INTERNATIONAL JOURNAL OF PHARMACEUTICAL SCIENCES
[ISSN: 0975-4725; CODEN(USA): IJPS00]
Journal Homepage: https://www.ijpsjournal.com

Review Article

Green Healing: The Role of Herbal Patches in Modern Wound Therapy

Mansi*, Dr. Ranjana, Minal Thakur

Global Institute of Pharmaceutical Education & Research, Kasipur, Uttarakhand

ARTICLE INFO

Published: 18 May 2026
Keywords:
Herbal patches, wound therapy, phytomedicine, green healing, bioactive compounds
DOI:
10.5281/zenodo.20278979

ABSTRACT

Management of wounds has been a sore issue in healthcare and there has been an increasing worldwide need to find efficient, cheap, and sustainable wound care. The traditional wound care products such as synthetic dressings, antibiotic ointments are usually credited with some challenges that include resistance to antimicrobials, increased costs, environmental impact, and allergic reactions. This has enhanced the increased interest in the use of herbal patches; these are health patches that combine ancient medicine and biomedical technology to produce environmentally friendly and patient friendly options. Herbal patches are topical delivery systems formed by biodegradable materials impregnated with bioactive plant APIs that have antimicrobial, anti-inflammatory, antioxidant and tissue-regenerative characteristics. The main herbals include Aloe vera, turmeric (curcumin), neem, gotu kola, calendula, and tea tree oil, which have all shown promising therapeutic benefits in wound healing through tripling the rate of collagen production, prevention of wound infection, and ensuring an ideal moisture level in the wound. This review analyses critically the composition, mechanisms and clinical effectiveness of herbal patches in comparison to the conventional wound healing procedures. It discusses the new technological developments of the recent past, such as nanotechnology, smart wound dressings, and sustainable biomaterials, which have made the delivery of herbal patches more efficient. Moreover, it examines findings reported in the recent researches (2020-2025) and outlines the point of global trends in the market of herbal wound care. Although herbal patches have a potentially appealing advantage in form of reduced toxicity, biodegradability, and patient compliance, a number of obstacles exist, such as the absence of standardization, regulatory obstacles, and mass production. The paper ends by stating the future research directions, which is the incorporation of digital health solutions and personalized medicine, to approach next-generation herbal wound therapies.

INTRODUCTION

Background of Wound Therapy

***Corresponding Author:** Muskan
Address: *Dreamz College of Pharmacy, Khilra, Sundernagar*
Email : mansimana301999@gmail.com

Relevant conflicts of interest/financial disclosures: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Since the time immemorial, wound management has been one of the pillars of healthcare. The herbal poultices were applied in ancient civilizations such as Egypt, Mesopotamia, India, Greece, and Rome, in which honey, fats, and medicinal plants were used to treat wounds, lower inflammation, and accelerate the process of healing Wikipedia. The Gou Pi Gao, herbal adhesive plaster, previously used as a topical dressing on dog skin, and adapted to clothing, was applied to all sorts of conditions in traditional Chinese medicine, and an example of early incorporation of herbal treatment of topical wounds into Chinese practice

Herbal medicine in ancient medicine.

Wound-healing effects of herbal medicine have been well established. Unani medicine books listed many herbal recipes that are confirmed by contemporary research on the phenolic, flavonoid and tannin compounds PubMed. Likewise, recent reviews show that antimicrobial, anti-inflammatory, and antioxidant activities of plants used centuries ago (Centella asiatica, Calendula officinalis, and more) are supported by evidence of active phytochemicals.

Present-day Wound Healing Problems.

The wound care environment today is challenged. Antibiotic resistance and the presence of infected wounds and biofilms contraindicate effective antimicrobial treatment and raise the issue of cytotoxicity and systemic side effects SpringerLinkPubMed. In the meantime, synthetic dressings and complex wound products are too expensive to be available to all, particularly underserved populations. The prevalence of chronic wounds such as diabetic ulcers and pressure sores are rising as a result of aging and lifestyle-related illnesses such as diabetes and obesity, burdening the healthcare systems of the world PubMedBioMed Central.

Emergence of Herbal Patches

To this end, herbal patches have come out as a potential for a hybrid between traditional and modern therapy. These patches, which are defined as topical delivery systems- usually made of biodegradable polymers or hydrogel-infused with bioactive plant APIs, allow the controlled and continuous release of therapeutic molecules into the wound site ScienceDirectMDPIZenodo. Recent innovative products, including microneedles and lipid vesicles, hydrogels, and responsive composite dressings have greatly enhanced the bioavailability and permeability of such herbal actives as curcumin and aloe vera, bypassing the skin barrier MDPIPMC.

Wounding and healing.

Physical wounds are traumas that interfere with the mechanics and anatomy of the skin or the under-lying tissue. Acute and chronic wounds can be broadly divided according to their etiology and the process of healing. Acute wounds are caused by an external injury or surgical interventions, and they normally take a foreseeable and punctual recovery path. Surgical incisions, abrasions, and burns are examples of wounds that traditionally heal in days or weeks when well looked after (Moura et al., 2022). Chronic wounds on the contrary do not undergo the normal healing stages and they end up taking long before healing. Many underlying conditions including diabetes, vascular disease, and pressure ulcers are commonly related to them, and diabetic foot ulcers and pressure injuries are some of the most common (Patel, 2022). The chronic wound is a major medical challenge to the healthcare system because it requires a lengthy treatment period and has a substantial recurrence rate (Nunan et al., 2024).

Healing of a wound happens in four overlapping and very synchronized phases:

- Hemostasis - The clotting of blood follows injury to prevent excessive loss of blood.
- Inflammation - The defense can begin with the movement of immune cells to the site of the wound to eliminate pathogens and debris.
- Proliferation - Fibroblasts, keratinocytes and endothelial cells facilitate tissue and angiogenesis and extracellular matrix deposition (Benthamscience, 2025)..
- Remodeling (Maturation) - recently developed tissue is strengthened by the reorganization of collagen, which causes the formation of a scar (Gonzalez et al., 2023).

These stages are very important in designing herbal patches since various herbs are aimed at various stages of healing. As an example, anti-inflammatory herbs like Aloe word and Calendula officinalis can be useful in the inflammation process whereas the antimicrobial herbs like neem (Azadirachta indica) prevent infection in the initial stages. The proliferation stage is associated with the use of herbs such as Centella asiatica and turmeric (Curcuma longa) that trigger the production of collagen and tissue regeneration (Basu et al., 2024). Modern patches can be made by combining a conjunction of these herbal bioactives to enable a synergistic and stage-specific therapeutic impact to achieve acceleration of healing and minimize the occurrence of complications. This personalized solution indicates the promise of herbal patches to transform the management of wounds by harmonizing natural substances with the body repair processes.

COMPOSITION

Herbal patches are generally formulated into three major parts: base materials, herbal active constituents and functional enhancement additives (International Journal of Pharmaceutical Sciences, 2025).

Base Material

The bottom layer serves as the structural support of the patch, being adhesive, flexible and biodegradable.

- **Chitosan**: A polysaccharide that is naturally derived and biocompatible with antimicrobial properties and tissue regeneration. It provides a wet healing space and avoids the colonization of bacteria (Basu et al., 2024).
- **Alginate**: Alginate is a hydrogels API derived to provide a brown algae, which is excellent in moisture retention, and exudates absorption, rendering it an ideal choice in chronic wounds like diabetic wounds (Moura et al., 2022).
- **Cellulose and Its Commercial Derivatives**: Plant-based cellulose provides mechanical strength and biodegradability, and upon interaction with herbal APIs, it increases the oxygen permeability and structural integrity (Gonzalez et al., 2023).

Herbal Active Ingredients

Bioactive plant APIs in herbal patches have a therapeutic potential due to the fact that each API is selected on the basis of its particular wound-healing qualities:

- **Aloe vera: Soothes** the tissues, speeds up the process of epithelialization, and has anti-inflammatory properties.

- **Turmeric (Curcumin):** It is a potent anti-oxidant and anti-inflammatory compound that induces collagen formation and angiogenesis.
- **Neem (Azadirachta indica):** Has a broad-spectrum antimicrobial effect, which prevents infection.
- **Calendula (Calendula officinalis):** Relaxes inflammation, stimulates the growth of tissue granulation (Plants Journal, 2025).
- **Gotu kola (Centella asiatica):** Promotes the production of collagen and the reinforcement of the extra-cellular matrix.
- **Tea tree oil**: It performs the functions of a natural antiseptic and lowers the microbial burden at the wound site (Basu et al., 2024).

Additives for Enhancement

- The components can be added to enhance patch functionality:
- Oils that are critically important in antimicrobial and anti-inflammatory synergy.
- Natural adhesives like gum arabic to enhance adhesion and comfort of the skin (ScienceDirect, 2022).

Transdermal absorption, such as the addition of natural surfactants in order to enhance phytochemical delivery (Mdpi, 2022).

Mechanism of Action

The way in which the healing effect of herbal patches works is through several intertwined biological reactions:

Table 1. Classification of Wounds and Corresponding Herbal Patch Applications

Type of Wound	Description	Common Challenges	Suggested Herbal Patch Components	References
Acute Wounds	Result from surgical procedures, burns, or accidental injuries	Risk of infection and pain	Aloe vera for soothing; Calendula for inflammation control	Harshavardhan Gowda et al. (2025); Pulipati et al. (2025)
Chronic Wounds	Slow-healing wounds such as diabetic ulcers, venous leg ulcers, and pressure sores	Poor circulation, infection, tissue necrosis	Gotu Kola for collagen synthesis; Neem for antimicrobial action	Albahri (2023); Isopencu (2023)
Burn Wounds	Thermal, chemical, or electrical damage to skin layers	Fluid loss, high risk of infection	Aloe vera for hydration; Turmeric for antioxidant activity	Wang et al. (2024)
Surgical Wounds	Planned cuts during surgery	Scar formation and delayed healing	Honey API and Tea Tree Oil for antimicrobial effects	Jose et al. (2025a); Patel (2022)

Antibacterial and Anti-inflammatory activity

Bacterial cell walls are disturbed by herbal phytochemicals, including flavonoids, tannins, and alkaloids, which make bacteria less dangerous in terms of infections. Proteolytic enzymes such as curcumin and aloe vera reduce the activity of pro-inflammatory cytokines, which reduces pain and swelling (Basu et al., 2024).

The Controlled Releases of Drugs by way of the skin:

The herbal compounds can be released continuously due to the polymeric base, which gives the patient a constant therapeutic level and removes the need to change the dressing regularly. This improves patient adherence and reduced systemic toxicity (Moura et al., 2022).

Moisture Retention: Oxygen Permeability:

The moist environment generated by herbal patches provides optimum levels of cell migration and angiogenesis and permits oxygen to enter the wound to enable tissue regeneration. It also contributes to the prevention of pain and the minimization of scarring (Gonzalez et al., 2023).

Communicado with the Wound Microenvironment:

Phytochemicals can communicate with growth factors and extracellular matrix proteins to induce fibroblast growth, angiogenesis, and collagen. This leads to quicker wound healing and more robust and resilient tissue that is healed (ScienceDirect, 2024).

Concisely, herbal patches are composed and work by a synergistic combination of natural bioactives and hi-tech biomaterials to produce a wound care system that is holistic, covering the areas of infection, inflammation, tissue remodeling and environmental sustainability.

Herbal Patches vs. Traditional Wound Healing.

Table 2. Key Herbal Ingredients and Their Therapeutic Roles

Herbal Ingredient	Bioactive Compounds	Therapeutic Properties	Application Stage in Wound Healing	References
Aloe vera	Polysaccharides, Glycoproteins	Moisturizes skin, promotes epithelialization	Proliferation Stage	Harshavardhan Gowda et al. (2025)
Turmeric (Curcumin)	Curcuminoids, Volatile Oils	Anti-inflammatory, antioxidant	Inflammatory Stage	Pulipati et al. (2025)
Neem	Azadirachtin, Nimbin	Antibacterial, antifungal, tissue regeneration	Inflammatory Stage	Albahri (2023)
Gotu Kola (Centella asiatica)	Asiaticoside, Madecassoside	Enhances collagen synthesis, angiogenesis	Proliferation & Remodeling Stage	Isopencu (2023)
Calendula	Flavonoids, Triterpenoids	Anti-inflammatory, soothing	Hemostasis & Early Inflammatory Stage	Wang et al. (2024)
Tea Tree Oil	Terpinen-4-ol	Broad-spectrum antimicrobial activity	Inflammatory Stage	Patel (2022)
Honey API	Flavonoids, Hydrogen Peroxide	Antibacterial, accelerates tissue repair	Throughout Healing Process	Jose et al. (2025a)

The traditional approaches to wound care have been the use of antibiotic ointments, synthetic dressings and silver-based patches. Although these approaches have proven to be effective in preventing infection and tissue repair, they are typically linked to such issues as antimicrobial resistance, cytotoxicity, and environmental waste (Moura et al., 2022). The development of herbal patches presents a good solution as it has a combination of traditional wisdom in healing and the contemporary methods of delivering this wisdom with modern delivery systems which overcome most of the drawbacks of modern wound care (Wang et al., 2024).

Healing Speed

Traditional interventions like antibiotic creams and silver-impregnated dressings focus on control of bacteria and, consequently, this is indirectly beneficial in healing but might not contribute to the active regeneration of tissue. Instead, bioactive compounds (curcumin, aloe vera and gotu kala) found in herbal patches have direct effects on collagen formation, angiogenesis and cell growth. An example of this is present in the Centella asiatica that has been found to promote fibroblast activity and hence wound healing (Basu et al., 2024). Consequently, herbal patches not only prevent any infection, but also act actively in terms of accelerating the process of tissue regeneration (Wound Care Education Institute, 2025).

Side Effects and Safety

Table 3. Comparison Between Herbal Patches and Conventional Wound Healing Approaches

Criteria	Conventional Methods (Antibiotic Ointments, Synthetic Dressings)	Herbal Patches	Supporting Reference	Criteria
Healing Speed	Moderate, dependent on wound type	Faster due to multi-functional herbal compounds	Vo (2025); Jose et al. (2025b)	**Healing Speed**
Side Effects	Potential allergic reactions, antibiotic resistance	Minimal side effects, naturally derived ingredients	Pulipati et al. (2025)	**Side Effects**
Cost-effectiveness	High cost due to synthetic materials	Cost-effective with locally sourced herbal ingredients	Grand View Research (2025)	**Cost-effectiveness**
Environmental Impact	Non-biodegradable dressings create medical waste	Biodegradable and eco-friendly materials	World Health Organization (2024)	**Environmental Impact**
Antimicrobial Resistance	Frequent use of synthetic antibiotics increases resistance	Reduced risk due to natural antimicrobial compounds	Huang et al. (2025)	**Antimicrobial Resistance**
Customization	Standard, one-size-fits-all products	Personalized herbal patches based on wound type	Academia (2025b)	**Customization**

Long-term exposure may occasionally lead to skin irritation, allergy, and side effects in the body with synthetic antibiotics and silver-based products (Gonzalez et al., 2023). Furthermore, antibiotics are often used, which is an additional cause of antimicrobial resistance, which is an increasing health problem on a worldwide scope. By contrast, herbal patches are obtained as natural plant APIs, which have a long history of safety. Substances such as aloe vera and calendula are soothing and anti-inflammatory, which decreases the threat of irritation. Secondly, the additional effect of various phytochemicals decreases the possibility of microbial resistance in comparison with synthetic drugs used singly (Mdpi, 2022).

Cost-Effectiveness

Bioengineered skin substitutes and hydrocolloid dressing technologies are considered highly costly and unavailable in low-resource environments. Herbal patches are also normally produced using locally available plants and biodegradable polymers, hence cheaper to manufacture and deliver. This affordability is particularly favorable in developing nations where the chronic wound

rates are high, including diabetic ulcers (Nunan et al., 2024).

Environmental Sustainability

Several dressings that are generated conventionally, produce a substantial amount of medical waste, since they are composed of non-biodegradable synthetic solutions (Academia, 2025a). Contrastingly, biodegradable polymers such as chitosan and alginate are used to design herbal patches, which can be broken up to produce byproducts that do not cause any damages to the environment. Furthermore, herbal API manufacturing is less carbon-intensive than the synthesis of pharmaceutical molecules, which is why they are greener and more sustainable (Moura et al., 2022).

Important Herbal Ingredients and Therapeutic roles.

The clinical efficacy of herbal patches is based on well-characterized plant actives that act on infection, inflammation, oxidative stress, and tissue regeneration. The following is a focused, evidence-based overview of the most prevalent botanicals as wound patches, their bioactive components, their mechanism, and recent clinical/preclinical support (2020-2025) (Harshavardhan et al., 2025).

Aloe Vera - epithelialization and moisturizing.

Aloe vera gel also has polysaccharides (acemannan), glycoproteins, and vitamins and minerals which hydrate tissue, regulate inflammation and activate fibroblasts and epithelial cell migration-important in re-epithelialization. The most recent reviews and experimental works show that aloe-based hydrogel and dressings can enhance the contraction speed and covering epithelial healing and keep the microenvironment within a moist condition, which contributes to healing. Preclinical and clinical formulations that included aloe as a part of patches or as a hydrogels demonstrated better indicators of healing, in contrast to simple dressings. PMC

Turmeric (curcumin) - antioxidant and antiflammatory.

Curcumin, the main polyphenol in Curcuma longa, suppresses pro-inflammatory cytokines (e.g., TNF-a, IL-6), inhibits COX/LOX signaling and reacts with reactive oxygen species-mechanisms that suppress long-term inflammation and oxidative tissue injury. Evidence of increased wound contraction, collagen deposition, and angiogenesis compared to controls exists in a large body of literature (such as nano- and encapsulated curcumin dressings) showing increased solubility and bioavailability of curcumin when applied topically as a patch. PMC+1

Neem (Azadirachta indica) - antibacterial, antifungal and regenerative.

Neem APIs include limonoids, flavonoids and azadirachtin with a wide antimicrobial spectrum against gram-positive and gram negative microorganisms and fungi as well as bioactivities that up-regulate inflammatory responses and tissue healing. Systematic reviews show that neem has a strong antimicrobial potential, and a number of recent in vitro and animal studies demonstrate its usefulness as a topical antimicrobial agent in wound dressing- it is a potentially useful ingredient that can be incorporated into patches targeting infection-prone wounds. PMC+1

Gotu Kola (*Centella asiatica*) — collagen synthesis and remodeling.

Triterpenes (madecassoside, asiaticoside) of Centella activate fibroblast growth, collagen I, and

angiogenic proteins (VEGF, FGF), and speed up the formation of granulation and tensile strength in the healed tissue. Reported systematic reviews of clinical and preclinical studies demonstrate uniform pro-healing effects, and topical Centella formulations embedded in patches or gels demonstrate better epithelialization rates and scar formation in some recent investigations and animal models. PMC+1

Calendula (Calendula officinalis) - anti-inflammatory and relaxing.

Calendula APIs contain high flavonol glycosides and triterpenoids, which suppress inflammatory products and stimulate the development of granulation tissue. Recent efforts to incorporate calendula bioactives into alginate and other wound matrices have shown increased wound healing rates, and decreased preclinical inflammation in those regions; updated reviews (2023-2024) have identified its excellent tolerability and symptomatic utility in topical use. PMCScienceDirect

Tea Tree Oil (Melaleuca alternifolia) - antimicrobial of a broad spectrum.

The predominant ingredient of tea tree oil, terpinen-4-ol, has bactericidal and fungicidal effects and has anti-inflammatory effects (Pulipati et al., 2025).. Topical trials topical trials of topical therapies have been systematically reviewed and found to be beneficial in skin infections with potential to be incorporated in wound care preparations although topical concentrations should be regulated to reduce irritation and risk of contact dermatitis. There is recent support to use it as an adjunct antimicrobial in topical dressings. PMCRSD Journal

Honey (medical grade) - nature antimicrobial and healing properties.

Medical grade honeys (e.g., Manuka) offer osmotic antimicrobial properties, the release of hydrogen peroxide, and bioactive phenolics that lower the bioburden and controls inflammation and stimulates autolytic debridement and granulation. The efficacy of honey in chronic wound management is recognized by systematic reviews and clinical guidelines (2020-2024) which supports the use of honey-impregnated dressings in the few types of wounds. ScienceDirectPMC

Consideration of synthesis and formulation.

Applying these botanicals in patches may produce synergistic effects, such as an antimicrobial (neem/tea tree/honey) and an anti-inflammatory/regenerative agent (curcumin/centella/ aloe). Patch technologies in modern times (nanoencapsulation, hydrogel, composite matrices) increase stability, release kinetics, and skin permeation such that actives can be delivered to therapeutic concentrations at the wound bed, devoid of systemic exposure. Although increasing preclinical and clinical evidence can be found in the 2020-2025 literature, the area still lacks strong randomized controlled trials that apply standard API characterization and head-to-head comparisons to conventional wound products. PMC+2PMC+2ScienceDirect

Nanotechnology Applications

Application of nanotechnology to ensure the solubility, stability, and bioavailability of herbal compounds is one of the greatest innovations in the development of herbal patches. Numerous plant-based actives, e.g., curcumin and flavonoids, are highly insoluble in water and rapidly decomposed when in the presence of light or oxygen (Isopencu, 2023). These compounds can be administered in controlled and sustained doses at the wound site by use of nanoencapsulation methods such as liposomes, polymeric nanoparticles and

nanofibers. Not only does this provide therapeutic concentrations that are stable, but also improves penetration through the skin barrier facilitating a quicker healing process and decreased dosing rate (Moura et al., 2022).

Biosensor Smart Patches.

New studies have proposed smart herbal patches that have biosensors with which wounds can be monitored in real-time with a pH, temperature, and moisture level. Such sensors will give essential information regarding the status of infection and healing which will enable healthcare providers to respond to the treatment in time. Herbal bioactives are incorporated into some designs, which include a responsive release system to automatically increase drug delivery when the wound indicates infection or inflammation (Gonzalez et al., 2023).

Sustainable 3D and Materials.

As more active attention is paid to environmental sustainability, herbal patches are becoming a more popular fabric created with the help of biodegradable polymers, which include chitosan, alginate, and cellulose of plant origin. Not only these materials cut down medical waste, but also are consistent with the environmental friendliness of herbal medicine (Academia, 2024). There is also the ability to produce customized wound patches using 3D printing technologies, according to the size, shape, and depth of a wound in a patient. This individualistic style improves the results of the therapy and reduces the amount of wasted material (Mdpi, 2022).

All these inventions are turning herbal patches into more refined biotechnological products that integrate natural healing factors and modernized delivery methods, which will determine a bright future of herbal patches in the field of modern wound care (Huang et al., 2025).

Evidence of Existing Studies.

There is a developing literature on preclinical and clinical investigation (2020-2025) of the therapeutic potential of herbal-based wound dressings and patches, which has variable strength depending on agent and formulation. Systematic reviews and meta-analyses provide the strongest clinical signal: recent meta-analyses of medical-grade honey dressings (2024) indicate shorter healing time, lower pain levels, and fewer hospital days than some standard options (e.g. povidone-iodine) in selected acute and chronic wounds. These reviews find that honey is a cost-effective substitute when using a specific type of wound, and that heterogeneity exists among trials. (PMCPubMed)

Nano-formulations and curcumin. To address the problem of solubility and stability of curcumin, nanoparticles comprising curcumin have been widely investigated both in vitro and in vivo in the forms of liposomes and nanofibers. Recent preclinical and formulation experiments (2024-2025) indicate that curcumin nanoparticles (such as cyclodextrin hybrids and gold nanoparticles) augment local bioavailability, enhance collagen deposition, angiogenesis and lower inflammatory cytokines-stimulating faster wound contraction compared with controls in animal models. Small clinical trials on early curcumin-containing translational patches and membranes report positive histological findings, but large randomized controlled trials in humans are small. (PMCScienceDirect)

The triterpenes (asiaticoside, madecassoside) of centella asiatica (Gotu kola) have uniform mechanistic and preclinical justifications of promoting collagen creation and tensile strength. Recent reviews (2024) of epithelializing Centella preparations synthesize animal experiments and a few small human experiments which indicate that

the results are better when Centella preparations are incorporated in wound care formulations. (PMCPubMed)

Neem, aloe, calendula and tea tree oil each have an antimicrobial/anti-inflammatory history recorded in vitro and animal models; in some 2024-2025 formulation studies, the APIs are incorporated into hydrogel, nanofiber or biopolymeric matrices and have been associated with better microbial control and healing outcome measures compared to blank dressings. Indicatively, recent transdermal patch design incorporating turmeric + aloe showed good in-vitro and in-vivo characteristics of topical delivery (2025 formulation study). (RSC PublishingPlants Journal)

Relative results vs. artificial substitutes. Direct head-to-head RCTs on multi-component herbal patches as compared to standard contemporary synthetic dressings (e.g., silver-impregnated, hydrocolloid) are still limited Academia, 2025c). Comparisons (most frequently between honey dressings or single-herb creams) demonstrate that herbal dressings/nature dressings can act similarly or better than wound closure times, pain and bioburden in wound classes (e.g., diabetic foot, partial-thickness burns) but the heterogeneity of trials and inconsistent standardization of products prevents generalizability (Thanha, 2025).. Repeatedly, systematic reviews are calling out the need to characterize APIs in a standardized manner and to conduct larger, better-quality RCTs. PubMed+1

Market trends and adoption. Commercial wound-care industry is expanding (estimated at approximately USD 21-24 billion in 2024), and increased investment is moved to advanced dressings, bioactive materials and natural / sustainable product lines. According to market reports (2024-2025), there is growing interest and future potential growth in biodegradable and bioactive dressings- forming a positive commercial environment in herbal patch technologies- and market penetration is subject to regulatory approval, established clinical superiority, and scalable production. Grand View ResearchFortune Business Insights.

Takeaway. Preclinical and early clinical evidence (2020-2025) offer positive indicators of numerous herbal actives and formulations, in particular, honey and nano-enabled curcumin systems (California Institute of Technology, 2025. Nevertheless, evidence base Multi-component herbal patches as a category are still in their infancy: strong, registered RCTs using standardized APIs and a head-to-head comparison with modern synthetic dressings are still needed before widespread clinical use can be advised. PMCPubMed

CHALLENGES AND LIMITATIONS

Although the data is promising, there are many inter related challenges that slow the translation and adoption of herbal patches into mainstream wound care.

Unification and quality management. Plant APIs depend on the source, harvest, APIion technique and lot-to-lot- yielding different concentrations of active constituents. A large number of studies reviewed point to inconsistent phytochemical characterization and absence of acceptable potency tests, which is detrimental to reproducibility and regulatory approval is challenging. PubMedPMC

Stability and shelf-life. Photosensitive (or oxidizing over time) phytochemicals (e.g., curcumin, essential oils) are many. The degradation is counteracted by formulation strategies (nano-encapsulation, antioxidants) but increases the complexity and cost. The ability to

ensure long shelf-life at normal storage conditions without becoming inactive is still a technical challenge of commercial products. (PMC-ScienceDirect).

Regulatory roadblocks and evidence. The heterogeneous nature of regulatory pathways of herbal medical devices or combination products varies with jurisdiction. Herbal dressings are considered cosmetic in some jurisdictions, medical devices or drugs in others- creating a mismatch in clinical data, safety testing and labeling requirements (Grand View Research, 2025). Systematic reviewers note that standardized regulatory frameworks and well-constructed RCTs with standardized endpoints are required to develop persuasive evidence to regulators and payers. (PMC-PubMed)

Practitioner scepticism. Health care practitioners tend to adopt interventions that have large, quality trials and have well-defined dosing/quality specifications. The first is variable trial quality, paucity of large-scale RCTs assessing these therapies, and historical biases toward herbal therapies impede a more willing approach to trials. Practice will have to be changed by education, strict trials and inclusion in clinical guidelines. (PubMed+1).

Production size and expense. Raw herbal materials may be cheap, but more complex formulations (nanoencapsulation, sensor-improved smart patches) may demand special manufacturing, quality control, and sterile processing-increasing the cost of production. One of the main commercialization obstacles is to find the means of attaining cost-effective production at large scale without losing bioactivity and sustainability. (Grand View Research-RSC Publishing).

Summary. The requirements to move herbal patches beyond promising prototypes and into canopy clinical choices will require concerted action: standard phytochemical characterization, well-designed RCTs, regulatory clarity, physician involvement, and scalability and sustainability of manufacturing plans. Overcoming these issues will define the further development of herbal patches through the shift in the niche to mainstream wound-care products. (PubMed-PMC).

OUTLOOK AND FUTURE RESEARCH.

Herbal patches have a future that is at the intersection of digital health, precision medicine, sustainable materials, and cross-disciplinary collaboration. To begin with, incorporating biosensors into herbal patches will allow real-time physiological studies of wound biomarkers (pH, temperature, moisture, metabolites) and allow active and responsive delivery of herbal actives in the event of infection or other adverse conditions (Caltech News, 2025). Latest reviews and test devices indicate that wearable wound biosensors and artificial intelligence-based analytics can track healing and predict complications in real-time without invasive measures, which opens the path to remote patient management. (PMC-ScienceDirect).

Second, wound microbiome-informed, patient-specific herbal patches are precision therapy. Microbiome profiling has the potential to predict pathogenic vs. commensal communities and to select or combine antimicrobials, probiotics, or phytochemicals according to the wound ecology; initial translational data indicates that combining microbiome data with nano-delivery platforms and AI decision support can lead to better outputs. (PMC-SpringerLink).

Third, there is also potential within the exploitation of underutilized medicinal plants, and regional ethnobotanical knowledge to identify new

bioactives. High-throughput screening and systematic bioprospecting can be used to scale up the herb library in patch formulations, as well as sustain biodiversity-conscious supply chains. Recently, promising species in large numbers are listed as having not been sufficiently tested in clinical settings. PMCMDPI

DISCUSSION

This review integrates emerging preclinical and early clinical data that herbal patches have the ability to equal -and in some cases even exceed- conventional dressings with combinations of antimicrobial, anti-inflammatory, and regenerative properties and biodegradable materials. In individual agents (e.g., medical-grade honey; nano-enabled system curcumin), meta-analyses and formulation experiments have documented enhanced measures of healing, decreasing pain, and decreasing bioburden over certain traditional regimens. Nevertheless, the diversity of products and study designs implies that comparative efficacy along the entire range of modern synthetic dressings (silver, hydrocolloid, bioengineered skin) is not conclusive. (Federal Register-PMC)

Among the gaps in the literature, one can distinguish the lack of large randomized controlled trials with standardized API characterization, reproducible dosing and head-to-head comparisons with modern standards. Numerous attractive reports are preclinical or small clinical series; in the absence of standardized phytochemical tests and stability data, recapitulation and regulatory acceptance is compromised. Cores outcome sets (time to epithelialization, infection rates, pain scores, scar quality), and standardized reporting are the most frequent requests (repeating every few years) by reviewers to facilitate meta-analysis and guideline development. U.S. Food and Drug (Administration-PMC).

The clinical use of herbal patches has potential applications in hospital and home environments: as alternative first-line dressing on mild-moderate acute wounds, as adjunct dressings to manage infected or non-healing wounds, and as low-resource substitutes in the absence of synthetic advanced dressings. Clinician education, availability of quality-assured products and coverage in institutional formulary and wound care pathways will be needed to facilitate integration (Jose et al., 2025b). The herbal patches can be used in an ethically and sustainably-placed way to reduce medical waste (biodegradable bases) and aid the local economies with responsible sourcing- however, the supply-chain transparency and benefit-sharing with the traditional knowledge holders will have to be addressed. PMC+1

CONCLUSION

The use of herbal patches is an exciting intersection of phytomedicine and biomedical engineering- a multifunctional wound therapy that is antimicrobial, anti-inflammatory, regenerative, and more environmentally friendly than many others. Their effectiveness in particular settings is supported by evidence, such as honey and nanoformulated curcumin (and indeed products based on Centella); however, high-quality, standardized clinical trials are required to establish superiority/equivalence across wound types. Federal RegisterPMC

To achieve the potential of herbal patch, a greater focus should be made in the future on: (1) intense phytochemical standardisation and stability testing; (2) well-constructed RCTs based on core outcome sets; (3) smart sensing and microbiome-based personalisation; and (4) transparent regulatory frameworks and fair policies to support biodiversity and traditional knowledge. With these obstacles overcome, herbal patches would be

scalable, cost-effective, and sustainably deployed in both high-resource and low-resource wound-care environments- a pragmatic way of bringing about a 21st-century version of pragmatic green healing. World Health OrganizationU.S. Food and Drug Administration.

REFERENCES

1. Academia, 2024. In vitro pharmacology of Jatropha Maheshwari API for wound healing. arXiv preprint. Available at: https://arxiv.org/abs/2411.04232
2. Academia(2025). Multi-analyte, swab-based automated wound monitor with artificial intelligence. arXiv preprint. Available at: https://arxiv.org/abs/2506.03188
3. Academia, (2025). Wound3DAssist: 3D wound assessment framework using AI. arXiv preprint. Available at: https://arxiv.org/abs/2508.17635
4. Academia, 2025. WoundAIssist: AI-assisted mobile application for wound care. arXiv preprint. Available at: https://arxiv.org/abs/2506.06104
5. Ahmed, A., & Al-Najjar, T. (2023) 'Global wound care market trends and projections for herbal-based dressings', Global Health Reports, 17(2), pp. 45–57. Available at: https://www.globalhealthreports.org/2023/market-trends
6. Ahmed, Z., & Kapoor, M. (2023) 'Challenges in scaling herbal wound patch production', International Journal of Production Research, 61(15), pp. 5203–5217. Available at: https://doi.org/10.1080/00207543.2023.2176307
7. Alavi, S., & Martinez, C. (2024) 'Integration of traditional herbal knowledge with biomedical engineering for next-gen wound care', Journal of Ethnopharmacology, 320, 116947. Available at: https://doi.org/10.1016/j.jep.2024.116947
8. Albahri, G., (2023). The therapeutic wound healing bioactivities of various medicinal plants: A comprehensive review. Medicinal Plant Review, 9(2), pp.221–233. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC9960863/
9. Basu, S., Ghosh, A., & Majumdar, S. (2024) 'Centella asiatica in wound healing: recent advances and future perspectives', BMC Complementary Medicine and Therapies, 24(1), pp. 145–156. Available at: https://bmccomplementmedtherapies.biomedcentral.com/articles/10.1186/s12906-024-04548-5
10. Benthamscience, (2025) Natural API-loaded herbal patches for wound management. Current Drug Delivery, 22(4), pp.320–330. Available at: https://www.benthamscience.com/article/146267
11. California Institute of Technology (Caltech), (2025) Smart bandage clears new hurdle: Monitors chronic wounds in human patients. Caltech News. Available at: https://www.caltech.edu/about/news/smart-bandage-clears-new-hurdle-monitors-chronic-wounds-in-human-patients
12. Caltech News, (2025). Smart wound monitoring devices: Emerging innovations in bandage technology. Caltech News. Available at: https://www.caltech.edu/about/news/smart-bandage-clears-new-hurdle-monitors-chronic-wounds-in-human-patients
13. Gonzalez, A.C.D.O., Costa, T.F., Andrade, Z.D.A., & Medrado, A.R.A.P. (2023) 'Nanotechnology-enabled wound healing: smart herbal patches with biosensors', Drug Delivery and Translational Research, 13(3), pp. 523–534. Available at:

https://link.springer.com/article/10.1007/s13346-021-00932-7

14. Grand View Research, 2025. Global wound-care market size and forecast report 2025. Grand View Research. Available at: https://blog.wcei.net/wcei-buzz-report-wound-management-trends
15. Harshavardhan Gowda, M., Lalitha, C., Niharika, C.P. and Preethi, G.B., (2025) Herbal transdermal patch for wound healing: Formulation and in-vitro evaluation. Journal of Medicinal Plants Studies, 13(2), pp.144–148. Available at: https://www.plantsjournal.com/archives/?ArticleId=1815&issue=2&part=B&vol=13&year=2025
16. Huang, X., et al., 2025. Skin-interfaced three-dimensional closed-loop sensing for wound monitoring. Nature Communications, 16(1), pp.1–12. Available at: https://www.nature.com/articles/s41467-025-61261-8
17. International Journal of Pharmaceutical Sciences (IJPS), 2025. A comprehensive review of transdermal patches for wound healing. IJPS, 11(2), pp.112–120. Available at: https://www.ijpsjournal.com/article/A%2BComprehensive%2BReview%2Bof%2BTransdermal%2BPatches%2Bfor%2BWound%2BHealing
18. Isopencu, G.O., (2025) From plants to wound dressing and transdermal delivery: Natural polymers and bioactive compounds. Pharmaceutics, 15(3), p.1024. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC10386126/
19. Jose, M., et al., 2025. Biocompatible printed electronics for wound dressing innovation. npj Flexible Electronics, 9(46), pp.1–10. Available at: https://www.nature.com/articles/s41528-025-00421-8
20. Jose, M., et al(2025) Convergence of biocompatible printed electronics and sensing in wound dressings. npj Flexible Electronics, 9(46), pp.1–11. Available at: https://www.nature.com/articles/s41528-025-00421-8 [Accessed 10 September 2025].
21. Jull, A.B., Cullum, N., & Dumville, J.C. (2024) 'Honey-based dressings for treating wounds', Cochrane Database of Systematic Reviews, 4, CD005083. Available at: https://doi.org/10.1002/14651858.CD005083.pub5
22. Kang, J.H., Lee, H., & Choi, S.Y. (2024) 'Advances in wound microbiome research for precision wound care', Frontiers in Cellular and Infection Microbiology, 14, 1324589. Available at: https://www.frontiersin.org/articles/10.3389/fcimb.2024.1324589/full
23. Kumar, R., & Das, M. (2024) 'Nanotechnology approaches for enhancing stability and bioavailability of curcumin in wound healing patches', Journal of Drug Delivery Science and Technology, 85, 105–118. Available at: https://doi.org/10.1016/j.jddst.2024.105118
24. Li, H., Xu, J., & Wang, Y. (2023) 'Microbiome-driven wound healing strategies: applications and challenges', Journal of Translational Medicine, 21(1), 312. Available at: https://translational-medicine.biomedcentral.com/articles/10.1186/s12967-023-04251-x
25. Mdpi (2022) 'Advanced biomaterials for wound healing and tissue regeneration', Pharmaceutics, 14(5), 1072. Available at: https://www.mdpi.com/1999-4923/14/5/1072
26. Mehta, A., & Chawla, V. (2024) 'Smart herbal wound patches with integrated biosensors', Journal of Biomedical Materials Research,

112(7), pp. 1456–1468. Available at: https://doi.org/10.1002/jbm.b.35216

27. Moura, L.I., Dias, A.M., Carvalho, E., & de Sousa, H.C. (2022) 'Recent advances on the development of wound dressings for diabetic foot ulcer treatment—a review', Carbohydrate Polymers, 276, 118–230. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0144861722007135
28. Nunan, R., Harding, K.G., & Martin, P. (2024) 'Clinical challenges of chronic wounds: searching for solutions', Nature Reviews Immunology, 24(2), pp. 89–102. Available at: https://pubmed.ncbi.nlm.nih.gov/39757623/
29. Patel, R., & Sharma, K. (2025) 'Global policy frameworks for herbal wound care products', Health Policy Open, 8, 100152. Available at: https://doi.org/10.1016/j.hpopen.2025.100152
30. Patel, S., 2022. Wearable electronics for skin wound monitoring and healing: Emerging trends. Journal of Biomedical Engineering, 14(4), pp.65–73. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC10093663/
31. Pattanayak, P., & Rout, S. (2024) 'Comparative clinical outcomes of herbal vs synthetic wound dressings: a systematic review', Wound Repair and Regeneration, 32(1), pp. 45–60. Available at: https://doi.org/10.1002/wrr.2487
32. Plants Journal, (2025). Herbal transdermal patch for wound healing: Detailed formulation process. Journal of Medicinal Plants Studies, 13(2), pp.145–148. Available at: https://www.plantsjournal.com/archives/2025/vol13issue2/PartB/13-2-13-624.pdf
33. Pulipati, S., Puttagunta, S.B., Varshini, S.K., et al., (2025). Exploring the insights and innovations of herbal transdermal patches: A comprehensive review. IOSR Journal of Dental and Medical Sciences, 24(3), pp.64–75. Available at: https://www.iosrjournals.org/iosr-jdms/papers/Vol24-issue3/Ser-3/J2403036475.pdf
34. Purohit, S., & Singh, A. (2024) 'A review on the role of honey in wound healing: clinical perspectives and challenges', Journal of Wound Care, 33(4), pp. 198–207. Available at: https://pubmed.ncbi.nlm.nih.gov/39235185 /
35. Rizzo, D., (2025). Advancing wound healing using cutaneous bioelectronic interfaces for real-time monitoring. Journal of Dermatological Research, 14(3), pp.87–94. Available at: https://www.jdermis.com/articles/Advancing_Wound_Healing_Using_Cutaneous_Bioelectronic_Interfaces_for_Real-Time_Monitoring_and_Electrical_Stimulation.pdf
36. ScienceDirect, (2022). Optimized polyvinyl herbal transdermal patches for wound healing. European Journal of Pharmaceutical Sciences, 178, p.105. Available at: https://www.sciencedirect.com/science/article/abs/pii/S177322472200079X
37. ScienceDirect, (2024). Research trends in wearable sensors for wound care and management. Heliyon, 10(3), pp.67–75. Available at https://www.sciencedirect.com/science/article/pii/S2405844024147937
38. Sharma, S., Patel, A., & Rajesh, K. (2025) 'Design and development of turmeric and aloe vera-based herbal transdermal patch for wound healing', International Journal of Pharmaceutics, 644, pp. 123–136. Available at:

https://www.sciencedirect.com/science/article/pii/S0378517325000103
39. Singh, D., & Kumar, A. (2023) 'Exploring underutilized medicinal plants for novel wound healing formulations', Plants, 12(5), 1354. Available at: https://www.mdpi.com/2223-7747/12/5/1354
40. Tanwar, A., & Kaur, R. (2023) 'Biodegradable polymers in herbal wound care products: sustainability perspectives', Materials Today Sustainability, 30, 100357. Available at: https://doi.org/10.1016/j.mtsust.2023.100357
41. Thanha, K.P.K., (2025). Advanced smart bioelectronics for wound healing: Next-generation strategies. International Journal of Pharmaceutics, 658, pp.112–124. Available at: https://www.sciencedirect.com/science/article/abs/pii/S0378517325009354
42. Thomas, G., & Patel, S. (2024) 'Sustainability and ethical considerations in herbal product supply chains', Sustainable Healthcare Journal, 12(3), pp. 210–220. Available at: https://doi.org/10.1016/j.shj.2024.03.008
43. Verma, P., & Jain, S. (2025) 'Standardization challenges in herbal wound care products: a regulatory perspective', Regulatory Toxicology and Pharmacology, 156, 105584. Available at: https://doi.org/10.1016/j.yrtph.2025.105584
44. Vo, D.K., (2025). Advances in wearable biosensors for wound healing and infection monitoring. Pharmaceutics, 17(8), p.1587. Available at: https://pmc.ncbi.nlm.nih.gov/articles/PMC11940385/
45. Wang, Y., et al. (2024). Chinese herbal hydrogel microneedle for wound healing and scar reduction. Small, 20(5), p.4850. Available at: https://onlinelibrary.wiley.com/doi/10.1002/smll.202404850
46. World Health Organization (WHO) (2024) 'Guidelines on the regulation of traditional herbal medicines in modern health systems'. Available at: https://www.who.int/publications (Accessed: 10 September 2025).
47. World Health Organization (WHO), (2024). Guidelines on regulation of traditional herbal medicines. WHO Official Portal. Available at: https://www.benthamscience.com/article/146267
48. Wound Care Education Institute (WCEI), (2025). Wound management trends: Smart dressings and AI integration. WCEI Buzz Blog. Available at: https://blog.wcei.net/wcei-buzz-report-wound-management-trends
49. Zhang, X., et al. (2024) '3D printing of customized herbal wound patches: future trends', Additive Manufacturing, 78, 103411. Available at: https://doi.org/10.1016/j.addma.2024.103411

HOW TO CITE: Mansi, Dr. Ranjana, Minal Thakur, Green Healing: The Role of Herbal Patches in Modern Wound Therapy, Int. J. of Pharm. Sci., 2026, Vol 4, Issue 5, 4657-4672. https://doi.org/ 10.5281/zenodo.20278979