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Artificial implants in biomedical engineering: the role of biomaterials and 3d printing technology

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Abstract

Artificial implants in biomedical engineering represent an important and promising field that helps address medical issues and improve the quality of life for patients. The research and development of artificial implants involve scientists from various disciplines, such as biomedical engineering, materials science, and tissue engineering. The utilization of advanced technologies, such as 3D printing, allows for the creation of personalized implants, optimization of their design, and enhanced biocompatibility with tissues. The advancement of artificial implants holds significant potential in improving the treatment of various medical conditions and challenges, and it continues to be an active area of research and development.

Keywords: artificial implants, biomaterials, regenerative medicine, 3D printing.

Introduction

Artificial implants are important medical devices used for restoration, support, or enhancement of human body functions. In biomedical engineering, artificial implants are employed in various fields such as orthopedics, cardiology, neurosurgery, dentistry, and others. They can be made from different materials including metals, ceramics, plastics, or composite materials (e.g., joint replacements used to replace damaged or diseased joints like the knee or hip). Such implants typically consist of metallic components that are implanted into the bone, as well as polymeric or ceramic components that provide joint mobility.

Research Findings

Many scientific papers on this topic are published in various scientific journals and conferences, particularly among prominent experts in the field of artificial implants in biomedical engineering, notable researchers include Robert Langer [1] (investigating the current state and future directions of tissue engineering, including the use of artificial implants, the use of biomaterials for drug delivery, and their application in regenerative medicine), Buddy D. Ratner [2] (author of numerous works in biomedical engineering and materials science, focusing on issues related to material and implant biocompatibility, surface modification methods of biomaterials to enhance their interaction with biological systems, and studying the body's response to biomaterials in the context of artificial implants), William M. Bonfield (researching the use of novel materials for the restoration of damaged bones and cartilage, and the use of bioceramics in medicine), Antonios G. Mikos [3] (a renowned scientist in the development of tissue engineering materials and artificial implants, his research focuses on the use of biocompatible materials and 3D printing technologies for manufacturing artificial implants, studying the use of biomimetic materials in tissue engineering, principles of design and fabrication of structural matrices for tissue engineering, and the application of biodegradable polymers in tissue engineering for creating implants that can degrade over time in biological systems), and Molly S. Shoichet (specializing in the development of new materials for neuroengineering, tissue engineering strategies for nervous system repair, investigating the use of injectable hydrogels for regenerative engineering).

Despite significant advancements in the development of methods and technologies for artificial implants, there are several unresolved challenges, including biocompatibility, wound healing speed after invasive interventions, and long-term implant stability.

With the advancement of modern 3D printing technologies, it is increasingly being utilized for the printing (fabrication) of artificial implants. Its key advantages include:

1) personalized individual treatment (3D printing allows the creation of implants that precisely match the unique anatomical features of patients);

2) rapid prototyping and manufacturing (3D printing enables quick creation of implant prototypes with high accuracy and complex geometry, facilitating the rapid evaluation of implant designs, making corrections, and optimizing them prior to production on the manufacturing line);

3) complexity and geometric intricacy (enabling the production of implants with intricate geometries that are difficult or impossible to manufacture using traditional methods);

4) innovation in the use of new materials (new materials may exhibit enhanced biocompatibility with human tissues).

Although 3D printing opens up numerous possibilities in the creation of artificial implants, it also presents some challenges that need to be considered: a) design and accuracy - incorrect design can lead to insufficient functionality or patient discomfort, and printing accuracy also influences the quality of the implant and its interaction with surrounding tissues; b) validation and regulation - determining their safety, effectiveness, and compliance with standards; c) time and cost - it can be a time- and resource-intensive process, especially when creating complex structures or large volumes of implants. This can affect the accessibility and cost of artificial implants for patients.

To optimize time and material costs in the manufacturing of 3D-printed artificial implants, the following methods are employed: I) topological optimization; II) generative design; III) shape optimization methods; IV) simulation and analysis methods; V) computer modeling and virtual environments.

Conclusions

3D-printing influences the development and production of implants, providing new possibilities and advantages. The utilization of 3D-printing enables implant personalization, precise three-dimensional modeling, rapid prototyping, and manufacturing of implants, including complex geometries. Additionally, this approach promotes innovation in materials science and the development of new materials. As a result of these factors, 3D-printing paves the way for improving implants, enhancing their accuracy, fit, and functionality, while also accelerating the process of developing new solutions for medical needs.

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ШТУЧНІ ІМПЛАНТИ В БІОМЕДИЧНІЙ ІНЖЕНЕРІЇ: РОЛЬ БІОМАТЕРІАЛІВ ТА ТЕХНОЛОГІЇ 3D-ДРУКУ

Анотація

Штучні імпланти в біомедичній інженерії є важливою та перспективною галуззю, яка допомагає вирішувати медичні проблеми і поліпшувати якість життя пацієнтів. Дослідження та розвиток штучних імплантів залучають вчених з різних галузей, таких як біомедична інженерія, матеріалознавство та тканинна інженерія. Використання передових технологій, таких як 3D-друк, дозволяє створювати персоналізовані імпланти, оптимізувати їх дизайн та забезпечувати кращу біосумісність з тканинами. Розвиток штучних імплантів має значний потенціал у покращенні лікування різних медичних станів та викликів, і продовжує бути активною областю досліджень і розвитку.

Ключові слова: штучні імпланти, біоматеріали, регенеративна медицина, 3D-друк.

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