Transactions on Additive Manufacturing Meets Medicine
Trans. AMMM, 2023, Vol. 5, No 1, Suppl. 1, Article ID 814, 2 Pages

Infinite Science Publishing

Abstract

Semi-automatic bone scaffold design workflow

B. Herath[1,2,3*], M. Laubach[1,2,6], S. Suresh[1,2,4], B. Schmutz[1,2,3], J. P. Little[1,2,4], P. K. D. V. Yarlagadda[1,2], D. W. Hutmacher[1,2,5], and M.-L. Wille[1,2,5]

[1] *ARC Training Centre for M3D Innovation, Queensland University of Technology (QUT), Brisbane, Australia*
[2] *Centre for Biomedical Technologies, School of Mechanical, Medical and Process Engineering, Faculty of Engineering, QUT, Brisbane, Australia*
[3] *Jamieson Trauma Institute, Metro North Hospital and Health Service, Brisbane, Australia*
[4] *Biomechanics and Spine Research Group at the Center for Children's Health Research, QUT, Brisbane, Australia*
[5] *Max Planck Queensland Centre for the Materials Science of Extracellular Matrices, QUT, Brisbane, Australia*
[6] *Department of Orthopaedics and Trauma Surgery, Musculoskeletal University Center Munich (MUM), LMU University Hospital, Munich, Germany*
[*] *Corresponding author, email: b.herath@qut.edu.au*

Recently introduced scaffold-guided bone regeneration (SGBR) is a novel method to treat large bone defects [1] which is an alternative to using autologous bone graft (ABG) alone. A patient-specific SGBR scaffold is designed to match the defect of the patient in shape and size, 3D printed using a bioresorbable polymer and is surgically implanted with ABG.

A semi-automatic modular workflow was developed to create patient-specific SGBR designs for a given bone defect model and create scaffolds based on a multitude of pore architectures with varying porosities. The workflow was implemented within Rhinoceros 3D and Grasshopper (R&G) software (Robert McNeel & Associates, Washington, USA). A dedicated plugin for R&G was developed which enables Functional-representation modelling techniques that enable fast and robust Boolean operations free from spontaneous surface mesh errors that inhibit 3D printing.

The workflow was validated by applying it to a complex multi-fragmentary femoral bone defect. It was able to design scaffolds for a given surgical approach complete with fixation points as requested by surgeons in a timely manner. The designs were inspected for patient-specific fit digitally as well as physically via 3D printed prototypes using fused filament fabrication with polylactic acid. The output models were found to have no mesh errors when checked with commercial slicing software Simplify3D (Simplify3D, Ohio, USA). In conclusion, the developed workflow is successful in designing patient-specific scaffolds with real-time responsiveness.

Author's Statement

The complete study has been published in the journal Virtual and Physical Prototyping (DOI: 10.1080/17452759.2023.2246434). Conflict of interest: D.W.H. is a cofounder and shareholder of Osteopore International Pty Ltd. The remaining authors state no conflict of interest. Ethical approval: The research related to human use complies with all the relevant national regulations, institutional policies and was performed in accordance with the tenets of the Helsinki Declaration, and has been approved by the authors' institutional review board or equivalent committee [QUT Human Ethics Exemption Number 20210001814[a]]. Acknowledgments: The authors would like to thank Prof. Hildebrand and Dr. Delbrück (Department of Orthopaedics, Trauma and Reconstructive Surgery, RWTH Aachen University Hospital, Germany) for their collaboration and provision of the CT data relevant to the femoral bone defect. Research funding: This work was supported by the Australian Research Council (ARC) Industrial Transformation Training Centre for Multiscale 3D Imaging, Modelling, and Manufacturing (M3D Innovation) [IC 180100008], and the Jamieson Trauma Institute (PhD scholarship for B. Herath), a collaboration of Metro North Hospital and Health Service and the Motor Accident Insurance Commission. The authors would also like to gratefully acknowledge the support of the Alexander von Humboldt Foundation and the QUT, jointly funding a Feodor Lynen Research Fellowship of the Alexander von Humboldt Foundation awarded to Markus Laubach.

References

[1] M. Laubach et al., Clinical translation of a patient-specific scaffold-guided bone regeneration concept in four cases with large long bone defects, J Orthop Translat, vol. 34, pp. 73–84, May 2022

DOI: 10.18416/AMMM.2023.2309814