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EDITORIAL

Bioprinting for tissue engineering and modeling

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Bioprinting has emerged as a transformative technology in tissue engineering and regenerative medicine, enabling the precise spatial arrangement of cells, biomaterials, and bioactive molecules to fabricate complex, functional tissue constructs. This Special Issue of the *International Journal of Bioprinting*, titled "Bioprinting for Tissue Engineering and Modeling," presents six original research articles that exemplify the diversity and innovation in this rapidly evolving field. These contributions span applications in ocular drug delivery, bone regeneration, respiratory disease modeling, pluripotent stem cell expansion, bioink optimization, and multi-material printing strategies.

In the first article, Khoshnood et al.[1] developed a 3D-bioprinted gellan gum–polyethyleneimine (GG–PEI) hydrogel system loaded with betamethasone for ocular drug delivery. The constructs demonstrated favorable mechanical properties, high transparency, and sustained drug release, making them suitable for treating ocular inflammation. This study highlights the potential of bioprinting in creating personalized, site-specific drug delivery systems.

Kühl et al.[2] investigated the incorporation of nanosilicates into gelatin methacryloyl (GelMA) bioinks for digital light processing (DLP)-based bioprinting of bone constructs. Their findings revealed enhanced mechanical strength and improved mesenchymal stem cell (MSC) proliferation and osteogenic differentiation. This work underscores the importance of nanomaterial-enhanced bioinks in improving the structural and biological performance of bioprinted bone scaffolds.

Zimmerling et al.[3] presented a 3D-bioprinted respiratory disease model that simulates infection dynamics under various culture conditions. The model incorporates human bronchial epithelial cells and mimics the airway microenvironment, offering a valuable platform for studying host–pathogen interactions and evaluating therapeutic interventions. The study emphasizes the role of controlled release and microenvironmental factors in replicating disease progression.

Komosa et al.[4] addressed the challenge of pluripotent stem cell (PSC) expansion by developing a GelMA-based bioprinted construct that supports robust and reproducible PSC growth. The study systematically evaluates the influence of construct geometry, stiffness, and culture conditions on PSC proliferation and pluripotency maintenance. This work contributes to the development of scalable platforms for stem cell expansion and differentiation.

Lim et al.[5] optimized a composite bioink composed of alginate, gelatin, and dextran-aldehyde for 3D bioprinting and cell engraftment. The study demonstrates that the optimized formulation supports high cell viability, print fidelity, and tissue integration.

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This bioink system holds promise for applications in soft tissue engineering and regenerative therapies.

Finally, Gharraei et al.[6] introduced a novel multi-material bioprinting process using a helical mixer to fabricate fibers with controlled composition. This technique enables the continuous mixing of multiple bioinks during extrusion, allowing for spatially heterogeneous constructs with tunable mechanical and biological properties. The approach opens new avenues for engineering complex tissue interfaces and gradient structures.

The field of bioprinting has witnessed exponential growth over the past decade, driven by advances in biomaterials, printing technologies, and cellular engineering. As researchers continue to refine the resolution, speed, and fidelity of bioprinting systems, the ability to replicate native tissue architecture with increasing complexity becomes more feasible. This progress is not only technological but also conceptual, as interdisciplinary collaborations between engineers, biologists, and clinicians foster innovative approaches to longstanding challenges in tissue engineering.

One of the most promising aspects of bioprinting is its potential to address the shortage of donor organs and tissues. By enabling the fabrication of patient-specific constructs, bioprinting offers a pathway toward personalized regenerative therapies. For instance, the use of patient-derived cells in bioinks can reduce the risk of immune rejection and improve integration with host tissues.[7] Moreover, the ability to customize scaffold geometry and mechanical properties allows for the creation of constructs tailored to the anatomical and functional requirements of individual patients.

In addition to therapeutic applications, bioprinting is revolutionizing the field of *in vitro* modeling. Traditional two-dimensional cell cultures often fail to recapitulate the complex microenvironment of native tissues, limiting their utility in drug discovery and disease research. Bioprinted models, by contrast, can incorporate multiple cell types, extracellular matrix components, and spatial organization, providing more physiologically relevant platforms. These models are particularly valuable for studying diseases such as cancer, fibrosis, and infectious diseases, where cell–cell and cell–matrix interactions play critical roles.[8,9]

The integration of bioprinting with other emerging technologies further expands its capabilities. For example, combining bioprinting with microfluidics enables the creation of organ-on-a-chip systems that mimic the dynamic flow conditions of the human body.[10] Similarly, the use of artificial intelligence and machine learning can optimize printing parameters and predict construct behavior, enhancing reproducibility and efficiency.[11,12] These synergies are paving the way for next-generation biofabrication platforms that are smarter, faster, and more versatile.

Despite these advancements, several challenges remain. Ensuring the long-term viability and functionality of bioprinted tissues, achieving vascularization and innervation, and scaling up production for clinical use are active areas of research. Regulatory considerations also play a crucial role, as the translation of bioprinted products from bench to bedside requires rigorous validation and standardization. Addressing these challenges will require continued investment in research, infrastructure, and interdisciplinary training.

Educational initiatives and workforce development are pivotal to sustaining the rapid advancements in bioprinting. As the field evolves, there is an increasing demand for professionals who possess interdisciplinary expertise in both biological sciences and engineering. Recognizing this need, academic institutions have begun to introduce specialized curricula and training programs in bioprinting and biofabrication. These initiatives aim to equip emerging scientists and engineers with the theoretical knowledge and practical skills necessary to innovate in scaffold design, bioink formulation, and bioprinting technologies.[13,14]

In conclusion, the articles featured in this Special Issue not only highlight the current achievements in bioprinting for tissue engineering and modeling but also point toward a future where engineered tissues and organs become integral components of medical practice. The diversity of approaches and applications presented here reflects the richness of the field and its potential to transform healthcare. We anticipate that continued collaboration, innovation, and investment will accelerate the realization of bioprinting's full potential.

Conflict of interest

Both Dr. Liqun Ning and Dr. Xiongbiao Chen are Guest Editors for this Special Issue. Dr. Xiongbiao Chen is also a co-author for two of the six papers published in this Special Issue. The authors declare they have no competing interests.

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