DEVELOPMENT OF DESIGN AUTOMATION AND SINTER-BASED AM PROCESSES FOR PATIENT-SPECIFIC FINGER JOINT IMPLANTS

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intern

Fraunhofer IAPT – Process Technologies

Metal (Powder bed)

SLM 500HL (SLM Solutions)

Concept M2 (Concept Laser)

EOS M290 (EOS)

TruPrint 1000 (Trumpf)

SLM 250HL (SLM Solutions)

EOS M 270 (EOS)

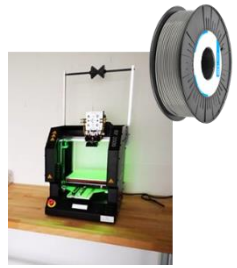
AconityLAB (Aconity)

DMP 350 Flex (3D Systems)

Metal (Sinter AM)

Pellet based piston extrusion

Renkforce Metal FFF



Desktop Metal Studio System

Digital Metal DM P2500

Polymers

EOS P390 (EOS)

EOS P396 (EOS)

Ultimaker S5 (Ultimaker)

Fortus 450mc (Stratasys)

Sources: SLM Solutions, Concept Laser, EOS, Trumpf, 3D Systems, Aconity, Desktop Metal, Stratasys

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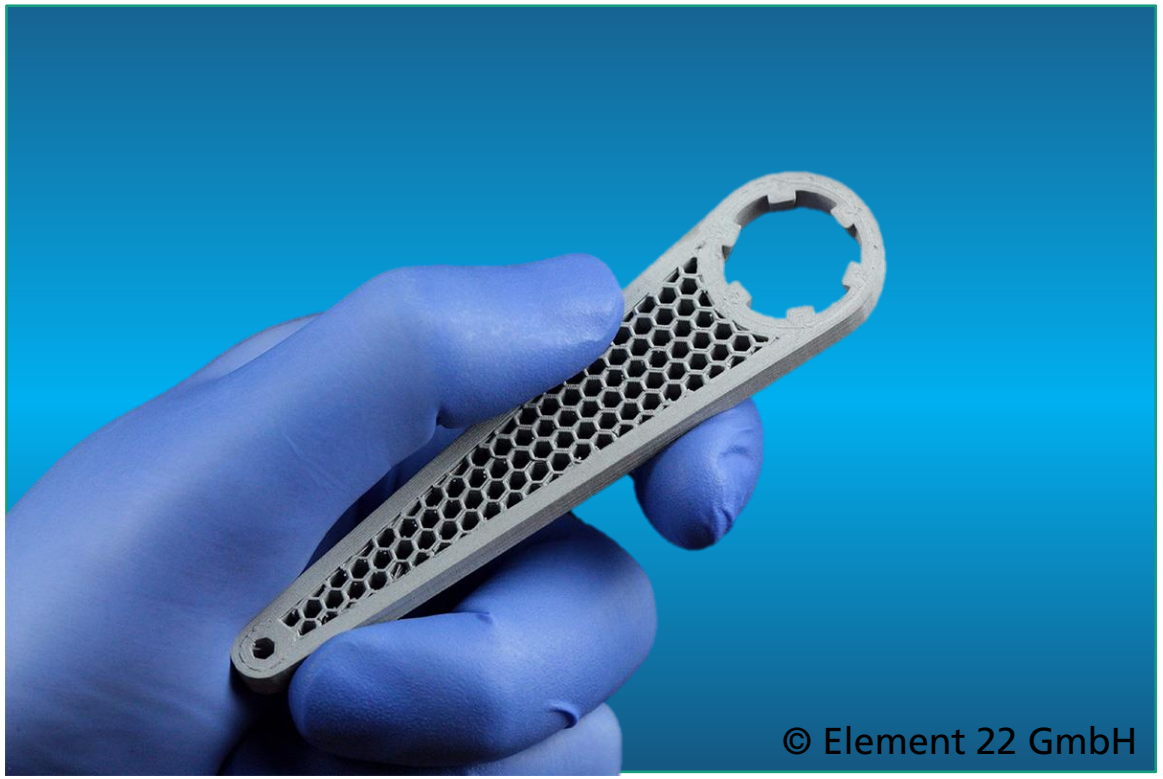
Sinter based AM at Fraunhofer IAPT



Pellet Printing – developed in Project SinTiM

Binder Jetting – printed and sintered @Digital Metal

State of the art and goals of FingerKIt

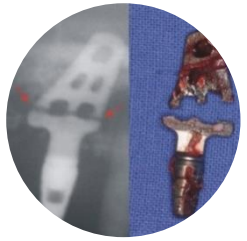
Rheumatoid arthritis → Stiffening of finger joints
→ Reduced mobility and quality of life

Stress for the patient during diagnostics (CT)

Limiting factors for implant design: manual effort, time and costs in the design of custom implants

Goal 1:

AI-based, automated implant design



Frequent failure of standard implants due to insufficient individual mechanical balance and osseointegration

High manufacturing effort and costs for individual implants made of metal and ceramics

Goal 2:

Material qualification and near net shape forming

Complex testing for biological and biomechanical properties

Questions about documentation, technology and standardization for AI that cannot be answered from the market

Goal 3:

Certification compliant evaluation

FingerKIt

Development and evaluation center for personalized implants

Artificial Intelligence @ FingerKIt

Segmentation of CT Data:
3D Shape Model

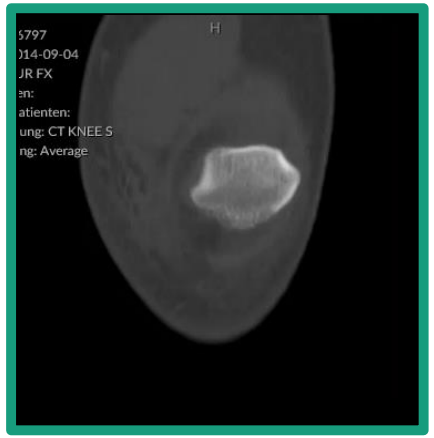
Creation of simulated 2D X-ray images
Matching

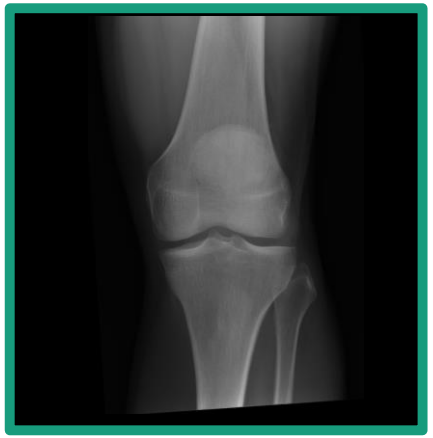
Back calculation:
2D-X-ray
→ 3D model

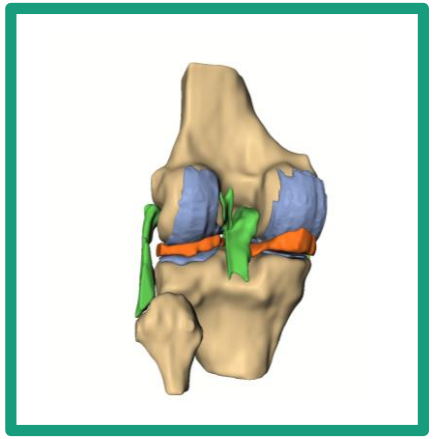
IAPT:
Automated implant design

MEVIS

Deep Learning







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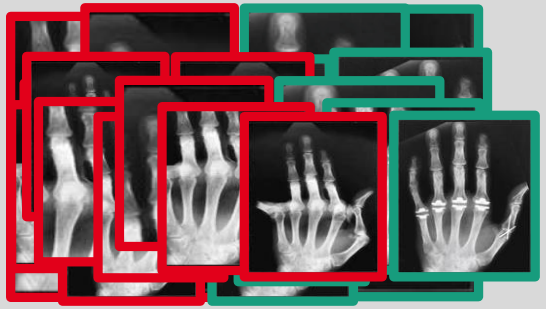
2D X Ray data → 3D joint model → 3D implant model

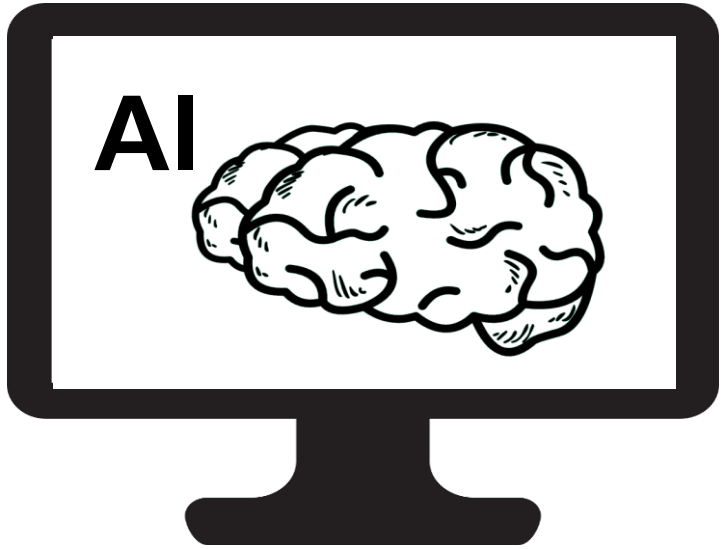
Artificial intelligence @ FingerKIt: from X-ray image to implant

Training phase (MEVIS, IAPT):

- Training on many X-ray images and matching implants
- AI system learns the relationship between joint model and implant
- Training database for defining individual gold standards



Data base



Autogeneration (IAPT):

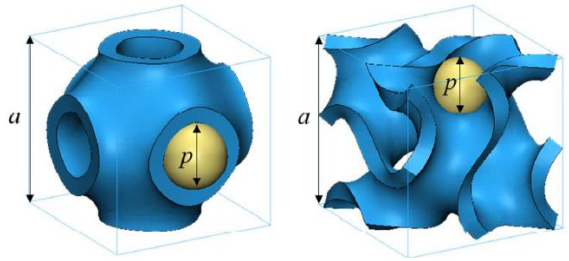
- Trained algorithm can automatically design patient-specific implant

Input:
X-rax image

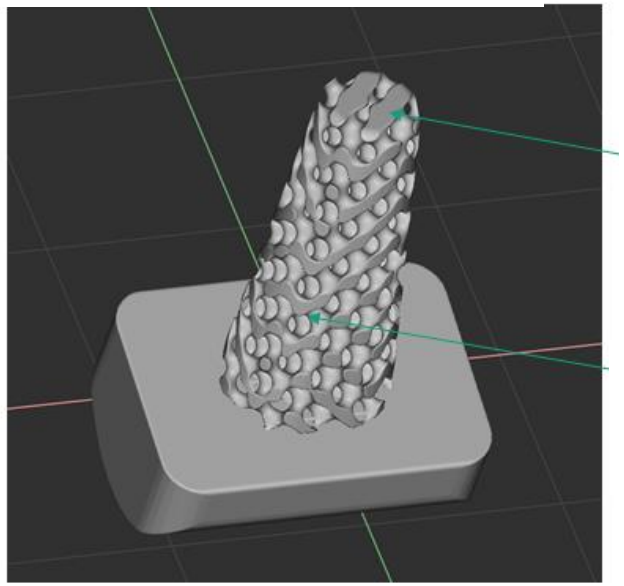
Output:
Implant design

Design and automation concept

Use of TPMS structures → parametrization



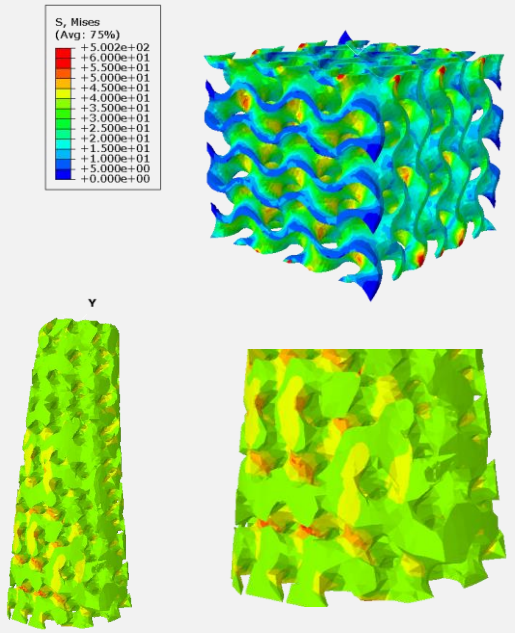
Parametric design allows adjustment to conditions given from imaging



Gradient forming
- Manufacturability
- Osseointegration
- Stress shielding

Elimination of overhangs
- By transformation
- By integrated supports

Training of the algorithm based on the initial designs and numerical simulation



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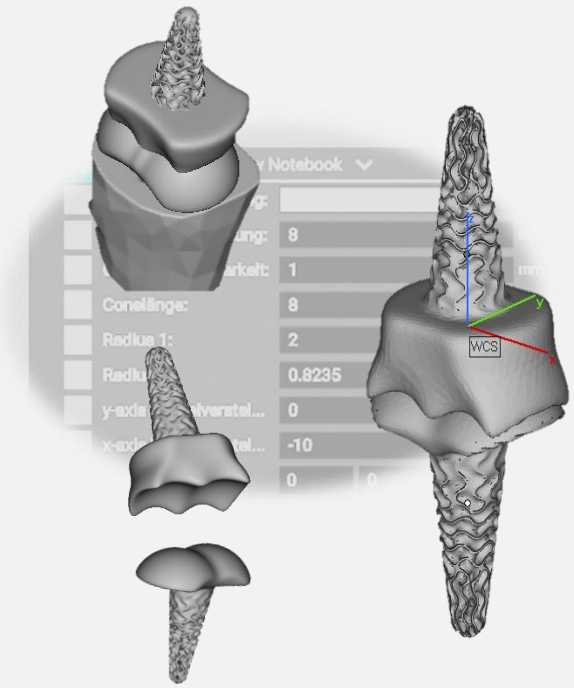
AI system learns correlation between joint model and implant

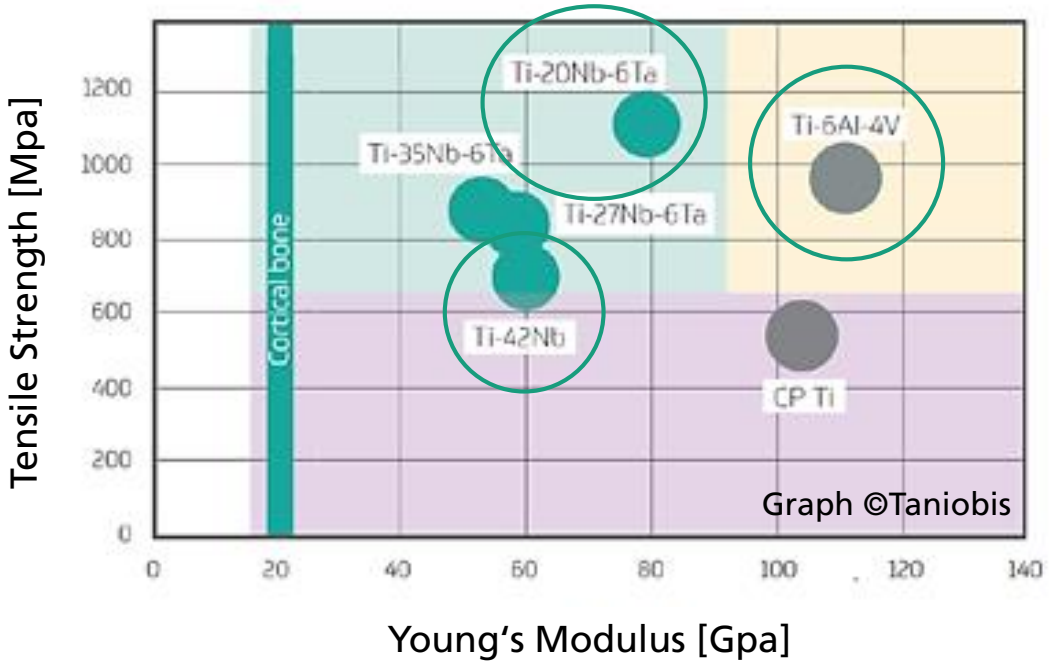
Autogeneration: Trained algorithm automatically designs patient-specific implant



Automated implant designs

Testing of titanium material variants

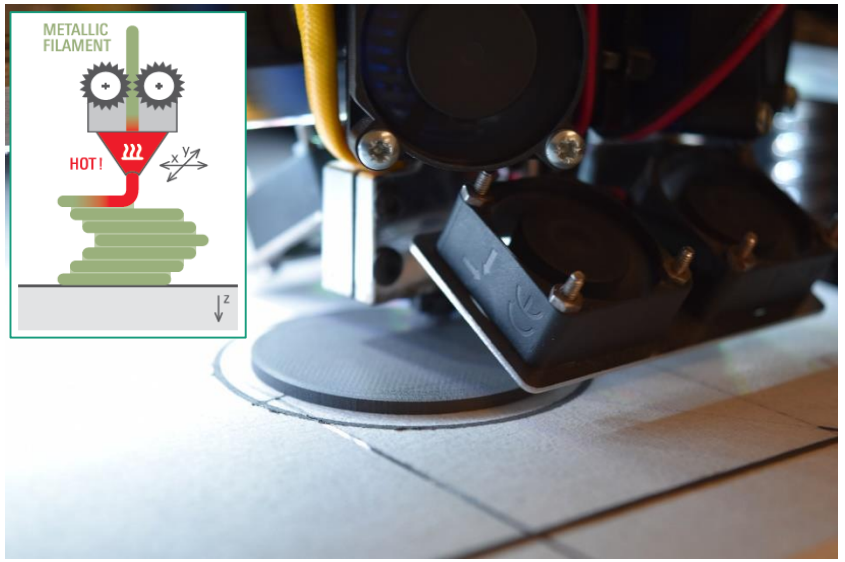
Mechanical properties of different titanium implant materials



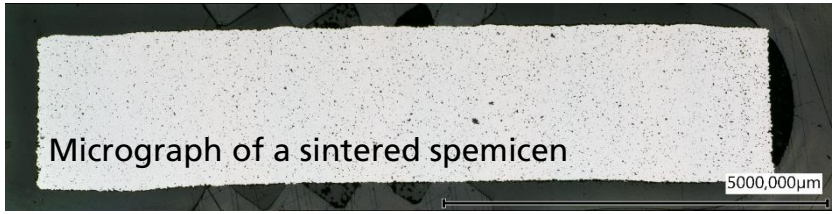
Ti-6Al-4V: Standard implantat material

Ti-20Nb-6Ta: lower Young's modulus, better adaption to bone

Ti-42Nb: further optimizied Young's modulus and reduced mechanical strength



Printed discs for mechanical and biological testing



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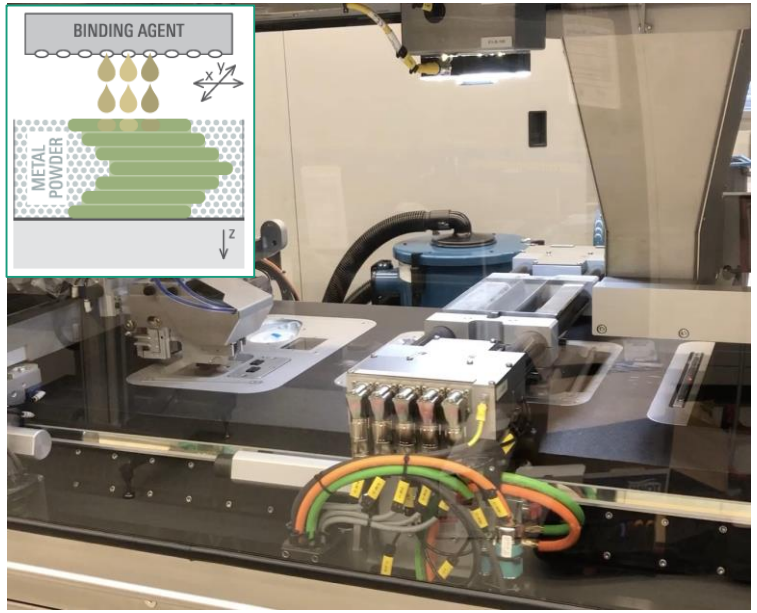
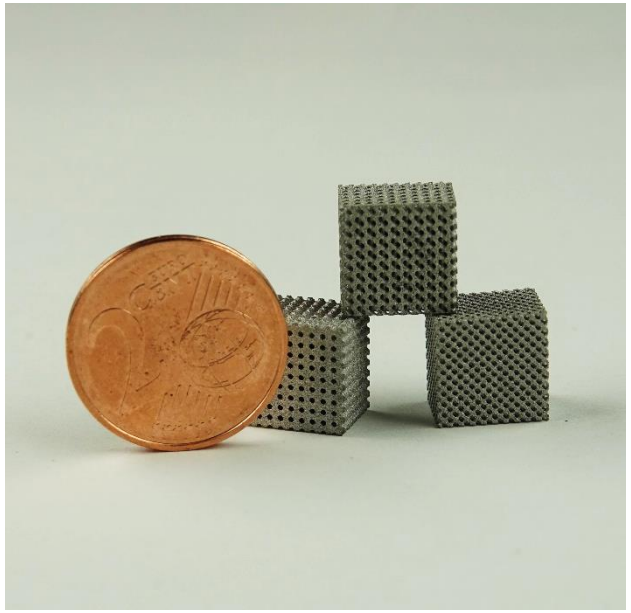
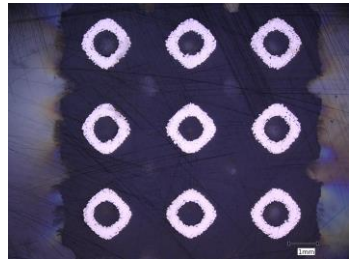
Transfer to Binder Jetting

- Process: Printing – curing – depowdering – debinding – sintering
- No supports required, nesting possible
- Particular suitability of the process for series production of precise, customizable components







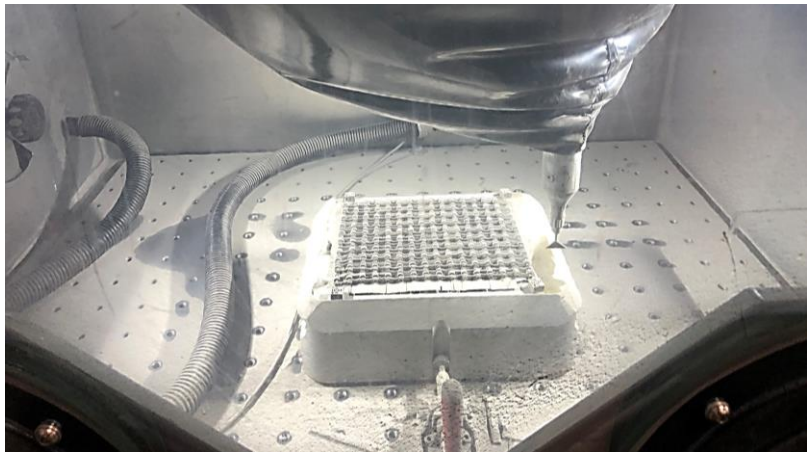
- First components with densities > 96% produced (stainless steel)
- Next step: Transfer to titanium alloys

Depowdering – a „side“ aspect in the process chain?

- Currently, components are unpacked or depowdered manually
- Components are blown free by compressed air and then transported by hand
  - Components can be easily destroyed by handling
  - Difficult reproducibility
  - Time consuming (one to several hours for a build job)

Residue-free removal of powders is crucial for quality not only for medical components

manual



semi-automatic

Certification-compliant evaluation of personalized implants

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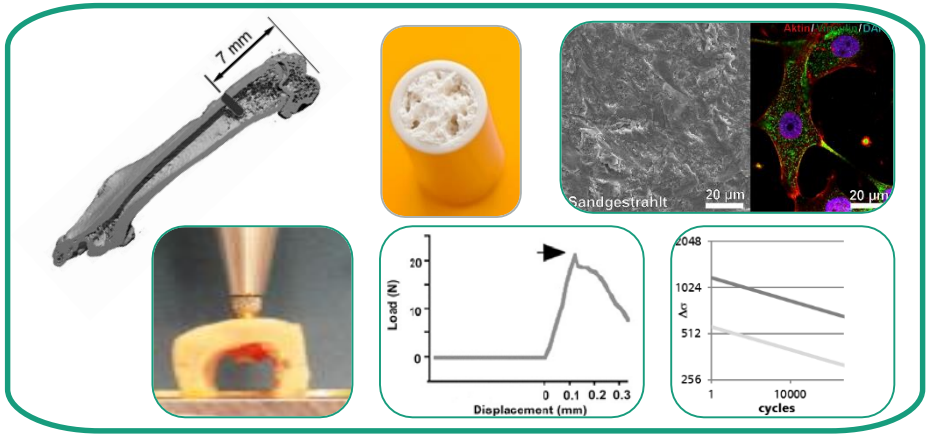
In-vivo models and validation

- Evaluation of surface structures with regard to osseointegration
- Certification-compliant testing concept for small joints via static and dynamic testing (IWM)
- In-vivo model for osseointegration



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Regulatory

- Requirements analysis for cross-institute PQM platform
- Testing of the system at the institutes
- CE-compliant documentation in digital development file
- Strategies for market introduction

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Thank you for your attention!

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