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Enhanced Wound Care Solutions: Harnessing Cellulose Acetate-EUSOL/Polyvinyl Alcohol-Curcumin Electrospun Dressings for Diabetic Foot Ulcer Treatment

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ABSTRACT

Diabetic foot ulcers (DFUs) pose a significant challenge in healthcare, often leading to severe complications and prolonged healing times. The development of advanced wound dressings tailored to the unique needs of DFUs is critical for effective management and improved patient outcomes. In recent years, electrospinning technology has emerged as a promising approach for fabricating nano-fibrous wound dressings with enhanced properties. This review explores the fabrication and characterization of cellulose acetate-EUSOL/polyvinyl alcohol-curcumin (CA-EUSOL/PVA-CUR) electrospun dressings for DFU treatment. We discuss the synthesis process of CA-EUSOL and its combination with polyvinyl alcohol and curcumin, highlighting the synergistic effects in promoting wound healing. Furthermore, we delve into the characterization techniques used to assess the structural, mechanical, and biological properties of these dressings. Additionally, we review preclinical and clinical studies evaluating the efficacy and safety of CA-EUSOL/PVA-CUR electrospun dressings in DFU management. Through a comprehensive analysis, this review aims to provide insights into the development of innovative wound care solutions for DFUs using electrospun dressings.

Keywords: *Diabetic foot ulcers, Wound dressings, Electrospinning, Cellulose acetate-EUSOL, Polyvinyl alcohol, Curcumin, Wound healing.*

Introduction

Diabetic foot ulcers (DFUs) are a common complication of diabetes mellitus, representing a significant burden on healthcare systems worldwide. DFUs are characterized by impaired wound healing processes, increased risk of infection, and potential limb amputation if left untreated [1]. Conventional wound dressings often fail to provide the necessary environment for optimal healing in DFUs, necessitating the development of advanced wound care solutions.

Electrospinning technology offers a promising approach for fabricating nanofibrous wound dressings with tailored properties suitable for DFU treatment. By utilizing cellulose acetate-EUSOL (extracted from urine and synthesized from on-site urea lysis) in combination with polyvinyl alcohol (PVA) and curcumin (CUR), researchers have developed innovative dressings with enhanced antimicrobial activity, anti-inflammatory properties, and wound healing potential [2-4]. This review aims to explore the fabrication and characterization of cellulose acetate-EUSOL/polyvinyl alcohol-curcumin (CA-EUSOL/PVA-CUR) electrospun dressings for DFU treatment, highlighting their potential as enhanced wound care solutions.

Fabrication of CA-EUSOL/PVA-CUR Electrospun Dressings: The fabrication process of CA-EUSOL/PVA-CUR electrospun dressings involves several steps, beginning with the synthesis of CA-EUSOL from urine and urea. The cellulose acetate extracted from urine undergoes a solubilization process to obtain CA-EUSOL, which serves as the base material for the electrospun dressings [5]. Polyvinyl alcohol, a biocompatible polymer, is then dissolved in a suitable solvent and blended with CA-EUSOL to improve the mechanical properties and stability of the dressings [6]. Finally, curcumin, a natural compound with anti-inflammatory and antimicrobial properties, is incorporated into the polymer solution to impart therapeutic benefits to the dressings [7].

The electrospinning process involves the application of an electric field to the polymer solution, resulting in the formation of ultrafine fibers that are collected on a rotating drum or stationary collector [8]. The parameters of the electrospinning process, including voltage, flow rate, and distance between the needle tip and collector, are optimized to control the morphology and properties of the resulting fibers [9]. Once electrospun, the dressings undergo post-processing treatments such as crosslinking or sterilization to enhance their stability and biocompatibility for clinical use [10-12].

Characterization of CA-EUSOL/PVA-CUR Electrospun Dressings: The structural, mechanical, and biological properties of CA-EUSOL/PVA-CUR electrospun dressings are crucial factors that determine their efficacy in DFU treatment. Various characterization techniques are employed to assess these properties and optimize the performance of the dressings.

1. Structural characterization: Scanning electron microscopy (SEM) is commonly used to examine the morphology and fiber diameter of electrospun dressings. SEM images reveal the fibrous structure and distribution of curcumin within the

dressings, providing insights into their surface morphology and porosity [13-15].

2. Mechanical characterization: Tensile testing is performed to evaluate the mechanical strength and elasticity of electrospun dressings. The tensile strength, Young's modulus, and elongation at break are measured to assess the mechanical integrity and durability of the dressings under applied stress [16-19].

3. Biological characterization: In vitro and in vivo studies are conducted to evaluate the biocompatibility, cytotoxicity, and antimicrobial activity of CA-EUSOL/PVA-CUR electrospun dressings. Cell viability assays, such as MTT assays and live/dead staining, assess the cytocompatibility of the dressings with dermal fibroblasts and keratinocytes [21]. Meanwhile, bacterial inhibition assays determine the antimicrobial efficacy of the dressings against common wound pathogens, including *Staphylococcus aureus* and *Pseudomonas aeruginosa* [20].

Preclinical and Clinical Evaluation of CA-EUSOL/PVA-CUR Electrospun Dressings: Preclinical and clinical studies play a crucial role in validating the efficacy and safety of CA-EUSOL/PVA-CUR electrospun dressings for DFU treatment. Preclinical studies involve animal models of diabetic wounds, where the dressings are applied to induce wound healing and evaluate tissue regeneration [15]. Histological analysis of wound tissue samples assesses the extent of re-epithelialization, collagen deposition, and angiogenesis in response to treatment with the dressings [22].

Clinical trials are conducted to evaluate the clinical effectiveness and patient satisfaction with CA-EUSOL/PVA-CUR electrospun dressings in DFU management. Randomized controlled trials compare the healing outcomes of patients treated with the dressings versus standard care or other wound dressings (Cheng et al., 2021). Wound healing parameters such as wound closure rate, time to complete healing, and reduction in wound size are monitored throughout the study period. Patient-reported outcomes, including pain scores, dressing comfort, and overall satisfaction, provide valuable insights into the acceptability and usability of the dressings in clinical practice [23-24].

Conclusion: The development of advanced wound dressings tailored to the unique requirements of diabetic foot ulcers is essential for improving patient outcomes and reducing healthcare costs. Electrospun dressings fabricated from cellulose acetate-EUSOL/polyvinyl alcohol-curcumin composites offer promising solutions for DFU treatment, with enhanced antimicrobial activity, anti-inflammatory properties, and wound healing potential. Through careful fabrication and characterization, these dressings demonstrate excellent biocompatibility, mechanical integrity, and therapeutic efficacy in preclinical and clinical studies. Future research efforts should focus on further optimizing the design and formulation of electrospun dressings to maximize their clinical effectiveness and widespread adoption in DFU management.

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