EPiC Series in Health Sciences
Volume 1, 2017, Pages 70–73
CAOS 2017. 17th Annual Meeting of the International Society for Computer Assisted Orthopaedic Surgery

Design of Flexible Implants for Preservation of Physiological Mobility exploiting Additive Manufacturing

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1 Introduction

Due to tumors or bone fractures caused by high mechanical impact, the affected tissue has to be removed. The implantation of a stabilizing replacement is a common solution for defect bridging and support of bone ossification. Preserving the physiological mobility after the treatment could prevent stress shielding or overload of the surrounding muscles and ligaments. [1]

In case of a critical vertebral body defect, the body and its attached disks have to be removed. Thereafter the adjacent vertebral bodies are braced together resulting in limited physiological spine movability. A flexible implant adapted to and preserving the patient-specific physiological spine mobility would be a desirable solution. [2] [3]

To realize such an implant additive manufacturing (AM) can be used as a key technology. AM offers the following advantages: The build-up of almost any desired complex geometry shape, without additional costs. A monolithic geometry with enhanced functionalities combined in only one part and one material. A cost-efficient implant individualization based on patient specific requirements. [4]

Relating to flexibility, the integration of solid state hinges tailored to the patient specific physiological mobility is possible. Hereby, assembly work is neglectable and abrasion will be prevented due to the absence of friction partners. A challenge to overcome will be the durability of the design. It is limited by the fatigue of the material caused by implant motion.

2 MATERIALS AND METHODS

Since Ti6Al4V is a common material for medical implants as well as in AM, it is used in this scientific study. For the design of a flexible implant, two initial approaches are taken into consideration: Using design methodology tools, a systematic generation of possible solutions is achieved. Furthermore, already existing solid state hinges made of plastics with AM are taken as archetype and their design is adapted to the metal laser powder bed fusion (L-PBF) process. Therefore, an initial geometry design, based on a solid state hinge demonstrator made by TNO was created with Inventor 2016. By the application of simulation software tools the flexion behavior of the solid state hinge can be analyzed.

3 RESULTS

By abstracting the vertebrae body segment, two contact surfaces, two joints with rotational degree of freedom (DOF) and axial suspension as well as one solid connection could be identified, see Figure 1. It should be noted that in the initial design translational motion is neglected as well as only a two dimensional case is considered. As a first implant design, the abstracted joints are replaced by the designed hinges.

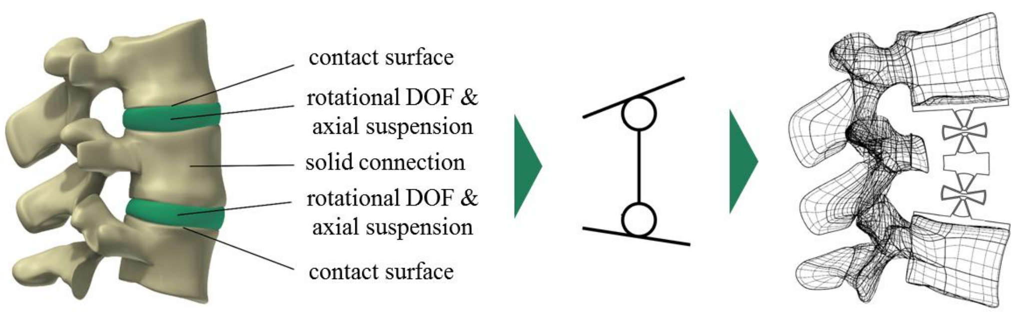

Figure 1: CAD-model of a vertebrae body segment (left), biomechanical abstraction (middle), implementation of initial solid state hinge design (right)

Initial results show that the simulation of the flexion behavior corresponds with the AM specimen, see Figure 2. The applied force necessary for bending the specimen depends on the thickness of the struts.

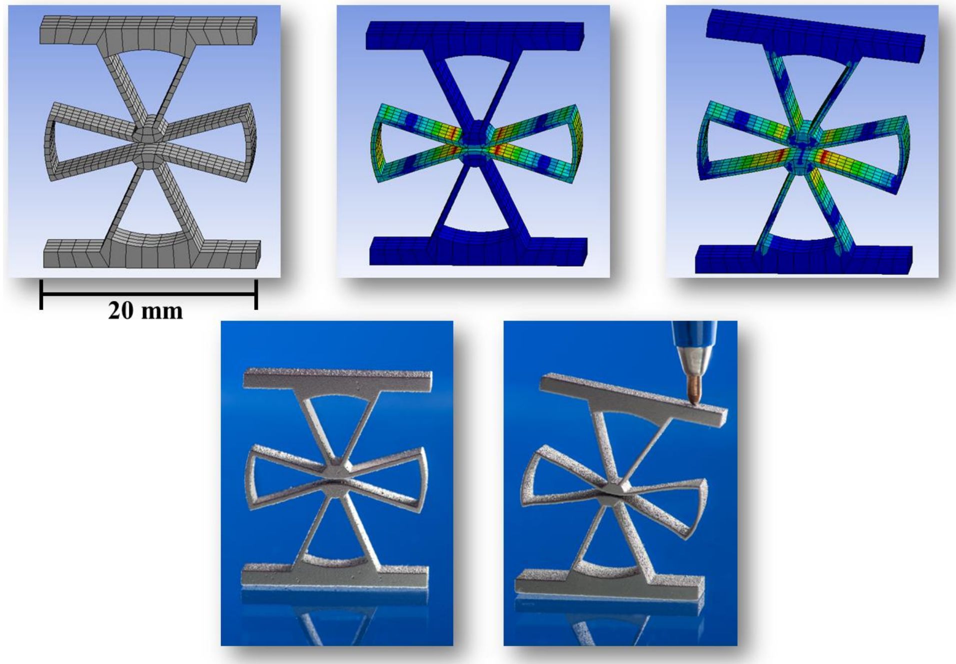

Figure 2: Flexion behavior simulation of the initial solid state hinge design with Abaqus CAE 2017, undeformed (top left), vertical force applied (top middle), vertical decentral force applied (top right); AM specimen, undeformed (bottom left), vertical decentral force applied (bottom right)

4 DISCUSSION

AM seems to be a promising technology for the implementation of flexible features for implants. Nevertheless, additional research is required to investigate the performance of solid state hinges made by L-PBF regarding strut thickness and the resulting flexibility. Compared to [2], friction caused by motion of two parts can be avoided. Unlike in [5], the monolithic geometry renders assembly work redundant. To proof the performance of AM solid state hinges, their durability in context to the fatigue limit of the material still has to be assessed. A more specific design methodology process and it's adaption to the generation of solid state hinges is a way to create systematically flexible implants.

5 REFERENCES

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6 DISCUSSION

This work has been carried out within the framework of the project “EITPSI” funded by the German ministry of education and research (BMBF) under grant number 13GW0116.