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Next-generation biomaterials: Engineering responsive hydrogels for targeted drug delivery in chronic wounds

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A B S T R A C T

Chronic wounds have clinical implications due to their slow tissue healing and advancement, and because they are susceptible to infections. This paper centers on responsive hydrogels that can be designed to deliver drugs specifically to the wound site in a spatial and temporal patient-specific drug release way, and their ability to respond to the wound environment. By integrating drugs and bioactive agent into biocompatible and hydrophilic polymer networks, these responsive hydrogels could demonstrate controlled drug release.

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Chronic wounds, such as diabetic ulcers, present significant clinical challenges due to their complicated microenvironment with continuous inflammation, bacterial infection, and impaired tissue regeneration [1]. Advanced biomaterials, particularly responsive hydrogels, have recently emerged as very promising delivery platforms for targeted drug delivery and enhanced wound healing [2-4].

Hydrogels are 3D networks of hydrophilic polymers that have a high degree of hydrophilic properties that can facilitate the transport of nutrients and the removal of wastes. The three-dimensional polymeric network is porous to allow cell adhesion, growth, and mobility [5, 6]. The mechanical properties are modifiable to allow for the mechanical properties of the hydrogels are modified to match those of the surrounding tissue to evenly distribute stress, and integrate into the wound environment [7]. Injectable and in situ polymerizable hydrogels can be applied for minimally invasive applications and also they are useful for irregular wound shapes [5, 8].

Responsive hydrogels are engineered to recognize and respond to certain wound environments, for example temperature, pH, reactive oxygen species (ROS), enzymes and glucose [9]. This responsiveness provides targeted and on-demand delivery of therapeutic agents, tailored to the healing phase and specific pathologies of the wound [9]. When it comes to diabetic wounds, hydrogels that detect and respond to pH can trigger the localized release of antibacterial agents and growth factors, which ultimately, can produce better treatment outcomes at the various healing phases [9, 10].

Responsive hydrogels are also able to deliver multiple therapeutic agents in a controlled manner, (e.g. silver nanoparticles that will provide antibacterial function, curcumin for inflammation control together with vascular endothelial growth factor (VEGF) for neovascularization) [9]. This controlled, time- and spatially delivered approach has the potential to mimic the body's natural wound-healing response, and contribute to the removal of bacteria, reduction of inflammation and tissue regeneration [10, 11].

Therefore, responsive hydrogels are a revolution in chronic wound care in that they provide targeted, controlled, multi-modal therapy in response to the wound environment [12, 13].

In summary, next generation responsive hydrogels offer a revolutionary biomaterial platform for targeted localized drug delivery treatment of chronic wounds. Through responsive signals in the wound microenvironment, these engineered hydrogels allow for the precise, controlled, and multifunctional releasing and spatially distributing of therapeutic agents.

Therefore, next generation responsive hydrogels offer incredible potential to promote healing, reduce the likelihood of complications, and improve patient care of patients with chronic wounds. Current research was focused on hydrogel responsiveness, and integration with novel drug delivery systems to promote healing outcomes and increase patient quality of life.

Author Contributions

Zahra Kheradmand: Conceptualization, Writing – original draft, Writing – review & editing. The author read and approved the final version of manuscript.

Declaration of competing interest

The author declares that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data is available.

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Ethical issues

The author confirms full adherence to all ethical guidelines, including the prevention of plagiarism, data fabrication, and double publication.

References

[1] Hu Z, Zhao K, Rao X, Chen X, Niu Y, Zhang Q, et al. Microenvironment-responsive Bletilla polysaccharide hydrogel with photothermal antibacterial and macrophage polarization-regulating properties for diabetic wound healing. International Journal of Biological Macromolecules. 2024;283:137819. DOI: https://doi.org/10.1016/j.ijbiomac.2024.137819.

[2] Jiang Y, Zhu C, Ma X, Fan D. Janus hydrogels: merging boundaries in tissue engineering for enhanced biomaterials and regenerative therapies. Biomaterials Science. 2024;12(10):2504-20. DOI: https://doi.org/10.1039/D3BM01875J.

[3] Lin X, Zhang X, Wang Y, Chen W, Zhu Z, Wang S. Hydrogels and hydrogel-based drug delivery systems for promoting refractory wound healing: Applications and prospects. Int J Biol Macromol. 2025;285:138098. DOI: https://doi.org/10.1016/j.ijbiomac.2024.138098.

[4] Salehi M, Mirhaj M, Banitorfi Hoveizavi N, Tavakoli M, Mahheidari N. Advancements in Wound Dressings: The Role of Chitin/Chitosan-based Biocomposites. Journal of Composites and Compounds. 2025;7(23). DOI: https://doi.org/10.61186/jcc.7.2.2.

[5] Sawadkar P, Lali F, Garcia-Gareta E, Garrido BG, Chaudhry A, Matharu P, et al. Innovative hydrogels in cutaneous wound healing: current status and future perspectives. Frontiers in Bioengineering and Biotechnology. 2025;13:1454903. DOI: https://doi.org/10.3389/fbioe.2025.1454903.

[6] Askari S, Amerei Bozcheloei Z. Piezoelectric composites in neural tissue engineering: material and fabrication techniques. Journal of Composites and Compounds. 2022;4(10):37-46. DOI: https://doi.org/10.52547/jcc.4.1.5.

[7] Nazar LA, Al-salman SS, Torki SH, Al-Musawi MH, Najafinezhad A, Noory P, et al. 3D printed PHB-dextran-whitlockite porous construct coated with sildenafil-loaded nanofibers: a hybrid scaffold for craniofacial reconstruction. International Journal of Biological Macromolecules. 2025;314:144352. DOI: https://doi.org/10.1016/j.ijbiomac.2025.144352.

[8] Gao Y, Li Z, Huang J, Zhao M, Wu J. In situ formation of injectable hydrogels for chronic wound healing. Journal of Materials Chemistry B. 2020;8(38):8768-80. DOI: https://doi.org/10.1039/d0tb01074j.

[9] Jia X, Dou Z, Zhang Y, Li F, Xing B, Hu Z, et al. Smart responsive and controlled-release hydrogels for chronic wound treatment. Pharmaceutics. 2023;15(12):2735. DOI: https://doi.org/10.3390/pharmaceutics15122735.

[10] Li Y, Gong H, Gan T, Ma X, Geng Q, Yin S, et al. Smart Hydrogel Dressing Enhances the Healing of Chronic Infectious Diabetic Wounds through Dual-Barrier Drug Delivery Action. Biomacromolecules. 2024;25(10):6814-29. DOI: https://doi.org/10.1021/acs.biomac.4c01041.

[11] Sindhi K, Pingili RB, Beldar V, Bhattacharya S, Rahaman J, Mukherjee D. The role of biomaterials-based scaffolds in advancing skin tissue construct. Journal of Tissue Viability. 2025:100858. DOI: https://doi.org/10.1016/j.jtv.2025.100858.

[12] Fan Y, Wang H, Wang C, Xing Y, Liu S, Feng L, et al. Advances in smart-response hydrogels for skin wound repair. Polymers. 2024;16(19):2818. DOI: https://doi.org/10.3390/polym16192818.

[13] Dinescu VC, Martin L, Bica M, Vasile RC, Gresita A, Bunescu M, et al. Hydrogel-Based Innovations in Carpal Tunnel Syndrome: Bridging Pathophysiological Complexities and Translational Therapeutic Gaps. Gels. 2025;11(1):52. DOI: https://doi.org/10.3390/gels11010052.