Protein-based Multifaceted Hybrid Hydrogels as Wound Dressing for Rapid Diabetic Wound Healing

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By

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Chapter 6

Conclusion and Future Scope

This thesis presents a significant advancement in wound healing materials by developing novel, multifunctional hydrogel dressings optimized for diabetic wound care. Three distinct hydrogel types were explored, each tailored to address specific challenges associated with chronic wound healing in diabetes. The first component, a 3D printed BSA-Aloe Vera (AV) hydrogel, emerged as a pioneering formulation that combines the bioactivity of BSA with the regenerative properties of AV. Notably, the A6B8 variant showcased optimal structural and functional characteristics, such as high swelling and water uptake, leading to remarkable in vitro and in vivo wound healing outcomes. The promising results, including enhanced collagen deposition and angiogenesis, highlight its potential for personalized wound care.

Table 4.1 Summary and comparison of synthesized hydrogels for their diabetic healing properties

Hydrogel	Healing Time	3D Printability	Antibacterial	Cost effective	Remark
BSA+AV	21 days	**Fair**	**Fair**	**Excellent**	
BSA+HA	15 Days	**Excellent**	**Good**	**Fair**	
BSA+CNT	15 Days	**Excellent (Under exp)**	**Excellent**	**Good**	Conductive,4D Printing

In the second component, a self-assembled BSA-HA nanohydrogel demonstrated unique biocompatibility and efficacy. This composite hydrogel, especially in its 2H-8B form, supported cell migration, proliferation, and faster wound closure, creating an ideal moist environment that promotes angiogenesis and epidermal regeneration. Its anti-inflammatory and immunosuppressive properties further underline its suitability for diabetic wounds, showcasing it as a multifunctional platform for wound care. The third innovation involved a CNT-based conductive protein-cellulose hydrogel, which added photothermal therapy capabilities. The CNT inclusion significantly enhanced wound healing by enabling NIR-based photothermal treatment, promoting collagen formation and angiogenesis while reducing inflammation. Furthermore, the hydrogel's integration with photoacoustic imaging provided a means for real-time wound assessment, combining therapeutic and diagnostic functions in a single platform.

For the future scope of this research on protein-based hybrid hydrogels, the following areas are critical: **clinical trials, commercialization, and development of more advanced targeted hydrogels.** However, further steps are necessary to fully realize their potential in clinical and commercial contexts. Conducting clinical trials is essential to assess the safety, efficacy, and biocompatibility of these hydrogels in human subjects, which will validate their therapeutic effects observed in preclinical studies. Moreover, commercialization of the hydrogel formulations could transform diabetic wound care by providing an accessible and efficient treatment option for patients. Additionally, the development of even more advanced, targeted hydrogels could enhance the precision and effectiveness of treatment. These hydrogels might be engineered to deliver controlled drug release, facilitate targeted cell responses, or incorporate novel functionalities to address complex wound healing challenges.