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Smart Scaffolds for Complex Tissue Reconstruction: A Systematic Review

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ABSTRACT

Introduction: The field of tissue engineering has been revolutionized by the advent of innovative scaffolds, which integrate advanced biomaterials and technologies to facilitate complex tissue reconstruction. These scaffolds mimic the natural extracellular matrix, promote cellular interactions, and support tissue regeneration. This systematic review aims to evaluate the current state of innovative scaffolds in complex tissue reconstruction, highlighting their design, functionality, and clinical applications.

Search Strategy: A comprehensive literature search was conducted across multiple databases, including PubMed, Scopus, and Google Scholar, for articles published from 2000 to 2023. Keywords used in the search in title, keywords, and abstract included ["smart scaffolds" or "biomaterials" or "3D printing"] and ["tissue engineering" or tissue reconstruction" or "regenerative medicine" or "tissue repair"]. Inclusion criteria comprised original research articles, reviews, and clinical studies that discussed innovative scaffold development, characterization, and application. Exclusion criteria included studies not in English, conference abstracts, and articles without full-text availability.

Results: The search yielded 1,256 articles, of which 102 met the inclusion criteria. The review identified various innovative scaffold materials, including natural polymers (e.g., collagen, chitosan), synthetic polymers (e.g., PLGA, PEG), and hybrid composites. Advanced fabrication techniques such as 3D printing, electrospinning, and bioprinting were frequently employed. Key functionalities of innovative scaffolds included controlled drug delivery, stimuli-responsive properties, and the incorporation of growth factors. Clinical applications spanned a range of tissues, including bone, cartilage, skin, and neural tissues. The results indicated that innovative scaffolds significantly enhance tissue regeneration, with several studies demonstrating improved outcomes in preclinical and clinical settings.

Conclusion and Discussion: Smart scaffolds represent a promising approach for complex tissue reconstruction, offering tailored structural and functional properties that facilitate tissue regeneration. This systematic review underscores the importance of interdisciplinary collaboration in advancing scaffold design and application. Future research should focus on optimizing scaffold properties, understanding long-term biocompatibility, and conducting large-scale clinical trials to validate efficacy. The integration of emerging technologies, such as bioprinting and nanotechnology, is anticipated to further enhance the capabilities of innovative scaffolds in regenerative medicine.

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