OPEN ACCESS Freely available online

ISSN: 2157-7633
Journal of Stem Cell Research & Therapy

Commentary

3D Immunoregenerative Medicine: Engineering Immune-Centric Tissue Repair Systems

Qingguo Teng*

Institute of Medical Sciences, The Second Qilu Hospital & Shandong University Center for Orthopaedics, Cheeloo College of Medicine, Shandong University, Jinan, China

DESCRIPTION

3D Immunoregenerative medicine is an emerging interdisciplinary field that combines immunology, regenerative medicine and three-dimensional (3D) bioengineering to restore, rebuild and regulate damaged tissues through controlled immune interactions. Unlike traditional regenerative approaches that focus only on tissue replacement, this field emphasizes the vital role of the immune system in guiding healing, tissue integration and long-term functional recovery.

At the core of immunoregenerative medicine is the understanding that the immune system is not only a defense mechanism but also a key regulator of tissue regeneration. Immune cells such as macrophages, T cells, dendritic cells and neutrophils actively influence inflammation, stem cell activation, angiogenesis and extracellular matrix remodeling. By controlling immune responses in a spatially organized 3D environment, scientists aim to enhance tissue repair while preventing chronic inflammation or rejection.

The integration of 3D technologies such as bioprinting, organoids and biomaterial scaffolds has significantly advanced this field. Three-dimensional structures provide a more realistic microenvironment compared to traditional two-dimensional cell cultures. These systems allow immune cells and regenerative cells to interact in spatially controlled conditions that closely mimic in vivo tissue architecture. This improves the accuracy of disease modeling and therapeutic development.

3D bioprinting plays a major role in immunoregenerative medicine by enabling the fabrication of complex tissue constructs embedded with immune cells, stem cells and bioactive molecules. These printed tissues can be designed to replicate organs such as skin, cartilage, liver, or vascular networks while incorporating immune-regulatory components. This allows researchers to study how immune responses influence tissue regeneration in real time.

Macrophage polarization is one of the most important aspects of immune regulation in regenerative systems. Macrophages can shift between pro-inflammatory (M1) and anti-inflammatory (M2) states. In 3D regenerative environments, promoting a balanced transition toward the M2 phenotype is essential for tissue repair and healing. Improper immune activation can lead to fibrosis, graft rejection, or chronic inflammation.

Stem cells also play a central role in 3D immunoregenerative systems. Their behavior is strongly influenced by immune signals within the microenvironment. In turn, stem cells can modulate immune responses by secreting cytokines and extracellular vesicles. This bidirectional communication creates a dynamic feedback loop that is essential for successful tissue regeneration and integration.

Biomaterial scaffolds used in 3D immunoregenerative medicine are designed not only to support cell growth but also to actively regulate immune responses. These materials can be engineered to release immunomodulatory factors, control inflammation and enhance tissue compatibility. Smart biomaterials can respond to environmental signals such as pH, enzymes, or cytokines, making them highly adaptable for therapeutic use.

One of the major applications of 3D immunoregenerative medicine is in organ repair and transplantation. Engineered tissues with immune-compatible properties can reduce the risk of rejection and eliminate the need for long-term immunosuppressive drugs. This has significant implications for treating conditions such as liver failure, heart disease and severe burns.

Cancer immunotherapy is another area where this field is making an impact. 3D tumor models integrated with immune cells allow researchers to study tumor-immune interactions in a realistic environment. This helps in designing more effective immunotherapies and understanding how tumors evade immune surveillance. Personalized tumor models can also be used to test patient-specific immune responses to treatment.

Correspondence to: Qingguo Teng, Institute of Medical Sciences, The Second Qilu Hospital & Shandong University Center for Orthopaedics, Cheeloo College of Medicine, Shandong University, Jinan, China, Email: tengqingguo@qq.edu.cn

Received: Received: 02-Jan-2025, Manuscript No. JSCRT-25-32033; **Editor assigned**: 04-Jan-2025, Pre QC No. JSCRT-25-32033(PQ); **Reviewed:** 18-Jan-2025, QC No. JSCRT-25-32033; **Revised:** 25-Jan-2025, Manuscrit No.JSCRT-25-32033(R); **Published:** 01-Mar-2025, DOI: 10.35248/2157-7633.25.15.654.

Citation: Teng Q (2025). 3D Immunoregenerative Medicine: Engineering Immune-Centric Tissue Repair Systems. J Stem Cell Res Ther.15:654.

Despite its potential, the field faces several challenges. Replicating the full complexity of the immune system within 3D structures is extremely difficult. Maintaining long-term viability and functional stability of immune cells in engineered tissues also remains a challenge. Additionally, scaling up these systems for clinical applications requires advanced manufacturing technologies and strict regulatory frameworks.

3D immunoregenerative medicine represents a powerful convergence of immune science, tissue engineering and advanced biomaterials. By integrating immune regulation directly into 3D regenerative systems, this field offers new possibilities for repairing damaged tissues, improving organ transplantation outcomes and advancing cancer immunotherapy. Although technical and translational challenges remain, ongoing innovations in bioprinting, biomaterials and immune engineering are rapidly accelerating progress. Ultimately, 3D immunoregenerative medicine is shaping a future where healing is not only structural but also immunologically intelligent and precisely controlled.