Chapter 10
Scaffold for Tissue Engineering Design Fabrication and Applications

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ABSTRACT

Recently, Tissue engineering (TE) has been rapidly growing field in biomedical field, it provides the solutions to the problem such as immunological rejection and a shortage of available donors. TE scaffolds encourage cell adhesion, proliferation, and differentiation by simulating the extracellular matrix with three-dimensional matrices. Current, advancements in artificial intelligence (AI) and nanotechnology have improved the design, pore size, mechanical properties. However, scaffolds lack the ability of vascularization, immune compatibility, and scalability. In order to address this issue, scaffolds surface-functionalized with anti-inflammatory cyto-

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kines such as IL-10 that can increase the integration, less rejection, and long-term performance. Therefore, it is considered that the combination of nanotechnology and AI scaffold design will enhance bioactivity, mechanical strength, and cellular behavior modeling. Regenerative medicine is poised for a revolution due to significant advancements in scaffold-based TE.

INTRODUCTION

Many conditions and illnesses could have severe consequences on the body, including organ failure and, in some cases, even possible death; other conditions can only be well controlled. Although current methods, such as autografting, which is the procedure of transplanting an organ or tissue from the same organism, and allografting, which is transplanting of an organ or tissue from one member of the same species to another, also come to replace or repair damaged tissues or organs but it is not readily accessible. There is a risk of producing an immune response in a patient and spreading infectious diseases. Tissue engineering holds great promise in regenerative healthcare, particularly in developing biomimetic scaffolds that can significantly mitigate the environmental impact on various aspects of medical research (Tajurahim et al., 2025).

The historical development of scaffold-based tissue engineering and Bioprinting is the key to the development of regenerative medicine. Autografts and natural biomaterials were the primary reliance in the initial years of tissue engineering but were not scalable and not highly biocompatible. Synthetic scaffolds, bioactive composites, and sophisticated polymeric matrices have, over time, transformed tissue engineering with better control over mechanical properties and degradation rates. The development of 3D Bioprinting in the early 2000s brought unprecedented precision in scaffold production, enabling the production of patient-specific tissue architecture. Volumetric Bioprinting, light-based printing, and artificial intelligence-based scaffold design are revolutionizing regenerative medicine. Incorporating nanotechnology, innovative biomaterials, and bioinformatics, the latest bioprinting technologies now allow real-time tissue growth modeling and organ regeneration, a breakthrough in healthcare (Gharibshahian et al., 2024). These techniques provide the solution to address the shortcomings of the existing scaffold materials and tissue engineering. Scaffolds, which are biomaterials used to assist with the development of tissue repair, augmentation, and maintenance, are part of tissue engineering. Other functions of these cells include working as the template for repairing and regenerating the damaged tissue and delivering the best possible way for different elements to ensure their cell is still alive, experiencing proliferation, and finally, differentiation (Suamte et al., 2023). In recent advancements, porous scaffold bio-