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Advancements in the Management of Diabetic Foot Ulcers: Integrating Artificial Intelligence and Herbal Therapies

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Abstract

Diabetic foot ulcers (DFU) are among the most complicated issues of diabetes mellitus. It can lead to suffering for diabetics because of the risk of amputation and the associated high rates of morbidity in severe cases. There have been significant developments in the use of both modern technology and complementary medicine for the treatment of DFUs. In this review, we will discuss the two recent approaches for the treatment of DFU- artificial intelligence (AI) and herbal therapies. With creation of more advanced ways to diagnose DFU and using AI to assist for early detection, the science of DFU management has changed. There are several different types of machine learning models, including convolutional neural networks (CNNs), which have proven to be effective for classifying DFU and predicting outcomes for individuals diagnosed with DFU and analyzing the outcomes for individuals suffering with DFU as determined by severity of ulceration. Additionally, AI based approaches allow for DFU detection through remote monitoring. Herbal therapies have become popular for enhancing wound healing because of phytochemical compounds found in Curcuma longa (turmeric), Allium sativum (garlic), and Calendula officinalis (calendula). Phytochemicals components of these herbs exhibit antimicrobial and anti-inflammatory as well as antioxidant properties, which can stimulate tissue repair and lower infection risks. In general, integrating AI with herbal therapy offers a comprehensive approach to DFU management due to both objectivity of AI and low costs of herbs. Although AI provides objective information for clinical decision, herbal remedies provide cost effective alternatives to patient. Future studies should focus on clinical trials that assess the effectiveness and safety of both methods to develop standard treatments.

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1. Introduction

Diabetic foot ulcers are complex skin wounds that adversely affected individuals, resulting to higher morbidity and mortality rates and reduced quality of life (Nawaz et al., 2024). These ulcers are recognized as a complication of diabetes mellitus, affecting 15-20% of individuals with the condition accounting for over 85% of all non-traumatic limb amputations (Dawi et al., 2025). Traditionally, the treatment of

DFUs has focused on wound cleaning and debridement, infection management, and offloading pressure from affected area. Simultaneously, innovative treatment methods of these wounds are being actively developed.

2. Artificial Intelligence in DFU Management

DFUs represent a significant complication linked to diabetes mellitus, contributing to higher morbidity, reduced quality of life and increased healthcare costs. The complexity and variability of DFUs pose significant challenges in diagnosis and treatment, motivating the exploration of Artificial intelligence (AI) as a new tool to improve patient outcomes. Application of AI in managing DFUs include diagnostic support, remote monitoring, and predictive analytics. Recent developments in this field have included the following:

3. Image-Based Detection Systems:

There have been considerable developments in the area of AI-assisted diagnosis and classification of DFUs using image methods. A multicenter proof-of-concept clinical studies conducted that an AI system integrated into smartphones is capable of producing highly accurate results of DFU detection in a variety of settings (Cassidy et al., 2023). Furthermore, the DFU_XAI framework has assisted to fill the gap in the interpretability of the deep learning models for better diagnostics to clinicians without losing accuracy (Rathore et al., 2025). Furthermore, CNNs have been used effectively in the classification and recognition, in real time of DFUs with the use of parallel hardware tools which process the image data with accuracy and speed. Thus, this helps in early diagnosis and better monitoring capabilities (Fadhel et al., 2024). AI systems have also been demonstrated to classify ulcers based on severity, wound attributes and healing potential, which makes personalized therapy possible. These studies show DFU management can be transformed with the use of AI-based imaging analysis through increased access to DFU information, improved interpretability of imaging and better clinical decision making in many different healthcare facilities (Alkhalefah et al., 2025).

4. Remote Monitoring and Telemedicine

Remote monitoring using AI is providing to be a transformative approach in the treatment of DFU with advancements in technology, including the emergence of wearable sensors such as continuous glucose monitors (CGMs), smart insoles, and temperature sensors, continuous health data can be acquired and used in conjugation with telemedicine to remotely monitor wounds progression and overall health without requiring frequent hospital visits (Ardelean et al., 2025). In turn, this allows for the development of personalized and optimal treatments for patients who do not have access to health facilities since their data will already have been analyzed using machine learning and AI algorithms. Smartphone based monitoring tools enable patients to take photos of their wounds and submit them for analysis. Recent research indicates that such as app allows for the automated processing of the submitted pictures and offers an evaluation of the condition and a recommendation on how to proceed with the treatment based on this information (Alkhalefah et al., 2025). Recent studies have demonstrated the effectiveness of these types of applications, since they have proven to have to have potential for the success rate of given therapies by the use of machine learning algorithms and large datasets of treatment outcomes (Guan et al., 2024). Digital health metrics are used in combination with sophisticated software algorithms to improve the risk analysis, so that clinicians and their patients can know the approximate timeline for healing and what steps can be taken to speed-up the healing process (Cay et al., 2024). This combination of advanced technologies help improve access and continuity of care through the use of self-management tools for patients, which should improve clinical outcomes and reduce health disparities in DFU care.

5. Predictive Modeling

AI-driven predictive modelling helps in transforming the prevention and treatment planning of DFUs by facilitating early risk detection, healing and efficient patient classification (Ardelean et al., 2025). With the use of predictive models, healthcare providers can track the progress of the patients DFU and make changes as per requirement (Guan et al. 2024). In addition, AI will classify patients based on risk levels, which help the healthcare provider to prioritize the patient care levels, allocate resources more effectively and customize treatment guidelines which are based on the individual patient. Recent researches emphasize on the need to combine wearable sensor data to further improve risk assessment and to provide a framework for the patient to manage their conditions. This predictive approach enhances clinical decision-making, promotes preventive care, and supports long-term monitoring, ultimately improving patient outcomes

and reducing the burden of diabetic foot complications in patients with diabetes.

6. Herbal Therapies in DFU Treatment

Allicin sativum (garlic) have been demonstrated to have antibacterial qualities, enhance blood flow and provide antioxidant protection. Further, preclinical research suggests that garlic can help cure wounds, but there are only some clinical studies which particularly address the use of garlic for FFUs (Narzary et al, 2023, Fuloria et al., 2022). Randomized controlled trials showing that Plantago major (plantain) enhances the healing process by providing safe, low-cost and effective ways to heal wounds. Plantago major has also demonstrated the capability of epithelializing, showing antioxidative properties and reducing inflammation through the presence of aucubin and chlorogenic acid. Further, its efficacy is seen through researches representing synergistic effect between Platago major and Aloe vera (Fuloria et al., 2022). There are several ongoing researches which aim to determine and improve the mechanism for therapeutic response and carry out more trials at larger scale. However, based on current researches, close monitoring, use of standardized formulations and the use of conventional treatment methods are important to improve the overall efficacy.

Table 1: Herbal Agents and Their Active Compounds in Wound Healing

Herb	Active Compounds	Mechanism of Action	References
Curcuma longa	Curcumin, demethoxycurcumin, bisdemethoxycurcumin	Anti-inflammatory, antioxidant, Promotes wound healing, anti-microbial	Fuloria et al.,2022
Allium sativum	Allicin, flavonoids	Antimicrobial, collagen synthesis, Anti-inflammation	Sasi et al.,2021
Aloe Vera	Acemannan, aloin, aloesin, Vitamins A, C, E	Anti-inflammation, anti-microbial, promotes angiogenesis, enhances collagen synthesis	Najafian et al.,2019
Honey	Glucose oxidase, hydrogen peroxide, phenolic compounds, and amino acids	Anti-inflammation, anti-microbial, promotes granulation tissue formation, wound debridement	Bezerra et al.,2023
Plantago major (Plantain)	Flavonoids, terpenoids, iridoid glycosides, phenolic glycosides, polysaccharides	Wound healing, Anti-inflammation, anti-microbial, antiviral, promotes fibroblast proliferation, collagen deposition, angiogenesis, re-epithelialization	Zhakipbekov et al.,2023

7. Integrating AI and Herbal Therapies

Artificial intelligence (AI), particularly generative AI methods. DFU classification, prediction, segmentation, detection nd classification through smartphone AI system has been clinically validated for direct DFU detection (Alkhalefah et al., 2025). Further, macine learning technologies have been employed to improve the assessment of wounds and approximate healing time. Continuous monitoring of wounds using AI and wearable technology also helps to address the issue of data availability through generative AI (Ardelean et al., 2025). Multiple researches have demonstrated various herbal treatments for DFU management, many natural products such as eugenol, thymol, carvocrol, curcumin and aloe vera carry antimicrobial properties and inhibit biofilm formation (Nazari et al., 2025, Kumar et al., 2023). Other supported treatment methods include naringin at therapeutic dosages, which demonstrated significant healing properties by increasing the levels of several important growth factors (e.g. VEGF-c, TGF-β, IGF-1) and Plantago major ointment which decreases the time requirement for healing the wound in comparison to other forms of treatment. (Narzary et al, 2023, Miraj et al., 2023). There are many researches but some limitations still prevail in potential synergies between AI and herbal therapies include AI-guided slection of herbal treatments based on characteristics of wounds (Narzary et al, 2023, Kumar et al., 2023).

8. Challenges and Future Directions

In spite of promising numbers, several obstacles block the expansion of AI and herbal therapies for

treating DFUs (diabetic foot ulcers). More research is needed to prove how well both of these methods work together as treatment options on a large scale in multi-center trials. In addition, when adding AI tools into clinical practice there are many significant things that must be confronted such as issues around data privacy, data sharing between systems, training of clinicians who will use these tools, etc. Regulations for herbal products vary based on regionally. Thus, having clear procedures for ensuring better quality of all the products that are utilized by patients is important, for the safe use of all the appropriate regulations. Collaboration among manufacturers, researchers and the regulatory agency is required to create an evidence-based policy for the use of herbal products combined with AI technologies as treatment options. Patient education is a crucial part for helping them obtain optimal results from using herbal products combined with AI in the treatment plan. This can also help understand all the advantages and disadvantages of using AI technology and herbal medicine together. The combined use of both also provides a unique and innovative method for patient care, as AI's ability to enhance diagnostically accurate diagnosis, remotely monitor patients and develop predictive analysis for speeding the wound healing process. Future studies evaluating the overall effectiveness of these treatment models should be established, protocols standardized and any other barriers related to documenting evidence related to effectiveness of the models need to be addressed through regulations and education.

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