DEVELOPMENT OF A CARRAGEENAN/PEG-BASED HYDROGEL INCORPORATED WITH HYDROXYAPATITE NANOPARTICLES AND ALOE VERA FOR POTENTIAL WOUND HEALING APPLICATIONS

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Abstract

Wound healing remains a major global healthcare challenge, driving demand for advanced wound dressing materials that go beyond dry, painful conventional gauze. Hydrogels are promising alternatives due to their biocompatible, porous, hydrophilic structure that maintains a moist wound environment. This study aimed to develop a novel multifunctional carrageenan (CG) and polyethylene glycol (PEG) hydrogel, incorporated with Aloe vera extract and hydroxyapatite nanoparticles (nHAp), as a potential wound dressing. nHAp was synthesized via wet chemical precipitation. Hydrogel formulations were prepared and optimized based on swelling behavior, gel and sol content, porosity, and handling characteristics. The optimized formulation consisted of 0.375 g CG, 0.25 g PEG, 5 mL Aloe vera extract, and 0.30 g nHAp in a total volume of 30 mL. The optimized hydrogel was characterized using Fourier-transform infrared spectroscopy (FT-IR) and X-ray diffraction (XRD). Its swelling behavior in distilled water and phosphate-buffered saline (PBS), along with gel content, sol content, and porosity were evaluated. Antibacterial activity against *Staphylococcus aureus* and *Escherichia coli* was assessed via agar well diffusion method, using gentamicin as the positive control and sterile distilled water as the negative control. The hydrogel exhibited high porosity (99.76%) and swelling capacity (up to ~670% in distilled water), high sol content (78.81%) and low gel content (21.18%). However, the high porosity and loosely crosslinked polymer network may compromise mechanical strength and structural stability. The hydrogel without nHAp exhibited antibacterial activity against *S. aureus* (16.7 ± 0.58 mm), while no inhibition was observed against *E. coli*. In contrast, incorporation of nHAp eliminated inhibition zones against both strains, likely due to interactions between Ca^{2+} sites and microbial cell wall components. The positive control showed inhibition zones of 20.66 ± 0.58 mm against *S. aureus* and 16.67 ± 0.58 mm against *E. coli*. FT-IR confirmed the presence of characteristic functional groups of the incorporated components, while XRD confirmed crystalline nHAp formation. Qualitative handling observations indicated that the hydrogel could be bent, stretched, and conformed to the skin surface. Further studies should evaluate mechanical properties and cytocompatibility, improve antimicrobial activity, expand antimicrobial testing to clinically relevant wound pathogens, scratch assays, and *in vivo* wound healing performance. Overall, the developed CG/PEG/Aloe vera/nHAp hydrogel demonstrates potential as a multifunctional alternative to conventional wound dressings.

Keywords: Hydrogels, Carrageenan, Polyethylene glycol (PEG), Aloe vera, Hydroxyapatite nanoparticles