Development of Tunable Alginate–Gelatin Bioinks for 3D Bioprinted Triple-Negative Breast Cancer Models

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Key Words: 3D Bioprinting, Alginate–Gelatin Hydrogel, Breast Cancer Model, Triple-Negative Breast Cancer (TNBC)

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Breast cancer remains one of the most prevalent malignancies worldwide, highlighting the need for more physiologically relevant *in vitro* tumor models [1]. Traditional two-dimensional cultures fail to replicate the complexity of the tumor microenvironment, including extracellular matrix interactions and spatial organization. In this study, alginate–gelatin hydrogel systems were investigated as bioinks for the development of 3D bioprinted breast tumor models. Four formulations with varying polymer ratios were prepared and ionically crosslinked using $CaCl_2$. Physicochemical and rheological properties were evaluated to determine printability and mechanical suitability. The optimal formulation (A2G2) was selected for extrusion-based bioprinting and used to encapsulate triple-negative breast cancer cell lines (MDA-MB-231 and HCC-1937). The hydrogels exhibited homogeneous microstructures, stable swelling behavior, and dominant elastic properties with shear-thinning characteristics, enabling precise printing and structural stability. Controlled gelatin release (70–80% retention after 21 days) preserved cell-adhesive features within the matrix. Biological analyses demonstrated high cell viability, homogeneous cell distribution, and increasing metabolic activity over time. Furthermore, gene expression analysis showed that the hydrogel microenvironment modulated the expression of several markers associated with proliferation, extracellular matrix remodeling, and cell–matrix interactions, including Ki67, MMP2, MMP14, COL1, and Integrin β1, in both TNBC cell lines. Overall, these findings demonstrate that alginate–gelatin hydrogels provide a suitable and tunable platform for the development of biologically relevant 3D breast cancer models, with potential applications in disease modeling and drug screening [2,3].

References

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