

PREFACE

This dissertation chronicles my research journey into developing protein-based multifunctional hydrogels tailored for diabetic wound healing, a critical area of biomedical research aimed at improving patient care for those with chronic wounds. Diabetic wounds represent a significant healthcare challenge worldwide due to their complexity, slow healing rates, and high risk of infection. These factors inspired me to focus on creating advanced materials that would not only promote rapid healing but also provide sustained therapeutic benefits throughout the wound recovery process. My research delves into designing hydrogels that integrate bioactivity, structural integrity, and therapeutic properties to address the multifaceted requirements of diabetic wound management.

The first segment of this research is dedicated to formulating a 3D-printable hydrogel that combines Bovine Serum Albumin (BSA) with Aloe Vera (AV). This 3D-printable hydrogel was systematically optimized to achieve high swelling, water retention, and biocompatibility—characteristics that are essential for maintaining a hydrated wound environment and supporting cellular activity. Specific compositions, like the A6B8 variant, emerged as optimal formulations for promoting collagen deposition, angiogenesis, and tissue regeneration in diabetic wounds. The potential for personalized wound care with a hydrogel that is both antibacterial and cost-effective demonstrates its promising role as a practical wound dressing for diabetic patients.

The second phase of this research explores a self-assembled BSA-HA hydrogel, leveraging the natural biocompatibility of BSA and hyaluronic acid (HA) to create a scaffold conducive to cell migration and proliferation. This nanohydrogel, especially in its 2H-8B form, has been carefully designed to facilitate rapid wound closure by creating a moist

environment that encourages angiogenesis and epidermal regeneration. Beyond its biocompatibility, the nanohydrogel's anti-inflammatory and immunomodulatory properties reduce inflammation and mitigate complications often associated with chronic diabetic wounds, positioning it as an ideal dressing for long-term care.

In the final phase of this work, I explored the integration of carbon nanotubes (CNTs) into a protein-cellulose hydrogel, adding a conductive element that enables photothermal therapy. This innovation represents a leap toward multifunctional wound dressings. By incorporating near-infrared (NIR) photothermal therapy capabilities, this hydrogel offers enhanced collagen formation, increased angiogenesis, and inflammation reduction. The additional feature of photoacoustic imaging allows for real-time wound assessment, which is invaluable for monitoring healing progress and adjusting treatments accordingly. Together, these properties highlight the versatility and potential impact of CNT-based hydrogels in the field of wound management.

This research represents a meaningful advancement in diabetic wound care by introducing a suite of biomaterial solutions designed to improve healing outcomes and quality of life for patients. The combined therapeutic and diagnostic capabilities of these hydrogels present an innovative approach to wound management, addressing the immediate needs of diabetic wound care and paving the way for future advancements in chronic wound treatments.

Completing this thesis has been a deeply fulfilling experience that required dedication, resilience, and a commitment to the pursuit of scientific discovery. I am profoundly grateful to my advisor, Dr Avnish Singh Parmar, for their invaluable guidance, support, and mentorship. My heartfelt thanks also go to my committee members, lab colleagues,

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