OPTIMIZING BONE REGENERATION IN 3D SCAFFOLDS WITH COMPUTER-AIDED TECHNOLOGY

Pablo Martín-Compaired (1), Gabriele Nasello (2), María Angeles Pérez (1)

1. Instituto de Investigación en Ingeniería de Aragón (I3A)-University of Zaragoza; 2. KU Leuven, Belgium

Introduction

Bone regeneration is a crucial aspect of modern medicine, especially in cases of injury or disease that affect the skeleton, i.e., large bone defects. 3D scaffolds have emerged as a promising solution to support and guide the growth of new bone tissue. The integration of computer-aided technology has the potential to further optimize the bone regeneration process in these scaffolds by allowing for more precise and effective design and control. This combination of cutting-edge technology and medical application has exciting implications for the future of regenerative medicine. Recently, triply periodic minimal surfaces (TPMS) scaffolds have gained high interest in tissue engineering [1]. They are thought to resemble the bone microarchitecture due to their biomimetic geometry. Therefore, The goal of this study is to examine different TPMS structures and see how a mechano-driven bone regeneration model [2] can help design and optimize stabilization with various fixation systems. (Figure 1).

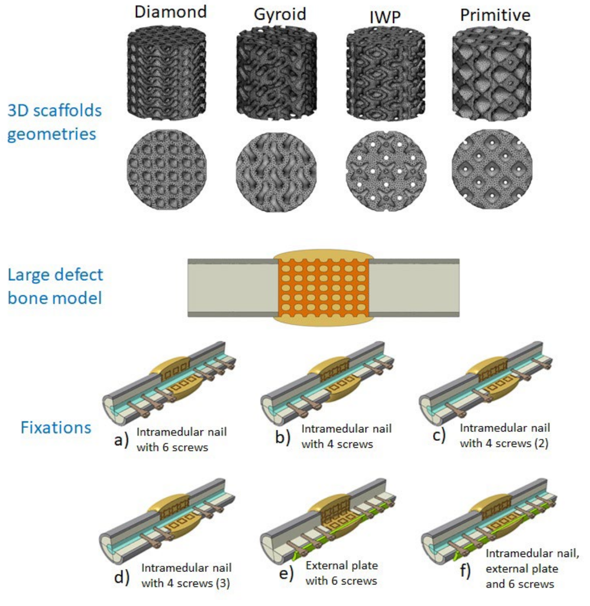

Figure 1: Triply periodic minimal surfaces (TPMS) scaffolds considered for the large bone defect stabilized with 6 different fixation systems.

Material and methods

A bone regeneration model [2], developed earlier, was used to forecast bone growth over time. The study focused on a large bone defect (3.6cm length, 3cm diameter). Four TPMS structures (diamond, gyroid, IWP, and primitive) with three different porosities (50%, 60%, 70%) were analyzed using PLA as the scaffold material. Six different fixation systems were evaluated (Figure 1), considering the weight of a 70kg patient for 16 weeks after implantation. This was implemented in a finite element code (Abaqus).

Results and discussion

First, bone ingrowth was analysed for the four different TPMS scaffolds and three different porosities, without fixation system. As a general rule, it was observed how bone ingrowth was concentric to the bone callus due to its geometric characteristics and the established boundary conditions. With higher porosity scaffolds more bone was formed compared to the ones with lower porosity scaffold.

Then, to simulate the effect of the fixation systems, the IWP with a 70% of porosity was chosen. Bone ingrowth was then estimated (Figure 2).

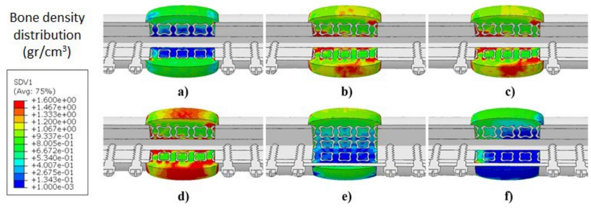

Figure 2: Bone density distribution predicted for the different fixation times after 16 weeks from implantation.

Bone ingrowth was heavily influenced by the chosen fixation system. A stiffer fixation (Figure 2f) reduces bone ingrowth, while a more flexible one (Figure 2d) promotes it.

In conclusion, we used computer aided technology based on a mechano-driven bone regeneration model and finite element simulations to optimize and predict bone regeneration within different scaffold designs and different fixation systems for long bone large defects. Computer model predictions suggest that higher porous scaffolds with less rigid fixations are more favorable. Future studies should focus on the experimental validation of these findings so that they can be used for the optimization of scaffold design to support bone regeneration in long bone large defects.

References

1. Dong and Zhao, Eng Regen, 2: 154-162, 2021.
2. Nasello et al., *Bone*, 144, 2021.

Acknowledgements

This work has been supported by the Spanish Ministry of Economy and Competitiveness through the project (PID2020-113819RB-I00).