ENHANCING OSSEOINTEGRATION USING COMPLEX POROUS STRUCTURES

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Introduction

Cellular porous structures can potentially overcome the shortcomings of current solid orthopaedic implants [1]. In addition to their mechanical performance, their architectural properties may also play a critical role in the diffusion of nutrients and cell proliferation and differentiation [2]. To achieve an ideal balance of these properties, mechanobiology needs to be scrutinized as it is necessary to (1) consider the biological interaction of the structures with the surrounding tissue and (2) to study the relationship between mechanical loads on the structure and bone regeneration. The aim of this work is to investigate the design of complex porous structures and study their impact on bone mechanobiology based on an advanced computational patient-specific model.

Materials and methods

A uniaxial compression test at 10% strain and a mechano-driven regeneration model applied to a goat tibia [3] (*Figure 1*) were used to computationally study the behavior of six cylindrical porous scaffolds. Three triply periodic minimal surface geometries (skeletal based Gyroid *SK-G*, sheet based Gyroid *G* and Schwarz Primitive *SP*) with two porosities (70% and 90%) were considered. Bone material properties were inferred from a CT scan and the scaffold was made of titanium.

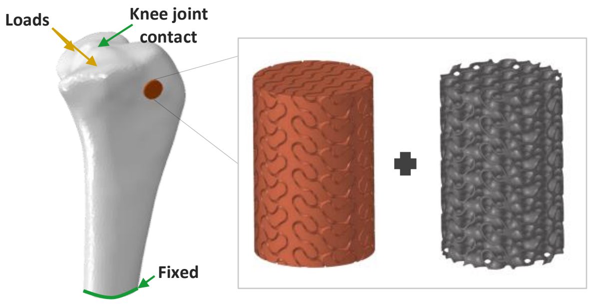

Figure 1: Computational model overview.

Results

The highest elastic modulus was found for the G70, which was 12 times higher than the value for the SK-G90. Furthermore, the structure with the highest bone ingrowth, SK-G90, reported a value 5 times higher than the one with the worst performance (SP70) (*Figure 2*). *Figure 3* shows the regions of the granulation tissue that develop into bone for the two extreme cases.

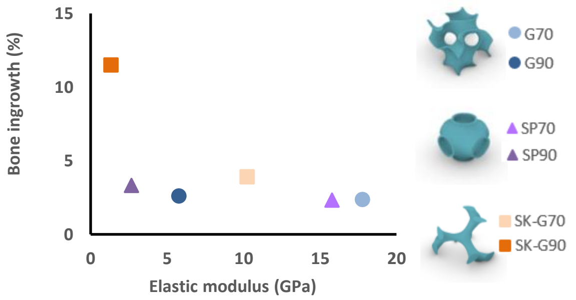

Figure 2: Elastic modulus vs percentage of bone ingrowth in the studied structures.

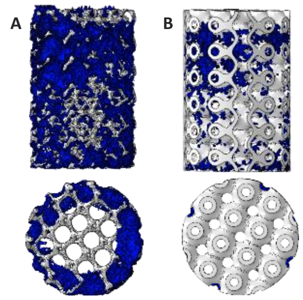

Figure 3: Bone ingrowth for SK-G90 (A) and SP70 (B).

Discussion

The mechanobiological properties of complex porous structures were successfully characterized. The results show that mechanobiological models provide additional insight about the response of the structures. Although the elastic modulus can be tuned by geometry and porosity, the same cannot be described for the bone ingrowth. This indicates that the geometry of each structure plays an important role in the bone regeneration process. As future lines of work, a validation of these results as well as a study with new designs to promote bone differentiation in the core of the structures will be investigated.

References

1. Alaña et al., *Comput. Biol. Med.*, 150, 2022.
2. Asbai-Ghoudan et al., *J. Mech. Behav. Biomed. Mater.*, 124, 2021.
3. Nasello et al., *Bone*, 144, 2021.

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