Bone & Joint

Article alerts Social media

Orthopaedic Proceedings

Current issue Archive About

RESEARCH

FULL ACCESS

CUSTOM 3D-PRINTED INTRAMEDULLARY NAILS: A NOVEL PRECLINICAL MODEL FOR ADDRESSIN CRITICAL-SIZED BONE DEFECTS

European Orthopaedic Research Society (EORS) and ARI Orthopaedics - AO Orthopaedic Research Summit 2025, Davos, Switzerland, 16–19 June 2025. Part 2 of 4.

Julie Manon Alexandre Englebert Robin Evrard Julia Vettese Thomas Schubert Olivier Cornu

Cite this

Abstract

Critical-sized bone defects (CSBDs) represent a major challenge in orthopaedic and trauma surgery. Translational research requires preclinical models that reliably replicate human conditions. This study aimed to develop and evaluate a custom-made 3D-printed titanium intramedullary nail (IMN) specifically designed for CSBDs in minipigs. The main objectives were to determine the feasibility of designing an anatomically adapted IMN for minipig femurs, evaluate its capacity for consistent and reproducible surgical procedures, and assess its ability to promote bone healing.

The IMN was custom-designed using CT data from minipig femurs, optimizing parameters such as femoral curvature, length, and medullary canal diameter. Following 3D printing in titanium, the IMNs underwent *in vitro* testing before their use in *in vivo* experiments. Female Aachen minipigs underwent bilateral femoral surgeries, wherein CSBDs were created and stabilized using the custom IMNs, specific cutting guides clipped onto an ancillary. Post-operative follow-up included blood tests, radiographs and CT imaging every two weeks, and femurs were explanted after three months to assess mechanical stability and consolidation.

The custom IMNs fit with minipig femoral anatomy, enabling reproducible CSBD creation and consistent surgical procedures. Symmetric double osteotomies were performed successfully, and bone allografts showed minimal discrepancies in morphology. While distal osteotomy sites demonstrated stable consolidation in most cases, proximal fixation posed challenges, leading to non-union in certain instances. These issues underscore the need for improved screw placement and additional mechanical support.

The custom 3D-printed IMN offers significant potential for preclinical modeling of CSBDs, facilitating the study of both surgical procedures and biological responses to bone grafts. Furthermore, this model serves as a platform to explore advanced reconstructive strategies, such as the induced membrane technique pioneered by Prof. Masquelet, which promotes bioactive responses around allografts. Proximal fixation challenges identified in this study highlight the importance of iterative design improvements to enhance stability and mimic human clinical scenarios more effectively.

This preclinical model using custom 3D-printed IMNs represents a promising step forward in the study of CSBDs. It enables the evaluation of innovative surgical techniques and supports translational research aimed at improving outcomes for patients with complex orthopaedic conditions.

*Email: julie.manon@uclouvain.be