LUPINE PUBLISHERS
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Archives of Nanomedicine: Open Access Journal

DOI: 10.32474/ANOAJ.2018.01.000113

ISSN 2637-6660

Mini Review

Printable Self-Assembled Peptide Bio-Inks: Promising Future Applications in Nanomedicine

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Received: May 21, 2018; **Published:** May 29, 2018

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Abstract

In the current era of research and development, nanotechnology and additive manufacturing play a key role in the industry as well as in the healthcare applications. In order to explore medicinal applications, researchers focus on the design and synthesis of biocompatible nanoparticles and nanomaterials. Molecular self-assembly is a powerful approach for the fabrication of supramolecular functional materials. Self-assembly offers the integration of nanotechnology with the additive manufacturing for the fabrication of three dimensional (3D) printed objects. The cross-linked peptide hydrogels are gaining attention as potential bio-ink for the 3D bio-fabrication. The current article focuses on the scope of the printable peptide containing hydrogels as bio-ink in the fields of nanomedicine, drug delivery and tissue engineering.

Keywords: Nanostructures; Self-Assembly Process; Fabrication; Nanomedicine; Hydrogel Networks; Printable Peptides; Structural Transition; Nanofibrous; *In Situ; In Vivo*

Introduction

Design and the development of smart nanostructures that can diagnose and simultaneously cure the health problems are the main goals of the nanomedicine. Self-assembling bio-compatible functional nanomaterials and their therapeutic activity under biological environment are the key steps in order to develop effective nanomedicine. Among various approaches to fabricate nanostructures, self-assembly offers to fabricate supramolecular functional nanostructures from their individual building blocks. Self-assembly process involves through bottom-up approach to construct supramolecular nanostructures. The nanostructures including nanofibers, nanovesicles and micelles are formed through intra- and intermolecular covalent and non-covalent interactions. Self-assembles nanostructures formed by bioactive materials can be integrated with additive manufacturing for developing effective nanomedicine. The layer-by-layer bio-fabrication methods are introduced in healthcare due to their applications in 3D drug delivery systems, matured tissue cultures and in-vitro organ fabrications [1]. Fabrication of patient-specific therapeutic system facilitates more personalized and beneficial medicinal results. 3D printing allows low cost and rapid printing of biomaterials that are composed of drug molecules as well as embedded living cells [2]. The application of printing technologies for nanomedicine requires the development of suitable materials, which endure not only the process itself but also help to keep the biological entities stable. 3D bio-fabrication of nanomaterials is a favourable strategy over direct 3D fabrication at nanoscale resolutions (Figure 1). Running parallel to nanomedicine and 3D printing technology, various types of self-assembled printable materials have been developed by researchers for medicinal applications. Self-assembled high water containing nanostructures and extra-cellular native environment mimicking hydrogels are promising candidates for medicinal applications such as drug delivery as well as tissue engineering. The development of nanomedicine bio-fabrication has been less explored due to lack of suitable bio-inks. A number of hydrogels have been introduced by worldwide researchers using various natural and synthetic molecules. Among them, self-assembling printable peptide containing hydrogels are the promising biocompatible material for healthcare applications. In order to avoid the premature collapse of the printed structure, suitable bio-inks need to be developed carefully. An ideal peptide bio-ink should compose of supramolecular nanostructure with mechanical rigidity and shape fidelity. Peptides have the ability to adopt specific structures which can easily tune by amino acid sequences with tunable physical and chemical properties. Peptides self-assembled through various covalent and non-covalent interactions such as hydrogen bonding, van der Waal forces to construct different nanostructures including nanofibers, micelles and nanotubular structures. The peptide nanostructures with high bioactivity provide controlled, biomimetic environment for cells in regenerative medicine and drug trapping sites for site-selective drug delivery.

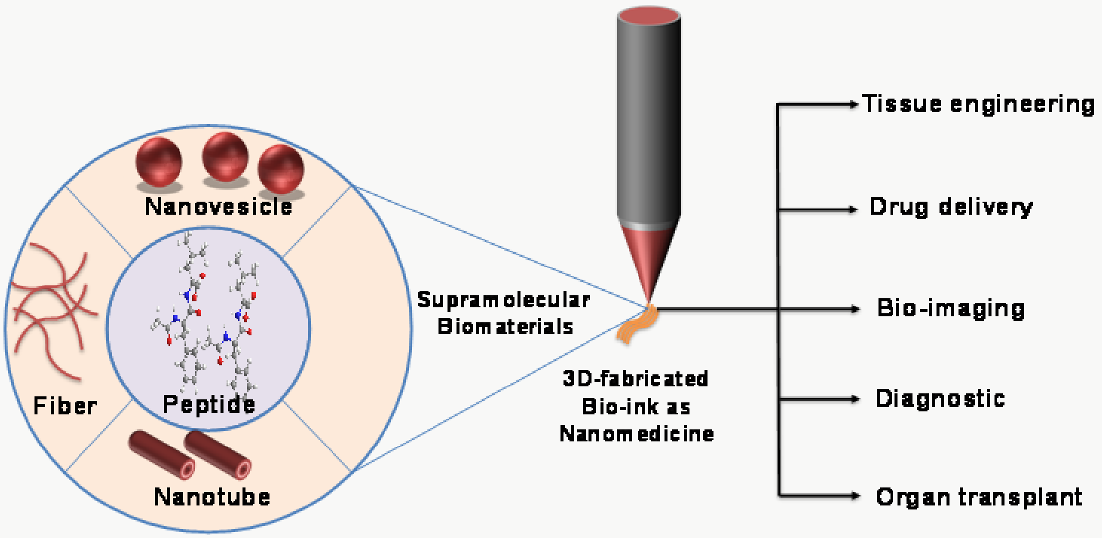

Figure 1: Schematic representation of nanomedicine fabricated by integrating peptide self-assembly with 3D- bio-fabrication.

Printable peptides are promising candidates for regenerative nanomedicines. Recently, Das reported injectable nanofibrous self-assembled of Amoc (9-anthracenemethoxycarbonyl)-capped dipeptide hydrogels. These nanofibrous hydrogels show antibacterial property and promote cell proliferation of human white blood cells [3]. The acylated peptide containing two to five hydrophobic amino acids with polar C-terminal residue self-assembles in 3D nanofibrous structure [4]. The reported peptides undergo a remarkable structural transition under the influence of salt and peptide concentrations in order to increase the stiffness of hydrogels. These injectable nanofibrous peptide hydrogels further encapsulate human umbilical vein endothelial cells to stimulate blood vessel development. Incorporation of active biomolecules such as DNA, RNA with the peptide is also an important strategy to develop printable peptide-based regenerative nanomedicine. A polypeptide - DNA conjugate forms *in situ* biocompatible hydrogel bio-ink [5]. The resultant properties of polypeptide and DNA components result in the hydrogel networks suitable for viable and functional living cells under physiological conditions. Mimicking in vivo environment by layer by layer neuronal cells in three-dimensional models is difficult during in vitro brain model development. The brain is an enormously complex organ, which is structured into various regions of layered tissue. Lozano et al. developed bio-ink by cross linking of RGD peptide with gellan gum [6]. The resultant polypeptide polymer hydrogel shows cross linked porous nanostructures which enable to encapsulate and provide the supportive environment for primary cortical neurons. Neural network formation in cell supportive matrix offers the opportunity to provide prototype brain-like structures for healthcare applications like understanding of brain injuries and neurodegenerative diseases.

Conclusion

Sophisticated targeted drug delivery and regenerative therapeutics have gained increasing attention during recent years. In comparison with conventional drug delivery, 3D bio-fabrication allows manufacturing of patient specific-drug delivery systems. Above mentioned examples show the potential of printable peptide-based hydrogel networks, which can resolve tissue engineering and regenerative therapeutics problems. Few examples have shown the printed 3D networks worth for antibacterial and microbial activity. Development of new peptide-based materials and their implementation in printable nanomedicine is the key challenges to become the mainstream technology. 3D printed biomaterials need to upgrade in order to achieve four-dimensional printing in healthcare applications.

References

1. RG Jadhav, AK Das (2017) Four dimensional printing in healthcare. 3D Printing in Medicine. Woodhead Publishing 2017: 207-218.
2. A Biswas, S Malferrari, DM Kalaskar, AK Das (2018) Arylboronate esters mediated self-healable and biocompatible dynamic G-quadruplex hydrogels as promising 3D-bioinks. Chem Commun 54: 1778-1781.
3. PK Gavel, D Dev, HS Parmar, S Bhasin, AK Das (2018) Investigations of Peptide-Based Biocompatible Injectable Shape Memory Hydrogels: Differential Biological Effects on Bacterial and Human Blood Cells. ACS Appl Mater Interfaces 10(13): 10729-10740.
4. Y Loo, A Lakshmanan, M Ni, LL Toh, S Wang, et al. (2015) Peptide Bioink: Self-Assembling Nanofibrous Scaffolds for Three Dimensional Organotypic Cultures. Nano Lett 15 (10): 6919-6925.

5. C Li, A Faulkner-Jones, AR Dun, J Jin, P Chen, et al. (2015) Rapid Formation of a Supramolecular Polypeptide–DNA Hydrogel for In Situ Three-Dimensional Multilayer Bioprinting. Angew Chem Int Ed 54(13): 3957-3961.
6. R Lozano, L Stevens, BC Thompson, KJ Gilmore, R Gorkin, et al. (2015) 3D printing of layered brain-like structures using peptide modified gellan gum substrates. Biomaterials 67: 264-273.

DOI: 10.32474/ANOAJ.2018.01.000113