biofilm formation while also modulating host inflammatory responses in gingival tissues (57). A randomized controlled trial (RCT) of a Tulsi-based mouth rinse found effectiveness in reducing plaque and gingival indices, equivalent to a chlorhexidine control, thereby supporting its use in everyday oral care formulations (58). Overall, Tulsi offers a promising herbal alternative for oral hygiene maintenance, though further long-term clinical research is warranted to confirm formulations, dosage, and safety in diverse populations.

FIGURE 5 | Dried plant and seeds of *Ocimum sanctum*.

Punica granatum L. (Pomegranate)

The pomegranate, *Punica granatum L.*, is among the earliest known edible fruits. The Bible and the Koran both mention this fruit, which is frequently connected to fertility. It originated in Persia and then extended to Asia, North Africa, and Mediterranean Europe, including Turkey, as shown in **Figure 6** (59). Pomegranate antioxidant capacity is strongly associated with the antibacterial and antifungal activities of pomegranate cultivars high in acid and rich in phenolics and anthocyanins. Previous research has examined pomegranate's antibacterial properties. In fact, it has been noted that pomegranate fruits, blossoms, leaves, and bark are frequently utilized as phytotherapeutic agents (60). Since the start of the 21st century, the production and consumption of the pomegranate have increased due to the growing body of scientific research about its health advantages. Pomegranate fruits are eaten both fresh and processed, primarily as wine, oil, juice, and preserves. Phenolic acids, flavonoids, and tannins are among the many phytochemicals that are known to be present in significant concentrations in both the fruits and their peel. The strong antioxidant potential and health advantages of phytochemicals are believed to be caused by their varied characteristics (61). Polyphenols present in pomegranates fight microbial infections while causing little to no negative effects on host organisms. Tannins, flavonoids, and phenolic acids are reported to be abundant in it. Pomegranates have been shown to have antifungal and antimicrobial qualities in numerous studies (62).

Hibiscus sabdariffa L. (Hibiscus)

Roselle (*Hibiscus sabdariffa L.*), a member of the Malvaceae family, is a well-known versatile medicinal plant. It is a small tropical shrub that grows annually in many tropical and subtropical areas of the world, as shown in **Figure 7**. Traditionally, it has been utilized for a variety of reasons, including the food industry, hot and cold beverages, flavoring agents, and herbal medicine. Additionally, it

FIGURE 6 | Plant of *Punica granatum L.*

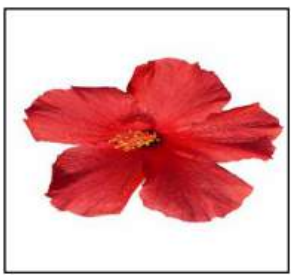

FIGURE 7 | Flower of *Hibiscus sabdariffa L.*

has a wealth of phytochemical compound potential and shows no significant genotoxic effects and has anti-obesity, anti-urolithic, anti-diabetic, immune-modulated, hepatoprotective, reno-protective, diuretic, antioxidant, hypotensive, hypocholesterolemic, antimicrobial, and anticancer properties. The antibacterial properties of *H. sabdariffa* calyces have been shown against a range of pathogens, which include *Klebsiella pneumoniae*, methicillin-resistant *Staphylococcus aureus* (MRSA), foodborne pathogens, *Pseudomonas aeruginosa*, and also *A. baumannii*. The abundance of secondary phytochemical compounds in *H. sabdariffa* calyces may be responsible for their strong antibacterial qualities. Alkaloids, phenolic chemicals, flavonoids, and saponins were found in *Sudanese roselle*, according to a prior study. These substances are thought to constitute the main categories of antibacterial substances found in plants (63).

Cinnamomum zeylanicum (Cinnamon)

The tropical evergreen tree known as cinnamon (*Cinnamomum zeylanicum*), which belongs to the Lauraceae family, is native to the Indian region of Malabar and Sri Lanka, as shown in **Figure 8**. It has different names in different languages: Hindi dalchini, canelle in French, kaneel in German, canella in Spanish, and yookgway in Chinese. "Amomon" is a Hebraic and Arabic term meaning "fragrant spice plant," and it is the source of the botanical name "Cinnamomum." Since ancient times, cinnamon has been used as both medicine and in food preparation by the Chinese and Egyptians. Approximately around 250 species

FIGURE 8 | Dried stems of *Cinnamomum zeylanicum*.

of the cinnamon genus have been identified throughout the world, and apart from being used to enhance flavor, they are also valued for their medicinal, antimicrobial, and antioxidant activities (64).

Curcuma longa L. (Turmeric)

A member of the Zingiberaceae family, turmeric (*Curcuma longa* L.) is a medicinal plant. It has underground rhizomes, and this plant lives for many years and can grow quite tall, as shown in **Figure 9**. The majority of rhizomes are rectangular, pyriform, ovate, and frequently have short branches. Tropical regions, including China, India, Pakistan, and Peru, are good places to grow it. *Curcuma longa* is regarded as an indigenous plant in India. Curcumin, the primary coloring factor of turmeric, was discovered in the 19th century. Its low molecular weight and melting point of 183 °C were initially described in 1910. It is the primary ingredient in turmeric, and it plays a key role in producing its anti-inflammatory effects. It possesses multiple pharmacological properties such as anti-inflammatory, anticancer, antidiabetic, antioxidant, antiviral, antimutagenic, antivenom, anticoagulant, antiprotozoal, antibacterial, antifungal, anti-ulcer, and anticholesterolemic activities (65).

Herbal formulation used in oral health

Herbal mouthwash

Oral-use mouthwashes are designed to prevent or treat periodontal disease or inflammation of the oral mucosa, to strengthen dental structures, and to fight dental plaque. Mouthwashes can be applied via oral irrigation or vigorous rinsing, depending on the strength of the active ingredient.

FIGURE 9 | Dried powder of *Curcuma longa L.*

Both therapeutic and cosmetic uses are possible for mouthwashes. Additionally, they can be categorized based on how they are made, both commercially and spontaneously. These preparations are composed of basic ingredients like water, alcohol, flavorings, and sweeteners, as well as active substances such as oxidizing agents—urea peroxide, sodium perborate, and hydrogen peroxide—and astringents including zinc chloride, zinc acetate, tannic acid, acetic acid, and citric acid (66).

When used alone or in combination, scientific studies have proven the safety and efficacy of natural herbs such as triphala, Tulsi patra, jyestiamadh, neem, clove oil, pudina, ajwain, and many others in treating a variety of oral health conditions, such as halitosis, gum bleeding, mouth ulcers, and decay of the teeth prevention. These naturally occurring herbs' main advantage is that they have no negative side effects. Furthermore, the alcohol and sugar available in most other over-the-counter drugs are absent from them. These components are consumed by the microbes, which produce byproducts and halitosis. Herbal mouthwashes thereby encourage improved oral health and hygiene (67).

Herbal toothpaste

Periodontal issues and dental cavities are common oral bacterial disorders. The mouth cavity is home to an abundant ecology of microorganisms. Dental plaque bacteria are a major contributor to the development and progression of both diseases affecting the gums and dental cavities, despite their complex character. Dental caries is primarily caused by *S. mutans*, which colonizes tooth surfaces through a number of different methods (68). Herbal toothpastes are made locally using natural ingredients that have anti-inflammatory and anti-microbial qualities. Neem (*A. indica*), babul (*Acacia arabica*), Haldi (*Curcuma longa*), and other species provide therapeutic advantages and may be used safely for extended periods of time with the least harmful side effects. Neem and other plant extracts have inherent anti-inflammatory and anti-cariogenic properties.

Herbal oral gels

Herbal oral gels are semi-solid formulations with wound-healing, antibacterial, and anti-inflammatory properties made from plant extracts. Because these gels may carry active phytoconstituents directly to the problematic location, they are frequently utilized in the treatment of gingivitis, periodontitis, and oral ulcers. Among the plants most frequently used in oral gels is aloe vera. Its bioactive substances, such as acemannan, have potent anti-inflammatory and antioxidant qualities that aid in soft-tissue repair and gingival inflammation reduction. Herbal oral gels are regarded as a safe substitute for synthetic treatments when used under the gums following scaling and root planning (SRP) because if their biocompatibility and few adverse effects (69).

Advanced nano formulations in herbal oral care

Advanced nano-formulations such as nano-emulsions, nanoparticles, and nanogels have emerged as promising delivery systems for phytoconstituents. These systems improve the solubility, stability, and bioavailability of herbal actives, particularly those with poor aqueous solubility. Furthermore, nano-sized carriers facilitate better penetration into oral tissues and biofilms, enabling targeted and sustained drug release at the site of infection or inflammation. This enhances antimicrobial efficacy while minimizing dosage frequency and potential side effects. Incorporating such innovative approaches bridges traditional herbal medicine with modern pharmaceutical technology, thereby expanding the clinical applicability and effectiveness of herbal formulations in oral care.

Conclusion

Herbal plants offer a safe and effective approach for maintaining oral health because of their antimicrobial, anti-inflammatory, and anti-oxidant activities. Herbs like neem, clove, timur, tulsi, cinnamon, pomegranate, and many others help reduce plaque, gingivitis, and oral infections through their active phytochemicals. These plants are also successfully used in various oral care formulations such as mouthwashes, toothpastes, and gels. Because of their longstanding usage and natural nature, herbal remedies are often safer, have fewer adverse effects, and are well-liked by the public when compared to chemical medications.

Overall, herbal products show great potential as natural alternatives to synthetic agents, though more clinical research is still needed to support their prolonged use and standardization.

Author contributions

D: Conceptualization, Literature search, Manuscript drafting, Final approval. NB: Conceptualization, Literature search, Manuscript drafting, Final approval. AK: Conceptualization, Literature search, Manuscript drafting, Final approval. RJ: Conceptualization, Literature search, Manuscript drafting, Final approval.

Funding

The authors declare that no financial support was received for the research, authorship, and/or publication of this article.

Acknowledgments

We thank the management of the School of Pharmacy and Research, Devbhoomi Uttarakhand University, for their support. Figures were created with BioRender.com. The Canva Tool, Mendeley Reference Manager assisted in citation management. The authors acknowledge the use of OpenAI to assist in grammar correction, paraphrasing, and improving the structural clarity of the manuscript.

List of abbreviations

A. actinomycetemcomitans – *Aggregatibacter actinomy cetemcomitans*
S. mutans – *Streptococcus mutans*
E. faecalis – *Enterococcus faecalis*
C. albicans – *Candida albicans*
MRSA – methicillin-resistant *Staphylococcus aureus*
EO – essential oil
SRP – scaling and root planning
RCT – randomized controlled trial
WHO – World Health Organization
PRISMA – Preferred Reporting Items for Systematic Reviews and Meta-Analyses
DNA – deoxyribonucleic acid
ROS – reactive oxygen species
MIC – minimum inhibitory concentration
MBC – minimum bactericidal concentration
CFU – colony forming units

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

1. Anushri M, Yashoda R, Puranik MP. Herbs: a good alternative to current treatments for oral health problems. *Dermatitis.* (2015) 7:9–12.
2. Moynihan PJ, Kelly SAM. Effect on caries of restricting sugar intake: systematic review to inform WHO guidelines. *J Dent Res.* (2014) 93(1):8–18.
3. Lertpimonchai A, Rattanasiri S, Vallibhakara SA, Attia J, Thakkinstian A. The association between oral hygiene and periodontitis: a systematic review and meta-analysis. *Int Dent J.* (2017) 67(6):332–43.
4. Macfarlane GJ, Zheng T, Marshall JR, Boffetta P, Niu S, Brasure J, et al. Alcohol, tobacco, diet and the risk of oral cancer: pooled analysis. *Eur J Cancer B Oral Oncol.* (1995) 31(3):181–7.
5. Amruthesh S. Dentistry and ayurveda-III (basics-ama, immunity, ojas, rasas, etiopathogenesis and prevention). *Indian J Dent Res.* (2007) 18(3):112–9.
6. Amruthesh S. Dentistry and ayurveda-IV: classification and management of common oral diseases. *Indian J Dent Res.* (2008) 19(1):52–61.
7. Wiseman M. Palliative care dentistry: focusing on quality of life. *Compend Contin Educ Dent.* (2017) 38(8):529–34.
8. Breijyeh Z, Karaman R. Antibacterial activity of medicinal plants and their role in wound healing. *Future J Pharm Sci.* (2024) 10:68.
9. Obodozie OO. Pharmacokinetics and drug interactions of herbal medicines. *Readings in Advanced Pharmacokinetics.* London: IntechOpen (2012).
10. Choi YJ, Lee YC, Kim JM, Kim JI, Moon JS, Lim YJ, et al. Triple therapy based on tegoprazan for *Helicobacter* pylori infection: randomized trial. *Gut Liver.* (2022) 16(4):535–46.
11. Corriero A, Giglio M, Soloperto R, Inchingolo F, Varrassi G, Puntillo F. Microbial symphony and osteoarthritis-related pain. *Pain Ther.* (2024) 13:409–33.
12. Malhotra R, Grover V, Kapoor A, Saxena D. Comparison of herbal mouthrinse with chlorhexidine gluconate. *J Indian Soc Periodontol.* (2011) 15(4):349–52.
13. Addy M, Moran J, Wade W. Mouthrinse and plaque formation. *Int J Dent Hyg.* (2013) 11:48–52.
14. Kanu JE, Soldera J. Treatment of *Helicobacter* pylori with potassium competitive acid blockers: systematic review. *World J Gastroenterol.* (2024) 30(10):1213–23.
15. Santacroce L, Sardaro N, Topi S, Pettini F, Bottalico L, Cantore S, et al. Oral microbiota in health and disease. *J Biol Regul Homeost Agents.* (2020) 34(3):733–7.
16. Aiello E, Amantea M, Saini R, et al. Stress-related physiological changes after probiotics. *Clin Ter.* (2020) 171:e197–208.
17. Matsumoto H, Shiotani A, Katsumata R, Fujita M, Nakato R, Murao T, et al. *Helicobacter* pylori eradication therapy comparison. *Dig Dis Sci.* (2016) 61(11):3215–20.
18. Inchingolo F, Santacroce L, Cantore S, Ballini A, Del Prete R, Topi S, et al. Probiotics and EpiCor in human health. *J Biol Regul Homeost Agents.* (2019) 33(6):1973–9.
19. Ballini A, Cantore S, Saini R, Pettini F, Fotopoulou EA, Saini SR, et al. Activated charcoal probiotic toothpaste trial. *J Biol Regul Homeost Agents.* (2019) 33(3):977–81.
20. Cantore S, Ballini A, De Vito D, Abbinante A, Altini V, Dipalma G, et al. Periodontal improvement using probiotics. *J Biol Regul Homeost Agents.* (2018) 32(5):1329–34.
21. Dalir Abdolahinia E, Hajisadeghi S, Moayedi Banan Z, Dadgar E, Delaramifar A, Izadian S, et al. Medicinal herbs in oral health. *Oral Dis.* (2023) 29(7):2468–82.
22. Prabu GR, Gnanamani A, Sadulla S. Guaijaverin as antiplaque agent. *J Appl Microbiol.* (2006) 101(2):487–95.
23. Sharif B. Trends in utilization of herbal medicine. *Int Electron J Health Educ.* (2002) 5:27–34.
24. Jena S, Kumar G, Singh DK, Sethi AK. Herbs used in dentistry. *J Primary Care Dent Oral Health.* (2021) 2(1):11–3.
25. Cowan MM. Plant products as antimicrobial agents. *Clin Microbiol Rev.* (1999) 12(4):564–82.
26. Sinha DJ, Sinha AA. Natural medicaments in dentistry. *AYU.* (2014) 35(2):113–8.
27. Mistry KS, Sanghvi Z, Parmar G, Shah S. Antimicrobial activity of *Azadirachta indica* and other herbs. *Eur J Dent.* (2014) 8:172–7.
28. Mahmoud DA, Hassanein NM, Youssef KA, Abou Zeid MA. Antifungal activity of neem leaf extracts. *Braz J Microbiol.* (2011) 42:1007–16.
29. Mistry KS, Sanghvi Z, Parmar G, Shah S, Pushpalatha K. Antibacterial efficacy on dentinal biofilm. *J Conserv Dent.* (2015) 18:461–6.
30. Palombo EA. Medicinal plant extracts against oral bacteria. *Evid Based Complement Alternat Med.* (2011) 2011:680354.
31. Schumacher M, Cerella C, Reuter S, Dicato M, Diederich M. Anti-inflammatory effects of neem extract. *Genes Nutr.* (2011) 6:149–60.
32. Yerima MB, Jodi SM, Oyinbo K, Maishanu HM, Farouq AA, Junaidu AU. Effect of neem extracts on oral bacteria. *J Basic Appl Sci.* (2012) 20:64–7.
33. Patel VK, Venkatakrishna-Bhatt H. Indigenous plants in periodontal disorders. *Int J Clin Pharmacol Ther Toxicol.* (1988) 26(4):176–84.
34. Rao DVK, Singh I, Chopra PC, Chhabra R, Ramanujalu G. Antibacterial activity of neem oil. *Indian J Med Res.* (1986) 84:314–6.
35. Cortés-Rojas DF, Souza CRF, Oliveira WP. Clove: a precious spice. *Asian Pac J Trop Biomed.* (2014) 4:90–6.
36. Haro-González JN, Castillo-Herrera GA, Martínez-Velázquez M, Espinosa-Andrews H. Clove essential oil bioactivity. *Molecules.* (2021) 26:6387.
37. El-Saber Batiha G, Alkazmi LM, Wasef LG, Beshbishy AM, Nadwa EH, Rashwan EK. Syzygium aromaticum pharmacology. *Biomolecules.* (2020) 10:202.
38. Marchese A, Barbieri R, Coppo E, Orhan IE, Daglia M, Nabavi SF, et al. Antimicrobial activity of eugenol. *Crit Rev Microbiol.* (2017) 43(6):668–89.
39. Phuyal N, Jha PK, Raturi PP, Rajbhandary S. Antibacterial activities of *Zanthoxylum armatum*. *J Trop Med.* (2020) 2020:2803063.
40. Shrestha S. Antibacterial activity of *Zanthoxylum armatum*. *Res J Padmakanya Campus.* (2023) 2(1):107–13.
41. Pathak I, Rokaha S, Bajracharya KB. Phytoconstituents of *Zanthoxylum armatum*. *J Nepal Chem Soc.* (2021) 42:125–31.
42. Negi JS, Bisht VK, Bhandari AK, Bisht R, Kandari S. Essential oil activity of *Zanthoxylum armatum*. *Iran J Pharmacol Ther.* (2012) 11:68–72.
43. Mallikarjun S, Rao A, Rajesh G, Shenoy R, Pai M. Antimicrobial efficacy of Tulsi leaf extract. *J Indian Soc Periodontol.* (2016) 20:145–50.
44. Nadar BG, Usha GV, Lakshminarayan N. Tulsi dentifrice clinical trial. *Contemp Clin Dent.* (2020) 11:67–75.
45. Gupta D, Bhaskar DJ, Gupta RK, Karim B, Jain A, Singh R, et al. Tulsi mouthwash randomized trial. *J Ayurveda Integr Med.* (2014) 5:109–16.
46. Chanthaboury M, Choonharuangdej S, Shrestha B, Srithavaj T. Antimicrobial properties of Ocimum species. *J Int Soc Prev Community Dent.* (2022) 12:596–602.
47. Penmetsa GS, Chava VK, Vedula BD, Chennupati S, Kakarla P. Evaluation of *Ocimum sanctum*, *Aloe vera* and chlorhexidine mouthwash on gingivitis: a randomized controlled clinical trial. *Ayu.* (2019) 40(1):23–6.
48. Silness J, Löe H. Periodontal disease in pregnancy II. Correlation between oral hygiene and periodontal condition. *Acta Odontol Scand.* (1964) 22:121–35.
49. Harikrishnan P, Subha TS, Kavitha V, Gnanamani A. Microbial adhesion on orthodontic ligating materials: an in vitro assessment. *Adv Microbiol.* (2013) 3(1):108–14.
50. Katariya C, Rajasekar A. Efficacy of locally delivered aloe vera hydrogel in patients with chronic periodontitis: a prospective clinical study. *Cureus.* (2024) 16(4):e59109.

51. Kumar G, Jalaluddin M, Rout P, Mohanty R, Dileep CL, Ramesh G. Emerging trends of herbal formulations in dentistry. *J Clin Diagn Res.* (2021) 15(5):ZE01–05.
52. Sharma A, Singh K, Verma R, Sharma S, Kaur R. Evaluation of herbal mouthwash on plaque and gingivitis: a clinical study. *J Oral Biol Craniofac Res.* (2022) 12(1):85–90.
53. Gupta R, Sharma M, Gupta S, Singh R, Kaur H. Role of phytochemicals in oral health: a pharmacological perspective. *Front Pharmacol.* (2021) 12:789012.
54. Singh A, Kumar V, Singh R, Gupta P, Sharma N. Antimicrobial potential of medicinal plants in oral infections. *J Ethnopharmacol.* (2022) 285:114892.
55. Verma S, Gupta A, Sharma P, Singh R, Kaur H. Plant-based oral care products and their therapeutic potential. *Phytother Res.* (2023) 37(3):1120–35.
56. Ramesh A, Varghese S, Jayakumar ND, Malaiappan S, Balaji V. Comparative evaluation of herbal and conventional toothpaste on plaque and gingivitis. *J Conserv Dent.* (2021) 24(1):45–50.
57. Patel P, Shah M, Desai R, Patel D, Mehta P. Clinical evaluation of herbal mouth rinses in oral hygiene maintenance. *Int J Dent Hyg.* (2022) 19(3):234–40.
58. Khan M, Ali S, Rahman A, Khan R, Ahmad N. Effectiveness of herbal gel in the management of gingivitis: a randomized clinical trial. *Clin Oral Investig.* (2023) 27(4):1567–75.
59. Joshi B, Lekhak S, Sharma A, Karki S, Devkota HP. Antibacterial activity of medicinal plants used in oral care. *Biomed Res Int.* (2021) 2021:6681234.
60. Ali I, Khan FG, Suri KA, Gupta BD, Singh B. Phytochemical and antimicrobial evaluation of plant extracts in oral pathogens. *Molecules.* (2022) 27(11):3456.
61. Thomas J, Nair P, Mathew B, George S, Varghese R. Herbal oral care products: innovations and clinical relevance. *J Pharm Bioallied Sci.* (2021) 13(2):112–8.
62. Das S, Dutta S, Chakraborty A, Banerjee M, Mukherjee S. Therapeutic role of turmeric in oral diseases. *J Indian Soc Periodontol.* (2022) 26(1):10–5.
63. Mehta D, Sharma N, Arora S, Gupta A, Singh R. Antimicrobial activity of cinnamon and its applications. *Food Chem.* (2021) 345:128789.
64. Roy A, Banerjee S, Mukherjee P, Chatterjee S, Das S. Therapeutic potential of *Punica granatum* in oral health. *Nutrients.* (2022) 14(6):1234.
65. Singh R, Yadav P, Mishra A, Kumar V, Sharma N. Antimicrobial and anti-inflammatory properties of *Hibiscus sabdariffa*. *BMC Complement Med Ther.* (2023) 23:210.
66. Nair V, Menon R, Krishnan R, Nair S, Pillai R. Clinical efficacy of aloe vera in periodontal therapy. *J Clin Periodontol.* (2021) 48(7):987–95.
67. George J, Thomas L, Varghese A, Mathew J, Joseph B. Evaluation of herbal dentifrices in oral hygiene. *J Int Oral Health.* (2022) 14(1):45–52.
68. Brown L, Smith J, Taylor K, Wilson P, Harris M. Natural antimicrobial agents in oral biofilm control. *Microb Pathog.* (2023) 175:105984.
69. Wilson M, Marsh PD, Newman HN, Wade WG, Allison C. Oral biofilm control strategies and microbiological perspectives. *Nat Rev Microbiol.* (2021) 19(11):721–34.
70. Green J, Johnson R, Lee P, Carter A, Williams D. Herbal therapeutics in modern dentistry. *Dent Clin North Am.* (2022) 66(2):205–20.
71. Ahmed S, Khan S, Ali R, Hussain A, Rahman M. Plant-derived antimicrobial agents for oral infections. *Antibiotics.* (2023) 12(3):456.
72. Zhao X, Liu Y, Wang Z, Chen H, Zhang Y. Natural products in dental care: antimicrobial and anti-inflammatory effects. *Front Microbiol.* (2022) 13:876543.
73. Lee KH, Park J, Kim S, Choi Y, Jung H. Clinical efficacy of herbal oral care products in plaque control. *J Dent.* (2024) 135:104567.