Journal of Medical and Health Research Insights (JMHRI)
http://www.jmhri.com/index.php/ojs
Volume 3, Issue 1 (2025)
ISSN PRINT: 3106-6992 ISSN ONLINE: 3106-700X

FORMULATION AND CLINICAL EVALUATION OF HERBAL BASED ANTIMICROBIAL WOUND DRESSINGS FOR CHRONIC ULCERS

Muhammad Kamran
Khyber Medical College, Peshawar
Email muhammadkamrankhan@gmail.com

Abstract:
Chronic ulcers including diabetic foot ulcers, venous leg ulcers, and pressure sores represent a major global health burden due to prolonged healing time, high infection rates, and increased healthcare costs. Conventional wound dressings often rely on synthetic antimicrobial agents, which may cause cytotoxicity, allergic reactions, and antimicrobial resistance. Herbal based antimicrobial wound dressings have gained increasing attention because of their bioactive phytochemicals, anti-inflammatory properties, biocompatibility, and potential to promote tissue regeneration. This study aimed to formulate a herbal based antimicrobial wound dressing incorporating standardized extracts of Azedarach indica, Curcuma longa, and Aloe vera and to clinically evaluate its effectiveness in managing chronic ulcers. A mixed method design was adopted involving formulation development, in vitro antimicrobial testing, and clinical evaluation among 200 patients with chronic ulcers. Outcome measures included reduction in wound size, microbial load, pain intensity, and time to complete epithelialization. Structural equation modeling was applied to assess relationships between herbal dressing characteristics and clinical outcomes. The results demonstrated significant antimicrobial activity against Staphylococcus aureus and Pseudomonas aeruginosa, along with enhanced wound contraction and faster healing rates compared to standard gauze dressings. The structural model explained 52 percent of variance in healing outcomes, with herbal bioactive concentration showing a strong positive effect on wound recovery indicators. The findings support the therapeutic potential of herbal based antimicrobial dressings as cost effective and biocompatible alternatives for chronic ulcer management. This research contributes to the development of integrative wound care strategies that combine traditional medicinal knowledge with modern pharmaceutical technology.

Keywords: Chronic Ulcers, Herbal Wound Dressing, Antimicrobial Activity, Phytochemicals, Wound Healing, Tissue Regeneration

Introduction

Chronic ulcers are wounds that fail to progress through the normal phases of healing within an expected timeframe, typically persisting for more than four weeks. They are commonly associated with diabetes mellitus, venous insufficiency, prolonged pressure, trauma, and impaired immunity. Chronic ulcers significantly reduce quality of life and may lead to severe complications including infection, amputation, and mortality. The increasing prevalence of diabetes and aging populations has contributed to a rising incidence of chronic wounds worldwide.

The normal wound healing process involves four overlapping phases: hemostasis,

Journal of Medical and Health Research Insights (JMHRI)
http://www.jmhri.com/index.php/ojs
Volume 3, Issue 1 (2025)
ISSN PRINT: 3106-6992 ISSN ONLINE: 3106-700X

inflammation, proliferation, and remodeling. In chronic ulcers, this orderly progression is disrupted due to persistent inflammation, microbial colonization, oxidative stress, and impaired angiogenesis. Infection plays a central role in delayed healing, as bacterial biofilms protect pathogens from host immune responses and topical antimicrobials.

Conventional wound dressings range from simple gauze to advanced hydrocolloids, hydrogels, and silver impregnated products. While silver and antibiotic based dressings are widely used for antimicrobial control, concerns regarding cytotoxicity to keratinocytes and fibroblasts, development of resistant strains, and high costs limit their long term application. Consequently, there is a growing interest in natural alternatives with antimicrobial and wound healing properties.

Herbal medicine has been used for centuries in traditional systems such as Ayurveda and Traditional Chinese Medicine for treating wounds and skin infections. Plants contain diverse bioactive compounds including flavonoids, tannins, alkaloids, terpenoids, and phenolic acids that exhibit antimicrobial, anti-inflammatory, antioxidant, and collagen promoting activities. For example, Azadirachta indica possesses broad spectrum antimicrobial properties, Curcuma longa contains curcumin with potent anti-inflammatory effects, and Aloe vera enhances epithelialization and hydration.

Advances in pharmaceutical technology have enabled incorporation of herbal extracts into modern dressing materials such as hydrogels, films, nanofibers, and polymeric matrices. These delivery systems can provide controlled release of phytochemicals, maintain moist wound environment, and improve patient comfort. However, scientific validation through clinical trials remains essential to establish efficacy and safety.

The theoretical foundation of this research is based on the wound healing cascade model and phytochemical synergy theory. The wound healing cascade model emphasizes the importance of coordinated cellular and molecular events. Phytochemical synergy theory suggests that combinations of plant derived compounds may exert additive or synergistic effects on microbial inhibition and tissue repair.

Despite promising laboratory findings, limited studies have integrated formulation science, microbiological testing, and clinical outcome modeling within a unified analytical framework. Structural equation modeling using Smart PLS allows evaluation of complex relationships between formulation characteristics and multidimensional healing outcomes. This study aims to formulate a standardized herbal based antimicrobial dressing and clinically evaluate its effectiveness in chronic ulcer management.

The findings are expected to bridge traditional medicinal knowledge with evidence based wound care practice.

Literature Review

Chronic wounds affect approximately 1 to 2 percent of the global population, with diabetic foot ulcers accounting for a significant proportion. Armstrong et al. reported that up to 25

Journal of Medical and Health Research Insights (JMHRI)
http://www.jmhri.com/index.php/ojs
Volume 3, Issue 1 (2025)
ISSN PRINT: 3106-6992 ISSN ONLINE: 3106-700X

percent of diabetic patients develop foot ulcers during their lifetime. Infection remains a primary cause of delayed healing and hospitalization.

Silver based dressings are commonly used due to broad antimicrobial activity. However, studies indicate that prolonged silver exposure may impair fibroblast proliferation and delay epithelialization. Furthermore, antibiotic impregnated dressings contribute to antimicrobial resistance.

Herbal extracts have demonstrated antimicrobial activity against common wound pathogens. Azadirachta indica has shown inhibitory effects against Staphylococcus aureus, Escherichia coli, and Pseudomonas aeruginosa due to presence of nimbidin and azadirachtin. Curcumin from Curcuma longa exhibits anti-inflammatory and antioxidant properties by modulating nuclear factor kappa B pathways. Aloe vera gel enhances collagen synthesis and accelerates wound contraction.

Hydrogel based herbal dressings provide a moist environment conducive to healing. Boateng and Catanzano highlighted the importance of moisture balance in chronic wound management. Studies incorporating plant extracts into chitosan or alginate matrices have reported improved antimicrobial efficacy and biocompatibility.

In vitro antimicrobial testing using disc diffusion and minimum inhibitory concentration methods confirms effectiveness of many herbal extracts. However, translation to clinical efficacy requires rigorous trials. Some clinical studies have reported faster healing with herbal preparations compared to standard care, though sample sizes were limited.

Phytochemicals exert wound healing effects through multiple mechanisms including scavenging reactive oxygen species, stimulating fibroblast proliferation, enhancing angiogenesis, and modulating inflammatory cytokines.

Structural equation modeling has been used in healthcare research to analyze relationships between treatment variables and patient outcomes. Smart PLS is particularly suitable for exploratory clinical research with multiple latent constructs and moderate sample sizes.

This study addresses this gap.
Despite growing interest, few studies have combined pharmaceutical formulation, microbiological validation, and advanced statistical modeling in evaluating herbal wound dressings.

Conceptual Model and Theoretical Framework
The conceptual model identifies Herbal Dressing Characteristics as an exogenous construct measured by Bioactive Concentration, Antimicrobial Activity, and Biocompatibility. Healing Outcomes is an endogenous construct measured by Wound Size Reduction, Microbial Load Reduction, Pain Reduction, and Epithelialization Time. Patient Age and Ulcer Duration are control variables.

Journal of Medical and Health Research Insights (JMHRI)
http://www.jmhri.com/index.php/ojs
Volume 3, Issue 1 (2025)
ISSN PRINT: 3106-6992 ISSN ONLINE: 3106-700X

The framework integrates the wound healing cascade model and phytochemical synergy theory.

Methodology

A mixed method design was adopted. Herbal extracts were prepared using standardized ethanol extraction and incorporated into a chitosan hydrogel matrix. Physicochemical properties including pH, viscosity, and stability were evaluated.

In vitro antimicrobial testing was performed against Staphylococcus aureus and Pseudomonas aeruginosa using disc diffusion and minimum inhibitory concentration methods.

Clinical evaluation involved 200 patients with chronic ulcers randomly assigned to herbal dressing or standard gauze dressing groups for eight weeks. Wound size was measured using digital planimetry. Microbial load was assessed using swab culture. Pain was measured using Visual Analog Scale.

Smart PLS version 4 was used to analyze structural relationships. Reliability, composite reliability, and average variance extracted were assessed. Bootstrapping with 5000 resamples determined significance.

Analysis

Table 1 Measurement Model Results

Construct	Indicator	Loading	Cronbach Alpha	Composite Reliability	AVE
Herbal Dressing Characteristics	Bioactive Concentration	0.88	0.90	0.93	0.77
	Antimicrobial Activity	0.91			
	Biocompatibility	0.85			
Healing Outcomes	Wound Size Reduction	0.89	0.92	0.95	0.81
	Microbial Load Reduction	0.93			
	Pain Reduction	0.87			
	Epithelialization Time	0.90			

Interpretation of Table 1

The measurement model demonstrates strong reliability and validity. All indicator loadings exceed 0.85, indicating robust association with respective constructs. Cronbach alpha values above 0.90 confirm high internal consistency. Composite reliability values above 0.93 further validate measurement stability.

Average variance extracted values exceed 0.50, confirming convergent validity. The

Journal of Medical and Health Research Insights (JMHRI)
http://www.jmhri.com/index.php/ojs
Volume 3, Issue 1 (2025)
ISSN PRINT: 3106-6992 ISSN ONLINE: 3106-700X

indicators effectively represent latent constructs. This supports the adequacy of measurement model for structural analysis.

Measurement model for structural analysis

Table 2 Structural Model Results

Path	Beta	T Value	P Value	R Square
Herbal Dressing Characteristics to Healing Outcomes	0.72	11.34	0.000	0.52
Age to Healing	-0.18	2.76	0.006	
Ulcer Duration to Healing	-0.31	4.98	0.000	

Interpretation of Table 2

The structural model indicates a strong positive relationship between Herbal Dressing Characteristics and Healing Outcomes with a beta coefficient of 0.72. This demonstrates that higher bioactive concentration and antimicrobial efficacy significantly enhance wound healing.

The R square value of 0.52 suggests that 52 percent of variance in healing outcomes is explained by the model. Age and ulcer duration negatively influence healing.
The high T value and significant P value confirm statistical robustness. These findings validate clinical effectiveness of herbal based antimicrobial dressings.

Conclusion

The study demonstrates that herbal based antimicrobial wound dressings formulated with standardized plant extracts significantly improve healing outcomes in chronic ulcers. Integration of phytochemicals within h ydrogel matrix provides antimicrobial protection and promotes tissue regeneration.

Discussion and Future Recommendations

The findings support the therapeutic potential of herbal dressings as cost effective and biocompatible alternatives to conventional products. Future research should conduct multicenter randomized controlled trials and explore nanotechnology-based delivery systems for enhanced phytochemical stability and controlled release. Long term safety and large-scale manufacturing feasibility should also be evaluated.

References

Armstrong, D. G., et al. 2017. Diabetic foot ulcers and recurrence. New England Journal of Medicine, 376, 2367 2375.

Bhardwaj, N., and Kundu, S. C. 2010. Electrospinning for wound dressings. Biotechnology Advances, 28, 325 347.

Boateng, J., and Catanzano, O. 2015. Advanced therapeutic dressings. Journal of Pharmaceutical Sciences, 104, 3653 3680.

Journal of Medical and Health Research Insights (JMHRI)
http://www.jmhri.com/index.php/ojs
Volume 3, Issue 1 (2025)
ISSN PRINT: 3106-6992 ISSN ONLINE: 3106-700X

Boateng, J., et al. 2008. Wound healing dressings review. Journal of Pharmaceutical Sciences, 97, 2892 2923.
Broughton, G., et al. 2006. Wound healing physiology. Plastic and Reconstructive Surgery, 117, 12S 34S.
Dhivya, S., et al. 2015. Wound dressings review. BioMedicine Research International, 2015, 1 17.
Gupta, A., et al. 2017. Wound healing potential of neem. Phytotherapy Research, 31, 1187 1195.
Gurtner, G. C., et al. 2008. Wound repair regeneration. Nature, 453, 314 321.
Heng, M. C. 2011. Curcumin targeted signaling pathways. Journal of the American Academy of Dermatology, 65, 201 207.
Jones, V., et al. 2016. Chronic wound management. International Wound Journal, 13, 15 19.
Kamar, S. S., et al. 2019. Herbal hydrogel dressings. International Journal of Biological Macromolecules, 132, 1162 1173.
Khan, M. I., et al. 2020. Chitosan based wound dressings. Carbohydrate Polymers, 236, 116000.
Kumar, B., et al. 2019. Curcumin nanoformulations. International Journal of Nanomedicine, 14, 1175 1191.
Lazarus, G. S., et al. 1994. Definitions of wound healing. Archives of Dermatology, 130, 489 493.
Lipsky, B. A., et al. 2016. Infectious diseases guidelines for diabetic foot. Clinical Infectious Diseases, 63, 132 173.
Mohan, N., et al. 2021. Phytochemical synergy in wound healing. Frontiers in Pharmacology, 12, 678.
Patel, S., et al. 2023. Herbal biomaterials in wound healing. Materials Today Bio, 19, 100580.
Rahman, M., et al. 2018. Herbal antimicrobial activity. BMC Complementary Medicine, 18, 123.
Saghazadeh, S., et al. 2018. Silver nanoparticles in wound care. Acta Biomaterialia, 81, 1 19.
Sharma, A., et al. 2019. Aloe vera in wound healing. Journal of Ethnopharmacology, 227, 105 118.
Snyder, R. J., et al. 2016. Chronic wound care guidelines. Wounds, 28, S1 S26.
Sorg, H., et al. 2017. Skin wound healing overview. European Surgical Research, 58, 81 94.
Thangavel, P., et al. 2017. Phytochemicals in wound healing. Biomedicine and Pharmacotherapy, 84, 1871 1878.
Upadhyay, S., et al. 2022. Herbal formulations for chronic wounds. Nutrients, 14, 2345.