Integrated 4D and 3D Bioprinting applications in bone tissue engineering

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ABSTRACT

Three-dimensional (3D) bioprinting has been developed to effectively and rapidly pattern living cells and biomaterials, aiming to create complex bioconstructs. Four-dimensional (4D) bioprinting, in which the concept of time is integrated with 3D bioprinting as the fourth dimension, has currently emerged as the next-generation solution of tissue engineering as it presents the possibility of constructing complex, functional structures. 4D bioprinting can be used to fabricate dynamic 3D-patterned biological architectures that will change their shapes under various stimuli by employing stimuli-responsive materials. The functional transformation and maturation of printed cell-laden constructs over time are also regarded as 4D bioprinting, providing unprecedented potential for bone tissue engineering. The shape memory properties of printed structures cater to the need for personalized bone defect repair and the functional maturation procedures promote the osteogenic differentiation of stem cells. In this review, we introduce the application of different stimuli-responsive biomaterials in tissue engineering and a series of 4D bioprinting strategies based on functional transformation of printed structures. Furthermore, the application of 4D bioprinting in bone tissue engineering, as well as the current challenges and future perspectives will be discussed.

Keywords: 3D bioprinting, 4D bioprinting, stimuli-responsive materials, tissue engineering

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