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A Review on Indian Medicinal Plants for Wound Healing: From Ethnomedicine to Experimental Evidence

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Abstract:

Diabetic wounds represent a major clinical challenge due to impaired angiogenesis, prolonged inflammation, oxidative stress, and reduced collagen synthesis. Plant-based therapies offer promising alternatives owing to their multi-targeted biological actions. Bauhinia variegata Linn., a medicinal plant widely used in traditional medicine, possesses potent anti-inflammatory and antioxidant properties. The present study aimed to comparatively evaluate the wound healing efficacy of ethanolic extracts of B. variegata leaves and flowers in streptozotocin-induced diabetic rats. Excision wound models were employed, and healing was assessed by percentage wound contraction, epithelialization period, and histopathological examination. Both extracts significantly improved wound healing compared to diabetic controls, with the flower extract demonstrating superior efficacy. Enhanced collagen deposition, fibroblast proliferation, and neovascularization were observed in treated groups. The findings suggest that B. variegata, particularly its flowers, holds strong potential as a natural therapeutic agent for diabetic wound management.

Keywords: Bauhinia variegata; diabetic wound healing; phytochemicals; herbal medicine; streptozotocin.

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1. INTRODUCTION

Diabetes mellitus is a chronic metabolic disorder characterized by persistent hyperglycemia and associated microvascular and macrovascular complications. Among these, delayed wound healing remains one of the most severe clinical challenges, often leading to chronic ulcers, infections, and amputations. The impaired healing process

is mainly attributed to excessive oxidative stress, prolonged inflammatory responses, endothelial dysfunction, and compromised collagen synthesis.

Current wound management strategies rely heavily on antibiotics and synthetic agents; however, long-term use may lead to resistance, toxicity, and high treatment costs. Consequently, there is increasing interest in medicinal plants as safer and more effective alternatives. Herbal medicines offer synergistic actions by modulating multiple biological pathways involved in wound repair.

Bauhinia variegata Linn., belonging to the family Fabaceae, is traditionally employed for the treatment of wounds, ulcers, skin infections, and inflammatory disorders. Despite its extensive ethnomedicinal usage, comparative scientific evidence on the wound healing potential of its different plant parts under diabetic conditions is limited. Therefore, the present study focuses on the comparative evaluation of leaf and flower extracts of *B. variegata* in diabetic wound healing.

2. Pathophysiology of Wound Healing in Diabetes

Normal wound healing involves four overlapping phases: hemostasis, inflammation, proliferation, and remodeling. Each phase requires precise cellular coordination and biochemical signaling. In diabetic conditions, hyperglycemia disrupts these phases by impairing macrophage function, reducing fibroblast migration, inhibiting angiogenesis, and increasing reactive oxygen species (ROS) production.

Persistent oxidative stress and inflammatory mediators delay epithelialization and collagen remodeling, resulting in chronic non-healing wounds. Therefore, therapeutic agents capable of reducing oxidative stress, controlling inflammation, and enhancing tissue regeneration are crucial for diabetic wound management.

3. Role of Medicinal Plants in Wound Healing

Medicinal plants have been widely investigated for wound healing due to their rich phytochemical composition. Bioactive compounds such as flavonoids, phenolics, tannins, and saponins exhibit antioxidant, antimicrobial, anti-inflammatory, and angiogenic properties. These compounds collectively promote fibroblast proliferation, collagen synthesis, and re-epithelialization, making herbal therapies particularly effective in chronic and diabetic wounds.

3.1 Other Medicinal Plants with Proven Wound Healing Potential

In addition to Bauhinia variegata, several medicinal plants have been scientifically reported to possess significant wound healing activity, particularly under diabetic and chronic wound conditions. These plants exert their effects through antioxidant, anti-inflammatory, antimicrobial, and collagen-stimulating mechanisms, which are crucial for effective tissue repair.

Aloe vera (L.) Burm.f.

Aloe vera is one of the most extensively studied medicinal plants for wound healing. Its gel contains polysaccharides, glycoproteins, vitamins, and enzymes that promote fibroblast proliferation, collagen synthesis, angiogenesis, and re-epithelialization. In diabetic wound models, Aloe vera has been shown to reduce inflammation and oxidative stress, thereby accelerating wound contraction and healing.

Centellaasiatica (L.) Urban

Centellaasiatica is well known for its wound healing and skin regenerative properties. The plant contains triterpenoids such as asiaticoside and madecassoside, which enhance collagen synthesis, tensile strength, and angiogenesis. Studies in diabetic animals have demonstrated improved granulation tissue formation and faster epithelialization following treatment with Centellaasiatica extracts.

Curcuma longa Linn.

Curcuma longa (turmeric) possesses potent anti-inflammatory, antioxidant, and antimicrobial properties due to the presence of curcumin. Curcumin modulates inflammatory cytokines, reduces oxidative stress, and stimulates fibroblast migration and collagen deposition. Its efficacy in diabetic wound healing has been well documented, making it a valuable natural therapeutic agent.

Azadirachtaindica A. Juss.

Azadirachtaindica (neem) has been traditionally used for treating wounds, ulcers, and skin infections. Neem leaves and bark contain flavonoids, tannins, and limonoids that exhibit strong antimicrobial and anti-inflammatory effects. In diabetic wound models, neem extracts have been reported to enhance wound contraction, reduce microbial load, and improve histopathological healing parameters.

Tridaxprocumbens Linn.

Tridaxprocumbens is widely used in folk medicine for wound healing. The plant is rich in flavonoids, carotenoids, and alkaloids, which promote hemostasis, collagen formation, and epithelialization. Experimental studies have shown its effectiveness in accelerating wound healing even in compromised conditions such as diabetes.

Terminalia arjuna (Roxb.) Wight &Arn.

Terminalia arjuna bark is rich in polyphenols, tannins, and triterpenoids. These constituents exhibit antioxidant and collagen-stabilizing properties that enhance wound tensile strength and tissue remodeling. Its role in improving healing outcomes in diabetic wounds has also been reported.

The wound healing efficacy of these medicinal plants, similar to Bauhinia variegata, highlights the importance of phytoconstituent-rich herbal therapies in managing diabetic wounds. Comparative and combinational studies involving such plants may further enhance therapeutic outcomes and support the development of effective plant-based wound healing formulations.

4. Botanical, Ethnomedicinal and Pharmacological Profile of *Bauhinia variegata*

4.1 Botanical Description and Taxonomy

Bauhinia variegata Linn. is a medium-sized deciduous tree belonging to the family Fabaceae (subfamily Caesalpinioideae). The genus *Bauhinia* comprises more than 300 species distributed predominantly in tropical and subtropical regions. *B. variegata* is widely cultivated and naturally distributed throughout India, Southeast Asia, and parts of China due to its ornamental and medicinal importance.

The plant is easily recognized by its distinctive bilobed leaves, which resemble the shape of a camel's hoof—a characteristic feature that gives the genus its name. The leaves are broad, coriaceous, and deeply cleft at the apex, with a smooth surface and prominent venation. Flowers are large, showy, and fragrant, exhibiting colors ranging from white to pale pink and deep purple. The inflorescences are borne in axillary or terminal clusters, and the flowering season typically occurs during late winter to early spring. The fruit is a flat, dehiscent legume containing several seeds.

From a botanical perspective, the flowers of *B. variegata* represent a metabolically active organ, often rich in secondary metabolites involved in plant defense and pollinator attraction, whereas the leaves serve as primary sites for biosynthesis and accumulation of polyphenolic compounds.

4.2 Ethnomedicinal Significance

Bauhinia variegata has been extensively used in traditional systems of medicine, including Ayurveda, Unani, and folk medicine, for the management of various ailments. Different parts of the plant are employed depending on the therapeutic application. Leaves and flowers are traditionally applied as pastes or decoctions for the treatment of wounds, ulcers, boils, and inflammatory skin conditions. The bark is used in disorders such as goiter, dysentery, and glandular swellings, while the flowers are also consumed as a dietary vegetable in certain regions, indicating their safety and nutritional value.

The topical application of *B. variegata* leaf and flower preparations in wound management is believed to accelerate healing by reducing inflammation, preventing microbial infection, and promoting tissue regeneration. The long-standing traditional use of these plant parts strongly suggests their therapeutic efficacy and provides a rational basis for scientific validation in diabetic wound healing models.

4.3 Phytochemical Profile of Leaves and Flowers

Phytochemical investigations of *Bauhinia variegata* have revealed a diverse array of secondary metabolites, many of which are known to play a crucial role in wound healing. Both leaves and flowers contain significant quantities of flavonoids, phenolic compounds, tannins, saponins, glycosides, and terpenoids. However, qualitative and quantitative variations in phytochemical composition are observed between different plant parts.

Flavonoids such as quercetin and kaempferol derivatives are abundantly present and are well recognized for their potent antioxidant and anti-inflammatory properties. Phenolic compounds contribute to free-radical scavenging activity and protection of cellular structures from oxidative damage. Tannins are known to promote wound contraction by forming a protective layer over the wound surface and enhancing collagen cross-linking. Saponins stimulate fibroblast proliferation and angiogenesis, which are critical for granulation tissue formation and re-epithelialization.

Notably, flowers of *B. variegata* are reported to possess a higher concentration of phenolic and flavonoid constituents compared to leaves, which may explain their superior wound healing potential observed in experimental studies.

4.4 Pharmacological Relevance in Wound Healing

The wound healing activity of *Bauhinia variegata* can be attributed to its ability to modulate multiple biological pathways involved in tissue repair. The antioxidant constituents neutralize reactive oxygen species, thereby reducing oxidative stress at the wound site—a key factor responsible for delayed healing in diabetic conditions. Anti-inflammatory compounds help in limiting prolonged inflammation and facilitate timely progression to the proliferative phase of healing.

Additionally, the antimicrobial properties of *B. variegata* extracts reduce the risk of secondary wound infections, which are commonly associated with diabetic ulcers. Enhanced collagen synthesis, fibroblast migration, and neovascularization further contribute to improved wound contraction and tensile strength of regenerated tissue.

The synergistic action of these phytoconstituents enables *B. variegata* to effectively support various stages of wound healing, making it particularly beneficial in chronic and diabetic wounds where multiple pathological factors coexist.

4.5 Rationale for Selection of Leaves and Flowers

The selection of leaves and flowers for the present study was based on their traditional use, availability, and phytochemical richness. Leaves serve as primary metabolic centers and are known to accumulate polyphenolic compounds, while flowers are biologically active reproductive organs enriched with flavonoids and phenolics. Comparative evaluation of these plant parts provides valuable insight into part-specific therapeutic efficacy and supports the rational development of plant-based wound healing formulations.

5. Phytochemical Composition

Phytochemical investigations of *B. variegata* have revealed the presence of:

- Flavonoids (quercetin, kaempferol derivatives)
- Phenolic compounds
- Tannins
- Saponins
- Glycosides
- Terpenoids

These compounds play a crucial role in wound healing by neutralizing free radicals, enhancing collagen deposition, reducing microbial load, and promoting tissue regeneration.

6. Materials and Methods

6.1 Plant Material and Extraction

Leaves and flowers of *B. variegata* were collected, authenticated, shade-dried, and subjected to ethanolic extraction using standard procedures.

6.2 Experimental Animals and Induction of Diabetes

Diabetes was induced in Wistar rats using streptozotocin. Animals with confirmed hyperglycemia were selected for wound healing studies.

6.3 Wound Healing Evaluation

An excision wound model was employed. Wound contraction percentage, epithelialization period, and histopathological changes were evaluated to assess healing efficacy.

9. Conclusion

The present study demonstrates that ethanolic extracts of *Bauhinia variegata*, particularly its flowers, significantly accelerate wound healing in streptozotocin-induced diabetic rats. The findings scientifically validate its ethnomedicinal use and highlight its potential as a natural therapeutic agent for diabetic wound care.

10. Future Perspectives

Further studies involving isolation of active phytoconstituents, mechanistic evaluation, formulation development, and clinical trials are essential to translate these findings into clinical applications.

11. Conflict of Interest

The authors declare no conflict of interest.

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