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Herbal Oral Sprays in Modern Dentistry: A Comprehensive Review of Phytotherapy, Formulation Strategies and therapeutic Applications

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Abstract: Oral diseases, encompassing dental caries and periodontal conditions, persist as a profound global public health challenge, affecting billions and significantly compromising systemic well-being and quality of life. Although synthetic antimicrobial and anti-inflammatory agents remain conventional therapeutic choices, their chronic application is increasingly associated with deleterious effects, including emergent antimicrobial resistance, mucosal irritation, tooth discoloration and disruption of the indigenous oral microbiota. Consequently, research focus has shifted toward herbal formulations as safer, biocompatible alternatives. Herbal oral sprays have emerged as an optimized delivery platform, facilitating the precise, direct administration of bioactive phytoconstituents to the oral mucosa. This modality ensures rapid therapeutic onset, localized efficacy and enhanced patient compliance while effectively bypassing hepatic first-pass metabolism.

Diverse medicinal taxa including *Azadirachta indica*, *Syzygium aromaticum*, *Aloe vera, Mentha piperita, Ocimum sanctum, Glycyrrhiza glabra, Curcuma longa* and *Matricaria chamomilla,* possess comprehensive pharmacological profiles including antimicrobial, anti-inflammatory, antioxidant, analgesic and immunomodulatory properties. This review evaluates current scientific evidence concerning oral disease pathophysiology, innovative formulation strategies and rigorous quality assessment parameters. Furthermore, it highlights advanced delivery techniques, such as nanotechnology-based systems and mucoadhesive hydrogels, designed to optimize bioavailability and mucosal retention time. While these herbal systems offer transformative potential for managing halitosis, candidiasis and aphthous ulcers, achieving successful clinical translation necessitates standardized manufacturing protocols, robust clinical trials and international regulatory

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harmonization. Ultimately, herbal oral sprays represent a sophisticated, patient-friendly advancement in modern phytotherapy, integrating traditional ethnobotanical knowledge with contemporary pharmaceutical sciences to ensure superior oral health outcomes and sustained global patient well-being.

***Keywords*:** Herbal oral spray, Oral diseases, Phytoconstituents, Oral drug delivery, Dental diseases.

1. INTRODUCTION

Oral health is an indispensable component of general health and well-being, which extends beyond the absence of dental diseases to encompass the ability to perform essential physiological functions such as mastication, swallowing, speech, taste perception and facial expression without discomfort or functional impairment. Healthy oral tissues are fundamental for nutrition, communication and psychosocial well-being, whereas oral disorders can significantly compromise an individual's quality of life and contribute to systemic health complications. According to the World Health Organization (WHO), oral diseases affect approximately 3.5 billion people worldwide, making them among the most prevalent non-communicable diseases. Untreated dental caries of permanent teeth remains the most common health condition globally, while severe periodontal disease, edentulism, oral cancers and oral infections continue to impose a substantial clinical and economic burden on healthcare systems [1].

The oral cavity represents a highly specialized anatomical environment composed of the lips, tongue, teeth, gingiva, palate, salivary glands and oral mucosa, all functioning collectively to maintain homeostasis. It is home to one of the most diverse and complex microbial communities in the human body, known as the oral microbiota. Under healthy conditions, these microorganisms exist in a symbiotic relationship with the host; however, disruptions in this ecological balance—often caused by poor oral hygiene, dietary habits, tobacco use or systemic diseases—can lead to the overgrowth of pathogenic species and the development of infections [2].

Conventional management of oral diseases relies heavily on synthetic antimicrobial agents like chlorhexidine, cetyl pyridinium chloride and triclosan, as well as various anti-inflammatory drugs. While effective, these agents are often associated with limitations. For instance, the long-term use of chlorhexidine can cause tooth staining, altered taste sensation and oral mucosal irritation. Furthermore, the rising concern of microbial resistance and the desire for more "natural" and "clean-label" products have shifted both consumer and clinical interest

toward phytotherapeutic alternatives. Herbal medicine, with its rich history of using plants like neem, clove and turmeric for oral care, offers a vast reservoir of bioactive compounds that can be harnessed through modern pharmaceutical technologies [3].

Herbal oral sprays have emerged as a particularly attractive dosage form in this context. Unlike traditional mouthwashes, which may be difficult to use for some patients or require significant rinsing time, oral sprays allow for precise, metered delivery of active ingredients directly to the affected site. This localized delivery minimizes systemic exposure and maximizes the therapeutic concentration at the target area, such as a painful ulcer or an inflamed gum. Additionally, the highly vascularized nature of the oral mucosa facilitates rapid absorption for some constituents, bypassing the first-pass metabolism that often limits the efficacy of oral herbal supplements. This review aims to provide a comprehensive overview of the current state of herbal oral sprays, from the selection of medicinal plants to the latest advances in nanotechnology-based delivery systems [4].

2. PATHOPHYSIOLOGY OF COMMON ORAL DISEASES

The development of effective herbal oral sprays requires a deep understanding of the underlying disease processes they are intended to treat. Most common oral ailments share common themes of microbial dysbiosis, biofilm formation and host-mediated inflammation [5]. Fig .1 includes pathogenesis of common oral diseases.

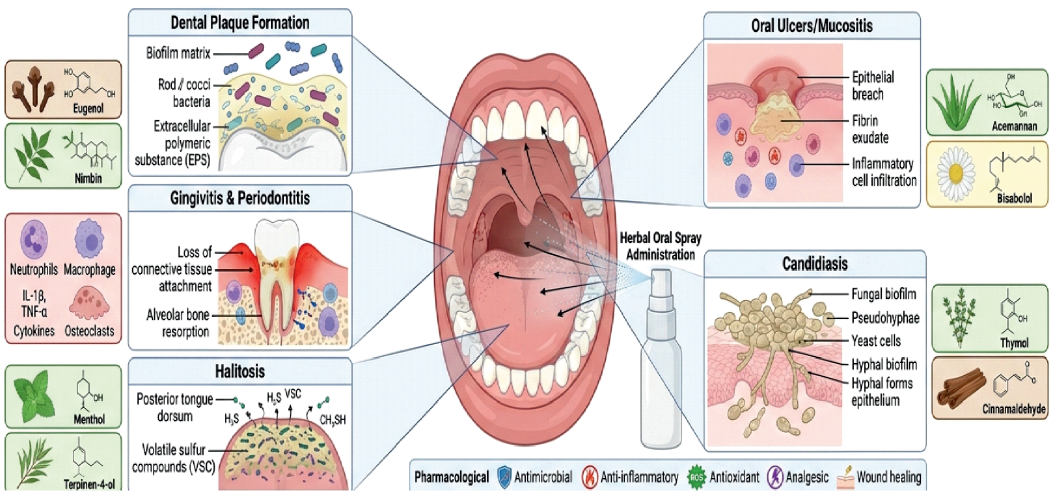


Figure 1: Pathogenesis of Common Oral diseases and Herbal spray intervention sites

2.1. Dental Plaque and Biofilm Dynamics

Dental plaque is not merely a collection of bacteria; it is a highly organized microbial biofilm. The process begins within minutes of tooth cleaning when salivary proteins and glycoproteins deposit on the tooth surface to form the "acquired pellicle." Early colonizers, primarily *Streptococcus* species, adhere to this pellicle. Over time, these bacteria produce extracellular polysaccharides (EPS) that form a protective matrix, allowing for the recruitment of secondary colonizers, including more pathogenic anaerobic species. If left undisturbed, this biofilm matures and becomes resistant to both the host immune response and traditional antimicrobial agents. Within this protective environment, bacteria like *Streptococcus mutans* ferment dietary sugars to produce organic acids, which drop the local pH below the "critical" level (approximately 5.5), leading to the demineralization of the underlying enamel and the initiation of dental caries [6].

2.2. Periodontal Disease Progression

Periodontal diseases are chronic inflammatory conditions initiated by the accumulation of subgingival plaque. In its earliest form, gingivitis, the inflammatory response is confined to the soft tissues, resulting in redness, swelling and bleeding. This is a reversible condition if the plaque is removed. However, in susceptible individuals, the inflammation can progress to periodontitis. This involves a shift in the microbial community toward "red complex" pathogens like *Porphyromonas gingivalis*, *Tannerella forsythia* and *Treponema denticola*. These bacteria trigger an intense host immune response, characterized by the release of pro-inflammatory cytokines (such as IL-1β, IL-6, and TNF-α), matrix metalloproteinases (MMPs), and reactive oxygen species (ROS). This chronic inflammatory environment eventually leads to the destruction of the periodontal ligament and the resorption of alveolar bone, which can result in tooth mobility and eventual loss [7].

2.3. Mechanisms of Oral Malodor (Halitosis)

Halitosis is predominantly an intra-oral phenomenon, occurring in approximately 80-90% of cases. It is caused by the metabolic activity of anaerobic Gram-negative bacteria found on the tongue dorsum and in periodontal pockets. These bacteria degrade sulphur-containing amino acids (like cysteine and methionine) found in saliva, gingival crevicular fluid and food debris. The primary end-products of this degradation are volatile sulphur compounds (VSCs), most notably hydrogen

sulphide (H_2S), methyl mercaptan (CH_3SH) and dimethyl sulphide ($(CH_3)_2S$). These compounds not only produce a foul odor but are also toxic to oral tissues and can exacerbate inflammatory conditions like periodontitis [8].

2.4. Mucosal Disorders and Infections

Recurrent aphthous stomatitis (RAS) and oral mucositis are common inflammatory conditions affecting the oral mucosa. RAS is characterized by painful, recurring ulcers that can interfere with eating and speech. While its etiology is multifactorial, it involves localized T-cell-mediated immune responses and oxidative stress. Oral mucositis is a frequent complication of cancer therapies like chemotherapy and radiation, where the rapid turnover of mucosal cells is disrupted, leading to inflammation, ulceration and a high risk of secondary infection. Oral candidiasis, on the other hand, is an opportunistic fungal infection caused by *Candida* species (chiefly *C. albicans*). It thrives when the host's local or systemic immunity is compromised, often forming biofilms on the tongue or under dentures, which can be difficult to eradicate with standard treatments [9].

3. PHYTOTHERAPEUTIC AGENTS IN ORAL HEALTHCARE

The efficacy of herbal oral sprays is derived from the complex mixture of secondary metabolites found in medicinal plants. These include alkaloids, flavonoids, terpenoids, polyphenols, and essential oils, which often work synergistically to provide a multi-targeted therapeutic approach [10].

3.1. Clove (*Syzygium aromaticum*)

Clove is perhaps the most iconic dental herb. Its essential oil contains up to 70-90% eugenol, along with eugenyl acetate and β-caryophyllene. Eugenol is a powerful antimicrobial agent that disrupts bacterial cell membranes and inhibits the growth of various oral pathogens, including *S. mutans* and *P. gingivalis*. Beyond its antimicrobial effects, clove oil is a potent analgesic and anti-inflammatory agent. It works by inhibiting prostaglandin synthesis and modulating the activity of sensory nerves, providing rapid relief from toothaches and gingival pain. Its antioxidant properties also help protect oral tissues from oxidative damage during inflammation [11].

3.2. Neem (*Azadirachta indica*)

Neem is widely referred to as the "village pharmacy" in many cultures due to its extensive medicinal properties. In oral care, neem leaves and bark are prized for

their potent antibiofilm and anti-inflammatory activities. Key bioactive compounds include azadirachtin, nimbidin, nimbolide and various quercetin glycosides. Neem has been shown to inhibit the adhesion of bacteria to the tooth surface, thereby preventing the formation of dental plaque. It also suppresses the production of pro-inflammatory cytokines and enzymes like collagenase, which are involved in the destruction of periodontal tissues. Its broad-spectrum antimicrobial activity extends to both Gram-positive and Gram-negative oral pathogens, making it a versatile component of oral healthcare formulations [12].

3.3. Aloe Vera (*Aloe barbadensis Miller*)

Aloe vera gel is a complex mixture of water, polysaccharides (particularly acemannan), anthraquinones (like aloin), vitamins and minerals. It is renowned for its wound-healing and soothing properties. In the oral cavity, aloe vera stimulates the proliferation of fibroblasts and the synthesis of collagen and elastic fibers, which are essential for tissue repair. It also possesses significant anti-inflammatory activity by inhibiting the cyclooxygenase pathway and reducing the production of bradykinin. Clinical studies have demonstrated that aloe vera can effectively reduce the pain and duration of aphthous ulcers, manage symptoms of gingivitis and alleviate the discomfort of dry mouth (xerostomia) [13].

3.4. Peppermint (*Mentha piperita*)

Peppermint is a staple in oral care products primarily due to its high menthol content, which provides a refreshing flavour and a characteristic cooling sensation. This cooling effect is mediated by the activation of TRPM8 receptors on sensory nerves, providing immediate symptomatic relief from oral irritation and sore throats. However, peppermint's benefits go beyond its sensory properties. Its essential oil possesses significant antimicrobial activity against a wide range of oral bacteria and fungi. It also exhibits mild analgesic, antioxidant and anti-inflammatory effects. Consequently, peppermint is frequently included in herbal oral sprays to manage halitosis and maintain general oral hygiene [14].

3.5. Liquorice (*Glycyrrhiza glabra*)

Liquorice has gained attention in dentistry for its unique ability to prevent dental caries and treat mucosal lesions. Its primary bioactive compounds are glycyrrhizin, glycyrrhetinic acid, and glabridin. Glycyrrhizin has been shown

to inhibit the adherence of *Streptococcus mutans* to the tooth surface, a critical step in the development of caries. Furthermore, liquorice extracts possess potent anti-inflammatory and antiviral properties. They can reduce the production of inflammatory mediators and promote the healing of the oral mucosa, making them highly effective for treating sore throats, oral mucositis and recurrent aphthous ulcers. Its natural sweetness also helps improve the palatability of herbal formulations [15].

3.6. Turmeric (*Curcuma longa*)

The therapeutic potential of turmeric is largely attributed to curcumin, a polyphenolic compound with extraordinary antioxidant and anti-inflammatory properties. Curcumin works by inhibiting several key molecular targets involved in inflammation, such as NF-κB, COX-2 and various pro-inflammatory cytokines. In the context of oral health, curcumin has been shown to reduce the accumulation of dental plaque and the severity of gingival inflammation. It also promotes wound healing by enhancing collagen maturation and reducing oxidative stress at the site of injury. Randomized clinical trials have supported the use of curcumin-based formulations as an effective adjunctive therapy for periodontal diseases [16].

3.7. Holy Basil (*Ocimum tenuiflorum / Ocimum sanctum*)

Holy Basil, or Tulsi, is highly regarded in Ayurvedic medicine for its "adaptogenic" and health-promoting properties. Its chemical profile includes eugenol, ursolic acid, rosmarinic acid, and various flavonoids. Tulsi extracts exhibit potent antimicrobial activity against cariogenic bacteria and periodontal pathogens. Eugenol and ursolic acid contribute to its anti-inflammatory and antioxidant effects, helping to protect and heal inflamed gingival tissues. It is an ideal ingredient for sprays aimed at plaque control, gingivitis management, and halitosis reduction [17].

3.8. Chamomile (*Matricaria chamomilla*)

Chamomile is widely recognized for its gentle yet effective anti-inflammatory and soothing properties. Its essential oil contains chamazulene and α-bisabolol, while its flowers are rich in flavonoids like apigenin and luteolin. Chamomile works by inhibiting both the cyclooxygenase and lipoxygenase pathways, leading to a reduction in the synthesis of prostaglandins and leukotrienes. It also promotes epithelial regeneration and has mild antimicrobial effects. Chamomile is frequently

used in oral sprays to treat inflamed oral mucosa, painful ulcers, and to support wound healing after dental extractions [18].

3.9. Tea Tree (*Melaleuca alternifolia*)

Tea tree oil is a powerful broad-spectrum antimicrobial agent, with its activity primarily attributed to terpinen-4-ol. It works by damaging the cell membranes of bacteria and fungi, leading to the leakage of intracellular components and cell death. Tea tree oil is particularly effective against *Candida albicans* and various anaerobic periodontal pathogens. It also possesses anti-inflammatory properties, suppressing the production of pro-inflammatory cytokines. Due to its potency, it is often used in standardized concentrations in oral sprays for managing oral candidiasis and periodontal infections [19].

3.10. Thyme (*Thymus vulgaris*)

Thyme is an aromatic herb whose essential oil is rich in thymol and carvacrol. These compounds are potent antimicrobial agents that disrupt microbial cell membranes and interfere with essential enzyme activities. Thyme extracts have demonstrated effectiveness against *S. mutans, C. albicans* and many other oral pathogens. Additionally, thyme possesses antioxidant and anti-inflammatory properties that support the healing of oral tissues. It is a valuable component of sprays intended for plaque reduction and the prevention of fungal infections [20].

3.11. Ginger (*Zingiber officinale*)

Ginger is well-known for its pungent flavour and its extensive medicinal benefits. It contains bioactive phenolic compounds like gingerols and shogaols, which exhibit potent antioxidant and anti-inflammatory activities. Ginger works by inhibiting key inflammatory signaling pathways, including NF-κB and the arachidonic acid cascade. It also has antibacterial activity against several oral pathogens. Its analgesic and soothing effects make it particularly useful for providing relief from sore throats and other inflammatory conditions of the oral cavity [21].

3.12. Propolis

Propolis, a resinous substance collected by honeybees from various plant sources, is a powerhouse of bioactive compounds, including flavonoids, phenolic acids (like CAPE) and terpenoids. It possesses exceptional antimicrobial, anti-inflammatory

and wound-healing properties. Propolis has been shown to inhibit bacterial adherence, reduce the release of inflammatory mediators, and accelerate the regeneration of oral tissues. Clinical evidence supports its use for treating recurrent aphthous ulcers, periodontal disease and oral mucositis. Its inclusion in herbal oral sprays can significantly enhance therapeutic efficacy and promote faster recovery [22].

3.13. Additional Noteworthy Agents

- Pomegranate (*Punica granatum*): Rich in punicalagins and ellagic acid, which provide potent antioxidant and antibacterial effects, particularly against plaque bacteria.
- Fennel (*Foeniculum vulgare*): Contains anethole and fenchone, which help reduce VSC-producing bacteria and refresh the breath.
- Sage (*Salvia officinalis*): Traditionally used for pharyngitis and gingivitis due to its antimicrobial and anti-inflammatory rosmarinic acid content.
- Rosemary (*Rosmarinus officinalis*): Provides strong antioxidant and antimicrobial protection for the oral cavity.
- Betel Leaf (*Piper betel*): Contains hydroxychavicol, which is effective at disrupting biofilms and reducing halitosis.
- Cardamom (*Elettaria cardamomum*): Valued for its breath-freshening properties and its ability to reduce the overall microbial load in the mouth.
- Triphala : A polyherbal combination of three fruits (Amla, Haritaki and Bibhitaki) that has been shown to be as effective as some synthetic mouthwashes in reducing plaque and gingival inflammation [23].

4. FORMULATION STRATEGIES FOR HERBAL ORAL SPRAYS

The successful development of a herbal oral spray is a complex process that involves balancing the stability of the active ingredients with patient acceptability and therapeutic performance [24].

4.1. Selection and Standardization of Extracts

The quality of an herbal oral spray begins with the raw botanical materials. These must be correctly identified and authenticated. Factors such as geographical origin, harvesting season and extraction method can significantly impact the phytochemical

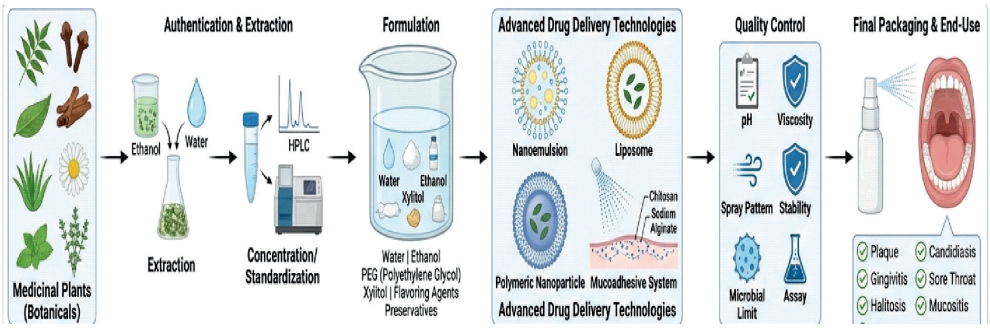


Figure 2: Formulation and advanced delivery of herbal oral sprays

profile of the plant. Standardization is therefore crucial to ensure that each batch of the product contains a consistent concentration of the key bioactive markers (e.g., eugenol in clove or glycyrrhizin in liquorice). This is achieved through sophisticated analytical techniques like High-Performance Liquid Chromatography (HPLC), Gas Chromatography-Mass Spectrometry (GC-MS) and Liquid Chromatography-Mass Spectrometry (LC-MS/MS) [25].

4.2. The Role of Excipients

Excipients are non-active ingredients that are essential for creating a stable and palatable formulation:

- Vehicles: Purified water is the most common solvent. However, many herbal constituents are lipophilic (oil-loving), so hydroethanolic systems (mixtures of water and ethanol) are often used to improve their solubility.
- Co-solvents: Substances like polyethylene glycol 400 (PEG 400), glycerol and propylene glycol are added to further enhance solubility and act as humectants to prevent the mouth from feeling dry.
- Solubilizers: Non ionic surfactants, such as Polysorbate 80 or Poloxamer 188, are used to create stable dispersions of essential oils and other hydrophobic compounds.
- Sweeteners: Since many herbal extracts are bitter, sweeteners like xylitol, sorbitol or stevia are added to improve taste. Xylitol is particularly beneficial as it also inhibits the growth of *S. mutans*.
- Flavouring Agents: Natural oils from peppermint, spearmint, or cinnamon are used to enhance the flavour and contribute to the breath-freshening effect.

- Preservatives: Ingredients like sodium benzoate or potassium sorbate are necessary to prevent microbial contamination and ensure a long shelf life.
- Buffering Agents: These maintain the pH of the formulation between 5.5 and 7.0, ensuring it is compatible with the oral mucosa and does not cause enamel erosion [26].

4.3. Manufacturing Steps

The production of herbal oral sprays follows a rigorous sequence under Good Manufacturing Practice (GMP) conditions:

1. Authentication: Identifying and verifying the plant materials.
2. Processing: Cleaning, drying, and pulverizing the plants.
3. Extraction: Using techniques like aqueous, hydroethanolic or supercritical fluid extraction to obtain the bioactive compounds.
4. Concentration and Filtration: Removing solid residues and concentrating the extract.
5. Standardization: Analyzing the extract to ensure it meets the required phytochemical specifications.
6. Vehicle Preparation: Mixing the solvents and co-solvents.
7. Incorporation: Adding the standardized extracts to the vehicle under constant stirring.
8. Additive Addition: Incorporating sweeteners, flavours, and preservatives.
9. pH Adjustment: Ensuring the final formulation is within the physiological oral range.
10. Homogenization: Ensuring a uniform distribution of all ingredients.
11. Final Filtration: Using membrane filters to ensure the product is clear and free of particulates.
12. Filling: Packaging the product into sterilized metered-dose spray containers [27].

4.4. Advanced Delivery Technologies

Recent advances in pharmaceutical science have introduced novel ways to deliver herbal ingredients more effectively:

- Nanoemulsions: These are dispersions of very small oil droplets in water. They can significantly increase the solubility and antimicrobial activity of essential oils by providing a larger surface area for interaction with microbes.
- Liposomes: Small vesicles made of phospholipids that can encapsulate both water-soluble and oil-soluble compounds. They protect sensitive phytochemicals from degradation and can enhance their penetration into the oral mucosa.
- Polymeric Nanoparticles: Biodegradable particles that provide controlled and sustained release of the active ingredients, prolonging their therapeutic effect.
- Mucoadhesive Systems: The addition of polymers like chitosan or sodium alginate allows the spray to "stick" to the oral mucosa for a longer period, increasing the residence time and local bioavailability of the phytoconstituents.
- Cyclodextrin Inclusion Complexes: These "bucket-like" molecules can house poorly soluble phytochemicals (like curcumin), greatly increasing their solubility and stability in aqueous formulations [28].

5. EVALUATION AND QUALITY CONTROL

To ensure that herbal oral sprays are safe, effective and consistent, they must undergo a comprehensive suite of evaluations [29]. Common Quality evaluation parameters and its method were incorporated in Table 1.

Table 1: Quality evaluation parameters for herbal oral sprays

Evaluation parameter	*Purpose*	*Common analytical method*
Organoleptic properties	Patient acceptability	Visual inspection
pH	Oral compatibility and stability	Digital pH meter
Viscosity	Sprayability and mucosal retention	Brookfield viscometer
Spray pattern	Uniform distribution	Spray pattern analysis
Plume geometry	Dose reproducibility	Plume imaging
Droplet size	Deposition efficiency	Laser diffraction
Delivered dose uniformity	Dose accuracy	Gravimetric method/HPLC
Drug content	Quantification of marker compounds	HPLC, HPTLC, UV–Visible spectroscopy
Microbial limit test	Product safety	USP/IP/Pharmacopoeial microbiological methods
Stability study	Shelf-life determination	ICH Q1A(R2) stability testing
Container closure integrity	Packaging quality	Leakage test
Pump performance	Uniform actuation	Spray pump evaluation

5.1. Physicochemical Evaluation

- Organoleptic Properties: The appearance, color, odor and taste are assessed, as these are critical for patient acceptance.
- pH Measurement: A digital pH meter is used to confirm the formulation is within the 5.5-7.0 range.
- Viscosity: Measured using a Brookfield viscometer to ensure the spray is easy to apply but thick enough to stay on the mucosal surface.
- Spray Performance: This includes analyzing the spray pattern (the shape and area of the spray) and the plume geometry (the three-dimensional shape of the spray cloud) to ensure uniform dose delivery.
- Droplet Size Distribution: Determined using laser diffraction techniques. The droplets should be small enough for uniform coverage but large enough to avoid being inhaled into the lungs.

5.2. Pharmaceutical Evaluation

- Uniformity of Delivered Dose: Each actuation of the spray pump must deliver the same volume and amount of active ingredient. This is checked gravimetrically (by weight) and by chemical analysis of the delivered spray.
- Drug Content (Assay): Validated analytical methods (like HPLC or UV-Visible spectrophotometry) are used to quantify the marker phytochemicals in the final product.

5.3. Microbiological and Stability Testing

- Microbial Limit Test: Since herbal materials can be naturally contaminated, products are tested for total aerobic microbial count, yeast and mould count and the absence of specific pathogens like *E. coli*.
- Stability Studies: Conducted according to ICH guidelines, these studies assess the product's quality over time under different environmental conditions (e.g., 25°C/60% RH and 40°C/75% RH). This helps determine the shelf life and appropriate storage conditions.

5.4. Packaging Evaluation

The spray container and pump mechanism must be compatible with the formulation and provide protection from light, oxygen, and moisture. Tests include leakage tests, pump performance evaluation, and container closure integrity [30].

6. THERAPEUTIC APPLICATIONS AND CLINICAL EVIDENCE

The multi-targeted pharmacological actions of medicinal plants allow herbal oral sprays to be used. Therapeutic applications of oral spays and their therapeutic effects included in table 2.

Table 2: Therapeutic applications of herbal oral sprays

Oral condition	*Major herbal ingredients*	*Principal therapeutic effects*
Dental plaque	Neem, Clove, Tulsi, Triphala	Antibacterial, antibiofilm
Gingivitis	Turmeric, Aloe vera, Neem	Anti-inflammatory, antimicrobial
Periodontitis	Pomegranate, Liquorice, Clove	Antioxidant, periodontal protection
Halitosis	Peppermint, Cardamom, Fennel	Breath freshening, antimicrobial
Oral candidiasis	Tea tree, Thyme, Clove	Antifungal, antibiofilm
Aphthous ulcers	Aloe vera, Chamomile, Propolis	Wound healing, analgesic
Oral mucositis	Liquorice, Propolis, Turmeric	Anti-inflammatory, epithelial regeneration
Sore throat	Ginger, Sage, Chamomile	Anti-inflammatory, soothing

6.1. Prevention and Management of Dental Plaque and Gingivitis

Biofilms are the root cause of many oral diseases. Herbal oral sprays containing neem, clove, tulsi, and Triphala have shown significant antibiofilm activity. They interfere with bacterial adhesion, disrupt the EPS matrix, and inhibit quorum sensing (bacterial communication). In patients with gingivitis, sprays containing curcumin, aloe vera and pomegranate have been shown to reduce gingival bleeding and inflammation by suppressing pro-inflammatory pathways and oxidative stress [32].

6.2. Halitosis and Breath Refreshing

Unlike many commercial breath fresheners that rely on high alcohol content, herbal oral sprays use essential oils (peppermint, fennel, cardamom) to provide immediate relief while also targeting the VSC-producing bacteria. This provides a more sustainable solution to oral mal odour without causing the mucosal dryness associated with alcohol-based products [33].

6.3. Oral Ulcers, Mucositis and Candidiasis

Managing painful mucosal lesions is a key application for herbal sprays. Aloe vera, chamomile, and propolis provide a soothing, protective layer over ulcers and accelerate the healing process by promoting epithelial regeneration. For

chemotherapy-induced mucositis, liquorice and curcumin sprays can significantly reduce the severity of inflammation. In cases of oral candidiasis, tea tree oil and thyme sprays offer a potent antifungal alternative, especially against resistant strains of Candida [34].

6.4. Sore Throat and Pharyngeal Inflammation

Herbal sprays are highly effective for sore throats because they deliver anti-inflammatory and antimicrobial agents (like ginger, sage and propolis) directly to the inflamed tissues of the pharynx. This can reduce swelling, alleviate pain and prevent secondary bacterial infections [35].

6.5. Post-operative and General Oral Care

After dental procedures like extractions or implant surgery, maintaining hygiene is critical. Herbal sprays with curcumin and propolis can support wound healing, reduce post-operative pain and prevent infection. They are also useful for general oral hygiene in patients who have difficulty with traditional brushing and flossing, such as those with physical or cognitive impairments [36].

7. MARKET STATUS AND CHALLENGES

The global market for herbal oral care products is expanding rapidly, driven by the increasing consumer preference for natural and clean-label healthcare. Many commercial herbal oral sprays are now available, often containing combinations of propolis, manuka honey, aloe vera and various essential oils for indications like sore throat, dry mouth, and halitosis [37,38].

Table 3: Examples of commercially available herbal oral spray products

Commercial product	*Major herbal ingredients*	*Primary indication*
Propolis Oral Spray	Propolis extract	Oral ulcers, sore throat, oral hygiene
Dentist Oral Spray	Peppermint, Clove, Tea tree, Sage	Halitosis, oral hygiene
Dr. Organic Aloe Vera Mouth Spray	Aloe vera, Peppermint	Dry mouth, oral freshness
Vogel Echinaforce Throat Spray	*Echinacea purpurea*, Sage	Sore throat, pharyngeal irritation
Manuka Health Oral Spray	Manuka honey, Propolis	Oral care, throat protection
Weleda Oral Care Spray	Sage, Myrrh, Chamomile	Gingival care, oral hygiene
Pro Fresh Oral Spray	Peppermint, Zinc compounds*	Halitosis management
Comvita Propolis Oral Spray	Propolis, Manuka honey	Sore throat and oral immune support

However, the commercial development of these products faces several challenges:

- Phytochemical Variability: Natural variations in plant constituents can lead to inconsistencies in product efficacy.
- Limited Clinical Evidence: While many plants have a long history of traditional use, there is a need for more high-quality, large-scale randomized controlled trials to satisfy the requirements of evidence-based dentistry.
- Stability Issues: Many phytochemicals, particularly essential oils and flavonoids, are sensitive to light and oxidation, necessitating specialized packaging and stabilization strategies.
- Regulatory Complexity: The regulation of herbal products varies significantly between countries, ranging from food supplements to traditional medicines or cosmetics, which can complicate international trade and marketing [39,40].

8. FUTURE PERSPECTIVES

The next generation of herbal oral sprays will likely be shaped by several emerging trends:

- Advanced Nanotechnology: The use of nanostructured lipid carriers (NLCs), phytosomes and smart, responsive delivery systems will further enhance the bioavailability and targeted delivery of phytoconstituents.
- Metabolomics and AI: Integrating metabolomic profiling with artificial intelligence can help identify the most effective combinations of herbal ingredients and predict their interactions with other drugs.
- Personalized Oral Care: The development of customized herbal formulations based on an individual's unique oral microbiota and genetic profile.
- Sustainability: A focus on eco-friendly extraction methods (like supercritical fluid extraction), biodegradable packaging, and sustainable sourcing of medicinal plants.
- Regulatory Harmonization: Increased collaboration between international regulatory bodies will help establish clearer standards for the quality and safety of herbal oral care products [41,42,43].

9. CONCLUSION

Herbal oral sprays represent a compelling intersection of traditional botanical knowledge and modern pharmaceutical science. By providing a convenient, effective and biocompatible platform for delivering a wide range of therapeutic agents, they offer a valuable alternative or adjunct to conventional oral healthcare products. Their broad-spectrum antimicrobial, anti-inflammatory and wound-healing properties make them suitable for managing everything from routine plaque control to complex mucosal disorders.

While challenges related to standardization and clinical validation remain, the ongoing integration of advanced delivery technologies and rigorous quality control measures is paving the way for their wider adoption in clinical practice. As we move toward a more holistic and natural approach to health, herbal oral sprays are set to become an essential tool in the global effort to improve oral health and well-being. Continued research, particularly in the form of robust clinical trials, will be the key to fully realizing their potential and ensuring that they meet the highest standards of evidence-based care [44,45].

REFERENCES

Shojaei AH. Buccal mucosa as a route for systemic drug delivery: a review. J Pharm Pharm Sci. 1998 Jan 1;1(1):15-30.

Mahomoodally MF, Sadeer N, Edoo M, Venugopala KN. The potential application of novel drug delivery systems for phytopharmaceuticals and natural extracts–current status and future perspectives. Mini Reviews in Medicinal Chemistry. 2021 Nov 1;21(18):2731-46.

Porter SR, Scully C. Oral malodour (halitosis). Bmj. 2006 Sep 21;333(7569):632-5.

Yaegaki K. Examination, classification, and treatment of halitosis; clinical perspective. Journal de l'Association denture canadienne. 2000;66:275-60.

Barnes J. Anderson lA, Phillipson JD. Herbal Medicines.

Grzanna R, Lindmark L, Frondoza CG. Ginger—an herbal medicinal product with broad anti-inflammatory actions. Journal of medicinal food. 2005 Jun;8(2):125-32.

Papapanou PN, Sanz M, Buduneli N, Dietrich T, Feres M, Fine DH, Flemmig TF, Garcia R, Giannobile WV, Graziani F, Greenwell H. Periodontitis: Consensus report of workgroup 2 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. Journal of periodontology. 2018 Jun;89:S173-82.

Prashant GM, Chandu GN, Murulikrishna KS, Shafiulla MD. The effect of mango and neem extract on four organisms causing dental caries: Streptococcus mutans, Streptococcus

salivavius, Streptococcus mitis:, and: Streptococcus sanguis:: An: in vitro: study. Indian journal of dental research. 2007 Oct 1;18(4):148-51.

George D, Bhat SS, Antony B. Aloe vera: A natural therapeutic agent for oral health. J Indian Soc Periodontol. 2009;13(2):71–74.

Jagannath N, et al. Triphala: A comprehensive review. J Ayurveda Integr Med. 2013;4(3):187–191. Ahuja A, Singh S. Anti Infect Agents. 2022;20(4):e050422203629.

Cowan MM. Plant products as antimicrobial agents. Clinical microbiology reviews. 1999 Oct 1;12(4):564-82.

Groppo FC, Ramacciato JC, Simoes RP, Flório FM, Sartoratto A. Antimicrobial activity of garlic, tea tree oil, and chlorhexidine against oral microorganisms. International dental journal. 2002 Dec 1;52(6):433-7.

Edgar NR, Saleh D, Miller RA. Recurrent aphthous stomatitis: a review. The Journal of clinical and aesthetic dermatology. 2017 Mar 1;10(3):26.

Preethi KC, Kuttan R. Wound healing activity of flower extract of Calendula officinalis. J Basic Clin Physiol Pharmacol. 2009;20(1):73-9. doi: 10.1515/jbcpp.2009.20.1.73. PMID: 19601397.

Sforcin JM, Bankova V. Propolis: is there a potential for the development of new drugs?. Journal of ethnopharmacology. 2011 Jan 27;133(2):253-60.

Chaieb, K., Hajlaoui, H., Zmantar, T., Kahla-Nakbi, A.B., Rouabhia, M., Mahdouani, K. and Bakhrouf, A., 2007. The chemical composition and biological activity of clove essential oil, Eugenia caryophyllata (Syzigium aromaticum L. Myrtaceae): a short review. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives, 21(6), pp.501-506.

Cortés-Rojas DF, De Souza CR, Oliveira WP. Clove (Syzygium aromaticum): a precious spice. Asian Pacific journal of tropical biomedicine. 2014 Feb 1;4(2):90-6

Chaieb K, Hajlaoui H, Zmantar T, Kahla-Nakbi AB, Rouabhia M, Mahdouani K, Bakhrouf A. The chemical composition and biological activity of clove essential oil, Eugenia caryophyllata (Syzigium aromaticum L. Myrtaceae): a short review. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives. 2007 Jun;21(6):501-6

Subapriya R, Nagini S. Medicinal properties of neem leaves: a review. Current Medicinal Chemistry-Anti-Cancer Agents. 2005 Mar 1;5(2):149-56.

Surjushe A, Vasani R, Saple D. Aloe vera: a short review. Indian journal of dermatology. 2008 Oct 1;53(4):163-6

McKay DL, Blumberg JB. A review of the bioactivity and potential health benefits of peppermint tea (Mentha piperita L.). Phytotherapy Research: An International Journal Devoted to

Pharmacological and Toxicological Evaluation of Natural Product Derivatives. 2006 Aug;20(8):619-33.

Eccles R. Menthol and related cooling compounds. Journal of Pharmacy and Pharmacology. 1994 Aug;46(8):618-30

Asl MN, Hosseinzadeh H. Review of pharmacological effects of Glycyrrhiza sp. and its bioactive compounds. Phytotherapy Research: An International Journal Devoted to Pharmacological and Toxicological Evaluation of Natural Product Derivatives. 2008 Jun;22(6):709-24.

Messier C, Epifano F, Genovese S, Grenier D. Licorice and its potential beneficial effects in common oro-dental diseases. Oral diseases. 2012 Jan;18(1):32-9.

Hewlings SJ, Kalman DS. Curcumin: A review of its effects on human health. Foods. 2017 Oct;6(10):92.

Aggarwal BB, Harikumar KB. Potential therapeutic effects of curcumin, the anti-inflammatory agent, against neurodegenerative, cardiovascular, pulmonary, metabolic, autoimmune and neoplastic diseases. The international journal of biochemistry & cell biology. 2009 Jan 1;41(1):40-59

Cohen MM. Tulsi-Ocimum sanctum: A herb for all reasons. Journal of Ayurveda and integrative medicine. 2014 Oct;5(4):251.

R C, R S, Mohideen K, Nandagopal P, Jayamani L, Jeyakumaran S. Anti-candidal Effect of Ocimum sanctum: A Systematic Review on Microbial Studies. Cureus. 2022 May 5;14(5):e24749. doi: 10.7759/cureus.24749. PMID: 35677004; PMCID: PMC9166562.

Srivastava JK, Shankar E, Gupta S. Chamomile: A herbal medicine of the past with a bright future. Molecular medicine reports. 2010 Nov 1;3(6):895-901.

Carson CF, Hammer KA, Riley TV. Melaleuca alternifolia (tea tree) oil: a review of antimicrobial and other medicinal properties. Clinical microbiology reviews. 2006 Jan;19(1):50-62.

Hammer KA, Carson CF, Riley TV. Antimicrobial activity of essential oils and other plant extracts. Journal of applied microbiology. 1999 Jun 1;86(6):985-90.

Marchese A, Orhan IE, Daglia M, Barbieri R, Di Lorenzo A, Nabavi SF, Gortzi O, Izadi M, Nabavi SM. Antibacterial and antifungal activities of thymol: A brief review of the literature. Food chemistry. 2016 Nov 1;210:402-14.

Salehi B, Mishra AP, Shukla I, Sharifi-Rad M, Contreras MD, Segura-Carretero A, Fathi H, Nasrabadi NN, Kobarfard F, Sharifi-Rad J. Thymol, thyme, and other plant sources: Health and potential uses. Phytotherapy research. 2018 Sep;32(9):1688-706.

Mao QQ, Xu XY, Cao SY, Gan RY, Corke H, Beta T, Li HB. Bioactive Compounds and Bioactivities of Ginger (Zingiber officinale Roscoe). Foods. 2019 May 30;8(6):185. doi: 10.3390/foods8060185. PMID: 31151279; PMCID: PMC6616534

Kuropatnicki AK, Szliszka E, Krol W. Historical aspects of propolis research in modern times. Evid Based Complement Alternat Med. 2013;2013:964149. doi: 10.1155/2013/964149. Epub 2013 Apr 28. PMID: 23710243; PMCID: PMC3655583.

Shojaei AH. Buccal mucosa as a route for systemic drug delivery: a review. J Pharm Pharm Sci. 1998 Jan 1;1(1):15-30.

European Medicines Agency. Guideline on quality of herbal medicinal products/traditional herbal medicinal products.

World Health Organization. WHO guidelines on good agricultural and collection practices [GACP] for medicinal plants. World Health Organization; 2003 Dec 16.

Mukherjee PK. Quality control and evaluation of herbal drugs: Evaluating natural products and traditional medicine. Elsevier; 2019 May 30.

Rowe RC, Sheskey PJ, Quinn ME, editors. Handbook of pharmaceutical excipients. London: Pharmaceutical press; 2006 Jan 30.

Date AA, Nagarsenker MS. Design and evaluation of self-nanoemulsifying drug delivery systems (SNEDDS) for cefpodoxime proxetil. International journal of pharmaceutics. 2007 Feb 1;329(1-2):166-72.

Torchilin VP. Recent advances with liposomes as pharmaceutical carriers. Nature reviews Drug discovery. 2005 Feb 1;4(2):145-60.

Bernkop-Schnürch A. Mucoadhesive systems in oral drug delivery. Drug discovery today: Technologies. 2005 Mar 1;2(1):83-7.

González-González O, Ramirez IO, Ramirez BI, O'Connell P, Ballesteros MP, Torrado JJ, Serrano DR. Drug stability: ICH versus accelerated predictive stability studies. Pharmaceutics. 2022 Oct 28;14(11):2324.

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