# NOVEL APPROACHES IN COMPUTER-AIDED SCAFFOLD DESIGN FOR BONE REGENERATION

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## Background

Large bone defects remain a clinical challenge, with a gold standard treatment – autologous bone graft transplantation – that presents many drawbacks. Design optimized scaffolds appear as a promising alternative however, bone scaffold design remains a trial and error approach where some specific properties (e.g. porosity, pore size) are individually optimized, not taking into account interactions between scaffold design parameters and their influence on the dynamics of the regeneration process.

## Recent Advances

Multiscale computer models of bone regeneration appear as a powerful tool towards scaffold design optimization however, it requires: 1) the validation of the models in terms of their ability to predict bone formation within the scaffold pores for different scaffold designs and 2) low computation time so that they can be integrated in an optimization framework. Several computer models of bone regeneration have been developed in the last decades (review [1]), however only few have compared model predictions with dedicated experimental data. In our group, we have combined in silico and pre-clinical studies to come to an understanding of the mechanisms behind uneventful (e.g. [2]) and compromised (e.g. [3]) bone healing. More recently, we have further developed these models to investigate the process of scaffold-supported bone regeneration [5,6] (Fig. 1), where we have tested the models against different experimental set-ups where different scaffolds designs have been used for bone regeneration in large defects. Using these validated models, we have then developed a computational framework, based on surrogate modelling techniques, that allows us to computationally optimize the design of scaffolds with the objective to achieve maximum bone regeneration [7].

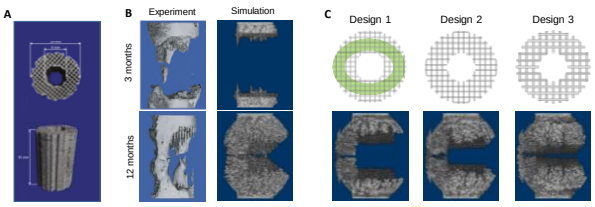


*Figure 1: Computer model predictions of bone regeneration within a strut-like PCL scaffold (A) implanted in a sheep tibia large bone defect [8]. (B) Comparison of computer model predictions of bone regeneration with in vivo data. (C) Computer model predictions of the influence of scaffold design on the healing outcome.*

Sara Checa is currently Professor at the Julius Wolff Institute, Charite Medical University Berlin. She obtained her PhD in Biomechanics at the University of Southampton in 2007. She was a post-doctoral fellow at Trinity Centre for Bioengineering, in Dublin, between 2007-2009 and at Stanford University in 2013. She holds a Guest Professorship at the Technical University of Berlin. Her present research mainly focuses on the development of multiscale computer tools to investigate the mechanisms behind bone tissue regeneration and to support the design of novel treatment strategies. She is an author of more than 60 publications in peer-reviewed journals, 6 chapter books and more than 90 contributions to International and National Conferences.

## Future directions

In the near future, we aim to test the potential of the models to predict bone healing outcome in patients and to use the developed tools to optimize patient treatment design, both in non-compromised and compromised conditions. In the long-term future, we would like to develop a computer tool that could help decision making in the clinic as well as contribute to the design on 3D printed support structures to promote the regeneration of bone.

## References

1. Borgiani et al., Front Physiol. 8; 8:287, 2017
2. Checa et al., Journal of Biomechanics; 44: 1237-45, 2011
3. Borgiani et al., J Bone Miner Res., 34, 1923-1937, 2019
4. Jaber et al., Frontiers in Bioengineering and Biotechnology, section Biomechanics 10: 995266, 2022
5. Perier-Metz et al., Acta Biomaterialia, 145: 329-341, 2022
6. Perier-Metz et al., Front. Bioeng. Biotechnol. 8:585799, 2020
7. Perier-Metz Front. Bioeng. Biotechnol. 10:980727, 2022
8. Cipitria et al., Journal of Bone and Mineral Research 27 (6), S. 1275 – 1288, 2012.

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