Selection of a Matrix Polymer for the Production of Biocomposite Structures Based on Amniotic Membrane Powder

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Abstract:

The development of effective wound dressings based on biopolymer matrices and amniotic membrane (AM) components represents a current focus in regenerative medicine. The amniotic membrane possesses a unique set of biological properties—immunological inertness, anti-inflammatory, angiogenic, and antimicrobial activity—which makes it a promising component for tissue-engineered constructs. At the same time, the choice of matrix polymer and crosslinking method has a decisive influence on the structural, mechanical, and functional characteristics of the biocomposite, which necessitates a comparative analysis of various matrix options.

The aim of this study was to conduct a comparative analysis of biocomposite structures based on sodium alginate and carboxymethylcellulose (CMC) hydrogels with suspended particles of decellularized human amniotic membrane matrix.

The AM powder was obtained by sequential decellularization, lyophilization, and grinding of the membrane, isolated during a cesarean section, to a particle size of 300–500 μm. Biocomposite structures were prepared based on five hydrogel variants: uncrosslinked sodium alginate, sodium alginate cross-linked with calcium chloride, uncross-linked CMC, CMC cross-linked with citric acid, and CMC cross-linked with copper sulfate. 0.5% of AM powder was incorporated into all matrices, followed by lyophilization. The samples were evaluated for physicomechanical parameters (density, swelling coefficients, gel fraction), microstructure, and AM particle distribution, as well as for antimicrobial activity by the disk diffusion method against *Staphylococcus aureus* (MRSA), *Pseudomonas aeruginosa, Escherichia coli,* and *Candida albicans*.

All the resulting biocomposites were air-dried (moisture content 1.2–3.5%), had a neutral or slightly acidic pH (5.8–7.3), and were characterized by a uniform distribution of AM particles within the matrix structure. Uncrosslinked matrices (sodium alginate, CMC) exhibited structural instability upon hydration, disintegrating in an aqueous medium. Crosslinked variants retained structural integrity,

confirmed by the presence of a detectable gel fraction. The biocomposite based on uncrosslinked sodium alginate exhibited the highest porosity (pore diameter 50–1,200 μm) and the lowest density (0.057 g/cm^3), ensuring the gradual release of AM particles during matrix bioresorption. CMC cross-linked with citric acid formed a flexible layered structure with the highest mass swelling coefficient (120±5%), possessing the potential of a moisture-retaining wound dressing. Structures based on alginates and CMC cross-linked with copper sulfate demonstrated pronounced antimicrobial activity, whereas uncross-linked CMC did not exhibit a significant antimicrobial effect. CMC with copper sulfate provided the broadest antimicrobial spectrum; however, the cytotoxicity of Cu^{2+} ions require further investigation.

Thus, the freeze-drying method for hydrogels allows for the reproducible production of biocomposite tissue-engineered structures with tunable structural and functional characteristics. The biocomposite based on non-crosslinked sodium alginate has been identified as the most promising option for delivering biologically active components of the amniotic membrane to the site of injury. The results obtained form the basis for the further development of wound dressings using components of the human amniotic membrane.

Keywords:
Amniotic membrane, biocomposite, tissue engineering, sodium alginate, carboxymethylcellulose, wound dressings, hydrogel.