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3D manufacturing of implants made of titanium alloy

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SWISS PHOTONICS

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Campus Muttenz
Grundstudium & Praktikum

Bio Park Rosental, Basel
Vertiefungen, Master-Studium

Kubuk 2018

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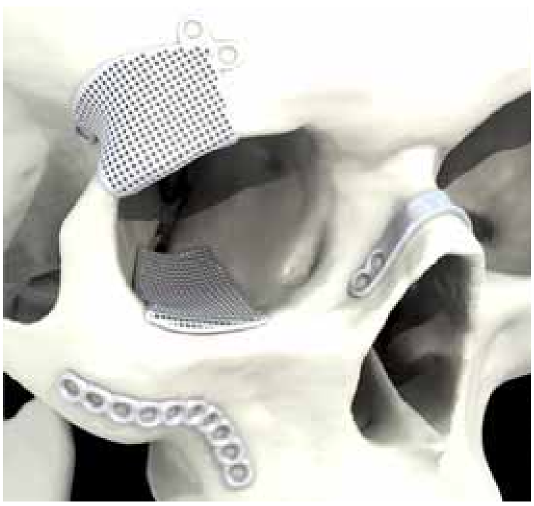
Open-porous shape memory implants for temporary or permanent bone replacement



virtual representation

physical representation

R. Schumacher, M. de Wild, S. Fabbri, A. Yildiz, E. Schkommodau, *Rapid Manufacturing of Individualized Ti-6Al-4V Bone Implants*, European Cells and Materials Vol. 17/22, 1 (2009).

R. Schumacher, M. de Wild, E. Schkommodau, D. Hradetzky, *Massgeschneiderte Knochenimplantate aus dem 3D-Drucker*, BaZ-Sonderbeilage "Life Sciences" vom 12. Mai (2012).

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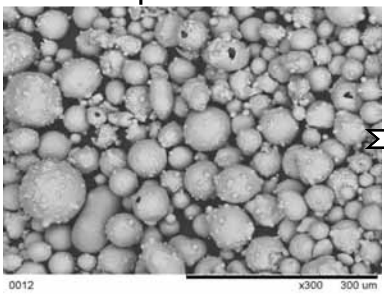
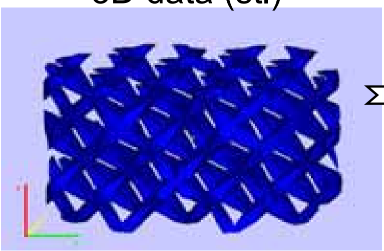
Fabrication of NiTi samples by selective laser melting

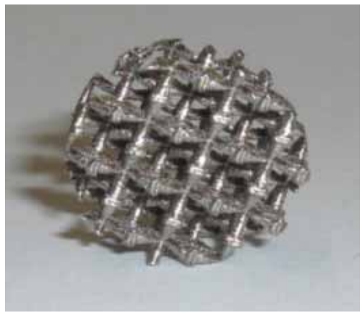
powder



3D data (stl)



Post processing if necessary (e.g. heat treatment, etching)



Processing parameters

Bormann T. *et al*., eCells Mater 20 (Suppl 1): 13, 2010.

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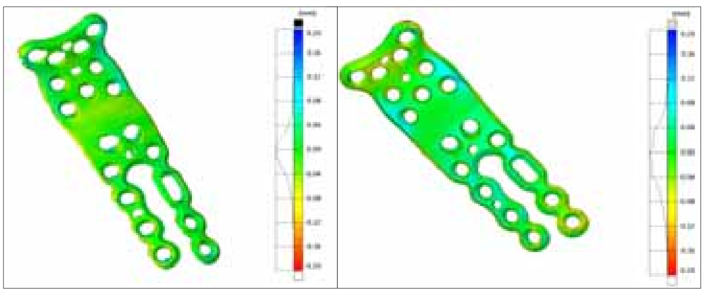
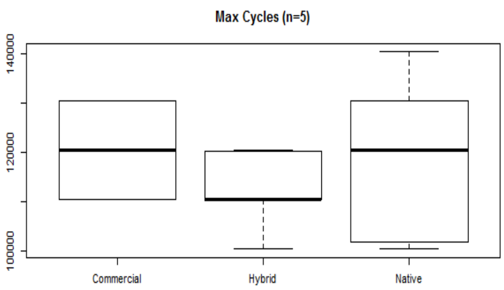
medartis®

Individualized implants for temporary or permanent bone replacement

Left: Medartis® wrist fusion plate spanning the radio-carpal and mid-carpal joint. Right: SLM replica.



Geometrical accuracy check. Left: before heat treatment. Right: after heat treatment.



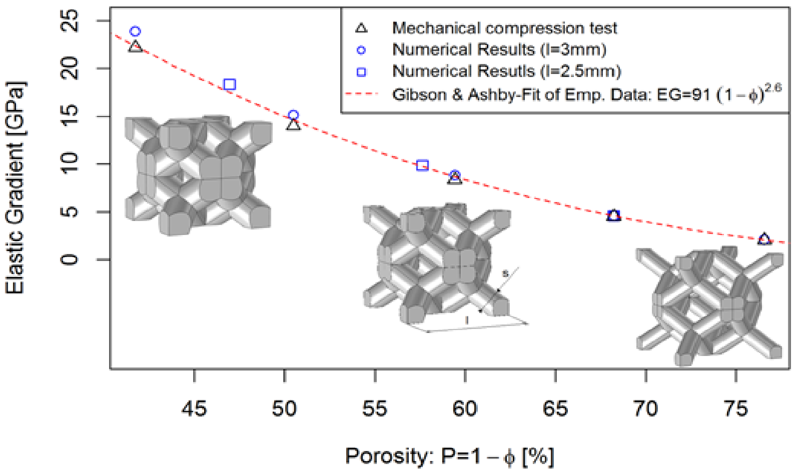
Fatigue test: Comparison between commercially machined plates and SLM plates.

R. Schumacher, P. Lamprecht, S. Zimmermann, M. de Wild, A. Spiegel, *Comparison of SLM and conventionally produced implants using dynamic biomechanical loading*, RapidTech Erfurt, 2013.

SLM 250HL

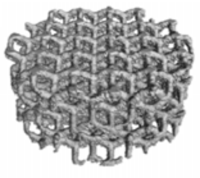
http://www.slm-solutions.com

Functional lattice structures: adapted stiffness



Ashbey-Gibson relation

Helsen, J.A. and H.J. Breme, *Metals as Biomaterials*. 1998.



S. Zimmermann, *Structure-Mechanical FEM Analysis and Physical Validation of Porous Bone Scaffolds*, Master thesis (2014).

CAD porosity [%]	µCT porosity [%]	Difference [%]
87.6	79.0	8.6
82.5	72.3	10.2
77.6	65.7	11.9
63.3	50.1	13.2
40.8	25.9	14.9
31.5	18.3	13.2
26.3	15.2	11.1

Comparison between CAD designed porosity and µCT analyzed porosity.

Hoffmann W., Fabbri S., Schumacher R., Zimmermann S., de Wild M., *FEM analysis of porous titanium bone scaffolds.* European Cells and Materials, 26; 28, Suppl. 4, (2013).

R. Schumacher, et al, *Manipulation of the elastic behaviour of artificial Titanium bone grafts*, European Cells and Materials Vol. 22. Suppl. 1, 10 (2011).

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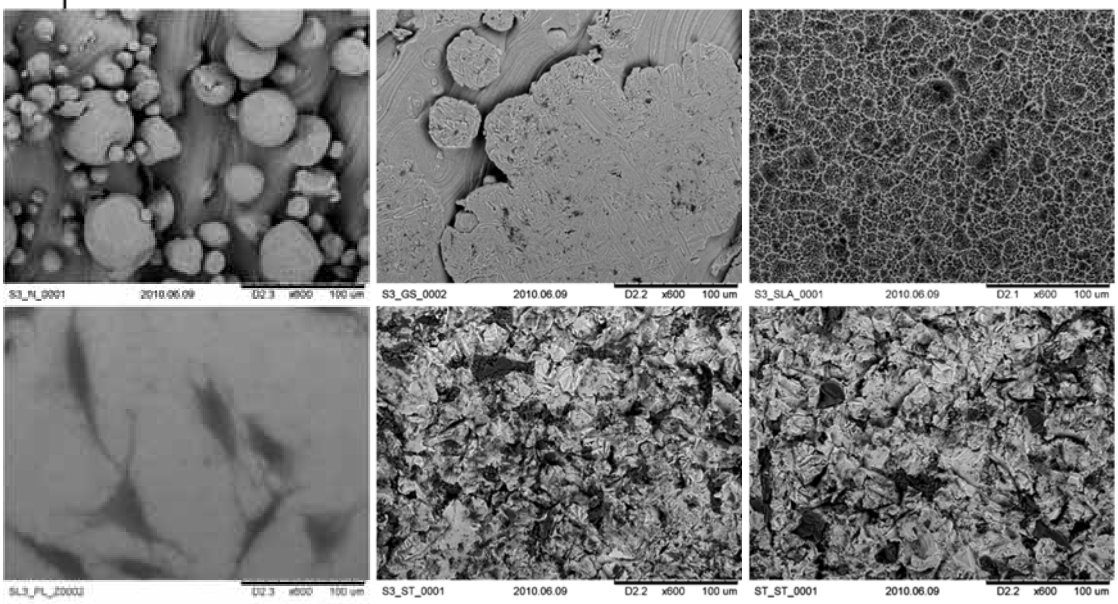
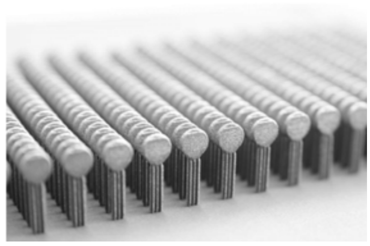
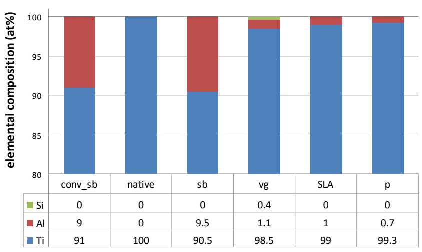
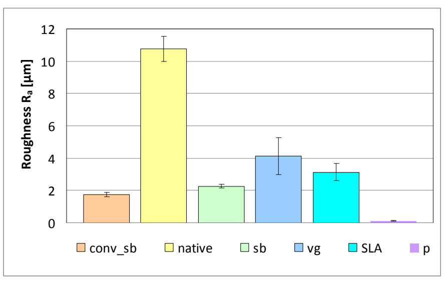
Cytocompatibility



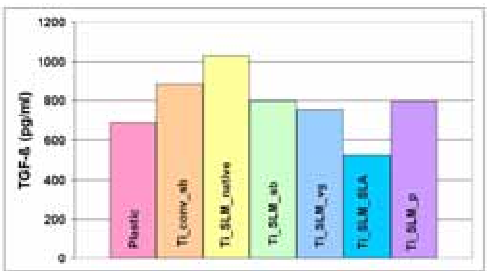




Roughness analysis.



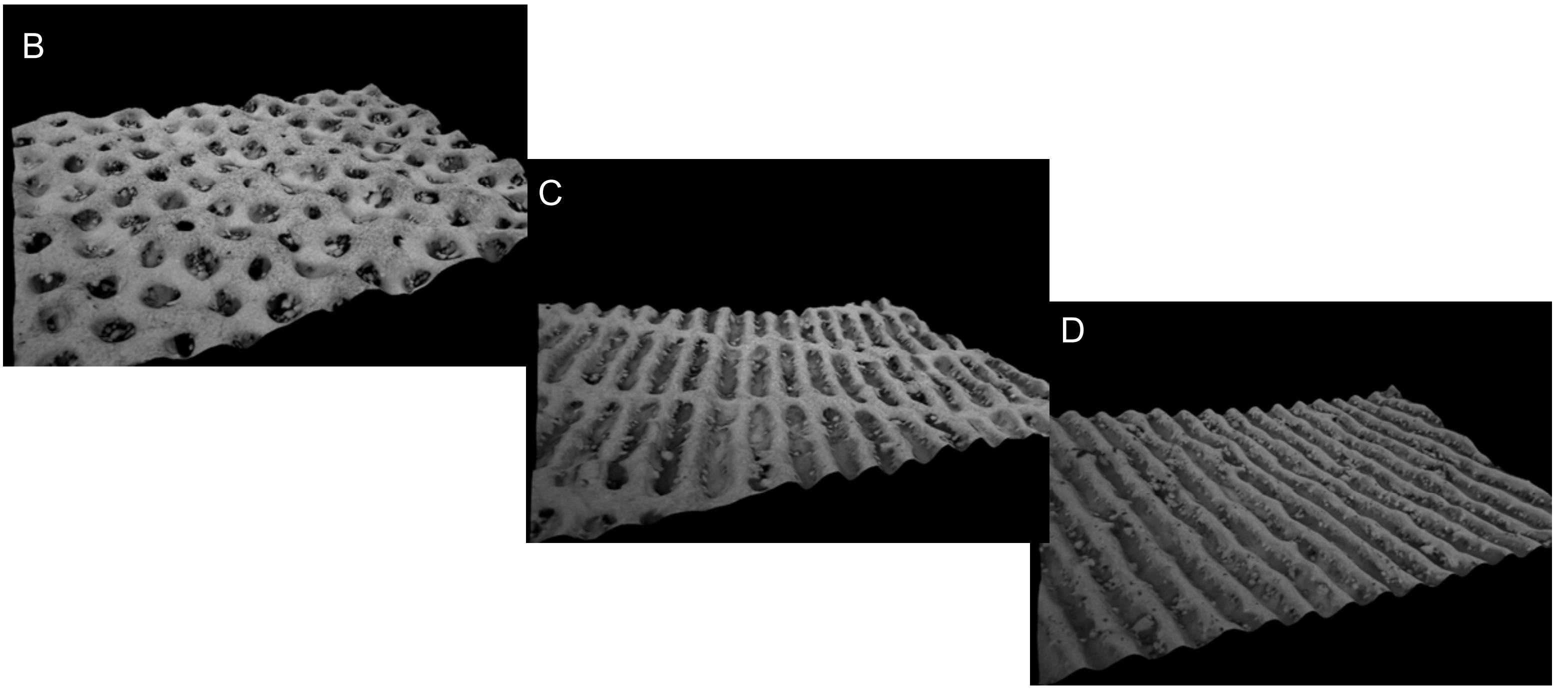
EDX elemental analysis.



TGF-β expression of MG63 cells on different surface topographies after 14 days.

M. de Wild, et al, *Surface Modification and In-vitro Investigation of Generatively Produced Implants*, Biomaterialien, 11, 157 (2010).

Reconstructed 3D representation



Three dimensional stereoscopic representation of the created structures type B, C and D.
B: **dots** of ø130 µm, separated by 170 µm in a hexagonal pattern,
C: **pits** of width 120 µm, separation of 120 µm and length of 1000 µm,
D: **lines** with a width of 120 µm and a distance of 120 µm.

M. de Wild, et al., *Production and in-vitro characterization of micro-structured implant surfaces*. In P.J. Bartolo et al (eds.), Innovative Developments in Design and Manufacturing; Advanced Research in Virtual and Rapid Prototyping – Proc. of VR@P5, Leiria. Taylor & Francis, Leiden: CRC Press Balkema, 111 - 114 (2011).

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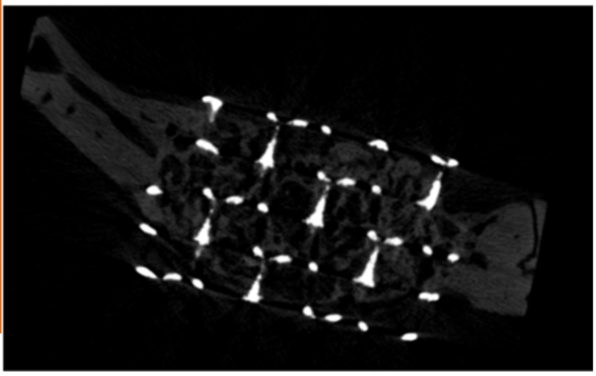
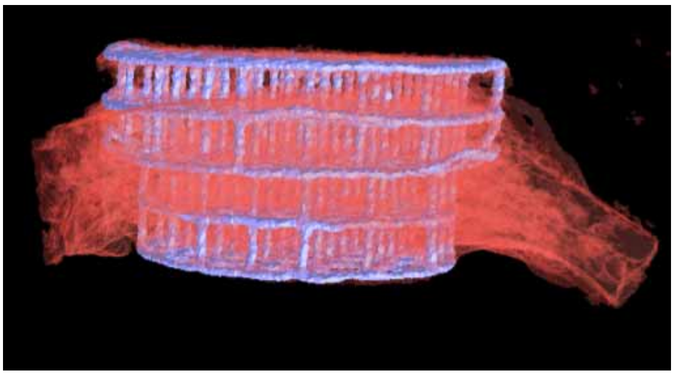
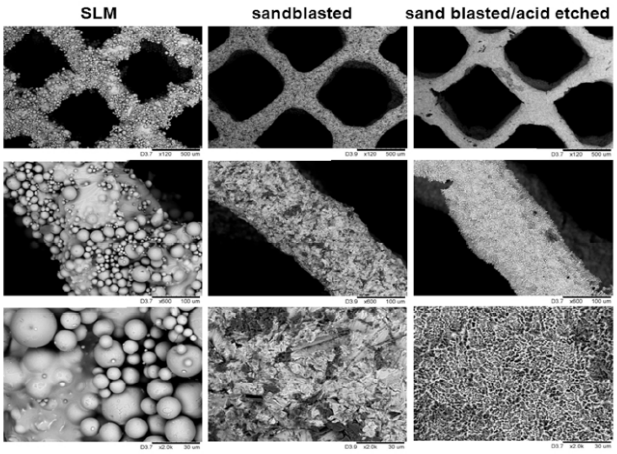
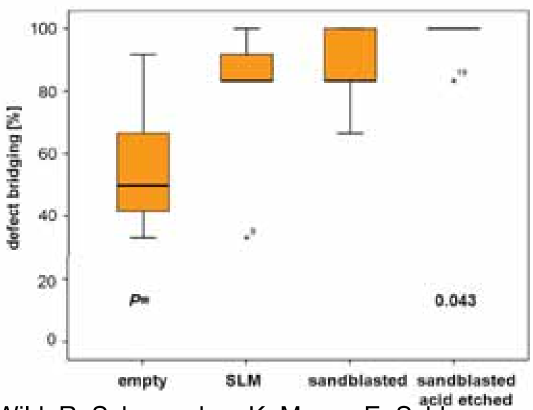
porous cpTi implants

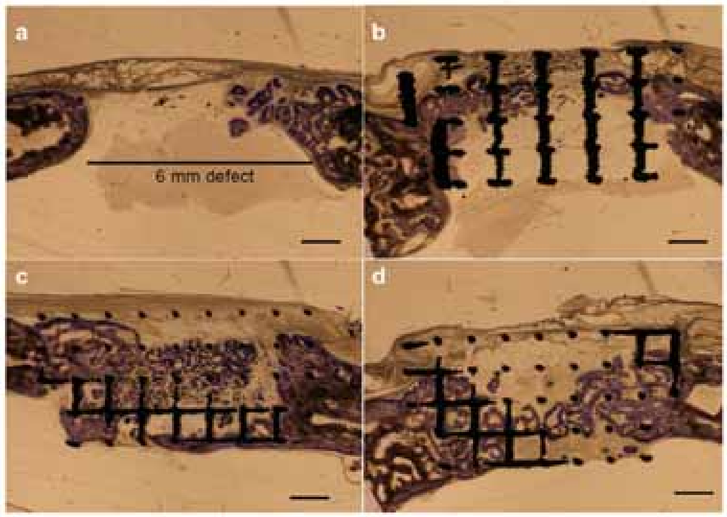


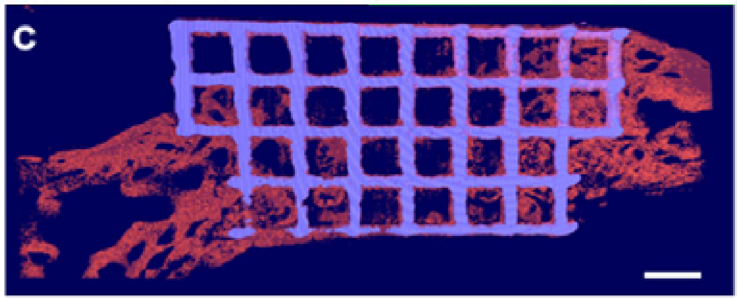


M. de Wild, R. Schumacher, K. Mayer, E. Schkommodau, D. Thoma, M. Bredell, A. Kruse, K.W. Grätz, F.E. Weber, *Bone regeneration by the osteoconductivity of porous titanium implants manufactured by selective laser melting: A histological and µCT study in the rabbit*, Tissue Engineering Part A, 19(23-24):2645-54 (2013).









M. de Wild, R. Schumacher, K. Mayer, E. Schkommodau, D. Thoma, M. Bredell, A. Kruse, K.W. Grätz, F.E. Weber, *Bone regeneration by the osteoconductivity of porous titanium implants manufactured by selective laser melting: A histological and μCT study in the rabbit*, Tissue Engineering Part A, 19(23-24):2645-54 (2013).

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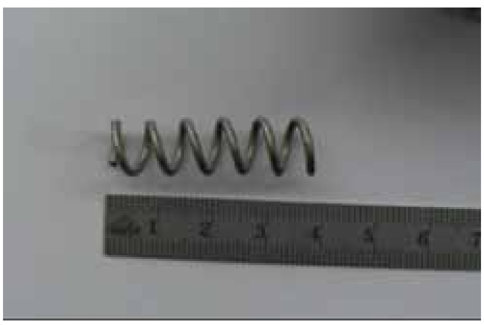
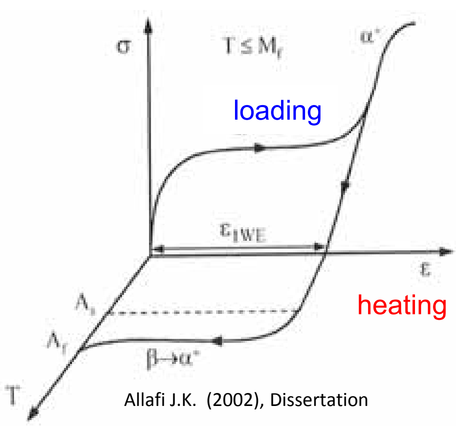
The shape memory effect

http://www.tradekorea.com/products/spinal_implant.html



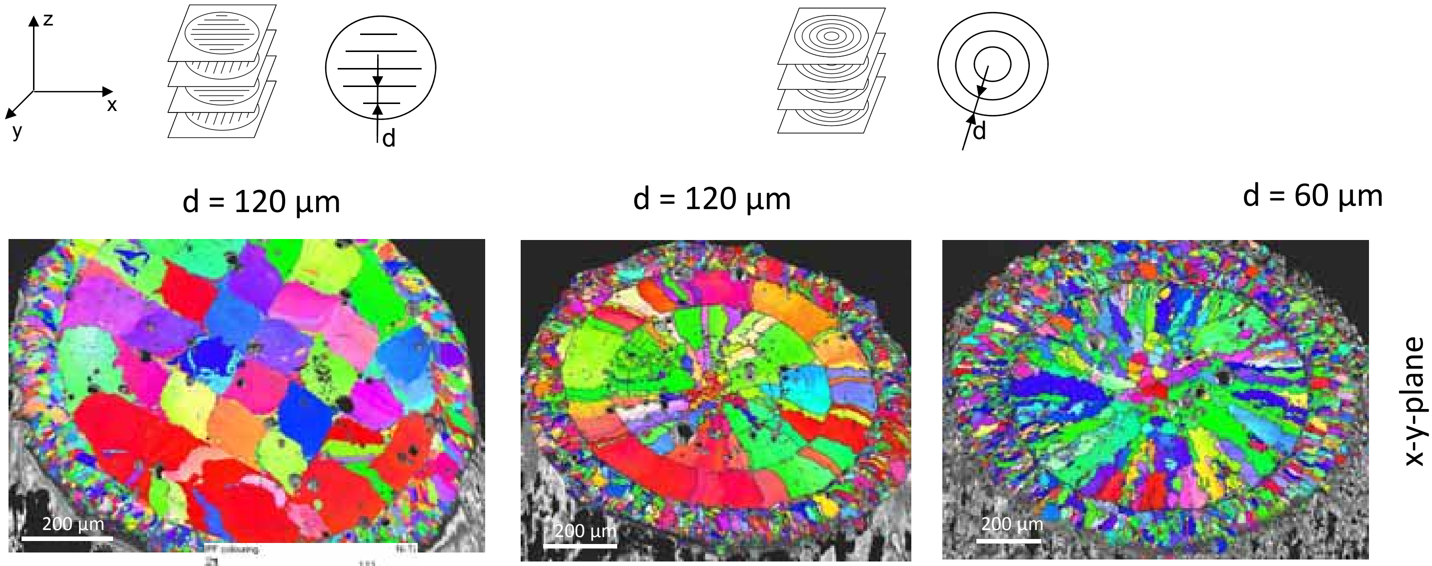


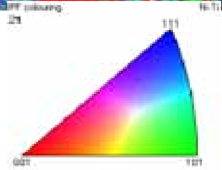
Allafi J.K. (2002), Dissertation

SLM fabricated sample | Elongated sample | Sample after heating

Therese Bormann, et al., *Determination of strain fields in porous shape memory alloys using micro computed tomography*, Proc. of SPIE Vol. 7804 78041M-1-9 (2010).

Microstructure depending on scanning strategy





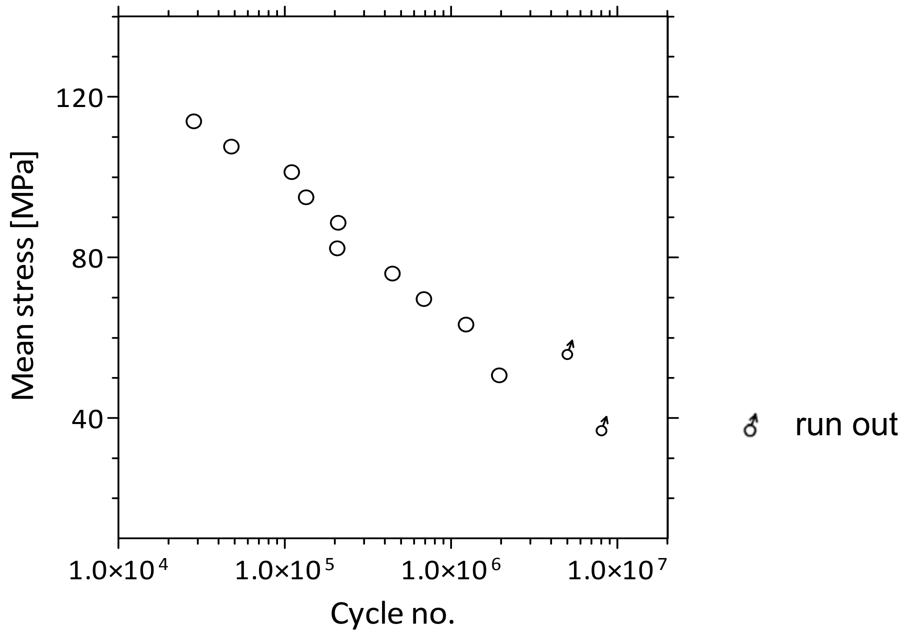
→ Electron backscatter diffraction reveals grain orientation (Cooperation with ETHZ).

T. Bormann, F. Beckmann, M. Schinhammer, H. Deyhle, M. de Wild, B. Müller, *Assessing the grain structure of highly X-ray absorbing metallic alloys*, Int. J. Mat. Res., 10.3139/146.111052 (2013).

Fatigue of NiTi scaffolds

Fatigue test at 600 N ± 120 N (76 ± 15 MPa)

Wöhler diagram

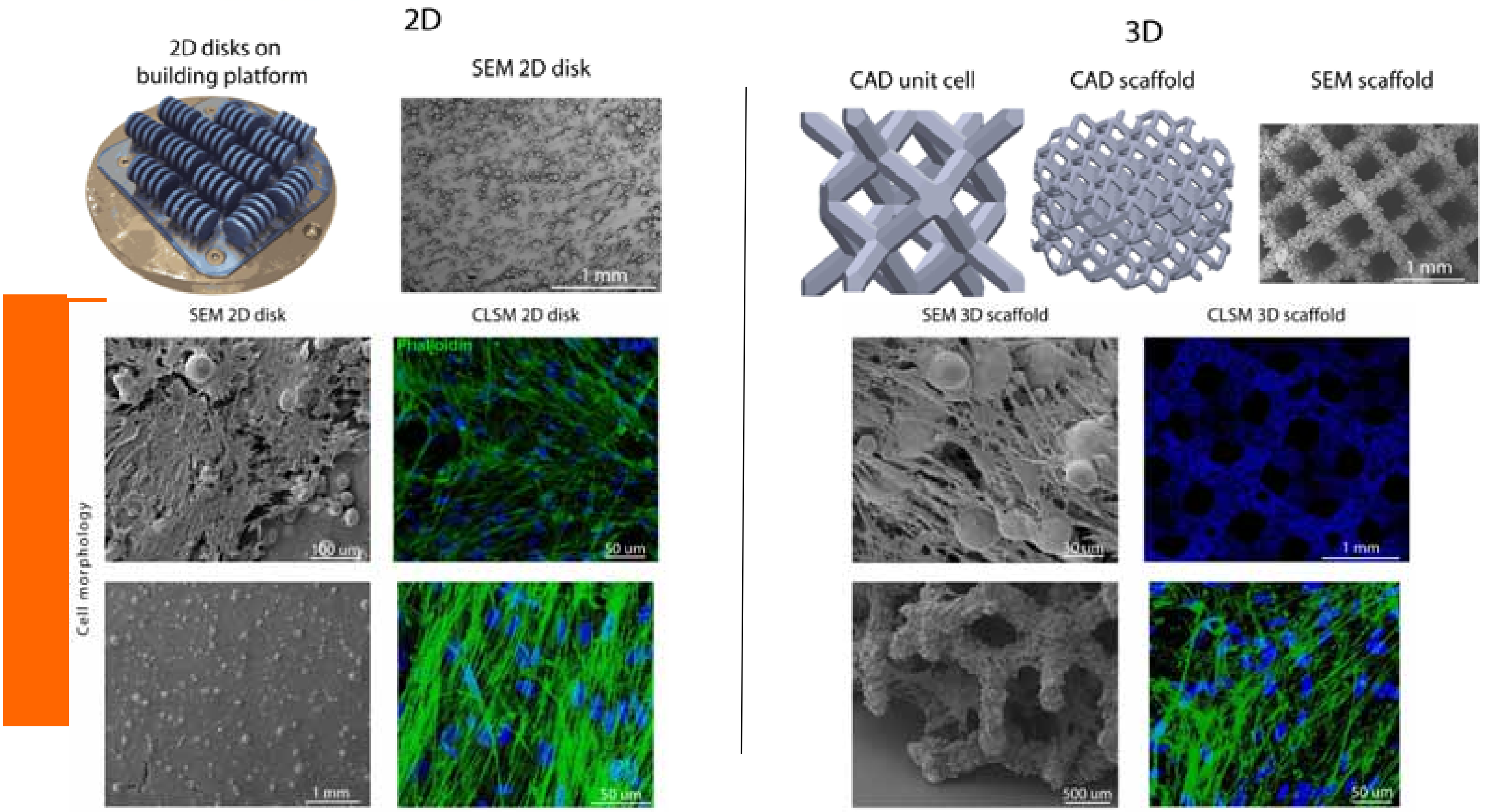


R = 2/3 (ratio between maximum and minimum stress)

Abortion criterion: $\Delta D_{max/min}$ = 0.04 mm

T. Bormann, B. Müller, W. Hoffmann, D. Wendt, M. de Wild, *Fatigue behaviour of selective-laser-melted nickel-titanium scaffolds*, ESB2014, 26th.

Smart NiTi constructs for 3D cell culture applications



W. Hoffmann, F.Schlottig, M.Mertmann, M. de Wild, D. Wendt, I. Martin, *The interplay between NiTi-SMA and human bone marrow-derived mesenchymal stromal cell*, Proceeding p. 46-47 of the 4th International Symposium Interface Biology of Implants IBI, 9.-11. May 2012, Warnemünde/Rostock (Germany).

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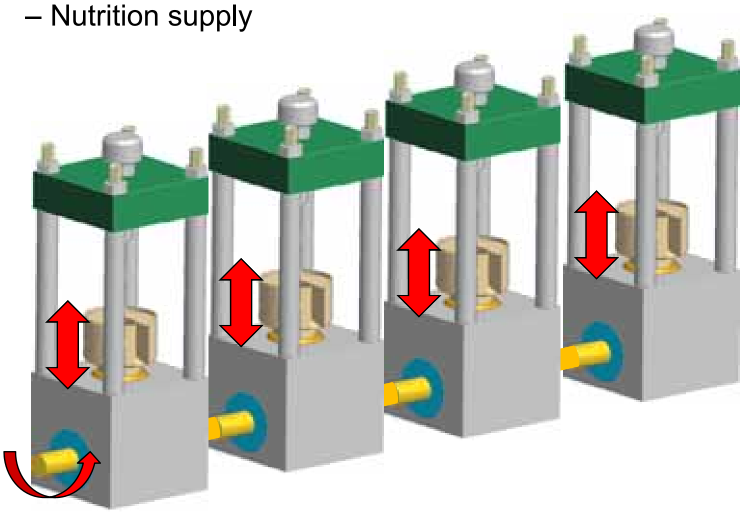
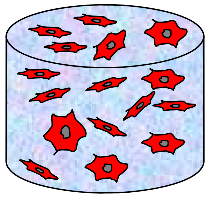
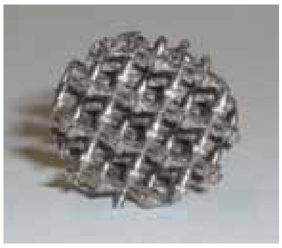
Compression Bioreactor (CBR)

- **Mechanical forces regulate progenitor cell differentiation and tissue formation (mechanobiology)**
- **Scaffolds contribute to mechano-transduction during *in vitro* culture**
- **CBR system as an *in vitro* model for wound healing processes post implant insertion**
  - Biochemical composition
  - Force transmission
  - Nutrition supply







European Patent Office Munich, priority application, EP 14/169756.

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Thank you for your attention!