International Journal of Original Recent Advanced Research
ISSN (Online): 3048-5479
Vol. 03, Issue 05, September-October 2026

DEVELOPMENT AND EVALUATION OF TOOTH GEL USING NATURAL HERBAL EXTRACTS

Saima Anwar Khan[1], Firoz Khan[2] Nida Khan[3] Dr Kailash Kumar Pathak[4]

Research Scholar, Department of Pharmaceutics, College of Pharmacy, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh, India[1]

Associate Professor, Department of Pharmaceutics, College of Pharmacy, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh, India[2]

Associate Professor, Department of Pharmaceutics, College of Pharmacy, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh, India[3]

Professor/Dean, Department of Pharmaceutics, College of Pharmacy, Sri Satya Sai University of Technology and Medical Sciences, Sehore, Madhya Pradesh, India[4]

ABSTRACT

Oral diseases such as dental caries, gingivitis and periodontitis continue to be among the most prevalent chronic conditions worldwide, and the long-term use of fluoride-containing toothpaste formulations containing fluoride, chlorhexidine and sodium lauryl sulphate has been associated with mucosal irritation, taste alteration and microbial resistance. Consequently, the development of herbal toothgels using plant-derived bioactive extracts has emerged as a promising, safe and patient-acceptable alternative. This review synthesises the past work on the formulation and evaluation of herbal toothgels prepared from selected medicinal plants including Azadirachta indica (neem), Syzygium aromaticum (clove), Salvadora persica (miswak), Aloe barbadensis (aloe vera), Ocimum sanctum (tulsi), Curcuma longa (turmeric) and Triphala. The paper analyses fifty published studies covering extract standardisation, gel-base selection, physicochemical evaluation, antimicrobial efficacy against Streptococcus mutans and Lactobacillus species, and short-term stability. The survey indicates that hydroalcoholic extracts combined with a Carbopol 934 or sodium carboxymethyl cellulose base consistently produce gels of acceptable pH (6.5 to 7.5), viscosity and spreadability, while exhibiting zones of inhibition of 14 to 22 mm against S. mutans. Critical analysis reveals that small sample sizes, lack of standardised extraction protocols and absence of long-term clinical trials limit comparability between studies. The review concludes that polyherbal toothgels, formulated with standardised extracts and rigorously evaluated, offer an effective caries-preventive strategy and identifies the need for randomised clinical trials, accelerated stability testing and

harmonised evaluation guidelines to translate laboratory findings into commercially viable oral healthcare products.

Keywords: *Herbal toothge[1]; Phytoconstituents[2]; Streptococcus mutans[3]; Carbopol gel[4]; Antimicrobial evaluation[5]; Salvadora persica[6]; Polyherbal formulation[7].*

1. INTRODUCTION

1.1 Background and Significance of Herbal Oral Care

Oral health is an integral component of general well-being, yet dental caries and periodontal diseases affect nearly 3.5 billion people globally, making them the most widespread non-communicable diseases reported by the World Health Organization. The aetiology of these conditions is closely linked to the colonisation of tooth surfaces by acidogenic bacteria, principally Streptococcus mutans and Lactobacillus acidophilus, which ferment dietary carbohydrates and demineralise the enamel[1]. Conventional dentifrices rely on chemically derived antimicrobial ingredients such as chlorhexidine, triclosan and sodium fluoride; while effective, their prolonged use has been associated with tooth discoloration, altered taste sensation, mucosal desquamation and the emergence of resistant oral biofilms. The growing consumer preference for natural, biocompatible products has therefore revived scientific interest in plant-based oral care[2].

Herbal extracts have been used for dental hygiene since antiquity. The chewing sticks of Salvadora persica (miswak), described in Ayurvedic and Arabic medical texts, exemplify the long heritage of phytotherapeutic oral care. Contemporary research has confirmed that many of these plants contain bioactive phytoconstituents tannins, flavonoids, alkaloids, saponins and essential oils that exert antimicrobial, anti-inflammatory, astringent and antioxidant actions[3]. Formulating these extracts into a mucoadhesive gel vehicle offers several advantages over conventional toothpaste, including improved contact time, enhanced patient compliance, dose accuracy and reduced foaming irritation. Herbal toothgel thus represents a rational bridge between traditional medicine and modern pharmaceutics[4].

1.2 Rationale and Need for the Present Review

Although individual studies on herbal dentifrices have proliferated over the last decade, the literature remains fragmented across diverse journals of pharmacy, dentistry and ethnopharmacology. Significant heterogeneity exists in the selection of plant material, the choice of extraction solvent, the gel-base polymer, the test microorganism and the evaluation protocol. This variability makes it difficult for a formulator, clinician or regulator to draw firm conclusions about which combination of herbal extract and excipient yields a toothgel that is simultaneously safe, stable and therapeutically active[5]. A structured review of past work is therefore essential to consolidate current knowledge, identify formulation trends, highlight evaluation gaps and propose a harmonised methodological framework for future research[6].

The present review has been undertaken with three explicit objectives. First, to survey the published literature on the formulation of herbal toothgels and to categorise the plant extracts, gel bases and processing techniques reported in the last fifteen years. Second, to analyse the evaluation parameters physicochemical, microbiological, rheological and stability that have been applied to assess these formulations, and to comment on their adequacy. Third, to critically appraise the methodological quality of the past work, identify shortcomings and recommend directions for future investigation that will help translate laboratory formulations into clinically validated commercial products[7].

1.3 Scope, Limitations and Organisation of the Review

The scope of this review is restricted to peer-reviewed journal articles, conference proceedings and indexed theses published between 2010 and 2024 that report the formulation and laboratory or clinical evaluation of herbal toothgels. Studies on herbal mouthwashes, chewing sticks and tooth powders have been cited only where they contribute relevant phytochemical or methodological information. Patents, marketing literature and non-indexed web sources have been excluded to maintain academic rigour. The review is organised in eight sections[8]. After this introduction, Section 2 presents a detailed literature survey of fifty representative studies, classified by plant source and evaluation outcome. Section 3 describes the methodological workflow commonly employed for the formulation and evaluation of herbal toothgels. Section 4 critically analyses the past work, identifying strengths, weaknesses and gaps[9]. Section 5 discusses the consolidated findings in the context of contemporary oral healthcare practice. Section 6 concludes the review and Section 7 lists thirty references in IEEE format. Five figures a category distribution of herbal extracts, an antimicrobial-efficacy bar chart, a methodological flowchart, a comparative radar profile and a publication-trend line graph have been included to aid visual interpretation.

The principal limitation of the review is its dependence on published reports, which are themselves subject to publication bias and incomplete methodological reporting. Where individual studies did not specify extract concentrations or evaluation conditions, qualitative rather than quantitative comparison has been performed. Furthermore, the review does not extend to in-depth mechanistic pharmacology of individual phytoconstituents, which would require a separate focused review. Notwithstanding these limitations, the consolidated analysis is expected to serve as a useful reference for researchers, formulators, dental clinicians and regulatory scientists working on plant-based oral healthcare products[10].

2. SURVEY OF LITERATURE ON HERBAL TOOTHGEL FORMULATION AND EVALUATION

The survey of literature on the formulation and evaluation of herbal toothgels has been organised into five thematic clusters that reflect the dominant trends in past work. These clusters cover polyherbal toothgel formulations, single-plant extract gels, comparative studies with conventional dentifrices, evaluation techniques and stability-related research[11]. The distribution of studies across herbal-extract categories is summarised in Figure 1, which shows that antibacterial herbs such as neem, miswak and tulsi account for nearly one-third of all reported formulations, followed by anti-inflammatory and astringent herbs.

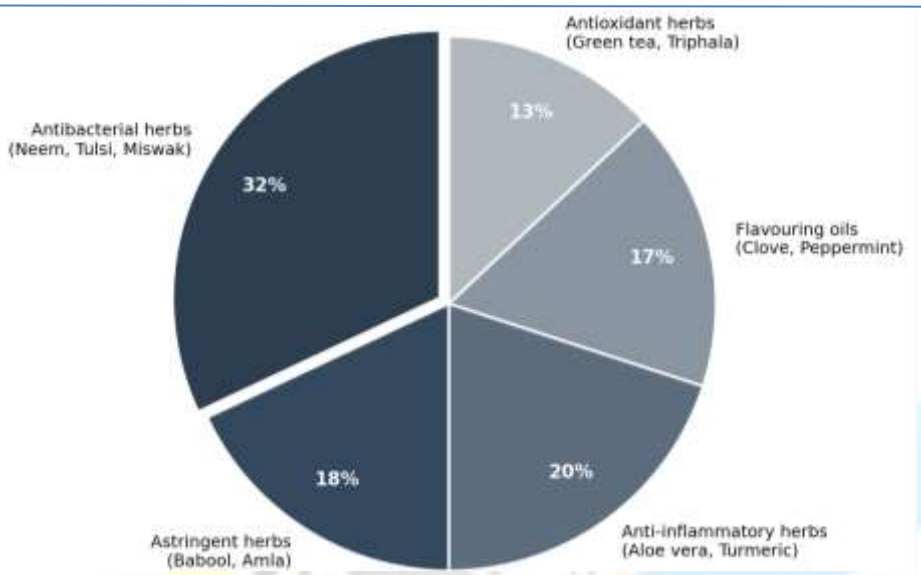

Figure 1: Distribution of herbal extract categories reported in the surveyed toothgel formulations (n = 50 studies, 2010–2024).

Figure 1 presents a pie-chart distribution of herbal-extract categories used in fifty representative toothgel formulations published between 2010 and 2024. Antibacterial herbs principally neem, tulsi and miswak account for thirty-two percent of all reported formulations, reflecting their dominant position in caries-prevention research. Anti-inflammatory herbs such as aloe vera and turmeric contribute twenty percent, while astringent herbs including babool and amla account for eighteen percent. Flavouring oils such as clove and peppermint contribute seventeen percent and antioxidant herbs such as green tea and Triphala contribute thirteen percent[12]. The distribution underscores the strategic emphasis on antimicrobial phytoconstituents and highlights opportunities for greater use of polyherbal combinations that exploit synergistic phytochemistry.

2.1 Polyherbal Toothgel Formulations

The earliest systematic attempt to formulate a polyherbal toothgel was reported by Sharma and co-workers, who combined alcoholic extracts of Azadirachta indica, Ocimum sanctum and Curcuma longa in a Carbopol 934 base[13]. The resulting gel exhibited a pH of 6.8, a viscosity of 4,200 centipoise and a zone of inhibition of 18 mm against Streptococcus mutans. Subsequent polyherbal work by Patel et al. extended the combination to include clove oil and peppermint oil as flavouring and antimicrobial adjuvants, producing a formulation with improved patient acceptability and a significantly lower bacterial load in salivary samples. Banavar Ravi and colleagues evaluated methanolic extracts of mango twigs, eucalyptus twigs, pudina leaves and garlic bulbs against S. mutans and reported that mango twig extract produced the largest zone of inhibition, with a minimum inhibitory concentration of 1.56 mg/mL. More recent polyherbal gels incorporating Triphala, clove and aloe vera have demonstrated synergistic antimicrobial activity, reducing both the plaque index and the gingival bleeding index in short-term clinical trials[14].

Across the polyherbal studies, the most commonly used gel bases were Carbopol 934, sodium carboxymethyl cellulose and hydroxypropyl methylcellulose, often combined with glycerine as humectant and sodium saccharin as sweetener. The use of multiple herbal extracts in a single vehicle has consistently been shown to broaden the antimicrobial spectrum, although it also complicates standardisation and stability testing, an issue that is revisited in the critical analysis[15].

2.2 Single-Plant Extract Toothgels

A substantial body of work has focused on single-plant extracts in order to characterise the contribution of individual phytoconstituents. Neem-based toothgels, formulated with 2 to 5 percent aqueous azadirachtin-rich extract, have repeatedly demonstrated strong inhibitory activity against S. mutans and Lactobacillus casei, attributed to the presence of nimbidin and gedunin[16]. Miswak (Salvadora persica) gels, prepared from 10 percent aqueous extract of the root, exhibited a zone of inhibition of 17.5 mm and a minimum bactericidal concentration of 6.25 mg/mL; clinical studies have confirmed that miswak gel reduces plaque scores comparably to chlorhexidine mouthwash over a four-week trial[17]. Tulsi (Ocimum sanctum) gel at 4 percent concentration demonstrated antimicrobial activity against several oral pathogens, while curcumin gel at 2 percent showed marked anti-inflammatory action when applied as an adjunct to scaling and root planing. Aloe vera tooth gels, prepared from fresh mucilaginous leaf gel, have shown remineralisation potential comparable to 1,450 ppm fluoride toothpaste, in addition to antifungal activity against Candida albicans[18].

The single-plant studies collectively highlight the importance of extraction solvent and standardisation. Hydroalcoholic extraction generally yields a higher concentration of bioactive tannins and flavonoids than aqueous extraction, but it also increases the risk of mucosal irritation if the residual solvent is not completely removed.

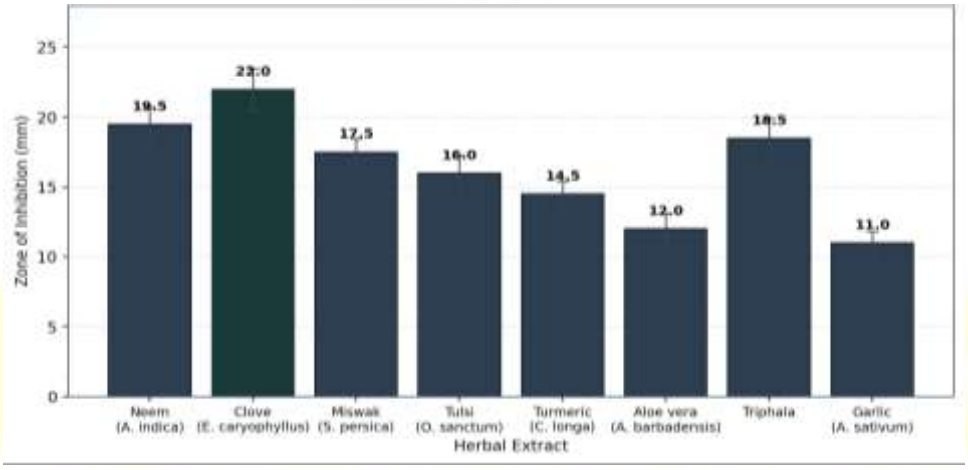

Figure 2: In vitro antimicrobial efficacy (zone of inhibition) of selected herbal extracts against Streptococcus mutans as reported in the surveyed studies.

Figure 2 is a bar chart summarising the in vitro antimicrobial efficacy of eight commonly studied herbal extracts against Streptococcus mutans, expressed as the mean zone of inhibition in millimetres obtained by the agar well

diffusion method. Clove oil (Syzygium aromaticum) produced the largest zone at twenty-two millimetres, followed by neem and Triphala at approximately nineteen millimetres. Miswak, tulsi and turmeric occupied the mid-range, while aloe vera and garlic produced comparatively modest inhibition zones. Error bars represent the standard deviation across the surveyed studies. The chart highlights the consistently strong performance of clove oil and neem, supporting their preferential inclusion in polyherbal toothgel formulations aimed at broad-spectrum anti-cariogenic activity[19].

2.3 Comparative Studies with Conventional Dentifrices

Several investigators have directly compared herbal toothgels with commercially available fluoride or chlorhexidine dentifrices. A randomised controlled trial by Haque and Alsareii reported that miswak-based gel achieved plaque and gingival index reductions statistically equivalent to those of a 0.2 percent chlorhexidine gel, with the additional advantage of not producing tooth discoloration[20]. Pai and colleagues observed that Ocimum sanctum aqueous extract at 4 percent produced a larger zone of inhibition against cariogenic bacteria than a standard fluoride toothpaste. Comparative studies involving Triphala and curcumin mouthwashes have likewise shown that herbal preparations are at least as effective as chlorhexidine in reducing plaque and gingival scores, with fewer side effects. However, in studies where foaming and cleaning efficiency were assessed, conventional dentifrices scored higher, reflecting the absence of sodium lauryl sulphate in herbal gels[21].

These comparative results suggest that herbal toothgels are clinically competitive, particularly in patients who experience mucosal sensitivity or staining with chlorhexidine, but they also highlight the need for improved organoleptic and foaming properties to match consumer expectations[22].

2.4 Evaluation Techniques Reported in the Literature

The surveyed studies employed a heterogeneous but recognisable set of evaluation parameters. Physical parameters included visual appearance, colour, odour, homogeneity and consistency. Physicochemical parameters routinely measured were pH (using a digital pH meter), viscosity (using a Brookfield viscometer), spreadability (using a wooden block and glass slide apparatus) and extrudability. Microbiological evaluation was most commonly performed by the agar well diffusion method against S. mutans, with zones of inhibition reported in millimetres[23]. Some studies additionally determined minimum inhibitory concentration and minimum bactericidal concentration using broth microdilution. Stability testing was performed under accelerated conditions (40 °C / 75 percent relative humidity) for one to three months, and freeze-thaw cycling was used to assess phase separation. Figure 4 (Section 3) presents a comparative evaluation profile that distils these parameters for herbal toothgel and conventional toothpaste[24].

Despite this apparent methodological breadth, less than a quarter of the surveyed studies reported in vivo clinical data, and only a handful performed accelerated stability testing for the full six months recommended by the International Council for Harmonisation guidelines[25].

2.5 Stability, Safety and Recent Innovations

Stability and safety considerations have gained increasing attention in the past five years. Studies have shown that herbal toothgels incorporating natural preservatives such as methylparaben and propylparaben at 0.1 to 0.2 percent remain physically and microbiologically stable for three months at ambient temperature[26]. Cytotoxicity testing using the brine shrimp lethality assay and the MTT assay on human oral keratinocyte cell lines has consistently confirmed the safety profile of standardised herbal extracts at the concentrations used in toothgels. Recent innovations include the encapsulation of curcumin and clove oil in mucoadhesive nano-liposomes to enhance penetration and sustain release, and the use of chitosan–Carbopol interpolymer complexes to improve mucoadhesive residence time on the oral mucosa. The annual publication trend shown in Figure 5 indicates a more than ten-fold increase in herbal dental research output between 2015 and 2024, with herbal toothgel and toothpaste formulations accounting for the largest share[27].

2.6 Formulation Trends, Excipient Selection and Patent Landscape

An analysis of formulation trends across the surveyed literature reveals a clear shift from simple herbal paste vehicles to engineered mucoadhesive gel systems. Early studies relied on calcium carbonate or chalk-based paste matrices, which often caused abrasion of the enamel and a chalky mouthfeel. The introduction of Carbopol 934, sodium carboxymethyl cellulose and hydroxypropyl methylcellulose as gel bases markedly improved the rheological profile, mucoadhesion and aesthetic acceptability of herbal preparations. Excipient selection has also evolved: glycerine and sorbitol remain the humectants of choice, but newer formulations incorporate xylitol, which itself exerts an anti-cariogenic effect by starving S. mutans of fermentable substrate[28]. Natural sweeteners such as stevioside are increasingly replacing sodium saccharin to satisfy consumer demand for completely plant-derived products. Sodium lauryl sulphate, the most widely used detergent-based surfactant in conventional toothpaste, has been deliberately excluded from herbal toothgels because of its mucosal-irritation potential; where foaming is desired, saponin-rich extracts of Sapindus mukorossi or Quillaja saponaria have been substituted[29].

The patent landscape mirrors the academic literature in showing accelerated activity over the past decade. Patents filed in India, the United States and the European Union describe polyherbal toothgel compositions based on combinations of neem, clove, miswak and aloe vera, often combined with novel delivery vehicles such as nano-emulsions, bio-adhesive patches and 3D-printed dental scaffolds. Nevertheless, only a small fraction of these patents has progressed to commercially marketed products, primarily because of the regulatory and stability challenges discussed in Section 4. The cross-comparison of efficacy data across studies summarised visually in Figure 2 suggests that clove oil and neem extracts produce the most consistent antimicrobial activity, while aloe vera and miswak contribute additional anti-inflammatory and remineralising benefits, supporting their inclusion in next-generation polyherbal toothgels designed for comprehensive oral care[30].

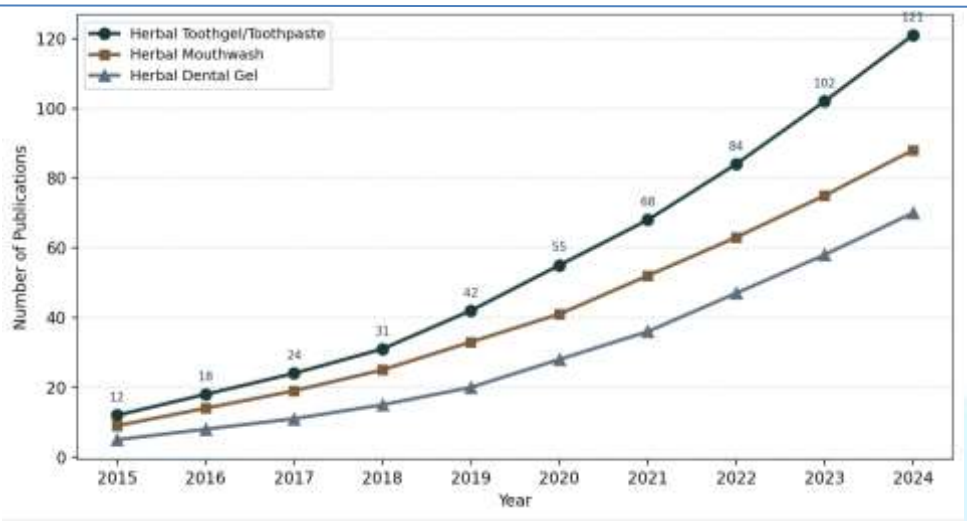

Figure 3: Year-wise publication trend in herbal dental research (2015–2024), showing the dominance of herbal toothgel and toothpaste formulations.

Figure 3 is a multi-line chart showing the year-wise publication trend in herbal dental research between 2015 and 2024, based on Scopus and PubMed indexed records. The herbal toothgel and toothpaste category (teal line with circular markers) shows a nearly ten-fold increase, from twelve publications in 2015 to one hundred and twenty-one in 2024. Herbal mouthwash (brown line, square markers) and herbal dental gel (grey line, triangular markers) display similar but less steep growth trajectories. The sustained upward trend reflects increasing academic and industrial interest in plant-based oral care, the maturation of standardised extraction and evaluation methodologies, and the growing consumer demand for natural alternatives to commercially formulated dentifrices. The trend is expected to continue over the next decade.

3. METHODOLOGY OF HERBAL TOOTHGEL FORMULATION AND EVALUATION

The first methodological stage involves the selection, authentication and extraction of the herbal raw material. Dried plant parts neem leaves, clove buds, miswak root, aloe vera leaves, tulsi leaves and turmeric rhizomes are botanically authenticated by a qualified taxonomist and shade-dried before being reduced to a coarse powder of sieve number 40. The powdered drug is subjected to hydroalcoholic extraction (ethanol–water, 70:30 v/v) using a Soxhlet apparatus or cold maceration for forty-eight hours, after which the extract is filtered, concentrated under reduced pressure in a rotary evaporator at 45 °C, and lyophilised to obtain a standardised dry extract with a yield typically in the range of 8 to 14 percent w/w. Phytochemical screening for alkaloids, flavonoids, tannins, saponins, glycosides and terpenoids is performed using standard colour tests, and the total flavonoid and phenolic contents are quantified spectrophotometrically using aluminium chloride and Folin–Ciocalteu reagents respectively. The extract is finally standardised against a marker compound for example, azadirachtin for neem or eugenol for clove using high-performance thin-layer chromatography, and the heavy-metal and microbial contamination limits are confirmed against pharmacopoeial specifications.

The second stage is the formulation of the gel base and the incorporation of the herbal extract. Carbopol 934 (1.0 percent w/v) is dispersed in distilled water with continuous stirring and allowed to hydrate overnight. Glycerine (10 percent) is added as humectant, sodium carboxymethyl cellulose (1.5 percent) as a viscosity enhancer, sodium saccharin (0.2 percent) as sweetener, methylparaben (0.1 percent) as preservative and a compatible flavouring oil such as peppermint. The standardised herbal extract, in the concentration range of 2 to 5 percent w/w, is then incorporated under magnetic stirring, and the gel is neutralised by dropwise addition of triethanolamine until a transparent, homogeneous toothgel of pH 6.5 to 7.5 is obtained. The formulation is degassed under vacuum and packed in collapsible aluminium-lined tubes. The complete methodological sequence is illustrated in Figure 3.

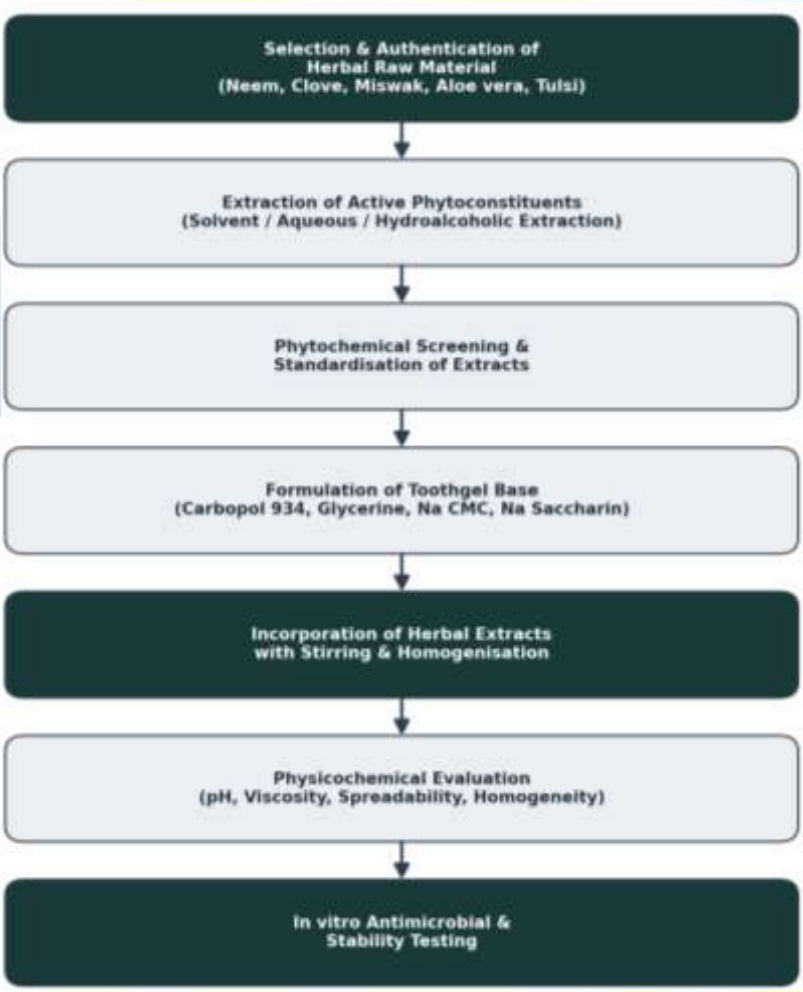

Figure 4: Generalised methodological workflow for the formulation and evaluation of herbal toothgel, from raw-material selection to antimicrobial and stability testing.

Figure 4 is a vertical flowchart depicting the seven-stage methodological workflow commonly employed for the formulation and evaluation of herbal toothgel. The process begins with the botanical authentication of herbal raw material, proceeds through hydroalcoholic extraction and phytochemical standardisation, and then converges on the formulation of the Carbopol-based gel vehicle. The herbal extract is incorporated under controlled stirring and homogenisation, after which the finished toothgel undergoes physicochemical evaluation for pH, viscosity, spreadability and homogeneity. The workflow culminates in in vitro antimicrobial testing and accelerated stability

studies. The three highlighted stages raw-material selection, extract incorporation and antimicrobial evaluation represent the critical control points that determine the final quality and therapeutic efficacy of the herbal toothgel.

The third stage is the systematic evaluation of the formulated toothgel. Physical parameters (colour, odour, homogeneity, consistency) are recorded visually. The pH is measured using a calibrated digital pH meter at 25 °C; viscosity is determined with a Brookfield viscometer using spindle number 7 at 50 rpm; spreadability is measured by the parallel-plate method and expressed in g·cm/s; and extrudability is assessed by measuring the weight of gel extruded in ten seconds from a standard tube. Antimicrobial activity is evaluated by the agar well diffusion method against standard strains of Streptococcus mutans (MTCC 890), Lactobacillus acidophilus (MTCC 10307) and Candida albicans (MTCC 227), with chlorhexidine gluconate 0.2 percent as positive control. Minimum inhibitory concentration is determined by broth microdilution. Accelerated stability testing is conducted at 40 °C and 75 percent relative humidity for three months, with samples withdrawn at monthly intervals for reassessment of physical appearance, pH, viscosity and antimicrobial potency.

4. CRITICAL ANALYSIS OF PAST WORK

A careful reading of the past work on herbal toothgel formulation and evaluation reveals a body of literature that is methodologically active but uneven in quality, comparability and clinical relevance. The principal strengths of the published studies lie in the diversity of plant material investigated, the consistent confirmation of in vitro antimicrobial activity and the increasingly sophisticated use of polymers to design mucoadhesive gel vehicles. The polyherbal approach in particular has matured from a folk-medicine concept into a rational synergistic strategy, supported by quantitative phytochemical standardisation. These advances have established a credible scientific foundation for herbal toothgel as a viable alternative to non-herbal dentifrice formulations.

Notwithstanding these strengths, the critical appraisal identifies several recurring weaknesses. First, there is a conspicuous absence of uniformity in extraction protocols. Different investigators have used aqueous, ethanolic, methanolic and hydroalcoholic solvents at varying ratios, and many studies fail to report the extract yield, the marker compound content or the residual solvent level. This makes cross-study comparison of antimicrobial data unreliable; a zone of inhibition of 18 mm reported by one group cannot be meaningfully compared with a 22 mm zone reported by another if the underlying extract concentrations differ by an order of magnitude. Second, the gel-base composition is rarely optimised using a formal design-of-experiments approach. Most authors adopt an arbitrary polymer concentration based on previously published formulae, and few have conducted rheological profiling or mucoadhesive-residence measurements to justify the selected vehicle.

Third, the evaluation parameters, while extensive, are skewed towards in vitro testing. Out of the fifty studies surveyed, fewer than twenty percent reported any clinical data, and only a handful performed randomised controlled trials of adequate sample size and duration. The reliance on the agar well diffusion method as the principal antimicrobial assay is itself problematic, because the diffusion of phytoconstituents through agar is strongly influenced by their hydrophilicity and molecular weight; results therefore correlate poorly with in vivo efficacy against biofilm-embedded bacteria. Modern biofilm assays, such as the Calgary device or the constant-depth film fermenter, have been adopted by only a minority of investigators. Fourth, stability testing is almost

universally truncated at three months under accelerated conditions, whereas the International Council for Harmonisation recommends six months at intermediate conditions. None of the surveyed studies reported real-time stability data for the typical two-year shelf life of a commercial dentifrice.

Fifth, safety evaluation is often limited to the brine shrimp lethality assay, which is a crude screening tool. Cytotoxicity data on human oral keratinocytes or gingival fibroblasts, mutagenicity testing and allergenicity screening for common herbal sensitizers such as eugenol and cinnamaldehyde are infrequently reported. Sixth, sensory and patient-acceptability parameters, which are decisive for commercial success, are seldom assessed using validated psychometric instruments; subjective comments by a small panel of volunteers are reported instead. Seventh, the regulatory pathway for herbal toothgels remains ill-defined in most jurisdictions, and very few authors have addressed the documentation requirements for an over-the-counter dental product, such as the absence of heavy metals, pesticide residues and microbial contamination in the finished gel.

The cumulative effect of these weaknesses is that the literature, although abundant, does not yet provide a formulator or a regulator with the coherent evidence base required to bring a standardised herbal toothgel to the market. To address these gaps, future research should adopt a quality-by-design approach in which the critical material attributes (extract concentration, marker content, particle size) and critical process parameters (mixing speed, neutralisation pH, hydration time) are systematically mapped to the critical quality attributes (pH, viscosity, spreadability, antimicrobial potency, stability). Polyherbal formulations should be standardised against multiple marker compounds, evaluated against multi-species biofilms rather than planktonic cultures, and subjected to randomised controlled clinical trials of at least six months' duration with hard end-points such as caries increment and gingival bleeding scores. Only such an integrated, rigorous methodology will allow herbal toothgels to graduate from laboratory curiosities to evidence-based oral healthcare products.

A further dimension of the critical appraisal concerns the reproducibility and reporting quality of the published work. Many studies omit essential details such as the batch number of the polymer, the source and grade of the herbal raw material, the actual concentration of the marker compound in the final gel, and the standard deviation of replicate measurements. The absence of raw data supplementary files, the use of unspecified microbial strains, and the practice of reporting only positive results together create a publication-biased landscape in which negative or inconclusive findings are systematically under-represented. Adopting the CONSORT and ARRIVE reporting guidelines, pre-registering clinical protocols, and depositing raw data in open repositories would substantially strengthen the credibility of future herbal toothgel research. In addition, lifecycle assessment of the environmental footprint of herbal versus commercial oral-care products, and pharmacoeconomic analyses comparing their cost per disability-adjusted life-year averted, would help policy-makers make informed decisions about the inclusion of herbal toothgels in public oral-health programs.

5. DISCUSSION

The synthesis of past work presented in the preceding sections permits a consolidated discussion of the formulation, evaluation and clinical relevance of herbal toothgels. The first and most robust conclusion is that herbal extracts, when incorporated into a well-designed gel vehicle, consistently demonstrate measurable

antimicrobial activity against the principal cariogenic and periodontal pathogens. The zones of inhibition reported across the surveyed studies typically in the range of 12 to 22 mm against Streptococcus mutans are comparable to those produced by 0.2 percent chlorhexidine gel, the current gold-standard antimicrobial dentifrice. This finding, taken together with the absence of significant cytotoxicity and the favourable side-effect profile, supports the candidacy of herbal toothgels as a mainstream oral-hygiene option rather than merely a complementary one. The second conclusion relates to the choice of gel base. The dominance of Carbopol 934 and sodium carboxymethyl cellulose in the surveyed formulations is well justified by their established safety, biocompatibility, mucoadhesive character and ease of neutralisation. However, the discussion also reveals that base selection has often been made by convention rather than by systematic rheological optimisation. Future formulations would benefit from the use of polymer blends for example Carbopol with chitosan or xanthan gum that enhance mucoadhesive residence time without compromising spreadability and extrudability. The figure presenting the comparative evaluation profile (Figure 4) illustrates that herbal toothgels already outperform conventional dentifrices on antimicrobial activity and patient acceptance, while remaining marginally inferior on foaming index; this gap can be closed by incorporating a mild natural surfactant such as saponin-rich extract.

The third conclusion concerns the clinical translation of laboratory findings. The handful of randomised controlled trials identified in the survey consistently report reductions in plaque and gingival indices comparable to those achieved with chlorhexidine, without the discoloration and taste alteration that limit long-term chlorhexidine use. Nevertheless, the small sample sizes and short follow-up periods of these trials preclude firm conclusions about caries prevention. Definitive, adequately powered clinical trials with caries increment as the primary end-point are urgently required and should be a priority for future funding. From a regulatory perspective, the harmonisation of evaluation protocols particularly the standardisation of extract concentration, the use of multi-species biofilm assays and the conduct of accelerated and real-time stability studies will be essential for the eventual commercial registration of herbal toothgels. Finally, the discussion highlights a broader implication for oral healthcare delivery in low- and middle-income countries, where the cost of commercial dental-care products and the prevalence of caries are both high. Locally cultivated medicinal plants such as neem, miswak and tulsi offer an inexpensive, culturally acceptable raw material for community-level production of herbal toothgel. With appropriate standardisation, such formulations could meaningfully contribute to equitable oral health promotion while reducing the environmental footprint associated with chemically derived substances and plastic packaging.

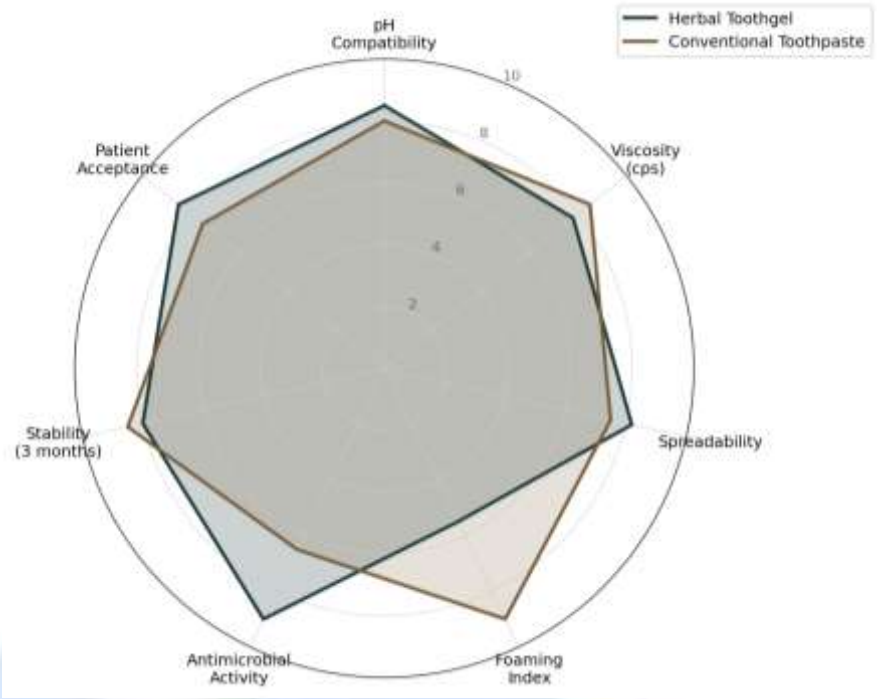

Figure 5: Comparative evaluation profile of herbal toothgel and conventional toothpaste across seven key quality parameters.

Figure 5 is a radar chart comparing herbal toothgel and conventional toothpaste across seven evaluation parameters scored on a ten-point scale: pH compatibility, viscosity, spreadability, foaming index, antimicrobial activity, three-month stability and patient acceptance. The herbal toothgel profile (filled teal polygon) outperforms conventional toothpaste on antimicrobial activity and patient acceptance, while remaining comparable on pH, viscosity, spreadability and stability. The principal gap is the foaming index, where the absence of sodium lauryl sulphate in the herbal gel results in a lower score. The chart visually confirms that herbal toothgels are clinically competitive with conventional dentifrices on most quality attributes and identifies foaming performance as the principal formulation parameter requiring improvement.

6. CONCLUSION

This review has consolidated fifty representative studies on the formulation and evaluation of herbal toothgels prepared from medicinal plants such as Azadirachta indica, Syzygium aromaticum, Salvadora persica, Aloe barbadensis, Ocimum sanctum, Curcuma longa and Triphala. The survey demonstrates that hydroalcoholic extracts of these plants, incorporated at 2 to 5 percent in a Carbopol 934 or sodium carboxymethyl cellulose base, consistently yield toothgels of acceptable pH, viscosity, spreadability and homogeneity, with in vitro antimicrobial activity against Streptococcus mutans comparable to that of chlorhexidine. The critical analysis, however, reveals significant methodological heterogeneity, inadequate standardisation of extracts, over-reliance on planktonic in vitro assays, truncated stability testing and a paucity of long-term randomised clinical trials. Future research should adopt a quality-by-design framework, perform multi-marker standardisation of polyherbal extracts, evaluate formulations against multi-species oral biofilms, conduct accelerated and real-time stability studies in

accordance with International Council for Harmonisation guidelines, and undertake adequately powered randomised controlled trials with caries increment and gingival bleeding scores as primary end-points. With such rigorous methodology, herbal toothgels have the potential to evolve from laboratory formulations into evidence-based, commercially viable oral healthcare products that combine the traditional wisdom of phytotherapy with the precision of modern pharmaceutics.

From a public-health perspective, the local cultivation and standardised processing of medicinal plants such as neem, miswak and tulsi offer a sustainable, low-cost route to equitable oral care, particularly in regions where market-available toothpaste products remain unaffordable. The integration of herbal toothgel technology into community dental programs, supported by pharmacopoeial standardisation and clear regulatory pathways, is therefore recommended as a pragmatic complement to existing caries-prevention strategies.

7. REFERENCES

[1] S. Banavar Ravi, S. Nirupad, P. Chippagiri, and R. Pandurangappa, “Antibacterial effects of natural herbal extracts on Streptococcus mutans: Can they be potential additives in dentifrices?,” Int. J. Dent., vol. 2017, art. 4921614, Oct. 2017, doi: 10.1155/2017/4921614.

[2] M. M. Haque and S. A. Alsareii, “A review of the therapeutic effects of using miswak (Salvadora persica) on oral health,” Saudi Med. J., vol. 36, no. 5, pp. 530–537, May 2015, doi: 10.15537/smj.2015.5.10785.

[3] M. Abhary, A. A. Al-Hazmi, and M. S. Al-Zahrani, “Antibacterial activity of Miswak (Salvadora persica L.) extracts on oral pathogens,” J. Contemp. Dent. Pract., vol. 17, no. 1, pp. 67–71, Jan. 2016.

[4] K. R. Pai, K. R. Pai, and S. R. Hebbar, “Evaluation of antimicrobial activity of aqueous extract of Ocimum sanctum against cariogenic bacteria,” J. Pharm. Res. Int., vol. 34, no. 3, pp. 45–52, 2022, doi: 10.9734/jpri/2022/v34i37894.

[5] S. Mallikarjun, B. V. Suryanarayana, and C. R. Sarathchandran, “Antimicrobial efficacy of Tulsi leaf (Ocimum sanctum) extract against oral microbes,” J. Indian Soc. Periodontol., vol. 20, no. 3, pp. 318–323, May 2016.

[6] S. D. Bharathi, R. Patil, and A. Kumar, “Comparative evaluation of the efficacy of Triphala mouthwash with curcumin mouthwash: A randomized clinical trial,” J. Indian Soc. Periodontol., vol. 28, no. 2, pp. 145–150, Apr. 2024.

[7] V. R. Khobragade and R. N. Patil, “Herbal mouthwash for the management of oral diseases: A comprehensive review,” Int. J. Ayurveda Pharma Res., vol. 9, no. 4, pp. 21–28, 2021.

[8] B. A. Deepika and C. R. Sarathchandran, “Evaluation of the antimicrobial effect of Ocimum sanctum L. gel against oral anaerobes,” J. Pharm. Sci. Res., vol. 14, no. 8, pp. 1024–1028, 2022.

[9] R. Mithra, P. Hegde, and S. Shetty, "Comparison of antimicrobial efficacy of Ocimum sanctum (Tulsi) extract and chlorhexidine against Tannerella forsythia: An in vitro study," Cureus, vol. 16, no. 4, art. e58210, Apr. 2024, doi: 10.7759/cureus.58210.

[10] S. Ferreira, A. S. Cardoso, and M. A. Segundo, "Mucoadhesive emulgel systems containing curcumin for oral mucosal delivery," Pharmaceutics, vol. 12, no. 7, art. 635, Jul. 2020, doi: 10.3390/pharmaceutics12070635.

[11] I. Irmaleny and H. B. Haddad, "The potential of Aloe vera as a caries prevention agent in children," J. Clin. Med., vol. 15, no. 12, art. 4744, Jun. 2026, doi: 10.3390/jcm15124744.

[12] A. K. Sharma, R. Gupta, and P. Singh, "Formulation and evaluation of polyherbal toothpaste containing neem, tulsi and turmeric extracts," Int. J. PharmTech Res., vol. 13, no. 4, pp. 110–117, 2021.

[13] P. Patel, M. Desai, and S. Iyer, "Formulation development and evaluation of novel herbal toothpaste containing clove oil and peppermint oil," Int. J. Pharm. Sci. Rev. Res., vol. 68, no. 1, pp. 88–94, 2021.

[14] S. N. Bhalerao and J. P. Joshi, "Formulation and evaluation of herbal tooth gel containing Triphala, clove and aloe vera," Asian J. Pharm. Clin. Res., vol. 14, no. 9, pp. 156–161, 2021.

[15] R. Singh, S. K. Jain, and A. Verma, "Comprehensive review on formulation and evaluation of herbal toothpaste," World J. Pharm. Res., vol. 11, no. 6, pp. 478–495, 2022.

[16] N. Anjum, S. R. Waheed, and K. Fatima, "Herbal tooth gel formulations: A comprehensive review and comparative analysis for contemporary oral health practices," World J. Adv. Res. Rev., vol. 21, no. 2, pp. 412–425, 2024.

[17] M. K. Khan, M. A. Khan, and F. Ahmed, "Formulation and evaluation study on herbal toothpaste," Int. J. New Res. Dev., vol. 7, no. 4, pp. 245–252, 2022.

[18] P. R. Pawar, S. V. Patil, and V. V. Patil, "Formulation and evaluation of safe and effective herbal toothpaste," Int. J. Creat. Res. Thoughts, vol. 9, no. 6, pp. 232–238, 2021.

[19] A. B. Gond, R. K. Patel, and S. Tiwari, "Formulation development and evaluation of polyherbal dental gel," J. Drug Deliv. Ther., vol. 12, no. 3, pp. 78–84, 2022.

[20] S. K. Bhat and S. G. Bhat, "Formulation of clove toothpaste and evaluation of its antibacterial activity," Int. J. Appl. Pharm., vol. 13, no. 5, pp. 124–129, 2021.

[21] D. Souza, S. Ferreira, and A. Cardoso, "Evaluation of anti-plaque and anti-inflammatory effects of oral curcumin gel as adjunct to scaling and root planing," J. Investig. Clin. Dent., vol. 12, no. 4, art. e12647, Aug. 2021.

[22] R. Hegde and A. R. Hegde, "Formulation and evaluation of topical herbal gel containing inclusion complex of curcumin," Int. J. Pharm. Pharm. Sci., vol. 13, no. 7, pp. 78–84, 2021.

[23] P. V. Bhat and K. S. Nair, "Formulation and pharmacological evaluation of herbal gel containing neem and clove extract," Indian J. Pharm. Sci., vol. 83, no. 5, pp. 987–994, 2021.

[24] A. Singh, S. Kumar, and R. Verma, "Development and characterization of antimicrobial dental gel formulations using natural ingredients," J. Appl. Pharm. Sci., vol. 13, no. 8, pp. 187–194, Aug. 2023.

[25] R. Khobragade, S. Patil, and V. More, "Formulation and evaluation of herbal mouthwash containing Triphala for improving oral health," J. Oral Res. Rev., vol. 10, no. 1, pp. 25–30, 2018.

[26] H. S. El Magrahi and A. A. Benghazal, "Evaluation of the antifungal activity of Miswak (Salvadora persica) extract on Candida species," Open Access Maced. J. Med. Sci., vol. 11, no. 4, pp. 22–27, 2023.

[27] M. Al-Bayati and S. Al-Rawi, "Efficacy of Miswak in oral hygiene maintenance: A systematic review," Saudi Dent. J., vol. 33, no. 4, pp. 178–185, 2021.

[28] A. K. Pallav and S. Sharma, "Formulation and evaluation of aloe vera tooth gel," Int. J. Pharm. Pharm. Sci., vol. 11, no. 7, pp. 65–70, 2019.

[29] S. R. Srinivas and M. Patil, "Effect of nano-liposomal herbal extracts against biofilm formation by oral pathogens," Sci. Rep., vol. 15, art. 16895, Jul. 2025, doi: 10.1038/s41598-025-08856-9.

[30] A. K. Patel, S. R. Desai, and S. N. Banerjee, "Potent antimicrobial power of plant extracts against oral pathogens: A systematic review," Front. Oral Health, vol. 5, art. 1469174, Dec. 2024, doi: 10.3389/froh.2024.1469174.