BONE RESPONSE ON OPEN-POROUS SCAFFOLDS FOR SEGMENTAL BONE DEFECTS – A NUMERICAL STUDY

Jan Wieding, Robert Souffrant, Cathérine Ruther, Rainer Bader

Biomechanics and Implant Technology Research Laboratory, Department of Orthopaedics, University Medicine Rostock, Germany

Introduction

For the treatment of bone defects different artificial materials are currently used. Nowadays, additive manufacturing (AM) techniques offer a wide range of design fabrication possibilities with various complex structures and subsequently controlled mechanical properties [Wieding, 2012]. These can be adjusted in order to cope with the requirements of the surrounding bone tissue. Although the mechanical properties of AM fabricated scaffolds have been extensively analyzed, less is known about their biomechanical performance and the influence on bone remodelling in-vivo. In order to determine the response of the bone stock due to the mechanical stimulus of the implant, three open-porous scaffolds with different mechanical properties have been numerically investigated and compared to in-vivo results.

Methods

Based on the CT-data of the metatarsal bone of the sheep hind limb (intact and treated with titanium scaffold), the numerical models for the bone remodelling have been investigated. This includes the reconstruction of the bone geometry (from intact bone) as well as localisation of the implant position (bone with implant). A 20 mm segmental defect was implemented into the mid-diaphysis of the intact bone, corresponding to the implanted scaffold position. FE model of the bone was meshed with tetrahedral elements with linear elastic material properties and inhomogeneous material distribution (derived from CT-data of the intact metatarsal bone). Three open-porous titanium scaffolds were inserted into the defect, exhibiting different values for the structural modulus (16.4, 14.4 and 11.5 GPa). Hereby, the numerical scaffold with 16.4 GPa exhibited the same stiffness as the in-vivo used scaffold, whereas the other two numerical scaffolds were less stiff. Furthermore, the area of the scaffold was surrounded by a callus formation, offering the possibility for bone growth within this region. Static load was applied to the metatarsal bone [Hutzschen-reuter, 1993].

Results

Fig. 1 shows the results for the in-vivo situation (a) and for the three numerical simulations (b to d). For the 16.4 GPa scaffold the numerical simulation revealed comparable results of the bone remodelling as observed in-vivo. Both scaffolds with lower stiffness showed a higher rate of bone remodelling due to the higher mechanical stimulus.

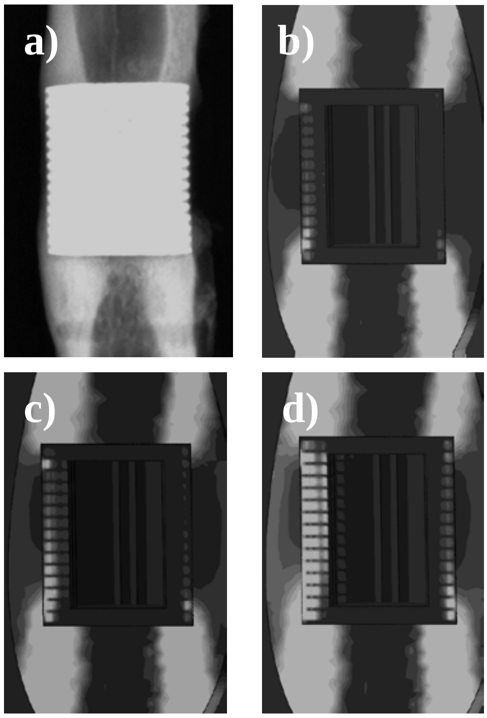

Figure 1: X-ray of scaffold implant after 12 weeks in-situ (a), numerical results of implants with structural modulus of 16.4 (b), 14.4 (c) and 11.5 GPa (d).

Discussion

In the present numerical study we could show the influence of the scaffold implant stiffness on the remodelling process within the bone stock. Comparing the results with in-vivo experiments revealed a realistic numerical approach and assessment of the numerical data.

References

Wieding *et al*, Materials, 5:1336-1347, 2012.
Hutzschenreuter *et al*, Anat. Histol. Embryol., 22:67-82, 1993.