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Smart hydrogel biopolymers for wound healing applications

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Smart hydrogel biopolymers incorporating responsive functionalities represent a major breakthrough in wound care technology. This study presents the synthesis and evaluation of pH-responsive chitosan–gelatin–polyethylene glycol (PEG) hybrid hydrogels for chronic wound management. Hydrogels were crosslinked using genipin, creating a flexible matrix capable of modulating drug release based on wound microenvironment acidity. Swelling behavior, degradation rate, and mechanical strength were optimized to mimic natural tissue properties. The hydrogels were loaded with antimicrobial peptides and growth factors to accelerate tissue regeneration. In vitro antibacterial assays demonstrated strong inhibition against Staphylococcus aureus and Pseudomonas aeruginosa. Human fibroblast proliferation increased by 70% on hydrogel surfaces compared to standard dressings. pH-triggered release profiles revealed that acidic conditions typical of infected wounds enhanced drug release by nearly 3-fold, ensuring targeted therapeutic action. Animal wound models confirmed significant wound closure within 10 days, with improved collagen organization and reduced inflammation. These findings emphasize the potential of intelligent biopolymer hydrogels to revolutionize wound management, offering a responsive, cost-effective, and biocompatible alternative to conventional therapies.