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3D-Printed Polyurethane Scaffolds for Bone Tissue Engineering: Techniques and Emerging Applications

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Abstract

Purpose

The primary purpose of this review article is to provide a comprehensive analysis of polyurethane (PU)-based 3D-printed scaffolds for bone tissue engineering (BTE). It aims to highlight the unique properties of PU, such as its mechanical strength and

biocompatibility, that make it suitable for scaffold fabrication. The review examines different 3D printing techniques, assessing their compatibility with PU and their impact on scaffold properties. Additionally, it explores the potential applications of PU-based scaffolds in BTE, including customizable implants and drug delivery. The article also addresses current market trends, challenges, and future research directions to facilitate the clinical translation of PU-based scaffolds.

Methods

The authors gathered information about PU from articles published up to 2024 and listed in PubMed, Web of Science, Elsevier, Google Scholar, and similar databases. The keywords used in our search included “Polyurethane,” “3D Printing,” “SLA,” “SLS,” “FDM,” “Scaffold,” and “Bone Tissue Engineering.”

Results

The review highlights PU as a promising material for 3D-printed scaffolds in BTE due to its excellent mechanical properties, biocompatibility, and flexibility. It critically examines 3D printing techniques like Fused Deposition Modeling (FDM), Inkjet Bioprinting, Stereolithography (SLA), and Selective Laser Sintering (SLS), focusing on their impact on scaffold architecture. PU scaffolds demonstrate suitable mechanical strength, bioactivity, and degradation rates for load-bearing applications and tissue regeneration. The study also emphasizes PU’s potential in customizable implants and drug delivery systems while discussing commercial trends and future research needs to improve clinical translation.

Conclusion

PU-based 3D-printed scaffolds hold significant promise for BTE due to their excellent mechanical properties, biocompatibility, and versatility. Continued research to address current challenges will be crucial to advancing their clinical translation and optimizing their effectiveness in promoting bone regeneration.



Future Works

The processing parameters of PU-based 3D printing techniques will be optimized to enhance scaffold architecture and mechanical properties. Additionally, integrating bioactive materials and growth factors into the PU scaffolds could improve biocompatibility and promote cell adhesion and proliferation. Investigating these

scaffolds' long-term degradation behavior and mechanical performance in load-bearing applications is essential. Finally, advancing clinical translation through comprehensive preclinical studies and exploring regulatory pathways will be critical to bringing PU-based scaffolds to market for BTE.

Lay Summary

This review article focuses on using PU-based 3D-printed scaffolds for BTE. PU is a flexible and durable polymer known for its strength and compatibility with the human body. It is an excellent material for creating scaffolds that closely mimic natural bone structures. The article explores PU's chemical properties, making it an excellent scaffold production choice. The various 3D printing techniques—such as FDM, Inkjet Bioprinting, SLA, and SLS—are examined for their ability to work with PU and how each method affects the design and functionality of the scaffolds. The discussion covers essential factors like mechanical strength, biocompatibility, and the rate at which PU scaffolds degrade over time. These are crucial for their effectiveness in supporting new tissue growth, especially in load-bearing applications.

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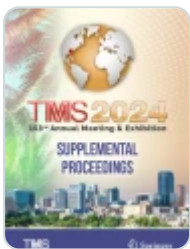
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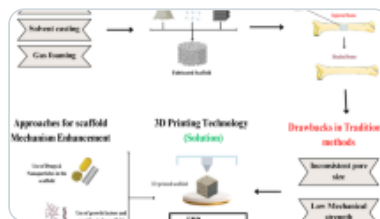
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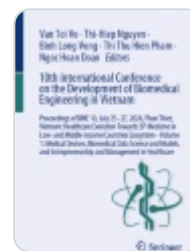
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Data Availability

The data supporting this study's findings is included in this article.

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Ethics declarations

Ethics Approval

On the behalf of all authors, the corresponding authors declared that no animal or human was involved in this study.

Conflict of Interest

The authors declare no competing interests.

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