REVIEW ARTICLE

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Wound Healing Medicinal Plants: An Exhaustive Literature Review

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Abstract: Wound healing possesses still great challenge for the medical community including the pharmaceutical industry. Due to the complexity involved in the pathophysiology of wound healing and wound management, coming up with efficient strategy to deal with is somewhat a test. Traditional medicines have been used by humans since ages and taking the wide spread of medicinal plants available for the same, they are valuable source even to deal with wound management. Therefore, this review focuses on brief about wound management and exhaustive literature coverage to deal with the same. Pharmaceutical industry should use these medicinal plants to come up with an effective strategy to deal the still daunting task of wound management.

INTRODUCTION

Wound healing still possess challenges for the Medical community, it is still challenge for the Pharmaceutical Industry, despite of being more advanced nowadays. Only 1-3 % of drugs listed in Western pharmacopeias are intended for cure and healing of wounds. It is because of this challenge that Medicinal plants possess huge potential to come up with extensive solution for the Wound healing at present. Moreover, Medicinal plants are now considered as rich source for treatment of wounds. [1] Proper and adequate nutrition is very important for dealing with wound and associated infection. Wound healing requires competency in wound repair functions or cellular repair functions, chemotactic factors, e.g., (Cytokines and growth factors) and local environment that promotes cell division, movement and differentiation. [2] Depletion of proteins and nutrients due to diet or malabsorption syndromes, can impair wound healing and increase the risk of developing Ulcers, rough or think skin, alopecia's and nail dystrophies. [2] Wound remains possible challenge for the medical community presenting the frequent cause of morbidity and mortality. It has been estimated that, Chronic wound affect 120 per 100000 people aged between 45 to 65 and rises to 800 people per 100000 people. The current estimation of chronic wounds is around 6 million people worldwide. Furthermore due to complications associated with wound, when healing does not occurs at natural pace, it may result into Chronic wounds, which are difficult to manage. [3] Healing is complex process involving coordination between diverse immunological and biological systems. It involves cascade of carefully and precise regulated steps. A brief Steps in wound healing includes, Coagulations and Hemostasis phase: The principal aim of these mechanism is to prevent exanguination. It is a way to protect the vascular system, keeping it intact, so that the vital functions remains unharmed despite the injury. Another step is inflammatory phase, with an aim of establishing an immune barrier to the invading micro-organisms. Followed by Inflammatory phase is the Proliferation stage, the proliferative phase starts on the third day after wounding and lasts for 2 weeks. It is characterized by fibroblasts migration and deposition of newly synthesized extracellular matrix, acting as replacement for the provisional network composed of fibrin and fibronectin. The last phase in wound healing process is the Remodeling phase. As the final phase of wound healing the remodeling phase is responsible for development of new epithelium and final Scar tissue formation. Due to challenges for proper management of wounds, it still holds a remarkable position in medical research. [3]

It's due to challenges for pharmaceutical industry to come up with effective and efficient medicines for treatment of wounds, that, there is bend towards, Traditional Medicines or Medicinal plants. Traditional medicines are used by humans since ages. The first record of traditional medicines by humans comes from the tablet around 2600 B.C. The tablet mentions the significance and use of essential oils from *Cedrus species* (Cedar), *Cupressus sempevirens* (Cypress), *Glycyrrhiza species* (licorice), *Commiphora species* (Myrrh) and *Papaver somniferum* (Poppy juice). Moreover more than 80% of the population residing in Asia and India prefer traditional medicines for their primary healthcare needs. [4] Out of the total 422, 000 flowering plants reported from the world, more than 50, 000 are used for medicinal purposes. In India more than 43 % of the total flowering plants are reported to be of medicinal importance. Indian system of medicines, like Ayurveda, Siddha, Unani, entirely and homeopathy partially depend either on plant materials or their derivatives for treating human ailments. About 25 % of drugs in modern pharmacopoeia were derived from plants (Phytomedicines) and many others were synthetic analogues built on prototype compounds isolated from plants. Apart from ethnobotanical property and primary healthcare system, medicinal plants were also the alternate source of income for the underprivileged communities. [5] Plant derived natural products such as, alkaloids, tannins, terpenes and flavonoids have received considerable attention in recent years due to their diverse pharmacological properties. [6] Research on wound healing agents, is one of the developing areas in modern biomedical sciences. Several drugs of plant, mineral and animal origin are described in traditional texts of Indian systems of medicine like Ayurveda, for their healing properties under the term "Vranaropka". Many plants have been explored for healing treatment of wounds, but still many remain unexplored. [7]

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Table 1: Normal Wound Healing Process [21]

Phases	Cellular and Bio-physiologic Events
Hemostasis	a. Vascular constriction b. Platelet aggregation, degranulation and fibrin formation (thrombus)
Inflammation	a. Neutrophil infiltration b. Monocyte Infiltration and differentiation to macrophage c. Lymphocyte infiltration
Proliferation	a. Re-epithelialization b. Angiogenesis c. Collagen synthesis d. Extracellular matrix formation
Remodeling	a. Collagen remodeling b. Vascular maturation and regression

Table 2: Factors Affecting Wound Healing Process [21]

Local	Systemic
Oxygenation	Age and gender
Infection	Sex hormones
Foreign body	Stress
Venous sufficiency	Ischemia
-	Diseases: diabetes, keloids, fibrosis, hereditary healing disorders, jaundice, uremia
-	Obesity
-	Medications: Glucocorticoid steroids, Non-steroidal Anti-inflammatory drugs, chemotherapy
-	Alcoholism and Smoking
-	Immunocompromised conditions, Cancer, Radiation therapies
-	AIDS
-	Nutrition

PATHOPHYSIOLOGY OF WOUNDS

What do we mean by the word Wound, according to Cambridge English dictionary, Wound means a damaged area of the body, such as hole or cut in the skin or flesh. [8] Wounds are physical injuries that result in an opening or break of the skin. Proper healing of wounds is essential for the restoration of disrupted anatomical continuity and disturbed functional status of the skin. Healing is a complex and intricate process initiated in response to an injury that restores the function and integrity of damaged tissues. Wound healing involves continuous cell–cell and cell–matrix interactions that allow the process to proceed in three overlapping phase's viz. inflammation (0–3days), cellular proliferation (3–12 days) and remodeling (3–6months). [9-10] Healing requires the collaborative efforts of many different tissues and cell lineages. [11] It involves platelet aggregation and blood clotting, formation of fibrin, an inflammatory response to injury, alteration in the ground substances, angiogenesis and re-epithelialization. Healing is not complete until the disrupted surfaces are firmly knit by collagen. [12] The basic principle of optimal wound healing is to minimize tissue damage and provide adequate tissue perfusion and oxygenation, proper nutrition and moist wound healing environment to restore the anatomical continuity and function of the affected part. [13] Cutaneous wound repair is accompanied by an ordered and definable sequence of biological events starting with wound closure and progressing to the repair and remodeling of damaged tissue. [14] In spite of tremendous advances in the pharmaceutical drug industry, the availability of drugs capable of stimulating the process of wound repair is still limited. [15] Moreover, the management of chronic wounds is another major problem due to the high cost of therapy and the presence of unwanted side effects. [16] It is consented that reactive oxygen species (ROS) are deleterious to wound healing process due to the harmful effects on cells and tissues. Absorbable synthetic biomaterials are considered to be degraded via ROS. [17] Free-radical-scavenging enzymes (FRSE) are a cyto-protective enzymatic group that has an essential role in the reduction, de-activation and removal of ROS as well as regulating wound healing process. Inflammation, which constitutes a part of the acute response, results in a coordinated influx of neutrophils at the wound site. These cells, through their characteristic "respiratory burst" activity, produce free radicals. [18] Wound related non-phagocytic cells also generate free radicals by involving non-phagocytic NAD(P)H oxidase mechanism. [19] Thus, the wound site is rich in both oxygen and nitrogen centered reactive species along with their derivatives. The presence of these radicals will result in oxidative stress leading to lipid peroxidation, DNA breakage and enzyme inactivation, including free-radical scavenger enzymes. Evidence for the role of oxidants in the pathogenesis of many diseases suggests that antioxidants may be of therapeutic use in these conditions. Topical applications of compounds with free-radical-scavenging properties in patients have shown to improve significantly wound healing and protect tissues from oxidative damage. [20]

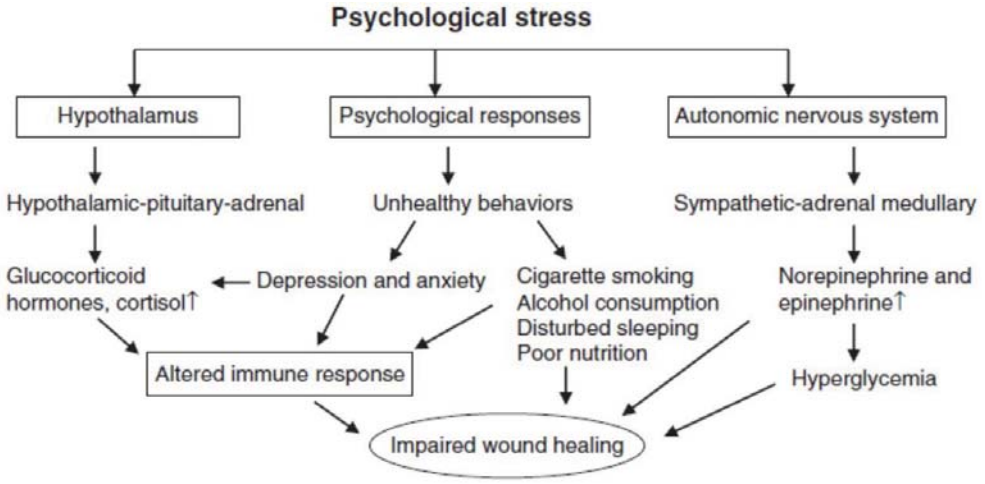

Figure 1: Stress impaired wound healing process [21]

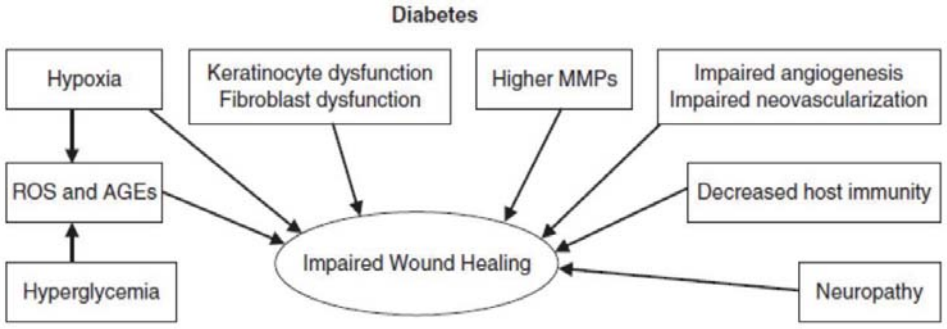

Figure 2: Diabetes impaired wound healing process [21]

NORMAL WOUND HEALING PROCESS

Normal wound healing process is shown in Table 1.

FACTORS AFFECTING WOUND HEALING

Multiple factors affect the wound healing process. In general terms the factors affecting the wound healing can be divided into two factors mainly; Local and Systemic. [21]

The effect of stress on wound healing is highly recognized among the medical community. Stress mediated wound healing is primarily mediated through the Hypothalamic-pituitary-adrenal, Sympathetic adrenal medullary axes and psychological response-induced unhealthy behaviors. [21]

BARRIERS TO WOUND HEALING

The overall aim of wound management is to heal the wound effectively. Both patients and healthcare professionals want wound to get heal as early as possible. In majority of wounds this outcome is achieved, these are acute cases of wounds. But, it becomes difficult in case of chronic wounds. Besides many other factors affecting the wound healing, there are other barriers which affect the effective wound healing. These barriers are described in Figure 3. [22]

PHARMACOLOGICAL PROFILE UPDATE OF WOUND HEALING PLANTS

Wound Healing Properties of *Jatyadi Taila*

Jatyadi Taila is a medicated oil formulation popularly used in treatment of various topical wounds. Though the formulation has its composition recorded in ancient Ayurvedic texts, there has been still no standardized record for its effectiveness in the proper wound management. Therefore the author has selected it as research formulation to see whether their exits pharmacological status in true management of wounds. Through proper HPLC methods and estimation of karanjin from rabbit plasma, supports the result and the results support the tradition efficacy of *Jatyadi taila* in proper wound management. The use of *Jatyadi taila* can thus be scientifically justified. Findings of the study provide base line data for designing further investigation on the therapeutic action of *Jatyadi taila* especially to evaluate wound healing efficacy in diabetes as well as in chronic ulcers. [23]

Wound Healing Property in *Dendrophthoe falcate* (L.F.) Ettingsh

Dendrophthoe falcata (L.f) Ettingsh (Loranthaceae), commonly known as 'Banda' (Hindi) is an evergreen shrub with bark smooth'grey, leaves opposite unequal, thick 1.6–25.4cm long, flowers single, orange-red or scarlet softly pubescent, berries soft ovoid-oblong, 1.3 cm diameter and indigenous to India, Srilanka, Thailand, Indo-china, Australia. The aerial parts are used in wounds, menstrual troubles, asthma, psychic disorders, pulmonary tuberculosis, in consumption and mania by the tribal of India. Validations of the ethnotherapeutic claims of the plant in wound healing activity was studied, besides anti-microbial activity and antioxidant activity were performed

Figure 3: Barriers to wound healing process [22]

to understand the mechanism of wound healing potency. The ethanolic extract of aerial parts of *Dendrophthoe falcata* ethanolic extract (DFEE) was investigated for the evaluation of its healing efficiency on excision and incisionwound models in rats. The results showed that *Dendrophthoe falcata* extract has potent wound healing capacity as evident from the wound contraction and increased tensile strength. Hydroxyproline and hexosamine expressions were also well correlative with the healing pattern observed. Three of the fractions A–C (petroleum ether, chloroform and ethanol, respectively) obtained fromthe extract exhibited significant antimicrobial activity against the organisms: *Staphylococcus aureus*, *Staphylococcus pyogenes*, *Staphylococcus epidermidis*, *Micrococcus luteus*, *Bacillus subtilis*, *Bacillus cereus*, *Klebsiella pneumoniae*, *Enterobacter aerogenes*, *Pseudomonas aeroginosa*, *Serratia marcescens* and five fungi *Candida albicans*, *Candida tropicalis*: dimorphic fungi, *Aspergillus fumigatus*, *Aspergillus niger*: systemic fungi and some infectious bacteria *Escherichia coli* and *Salmonella typhi*. The results also indicated that DFEE (*Dendrophthoe falcata* ethanolic extract) possesses potent antioxidant activity by inhibiting lipid peroxidation, reduced glutathione, super-oxide dismutase levels and increased the catalase activity. [24]

Wound Healing Property in *Glycosmis Arborea*

Glycosmis arborea Roxb (Rutacea), commonly known in Sanskrit as Ashvashakota is an odorous shrub found throughout India especially as undergrowth in forests. In Indian system of medicine 'Ayurveda', the plant is popularly known as Banuimbu (Hindi), Kulapannai (Tamil), Golugu (Telugu), Gurodagida (Kannadam). The plant is bitter in taste, astringent and used to treatcommondiseases such as fever, helminthiasis, rheumatism, inflammation, cough and bronchitis and as a febrifuge, vermifuge. Roots were used in facial inflammation, rheumatism, jaundice and anaemia. Hepato-protective activity of butanol extract of aerial parts is reported. The carbazole and acridine alkaloids isolated from *Glycosmis arborea* were reported to have inhibitory activity over Epstein–Barr virus and anti-tumor activity. The result was that topical application of *Glycosmis arborea* ointment (10%) in excision wound model significantly ($P < 0.05$) increased the percentage of wound contraction (96.91%) compared with control (60.27%) and decreased the epithelization time. The tensile strength significantly ($P < 0.05$) increased in Group-3 at 560.33±6.48 g when compared to control at 319.17±6.16 g. Rats treated with *Glycosmis arborea* extract (400 mg/kg) showed significant ($P < 0.05$) increase in hydroxyproline content at 54.94±0.96 mg/g when compared with control at 30.77±1.13 mg/g. Conclusion: The ethanolic extract of *Glycosmis arborea* facilitated wound healing significantly, corroborating the folk medicinal use of this plant. [25]

Wound Healing Property in Ghee Based Formulations

Formulation containing neomycin and ghee was evaluated for wound-healing potential on different experimental models of wounds in rats. The rats were divided into six groups of group 1 as control, group 2 as treated with neomycin only, group 3 as treated only with ghee, group 4 treated with F-1 formulation containing ghee 40% and neomycin 0.5%, group 5 treated with F-2 formulation containing ghee 50% and neomycin 0.5% and group 6 treated with F-3 formulation containing ghee and ointment base in all two wound models, each group consisting of six rats. Wound contraction ability in excision wound model was measured at different time intervals and study was continued until wound is completely healed. Tensile strength was measured in 10-day-old incision wound and quantitative estimation of hydroxy proline content in the healed tissue was determined in 10-day-old excision wound. Histological studies were done on 10-day-old

sections of regenerated tissue of incision wound. F-2 formulation containing ghee 50% and neomycin 0.5% showed statistically significant response, in terms of wound contracting ability, wound closure time, period of epithelization, tensile strength of the wound, regeneration of tissues at wound site when compared with the control group and these results were comparable to those of a reference neomycin ointment. [26]

Wound Healing Property in *Datura alba*

Datura alba Nees (Solanaccae) is popular all over the world for its medicinal uses in asthma, muscle spasm, whooping cough, hemorrhoids, skin ulcers, etc. In India, it is widely used traditionally for the relief of rheumatism and other painful affections. Ayurveda and Siddha practitioners use oil based preparations of this plant from ancient days to till date for all types of wounds. Hence, the present study was chosen to evaluate its scientific validity. The alcohol extract of the *D. alba* leaves were investigated for the evaluation of its healing efficiency on burn wound models in rats. The crude alcohol extract and one of the fractions exhibited antimicrobial effect against all the pathogens studied. A 10% (w/w) formulation of alcoholic extract was topically applied on thermal wounds. Complete wound closure was observed within 12 days in treated rats. The effect produced by the ointment, in terms of wound contracting ability, wound closure time, tissue regeneration at the wound site and histopathological characteristics were significant in treated rats. Collagen, hexosamine and gelatinase expressions were also well correlative with the healing pattern observed. The study thus provides a scientific rationale for the traditional use of this plant in the management of wounds. [27]

Wound Healing Property in *Trichosanthes dioica*

Trichosanthes dioica Roxb (TDR), family Cucurbitaceae (named pointed gourd) is a dioecious plant found in the plains of Northern India, extending to Assam and Bengal. Pointed gourd (TDR) is one of the most nutritive cucurbit vegetables and it holds a desirable position in the Indian market during the summer and rainy seasons. It is a perennial crop, highly accepted due to its availability for 8 months in a year (February-September). Being very rich in protein and vitamin A, it has certain medicinal properties and many reports are available regarding its role in lowering of blood sugar and serum triglycerides. The fruits are 5 to 9 cm, oblong, nearly spherical acute and smooth orange red when ripe. The seeds are ellipsoid, compressed and corrugated on the margin. The plant is alternative and the fruits possess cardio tonic and anthelmintic properties. The fruits are easily digestible and diuretic in nature. They are also known to have anti-ulcerous effects. The leaves of the plant are cordate, rigid, sinuate-dentate and rough on both surfaces. The leaves have been claimed for glycemic property. The juice of the leaf is useful to patches of alopecia areata. The seeds are reported to have anti-hyperglycemic properties. In view of these cited activities, observations and traditional uses of plant, the study was undertaken to explore the wound healing potential of methanolic extract of TDR in excision and incision experimental models. It was noted that the effect produced by the extract ointment showed significant ($P < 0.01$) healing in both the wound models when compared with control group. All parameters such as wound contraction, epithelialization period, hydroxyproline content, tensile strength and histopathological studies showed significant changes when compared to control. Conclusion: The result shows that TDR extract ointment demonstrates wound healing potential in both excision and incision models. [28]

Wound Healing Property in *Portulaca oleracea*

Portulaca oleracea L. (Portulacaceae), is commonlyknown as “Berbin” in Iraq, “Farfena” in Oman, “Rigla”in Egypt and Saudi Arabia, “Baqlah” or “Farfahinah” inJordan, Lebanon, Palestine and Syria. In US it is known as “Pusley,” “Pussly” and as “Purslane.” It is a warm climate, annual green herb, with branched and succulent stems which are decumbent near the base and ascending near the top to a height of 15–30 cm. The plant is fleshy, stout, succulent (water content of over 90%), with obovate to spathulate, obtuse opposite leaves tapering towards the base. The flowers are small, yellow and sessile in clusters of three to five on the forks and tips of the branches, opening in the morning only. The fruit is oblong and transversely dehiscent. The seeds are orbicular and 0.5 mm in diameter. It has a cosmopolitan distribution in Africa, China, India, Australia, Middle East, Europe and United States. The term *Portulaca* originates from Latin word “Portare” meaning to carry and “lac” meaning milk, referring to the milky sap of this plant. The species name *oleracea* originates from Latin, meaning, “pertaining to kitchen gardens,” referring to its use as a vegetable. Indeed, fat weed may be the best name for this vegetable weed, since its leaves and stems are very fleshy and succulent. In ancient times it was looked on as one of the anti-magic herbs and when strewn round abed was said to afford protection against evil spirits. People were told that it was a sure cure for blasting by lightening or planets and burning of gunpowder. The main feature of the plant, which raises its status above that of common weeds, is its edibility. The preliminary wound healing activity of *Portulaca oleracea* was studied using *Mus musculus* JVI-1. For this purpose fresh homogenized crude aerial part of *Portulaca oleracea* were applied topically on the excision wound surface as single and two doses in different amounts. Wound contraction and tensile strength measurements were used to evaluate the effect of *Portulaca oleracea* on wound healing. The results obtained indicated that *Portulaca oleracea* accelerates the wound healing process by decreasing the surface area of the wound and increasing the tensile strength. The greatest contraction was obtained at a single dose of 50 mg and the second greatest by two doses of 25 mg. Measurements of tensile strength and healed area were in agreement. [29]

Wound Healing Property in *Calotropis procera*

Calotropis procera (Asclepiadaceae) is a well-known plant in the Ayurvedic system of medicine. Based on its traditional use this plant was selected for evaluation of its

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wound healing potential. For this purpose four full thickness excisional wounds of 8.0 mm diameter were inflicted on the back of guinea pigs. Topical application of 20 ml of 1.0% sterile solution of the latex of *C. procera* twice daily was followed for 7 days. The latex significantly augmented the healing process by markedly increasing collagen, DNA and protein synthesis and epithelisation leading to reduction in wound area. Topical application of *C. procera* at the wound site produced significant wound healing activity, which may be due to its angiogenic and mitogenic potential. Its prohealing activity was conspicuous as all the observed healing parameters were significantly affected. As expected, the wounds after 7 days treatment with plant extract exhibited marked dryness of wound edges with regeneration of healing tissue and the wound area was also considerably reduced compared to controls indicating the healing potential of *Calotropis*. The extract also appears to stimulate significant reduction in wound size which might be due to enhanced epithelisation. Therefore it appears that the *Calotropis* extract possesses significant prohealing activity by affecting the healing at various phases of tissue repair. [30]

Wound Healing Property in *Hypericum perforatum* L

Olive oil extract of the flowering aerial parts of *Hypericum perforatum* L. (Hypericaceae) is a popular folk remedy for the treatment of wounds in Turkey. In order to prove the claimed utilization of the plant, the effects of the extracts and the fractions were investigated by using bioassay-guided procedures. For the wound healing activity assessment, *in-vivo* excision and incision wound models were applied. For the anti-inflammatory activity, an in vivo model, based on the inhibition of acetic acid-induced increase in capillary permeability was used as well. Moreover, a parallel study was run on *Hypericum scabrum* L., which is a widespread species of the gender but not known as a folk remedy for wound healing, to provide a preliminary data to compare and emphasize the selection of correct plant species. Initial investigations proved that the olive oil extract of *Hypericum perforatum* has a significant wound healing effect on excision (5.1–82.6 % inhibition) and circular incision (20.2–100.0 % inhibition) wound models. In order to determine the active wound healing ingredient(s), aerial parts of the plant was extracted with ethanol, noteworthy wound healing activity profile was observed with the wound models; between 18.3% and 95.6% in excision model and from 13.9% to 100.0% inhibitions in incision model were determined. The ethanolic extract was then submitted to successive solvent extractions with n-hexane, chloroform and ethyl acetate (EtOAc). Each solvent extract was also applied on the same wound models, consequently, EtOAc sub-extract was found to be the most active one by inhibiting wounds between 17.9% and 100.0% in excision model, subsequently between 9.4% and 100.0% in incision model. However, all subfractions obtained from the EtOAc subextract using Sephadex LH-20 column chromatography showed wound healing activity not more than the whole EtOAc subextract, which revealed that a possible synergistic activity that might be questioned. Among the active Sephadex fractions, Fr. A further yielded hyperoside, isoquercitrin, rutin and (−)-epicatechin and Fr. B yielded hypericin as the major components. Moreover, a dose-dependent anti-inflammatory activity was found for the ethanol extract, EtOAc subextract and Sephadex fractions of *Hypericum perforatum*. These results suggest that anti-inflammatory activity of the active fractions might have a contributory role in the wound healing effect of the plant. Conclusion: Results of the present study have proved that aerial parts of *Hypericum perforatum* possess remarkable wound healing and anti-inflammatory activities supporting the folkloric assertion of the plant in Turkish folk medicine. Flavonoids [hyperoside, isoquercitrin, rutin and (−)-epicatechin] and naphthoquinones (hypericins) were found as the active components of *Hypericum perforatum*. On the other hand, ethanol extract of *Hypericum scabrum* showed neither remarkable wound healing nor anti-inflammatory activity demonstrating the importance of correct plant species selection in therapeutic applications. [31]

Wound Healing Potential of *Rosmarinus officinalis* L

Rosmarinus officinalis L. (Family Lamiaceae), popularly named rosemary, is a perennial herb with fragrant evergreen linear leaves used as spice and a flavouring agent in food processing. Rosemary is grown in many parts of the world, including Jordan, where it is mostly cultivated or grown naturally and is named by the local inhabitants with Hasalbanor Iklilal-Jabal. The aerial parts of the herb has a long tradition of use as an antispasmodic in renal colic and dysmenorrhoea, anti-rheumatic, anti-aging, in relieving respiratory and digestive disorders, hypertension, kidney stones, sugars in blood, in stimulating circulation and nervous system and in treating skin diseases such as hair loss, infections and healing of wounds. Significant positive differences ($p<0.01$) between treated and control groups were observed at different aspects of diabetic wound healing process. Reduced inflammation and enhanced wound contraction, re-epithelialization, regeneration of granulation tissue, angiogenesis and collagen deposition were detected in the treated wounds. Conclusions: Results indicated that the essential oil of *Rosmarinus officinalis* was the most active in healing diabetic wounds and provide a scientific evidence for the traditional use of this herb in wound treatment. However, further scientific verification is required toconfirm and assesses the range of wound healing potential of essential oil of Rosemary chemotypes. [32]

Wound Healing Property in *Clerodendrum infortunatum* L

The genus Clerodendrum is very large and widely distributed in Asia, Australia, Africa and America. The major chemical components reported from the genus are phenolics, steroids, di- and triterpenes, flavonoids, volatile oils, etc. There are several reports on the phytochemical screening and pharmacological evaluation of few species of the genus Clerodendrum. *Clerodendrum infortunatum* L. is one of the commonly used plants in ethno-medicine for its

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various medicinal properties. Apart from its application as antipyretic and antihelmentic in ethnic medicine it is also used for relieving thirst and burning sensation, foul odours and diseases of the blood. Leaves of the plant are prescribed for tumors, certain skin diseases and scorpion stings. The medical practitioners of Bhadra Wild Life Sanctuary (Karnataka, India), are using the tender leaf paste to cure cut wounds and leprosy since long time. Keeping this in view, coupled with the fact that the genus Clerodendrum has a high content of secondary metabolites including flavonoid and phenolic compounds, the present study was designed by selecting *C. infortunatum* L. to estimate the antioxidant efficiency by employing free radical scavenging tests viz. 1,1-Diphenyl-2-picrylhydrazyl (DPPH), reducing power assays together with the evaluation of hepatoprotective and wound healing activity. The phytochemical studies have clearly demonstrated that the plant *C. infortunatum* is a rich source of phenolics and flavonoids. Therefore, the presence of these compounds in the plant extracts has exhibited strong antioxidant and pharmacological activities.

Among the three extracts the ethanol extract is found to be stronger in displaying the abilities of free radical scavenging, hepato-protectivity and wound healing. Furthermore, it is presumed that the presence of the antioxidant and pharmacological properties together could also be attributed to the presence of anti-mutagenic or anti-tumor abilities of the plant. This may further clarify the specific properties of the plant. It is believed that this plant could be exploited as a better economical and abundant bio-resource of phenolics and flavonoids for cosmetics and pharmaceutical industry. [33]

Wound Healing Property in *Tragia involucratai*

Tragia involucrata a well-known traditional plant used in tribal medicine of India, is locally known as "Senthoty or Poonaikanch chedi". The decoction of the leaves is being used by the tribal people of Western Ghats of Tamil Nadu (Kalrayan hills) for the treatment of skin infection, pain, swelling, children scabies and eczema. A decoction of the root is found to be useful in relieving bronchitis and the attendant fever. The methanolic extract of the root possessed significant anti-inflammatory and analgesic activity. The seed of this plant is used for a variety of ailments—severe headache, baldness, venereal complaints and mental illness. The methanol extract of the roots of *Tragia involucrata* topically tested at doses of 100 and 200 mg/kg exerted significant wound healing effect in Staphylococcus aureus-induced excision wound in rats. [34]

Wound Healing Property in *Mimosa pudica*

Mimosa pudica, commonly known as Lajjalu (Hindi), is called asa sensitive plant/touch-me-not in English. It is an annual or perennial herb belonging to family *Mimosaceae*. *Mimosa pudica* has been reported to contain mimosine (an alkaloid), free amino acids, -sitosterol, linoleic acid and oleic acid. The drug is also found to be rich in tannins and the total tannin content was reported to be 10% (w/w). The root of *Mimosa pudica* is reported to be used in the form of decoction in gravel and other similar urinary complaints and diseases arising from corrupt blood and bile. The root is also stated to have anti-convulsant activity. Successive extracts of the whole plant are reported to have antibacterial activity. In preliminary screening of *Mimosa pudica* extract was found to exhibitanti-venom activity against common sea snake (*Enhydrina schistosa*) poisoning. Prashanth *et al*. (2007) screened the root of *Mimosa pudica* for acetyl cholinesterase inhibitory activity and it was found that the roots have acetylcholine esterase inhibitory activity. Ayurveda reports utility of *Mimosa pudica* in arresting bleeding and enhancing wound healing process, however, the literature survey revealed that no systematic study had been carried out on wound healing activity. Hence, in the present study, an effort was made to establish wound healing potential of the plant using different models. Treatment of wound with ointment containing 2% (w/w) the methanolic and 2% (w/w) the total aqueous extract exhibited significant ($P < 0.001$) wound healing activity. The methanolic and total aqueous extracts were analyzed for total phenols content equivalent to Gallic acid. The content of total phenols was 11% (w/w) and 17% (w/w) in methanolic and total aqueous extract respectively. Conclusion: The methanolic extract exhibited good wound healing activity probably due to phenols constituents. [35]

Wound Healing Property in some Nigerian Plants

Study was conducted to evaluate methanolic extracts of *Ageratum conyzoides, Anthocleista djalonensis, Napoleona imperialis, Ocimum gratissimum* and *Psidium guajava* for antibacterial and wound healing properties. Antibacterial properties of the extracts were studied against eleven wound isolates (*Staphylococcus aureus* (four strains), *E. coli* (two strains), *Pseudomonas aeruginosa* (one strain), *Proteus* spp. (three strains) and *Shigella* spp. (one strain)) using the well diffusion method. Wound healing properties of *Ageratum conyzoides, Anthocleista djalonensis, Napoleonaea imperialis* and *Ocimum gratissimum* were determined using the excision wound model. Extract of *Napoleona imperialis* inhibited growth of all the test bacterial strains while *Psidium guajava* and *Anthocleista djalonensis* extracts prevented growth of 81.8 and 72.7% of the test organisms, respectively. *Ageratum conyzoides* and *Ocimum gratissimum* extracts did not inhibit growth of any of the test organisms. More than 90% wound healing was recorded in the extract and cicatrin® powder treated groups by 14 days post-surgery, where as 72% healing was observed in the distilled water-treated group. The percentage healing in the distilled water-treated group was significantly different ($P < 0.001$) from those of extract and antibiotic-treated groups. [36]

Wound Healing Property in *Centaurea sadleriana* Janka

The aerial parts of *Centaurea sadleriana* Janka, a species native to Hungary, have been used for the healing of wounds of livestock in Hungarian folk medicine. This is the first report of the ethnomedicinal use of this plant. This

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study was aimed at investigating the wound-healing efficiency of different extracts of *Centaurea sadleriana*. Experimental wounds inflicted on healthy rats by means of a branding iron were treated topically with different extracts and fractions of extracts of the aerial parts of *Centaurea sadleriana*. To assess the effectiveness of treatment, an absolute control (no treatment), a vehicle control (Carbomergel) and a positive control group (1% salicylic acid in Carbomer gel) were applied. Results: The n-hexane fraction of the methanol extract significantly accelerated the wound-healing process. This effect was rather similar to that of the positive control gel. Other fractions exhibited more moderate activities. Conclusions: The apolar fraction of the methanol extract of *Centaurea sadleriana* facilitated wound healing significantly, corroborating the folk medicinal use of this plant. [37]

Wound Healing Property in *Alium cepa* Linn

The plant *Allium cepa* Linn. Belonging to family Liliaceae. Contains kaempferol, ferulic acid, sitosterol, myritic acid, prostaglandins. The constituents are used as abortifaciant, bulb extract shown to have ecobolic effect in rats. Allium cepa Linn is reported to have the anti-diabetic, antioxidant, anti-hypertensive, antithromobotic, hypoglycemic, antihyperlipidemic [38]

Wound Healing Property in *Aloe vera*

It is one of the oldest healing plants known to human. Used topically for cuts, burns, bruises, acne and blemishes, insects stings, poisoning, welts, skin lesions, eczema, sunburns, also traditionally used for stomach and intestinal disorders and also it has to enhance immune systems. Aloe Vera leaf contains Vitamin C, Vitamin E and amino acids which are essential for wound healing. [38]

Wound Healing Property in *Musa sapientum*

Mua sapientum var. paradisiacal belong to family Musaceae. It consists of flavonoids (leucocyanidin) sterylacyl glycosides and sitoindisides I-IV. Sitoindoside IV was reported to mobilize and activate peritoneal macrophages with increase in DNA and [3H] thymidine uptake. Flavonoids are known to reduce lipid peroxidation flavonoids are also known to promote the wound healing process mainly due to their astringent and antimicrobial property, which results to be responsible for wound contraction and increased rate of epithelialization. [38]

Wound Healing Property in *Tectona grandis*

Tectona grandis Linn. Is commonly known as Indian teak and belongs to family Verabinaceae. It contains mainly carbohydrates, tannins and anthraquinone glycosides. *Tectona grandis* is used as anti-inflammatory agents and also used topically for the treatment of burns. It is mainly used for the injuries like burn, inflicted wound and skin ulcers. The extract applied topically or given orally promoted the breaking strength, wound contraction and collegenation. [38]

Wound Healing Property in *Adhatoda vasica* Linn.

Adhatoda vasica Linn. (Acanthaceae) known as chue mue, grows as weed in almost all parts of the India. Leaves and stems of the plant have been reported to contain an alkaloid mimosine, leaves also contain mucilage and root contains tannins. *Adhatoda vasica* is used for its antihyperglycemic, anti-diarrhoeal, anticonvulsant and cytotoxic properties. The plantalso contains turgorins, leaves and roots are used in treatment of piles and fistula. Paste of leaves is applied to hydrocele. The methanolic, chloroform and diethyl ether extract ointment (10%w/w) of *Adhatoda vasica* has significant wound healing activity. In both extract ointment, the methanolic extract ointment (10%w/w) showed significant effect when compare to standard drug and other two extract in excision wound model. [38]

Wound Healing Property in *Catharanthus roseus* Linn

Catharanthus roseus Linn is a member of the Apocyanaceae also known as *Vinca Rosea*, is native to the Caribbean Basin and has historically been used to treat a wide assortment of diseases. *Catharanthus roseus* has more than 400 known alkaloids, some of which are approved as antineoplastic agents to treat leukemia, Hodgkin's disease, malignant lymphomas, neuroblastoma, rhabdomyosarcoma, Wilms' tumor and other cancers. Its vasodilating and memory-enhancing properties have been shown to alleviate vascular dementia and Alzheimer's disease. Extracts from the dried or wet flowers and leaves of plants are applied as a paste on wounds in some rural communities. An ethanol extract of *Catharanthus roseu*s flower has properties that render it capable of promoting accelerated wound healing activity compared with placebo controls. [38]

Wound Healing Property in *Stevia rebaudiana*

Study was carried out to evaluate the wound healing potential of crude aqueous extract of *Stevia rebaudiana* (Bertoni) Bertoni, Asteraceae, in experimental animals. All experiments were conducted following standard procedures. The crude extract was administered topically in graded doses of 150, 250 and 500 mg/ kg b.w. was used for evaluating the wound healing potential in excision wound model for fourteen days and orally in the incision wound model for ten days, respectively. Povidone iodine ointment was used as standard (5.0% w/w). Dose dependent activities resulted in both the wound models when compared to the standard (povidone iodine) and the control. Topical application of crude aqueous extract of *S. rebaudiana* (500 mg/kg b.w) in excision wound model decreased significantly the wound area by 15th day, *i.e.* 48.2±2.0 compared with control 94.1±1.2. Epithelization time was decreased from 17.3±0.21 to 12.0±0.10 and hydroxylproline content was increased from 32.2±0.11 to67.6±0.10 when compared with control. In incision wound model breaking strength of wounds, wet and dry granulation of the tissue weight and hydroxyproline were increased significantly from control with AESR (Aqueous extract of *Stevia rebaudiana*). In conclusion, AESR leaves accelerated wound healing activity in mice and thus supports its traditional use. [39]

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Table 3: Other Wound Healing Plants [40]

S. No.	Plant Name	Family	Parts Analyzed for Wound Healing Property
1	*Achryanthes aspera* Linn	*Amaranthaceae*	Leaves
2	*Acorus calamus* Linn	*Araceae*	Leaves
3	*Allium cepa* Linn	*Liliaceae*	Bulbs
4	*Aloe arbore* Scens	*Aloeaceae*	Leaves
5	*Aloe ferox* Miller	*Xanthorrhoeaceae*	Leaves
6	*Aloe littoralis* Baker	*Asphodelaceae*	Leaves
7	*Aloe barbadensis* Linn.	*Liliaceae*	Leaves/ Whole plant
8	*Alternanthera brasilianai* Kuntz	*Amaranthaceae*	Leaves
9	*Alternanthera sessilis* Linn	*Amaranthaceae*	Leaves
10	*Ammannia baccifera* Linn	*Lythraceae*	Plant
11	*Anagallis arvensis* Linn	*Primulaceae*	Plant
12	*Anagallis foemina* Mill	*Myrsinaceae*	Plant
13	*Annona muricata* Linn	*Annonaceae*	Stem bark
14	*Anredera diffusa* (Moq.)	*Basellaceae*	Plant
15	*Argemone Mexicana* Linn.	*Papaveraceae*	Leaves
16	*Argyreia nervosa* (Burm.f) Bojer	*Convolvulaceae*	Leaves
17	*Aristolochia bracteolate* Lam	*Aristolochiaceae*	Leaves
18	*Aristolochia bracteata* Linn	*Aristolochiaceae*	Leaves
19	*Arisaema leschenaultia* Blume	*Arceae*	Tubers
20	*Asparagus racemosus* Wild	*Liliaceae*	Root
21	*Astilbe thunbergii* (Siebold and Zucc.)	*Saxifragaceae*	Rhizomes
22	*Avena sativa* Linn.	*Poaceae*	Whole plant
23	*Bauhinia pupurea* Linn.	*Caesalpiniaceae*	Leaves
24	*Berberis aristata* Linn.	*Berberidaceae*	Plant
25	*Beta vulgaris* Linn.	*Chenopodiaceae*	Root
26	*Blechnum orientale* Linn	*Blechnaceae*	Leaves
27	*Bombax malabaricum* DC	*Bombacaceae*	Bark
28	*Borassus flabellifer* Linn	*Arecaceae*	Fruit
29	*Brassica juncea* Linn	*Brassicaceae*	Leaves
30	*Bulbine frutescens* Wild	*Xanthorrhoeaceae*	Plant
31	*Bulbine natalensis* Baker	*Xanthorrhoeaceae*	Plant
32	*Capparis zeylanica* Linn	*Capparaceae*	Whole Plant/ Roots
33	*Carapa guianensis* Linn.	*Meliaceae*	Leaves
34	*Carica candamarcensis* Hook.F.	*Caricaceae*	Fruit
35	*Carica papaya* Linn.	*Caricaceae*	Leave/Fruit/ Latex/ Epicarps/ Root
36	*Caryocar coriaceum* Wittm	*Caryocaraceae*	Root
37	*Cassia occidentalis* Linn.	*Caesalpiniaceae*	Leaves
38	*Cecropia peltata* Linn.	*Cecropiaceae*	Leaves
39	*Centella asiatica* Linn.	*Apiaceae*	Leaves
40	*Cinnamomum zeylanicum* Linn.	*Lauraceae*	Whole Plant
41	*Cissus quadrangularis* Linn.	*Vitaceae*	Plant
42	*Cissus multistriata*	*Vitaceae*	Leaves
43	*Cleoma viscosa* Linn.	*Capparaceae*	Leaves/ Whole Plant
44	*Cleome rutidosperma* DC	*Capparaceae*	Root
45	*Coccinia indica* (W.A.)	*Cucurbitaceae*	Fruit
46	*Cocculus hirsutism* Linn.	*Menispermaceae*	Leaves
47	*Cocculus pendulus* (J.R. 7 Frost) Diels	*Menispermaceae*	Leaves
48	*Coronopus didymus* Linn.	*Brassicaceae*	Whole Plant
49	*Crinum zeylanicum* Linn.	*Amaryllidaceae*	Whole Plant
50	*Cuminum cyminum* Linn.	*Umbelliferae*	Seed
51	*Curculigo orchioides* Gaertn	*Amaryllidaceae*	Root tubers/ Root
52	*Cynodon dactylon* Linn.	*Poaceae*	Leaves/ Whole Plant
53	*Cyperus rotundus* Linn.	*Cyperaceae*	Tubers
54	*Datura alba* Nees	*Solanaceae*	Leaves
55	*Dendrophthoe falcate* Ettingsh	*Loranthaceae*	Aerial parts
56	*Eichornia crassipes* Solms	*Pontederiaceae*	Leaves
57	*Embelica ribes* Burm	*Myrsinaceae*	Leaves
58	*Fagonia schweinfurthii* Hadidi	*Zygophyllaceae*	Whole Plant
59	*Ginkgo biloba* Linn.	*Ginkgoaceae*	Leaves
60	*Hypericum perforatum* Linn.	*Hypericaceae*	Aerial parts
61	*Ipomoea batatas* Lam	*Covolvulaceae*	Tubers and peel
62	*Zizyphus oenoplia* Mill	*Rhamnaceae*	Leaves

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CONCLUSION

Traditional medicines hold great importance nowadays as more and more complicated diseases are coming up, which is proving to be great challenge for medical community. Appropriate transformation of traditional medicines in commercial use can help in dealing with proper wound management, moreover for other complicated diseases.

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