3D BIOPRINTING - DEDICATED BIOMATERIALS AND DEVICES

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[ENGINEERING OF BIOMATERIALS 163 (2021) 9]

Introduction

3D bioprinting became a promising approach for fabrication the complex biological constructs in the field of tissue engineering and regenerative medicine. It aims to overcome limitations of conventional tissue engineering methods by precise and controlled layer-by-layer assembly of biomaterials in a desired 3D pattern [1].

A traditional method in fabricating 3D tissue scaffolds involves seeding cells into a scaffold that provides structural and functional support to facilitate tissue regeneration. However, it is not applicable for tissues and organs with complex structure, as it does not provide a uniform cell distribution, has low cell density, slow vascularization, and limitation in the diffusion of nutrients and by-products. To address these issues, three-dimensional (3D) bioprinting was utilized and explored for the fabrication of tissues and organs using biomaterials, specific cells, and bioactive growth factors to promote tissue regeneration and effectively restore its functions.

A direct bioprinting allows the introduction of biological material in the entire volume of the printed object. Research work on cells, tissues and organs printing is aimed at fulfilling demands of organ shortage, cell patterning for better tissue fabrication, and building better disease models.

An indirect bioprinting is the production of structures that do not contain biological material, but can fulfill their specified function (supporting, protective, scaffolding for overgrown tissues, etc.), remaining biocompatible with the cells, tissues and fluids with which they are in contact. Both of these bioprinting branches have a revolutionary impact on biomedical engineering and medicine.

Materials and Methods

The two important factors that determine an effective 3D bioprinting process are the bioink/biomaterial and the bioprinter.

Biomaterials use for 3D printing process can represent various groups: polymers, ceramics, hydrogels, and metals. Different parameters should be considered in choosing materials for bioprinting [5]. Ideal material should be biocompatible, has appropriate mechanical and rheological properties to withstand bioprinting process and degradation [6].

The most commonly used 3D printing technologies for biomedical applications can be broadly categorized as either extrusion [2], particle fusion-based, droplet [3], or laser-based [4]. Each of these categories contains subgroups that use slight mechanical or chemical variations on each technique, which affect the material properties required for successful design and printing of the ink material. Each of these techniques has dedicated printers or variations of the existing ones.

The latest literature reports present countless studies on the possibilities of different bioprinting modalities. The selection of bioinks for each of them usually varies based on the ink's rheology, viscosity, crosslinking chemistry, and biocompatibility. Significant advancements have been made to integrate secondary techniques accompanying the modalities of bioprinting [7].

Results and Discussion

Two main aspects related to 3D bioprinting will be discussed: 1) materials that can be used as a bioink (for both indirect and direct printing) – what are the limitations and biggest challenges for them currently and 2) printing devices that can meet the requirements related to the increasing complexity of printed objects and their decreasing sizes determining the need to achieve very high printing accuracy.

Hydrogel materials are very good materials for the bioink, although there are still many parameters that pose a challenge in terms of obtaining their assumed and repeatable features. The possibility of introducing additional components into them allows for targeting their properties in terms of a given application in a given area of medicine. The bioactivity and properties of alginate-based hydrogels are deteriorated not only by their composition, but also by the order of mixing, the solvent used, type, cross-linking time and concentration of the cross-linking solution. On the other hand, the properties of hydrogels mean that they create protective conditions for cells during 3D printing, thanks to which it is possible to maintain their high survival rate.

In the field of thermoplastic polymers, a very desirable property is their controlled degradation, including degradation in a very short time corresponding to the tissue healing rate. Such possibilities can be obtained by combining various polymers, which creates a real challenge to create a suitable filament from them, in order to then be able to verify printability, accuracy and properties after thermal treatment, which is the 3D printing process itself.

Conclusions

Printability of a biomaterial is strictly determined by the printing technique. Although it is possible to print the same material using multiple printing techniques, the form and composition of the printable material, varies significantly. The applications of 3D bioprinting are not limited to organ printing. It also holds great promise in less explored avenues, such as using scaffolds for drug delivery, studying disease mechanisms, or creating personalized medicines. Currently, a limited number of bioinks exist which are both bioprintable and which accurately represent the tissue architecture needed to restore organ function post-printing.

Acknowledgments

Research conducted within the project MATURO 3D (TECHMATSTRATEG2/407770/2/NCBR/2020) financed by The National Centre for Research and Development, Poland.

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