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Unlocking the Potential of Medicinal Plants in Treatment of Wound Healing: A Systematic Review

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Abstract

Wound healing, a natural process, involves the restoration of injured tissue. However, the pace of healing is often slow, and the risk of microbial infection is significant, necessitating substances that accelerate the healing process. Medicinal plants, historically employed to address ailments like ulcers, wound healing, skin infections, and inflammation, have demonstrated efficacy in treatment of wound through diverse mechanisms. These mechanisms involve the up-regulation of VEGF and TGF-β, activation of NF-κB, enhancement of iNOS and alpha-1 type-1 collagen expression, and antioxidant activity. Wounds can be categorized as acute or chronic, depending on the underlying cause. Acute wounds typically result from cuts or surgical incisions, while chronic wounds are those that fail to undergo the normal healing processes, leading to pathologic inflammation. The utilization of medicinal plants in wound healing is longstanding, with various plants traditionally employed to treat cuts, wounds, and burns. For instance, Aloe vera and H. rosasinensis expedite wound healing by enhancing the production of VEGF and TGF-β, crucial for angiogenesis. Additionally, the PI3K pathway plays a vital role in wound healing by facilitating cell proliferation. Medicinal plants have demonstrated the ability to treat wound healing by the PI3K pathway.

Keyword: Wounds, Medicinal Plants, Wound Healers, Plant extracts

INTRODUCTION

Medical plant materials and the herbal treatments derived from them constitute a significant portion of the global medical market. Across history, herbal remedies and therapies have held a pivotal role in the treatment of various diseases. Despite the extensive literature documenting their healing properties, there remains a less standardized procedure for quality control concerning the identification of plant materials. Standardization of herbal plants ensures uniformity and pharmacological actions. Herbal products undergo rigorous testing for identification (characterization), quality, and the presence of extracts, as it is crucial to assess their medicinal efficacy, including understanding their pharmacological action, to establish authenticity. [1] Herbal remedies has the ability to treat different disorders such as ulcers, wound healing, skin infections, inflammation leprosy, venereal disease. [2] Debridement, disinfection, and maintaining a moist environment to facilitate optimal natural healing are among the herbal remedies employed in wound care. Various cultures with rich folklore traditions utilize a diverse range of plants for treating cuts, wounds, and burns. [3,4]

Wounds are characterized by the disruption of a tissue's cellular and anatomical continuity, whether or not microbial infection is present, resulting from accidents or cuts with sharp edges. While it is a natural process by which the body addresses tissue damage, the healing rate is often slow, and the risk of microbial infection is significant. This underscores the demand for substances that expedite the healing process. Wound healers play a decisive role in the arsenal of essential medications for soldiers, facilitating their swift return to the battlefield. Moreover, wound healers diminish the need for different treatments such as antibiotics, thereby reducing the potential adverse effects associated with their use.[5] India has a long history of plant-based expertise in healing. In India, tribals and folklore traditions employ a wide range of plants, plant extracts, decoctions, and pastes to cure cuts, wounds, and burns. Aside from that, there is no synthetic medicine formulation on the market that may make claims about wound healing qualities. The medications available are either bacteriostatic or bactericidal, and in these circumstances, healing is solely due to natural phenomena. [6,7]

Different types of wounds

Wounds are generally classified according to their underlying causes.

Acute wounds

Acute wounds induce tissue damage or injury, initiating a sequential reparative phase that systematically restores both anatomical and functional integrity. These wounds commonly result from any type of cuts and surgical incisions. [8]

Closed wounds

In these types of wounds, blood exits in the circulatory system of body but remains contained within the body, often manifesting as bruises.

Open wounds

Blood exits the body through an open wound, leading to visible bleeding. Open wounds can be classified into various types depending on their cause.

Incised wounds

This wound involves minimal tissue injury without any tissue loss, typically caused by sharp instruments like scalpels and knives.

Tear or laceration wounds

This non-surgical injury commonly occurs alongside other types of trauma, leading to tissue loss and damage.

Puncture wounds

These are caused by an instrument, such as a nail or a needle, puncturing the skin. Infection is prevalent in these wounds because dirt can enter deeply.

Abrasive or superficial wounds

Falling on to a coarse surface results in abrasion, where the top layer of the skin, known as the epidermis, is scraped away, exposing nerve endings and causing discomfort.

Penetration wounds

Penetration wounds commonly occur when an object, like a knife, enters and exits the skin.

Gunshot wounds

They are frequently the result of a bullet or a comparable object passing through or penetrating the body.

Chronic wounds

Chronic wounds are those that fail to undergo the typical healing processes, leading to pathological inflammation and necessitating prolonged recovery periods. [9]

Mechanism of medicinal plants in wound healing

Medicinal plants facilitate wound healing through various mechanisms, such as up-regulating VEGF and TGF-β, activating NF-κB and interleukin-8, enhancing the expression of iNOS and alpha-1 type-1 collagen, and exhibiting antioxidant properties. Examples like Aloe vera and

Hibiscus rosa-sinensis promote wound healing by enhancing the production of VEGF and TGF-β. [10] VEGF's role in angiogenesis is well-established. These growth factors act on their respective receptors in keratinocytes and macrophages, playing vital roles in wound healing processes. In cases of chronic and non-healing wounds, inadequate vascularization is often observed. Studies on diabetic animal models have reported delayed wound healing, with impaired vascularization identified as the underlying cause for delayed wound closure, epithelialization, and granulation tissue development. [11] The pivotal role of VEGF in angiogenesis is widely acknowledged. These growth factors engage with their distinct receptors in keratinocytes and macrophages, executing essential functions in wound healing processes. Chronic and non-healing wounds are distinguished by inadequate vascularization. Studies using diabetic animal models have illustrated delayed wound healing, wherein impaired vascularization is attributed to delayed wound closure, epithelialization, and the development of granuloma tissue. [12] The PI3K pathway plays a critical role in wound healing by fostering cell proliferation. Activation of the PI3K pathway leads to the phosphorylation of Akt (serine/threonine-specific protein kinase) at serine 473. This signaling cascade has been demonstrated to be essential for the targeted migration of corneal and skin epithelial cells following damage or injury [13]. Research has indicated that medicinal plants facilitate wound healing through the PI3K pathway. For instance, C. officinalis tincture enhances wound healing by triggering the PI3K pathway. Similarly, an aqueous extract of Korean red ginseng stimulates both in vivo and in vitro angiogenesis by activating the PI3K/Akt pathways.[14] Chronic inflammation triggers NF-κB activation in both immune and non-immune cells. This activation results in heightened production of pro-inflammatory mediators, contributing to tissue damage. Conversely, inhibiting NF-κB may lead to harm and inflammatory conditions, as per multiple studies. Recent research indicates that NF-κB plays a beneficial role in epithelial cells, aiding in the preservation of immunological balance within these cells. [15] Plant extracts have demonstrated the ability to activate NF-κB, thereby fostering wound healing. For example, C. officinalis n-hexane extract augments NF-κB activity in human immortalized keratinocytes and dermal fibroblast cells.[16) The impact of recombinant interleukin-8 on HaCaT keratinocyte migration and adhesion was assessed. Interleukin-8 was found to enhance the migration and adherence of HaCaT keratinocytes. Intriguingly, inhibiting phospholipase C-γ (PLC-γ) completely halted HaCaT keratinocyte migration, indicating that interleukin-8 directs migration through the PLC-γ pathway. Furthermore, medicinal plant extracts also contribute to wound

healing by stimulating interleukin-8 activity. The n-hexane extract of C. officinalis was identified as enhancing interleukin-8 activity in human immortalized keratinocytes. [16] Nitric oxide is a small radical molecule. NO synthesis has been observed during the proliferative phase following wound formation. Elevated iNOS expression stimulates the release of NO, which influences collagen production, cell proliferation, and wound contraction. [17] Furthermore, iNOS controls keratinocyte growth. [18]

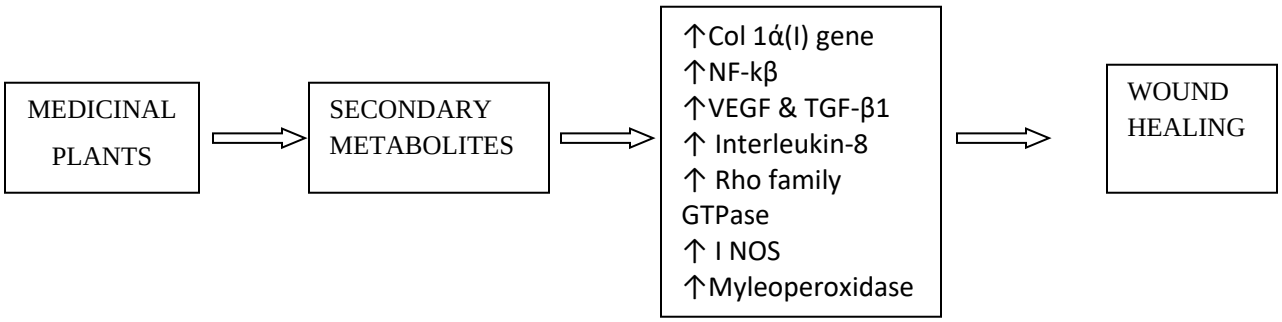

Fig. 1: Mechanism of medicinal plants in wound healing

The polysaccharide-rich extract of C. ferrea has been shown to boost iNOS activity. The Col 1α (I) gene encodes alpha-1 type 1 collagen. This gene promotes wound healing by producing the pro alpha-1 (I) chain, a component of type 1 collagen. This pro alpha-1 (I) chain is coupled with another pro alpha-1 (I) chain as well as a pro alpha-2 (I) chain to form a molecule of type I pro-collagen, which is then processed and rearranged to make type 1 collagen fibres. Topical use of D. elata ointment increases alpha-1 type 1 collagen, encoded by Col 1α (I) gene, which aids in wound healing. Rho family GTPases such as Rac-1, Rho-A, and Cdc-42 play a critical role in fibroblast cell proliferation and migration. [19] Cyclins, as well as cyclin-dependent kinases 1 and 2, play a role in the development of the cytoskeleton in fibroblasts. [20] C. tamurana has been

shown to promote mammalian cell migration to the damaged area by activating Rac-1, Rho-A, and Cdc-42 m-RNA, as well as Cdk 1 and 2 genes. Many shreds of evidence imply that wounds endure oxidative stress as a result of increased neutrophil activity, oxidants, and MPO activity. Increased neutrophil activity, resulting from oxidants and MPO activity, causes tissue destruction in chronic wounds. [21]

Healing of wounds

Wound healing occurs in three phases: inflammatory, proliferative, and remodelling. The inflammatory phase begins immediately after the damage and can extend up to 48 hours, and in some circumstances up to two weeks. This phase's hemostatic processes, which include vasoconstriction and platelet aggregation, stop bleeding immediately. Then vasodilation and phagocytosis occur at the location of the wound, causing inflammation.[22]

The proliferative phase commences subsequent to the inflammatory phase and extends for two to three weeks. Throughout this period, collagen fibers amass, and neovascularization occurs. The wound edges converge to reduce the wound area, while epithelial tissues form over the wound. The remodeling phase may persist for anywhere from three weeks to two years. During this phase, cross-linking between collagen fibers is enhanced through vitamin C-dependent hydroxylation, thereby increasing the tissue's tensile strength.[23]

Potential of Medicinal plants in wound healing

Numerous medicinal plants exhibit wound-healing properties. Extensive research has been conducted on the management of wound healing using medicinal plants. Below are some recent studies highlighting the significant wound healing efficacy of medicinal plants:

Aloe (Aloe vera)

Aloe vera contains various natural bioactive chemicals, including glycosides, polysaccharides, saponins, pyrocatechol, anthraquinones, acemannan, phytol, oleic acid, and water-soluble polysaccharides. Among these, acetone extracts of Aloe vera leaves demonstrate stronger antibacterial activity compared to alcohol and aqueous extracts. Gram-positive bacterial species are more susceptible to Aloe vera than gram-negative species. Saponins, acemannan, and anthraquinone derivatives possess antibacterial properties that have been confirmed. Acemannan, a significant Aloe vera mucopolysaccharide (mesoglycan), activates macrophages and T cells,

enhancing proinflammatory mRNA transcription, including IL-1α, IL-1β, IL-6, TNF-α, PGE2, and nitric oxide. Mesoglycan components bind to and neutralize endogenous mitogenic inhibitors and reactive oxygen species, facilitating phagocytosis. Additionally, glycans stabilize secreted cytokines, growth factors, and other bioactives, prolonging their activity. [24] The application of acemannan topically has been demonstrated to significantly reduce the duration required for wound closure by modulating the cyclin D1 and AKT/mTOR signaling pathways. [25]

Gingko biloba

Belonging to the Gingkoaceae family and commonly known as the Kew tree, Ginkgo biloba is extensively cultivated in Korea and China, propagated through seeds and vegetative methods. Studies have demonstrated its potent effects against dead space and excision wound models in male rats. Administration of a dose of 50 mg/kg significantly enhanced the breaking strength and hydroxyproline content of granulation in dead space wounds. Additionally, in the excision wound model, it was observed to reduce the duration of epithelization. G.B. activity is attributed to its high amino acid content, which quickly absorbed in the bloodstream and, when combined with vitamins, promotes wound healing by providing vital nutrients. In ancient Chinese medicine, it was utilised not just for wound healing but also as an anti-inflammatory and antiallergenic agent.[26]

Neem (Azadirachta indica)

Its efficacy in wound dressing was widely acknowledged due to its anti-ulcer, antifungal, antibacterial, antiviral, anticancer, and antioxidant properties. [27] The biocomposite film demonstrates significant anti-inflammatory and nitric oxide scavenging properties. Subsequently, the authors evaluated the antioxidant activity and biocompatibility of the collagen film incorporating neem extract using RAW 264.7 cell lines. Incorporating 400 μg/mL of neem extract into collagen films increased DPPH scavenging by 80% and cell viability by over 80%, as indicated by MTT assay results. Researchers explored the electrospinning potential of four different plant extracts—A. Indica, Indigofera aspalathoides, Memecylon edule (ME), and Myristica andamanica—combined with PCL for skin tissue engineering. A cell proliferation assay was employed to study the growth of human dermal fibroblasts (HDFs) on nanofibrous scaffolds, while F-actin and collagen staining were used to evaluate the interaction between

HDFs and scaffolds. The results indicated that HDF proliferation on PCL integrated with M. Edule was the lowest among all samples, yet it was 31% higher than PCL nanofibers alone after 9 days. Incorporating M. Edule into PCL led to increased cell density, with F-actin analysis confirming significant cell-to-cell contact. Collagen staining demonstrated the secretion of extracellular matrix (ECM) by cells on M. Edule-incorporated PCL. Moreover, M. Edule extract combined with nanofibers could enhance epidermal differentiation markers when exposed to human adipose-derived stem cells (ADSCs). [28]

German chamomile (Chamomilla recutita)

The research focused on assessing the efficacy of electrospun nanofibrous membranes made from poly caprolactone/polystyrene (PCL/PS) as wound dressings enriched with chamomile extract. Chamomile (C. Recutita (L.) Rauschert), belonging to the Asteraceae family, contains specific phenolics and flavonoids such as apigenin, quercetin, patuletin, luteolin, and their glucosides. Apigenin, a rare flavonoid found in chamomile, has been noted for its significant impact on wound healing. In vitro studies on antibacterial and antifungal properties demonstrated that the nanofibers exhibited effectiveness against microorganisms like Staphylococcus aureus (bacteria) and Candida albicans (fungi), with inhibitory zones measuring approximately 7.6 mm in diameter. Cell adherence and viability of mesenchymal stem cells on the nanofibers were confirmed through MTT assays. According to the authors, nanofibers infused with 15% chamomile extract could achieve a viability rate of 99 ± 60 percent, with approximately 5% of the wound area being healed after 14 days of treatment, as evidenced by a rat wound model. Wound inspection revealed enhanced reepithelization and collagen accumulation in dermal tissue, along with the absence of necrosis.[29]

Nelumba nucifera

Nelumbo nucifera, part of the Nymphacaceae family, is referred to as "Kamal" in Hindi and "Lotus" in English. It's a perennial aquatic herb that thrives in muddy environments, boasting large blossoms. Typically found in ponds and marshes, it reproduces using rhizomes. Nelumbo nucifera holds significance among natural and traditional healers who harvest its leaves and rhizomes, dry them, and burn them to produce ash, believed to possess wound-healing properties. Recent studies propose that utilizing a methanolic extract of Nelumbo nucifera rhizomes in ointment formulations can effectively treat various wound models in rats. The

impact was assessed across the excision wound model, the incision wound model, and the dead space wound model utilizing two distinct ointment concentrations (5% w/w and 10% w/w). In all concentrations, the ointment exhibited significant effects in all wound models. The extract ointment demonstrated substantial effects on wound contraction activity, wound closure duration, tensile strength, tissue regeneration at the wound site, and lysyl oxidase activity. [30]

Turmeric

It's alternatively referred to as Indian saffron or curcuma. This herb comprises both dried and fresh rhizomes from the Curcuma longa plant, a member of the Zingiberaceae family. It contains no less than 4% volatile oil. India contributes up to 90% of the global production. Curcuma longa stands as the most economically significant species, with rhizomes cultivated in India, China, and Sri Lanka. India leads in cultivation, with nearly 80,000 hectares devoted to producing 144,000 tonnes annually. The plants are cultivated for 7 to 9 months before harvesting the rhizomes, which are then subjected to roasting, drying, and processing into powder, oleo-resin, and curcumin. Powder extraction involves the use of solvents, water, or a combination of both. Containing approximately 5% volatile oil and resin, it consists primarily of starch grains, curcuminoids, and sesquiterpenes such as α and β pinene, α-phellandrene, camphor, and zingiberene. It serves as a condiment, spice, and coloring agent, especially in ointments and creams. Additionally, it finds utility in detecting boric acid. Traditionally, it has demonstrated anti-inflammatory, anti-cancer, and antiseptic properties. [31]

Bael

Also referred to as Bael Fruits or Indian Bael, it is derived from unripe or ripe fruits of the Aegel marmelos plant, belonging to the Rutaceae family. Endemic to India, it is also found in Myanmar and Sri Lanka. The pulp, with its crimson hue, offers a mucilaginous, astringent taste. The primary medicinal component is marmelosin, a furocoumarin. Additionally, it contains carbohydrates, proteins, volatile oil, and tannins. Rich in vitamins C and A, the pulp also contains two alkaloids, Omethylhalfordional and isopentylhalfordinol, identified from the fruits. Its applications include aiding digestion, stimulating appetite, and treating diarrhea and dysentery. Furthermore, it serves as a tonic, known for its wound-healing properties. [32]

Tulsi

This extract is derived from the herb Ocimum sanctum, belonging to the Labiatae family. Widely cultivated globally, it is a popular choice in gardens. Traditionally, Ocimum sanctum has been employed to address malarial fever, gastrointestinal issues, and hepatic infections. Additionally, its leaves are utilized for treating bronchitis, ringworm, skin ailments, and earaches. Known for enhancing nerve function and memory, Ocimum sanctum leaves are rich in tannins like gallic acid and chlorogenic acid, along with alkaloids, glycosides, and saponins, besides volatile oil. Notably, urosolic acid is a prominent active component of Holy Basil leaves, containing approximately 70% eugenol, carvenol, and eugenol-methylether. [33]

Eucalyptus

Also known as Dinkum Oil, this oil is derived from the steam distillation of fresh Eucalyptus globulus leaves from the Myrtaceae family. Native to Australia and Tasmania, it is also cultivated in the USA, Spain, Portugal, and India. The oil contains cineole, also known as eucalyptol, along with pinene, camphene, phellandrene, citronellal, and geranyl acetate. It is beneficial for treating burns, blisters, herpes, cuts, wounds, skin infections, and insect bites. Additionally, it can boost the immune system and is helpful in cases of chickenpox, colds, flu, and measles. Eucalyptus oil acts as a counterirritant, antimicrobial, and expectorant, making it useful for treating coughs and chronic bronchitis through inhalation. It is also a component of various liniments and ointments, and a solution of eucalyptus oil is used as nasal drops. [34]

Centella asiatica

Centella asiatica, also known as Brahmi, is a small trailing herb with white to crimson flowers that typically thrives in moist areas. It can be propagated through seeds or vegetative methods. Clinical trials involving formulations of aqueous extracts of Centella asiatica (including ointments, creams, and gels) have demonstrated that topical application three times daily for 24 days on open wound sites leads to faster epithelialization and quicker wound contraction compared to control wounds. Among the tested formulations, the gel showed superior results compared to the ointment and cream. [35]

Table 1: Parts and Metabolites of Medicinal plants used for treating different types of wounds

S. no.	Medicinal plants	Part used	Metabolites	Uses	Reference
1	Forest Champa (Spermadictyon	Roots	Triterpenes, sesquiterpenes, alkaloids	Chronic wound	[36]

	suaveolens)			healing	
2	Red sandalwood (Pterocarpus santalinus)	Bark wood	Santalin A and B, savinin, calocedrin, pterolinus K and L, and pterostilbenes	Acute/chronic wound healing	[37]
3	Turmeric (Curcuma longa)	Rhizomes	Curcumin, vitamin A, proteins	Chronic wound healing	[38]
4	Honey (Apis mellifera)	Secretion from hive	5-Hydroxyimidacloprid, 4,5-dihydroxyimidacloprid, desnitroimidacloprid, 6-chloronicotinic acid, olefin	Acute wound healing	[39]
5	Sesame (Sesamum indicum L.)	Seeds	Metronidazole, E and C vitamins, sesamolinol, sesamol, sesaminol, sesamolin	Acute/chronic wound healing	[40]
6	Trumpet tree (Cecropia peltata)	Leaves	Flavanoids, terpenes phenols, alkaloids, sterols, waxes, fats, tannins, gums, resin acids	Closed wound healing	[41]
7	Kencur (Kaempferia galanga)	Rhizomes	Amino acids, protein, carbohydrate, alkaloids, steroids, cholesterol, cardiac glycosides,	Incision wound healing	[42]
8	Carbonal (Mimosa tenuiflora)	Stem	Mimosine (an alkaloid), sitosterol, amino acids, linoleic acid, tannins, polyphenols, and oleic acid	Chronic wound healing	[43]
9	Theaceae (Camellia pubipetala)	Leaves	Flavonoids, theanine and caffeine	Excision wound healing	[44]
10	Betle Piper (Piper betle L.)	Leaves	Phenolic complex, betal-phenol, chavicol	Excision wound healing	[45]
11	common wireweed (Sida acuta)	Whole plant	Alkaloids, terpenes, and flavonoids	Excision, incision wound healing	[46]
12	Drumstick tree (Moringa oleifera)	Leaves	Vitamins vicenin-2, beta-carotene, phenolics, amino acid,	Excision, incision wound healing	[47]
13	Indian olive (Olea Europaea)	Leaves, oil	Biophenolics, Oleuropein secoiridoid, Luteolin	Incision wound healing	[48]

14	Jungle flame (Ixora coccinea)	Roots, leaves	Sesquiterpenes, Triterpenes, geranyl acetate, ursolicacid	Cutaneous, excision	[49]
15	Papaya (Caricapapaya)	Latex, fruit	Papain	Diabetic, burn, soft tissue wounds	[50]
16	Humble plant (Mimosa Pudica)	Whole plant	Mimosine (an alkaloid), sitosterol, amino acids, linoleic acid, tannins, polyphenols, and oleic acid	Excision wound healing	[51]
17	Adusa (Adhatoda vasica)	Leaves	Flavonoids, tannins	Excision wound healing	[52]
18	Bay (Sphagneticola trilobata)	Leaves	Flavonoids, terpenoids, alkaloid, and saponin	Incision wound healing	[53,54]
19	Aloe (Aloe vera)	Leaves	Anthaquinone, C and E vitamins, amino acids	Open wound healing	[55,56]
20	Druce (Prosopis cineraria)	Leaves	Patulitrin, diketones, spicigerin, β-sitosterol, stigmasterol, hentriacontane, octasanol, and prosogerin A, B, C, and D	Closed wound healing	[51]
21	Maidenhair (Ginkgo biloba)	Leaves and seeds	Flavonoids, lactones, and ginkgolic acid	Closed wound healing	[57]
22	Indian mulberry (Morinda citrifolia)	Leaves and fruit	Anthraquinones, steroid, phenol, tannin, and terpenoids	Closed wound healing	[58]
23	Club Moss (Lycopodium serratum)	Spores and whole fern	Alkaloids, steroids, tannins	Acute/chronic wound healing	[59]
24	Madagascar periwinkle (Catharanthus roseus)	Leaves	Monoterpenoids alkaloids, vinblastine, Vincristine	Acute/chronic wound healing	[60]
25	Asthma Weed (Euphorbia hirta)	Leaves	Saponins, tannins, flavonoids, alkaloids, glycosides	Chronic wound healing	[61]
26	Lawsonia alba (Lawsonia inermis)	Leaves and roots	Coumarins, naphthoquinone, flavonoids, sterols, triterpene, and xanthones	Chronic wound healing	[62]

27	Jandi or Ghaf (Prosopis cineraria)	Leaves and pods	Patulitrin, diketones, spicigerin, β-sitosterol, stigmasterol, hentriacontane, octasanol, and prosogerin A, B, C, and D	Cutaneous wound healing	[63]

Catharanthus roseus Linn.

Catharanthus Roseus Linn is a member of the Apocyanaceae family, often known as Vinca Rosea. It is native to the Caribbean Basin and has traditionally been used to cure a variety of ailments. Catharanthus roseus has about 400 identified alkaloids, some of which are used as anti-neoplastic drugs to treat leukaemia, Hodgkin's disease, malignant lymphomas, neuroblastoma, rhabdomyosarcoma, Wilms' tumour, and other malignancies. Its vasodilating and memory-enhancing qualities have been found to help treat vascular dementia and Alzheimer's disease. In some rural cultures, extracts from dried or wet plant blossoms and leaves are used to make a paste for wound treatment. An ethanol extract of Catharanthus roseus flower contains features that make it capable of boosting rapid wound healing activity when compared with placebo controls. [64]

Curcuma longa Linn.

Curcuma longa Linn. belongs to the Zingiberaceae family and is generally known in Hindi as turmeric and haldi. Curcuma longa has been shown to have antibacterial, antifungal, and antiinflammatory properties. The rhizomes are employed, and it contains curumin (diferuloyl methane), turmeric oil or turmerol, and 1,7-bis,6-heptadiene-3,5dione. Curcumin has significant anti-inflammatory and analgesic properties. Curcuma longa volatile oil has strong antibacterial and antiinflammatory properties. Curcuma longa also includes protein, lipids, and vitamins (A, B, and C), all of which play a vital role in wound healing and regeneration. Turmeric has been used to treat wounds in rats. [65]

Moringa oleifera Linn.

Moringa oleifera Linn. (Moringaceae) has been a staple of Indian cuisine for generations. The plant's leaves have also been shown to have antitumor, hypotensive, antioxidant, radioprotective, antiinflammatory, and diuretic activities. The aqueous extract was tested, and it was discovered

that there was a significant rise in wound closure rate, skin-breaking strength, granuloma breaking strength, hydroxyproline content, granuloma dry weight, and decrease in scar area. [66]

Sesamum indicum Linn.

Sesamum indicum Linn. (Pedaliaceae) is one of the world's oldest cultivated plants, used mostly for the oil-rich edible seeds. The presence of sesamol in the seeds gives them a strong antioxidant effect. Sesame seeds are traditionally used to cure wounds, particularly burns. Treatment with seeds and oil in a dead space wound model resulted in a considerable increase in the granulation tissue's breaking strength, dry weight, and hydroxyproline content. The results imply that Sesamum indicum seeds and oil, applied locally or supplied orally, has wound healing potential. [67]

Anthocephalus cadamba Roxb.

Anthocephalus cadamba Roxb. (Rubiaceae) is extensively dispersed throughout India and is used as a folk medicine to cure fever, anaemia, uterine problems, blood illnesses, skin ailments, leprosy, dysentery, and increase sperm quality. The leaves are advised as a gargle for stomatitis. Bark is mostly composed of triterpenes, saponins, and the indole alkaloids cadambine, 3adihydrocadambine, cadamine, isocadamine, and isodihydrocadambine. The wound healing activity results showed that applying hydro-alcoholic ointment resulted in a shorter epithelization period and a visibly smaller scar area. The tensile strength and hydroxyproline content both increased significantly. The crude hydroalcoholic extract greatly increased wound contraction. Thus, the plant extract might be useful as a wound healing agent. [68]

Lawsonia inermis Linn.

Lawsonia inermis Linn. (Lythraceae) leaves, sometimes known as henna, are used as a decoction or ointment to treat burns, skin inflammations, wounds, and ulcers. The leaves also contain antifungal and antibacterial properties. Henna is said to contain a naphthaquinone, lawsone, a natural colouring. The oral and topical administration of ethanol extracts of henna leaves with lawsone resulted in a considerable healing response in both wound models. Furthermore, topical use of ethanol extract and separated lawsone proved to be more efficacious than oral

administration. Thus, topical administration of ethanol extract can be successfully designed for wound healing activities. [69]

Lantana camara Linn.

Lantana camara Linn. (Verbanaceae), a shrub native to tropical America, has become totally naturalised as an ornamental plant throughout India. The herb contains abortifacient, antimalarial, anti-inflammatory, and wound healing effects. The hydro-alcoholic extract and fresh juice of leaves have favourably influenced wound contraction. [70]

Helianthus annus Linn.

Helianthus annus Linn belongs to the family Asteraceae. A beautiful annual herb with upright, rough, and hairy stems is commonly seen in swampy Indian gardens. In traditional medicine, tribals utilise the plant to treat eye inflammation, sores, dysuria, colic, tiger bites, and bone fractures. In a study, an alcoholic extract of the whole plant of Helianthus annus administered as an ointment to a rat's excised lesion resulted in a considerable reduction in total healing time. This was supported by histology, which revealed earlier appearances of fibroblasts. Early emergence and increased accumulation of mucopolysaccharides have been identified as indications of accelerated repair. [71]

CONCLUSION

Medicinal plants have the potential to be a valuable resource in wound healing. Standardization of medicinal plants is necessary to ensure consistency and therapeutic efficacy. Plants are efficient wound healers that treat wounds in a natural manner. This review focused on the cellular mechanisms of recently discovered medicinal plants with wound healing potential, which could be useful in therapeutic treatment and the creation of new wound healing medications for human use.

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