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Electrospinning as a versatile platform for engineering scaffolds in wound healing applications

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Electrospinning is a highly adaptable and scalable technique for the fabrication of nanofibrous scaffolds with high surface area, tunable porosity and structural similarity to the extracellular matrix, making it particularly attractive for wound healing applications. In this study, coaxial electrospinning was employed to develop drug-loaded poly(lactic acid) (PLA) and poly(ethylene oxide) (PEO) nanofibrous formulations for potential wound-healing applications. The fibers were designed with a PEO core containing clindamycin hydrochloride and diclofenac diethylamine (7:3 ratio) and a PLA shell intended to regulate drug release while maintaining structural integrity. To systematically evaluate the influence of processing conditions on fiber morphology, a Taguchi design of experiments (L9 orthogonal array) was employed, examining polymer solution concentration, applied voltage and flow rate. Scanning electron microscopy revealed that polymer concentration was the most influential parameter affecting fiber diameter homogeneity, followed by flow rate and applied voltage. The optimal electrospinning conditions (11 wt% PLA, 10 kV, 2 $mL \cdot h^{-1}$) produced fibers with the lowest coefficient of variation, indicating improved uniformity. Raman and near-infrared spectroscopy confirmed the presence of both polymer components, while characteristic drug signals were attenuated due to encapsulation within the PLA shell. Drug content analysis by high-performance liquid chromatography demonstrated homogeneous drug distribution, with recovery values exceeding 90%. Dissolution studies showed rapid release behavior, with approximately 90% of both drugs released within the first hour, attributed to partial shell discontinuity and the inherent brittleness of PLA. Water uptake studies indicated favorable swelling properties, while biodegradability assessment revealed an initial mass loss within the first week followed by a plateau, consistent with degradation governed primarily by the PEO-rich core. Overall, these results demonstrate the suitability of PLA/PEO coaxial electrospun fibers as drug-loaded nanofibrous formulations, while indicating the need for further formulation refinement to achieve prolonged and controlled drug release.

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