Biomimetic Synthetic Grafts for Patient-Specific Bone Repair

THE INVENTION

This technology uses algorithm-aided design and 3D printing to generate patient-specific biomimetic bone grafts. The system reproduces cortical and trabecular microarchitecture, including osteons, lamellae and Haversian canals, creating surrogates designed to mimic natural bone structure and mechanical behavior.

Innovative aspects and advantages

- **Patient-specific and customizable:** uses parametric design and medical imaging to replicate cortical and trabecular microarchitecture, adapting to the bone structure, density and pathology of individual cases.
- **High structural fidelity:** reproduces osteons, lamellae and trabecular organization, enabling realistic biomechanical behavior.
- **Simple and versatile manufacturing:** compatible with standard 3D printing technologies and multiple materials for rapid and scalable production.

IP Rights

PCT application 2026PCT/EP2025/079487 with priority date October 14th 2024.

Summary

Severe bone loss caused by trauma, tumors or degenerative diseases represents a major clinical challenge, with millions of bone grafting procedures performed annually. Current solutions present significant limitations: autografts are constrained by donor-site morbidity and limited availability, while allografts carry risks of immune rejection, disease transmission and structural degradation. Additionally, existing synthetic scaffolds fail to accurately replicate the complex architecture and mechanical behavior of natural bone, limiting their clinical performance.

This technology integrates algorithm-aided design and additive manufacturing to create synthetic bone grafts with high biomimetic fidelity.

The system generates digital bone models based on macro and microstructural parameters, including osteon density, lamellar organization and trabecular architecture, enabling accurate replication of cortical and trabecular bone.

Using parametric and AI-assisted design, the models can be adapted to patient-specific anatomy and physiological conditions. These designs are fabricated using high-resolution 3D printing technologies and optimized materials, enabling precise control of porosity, structural gradients and mechanical properties. Unlike conventional scaffolds, which often lack structural complexity and mechanical performance, this approach reproduces the hierarchical organization of bone and its mechanical behavior, supporting improved osteointegration and functional regeneration.

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Current state of development

- **TRL 3–4:** the technology has been validated at laboratory scale through the design, fabrication, and mechanical characterization of biomimetic bone models.

- **3D-printed prototypes** reproduce cortical and trabecular regions, including osteons, lamellae and Haversian canal systems, as confirmed by microscopy and micro-CT analysis.

- **Mechanical compression testing** shows that selected configurations achieve elastic modulus values and stress responses comparable to human femoral bone; while also demonstrating realistic microcrack propagation patterns within the osteonal structure, a feature not observed in conventional synthetic models.

- **Further validation** is ongoing to assess biocompatibility, cell response and osteointegration potential using biocompatible materials.

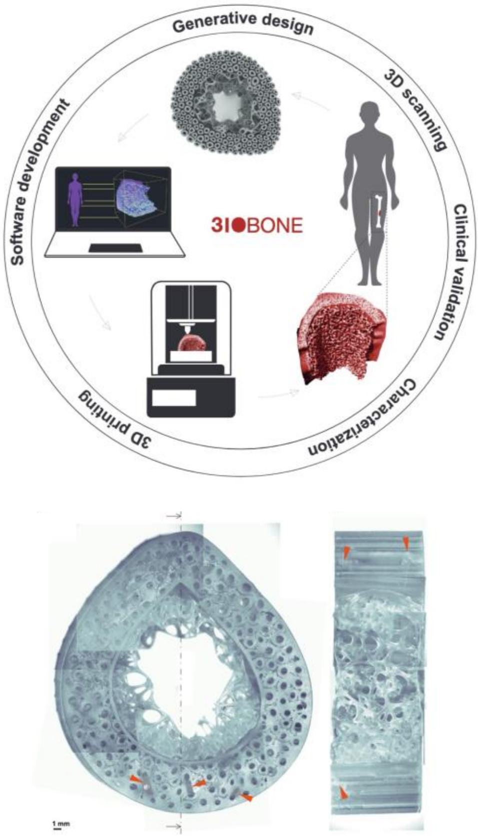

Fig. 1 (Top) End-to-end workflow of the PHyB project for patient-specific biomimetic bone reconstruction. (Bottom) Cross section reconstruction of the PHyB model by optical microscopy displaying the Haversian systems arrangement and trabecular tissue in the inside, and longitudinal section reconstruction.

Next steps

Validate biological performance and osteointegration potential. Optimize materials for clinical-grade applications. Advance toward preclinical validation and regulatory pathway.

Scientific Team

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