NATURAL-BASED MUCOADHESIVE PATCH INNOVATION USING *ACORUS CALAMUS* FOR ORAL MUCOSAL WOUND HEALING: A LITERATURE REVIEW

Keisya Daniyah Rahma*, Najma Nadia Ma'rufah[2], Kayza Cindy Aulia[3], Arin Oktaviani Suningdyastiningrum[3], Fatika Puteri Rosyi Prabowo[4]
* Universitas Duta Bangsa
*Correspondence Email : keisyadaniyah@email.com

ABSTRACT

Oral mucosal wounds are frequently exposed to saliva, mechanical movement, and microbial challenges, which can limit the retention and effectiveness of conventional topical treatments. Mucoadhesive patches offer a potential approach for maintaining local delivery at the wound site, while natural products may provide complementary biological activities. This literature review evaluates the potential of Acorus calamus as a natural active ingredient for an oral mucoadhesive patch intended for mucosal wound healing. Literature published from 2016 to 2026 was identified through PubMed, ScienceDirect, and Google Scholar. Following duplicate removal and eligibility screening, 11 studies were included in the qualitative synthesis. The reviewed evidence indicates that A. calamus exhibits antioxidant, anti-inflammatory, and antibacterial activities, while studies of natural-based mucoadhesive patches demonstrate potential for prolonged mucosal retention, localized delivery, and oral wound management. However, direct evidence combining A. calamus, mucoadhesive patch technology, and oral mucosal wound healing remains limited. Further studies are needed to optimize formulation characteristics, establish safety and stability, and validate wound-healing efficacy using appropriate oral mucosal models. The proposed approach may support the development of a localized and potentially sustainable strategy for oral wound management.

KEYWORDS

Acorus calamus; Herbal medicine; Mucoadhesive patch; Oral biology; Oral wound healing

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INTRODUCTION

Oral mucosal wounds may result from mechanical trauma, dental procedures, repeated irritation, infection, or inflammatory disorders. Although oral mucosa has a relatively high regenerative capacity, symptomatic or persistent lesions may cause pain and discomfort that interfere with eating, swallowing, speaking, and daily activities, ultimately affecting oral health-related quality of life (Pan et al., 2024; Samiraninezhad et al., 2024). The clinical impact becomes more relevant when wound closure is delayed or inflammation persists, as prolonged tissue disruption may compromise mucosal integrity and increase susceptibility to local microbial challenges. Following injury, oral wound healing involves coordinated interactions among epithelial cells, immune cells, fibroblasts, blood vessels, and the extracellular matrix through overlapping phases of inflammation, proliferation, re-epithelialization, and tissue remodeling (Chuhuaicura et al., 2025; Waasdorp et al., 2021). Therefore, despite the intrinsic regenerative capacity of oral mucosa, effective management remains important to reduce symptoms, support timely tissue repair, and restore normal mucosal function.

Conventional management of oral mucosal lesions commonly includes topical anti-inflammatory agents, analgesics, anesthetics, antiseptics, and protective formulations. However, the effectiveness of topical treatment is strongly influenced by the physiological conditions of the oral cavity. Continuous salivary flow and mechanical activities, including speaking, chewing, and swallowing, can dilute or remove topical preparations from the mucosal surface, resulting in short residence time and limited local exposure (Alghanem et al., 2023; Kumar et al., 2022). These limitations may require repeated application and reduce the efficiency of local treatment. Prolonged exposure to some topical agents may also increase the risk of local adverse effects, depending on the active compound and duration of use. Therefore, an effective local treatment requires adequate retention at the lesion site while maintaining therapeutic exposure within an acceptable safety range.

Natural products have considerable potential as sources of bioactive compounds because they may provide multiple biological activities that act on different aspects of the healing process. Antioxidant activity may help regulate oxidative stress, anti-inflammatory activity may limit excessive inflammatory responses, and antimicrobial activity may help control microorganisms at the wound site. These combined activities are relevant to oral mucosal wound healing, which is influenced by the balance between inflammation, oxidative stress, tissue regeneration, and the local microbial environment (Ferreira et al., 2022). *Acorus calamus* is one plant that exhibits these characteristics. Extracts of *A. calamus* have been reported to possess free-radical-scavenging, anti-inflammatory, and antibacterial activities against several microorganisms, indicating biological properties relevant to the wound environment (Haran et al., 2024). These properties support its consideration as a candidate natural active ingredient for localized oral wound management. From a green dentistry perspective, the use of plant-derived bioactive materials and localized delivery systems may also contribute to more resource-conscious oral healthcare by supporting the development of potentially sustainable therapeutic alternatives. However, this potential should be evaluated alongside extraction practices, formulation materials, safety, standardization, and environmental impact. Pharmacological activity alone cannot establish clinical efficacy in oral mucosal wound healing; therefore, further evidence is required to determine whether *A. calamus* can be effectively incorporated into a safe and sustainable oral delivery system.

Research on *A. calamus* and oral delivery systems has begun to address these two aspects, but they have not yet been fully integrated for oral mucosal wound healing. Suma et al., (2026) developed an oral bioadhesive formulation containing *A.calamus* rhizome extract and nano-hydroxyapatite. This study demonstrated the feasibility of incorporating *A.calamus* extract into a formulation designed for oral application. However, the formulation was developed primarily for white spot lesion prevention and enamel remineralization, rather than soft-tissue or oral mucosal wound healing. In parallel, research on natural-based patches has demonstrated increasing potential for oral-ulcer management. Natural and mucoadhesive patch systems have been investigated for their ability to retain active compounds at the mucosal surface and facilitate localized delivery (Bangar et al., 2026; Jamdagni et al., 2022; Mauceri et al., 2026; Wei et al., 2019). These findings indicate a clear research gap: although evidence exists for the biological activity of *A. calamus* and the development of mucoadhesive patches for oral wound management, the use of *A. calamus* as the active component of a natural-based mucoadhesive patch specifically designed for oral mucosal wound healing remains insufficiently investigated. This gap provides a basis for evaluating a delivery system that combines the biological properties of *A. calamus* with the functional advantages of mucoadhesive technology.

Based on this research gap, this review aims to synthesize evidence on the biological activities of *Acorus calamus*, oral mucosal wound healing, and advances in mucoadhesive patch technology. The review focuses on studies published between 2016 and 2026, with particular attention to the anti-inflammatory, antioxidant, and antimicrobial activities of *A. calamus* and their potential relevance to tissue repair. It further evaluates natural-based mucoadhesive patches for oral applications, particularly their ability to maintain active compounds at the wound site and support localized delivery. The available evidence is synthesized to identify research gaps and assess the feasibility of incorporating *A. calamus* into mucoadhesive patches for oral mucosal wound healing. The review also considers the potential contribution of this approach to sustainable oral healthcare through the use of natural bioactive resources and localized drug delivery. Finally, the findings are used to define priorities for further research, including formulation optimization, mucoadhesive performance, safety, stability, release characteristics, and wound-healing efficacy.

RESEARCH METHOD

Literature Search and Selection

This study employed a narrative literature review approach to identify, evaluate, and synthesize available evidence regarding the biological activities of *Acorus calamus*, oral mucosal wound healing mechanisms, and natural-based mucoadhesive or bioadhesive delivery systems. A comprehensive literature search was conducted across electronic databases, including PubMed, ScienceDirect, and Google Scholar, covering publications from 2016 to 2026. Identified records were systematically screened based on predefined eligibility criteria, and relevant findings were qualitatively synthesized across three primary evidence domains: (1) *A. calamus* biological activities, (2) oral mucoadhesive delivery technologies, and (3) natural-based oral wound-healing systems Figure 1.

Inclusion Criteria

Eligibility was limited to studies published from 2016 to 2026 that were written in English and focused on at least one core topic related to the biological properties of *Acorus calamus* relevant to tissue repair, oral mucosal wound healing, or natural-based mucoadhesive and oral bioadhesive delivery systems. Eligible study designs included original experimental studies employing *in vitro assays* (e.g., cell viability, scratch assays,

antioxidant, anti-inflammatory, or antibacterial evaluations), *in vivo animal models* (e.g., mucosal ulceration or excision models), or human clinical trials assessing therapeutic and mechanical outcomes. Comprehensive literature reviews providing critical supporting evidence were also included.

Information Sources and Search Strategy

Literature searches were executed in PubMed, ScienceDirect, and Google Scholar for articles published between 2016 and 2026. The search strategy combined Boolean operators with combinations of terms, including: "*Acorus calamus*," "oral wound healing," "oral mucosal wound," "mucoadhesive patch," "mucoadhesive," and "oral bioadhesive," alongside supplementary terms such as "antioxidant," "anti-inflammatory," "antibacterial," and "wound healing".

Exclusion Criteria

Studies were excluded if they were published prior to 2016, identified as duplicate records across databases, or were unrelated to the primary review objectives, particularly those focused exclusively on non-oral systemic or topical applications without relevant implications for oral mucosal tissue repair. Additionally, studies were excluded if they lacked sufficient qualitative or quantitative data to evaluate methodologic relevance, or if they belonged to non-original study types, such as conference abstracts, letters to the editor, editorials, or articles without accessible full text.

Study Selection and Eligibility Assessment

A total of 53 records were identified through the initial database search. Following the removal of 6 duplicate records, 47 records remained for title and abstract screening. Two records were excluded based on the publication year requirement, while 23 records were excluded for failing to meet the topic and model eligibility criteria. The remaining 22 full-text articles were thoroughly evaluated, of which 11 were excluded. Consequently, 11 primary studies were included in the qualitative synthesis (Haran et al., 2024; Page et al., 2021; Zhao et al., 2023).

Data Extraction and Synthesis

Data were systematically extracted regarding study characteristics, *A. calamus* plant parts and extract types, evaluated experimental models (*in vitro*, *in vivo*, or clinical), reported biological/pharmacological activities, oral delivery system characteristics, and therapeutic outcomes. For mucoadhesive systems, parameters including mucoadhesive strength, residence time, release kinetics, mechanical properties, and wound closure capacity were documented when available. Findings were synthesized narratively across the three defined evidence domains to assess the feasibility of *A. calamus*-loaded mucoadhesive patches and identify existing research gaps.

RESULT AND DISCUSSION

RESULT

Characteristics of the Included Studies

The included literature addressed three closely related areas, namely the biological activities of *Acorus calamus*, oral mucoadhesive delivery systems, and natural-based patches or films for oral mucosal lesions. The studies comprised experimental research, clinical studies, and relevant review articles. The research models ranged from chemical and cellular assays to animal models of oral ulcers and human clinical studies.

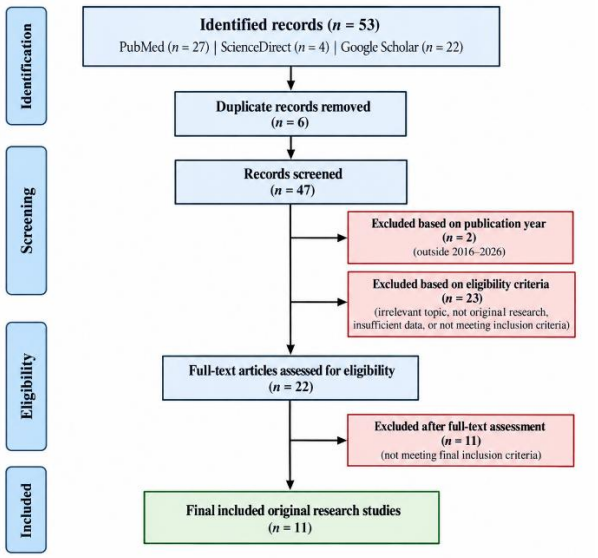


Figure 1. Flow diagram of the literature search and study selection process. A total of 53 records were identified from PubMed (n = 27), ScienceDirect (n = 4), and Google Scholar (n = 22). After removing 6 duplicate records, 47 records remained for screening. Two records were excluded based on the publication-year criterion, while 23 were excluded because they did not meet the eligibility criteria. The remaining 22 articles were assessed for full-text eligibility, of which 11 were excluded. Consequently, 11 studies were included in the qualitative synthesis.

Table 1. Characteristics of the 11 principal studies included in the review

Study	Study design/model	Main focus	Key finding
Jairam et al., (2025)	*In vitro*	*P. emblica* mucoadhesive patch	Wound closure + mucoadhesion
Zhang et al., (2025)	*In vitro* + *in vivo*	*Astragalus* microneedle	Oral-ulcer healing
Haran et al., (2024)	*In vitro*	*A. calamus* extract	Antioxidant, anti-inflammatory, antibacterial
(Daněk et al., 2017)	Clinical	Buccal film	Aphthous-lesion healing
Zhang et al.,(2019)	*In vitro* + *in vivo*	Mucoadhesive buccal film	Controlled release + ulcer repair
Wei et al., (2019)	Experimental	Nanofibrous mucoadhesive patch	Mouth-ulcer delivery
Giammarinaro et al., (2019)	Clinical/RCT	Mucoadhesive formulation	Aphthous-ulcer treatment
Shao & Zhou, (2020)	Clinical/RCT	Chitosan oral film	Reduced ulcer size
Chandrashekar et al., (2021)	Clinical	Curcumin buccal patch	Natural active + buccal delivery
Singh et al., (2021)	Experimental	Bacterial-cellulose adhesive	Oral adhesion + retention
S et al., (2026)	*In vitro* + *in vivo* + clinical	*A. calamus* bioadhesive	Oral bioadhesive feasibility

Table 1. Characteristics of the 11 principal studies included in the literature review. The table summarizes the publication year, study design and model, main intervention or research focus, principal findings, and relevance of each study to the

development of a natural-based mucoadhesive patch containing *Acorus calamus* for oral mucosal wound healing. Studies were categorized according to their biological, therapeutic, or formulation relevance. Duplicate records were excluded from the final synthesis.

Biological Characteristics and Pharmacological Activity of *Acorus calamus*.

The most direct evidence for the biological properties of *A. calamus* was provided by Haran et al., (2024). Using *A. calamus* leaf extract, the study demonstrated antioxidant activity through free-radical-scavenging and reducing assays, together with anti-inflammatory activity and antibacterial effects against selected microorganisms, including Pseudomonas aeruginosa and Staphylococcus aureus.

These activities are relevant to wound healing because oxidative stress, excessive inflammation, and microbial contamination can interfere with tissue repair. However, the evidence from Haran et al., (2024) remains primarily in vitro. Therefore, the findings provide biological plausibility rather than direct proof of oral mucosal wound-healing efficacy.

Table 2. Biological activities of *Acorus calamus* relevant to oral mucosal wound healing.

Activity	Evidence reported	Relevance to oral wound healing
Antioxidant	Free-radical-scavenging and reducing activity (Haran et al., 2024)	Potential regulation of oxidative stress
Anti-inflammatory	Anti-inflammatory assay activity (Haran et al., 2024)	Potential modulation of excessive inflammation
Antibacterial	Activity against selected bacteria (Haran et al., 2024)	Potential reduction of microbial burden
Oral bioadhesive application	Rhizome extract incorporated into oral bioadhesive (S et al., 2026)	Demonstrates formulation feasibility
Oral wound models	Oral wound models and regenerative therapies (Toma et al., 2021)	Supports the need for dedicated oral wound models

Table 2. Evidence related to the biological activities of *Acorus calamus* and their potential relevance to oral mucosal wound healing. The evidence includes antioxidant, anti-inflammatory, and antibacterial activities, incorporation of *A. calamus* rhizome extract into an oral bioadhesive formulation, and the relevance of dedicated oral wound models for further evaluation. Direct evidence of *A. calamus* efficacy in oral mucosal wound healing remains limited.

Evidence for *A. calamus* in Oral Bioadhesive Applications

S et al., (2026) provides the closest evidence connecting *A. calamus* with oral bioadhesive technology. The researchers developed an oral bioadhesive formulation containing nano-hydroxyapatite and *A. calamus* rhizome extract. The formulation was evaluated using extracted premolars and a randomized clinical study involving 40 participants. The primary target was white spot lesion management and enamel remineralization rather than soft-tissue wound healing.

The study therefore demonstrates that *A. calamus* can be incorporated into an oral bioadhesive formulation, but it should not be interpreted as evidence that *A. calamus* has

already been clinically demonstrated to heal oral mucosal wounds. This distinction is central to the research gap identified in the present review.

Natural-Based Mucoadhesive Patch Evidence

Evidence for mucoadhesive systems in oral lesions is substantially more developed. Daněk et al., (2017) reported that a flexible buccal film used to cover aphthous lesions significantly increased the healing rate compared with standard gel therapy. The study included 36 volunteers and also assessed subjective treatment outcomes.

Zhang et al., (2019) developed a bilayer mucoadhesive buccal film containing ornidazole and dexamethasone. The formulation was evaluated in vitro, in a rabbit oral-ulcer model, and for release in the human oral cavity. The study demonstrated the feasibility of combining local drug delivery with mucoadhesion for oral-ulcer management.

Wei et al., (2019) developed a multilayer nanofibrous mucoadhesive patch using electrospun meshes and hydroxypropyl methylcellulose. The resulting patch showed excellent adhesion to porcine buccal mucosa and was designed to accommodate compounds with analgesic, anti-inflammatory, and antimicrobial functions.

Experimental evidence is also available for natural-based mucoadhesive systems. Jairam et al., (2025) developed a patch containing Phyllanthus emblica extract, hydroxypropyl methylcellulose, and chitosan. In vitro testing using human gingival fibroblasts showed dose-dependent effects on cell viability and wound closure, with closure values of 50.12% and 67.44% at 12 hours for two extract concentrations and complete closure at 24 hours. These findings suggest that plant-derived extracts can be incorporated into mucoadhesive patch systems and may support oral wound closure.

Similarly, Zhang et al., (2025) developed an Astragalus polysaccharide microneedle patch for oral ulcers. The system combined local delivery with ROS scavenging and ferroptosis inhibition and achieved 88.2% wound closure in rats within six days.

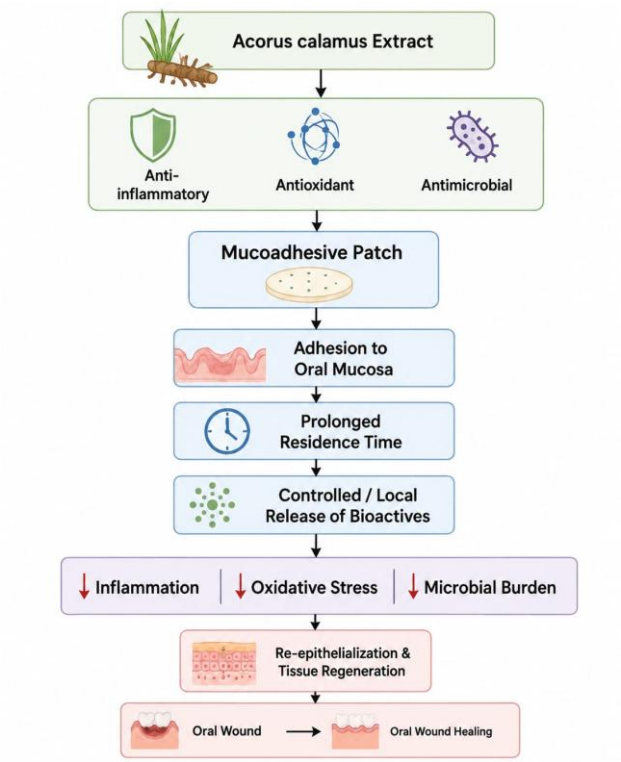


Figure 2. Proposed mechanism of an *Acorus calamus*-based mucoadhesive patch for oral mucosal wound healing. The figure illustrates the proposed relationship between *A. calamus* bioactive activities, mucoadhesive retention, localized release, modulation of inflammation and oxidative stress, reduction of microbial burden, and subsequent support of re-epithelialization and tissue repair. The mechanism represents a proposed model based on the available literature and does not indicate clinically established efficacy.

Evidence Synthesis and Research Gap

The evidence can be organized into three levels. The first concerns the biological activity of *A. calamus*. The second concerns its incorporation into an oral bioadhesive formulation. The third concerns natural-based mucoadhesive systems that have already been investigated for oral lesions.

The first two levels are supported by Haran et al., (2024) and S et al., (2026), respectively. However, the therapeutic target of the Suma et al., (2026) study was enamel white spot lesions rather than oral soft-tissue wounds. Conversely, Jairam et al., (2025) provides direct evidence linking a plant extract, mucoadhesive patch, and oral wound closure, but the plant used was P. emblica. The principal gap is therefore the absence of sufficient direct evidence combining *A. calamus* extract + mucoadhesive patch + oral mucosal wound healing within the same experimental system.

DISCUSSION

Biological Rationale for *A. calamus*

The antioxidant, anti-inflammatory, and antibacterial activities reported for *A. calamus* provide a reasonable biological basis for further investigation in oral wound management. Haran et al., (2024) demonstrated these activities in *A. calamus* leaf extract,

indicating that the plant possesses several properties relevant to the biological environment of a wound.

This relationship is mechanistically plausible because wound repair depends on controlled inflammation and oxidative balance, while microbial exposure is an additional consideration in the oral cavity. Nevertheless, the current evidence does not establish a direct causal relationship between these activities and oral mucosal wound closure. Further validation in oral wound models is therefore required.

Why Mucoadhesive Patches Are Relevant

The principal advantage of a mucoadhesive patch is prolonged contact with the target tissue. This characteristic is particularly important in the oral cavity, where saliva, swallowing, and mechanical movement can rapidly remove conventional topical preparations. Recent systematic evidence indicates that mucoadhesive systems can prolong drug release, protect lesions from mechanical irritation, and reduce pain and inflammation in oral mucosal diseases (Mauceri et al., 2026).

Clinical evidence supports this concept. Daněk et al., (2017) reported improved healing of aphthous lesions when a mucoadhesive film was used as a protective dressing, while Giammarinaro et al., (2019) evaluated a mucoadhesive local formulation in patients with aphthous ulcers. Thus, the value of the patch is not restricted to drug release. It also provides a physical barrier and may maintain a more stable local therapeutic environment.

Potential Mechanism of an *A. calamus*-Based Patch

An *A. calamus*-based patch could combine the biological activity of the extract with the retention properties of the delivery matrix. Once attached to the mucosa, the patch could maintain the extract at the wound surface while allowing gradual release. Antioxidant activity may help regulate oxidative stress, anti-inflammatory activity may contribute to control of excessive inflammation, and antibacterial activity may reduce microbial pressure.

Evidence from other natural-based systems supports this formulation concept. Jairam et al., (2025) demonstrated enhanced wound closure with P. emblica extracts incorporated into a mucoadhesive patch, while Zhang et al., (2025) demonstrated accelerated oral-ulcer healing using an Astragalus polysaccharide microneedle system.

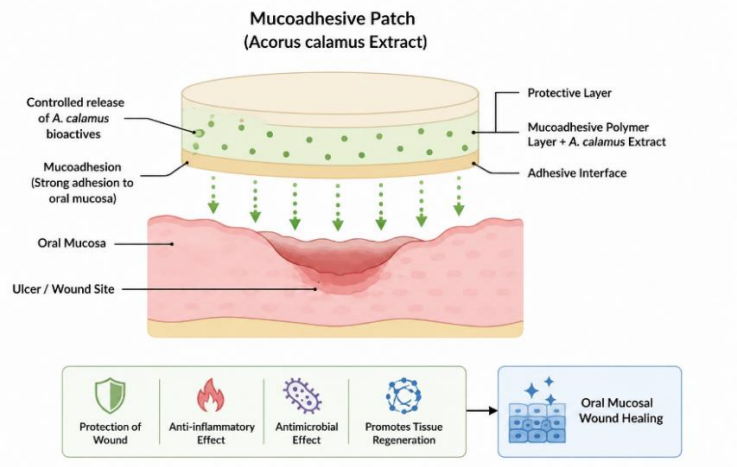


Figure 3. Conceptual design of an *Acorus calamus*-based mucoadhesive patch for localized oral mucosal wound management. The figure illustrates the proposed application of an *A. calamus*-loaded mucoadhesive patch on an oral mucosal wound. The patch consists of a protective layer, a mucoadhesive polymer layer containing *A. calamus* extract, and an adhesive interface that facilitates attachment to the oral mucosa. Controlled release of the bioactive compounds at the wound site is proposed to support wound protection, modulation of inflammation, antimicrobial activity, and tissue regeneration, thereby contributing to oral mucosal wound healing

Sustainable Oral Healthcare and Future Directions

The proposed *A. calamus*-based mucoadhesive patch may contribute to sustainable oral healthcare by combining a plant-derived bioactive ingredient with localized drug delivery. This approach is relevant to the principles of green dentistry, particularly through the potential use of renewable biological resources and more targeted therapeutic delivery. However, the sustainability of the formulation cannot be determined solely by its plant-derived origin. Environmental considerations should include cultivation, extraction, solvent use, manufacturing, packaging, storage, and disposal.

Further research should first establish the efficacy of *A. calamus* in appropriate oral mucosal wound models. Formulation studies should then optimize extract concentration and polymer composition and evaluate mucoadhesive strength, residence time, release behavior, mechanical properties, stability, and cytocompatibility. *In vivo* studies are also required to determine whether the reported biological activities translate into improved epithelial repair and tissue regeneration.

Overall, *A. calamus* represents a promising candidate for a natural-based mucoadhesive patch, but current evidence remains insufficient to establish its efficacy for oral mucosal wound healing. Future development should integrate biological efficacy, formulation performance, safety, and environmental considerations to support a more sustainable approach to oral wound management.

CONCLUSION

The available evidence indicates that *Acorus calamus* is a promising natural candidate for incorporation into an oral mucoadhesive patch because of its reported antioxidant, anti-inflammatory, and antibacterial activities. Evidence from natural-based mucoadhesive systems further demonstrates the potential of localized retention and controlled delivery for oral mucosal wound management. However, direct evidence combining *A. calamus*, mucoadhesive patch technology, and oral mucosal wound healing remains limited. Further research is required to optimize formulation characteristics, establish safety and stability, and evaluate wound-healing efficacy using appropriate in vitro and in vivo oral mucosal models. Overall, an *A. calamus*-based mucoadhesive patch represents a promising research direction for localized and potentially sustainable oral wound management, but its therapeutic efficacy requires further experimental and clinical validation.

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