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Effects of laser parameters and scanning strategy on structural and mechanical properties of 3D NiTi implants fabricated with selective laser melting

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Abstract:
The additive manufacturing method Selective Laser Melting (SLM) allows the creation of open-porous shape memory structure directly from CAD data. However, during the SLM process, laser parameters and scanning strategy must be carefully selected. In this study, we show that they have a significant effect on geometrical and mechanical properties of NiTi scaffolds for the treatment of large bone defects.

Keywords: *NiTi, shape memory alloy, SLM, scanning strategy, laser parameters*

Introduction

Implant morphology, biocompatibility and mechanical properties are strongly influenced by the SLM manufacturing process. This process is controlled by a variety of parameters which are stored in a material file: scanning strategy, laser energy, exposure time, point distance, hatch distance, minimal hatch length, fill contour offset, lens position, energy density, etc. The geometry, mechanical property and microscopic structure strongly depend on these settings [1]. The µCT and mechanical investigation give insight into the structural characteristics of the SLM processed scaffolds [2].

Methods

The NiTi scaffolds with a rhombo-dodecahedral unit cell and strut thicknesses around 300 µm (see fig. 1A) are produced with a Realizer 100 system (Borchen, Germany) equipped with a 100 W fiber laser [3]. The compressive strength was measured by a Zwick/Roell Z100 testing machine. The mass of the open-porous scaffolds was determined gravimetrically (Acculab). The materials porosity, defined as closed micro-pores within the metallic struts, was determined by analysing the 3D dataset obtained by a SkyScan 1172 µCT system with the CTAn software (SkyScan NV, Belgium), see fig. 1B.

Results

The scaffolds mass and therefore the overall porosity are found in the range of 0.145–0.366 g, resp. 71.6–88.7% when applying different laser parameters and scanning strategies. As expected, the compressive strength of the scaffolds is highly correlated to the structures mass, see fig 2A. The tomographic analyses reveal slightly more micro-pores in heavier scaffolds, see fig. 2B.

Discussion

The SLM process allows the creation of open-porous NiTi scaffolds with porosity up to 88%. The lattice material itself is very dense (density > 99.8%). The laser parameter and scanning strategy have to be considered as they affect the geometry and mechanical properties. These parameters were identified in order to improve the implant design and fabrication.

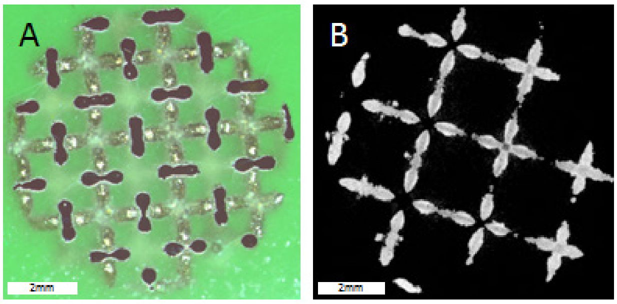

Figure 1: A) metallographic section of the NiTi scaffold. B) Cross section of reconstructed µCT dataset.

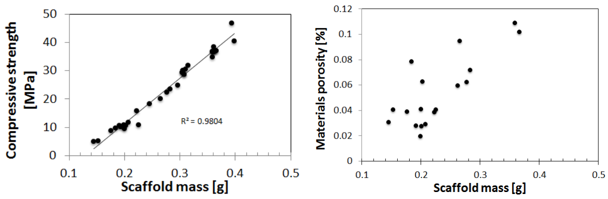

Figure 2: Correlation between the scaffold mass and A) the mechanical strength, B) the materials porosity.

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