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Controlling Mechanical Properties of NiTi Scaffolds built by Selective Laser Melting

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Introduction

NiTi, a biocompatible and FDA-approved material, is a promising candidate for load-bearing implants as it combines low stiffness with high strength and exhibits properties like the pseudoelasticity, the shape memory effect and high damping capacities [1]. Selective laser melting (SLM) allows the fabrication of complex shaped constructs like open porous parts or filigree lattice structures with struts as thin as 200 µm [2]. Using SLM for the fabrication of complex-shaped NiTi-scaffolds, we aim to develop bone implants with an improved ossseoinductive performance owing to mechanical stimulation of surrounding tissues.

Methods

NiTi scaffolds and tensile test specimens were produced from pre-alloyed NiTi powder by SLM. For the fabrication of lattice structures, laser power and scanning velocity were varied from 60 to 95 W and 122 to 171 mm/s, respectively, resulting in an overall energy input of 60, 70, 100 and 130 J/mm^3 [3]. Mechanical testing was performed at room temperature using a universal testing machine.

Results

The compressive strength in the NiTi-scaffolds increases from 450 N to 1600 N and the elastic modulus from 110 MPa to 660 MPa in dependence of the applied energy density. The reason for the altered mechanical properties is an increase in the strut diameter and specimen mass caused by laser paths with expanded widths at higher energy densities [4]. Load-relieve tensile tests show the characteristic pseudoelastic behaviour in an SLM built tensile test specimen. We detected a complete shape recovery of maximal 3.4% strain.

Conclusion

The mechanical properties of lattice structures were adjusted by applying different processing parameters during the SLM fabrication. This approach allows modifying the mechanical properties within certain areas of the scaffold just by varying the process parameters during the fabrication process. Such gradients permit the fabrication of nature-analogue anisotropic structures. Furthermore, the pseudoelastic behavior of SLM-built NiTi specimens was demonstrated. Tailoring structural and related mechanical properties of NiTi-scaffolds, we aim to realize implants, which mechanically stimulate the tissue for an enhanced osseoinductive performance.

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