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REVIEW ARTICLE

A Review on the Benefits of Polyherbal Dentifrice containing *Salvadora persica*

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Abstract: Natural oral hygiene solutions using phytotherapeutic agents offer a biocompatible alternative to conventional synthetic dentifrices. *Salvadora persica*, commonly known as Miswak, serves as a primary bioactive source for the prevention of dental caries, gingival inflammation, and periodontal disease. The combination of traditional botanical knowledge with modern pharmaceutical formulation techniques allows for the creation of stable, effective, and safe herbal toothpaste. These formulations utilize the synergistic effects of various plant extracts, including *Azadirachta indica* (Neem) and *Salvadora persica*, which provide potent antimicrobial, antioxidant, and anti-inflammatory properties. Beyond the active herbal components, the selection of appropriate pharmaceutical excipients such as calcium carbonate, hydrated silica, and xanthan gum ensures optimal abrasive action, rheological stability, and consumer acceptability. Evaluation of these herbal pastes through physical, chemical, and biological assays reveals that they maintain a neutral pH, show significant antimicrobial activity against cariogenic bacteria like *Streptococcus mutans*, and offer comparable cleaning efficiency to fluoride-based products without the associated risks of fluoride toxicity or mucosal irritation. Such a dentifrice can be a sustainable advancement in dental care, aligning with the global shift toward green pharmacy and chemical-free personal care products. The past literature shows that standardized herbal dentifrices provide a holistic approach to oral health, maintaining the microbial balance of the oral cavity while strengthening the structural integrity of the periodontium.

Keywords: *Salvadora persica*; Herbal Dentifrice; Dental Caries; Phytotherapy; Oral Hygiene

1. Introduction

Oral health is vital for systemic well-being, yet dental caries and periodontal diseases continue to be global public health challenges. The primary etiology of these conditions involves the accumulation of dental plaque, a complex biofilm dominated by acidogenic bacteria such as *Streptococcus mutans* [1]. While mechanical cleaning is the fundamental method for plaque removal, the efficacy of this process is significantly enhanced by the use of dentifrices. Conventional toothpastes rely heavily on synthetic chemical agents, including fluoride, triclosan, and sodium lauryl sulfate (SLS). Although these agents are effective, concerns regarding fluoride toxicity in pediatric populations, the development of antimicrobial resistance, and the irritant potential of synthetic detergents have led to a resurgence of interest in natural alternatives [2].

Phytotherapeutic dentifrices utilize medicinal plant extracts to provide therapeutic benefits through natural bioactive pathways. These formulations prioritize biocompatibility and long-term safety, making them suitable for diverse demographic groups [3]. Among the most historically significant and scientifically validated botanical sources for oral care is *Salvadora persica*, or the Miswak tree. Often referred to as the "toothbrush tree," its roots and twigs have been utilized for centuries as natural cleaning tools. Scientific investigation confirms that *S. persica* contains an array of pharmacologically active constituents, including salvadorine, trimethylamine, silica, sulfur, and natural fluorides, which collectively contribute to its plaque-inhibiting and gum-strengthening properties [4].

The formulation of a high-quality herbal toothpaste requires a meticulous balance between the active herbal extracts and the pharmaceutical base. The objective is to produce a stable paste that delivers the bioactive compounds effectively while providing the necessary abrasive and polishing actions [5]. The formulation achieves a broader spectrum of activity by combining Miswak with other potent herbs such as Neem (*Azadirachta indica*), addressing not only bacterial load but also gingival bleeding and halitosis [6].

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2. Classification of Herbal Oral Care Formulations

Herbal dentifrices are categorized based on several pharmaceutical and therapeutic criteria to ensure they meet specific clinical requirements.

2.1. Classification Based on Primary Botanical Constituents

The categorization often begins with the dominant herb used as the active pharmaceutical ingredient. Neem-based formulations are primarily selected for their intense antibacterial and antifungal properties, targeting chronic gingivitis. Miswak-based formulations are characterized by their high mineral content and natural cleansing fibers, which focus on mechanical plaque disruption and enamel remineralization [7]. Other variants may include clove-based pastes for analgesic benefits or aloe-vera-based gels for soothing mucosal irritations.

2.2. Classification Based on Therapeutic and Pharmacological Action

Dentifrices are also classified by their primary clinical objective. Antimicrobial herbal pastes are engineered to control the oral microflora and prevent secondary infections. Anti-inflammatory variants are specifically designed to treat periodontitis by reducing cytokines and mediators of inflammation in the gingival tissues [8]. Whitening formulations utilize natural silicates and fruit-derived enzymes to remove extrinsic stains without damaging the enamel. Furthermore, anti-caries formulations focus on raising the salivary pH and promoting the deposition of minerals into the tooth structure.

2.3. Classification Based on Physical State and Formulation Type

The rheological and physical properties define the delivery system. Gel-based herbal products are usually transparent or semi-translucent, utilizing hydrocolloids to create a lighter mouthfeel. Conventional paste-based formulations provide a more viscous and creamy texture, suitable for carrying a higher load of abrasive particles [9]. Traditional powder-based systems, while less common in modern urban settings, remain relevant for their high concentration of active botanicals and lack of water, which eliminates the need for complex preservative systems [10].

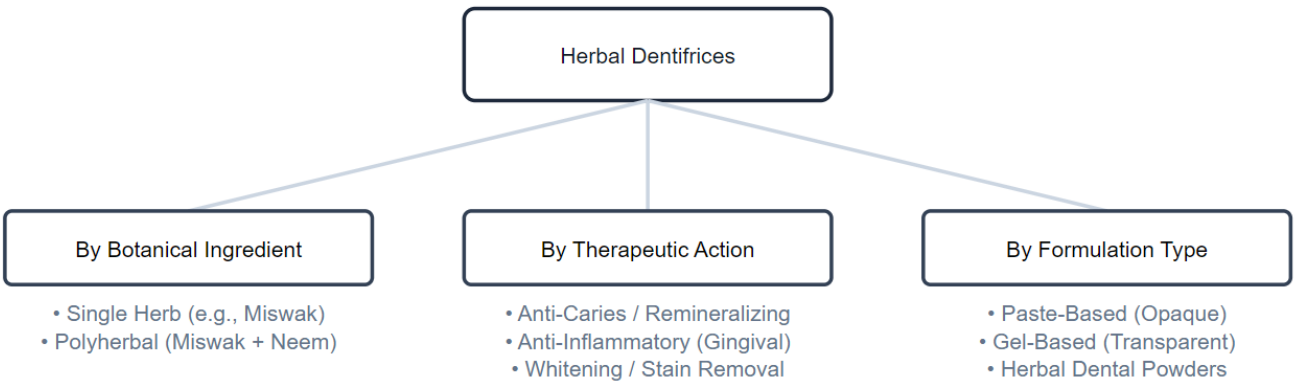

Figure 1. Classification of Herbal Oral Care Systems

3. Significance and Therapeutic Advantages of Herbal Systems

The shift toward botanical dental care is driven by several pharmacological advantages that herbal ingredients offer over their synthetic counterparts.

3.1. Safety and Biocompatibility

A primary advantage of herbal toothpastes is their high safety margin. Unlike conventional pastes that may pose a risk of dental fluorosis if swallowed by children, herbal variants are generally non-toxic [11]. The absence of synthetic dyes and artificial sweeteners reduces the risk of allergic reactions and oral ulcers. These formulations are particularly beneficial for individuals with xerostomia (dry mouth) or sensitive oral mucosa, as they avoid the harsh desiccating effects of high-concentration synthetic detergents [12].

3.2. Pharmacological Effects

Natural ingredients provide multiple therapeutic benefits simultaneously. While a synthetic agent might only target bacteria, a single herbal extract like Miswak can provide antimicrobial, astringent, and remineralizing effects [13]. The presence of essential oils like peppermint not only provides a refreshing flavor but also acts as a mild analgesic and antiseptic. This holistic action ensures that the overall oral environment is improved, rather than just treating a single symptom like bad breath or surface stains [14].

3.3. Environmental and Sustainable Considerations

From an ecological perspective, herbal formulations are increasingly preferred due to their biodegradability. The plant-based surfactants and binders used in these products do not persist in the environment or contribute to aquatic toxicity in the same manner as certain synthetic chemicals [15]. The sourcing of ingredients from sustainable botanical origins aligns with modern green chemistry principles, making herbal oral care a responsible choice for the conscious consumer [16].

4. Clinical and Empirical Evidence

The development of herbal dentifrices is supported by a growing body of clinical research that compares their efficacy to conventional fluoride-based products. This evidence base is essential for validating the transition from traditional use to standardized pharmaceutical applications.

4.1. Comparative Antimicrobial Efficacy in Pediatric Populations

Recent systematic investigations have focused on the role of herbal formulations in managing dental caries among children and adolescents. Clinical data suggests that herbal dentifrices exhibit antimicrobial activity against *Streptococcus mutans* and *Lactobacillus* species that is comparable to standard fluoride toothpastes [17]. Meta-analyses of multiple randomized trials indicate that while herbal pastes may not consistently show statistical superiority in terms of absolute caries prevention, they are equally effective in reducing bacterial plaque scores and maintaining oral cleanliness in younger patients. These findings support the use of herbal alternatives as a biocompatible strategy for pediatric oral health, particularly where fluoride overexposure is a concern [18].

4.2. Biofilm Management and Plaque Index Reduction

The ability of botanical extracts to modulate the oral biofilm is a primary focus of current literature. Studies evaluating polyherbal formulations containing *Salvadora persica* and *Azadirachta indica* have demonstrated significant reductions in the Plaque Index (PI) and Gingival Index (GI) [19]. The antimicrobial agents present in these plants work by inhibiting the initial adhesion of primary colonizers to the tooth pellicle and disrupting the structural integrity of the established biofilm. Comparative clinical trials often report that participants using herbal pastes achieve oral hygiene levels similar to those using conventional antimicrobial agents like chlorhexidine, but without the associated side effects such as tooth staining or altered taste perception [20].

4.3. Influence on Salivary pH and Mineralization

Beyond bacterial control, research has examined the biochemical impact of herbal ingredients on the oral environment. Analytical studies indicate that extracts of Miswak can favorably modulate salivary pH, shifting it toward a more alkaline state that discourages enamel demineralization [21]. The presence of natural minerals such as calcium and phosphorus in botanical sources assists in the remineralization of early carious lesions. This dual action of neutralizing acid and providing mineral ions suggests that herbal dentifrices can play a proactive role in maintaining the structural density of dental enamel [22].

Table 1. Comparison of Bioactive Mechanisms in Common Polyherbal Ingredients

Botanical Source	Active Principle	Primary Clinical Application	Antimicrobial Spectrum
Miswak	Benzyl isothiocyanate	Plaque control/Caries prevention	High (*S. mutans, Lactobacillus*)
Neem	Nimbidin / Azadirachtin	Gingivitis management	Moderate (*P. gingivalis*)
Clove	Eugenol	Analgesia / Antiseptic action	Moderate (Broad spectrum)
Peppermint	Menthol	Halitosis management	Low (Fungistatic)
Aloe Vera	Acemannan	Mucosal healing / Soothing	Low (Anti-inflammatory)

5. Detailed Profile of *Salvadora persica* (Miswak)

Salvadora persica represents the cornerstone of many herbal oral care systems due to its unique chemical composition and historically validated efficacy.

5.1. Botanical Characteristics and Distribution

Known as the "toothbrush tree," *S. persica* is a perennial evergreen shrub or small tree primarily found in the arid and semi-arid regions of the Middle East, Africa, and South Asia. The tree is characterized by its ability to thrive in saline and drought-prone environments. The roots and branches are fibrous and contain a high concentration of bioactive secondary metabolites, which are released upon mechanical manipulation, such as chewing or grinding into powder for toothpaste formulation [23].

5.2. Phytochemical Composition and Bioactive Components

The therapeutic efficacy of Miswak is attributed to a complex mixture of chemical constituents.

5.2.1. Primary Antimicrobial Agents

The most significant antimicrobial component in *S. persica* is benzyl isothiocyanate (BITC). This compound exhibits potent bactericidal activity against a wide range of oral pathogens. Additionally, the presence of alkaloids such as salvadorine provides a sustained antibacterial effect within the oral cavity [24]. These nitrogenous compounds interfere with bacterial cell wall synthesis and metabolic pathways, effectively reducing the microbial load on the tooth surfaces.

5.2.2. Mineral Content and Remineralizing Agents

Miswak is exceptionally rich in inorganic minerals. It contains high levels of chlorides, which prevent the formation of dental calculus, and silica, which acts as a natural, gentle abrasive for polishing the enamel [25]. The presence of natural fluoride, albeit in small and safe concentrations, along with calcium and potassium ions, facilitates the strengthening of the tooth structure and enhances the resistance of enamel to acid challenges [26].

5.2.3. Astringent and Protective Compounds

Tannins found in the root extract contribute to the astringent properties of Miswak, which help in tightening the gingival tissues and reducing bleeding gums. Vitamin C and various flavonoids provide antioxidant support, protecting the oral mucosa from oxidative stress and supporting the healing of minor oral lesions [27]. The presence of resins also forms a thin protective layer over the enamel, which can inhibit the further attachment of plaque-forming bacteria [28].

Table 2. Bioactive Phytochemical Constituents of *Salvadora persica* and Their Pharmacological Roles.

Chemical Constituent	Primary Functional Role	Pharmacological Mechanism
Salvadorine	Antibacterial agent	Inhibits bacterial growth and metabolic activity.
Benzyl Isothiocyanate (BITC)	Potent bactericide	Broad-spectrum antimicrobial action against cariogenic pathogens.
Tannins	Astringent	Promotes gingival health and reduces bleeding.
Silica	Mechanical abrasive	Facilitates removal of dental plaque and surface stains.
Sulfur Compounds	Antiseptic	Provides a natural barrier against oral infections.
Calcium & Phosphorus	Remineralizing agent	Supports the structural integrity of dental enamel.
Vitamin C	Antioxidant	Facilitates tissue repair and supports mucosal health.

5.3. Mechanisms of Action in Oral Health

The clinical benefits of Miswak are achieved through both mechanical and chemical pathways. During brushing, the fine silica particles and fibrous texture of the plant extract assist in the physical removal of plaque. Chemically, the release of BITC and salvadorine creates an environment that is hostile to acidogenic bacteria. Simultaneously, the stimulation of the parotid glands by the bitter-sweet components of the extract increases salivary flow, which enhances the natural buffering capacity of the mouth and provides a continuous cleansing effect [29].

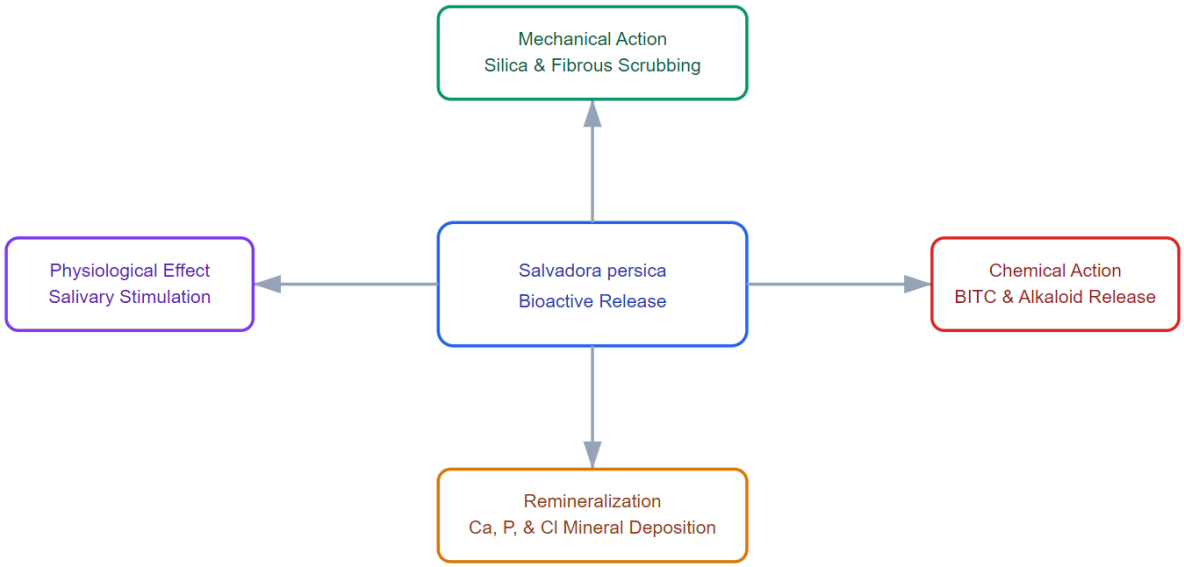

Figure 2. Mechanism of Action of *Salvadora persica* in the Oral Cavity

6. Pharmaceutical Considerations in Herbal Dentifrice Formulation

The transition from raw botanical extracts to a standardized pharmaceutical product requires a deep understanding of the interactions between bioactive plant metabolites and synthetic or natural excipients. A successful herbal dentifrice must maintain physical stability, chemical integrity of the actives, and consistent rheological properties over its intended shelf life [30].

6.1. Challenges with Herbal Ingredients

Incorporating plant extracts like *Salvadora persica* and *Azadirachta indica* into a toothpaste base poses several formulation challenges. Botanical materials are often complex mixtures of hydrophilic and lipophilic compounds, which can affect the emulsion stability and texture of the paste [31]. Furthermore, the natural pigments in these extracts can lead to color instability or unwanted staining if not properly stabilized. The formulation must also account for the potential degradation of volatile oils, such as peppermint oil, which are susceptible to oxidation and evaporation during the manufacturing process [32].

6.2. Influence of Particle Size and Morphology on Abrasive Action

A critical aspect of dentifrice performance is the Radioactive Dentin Abrasion (RDA) value, which is largely determined by the particle size and hardness of the abrasives used. In herbal systems, the use of calcium carbonate and hydrated silica is common, but the inherent silica content in Miswak roots also contributes to the mechanical cleaning phase [33]. Controlling the fineness of the botanical powders is essential; particles that are too coarse may cause gingival recession or enamel wear, while particles that are too fine may fail to remove stubborn dental stains or calculus [34].

7. Functional Roles of Pharmaceutical Excipients in Herbal Systems

To support the bioactive herbal components, a robust matrix of excipients is required. Each component is selected for its ability to enhance the delivery of the plant extracts while ensuring the product is palatable and easy to use.

7.1. Abrasive and Polishing Agents

Calcium carbonate serves as the primary mild abrasive in many herbal formulations. Beyond its mechanical cleaning role, it acts as a pH buffer and a potential source of calcium ions for remineralization [35]. Hydrated silica is often used synergistically to provide a controlled polishing effect, ensuring that the teeth are cleaned without excessive abrasion. The combination of these minerals ensures that the dentifrice effectively disrupts the dental pellicle and removes extrinsic stains caused by dietary habits [36].

7.2. Humectants and Consistency Modifiers

Glycerin is a vital component in herbal toothpastes, functioning as a humectant to prevent the paste from drying out when exposed to air. Its high hygroscopicity maintains the moisture content of the formulation, ensuring a smooth extrusion from the tube [37]. Additionally, glycerin serves as a solvent for certain herbal extracts and provides a subtle sweetness that masks the bitter taste of some medicinal plants.

7.3. Binding and Gelling Agents

The rheological profile of the toothpaste is primarily governed by binders such as xanthan gum. As a high-molecular-weight polysaccharide, xanthan gum creates a stable hydrocolloid matrix that prevents the separation of the solid abrasive particles from the liquid phase [38]. This "shear-thinning" behavior is crucial for consumer acceptability; the paste must remain firm on the brush but flow easily when pressure is applied during the brushing process [39].

7.4. Surfactants and Foaming Characteristics

Sodium Lauryl Sulfate (SLS) is frequently utilized as a surfactant to reduce the surface tension of the oral fluid. This action facilitates the even distribution of the herbal actives across the tooth surfaces and into the interdental spaces. The resulting foaming action assists in the suspension and removal of food debris and plaque [40]. In natural-focused formulations, the concentration of SLS is often carefully moderated to prevent mucosal irritation while maintaining effective cleaning power.

7.5. Taste Masking and Preservation

The sensory profile of herbal toothpastes is often challenged by the strong, sometimes pungent odors and tastes of botanical extracts. Sodium saccharine is employed as a non-cariogenic sweetener to improve palatability [41]. Peppermint oil acts as both a flavoring agent and a cooling sensory enhancer, providing the "freshness" associated with oral hygiene. Finally, the inclusion of sodium benzoate is essential to prevent microbial contamination. Since herbal extracts can serve as a nutrient source for fungi and bacteria, a robust preservative system is required to ensure the product remains safe throughout its use [42].

Table 3. Functional Role and Concentration of Pharmaceutical Excipients in Herbal Dentifrice

Component Category	Exemplar Material	Standard Concentration (%)	Functional Role in Formulation
Abrasive	Calcium Carbonate	35.0 – 45.0	Mechanical plaque removal and pH buffering.
Polishing Agent	Hydrated Silica	10.0 – 20.0	Enhancement of tooth luster and stain removal.
Humectant	Glycerin	20.0 – 25.0	Moisture retention and prevention of paste desiccation.
Binder	Xanthan Gum	0.8 – 1.5	Consistency modification and phase stability.
Surfactant	Sodium Lauryl Sulfate	1.0 – 2.0	Foaming action and distribution of active ingredients.
Preservative	Sodium Benzoate	0.3 – 0.6	Inhibition of microbial growth during shelf life.
Flavoring Agent	Peppermint Oil	0.5 – 1.0	Sensory enhancement and oral freshness.

8. Evaluation of Herbal Dentifrices

The assessment of herbal dentifrices involves a rigorous set of standardized tests to ensure that the final product meets pharmaceutical and safety requirements. These evaluations transition from basic organoleptic properties to complex chemical and biological assays.

8.1. Physicochemical Evaluation

The physical integrity of the toothpaste is fundamental to its clinical performance and consumer acceptance.

8.1.1. Organoleptic Properties

Initial screening focuses on sensory attributes such as color, odor, and taste, which must be consistent with the botanical extracts used. For instance, a *Salvadora persica* and Neem formulation typically exhibits a light brown or pale green hue with a characteristic

herbal-peppermint aroma [43]. Consistency and homogeneity are evaluated by extruding the paste onto a flat surface to ensure a smooth, lump-free texture. Spreadability is another vital parameter, measured by the ease with which the paste covers a surface under a defined load, reflecting its behavior during application to dental brushes [44].

8.1.2. pH Determination and Buffering Capacity

Maintaining a near-neutral pH is critical to prevent the demineralization of dental enamel. Analytical evaluation involves measuring the pH of a 10% aqueous suspension of the dentifrice. Standardized herbal formulations typically aim for a pH range of 6.5 to 7.5 [45]. A slightly alkaline shift is often preferred as it helps neutralize the acidic by-products of plaque bacteria, thereby creating an environment conducive to enamel remineralization and general oral health [46].

8.1.3. Foaming Power and Abrasivity Standards

Foaming ability is quantified by measuring the volume of foam produced when a specific amount of toothpaste is agitated with water. While moderate foam is desirable for the distribution of actives, excessive foaming can sometimes impede mechanical cleaning efficiency. Abrasivity is tested using standard scratching tests or radioactive dentin abrasion (RDA) methods to ensure that the natural silica in Miswak and the added calcium carbonate do not cause iatrogenic damage to the tooth structure [47].

Figure 3. Pharmaceutical Development and Quality Evaluation

8.2. Stability and Chemical Integrity Testing

Stability studies are conducted to ensure that the botanical actives remain potent throughout the product's shelf life.

8.2.1. Thermal Stability and Tube Inertness

Accelerated stability testing involves storing the formulation at elevated temperatures (e.g., 45°C) for several weeks to observe any phase separation, liquefaction, or changes in viscosity [48]. Furthermore, the interaction between the paste and its packaging material is assessed through tube inertness tests, ensuring that the essential oils and herbal compounds do not react with or corrode the container [49].

8.2.2. Moisture Content and Volatile Substance Analysis

The percentage of moisture and volatile matter is determined to ensure the humectant system is effective. High moisture loss can lead to the hardening of the paste, making it unusable, while excessive moisture might encourage microbial growth or lead to a runny consistency [50].

Table 4. Standardized Physicochemical Quality Control Parameters for Herbal Dentifrices.

Parameter	Specification / Standard	Method of Evaluation
Appearance	Homogeneous smooth paste	Visual inspection
pH (10% Suspension)	6.5 – 7.5	Potentiometric method
Spreadability	8.0 – 10.0 cm	Weight-based spread measurement
Foaming Power	Minimum 50 ml	Shaking test (standardized volume)
Abrasivity (RDA)	< 250 (Safe for enamel)	Radioactive Dentin Abrasion method
Thermal Stability	Stable at 45°C for 30 days	Accelerated stability testing
Heavy Metals	Within Pharmacopeial limits	Atomic Absorption Spectroscopy

9. Biological and Clinical Efficacy Evaluation

The therapeutic value of an herbal dentifrice is ultimately determined by its ability to inhibit pathogens and improve clinical oral indices.

9.1. *In Vitro* Antimicrobial Screening

Laboratory assays, such as the agar well diffusion method, are utilized to determine the Zone of Inhibition (ZOI) against specific cariogenic microorganisms. Extracts of Miswak and Neem have demonstrated significant inhibitory effects against *Streptococcus mutans*, *Staphylococcus aureus*, and *Candida albicans* [51]. The presence of benzyl isothiocyanate in *S. persica* is particularly effective in disrupting the metabolic pathways of these pathogens, confirming the scientific basis for its traditional use in oral hygiene [52].

Table 5. Summary of Clinical Efficacy Indicators for Miswak-Based Formulations

Clinical Parameter	Observation with Miswak Dentifrice	Comparison to Fluoride Formulations
Plaque Index (PI)	Significant reduction ($p < 0.05$)	Comparable efficacy
Gingival Index (GI)	Improved gingival health	Superior anti-inflammatory effect
Microbial Count	Reduced *S. mutans* colonies	Equivalent bactericidal action
Enamel Hardness	Increased surface microhardness	Comparable remineralization
Safety Profile	Non-toxic / Biocompatible	Higher safety in pediatric use

9.2. Clinical Outcomes and Gingival Health

Evidence from controlled clinical studies highlights the impact of regular herbal dentifrice use on periodontal health. Researchers often utilize the Plaque Index (PI) and the Gingival Index (GI) to quantify improvements. Clinical data suggests that polyherbal formulations can lead to a marked reduction in gingival bleeding and inflammation, comparable to synthetic antimicrobial agents but with higher patient compliance due to the lack of side effects [53]

10. Conclusion

The usage of *Salvadora persica* and other botanicals into modern dentifrices represents a significant advancement in preventive dentistry. The synergistic effect of mechanical cleaning and chemical biofilm disruption provides a comprehensive approach to managing oral microflora. Unlike synthetic formulations, herbal systems offer a multi-target mechanism of action, addressing bacterial load, oxidative stress, and mucosal health simultaneously. The future of herbal oral care lies in the standardization of extracts and the development of advanced delivery systems. Research is currently exploring the use of nano-emulsions and liposomal delivery to enhance the penetration of herbal actives into the dental biofilm. Additionally, the growing consumer demand for "green" and sustainable products suggests that herbal dentifrices will continue to gain market share, provided they are backed by robust clinical evidence and rigorous pharmaceutical quality control. The development of polyherbal dentifrices using *Salvadora persica* shows the successful translation of traditional botanical knowledge into a scientifically validated pharmaceutical product. These formulations provide an effective, safe, and biocompatible alternative to conventional synthetic toothpastes, offering significant benefits in the management of dental caries and periodontal disease. The combination of natural antimicrobial agents with standardized pharmaceutical excipients ensures a product that is both therapeutically potent and physically stable.

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