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A COMPREHENSIVE REVIEW ON WOUND HEALING MECHANISMS AND THE THERAPEUTIC ROLE OF HERBAL MEDICINAL PLANTS IN WOUND MANAGEMENT

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ABSTRACT

Wound healing is a complex physiological process that restores the integrity and function of damaged tissues through a coordinated sequence of cellular and molecular events. The process consists of four overlapping phases: hemostasis, inflammation, proliferation, and tissue remodeling. Effective wound healing depends on the interaction of inflammatory cells, cytokines, growth factors, extracellular matrix components, fibroblasts, and keratinocytes. Wounds may result from physical, chemical, thermal, electrical, or biological injuries and are classified according to cause, depth, skin involvement, etiology, surgical contamination, and healing duration. Chronic wounds, particularly diabetic ulcers, pressure ulcers, and venous ulcers, remain a significant healthcare challenge because of delayed healing and increased susceptibility to infection. Herbal medicinal plants have been extensively utilized in traditional medicine for centuries owing to their antimicrobial, anti-inflammatory, antioxidant, analgesic, and tissue regenerative properties. Medicinal plants such as *Azadirachta indica*, *Ocimum sanctum*, *Symplocos racemosa*, *Psoralea corylifolia*, *Curcuma longa*, *Centella asiatica*, *Calendula officinalis*, and *Berberis aristata* contain bioactive phytoconstituents that promote collagen synthesis, angiogenesis, fibroblast proliferation, and epithelial regeneration while reducing microbial infection and oxidative stress. Traditional natural products including honey and ghee further enhance wound repair through their moisturizing, antimicrobial, and anti-inflammatory effects. This review summarizes the classification of wounds, the physiological stages of wound healing, and the therapeutic

significance of herbal medicinal plants in wound management. The available evidence suggests that herbal medicines represent promising, safe, and cost-effective alternatives or complementary therapies for improving wound healing and tissue regeneration.

KEYWORDS: Wound healing, Herbal medicine, Medicinal plants, Inflammation, Antimicrobial activity.

1. INTRODUCTION

The skin is the integumentary and protective barrier in the body which maintains the physiochemical and thermal homeostasis provide passive and active transport, and responds to trauma and injury. Wounds are one of the amongst medical problems faced by the society. Wound are lacerations or disruptions of the skin or cutaneous layer that affects structure and function of the skin or other body tissue. Generally, lesion are created by all the stimuli that disrupt the physical continuity of the functional and structure of the tissues. These injuries may results from internal or external as well as physical, chemical, electric or thermal factors. A wound that does not show healing for 6 weeks is called as chronic wound, such wounds undergoes organelle damage or whole cell damage.

Cutaneous wound healing is major physiological process involving the collaboration of many cells and their product. The regeneration and tissue repair process having a sequence of molecular and cellular events that occur after the onset of tissue lesion in order to restore the damaged tissue. Tissue repair Process consist a growth factor that promotecell proliferation, thus causing an integration of dynamic changes that involves soluble mediators such as blood cells, the production of extracellular matrix which involves in healing of lesion. Wound healing is primarily divided into three distinct phases such as Inflammation, proliferation and remodelling of the tissue. Wound healing is a Natural and self regulated process which involves dermal cells, epidermal cells, ECM-Extracellular matrix, plasma derived protein, cytokine and growth factors, They are act together to initiate and support healing process.

Fig: 1 Wound By External Forces.

Fig: 2 Type of Diabetic Wound.

1.1 Classification of Wounds

The wounds are classified on the basis of the following,

By Causes

- Intentional wound: Wound occur during incision
- Unintentional wound: Wounds occur *during accidents and trauma without our* knowledge.

By Skin

- Open wound: Wound are exposing the underlying tduring incision, abrasion
- Closed wound: Where the underlying tissues are damaged and the skin is intact, bruises.

By Depths

- Superficial wound: Wound on the surface of epidermis.
- Partial wound: Wound occur on dermis layer.
- Full and deep wound: The Wound occur incutaneous and damages the organ.

Surgical Wound

- Class : Uninfected operative wounds; there is no inflammation.
- Class 2: Not an unusual contamination.
- Class 3: Accidental wound it occur by any contamination.
- Class 4: There is an old traumatic wound (devitalized tissues).

By The Healing Period

- Acute: Wound can be healed within a shorter duration.
- Chronic: Wound can be healed after a longer period.

By Etiology

- Pressure ulcer: Wound by the prolonged period of pressure
- Diabetic ulcer: Due to neuropathy and poor circulation.
- Venous ulcer: Due to improper function of venous valves especially in the legs.
- Arterial ulcer: This is caused by insufficient blood flow to the tissues.

1.2 Phases of Wound Healing

Phase I (Hemostasis): This phase involves a sequence of complex reactions leading tohemostas is and clot formation. usually, the clot includes fibrin mesh with aggregated platelets embedded in it. The mesh which traps the Crimson- colored red cells that are the major factor of the clot plug. Activation of factor XII (coagulation). Early, recovery period of injury, formation of fibrin within the wound. Fibronectin is a type of glycoprotein that migrates and attaches the cell and plays crucial role in wound healing and maturing the dermis layer. Usually, fibronectin is formed by the fibroblast and epithelial cells. After, the hemostasis mechanism The epithelial cell produces prostacyclin that inhibits the platelet aggregation.

Phase II (Inflammation): It occurs almost 1to 6 days after injury. After the formation of the clot(phase-I) . The body, which triggers the inflammatory mediators and the injured cells and any other pathogen, releases the chemical signals such as growth factors and cytokines, which involve TNF alpha, IL-1, PDGF. Which is revealed with the aid of the edema and the erythema at the place of lesion. The fibrin community, which re-establishes the homeostasis and forms a barrier towards the invasion of microorganisms, organizes the temporary matrix of cellular migration, which restores the function of skin. Inflammatory cells play a vital position in wound recovery contributing to the release of lysosomal enzymes and unreactive oxygen species . Where the neutrophils and macrophages are activated. Then, Neutrophils which clear away theinvading microbes and debris through phagocytosis and macrophages will develop a growth factor that initiates the tissue regeneration phase, usually containing signs such as redness, warmth, pain and swelling which are necessary for defense and signaling repair.

Phase III (Granulation/Proliferation): After7 days The fibroblast has migrated into the wound, laying down new collagen of sub types I and III. Endothelial cells and keratinocytes proliferate into the wound, fibroblasts deposit collagen and form a granulation tissue, and their cells promote angiogenesis(new blood vessels). The wound is suffused with glycosaminoglycans(GAGs) and fibronectin produced via fibroblast, GAGs includes heparansulfate, hyaluronic acid, chondroitin sulfate and keratan sulfate. GAGs are bonded to a protein core and matrix deposition. The major role in wound recovery and This phase lasts 4 weeks in uncontaminated wound.

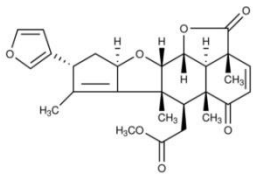
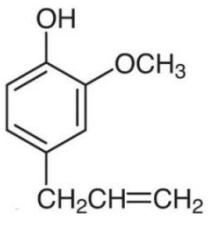
Phase IV (Remodelling Of Tissue): It begins 2 to 3 weeks after the onset of injury. The phase that produces maximum tensile electricity via degradation resynthesizes of the ECM and through reorganization. A normal tissue structure will occur and the granulation tissue is

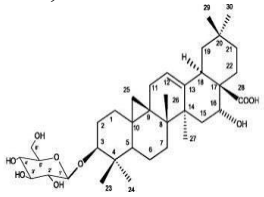
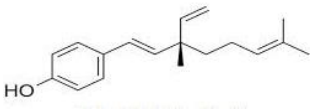
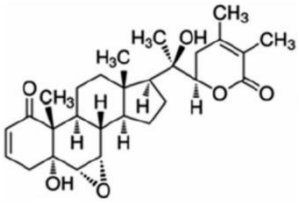
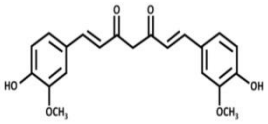
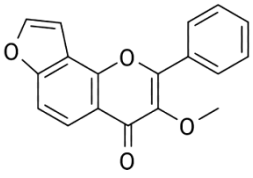
progressively revamped, and forming scar tissue exhibits growth in its attention to the collagen fiber. Collagen in the wound reorganised from the type III to type I, enhancing the tissue's strength. It reduces, and the variety of blood vessels in the wounded area decreases. After the 3rd week, the wounded area underwent steady change and the injury passed off. Maximum tensile strength of the wound is completed by the way of the 12^{th} week and results in scar best 80 % of tensile strength of the original skin that is replaced.

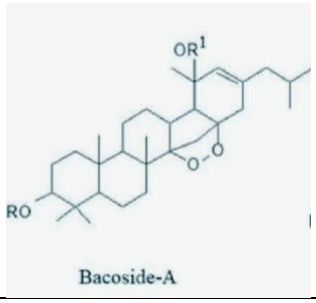
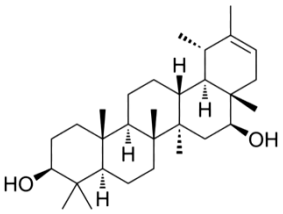
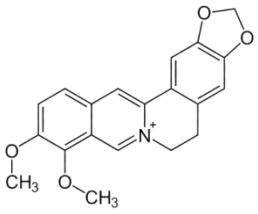
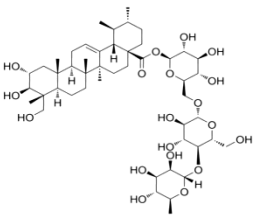
2. ROLE OF HERBAL PLANTS IN WOUND HEALING:

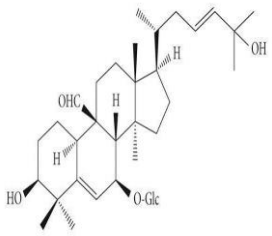
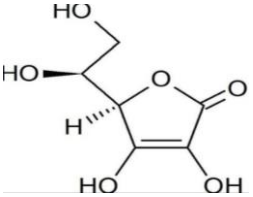
Many herbal plants have been reported to possess a wound-healing activity and are widely used in the treatment of wounds such as burns, cuts, ulcers. This article reviews about certain herbal plants such as Azadirachta indica, Ocimum sanctum, Psoralearacemosa, Psoralea corylifolia, Datura meteland know about the roles, properties and comparative study of herbal plants. The article mainly focuses on the herbal plants which having wound healing activity. Here, some example honey and ghee are chosen traditional medicine known for their healing benefits in Ayurveda and folk medicine, which are results through the scientific evidences available. several studies have demonstrated the role of individual applications of honey or ghee in wound management.

Table:1 Some Herbs With Botanical Name.

S. No	Common Name	Botanical Name	Phyto Constituents	Activity Of The Herb
1.	Neem 	"Azadirachta indica" family - meliaceae.	Azadirachtin, Nimbin, Nimbidin. 	Antibacterial, antifungal, anti-inflammatory.
2.	Tulsi 	"Ocimum sanctum Linn "family-lamiaceae.	Eugenol, carvacrol, linalool, ursolic acid. 	Antioxidant, adaptogenic, antibacterial.

3.	Lodhra 	"symplocos racemosa Roxb"family-symplocaceae.	Loturine, loturidine, catechin, sterols. 	Astringent, wound healing, antimicrobial.
4.	Bakuchi 	"Psoralea corylifolia Linn"family-leguminosae.	Psoralen, Isopsoralen, bakuchiol. 	Antimicrobial, anti-inflammatory.
7.	Datura Metel 	"Datura metel Linn"family-Solanaceae.	Atropine, Hyoscyamine, scopolamine. 	Antispasmodic, analgesic, sedative.
10.	Turmeric 	"Curcuma longa Linn"family-Zingiberaceae.	Curcumin, turmerone, demethoxycurcumin. 	Anti-inflammatory, antioxidant, wound healing.
11.	Karanja 	"Millettia pinnata"family-Fabaceae.	Flavonoids, fixed oil, phenolic compounds, triterpenoids. 	Skin diseases, ulcer, anti plasmodiac.

12.	Brahmi 	“Bacopa monnieri”family-Plantaginaceae.	Bacoside, saponins, alkaloids, glycosides. 	Anti-inflammatory, antioxidants.
13.	Marigold 	"Calendula officinalis”family-Asteraceae.	Flavonoids, Triterpenoids, *Carotenoids.* 	Minor cuts, Inflammation, anti-HIV.
14.	Daruharidra 	“Berberisaristata”family-Berberidaceae.	Alkaloids- berberine, flavonoids, phenolic compounds. 	Wound healing, Immunostimulant, laxative.
15.	Gotu Kola 	“Centellaasiatica”family-Apiaceae.	Pentacyclictriterpenoids, sesquiterpenes. 	Gastric ulcer, eczema, anxiety.
16.	Bitter Melon	“Momordicacharantia”family-Cucurbitaceae.	Flavonoids, phenolic compounds.	Antidiabetic, anti-inflammatory.

				
17.	Dragon Fruit 	"Hylocereusundatus"	Phenolic compounds, flavonoids and antioxidants. 	Anti-inflammatory, tissue regeneration.

3. DISCUSSION

Wound healing is a highly regulated biological process involving multiple cellular and molecular mechanisms that restore damaged tissue structure and function. Successful healing requires proper coordination between inflammatory cells, fibroblasts, endothelial cells, keratinocytes, extracellular matrix proteins, cytokines, and growth factors. The four sequential phases—hemostasis, inflammation, proliferation, and remodeling—occur in an overlapping manner to achieve complete tissue repair.

Initially, hemostasis prevents excessive blood loss through platelet aggregation and fibrin clot formation while providing a scaffold for migrating cells. During the inflammatory phase, neutrophils and macrophages remove microorganisms and necrotic tissue while secreting cytokines and growth factors essential for tissue regeneration. The proliferative phase is characterized by fibroblast proliferation, collagen deposition, angiogenesis, and re-epithelialization, resulting in granulation tissue formation. Finally, the remodeling phase strengthens the repaired tissue through collagen maturation and extracellular matrix reorganization, although healed tissue generally regains only about 80% of its original tensile strength.

Chronic wounds, including diabetic, pressure, venous, and arterial ulcers, often exhibit prolonged inflammation, impaired angiogenesis, oxidative stress, microbial infection, and

delayed collagen synthesis. These complications increase treatment duration, healthcare costs, and the risk of morbidity, emphasizing the need for effective and affordable therapeutic interventions.

Herbal medicinal plants have emerged as valuable sources of wound-healing agents due to the presence of diverse phytochemicals such as flavonoids, alkaloids, terpenoids, tannins, glycosides, phenolic compounds, and essential oils. Plants such as *Azadirachta indica* (Neem) possess potent antimicrobial and anti-inflammatory properties that reduce wound infection. *Ocimum sanctum* (Tulsi) exhibits antioxidant and antibacterial activities that protect tissues from oxidative damage. *Curcuma longa* (Turmeric) contains curcumin, which suppresses inflammatory mediators, enhances collagen synthesis, and accelerates tissue regeneration. *Centella asiatica* stimulates fibroblast proliferation, collagen production, and angiogenesis, thereby improving wound contraction and scar maturation. Likewise, *Calendula officinalis*, *Berberis aristata*, *Symplocos racemosa*, and *Psoralea corylifolia* contribute to wound repair through antimicrobial, antioxidant, and regenerative mechanisms.

Traditional remedies such as honey and ghee have also demonstrated significant wound-healing potential by maintaining a moist wound environment, preventing microbial growth, reducing inflammation, and promoting epithelialization. Their integration with herbal formulations offers additional therapeutic benefits.

Overall, current evidence indicates that herbal medicines provide a promising complementary approach for wound management. However, further pharmacological investigations, standardization of herbal formulations, toxicity studies, and well-designed clinical trials are required to validate their efficacy and ensure their safe clinical application.

4. CONCLUSION

Wound healing is a dynamic and complex biological process involving coordinated interactions among cells, cytokines, growth factors, and extracellular matrix components. Delayed wound healing, particularly in chronic wounds, remains a major clinical challenge. Herbal medicinal plants represent an important source of bioactive compounds with antimicrobial, anti-inflammatory, antioxidant, and tissue regenerative properties that effectively support different stages of wound repair. Plants such as *Azadirachta indica*, *Ocimum sanctum*, *Curcuma longa*, *Centella asiatica*, and *Calendula officinalis* have demonstrated considerable therapeutic potential in promoting collagen synthesis, angiogenesis, epithelialization, and wound contraction. The incorporation of traditional natural products such as honey and ghee further enhances healing outcomes. Although

available scientific evidence supports the effectiveness of herbal therapies, additional standardized experimental studies and clinical trials are essential to establish their safety, efficacy, dosage, and mechanisms of action. Herbal medicines therefore offer promising, economical, and biocompatible alternatives for future wound management and tissue regeneration strategies.

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