Development of a Multifunctional Hydrogel-Loaded Herbal Patch Based on *Tridax procumbens* and *Moringa oleifera* for Blood Clotting and Infection Control

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Abstract- The present study focuses on the development of a multifunctional herbal patch incorporating a hydrogel system containing extracts of *Tridax procumbens* and *Moringa oleifera* for rapid blood clotting and prevention of wound infection. Natural medicinal plants have gained considerable attention in wound management because of their safety, biocompatibility, and therapeutic potential. *Tridax procumbens* is traditionally known for its hemostatic activity, while *Moringa oleifera* possesses significant antimicrobial, anti-inflammatory, and antioxidant properties. The combination of these herbal extracts in a hydrogel-based patch was designed to provide both immediate bleeding control and protection against microbial contamination.

The hydrogel patch was prepared using suitable biocompatible polymers to obtain adequate flexibility, moisture retention, and skin adherence. The prepared formulation was evaluated for physical appearance, thickness, swelling behaviour, pH, uniformity, mechanical strength, and stability. The antimicrobial activity of the patch was tested against common wound-infecting microorganisms, and blood clotting efficiency was assessed using standard in-vitro methods.

The developed herbal hydrogel patch demonstrated satisfactory physicochemical characteristics, enhanced moisture balance, and good adhesion properties. The formulation showed effective antimicrobial activity and significantly reduced clotting time, indicating its potential use as a wound care dressing. The synergistic effect of *Tridax procumbens* and *Moringa oleifera* contributed to improved healing support and infection control.

The study concludes that the multifunctional hydrogel-loaded herbal patch may serve as a safe, economical, and effective alternative to conventional wound dressings for minor cuts, bleeding wounds, and infection prevention.

Keywords- *Tridax procumbens*, *Moringa oleifera*, Hydrogel patch, Hemostatic activity, Antimicrobial activity, Wound healing, Herbal formulation.

I.INTRODUCTION

Wound Healing:

Wound healing is a complex, dynamic biomechanical process as the body attempts to restore the integrity of traumatised or devitalized tissues. Chronic wounds are defined as longstanding tissue injuries that cannot be treated with conventional methods of wound dressing or closure, either due to local tissue factors or systemic factors.[1]

Recently, chronic wounds have been described as "complex wounds," a term more representative of the multifactorial dynamic tissue healing process. For a wound to be classified as a complex wound, it should show one of the following features [2]

1. Persistent for more than three months
2. Compromised vascularity or necrosis
3. Presence of infection
4. Associated comorbidities impair healing potential.

Understanding what a wound dressing needs to achieve requires a basic understanding of how the body naturally heals itself. Wound healing is not a single event but a carefully orchestrated biological cascade comprising four phases that overlap both temporally and spatially.

Phase 1: Hemostasis (Minutes): Immediately upon injury, damaged blood vessels constrict reflexively. Exposed collagen in the subendothelial tissue activates circulating platelets, which aggregate and

form a temporary platelet plug. Simultaneously, the coagulation cascade is triggered, ultimately converting fibrinogen to fibrin, which stabilizes the platelet plug into a firm clot. This phase is rapid; effective hemostasis is usually achieved within 10 minutes in a healthy individual, but it is the gateway to everything that follows.

Phase 2: Inflammation (Hours to Days): Neutrophils and macrophages are recruited to the wound site. Their primary role is phagocytosis, the engulfment and destruction of invading bacteria and cellular debris. [3]

Phase 3: Proliferation (Days to Weeks): Fibroblasts migrate into the wound and begin synthesizing collagen, gradually building the new extracellular matrix. Angiogenesis restores blood supply. Keratinocytes at the wound margins proliferate and migrate inward in a process called re-epithelialization.

Phase 4: Remodelling (Weeks to Months): The initially disorganized collagen network is remodelled and cross-linked into a stronger, more organised scar tissue. This phase can continue for up to two years in deep wounds. give references

An ideal wound dressing should actively support the transition between these phases rather than passively covering the wound. It should stop bleeding (hemostasis), prevent infection (antimicrobial), maintain moisture (preventing eschar formation which impedes re-epithelialization), and ideally deliver compounds that accelerate cellular proliferation. [4-5]

Open wounds:
Open wounds are injuries that involve a break in the skin and leave the internal tissue exposed.

Types of open wounds:
1. Laceration: It refers to a skin tear that can extend to underlying tissues, caused typically by blunt force trauma. Unlike abrasions, there is no loss of skin. For deep or extensive lacerations, medical attention may be necessary especially if a cut shows persistent bleeding.

2. Puncture Wound: A puncture wound involves the creation of a hole through all layers of the skin due to accidental contact with sharp objects like needles or nails. Animal bites can also lead to puncture wounds. Immediate medical attention is crucial in such cases since exposure to metal and animal bites can be risky. Metals are often contaminated, and animal bites can introduce bacteria or viruses from the animal's mouth, potentially causing rapid and severe infections if not promptly treated by a

3. Burn Wound: Burns occur due to excessive exposure to various agents such as heat, electricity, radiation, chemicals, or lasers. While minor burns can be managed at home, serious burns necessitate immediate medical intervention. Burn injuries can be categorized by their severity [6]

Wound Care and Healing
Dressings can be used to protect the wound and promote healing, and can be selected based on the amount of exudate, location, and extent of the wound. In addition, wound care should include the prevention and treatment of infections. Infections can slow healing and increase the risk of serious complications, such as sepsis. Topical and systemic antimicrobials can be used to prevent and treat wound infections. It is also important to consider factors related to the patient's nutrition and hydration. Proper nutrition is essential for tissue repair, and malnourished patients may have an increased risk of delayed healing. In addition, proper hydration is important for maintaining good blood circulation and promoting wound healing. There are several types of wound care dressings available, each with different properties and benefits. Hydrocolloid dressings are useful for wounds with little exudate, while alginate dressings are suitable for wounds with moderate to high exudate. Foam dressings and hydrogel dressings are also common options for wound care. In addition to wound care itself, it is also important to evaluate and treat underlying factors that can delay healing. Poor circulation, malnutrition, diabetes and other chronic diseases can negatively affect wound healing and should be addressed in the care plan.[6]
Aim
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Control.

Objective

1. Collect and prepare herbal extracts from *Tridax procumbens* and *Moringa oleifera*.
2. To formulate a biocompatible hydrogel matrix using suitable polymers such as chitosan.
3. To incorporate herbal extracts into the hydrogel patch for sustained therapeutic activity.
4. To evaluate the hemostatic (blood clotting) activity of the prepared herbal hydrogel patch.
5. To assess the antimicrobial activity of the patch against common wound pathogens, such as:
   a. *Staphylococcus aureus*
   b. *Escherichia coli*
6. To study the swelling behavior and moisture retention capacity of the hydrogel patch.
7. To evaluate the physical properties of the patch, including flexibility, texture, and stability.
8. To investigate the synergistic wound-healing effects of the combined hydrogel and herbal system.
9. To develop a natural, cost-effective, and multifunctional wound dressing material for biomedical applications.

Plant profile information

1. *Tridax procumbens*: The Hemostatic Powerhouse
Walk along any roadside in rural Maharashtra during the monsoon season and you will almost certainly encounter *Tridax procumbens* a low-growing, slightly hairy herb with small yellow-white flowers that most farmers and gardeners would classify, without hesitation, as a weed. It thrives in disturbed soils, spreads aggressively, and is largely ignored by the agricultural community. Yet for generations, village healers in South and Southeast Asia have known something that modern pharmacology is only beginning to formally confirm: the crushed leaves of this unremarkable weed stop bleeding with remarkable efficiency.

Tridax procumbens belongs to the family Asteraceae (the daisy family). Originally a native of the tropical Americas, it has naturalised across tropical Africa, Asia, and Australia. In India, it is known by various names: Ghamra in Hindi, Kambarmodi in Marathi and features prominently in the informal wound-care practices of rural communities. It is, in botanical terms, a cosmopolitan weed. In pharmacological terms, it is a highly promising hemostatic agent. [7,8]

Fig 1. Photograph of Tridax procumbens (Coat Buttons)

- Common name: Coatbuttons
- Family: Asteraceae
- Kingdom: Plantae
- Biological source: *Tridax* consists of fresh leaves
- Chemical constituents: flavonoid, flprocumbenetin, fatty acid, polysaccharide
- Uses: To treat bronchial catarrh, diarrhoea, dysentery and liver diseases

Step 1 A: Tridax Procumbens Extraction:

Fresh leaves of *Tridax procumbens* will be collected from the western part of India, during the month of June and July and will be properly identified and authenticated. The plant extract will be prepared by blending and macerating the air-dried leaves of *Tridax procumbens* with 0.9% (w/v) Nacl solution and kept at 400 C for 24 hours for extraction to take place.
The resulting mixture will be filtered and the extract recovered from the filtration by evaporation under reduced pressure in a Rotavapor with water bath set at 400 C. The resulting residue will be weighed and reconstituted in 0.9% (w/v) Nacl solution to a final concentration of 2000 mg/ml and kept wet-frozen in ampoules until ready for use.

Moringa oleifera: The Antimicrobial and Regenerative Agent

A plant that has attracted so much popular and scientific attention that it risks being oversold. It has been called, variously, the "MiracleTree," the"Tree of Life," and the "Ben Oil Tree," and various parts of the plant roots, bark, seeds, and leaves have been used in traditional medicine across South Asia, Africa, and the Caribbean for conditions ranging from malnutrition to inflammatory disorders.

Fig 2. Moringa *oleifera*

- Common name: Drumstick tree
- Family: moringaceae
- Kingdom: plantae
- Biological source: moringa consist of fresh leaves,stick, flowers
- Chemical constituents: flavonoids, alkaloids, saponins, tannin.
- Uses: It is widely cultivated for its young seed pods and leaves, used as vegetables and for traditional herbal medicine. It is also used for water purification.

Step 1 B: Extraction procedure

Moringa oleifera L. leaves extract was produced by the maceration method. The simplicia weighed as much as 200 grams, then put into the maceration container and soaked with 70% ethanol, then stirred until homogeneous. Subsequently, it was closed immediately and then stored in a room that is protected from the sunlight for five days while stirring it occasionally. After soaking for five days, the extract is filtered by using filter paper to obtain the filtrate (liquid extract). Next, the liquid extract is collected in a container and then evaporated. The Moringa leaves extract was made in three levels, namely 2% b/v and 8% b/v. *Moringa oleiferaL*. leaf extract was weighed 0.2 gram for 2% b/v, 0.4 gram for 4% b/v, and 0.8 gram for 8% b/v in the petri dish, then each level was dissolved with Na CMC up to 10 ml and stirred until it was homogeneous, then labelled. [9]

Fig 3. Plant extract soaked in Ethanol

Fig 4. After 24 hours

Fig 5. Filtration of extract

Step 2

1. Dissolve 5 g of PVA in distilled water at a temperature of 80 c magnetic stirrer.
2. Add 1 g HPMC, slowly/ sodium alginate/gelatin slowly by stirring using a magnetic stirrer at a speed of 30 rpm for 30 min.
3. Add 2ml PEG 400 and 1ml glycerin.
4. Add 5 gm of *Tridax moringa* leaf extract to t h e volume 50ml while still stirring, and the temperature is maintained at 40 °C.
5. Preparation printed using a hydrogel patch printer, with a thickness of 0.5cm,

a. dry at 40 °C for 24 hours.

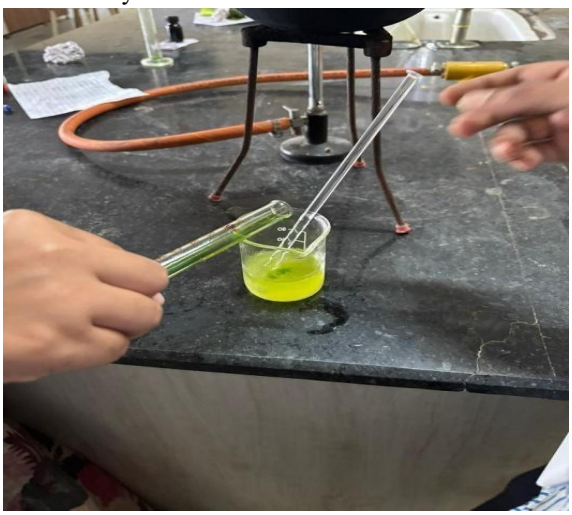

Fig 6. Adding plant extract into PEG 400 and 1ml glycerin

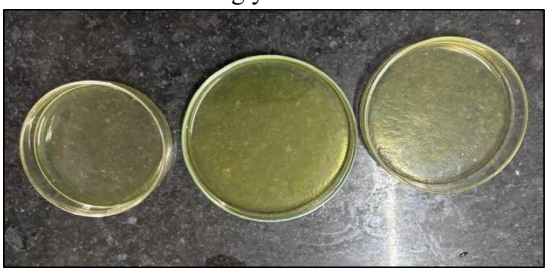

Fig 7. After 24 hours

The Synergistic Mechanism: A Phase Therapeutic Approach

The rationale for combining these two plants in a single delivery system is rooted in a concept well established in pharmacology: rational polypharmacy. Each extract addresses a different and sequential clinical need, and their combination creates a therapeutic profile that neither could achieve alone. Figure 11. illustrates this phased mechanism.[10]

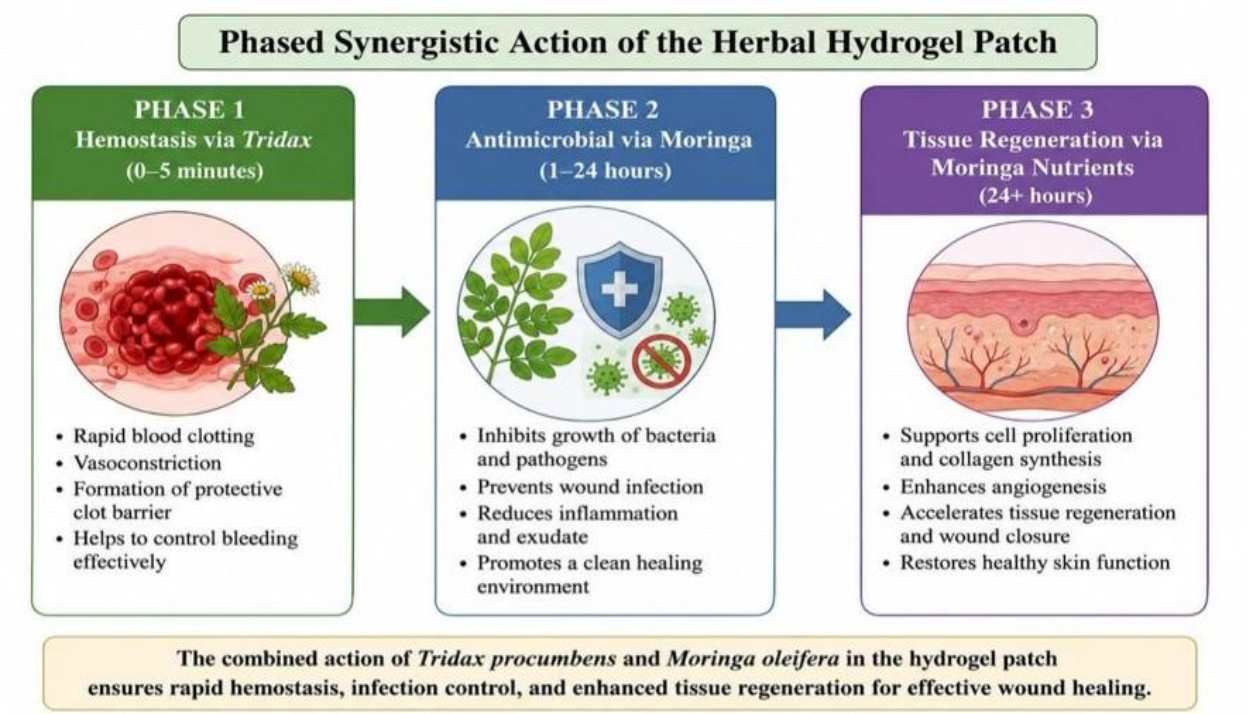

Figure11. Flowchart depicting the phased synergistic action of the herbal hydrogel patch: Phase 1 (Hemostasis via Tridax, 0–5 minutes), Phase 2 (Antimicrobial via Moringa, 1–24 hours), Phase 3 (Tissue Regeneration via Moringa nutrients,24+hours).

Phase 1. Immediate Hemostasis (0–5 minutes): Upon application to a bleeding wound, the hydrogel immediately absorbs blood and wound exudate. The hydrophilic polymer matrix swells, and the highly water-soluble *Tridax*tannins and alkaloids are mobilised into the wound fluid. Tannins precipitate wound surface proteins, physically sealing the capillary bed. Alkaloids stimulate local vasoconstriction. Together, these mechanisms dramatically reduce bleeding time.

Phase2. Antimicrobial Shield(1–24hours): As hemostasis is achieved and the inflammatory phase begins, *Moringa oleifera* compounds, particularly Pterygospermum permin and its isothiocyanate derivatives, are progressively released from the swelling hydrogel matrix as it absorbs more wound fluid. These compounds create a sustained antimicrobial environment within the wound, preventing the establishment of bacterial biofilms during the period of greatest infection risk.

Phase3. Tissue Regeneration Support(24+hours): As the wound transitions into the proliferative phase, the slow, sustained release of Moringa's vitamins, amino acids, and zinc provides the biochemical building blocks for collagen synthesis, fibroblast migration, and angiogenesis. The hydrogel matrix, gradually eroding, continues to maintain the moist microenvironment essential for epidermal cell migration. [11]

Factors Affecting Permeation

The principle transport mechanism across mammalian skin is by passive diffusion through primarily the trans-epidermal route at steady state or through the trans-appendageal route initially, at non-steady state. The factors that affect the permeability of the skin are classified into the following three categories:

A. Physicochemical properties of the permeate molecule

1. Partition coefficient: Drugs possessing both water and lipid solubility are favourably absorbed

through the skin. The transdermal permeability coefficient shows a linear dependence on the partition coefficient. Varying the vehicle may also alter the lipid/water partition coefficient of a drug molecule. The partition coefficient of a drug molecule may be altered by chemical modification without affecting the pharmacological activity of the drug.

2. Molecular size: There is an inverse relationship between transdermal flux and molecular weight of the molecule. The drug molecule selected as candidates for transdermal delivery tends to lie within a narrow range of molecular weight (100-500 Dalton).
3. Solubility / Melting point: Lipophilicity is a desired property of transdermal candidates as lipophilic hydrophilic molecules. Drugs with high melting points have relatively low aqueous solubility at normal temperature and pressure. Molecules tend to permeate the skin faster than others.
4. pH condition: The pH mainly affects the rates of absorption of acidic and basic drugs, whereas the unchanged form of the drug has better penetrating capacity. Transport of ionizable species from aqueous solutions shows strong pH dependence. According to the pH partition hypothesis, only the unionised form of the drug can permeate through the lipid barrier in a significant amount. [12,13]

B. Physicochemical properties of the drug delivery system partition

1. The affinity of the vehicle for the drug molecules: It can influence the release of the drug molecule from the carrier. Solubility in the carrier determines the release rate of the drug. The mechanism of drug release depends on whether the drug is dissolved or suspended in the delivery/carrier system and on the interfacial i. partition co-efficient of the drug from the delivery system to skin tissue.
2. Composition of drug delivery system: Composition of drug delivery system may affect not only the rate of drug release but also the permeability of the SC by means of hydration.
3. Enhancement of transdermal permeation: Due to the dead nature of the SC the release of the drug from the dosage form is less. Penetration enhancers thus can cause the physicochemical or physiological changes in SC and increase the penetration of the drug through the skin. Various chemical substances are found to possess such drug penetration-enhancing property. [14]

Physiological and pathological conditions of the skin:

1. Skin age: Foetal and infant skin appears to be more permeable than mature adult skin, and therefore percutaneous absorption of topical steroids occurs more rapidly in children than in adults. Water permeation has been shown to be the same in adults and in children.
2. Lipid film: The thin lipid film on the skin surface is formed by the excretion of sebaceous glands and cell lipids like sebum and epidermal cells, which contain emulsifying agent may provide a protective film to prevent the removal of natural moisturising factor from the skin and help in maintaining the barrier function of the SC.
3. Skin hydration: Hydration of SC can enhance transdermal permeability. The rate of penetration study of salicylic acid through skin with dry and hydrated corneum showed that when the tissues were hydrated, the rate of penetration of the most water-soluble esters increased more than that of the other esters.
4. Skin temperature: Raising skin temperature increases the rate of skin permeation. Rise in skin temperature may also increase vasodilation of blood vessels, which are in contact with skin, leading to an increase in percutaneous absorption. [15]

Pharmacological Properties

1. Antioxidant Activity: Flavonoids and phenolics neutralize ROS, reducing oxidative damage to tissues. In vitro studies demonstrate that ethanolic extracts achieve 80-90% DPPH scavenging at 100 pg/mL, protecting fibro blasts and keratinocytes from oxidative stress during the inflammatory phase of wound healing. Computational docking studies indicate flavonoids bind to growth factors (e.g., EGF, VEGF), enhancing cellular proliferation.

2. Anti-Inflammatory Effects: Triterpenoids and saponins inhibit inflammatory mediators, reducing edema and neutrophil infiltration. In rodent models, 5% ethanolic extract ointments decreased

TNF-o and COX-2 expression by 30-40%, accelerating the transition from inflammation to proliferation. This aligns with traditional uses for soothing burns and insect bites.

3. Antimicrobial Activity: Saponins and volatile oils disrupt bacterial and fungal cell membranes, with ethanolic extracts showing zones of inhibition of 18 + 2 mm (S. aureus) and 15 + 1 mm (E. coli) in vitro, comparable to gentamicin (20 + 1 mm). Green-synthesized silver nanoparticles (AgNPs) from leaf extracts, incorporated into chitosan gels (0.3 g/mL), reduced bacterial load by95%in infected wound models, addressing antibiotic-resistant pathogens.

4. Proliferative and Regenerative Effects: Procumbenase and flavonoids stimulate fibroblast migration (600/o closure in 24-hour scratch assays) and collagen synthesis, with a 2.53-fold increase in hydroxyproline levels (25.6 +2.1mg/g tissue vs. 10.1 + 1.5 mg/g in controls). Hexosamine levels rose by1.8-fold, and lysyl oxidase activity increased by 40%, enhancing extracellular matrix stabilization and tensile strength (450 30 g/cm2 vs. 280 25 g/cm2 in incision models).

5. Hemostatic and Astringent Properties: Tannins promote vasoconstriction and clot formation, reducing bleeding in fresh wounds. Leaf juice applications in traditional settings stop bleeding within minutes, forming a protective barrier that supports early wound closure. [16]

Evaluation

Physicochemical Evaluation

1. Organoleptic Properties:

Visual checks for colour, odour, texture, and smoothness. Thickness and Weight Uniformity: Ensures consistent thickness across the patch and uniform weight of the active ingredients.

2. Moisture Content and Uptake:

Assesses how much humidity the patch retains or absorbs to guarantee it remains stable and doesn't dry out in varying climates.

3. pH:

Confirms the patch is skin-friendly (typically in the \(5 - 9\) range) to prevent irritation or allergic reactions.

Fig 8. pH Paper

Fig 9. pH Meter

4. Skin Irritation Tests:

Conducted on animal or synthetic skin models to ensure the formulation causes no redness, swelling, or rashes. Antimicrobial & Anti-inflammatory Assays: Test the patch's effectiveness against common bacteria (like Staphylococcus aureus) or inflammation in lab environments.

Fig 10. Skin Irritation Tests

5. Adhesive Test:

The adhesive layer of the patch holds it in place for as

long as wanted and is nontoxic in order now not to irritate the skin. The substances for use in the patch, which include polymers, have to be non-poisonous and non-irritating, well-suited to the pores and skin.

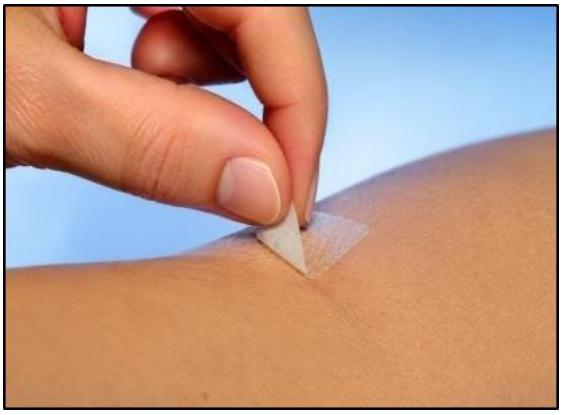

Fig 11. Adhesive Test

Results

1. Physical appearance

Sr.No.	Parameter	Formula
1.	Colour	Brownish Green
2.	State	Solid
3.	Thickness	0.3mm to 1.2mm

2. pH determination

Sr. No.	pH Paper Observation	pH Meter Range
1.	6.3	6.0 to 7.0

3. Sensitivity study observation

Sr. No.	Irritant Effect
1.	No

4. Adhesive strength

Sr No	Test	Result
1	Redness or inflammation	No
2	Itching, burning	No
3	Selling or development of a small blister	No

5. Swelling Index

The prepared hydrogel patch showed good swelling behavior, indicating its excellent fluid absorption capacity and hydrophilic nature. The patch absorbed an adequate amount of phosphate buffer solution and maintained its structural integrity during the study. The optimized formulation exhibited an appropriate swelling index, which is beneficial for maintaining a moist wound environment and promoting sustained drug release. The results confirmed that the formulated hydrogel patch possesses suitable swelling characteristics for effective wound healing application.

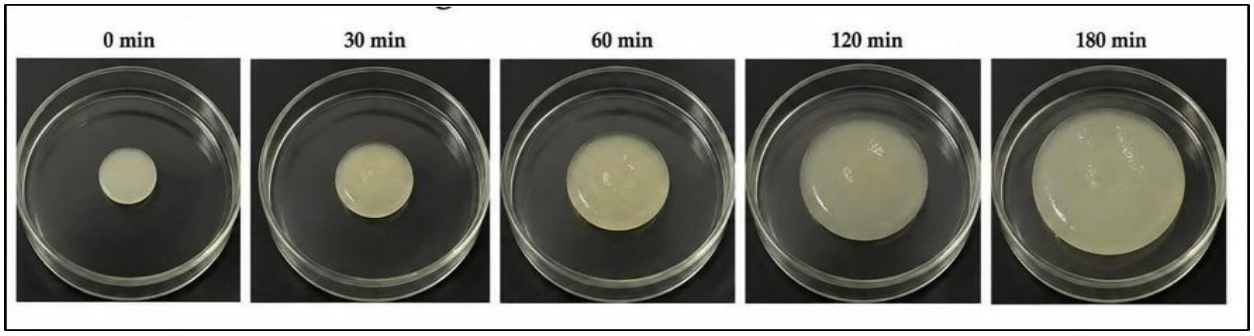

Fig 12. Swelling index

6. Antimicrobial Activity

The antimicrobial activity of the prepared hydrogel patch was evaluated against microorganisms by measuring the zone of inhibition. The formulated patch showed significant antimicrobial activity against the tested organisms, indicating effective inhibition of microbial growth. The optimized formulation exhibited a zone of inhibition, which may be due to the presence of active phytoconstituents from Tridax procumbens and Moringa oleifera extracts.

The results confirmed that the hydrogel patch shows good antimicrobial potential and can be useful for wound healing applications by preventing microbial infection

Fig 13. Antimicrobial activity

CONCLUSION

In the present study, an herbal hydrogel patch containing *Tridax procumbens* and *Moringa oleifera* extracts was successfully prepared and evaluated for wound healing applications. The developed patch showed good physical characteristics, proper flexibility, swelling capacity, and skin compatibility, making it suitable for topical use.

The combination of both herbal extracts provided multiple therapeutic benefits. *Tridax procumbens* helped in rapid blood clotting, while *Moringa oleifera* showed effective antimicrobial and healing-supportive properties. The formulation also maintained a moist environment around the wound, which is important for faster healing and protection from infection.

The antimicrobial and blood-clotting studies confirmed that the herbal hydrogel patch has the potential to control bleeding, prevent microbial growth, and support tissue repair. The synergistic effect of the selected herbal ingredients enhanced the overall wound healing activity of the formulation.

Therefore, the developed herbal hydrogel patch can be considered a natural, safe, cost-effective, and promising alternative to conventional wound dressings for the management of minor wounds and bleeding conditions. Further studies can be carried out to explore its clinical effectiveness and large-scale applications in wound care treatment.

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