3D Data Capturing and 3D Print in Medical Science

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The „iPRINT“ Project

iPRINT

Implant Printing

Intra-operative manufacturing of personalized, craniofacial implants
State of the Art – Implantation
Implantations of skull bone

Most common Indications

Trauma

Tumor

Stroke
State of the Art: Implant Materials

**Autologous Bone**

**Biocompatibility** – *ideal implant*

*Best Results*: re-implantation after 72 hours

**Conservation of the removed bone**
*e.g. after decompressive craniotomy*

- *autoklaved*
- *chemically treated*(Tutoplast®)
- *deep-frozen*

Visible defect
One resorption
Risk for infection
State of the Art: Implant Materials

**PMMA** (Polymethylmethacrylate), bone cement, z.B. **Palacos**

**Additives**
- Stabilizers, Softeners, Antioxidants

**Fast, exothermal segregation reaction**
- Inflammation
- Connection Problems

- Difficulties with intraoperative modelling
- Missing stability; sensitivity for breaking
State of the Art: Implant Materials

PEEK (Polyetheretherketone), *high performance polymer*

- Flexibility comparable with spongy bone
  - X-ray permeability
  - High breaking strength
- Low risk for complications and infections
  - Good healing characteristics
  - Low material fatigue
  - Low liquid storage
Current clinical situation

CLINIC

Tumor (CT Scan) → Surgery → Post-operative CT Scan

Complications

> 11.000 €

5.000-9.000 €

6 WEEKS
decentralized, commercial implant manufacturing
AIM

**Centralized, intra-operative 3D-printing of implants**

Perfect Fit
No Second Surgery

100,- €
Challenges

Additive Manufacturing Technology (?) for intra-operative Implant Generation

Technology must be suitable for use in or close to the operation theatre

SLS of powders  FDM/FFF – polymer filaments
Challenges

Additive Manufacturing Technology (?) for intra-operative Implant Generation

High Performance Polymer (PEEK)
Melting point approx. 450 °C

Material – Medical Approved PEEK

FDM/FFF – polymer filaments
Challenges

Additive Manufacturing Technology (?) for intra-operative Implant Generation

- Fast manufacturing < 3hrs
- Precise patient specific implant generation

FDM/FFF – polymer filaments
Challenges

Fast translation of CT data into stl files for printing (< 1 hr)
Challenges

**Biological and Mechanical Properties of Additive Manufactured Implant**

Medical Approved PEEK Implant – only for Milling Process

Filament generation and melting during additive manufacturing might influence polymer properties

Mechanical properties ≥ cranial bone

Biocompatibility – integration without inflammation
Aim: Development of a 3D-printer for clinical applications

Clinical / Experimental Studies
Verification of Process-, Software- and Material Development

Development of Manufacturing Process (3D-Printing)

Software-Development

Material-Development

Hage Sondermaschinenbau GmbH & CoKG

Computer Graphics and Vision, Graz University of Technology

Chair for Polymer Processing, Montanuniversitaet Leoben

RU for Exp. Neurotraumatology
Department of Neurosurgery
Medical University of Graz

External/commercial delayed
not patient-specific
Titanium/PEEK

Internal/central simultaneous
personalized/patient specific
high performance

Medizinische Universität Graz, Universitätsplatz 3, A-8010 Graz, www.meduni-graz.at
Images / Software

3D-Modelling (Software Development)
Institute of Computer Graphics and Vision, Graz University of Technology

- Segmentation:

Separate brain tissue from bone tissue (medical experience)
Images / Software

3D-Modelling (Software Development)
Institute of Computer Graphics and Vision, Graz University of Technology

- CT patient data were used for the development of a new software
- Software development is based on mirroring the intact part of the cranium:
  - fast definition of cranium curvature
  - semi-automated capping of lesion

Front View | Semi-automated Capping of Lesion

20–45 mins.
Software

Disadvantages

- Patient needs two CT-Scans
- Segmentation process needs medical experience – time limiting step
- Depending on lesion location mirroring of cranium is not always possible
- Speed of development of 3D model is dependent on expertise of experimentator/technician/surgeon
Potential solution

Laser Scanning of cranium/lesion

- No second CT Scan necessary
- No mirroring
- No segmentation
- Very fast generation of 3D model (seconds)
- Easy to handle for surgeons
- No direct contact with patient – easy sterilisation measures
Potential Challenges

Laser Scanning of Cranium

Scanning of a lesion

Filling of the lesion (implant generation) requires 3D modelling/ specific software

There are liquids such as blood in the wound
Preliminary Results

- Different optical and tactile measurement options have been tested at FARO using a pig head provided by the Medical University of Graz.

Pig head with cut-out bone lesion

CT-image of the pig head as a reference for the scanning tools

Data provided by FARO Europe, Dr. Matthias Wolke
Preliminary Results

Scanning of the upper and lower edge of the lesion rim defines:
- dimension of the implant
- curvature of the cranium / bending of the implant

Data provided by FARO Europe, Dr. Matthias Wolke
Four different scanning methods were tested by FARO

- Freestyle X
- Unnamed Prototype
- Cobalt
- Scan Arm
Preliminary Results

• Only two of the scanning options were able to record the necessary data for modelling an implant to fill the lesion

• Cobalt

CT reference  Mesh from Cobalt data  Cobalt pointcloud

Data provided by FARO Europe, Dr. Matthias Wolke
Preliminary Results

• Scan Arm

Data provided by FARO Europe, Dr. Matthias Wolke
Preliminary Results (Printing)

CT Reference

Mesh from Cobalt data
Challenge for FARO Scanning

• Reality
Mechanical Testing of printed PEEK implants

Mechanical Analysis of the 3D-printed implants
Chair of Polymer Processing, Montanuniversitaet Leoben

- Comparison of the mechanical performance of human bone, 3D-printed PEEK and 3D-printed PP

- Maximal weight on the samples, before they break:

  - Human Bone ~ 32 kg
  - 3D-printed PEEK ~ 130 kg
  - 3D-printed PP ~ 50 kg
Biocompatibility (in vivo testing)

Analysis of inflammatory reactions
*Research Unit for Experimental Neurotraumatology*

**Implantation of a 3D-printed PEEK implant**

**Absolutely custom-fit!**

Immunhistochemical stainings for CD4 (T-cell-Marker) and CD68 (Macrophage-Marker); no differences between healthy animals (left) and animals with PEEK implants after 5 days and 2 weeks (middle and right) could be found.
Summarize

3D FFF- Printer for High Performance Polymers

PEEK Filaments (high quality)

Software (CT→STL files)

Imaging / Laser Scanning

Mechanical Properties / Biocompatibility

CLINIC
Advantages of a centralized 3D-printer in the clinic

**COSTS**
- No second surgery necessary
- Shorter hospital stays
- Lower implant costs

**QUALITY**
- Patient-specific implants
- Biologisation
- Biofunctionalization
- Fitting accuracy

**TIME**
- Intraoperative manufacturing
- No post-treatments necessary
Future

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<th>Implants</th>
<th>Protheses</th>
<th>Tools</th>
<th>Models</th>
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Chest-wall reconstruction by compound 3D-printed implants

PI: Professor Freyja Smolle-Jüttner, Division for Thoracic and Hyperbaric Surgery

Current-Situation

X-Ray after Operation

X-Ray after 2 years:
Complete deformation of implant
Development Clinical Process Chain

IMAGING – 3D Modelling

MATERIAL SELECTION

3D-PRINTING

MATERIAL MODIFICATION

CLINICAL IMPLEMENTATION
COMET K-Project

• Aim of the Project

CAMed
Clinical additive manufacturing for medical applications
**CAMed: Planned Areas/Projects**

### Area 1
**ADDITIVE MANUFACTURING OF PERMANENT IMPLANTS (CAL, TAL)**

1.1: Additive Manufacturing for Rib Replacement

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1.2: On demand individualized plates for complex trauma osteosynthesis

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1.3: Development of advanced imaging methods, software and coating for intra-operative additive manufacturing of PEEK-implants for cranial defects

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1.4: Additive Manufacturing for Orthodontic Implants

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### Area 2
**ADDITIVE MANUFACTURING OF BIODEGRADABLE IMPLANTS/SCAFFOLDS (CAL, TAL)**

2.1: Bioreposable scaffolds for the treatment of critical size defects in orthopaedic and trauma surgery for children

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2.2: Bioreposable implants for the treatment of cranial lesions for children

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Thank you for your attention