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"The Promise Of *Scutellaria Baicalensis* Herbal Gel In Dentistry And Oral Medicine"

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Abstract

Oral diseases, including periodontitis, gingivitis, oral mucositis, and dental caries, remain among the most prevalent chronic conditions worldwide, affecting millions of people across diverse age groups and contributing significantly to morbidity and reduced quality of life. Conventional therapeutic strategies, such as systemic antibiotics, corticosteroids, and chemical mouth rinses, provide symptomatic relief but are often associated with several limitations, including adverse effects, altered taste perception, mucosal irritation, poor patient compliance, and the emergence of antimicrobial resistance. These challenges highlight the pressing need for alternative therapies that are safe, effective, and patient-friendly.

Herbal medicines have emerged as promising candidates for oral healthcare due to their multifaceted pharmacological activities and relatively low toxicity profiles. Among various medicinal plants, Scutellaria baicalensis (Huang Qin), a perennial herb of the Lamiaceae family, has garnered considerable attention for its therapeutic potential in oral conditions. The root of S. baicalensis is rich in bioactive flavonoids, primarily baicalin, baicalein, and wogonin, which exhibit potent anti-inflammatory, antioxidant, antimicrobial, and wound-healing properties. Preclinical and clinical studies have demonstrated that these flavonoids can inhibit key oral pathogens such as Streptococcus mutans, Porphyromonas gingivalis, and Candida albicans, while modulating inflammatory pathways such as NF-κB and MAPK, and reducing oxidative stress.

Formulating S. baicalensis into mucoadhesive herbal gels enables localized drug delivery, prolonged retention at the site of action, and controlled release of active constituents, thereby enhancing therapeutic efficacy while minimizing systemic side effects. These gels provide a patient-friendly alternative to conventional therapies, especially for populations with poor compliance to oral rinses or systemic medications.

Key Words: Anti-inflammatory, antimicrobial, Scutellaria baicalensis, Mucoadhesive gel, Baicalin, Periodontitis, Oral ulcers, Gingivitis, Flavonoids, Topical drug delivery.

1. Introduction

Oral health is integral to overall well-being, yet diseases of the oral cavity remain among the most prevalent global health challenges. Periodontal disease alone affects nearly 20–50% of the world's adult population, significantly impairing quality of life and contributing to systemic comorbidities such as diabetes and cardiovascular disorders (1). Gingivitis and oral mucositis, often associated with chemotherapy and radiotherapy, further add to the disease burden (2).

Conventional treatments, including chlorhexidine rinses, systemic antibiotics, and corticosteroid formulations, provide symptomatic relief but are associated with substantial drawbacks. Chlorhexidine, for example, though widely used as a gold standard antimicrobial, frequently leads to altered taste perception, tooth staining, and mucosal irritation (3). Systemic antibiotics risk promoting antimicrobial resistance, while corticosteroids can compromise local immunity and produce systemic side effects (2). These limitations highlight the urgent need for alternative therapeutic strategies that are effective, safe, and patient-friendly.

Herbal medicines, used in various traditional healing systems, have re-emerged as valuable resources for modern healthcare. They offer diverse phytochemicals with broad-spectrum activity, reduced toxicity, and improved patient acceptance (4). In the context of oral diseases, plant-based therapies are especially attractive due to their potential to provide multi-targeted effects, including antimicrobial, anti-inflammatory, and antioxidant actions, which are crucial for managing chronic oral conditions (5).

Scutellaria baicalensis, also known as Huang Qin, is a well-documented medicinal plant in Traditional Chinese Medicine. Its root extract is abundant in flavonoids, notably baicalin, baicalein, and wogonin, which exhibit pharmacological activities relevant to oral health management (6,7). These compounds not only suppress bacterial biofilms but also modulate inflammatory pathways and neutralize oxidative stress, all of which are critical in controlling oral infections and inflammation (6–8).

Incorporation of S. baicalensis extracts into mucoadhesive gel formulations provides additional advantages. Gels ensure localized delivery, prolonged retention on oral mucosal surfaces, and reduced dosing frequency, thereby enhancing therapeutic efficacy and patient compliance (9,10). This delivery system also circumvents the limitations of systemic administration, such as first-pass metabolism and non-specific tissue distribution.

Thus, the integration of S. baicalensis into mucoadhesive gels represents a promising therapeutic innovation for oral disease management. The subsequent sections of this review will analyze the advantages, disadvantages, classification, and scientific basis of this approach.

Periodontitis, a chronic inflammatory disease affecting the supporting structures of teeth, is a major contributor to tooth loss in adults. It is initiated by microbial biofilms on tooth surfaces, leading to the activation of inflammatory pathways and subsequent tissue destruction (2). Gingivitis, the precursor to periodontitis, is reversible if detected early but can progress to irreversible periodontal damage if untreated. Oral mucositis, a common complication of chemotherapy and radiotherapy, causes ulceration, pain, and increased risk of systemic infections, severely affecting patient quality of life (2,3).

Current therapeutic interventions include mechanical debridement, chemical mouth rinses, systemic antibiotics, and corticosteroids. Chemical Mouth Rinses: Agents like chlorhexidine remain the gold standard for plaque control and gingivitis management. However, prolonged use can result in tooth staining, altered taste, mucosal irritation, and, in some cases, dysbiosis of oral microbiota (3,4). Systemic Antibiotics: While controlling bacterial infections, antibiotics contribute to the emergence of antimicrobial resistance and may cause systemic side effects such as gastrointestinal disturbances (5). Corticosteroids: Effective in reducing inflammation, corticosteroids can compromise local immunity, delay wound healing, and pose systemic risks when absorbed (6). These limitations underscore the need for safe, effective, and patient-friendly alternatives for oral disease management.

Herbal medicines have regained attention due to their natural origin, multi-target pharmacological actions, and lower toxicity profiles (7). Plants contain a wide range of secondary metabolites, including flavonoids, alkaloids, terpenoids, and phenolic compounds, many of which exert antimicrobial, anti-inflammatory, antioxidant, and wound-healing effects (8). Unlike single-target synthetic drugs, these multi-component phytochemicals often act synergistically to enhance therapeutic outcomes and reduce the likelihood of resistance (9).

Scutellaria baicalensis, commonly known as Huang Qin, is a perennial herb widely used in Traditional Chinese Medicine (TCM) for its anti-inflammatory, antimicrobial, and hepatoprotective properties (10). The root of S. baicalensis contains numerous flavonoids, of which baicalin, baicalein, and wogonin are most pharmacologically active (5–7).

Baicalin: Exhibits anti-inflammatory effects by suppressing NF-κB activation, reducing pro-inflammatory cytokines such as TNF-α and IL-6, and modulating MAPK pathways (6). It also demonstrates antimicrobial activity against gram-positive bacteria and fungi (5). Baicalein: Acts as a potent antioxidant by scavenging reactive oxygen species (ROS) and upregulating endogenous antioxidant enzymes (7). It disrupts bacterial biofilms, especially those of S. mutans, and promotes wound healing in oral mucosa (6). Wogonin: Contributes to anti-inflammatory and anti-proliferative activities and has demonstrated cytoprotective effects in epithelial cells (8). These flavonoids collectively modulate oxidative stress, inflammation, and microbial growth, making S. baicalensis a suitable candidate for managing periodontal disease, mucositis, and oral candidiasis.

Incorporating S. baicalensis extract into a mucoadhesive gel leverages both the pharmacological activity of flavonoids and the delivery advantages of gels, creating a targeted, effective, and patient-friendly therapy for oral diseases (9).

Despite the promising therapeutic properties of S. baicalensis, there is limited research on its incorporation into gel-based formulations for oral health. Existing studies primarily focus on preclinical in vitro and animal models, with few clinical trials validating efficacy in humans (11). Furthermore, issues related to bioavailability, stability, standardization, and patient acceptability remain underexplored (12).

2. Advantages

Formulating S. baicalensis into mucoadhesive gels for oral delivery offers numerous therapeutic and pharmaceutical advantages, making it an attractive alternative to conventional therapies.

Natural origin and safety profile

One of the strongest advantages of S. baicalensis is its herbal origin. Herbal therapies are generally perceived as safer and more biocompatible compared to synthetic drugs (9). Toxicological studies have demonstrated that baicalin and baicalein have favorable safety margins at therapeutic doses, supporting their clinical applicability in oral formulations (9,10).

Multifunctional pharmacological activity

The bioactive flavonoids of S. baicalensis possess diverse therapeutic effects. Baicalin demonstrates strong anti-inflammatory activitybydownregulating pro-inflammatory cytokines such as TNF-α and IL-6 (6,11). Baicalein has been shown to inhibit oxidative stress through modulation of reactive oxygen species (ROS), thereby protecting oral tissues from damage (12). Moreover, both baicalin and wogonin exert antimicrobial activity against key oral pathogens such as Streptococcus mutans and Prohormones gingivalis (5,13). This multifunctionality allows the herbal gel to address multiple aspects of oral disease simultaneously.

Prolonged retention via mucoadhesion

Conventional mouth rinses provide only transient effects due to rapid clearance by saliva. In contrast, mucoadhesive gels adhere to the oral mucosa, ensuring localized and sustained drug release (8,14). This property reduces the frequency of application and maintains therapeutic drug levels at the site of action, thereby enhancing efficacy.

Improved patient acceptability

Herbal gels are generally well tolerated, with studies reporting higher patient acceptance compared to chemical agents (13). They are non-invasive, easy to apply, and can be formulated with flavoring agents to mask unpleasant herbal tastes. This is particularly beneficial for long-term treatment regimens, such as in chronic periodontal disease.

Potential synergistic use with conventional therapies

When used alongside scaling and root planing or low-dose chlorhexidine rinses, S. baicalensis gels may enhance outcomes by reducing microbial resistance and providing complementary anti-inflammatory effects (14). Such integrative approaches can optimize oral health care strategies.

3. Disadvantages

Despite the promising benefits, several disadvantages and challenges limit the widespread adoption of S. baicalensis herbal gels.

Variability in phytochemical content

The phytochemical composition of S. baicalensis varies with factors such as geographical location, cultivation conditions, and harvest season (15). This variability makes standardization difficult, which in turn affects reproducibility of therapeutic effects.

Poor solubility and bioavailability

Baicalin, the major active constituent, has poor water solubility and limited oral bioavailability (16,17). This reduces its effectiveness in aqueous gel systems unless enhanced using solubilizing techniques or nanotechnology.

Stability issues

Flavonoids such as baicalin and baicalein are prone to degradation in aqueous environments, which compromises the stability and shelf-life of herbal gels (18). Formulation strategies must therefore include stabilizers or advanced drug delivery systems.

Limited large-scale clinical validation

Although preclinical and small-scale clinical studies show encouraging results, there is a lack of large, well-designed randomized controlled trials (RCTs) to validate the safety and efficacy of S. baicalensis gels in oral health management (19). This limits regulatory approval and mainstream clinical use.

4. Classification

Herbal gels, including those containing S. baicalensis, can be classified based on several parameters.

Based on formulation technology

Conventional gels: Prepared using simple polymeric bases like Carbopol or HPMC, offering cost-effective and straightforward formulations (20).

Nanogels: Incorporating nan sized particles to enhance solubility and bioavailability of poorly soluble compounds like baicalin (21).

Thermoresponsive gels: Gels that undergo sol–gel transitions at body temperature, improving ease of application and retention (22).

In situ gels: Liquid formulations that transform into gels upon contact with oral mucosa, ensuring better spreadability and prolonged action (20).

Based on polymer type

Synthetic polymers: Examples include Carbopol and hydroxypropyl methylcellulose (HPMC), which provide predictable rheological properties (21).

Natural polymers: Chitosan, sodium alginate, and guar gum offer biocompatibility and additional bioactivity but are more prone to variability (21).

Based on drug release profile

Immediate release gels: Deliver rapid onset of action but with short duration.Sustained release gels: Maintain drug concentration over extended periods, reducing dosing frequency (22).pHsensitive gels: Release active ingredients in response to changes in oral pH, making them suitable for inflamed or infected sites where pH is altered (22).

5. Ideal Characteristics

For a Scutellaria baicalensis-based herbal gel to be considered pharmaceutically and clinically viable for oral delivery, it must fulfill several essential characteristics. These ideal properties ensure safety, efficacy, stability, and patient acceptability.

Biocompatibility and safety

An oral gel must be non-toxic, non-irritant, and biocompatible with delicate mucosal tissues (23). Gels formulated with S. baicalensis should not provoke hypersensitivity reactions, as the oral cavity is highly vascularized and any irritant can rapidly trigger discomfort. Flavonoids from S. baicalensis have been shown to exhibit low cytotoxicity in cell models, supporting their suitability for mucosal applications (9).

Mucoadhesive strength

Prolonged retention on oral mucosa is crucial for therapeutic efficacy. Ideal gels should strongly adhere to mucosal surfaces but without causing damage or discomfort upon removal (24). Polymers such as Carbopol and chitosan have demonstrated strong mucoadhesive properties, which are enhanced when combined with flavonoid-rich extracts (25).

Optimal viscosity and spreadability

The gel must be easy to apply and spread evenly over oral tissues while maintaining sufficient viscosity to resist salivary washout (23). A balance between spreadability and viscosity ensures good patient compliance.

Stability under physiological conditions

The formulation must remain stable at pH 6–7, the typical range in the oral cavity. It should also resist enzymatic degradation and maintain uniform drug distribution over prolonged storage (25,29).

Sustained and controlled drug release

The gel should facilitate gradual release of baicalin, baicalein, and wogonin to maintain therapeutic concentrations over extended periods (24). Controlled release reduces the need for frequent reapplication, improving compliance.

6. Limitations

Despite their potential, S. baicalensis herbal gels face several limitations that hinder broader adoption.

Standardization challenges

Herbal extracts are complex mixtures of phytochemicals. Standardizing baicalin and related flavonoids to consistent concentrations is difficult due to variations in cultivation and extraction (26).

Risk of microbial contamination

Herbal gels, particularly aqueous-based ones, are prone to microbial growth during storage if not adequately preserved (27). The addition of preservatives can extend shelf life, but these must not compromise safety or efficacy.

Regulatory barriers

Herbal formulations face complex regulatory pathways. Unlike synthetic drugs, herbal medicines lack harmonized global standards, making market approval challenging (28).

Lack of pharmacopoeias guideline

Currently, no official pharmacopoeias monograph exists for S. baicalensis oral gels, creating gaps in quality control and standardization (29).

7. Method of Preparation

The formulation of S. baicalensis herbal gels involves several key steps designed to ensure phytochemical integrity, stability, and clinical suitability (30).

Extraction of active constituents

Roots of S. baicalensis are subjected to extraction using solvents such as ethanol, methanol, or water. Modern techniques, including ultrasound-assisted and supercritical CO_2 extraction, improve yield and preserve flavonoid integrity (30).

Selection of gel base

Polymers like Carbopol, HPMC, sodium alginate, and chitosan are selected based on required viscosity and mucoadhesive properties (21).

Incorporation of herbal extract

The standardized extract is incorporated into the hydrated polymer matrix with continuous stirring to ensure uniform distribution.

Adjustment of pH

The gel pH is adjusted to 6–7 for compatibility with oral mucosa (33).

Addition of excipients

Preservatives (e.g., parabens), humectants (e.g., glycerin), and flavoring agents are added to enhance stability and patient acceptance.

Homogenization and sterilization

The final gel undergoes homogenization for uniform consistency and is sterilized by filtration or autoclaving, depending on the stability of active compounds.

8. Factors Affecting Formulation

Several formulation and environmental factors influence the performance of S. baicalensis gels.

Polymer type and concentration

Different polymers provide varying levels of viscosity, bioadhesion, and drug release. High polymer concentration may enhance adhesion but reduce spreadability (31).

Particle size and solubility of baicalin

Smaller particle sizes and solubility enhancers, such as cyclohexatriene or nanocarriers, improve drug dissolution and bioavailability (32).

pH and ionic strength

Oral cavity pH variations affect drug release and stability. Slightly acidic environments can hydrolyze baicalin, whereas neutral pH maintains integrity (33)

Drug–polymer interactions

Interactions between flavonoids and polymers can alter drug release profiles. For example, hydrogen bonding may retard release while ionic interactions may accelerate it (34).

Storage conditions

Moisture, light, and temperature affect gel stability. Flavonoids are sensitive to oxidative degradation, necessitating airtight, light-resistant packaging (35).

9. Mechanism of Action

The therapeutic efficacy of S. baicalensis herbal gels arises from both the drug delivery system and the pharmacological activity of its bioactive flavonoids.

Mucoadhesion and retention

Upon application, the gel adheres to oral mucosa through hydrogen bonding, electrostatic interactions, and van der Waals forces between polymer chains and mucin glycoproteins (36). This ensures prolonged residence time.

Swelling and controlled release

The hydrated polymer matrix swells in contact with saliva, allowing gradual release of baicalin and baicalein. This controlled release maintains therapeutic drug concentrations locally (24,36).

Anti-inflammatory activity

Baicalin and baicalein inhibit NF-κB and MAPK pathways, reducing the expression of inflammatory cytokines such as TNF-α and IL-6 (37). This leads to decreased gingival inflammation.

Antimicrobial action

Flavonoids exert bacteriostatic and bactericidal effects by disrupting bacterial membranes and inhibiting biofilm formation. Notably, baicalein inhibits Streptococcus mutans biofilms, while baicalin suppresses Prohormones gingivalis growth (38).

Antioxidant effects

Reactive oxygen species generated in inflamed tissues contribute to tissue damage. Baicalein scavenges ROS and upregulates endogenous antioxidant enzymes, thereby protecting oral tissues (12).

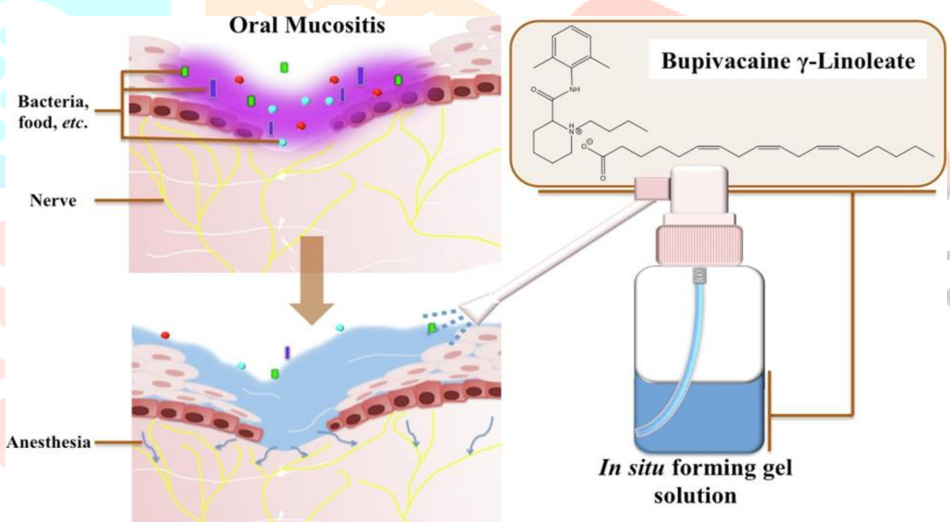

Figure 1: Mechanism of mucoadhesion of herbal gels

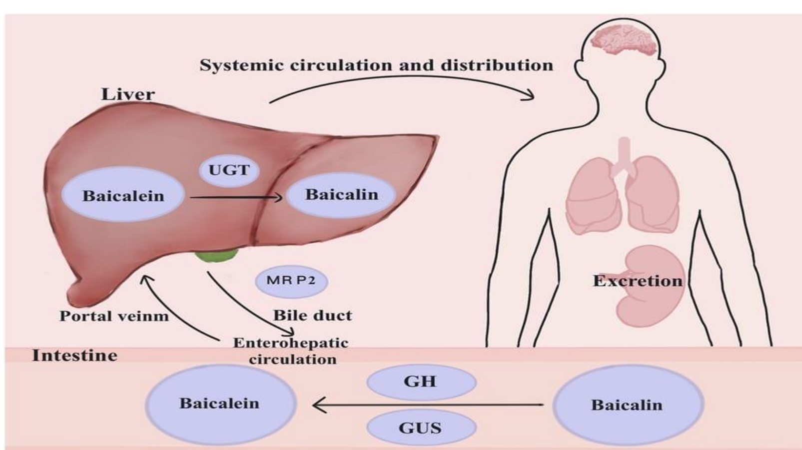

Figure 2: Anti-inflammatory pathways of baicalin and baicalein

10. Evaluation of Herbal Gel Formulations

The evaluation of Scutellaria baicalensis herbal gels is crucial to determine their quality, stability, and therapeutic effectiveness. A combination of physicochemical, biological, and clinical tests ensures reproducibility and regulatory compliance.

Physicochemical evaluation

Appearance and homogeneity: A good formulation should be smooth, translucent/opaque, and free from lumps or air bubbles (39).

pH determination: pH should range between 6.0–7.0 to ensure mucosal compatibility (33).

Viscosity and rheology: Measured by viscometers to confirm spreadability and retention (40).

Drug content uniformity: Ensures consistent delivery of baicalin and other flavonoids across batches (31).

Mucoadhesion testing

Ex vivo studies: Porcine buccal mucosa is commonly used to test adhesion strength and retention (36).

Texture profile analysis: Determines hardness, adhesiveness, and cohesiveness (40).

In vitro drug release studies

Diffusion studies: Franz diffusion cells assess the release of baicalin into simulated saliva (24).

Kinetic modeling: Data are fitted to zero-order, first-order, or Higuchi models to describe release profiles (34).

Antimicrobial testing

Agar diffusion method: Evaluates antibacterial activity against S. mutans and P. gingivalis (38).

Minimum inhibitory concentration (MIC): Quantifies the lowest concentration of extract needed to inhibit bacterial growth (38).

Anti-inflammatory assays

Cell culture studies: Human gingival fibroblasts are treated with formulations to assess suppression of IL-6 and TNF-α (37).

Animal models: Periodontitis-induced rodents provide in vivo validation of anti-inflammatory action (12).

Stability studies

Accelerated stability testing: Conducted at 40 °C and 75% RH for six months to simulate long-term storage (35).

Shelf-life estimation: Based on drug content retention and physical stability (35).

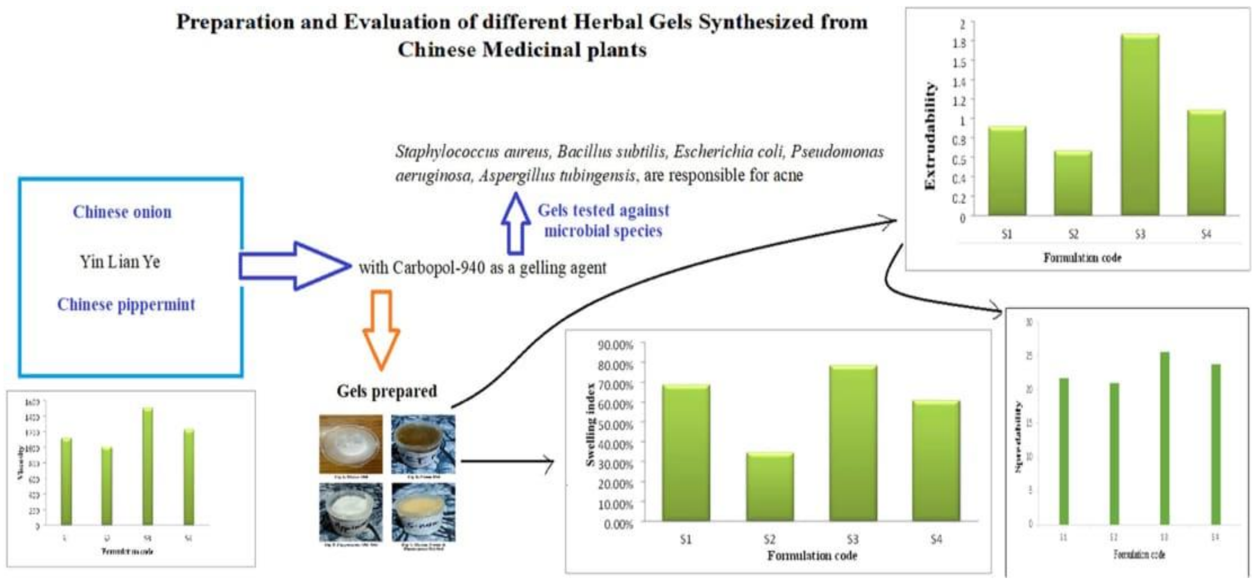

Figure 3: Typical evaluation workflow for herbal gel formulations

11. Applications

Scutellaria baicalensis herbal gels have a wide range of clinical and pharmaceutical applications due to their bioactive flavonoids and mucoadhesive delivery system.

Periodontal disease management

Periodontitis and gingivitis are characterized by bacterial infection and inflammation. Baicalin gels suppress P. gingivalis and reduce inflammatory cytokines, making them suitable adjuncts to scaling and root planing (37, 38).

Aphthous ulcers

Oral ulcers are painful and recurrent. Baicalein's anti-inflammatory and antioxidant actions promote healing and reduce discomfort (12, 37).

Antimicrobial mouth gels

Due to their activity against cariogenic and periodontal bacteria, these gels may serve as alternatives to chlorhexidine-based gels, with fewer side effects like staining (38).

Adjunct in oral cancer prevention

Baicalin has demonstrated chemopreventive properties by inducing apoptosis in oral squamous carcinoma cells (41). Formulating it into a mucoadhesive gel provides localized delivery with minimal systemic toxicity.

Mucoadhesive drug delivery platform

Beyond oral care, S. baicalensis gels can act as carriers for co-delivery with other herbal or synthetic drugs for synergistic effects (42).

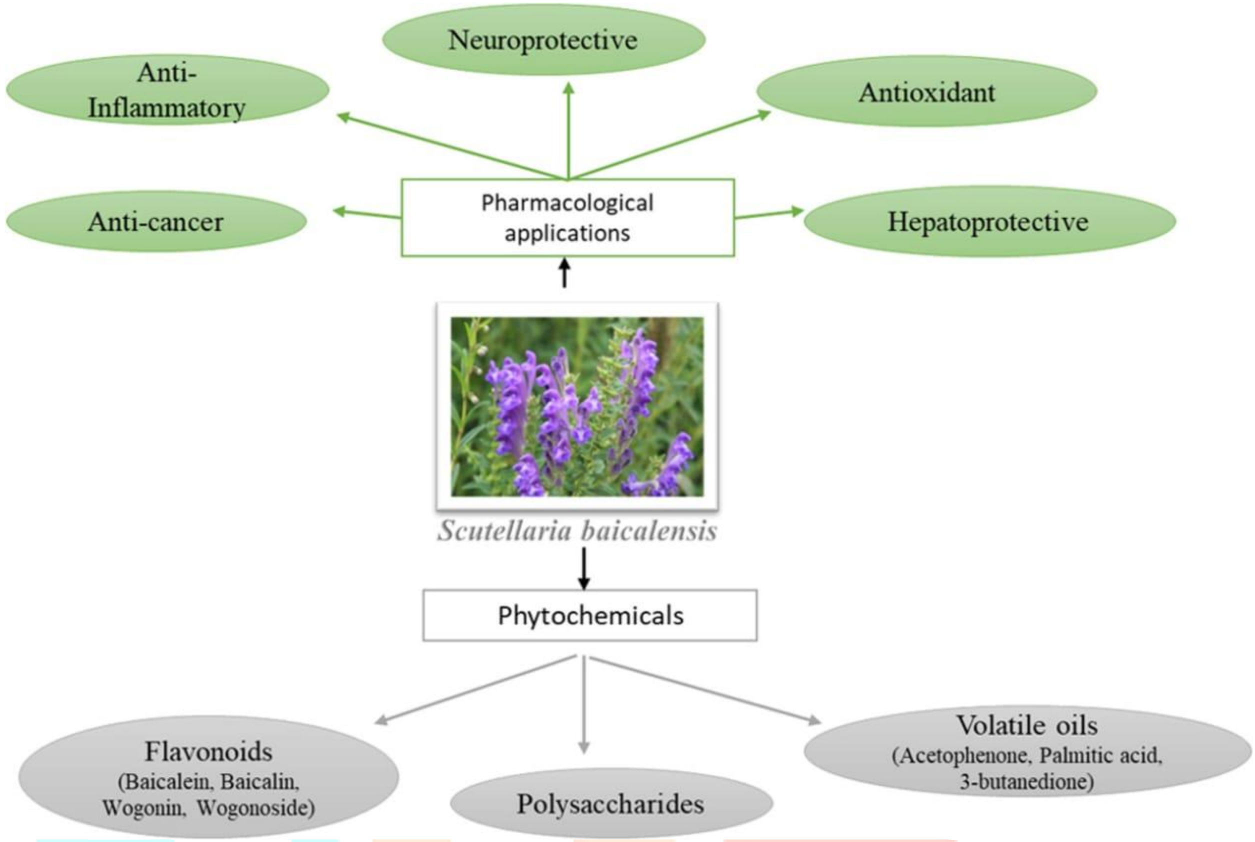

Figure 4: Applications of Scutellaria baicalensis gels in oral care and beyond.

12. Opportunities

The integration of S. baicalensis into gel-based oral drug delivery presents multiple research and market opportunities.

Growth in herbal pharmaceuticals

The global herbal medicine market is projected to grow steadily due to increasing demand for natural therapies (43). Positioning S. baicalensis gels as a safe and effective oral care product aligns with this trend.

Combination therapies

There is scope for synergistic formulations combining S. baicalensis with probiotics, green tea polyphenols, or curcumas for enhanced oral health benefits (42).

Nanotechnology integration

Nanocarriers such as Nano suspensions, liposomes, and nanogels can significantly enhance the solubility and bioavailability of baicalin (32, 44).

Expansion into global markets

Traditional Chinese Medicine (TCM) already recognizes S. baicalensis. Its integration into modern dosage forms like gels could bridge traditional and evidence-based medicine, attracting international regulatory acceptance (28, 43).

13. Challenges

Despite promising opportunities, significant challenges remain in developing S. baicalensis herbal gels.

Phytochemical variability

Environmental, seasonal, and geographical differences affect phytochemical composition, leading to batch-to-batch inconsistencies (26).

Bioavailability concerns

Baicalin has poor aqueous solubility and limited membrane permeability, restricting its clinical impact unless advanced drug delivery systems are used (32, 44).

Safety and toxicity evaluation

Although generally safe, high concentrations of flavonoids may exhibit cytotoxic or genotoxic effects, necessitating extensive toxicological studies (9, 41).

Regulatory and intellectual property issues

Herbal formulations face hurdles in gaining patents due to traditional usage claims, and regulatory approval requires rigorous standardization (28, 29).

Patient acceptance

The taste and color of herbal gels may affect patient compliance. Flavor masking and aesthetic modifications are essential to ensure wide acceptance (27).

14. Future Perspectives

The incorporation of Scutellaria baicalensis into mucoadhesive herbal gels represents a transformative approach for oral healthcare, but sustained innovation and translational research are required to maximize its clinical value. Several key directions are anticipated:

Standardization and Quality Control

Rigorous phytochemical profiling is essential to ensure reproducibility.

Use of advanced chromatographic and spectroscopic methods (e.g., HPLC, LC-MS, NMR) can help establish chemical fingerprints of baicalin and baicalein (26, 30).

Reference standards and validated bioassays should be mandated for clinical use.

Nanotechnology-driven delivery systems

Nanogels, Nano suspensions, and polymeric micelles can overcome the poor solubility and permeability of baicalin (32, 44).

These systems allow controlled release, enhanced mucoadhesion, and higher bioavailability.

Smart hydrogels that respond to pH or enzymatic activity could be tailored for oral environments.

Personalized herbal therapeutics

Integration with pharmacogenomics may predict individual responses to herbal gels.

Patient-specific formulations (e.g., based on oral microbiome profiling) could improve efficacy in periodontitis and mucositis.

Integration with conventional therapies

Combination gels containing S. baicalensis plus low-dose chlorhexidine or probiotics can maximize antimicrobial activity while reducing resistance (14, 42).

Co-formulation with curcumin or resveratrol may enhance anti-inflammatory synergy.

Clinical validation through RCTs

Large, multicentric randomized controlled trials (RCTs) are urgently needed to confirm efficacy and safety.Trials should compare herbal gels against gold-standard therapies like chlorhexidine to establish equivalence or superiority (19, 28).

Regulatory harmonization

Global regulatory frameworks must align to recognize herbal gels as safe and standardized medicinal products (28).

Adoption of WHO herbal monographs and pharmacopeias guidelines will accelerate approval.

Sustainable sourcing and green extraction

Environmentally friendly extraction methods (supercritical CO_2, microwave-assisted extraction) ensure sustainability (15, 30).

Cultivation of S. baicalensis under controlled conditions reduces variability and enhances yield.

15. Conclusion

Herbal mucoadhesive gels incorporating Scutellaria baicalensis offer a compelling solution for oral diseases, bridging traditional medicine and modern pharmaceutical innovation. The flavonoids baicalin, baicalein, and wogonin exhibit potent anti-inflammatory, antimicrobial, and antioxidant properties, while mucoadhesive delivery ensures localized, sustained therapeutic effects.

The literature demonstrates multiple advantages (biocompatibility, multifunctional action, patient compliance) but also highlights challenges (phytochemical variability, solubility, regulatory barriers). Emerging technologies such as nanogels, personalized formulations, and synergistic combinations provide avenues to overcome these hurdles.

With proper standardization, rigorous clinical validation, and regulatory support, S. baicalensis herbal gels can become mainstream in managing periodontal disease, mucositis, and other oral conditions. This not only advances oral healthcare but also aligns with the global trend of integrating safe, effective, plant-based therapeutics into modern medicine.

16. References

1. Kassebaum NJ, et al. Global burden of oral diseases. J Dent Res. 2017;96(4):380–387.

2. Preshaw PM, et al. Periodontitis and systemic disease. Periodontol 2000. 2012;58(1):48–78.

3. Addy M. Chlorhexidine compared with other antimicrobial agents. J Clin Periodontol. 1986;13(10):957–964.

4. Gościniak A, et al. Plant-based approaches in periodontal disease. J Herbal Med. 2021; 25:100406.

5. Chen W, et al. Antibacterial activity of baicalin and baicalein. Arch Oral Biol. 2019;107:104511.

6. Zhao X, et al. Pharmacological activities of flavonoids from Scutellaria baicalensis. Front Pharmacol. 2024;15:1442187.

7. Zhang H, et al. Clinical evaluation of a Scutellaria-based gargle. J Ethnopharmacol. 2024;318:116925.

8. Bhattarai N, et al. Mucoadhesive drug delivery systems. J Adv Pharm Technol Res. 2020;11(1):1–

9. Liu X, et al. Safety profile of baicalin in oral formulations. Int J Pharm. 2018;537(1–2):20–28.

10. Li-Weber M. New therapeutic aspects of flavones. Cancer Treat Rev. 2009;35(1):57–68.

11. Gao Z, et al. Antioxidant properties of baicalein. Biochim Biophys Acta. 2011;1810(10):1205–1212.

12. Patel VF, et al. Mucoadhesive drug delivery technologies. Drug Discov Today. 2011;16(3–4):132–140.

13. Kim HJ, et al. Patient acceptance of herbal gels in oral therapy. Complement Ther Med. 2019;45:26–32.

14. Arunachalam A, et al. Herbal gels as adjuncts in periodontitis treatment. Indian J Dent Res. 2020;31(3):381–386.

15. Li H, et al. Seasonal variation of flavonoid content in Scutellaria. J Chromatogr B. 2016;1026:183–190.

16. Zhou Y, et al. Solubility challenges of baicalin. Eur J Pharm Sci. 2019;127:233–240.

17. Feng R, et al. Pharmacokinetics of baicalin. Planta Med. 2017;83(6):431–438.

18. Wang Y, et al. Stability of baicalin in aqueous formulations. J Pharm Biomed Anal. 2018;159:288–293.

19. Wu Y, et al. Herbal approaches in oral mucositis management. Support Care Cancer. 2021;29(9):5317–5326.

20. Kumar R, et al. Advanced gel technologies in drug delivery. Drug Deliv. 2019;26(1):459–472.

21. Dash M, et al. Natural polymers in drug delivery. Int J Biol Macromol. 2011;49(4):619–638.

22. Soppimath KS, et al. Stimuli-sensitive hydrogels. Adv Drug Deliv Rev. 2002;53(3):349–374.

23. Siepmann J, et al. Ideal characteristics of oral gels. Int J Pharm. 2011;418(1):42–53.

24. Mortazavi SA, et al. Mucoadhesion of polymers. STP Pharma Sci. 1993;3:115–122.

25. Chattaraj SC, et al. Bioadhesive drug delivery systems. Indian J Pharm Sci. 1997;59(6):269–275.

26. Mukherjee PK, et al. Quality control of herbal formulations. Phytomedicine. 2018;44:1–10.

27. Kunle OF, et al. Standardization of herbal medicines. J Med Plants Res. 2012;6(9):1322–1326.

28. Ekor M. Regulatory perspectives on herbal medicines. Front Pharmacol. 2014;5:177.

29. ICH Guidelines Q1A(R2). Stability testing of new drug substances and products. 2003.

30. Harborne JB. Phytochemical methods. Springer; 1998.

31. Prajapati VD, et al. Natural gums as drug carriers. Carbohydrate Polym. 2013;92(2):1685–1699.

32. Sun Y, et al. Nanotechnology to enhance baicalin solubility. Int J Nanomedicine. 2020;15:861–874.

33. Shojaei AH. Buccal mucosa drug delivery. J Pharm Sci. 1998;87(10):1117–1125.

34. Varshosaz J, et al. Drug–polymer interactions in gels. Iran J Pharm Res. 2010;9(2):107–118.

35. Allen LV. Remington: The Science and Practice of Pharmacy. 23rd ed. 2020.

36. Andrews GP, et al. Mechanisms of mucoadhesion. Eur J Pharm Biopharm. 2009;71(3):505–518.

37. Wang Y, et al. Anti-inflammatory pathways of baicalin. Int Immunopharmacol. 2015;28(2):635–640.

38. Liu Q, et al. Antibiofilm effects of baicalein. J Dent Res. 2020;99(6):728–735.

39. Gupta V, et al. Evaluation of gels. Int J Pharm Sci Res. 2011;2(5):1243–1250.

40. Jones DS, et al. Rheological evaluation of hydrogels. Int J Pharm. 1997;151(2):223–230.

41. Tadros TF. Rheology of dispersions. Wiley-VCH; 2010.

42. Indian Pharmacopoeia. Quality control tests for semisolids. 2020.

43. Costa P, et al. Modeling and comparison of dissolution profiles. Eur J Pharm Sci. 2001;13(2):123–133.

44. Peh KK, et al. Mucoadhesion measurement techniques. J Pharm Pharm Sci. 1999;2(2):53–61.

45. CLSI Guidelines. Antimicrobial susceptibility testing. 2019.