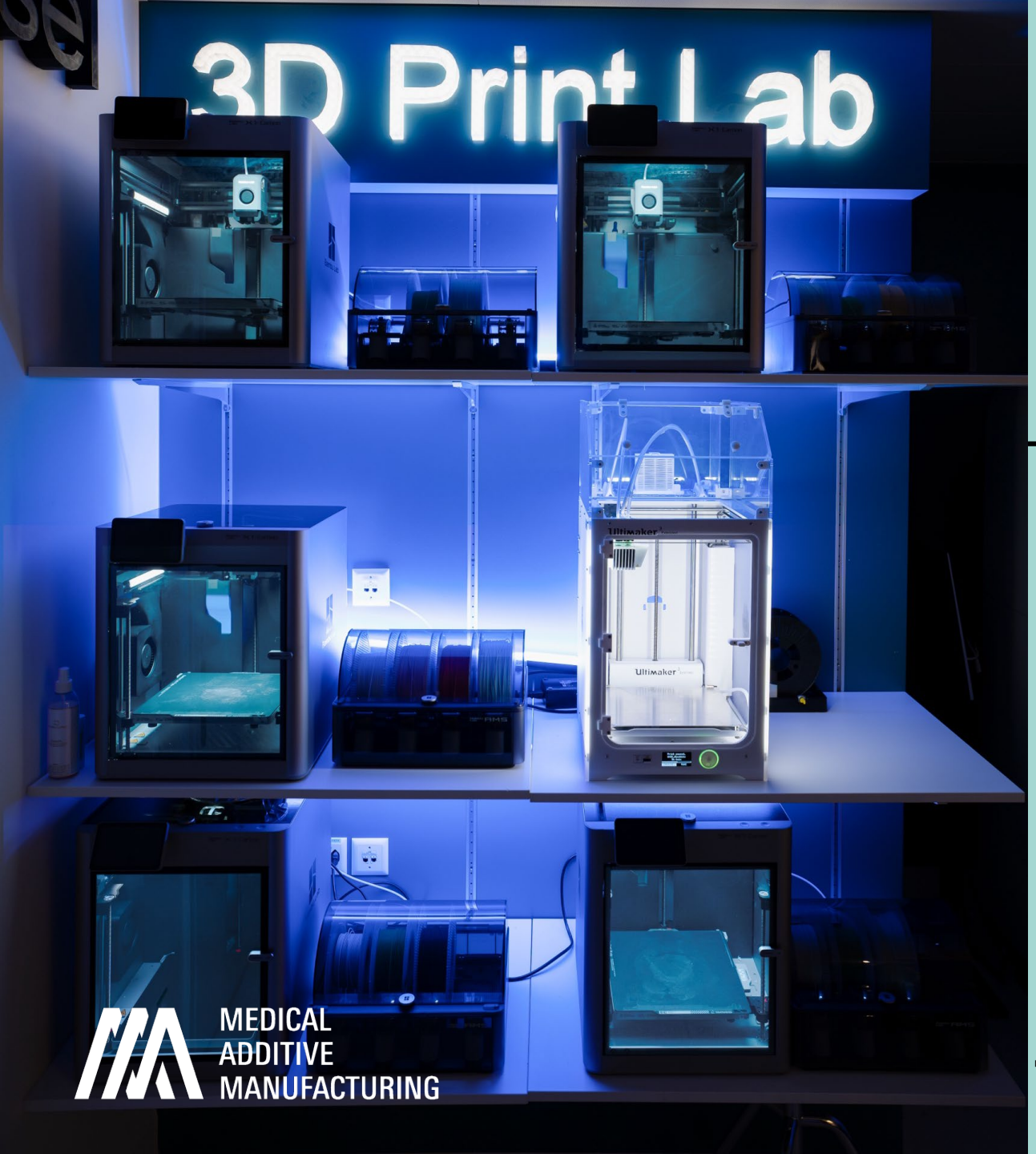


Innovation on Demand: 3D Printing at the Point of Care for Personalized Medicine

Dr. Neha Sharma

- *Oral and Cranio-Maxillofacial Surgery / 3D Print Lab University Hospital Basel*
- *Swiss Medical Additive Manufacturing RG / Department of Biomedical Engineering, University of Basel*

Munich, 7th March. 2024

University Hospital Basel

University of Basel
Department of Biomedical Engineering

Declaration: Potential Conflict of interest

MEDICAL ADDITIVE MANUFACTURING

Financial relationships with commercial entities related to health-care-related products:

- Co-Founder / Chief Medical Officer (CMO) : **POC APP AG**, Basel, Switzerland.


– BASEL
Image: Basel Tourism


– Oral and Cranio-Maxillofacial
Surgery / Radiology – 3D Print Lab
University Hospital
Basel

– Swiss Medical Additive Manufacturing Research Group / DBE
– Core Facility 3D Print Lab, University of Basel

University of Basel

Department of
Biomedical Engineering

Evolution of 3D Printing

MEDICAL ADDITIVE MANUFACTURING

1981: Marsh & Vannier: 3D objects

1986: Chuck Hull Stereolithography

1971: CT Scan Hounsfield

1985: Milling: Lambrecht & Brix

1970 1980 1990 2000 2010 2020 2025 2030 2035 2040

Evolution of 3D Printing

MEDICAL ADDITIVE MANUFACTURING

1971: CT Scan Hounsfield

1981: Marsh & Vannier: 3D objects

1985: Milling: Lambrecht & Brix

1986: Chuck Hull Stereolithography

1995: SLA & VSP: Zeilhofer, Sader et al.

2003: Titanium SLM Implants

1970 1980 1990 2000 2010 2020 2025 2030 2035 2040

Evolution of 3D Printing

MEDICAL ADDITIVE MANUFACTURING

2015/16: Interdiscipl. 3D Print Lab USB / Radiology & CMF

1981: Marsh & Vannier: 3D objects

1986: Chuck Hull Stereolithography

2003: Titanium SLM Implants

1971: CT Scan Hounsfield

1985: Milling: Lambrecht & Brix

1995: SLA & VSP: Zeilhofer, Sader et al

2012: 1st 3D Printer at Point-of-Care / USB. Thieringer

1970 1980 1990 2000 2010 2020 2025 2030 2035 2040

Evolution of 3D Printing

MEDICAL ADDITIVE MANUFACTURING

1971: CT Scan Hounsfield

1981: Marsh & Vannier: 3D objects

1985: Milling: Lambrecht & Brix

1986: Chuck Hull Stereolithography

1995: SLA & VSP: Zeilhofer, Sader et al.

2003: Titanium SLM Implants

2012: 1st 3D Printer at Point-of-Care / USB. Thieringer

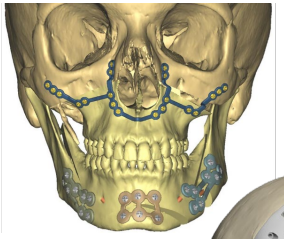
2015/16: Interdiscipl. 3D Print Lab USB Radiology & CMF

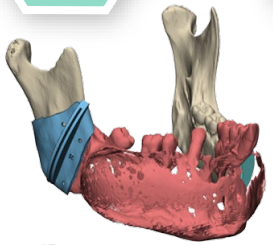
2021–2026: Innovation-Focus Regenerative Surgery USB

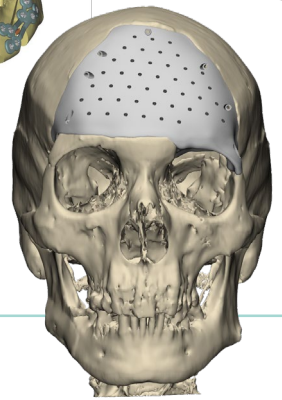
2022–2027: MIRACLE II Smart Implants, DBE

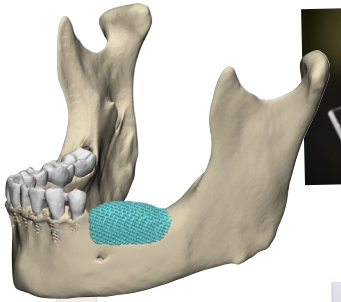
2023: 1st POC 3D Printed Implant Sharma, Thieringer et al.

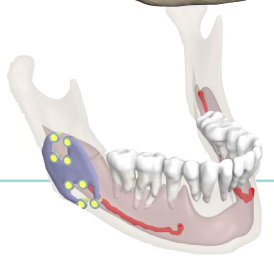
1970 1980 1990 2000 2010 2020 2025 2030 2035 2040

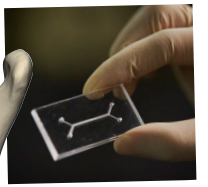


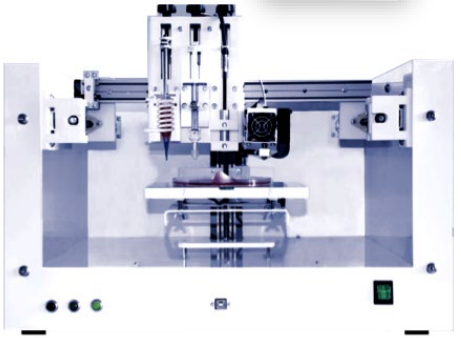












Technology Enhanced Surgery

MEDICAL ADDITIVE MANUFACTURING

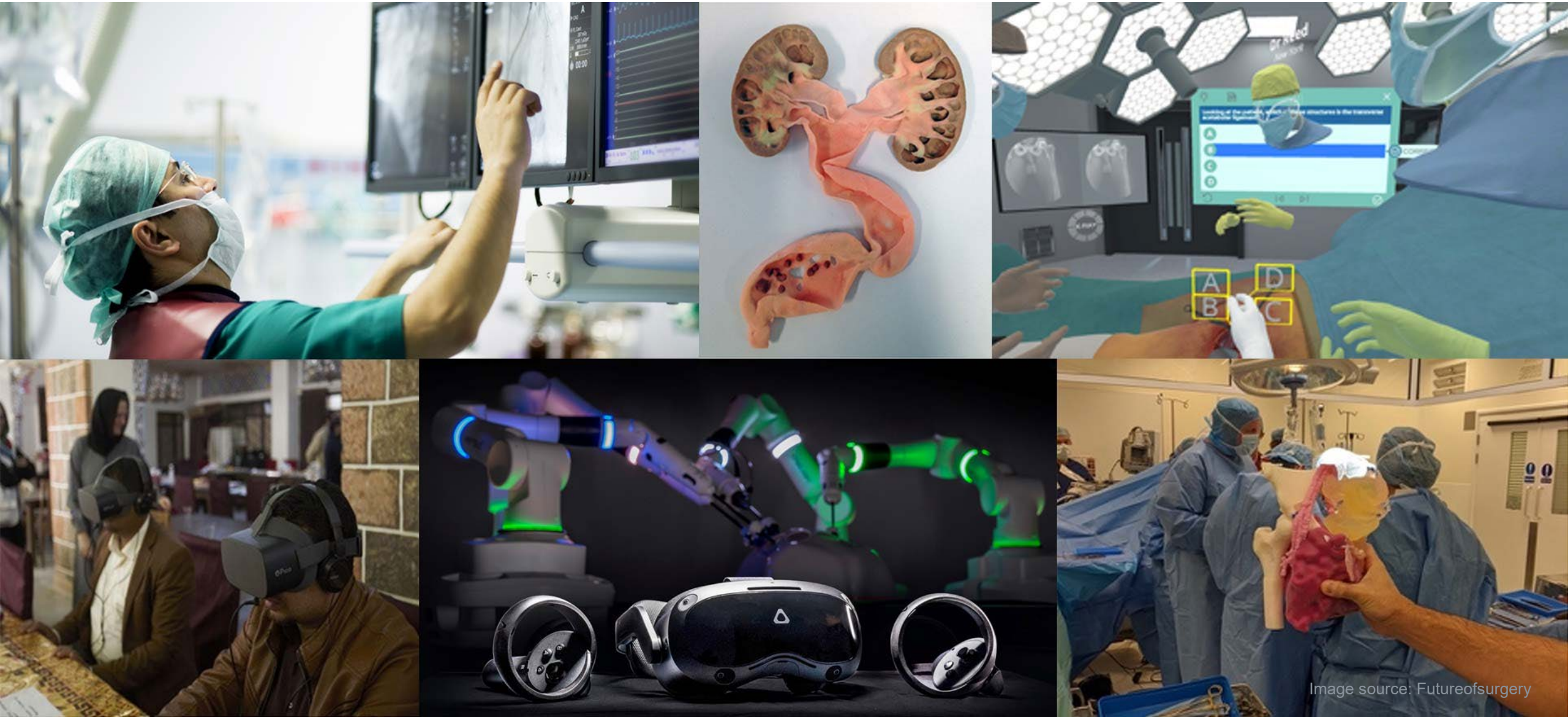
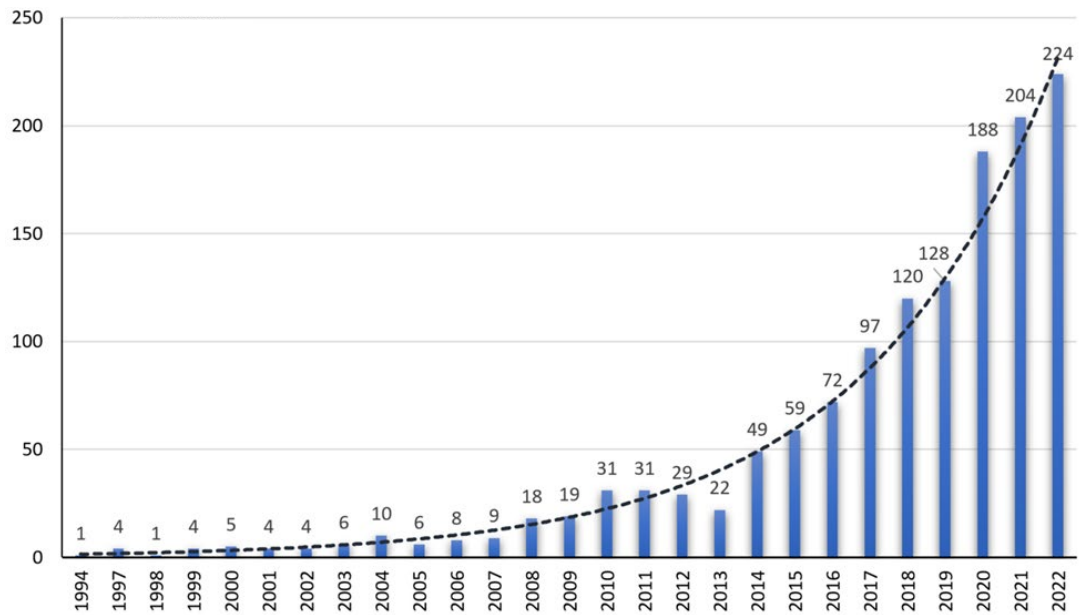


Image source: Futureofsurgery

MEDICAL ADDITIVE MANUFACTURING

The 2022 Commission on the **Future of Surgery** stated that "…..further developments in 3D printing are likely to make surgery more precise, or open avenues for surgical procedures currently too complex or with outcomes that are too poor."



Craniomaxillofacial Research & Innovation
Volume 8, January-December 2023

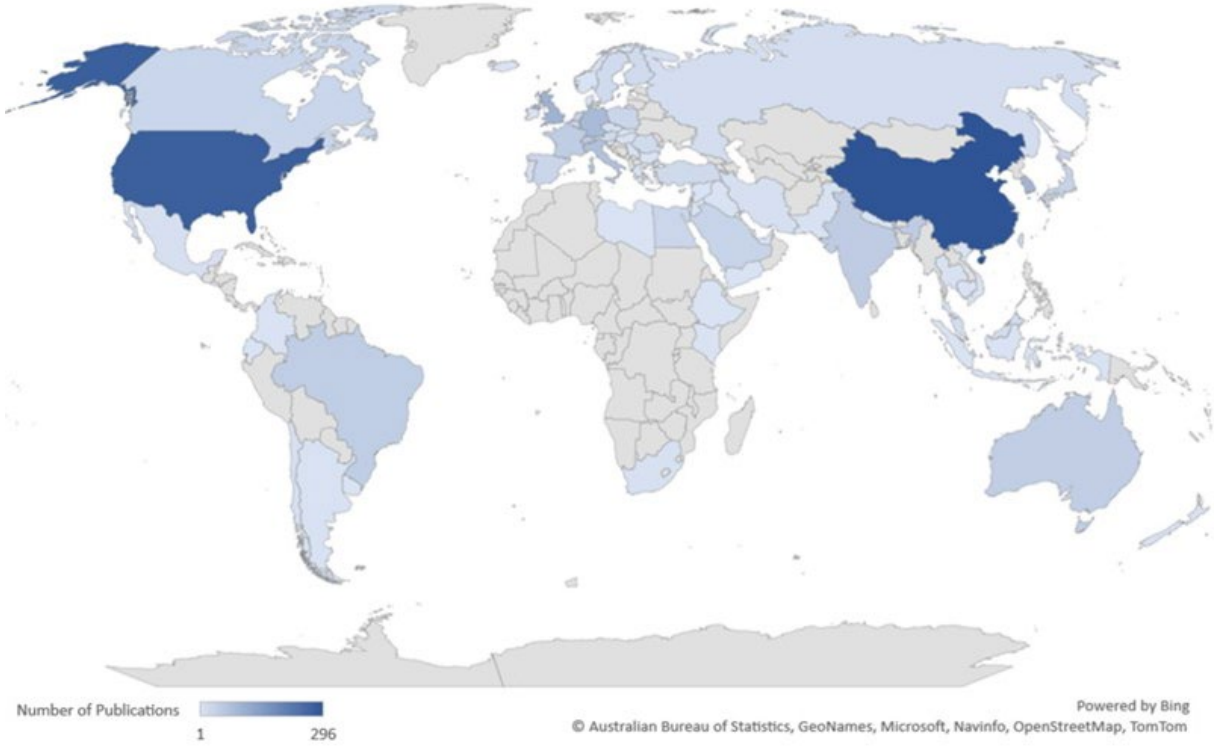
https://doi.org/10.1177/27528464231170964

SAGE journals

Review

Knowledge Domain and Innovation Trends Concerning Medical 3D Printing for Craniomaxillofacial Surgery Applications: A 30-Year Bibliometric and Visualized Analysis

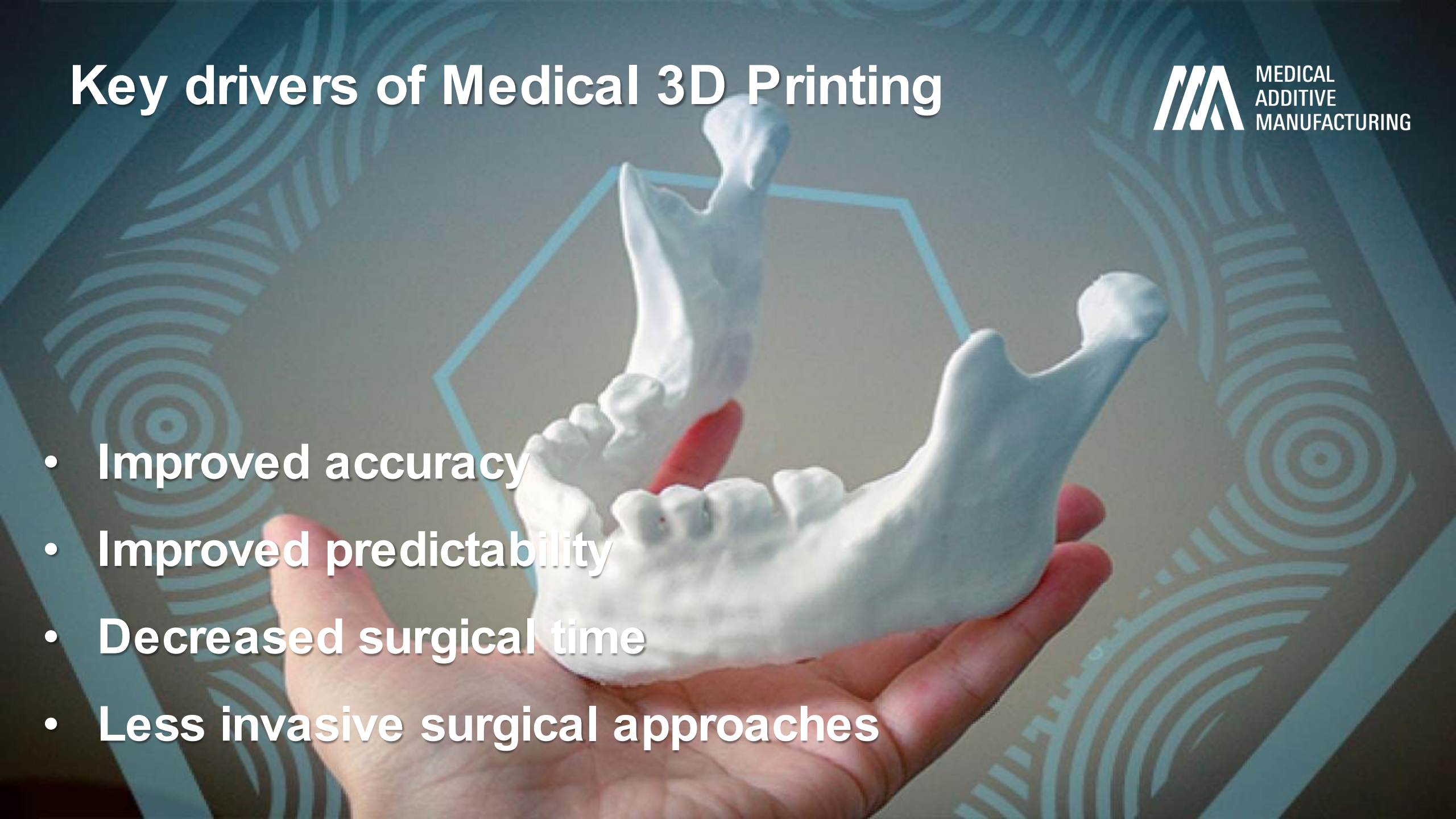
Vikas Modgill[1,2], Bogdan Balas[2], Minghan Chi[1,3], Philipp Honigmann[1,4,5], Florian M. Thieringer[1,3,*], and Neha Sharma[1,3,*]



Global Trend towards Medical 3D Printing

Key drivers of Medical 3D Printing

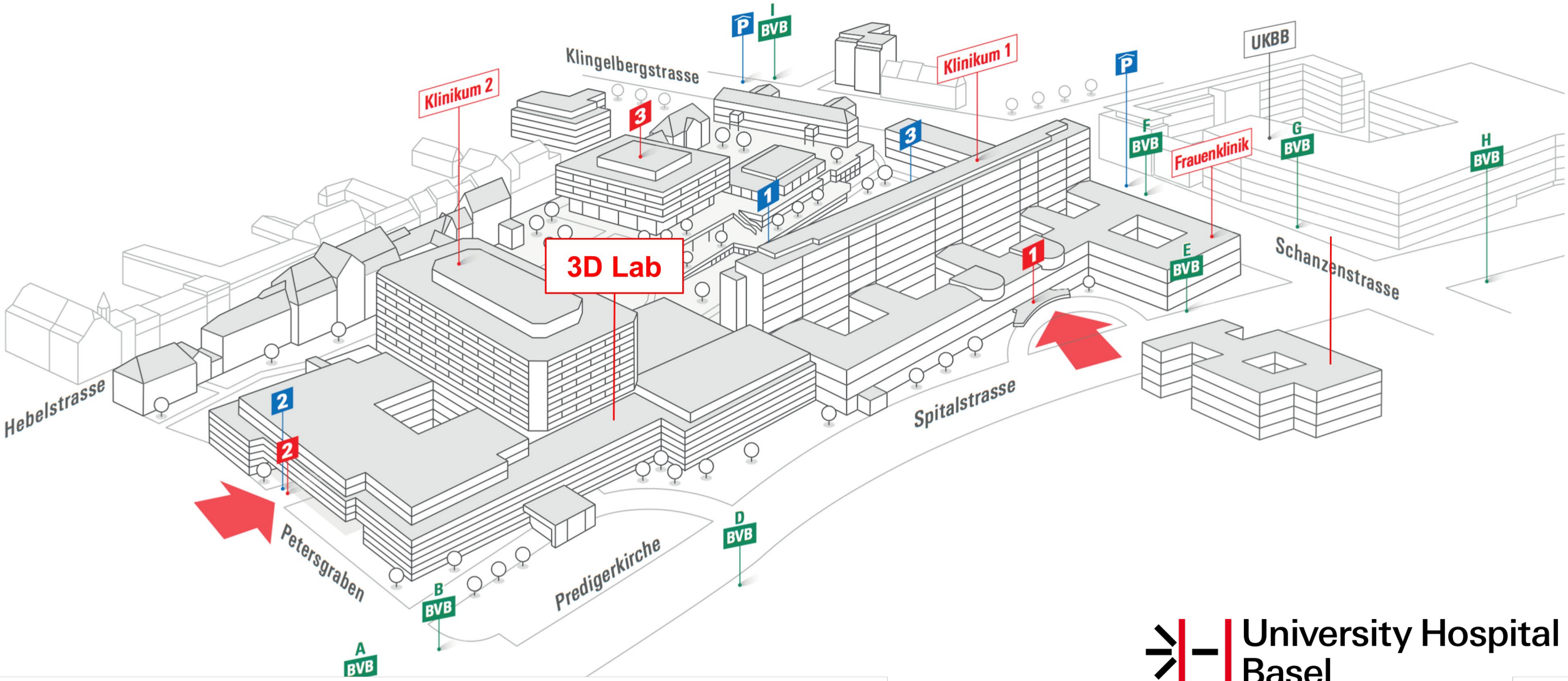
MEDICAL ADDITIVE MANUFACTURING



- Improved accuracy
- Improved predictability
- Decreased surgical time
- Less invasive surgical approaches

Central Location – Next to the radiology department / OR

MEDICAL ADDITIVE MANUFACTURING



University Hospital Basel

3D Print Lab / USB

MEDICAL ADDITIVE MANUFACTURING

3D PRINTING IN THE MEDICAL ENVIRONMENT

2018

Image source: 3D-Models for medicine, UNINOVA – University of Basel, Christian Flier, 11/2018

3D PRINTING IN THE MEDICAL

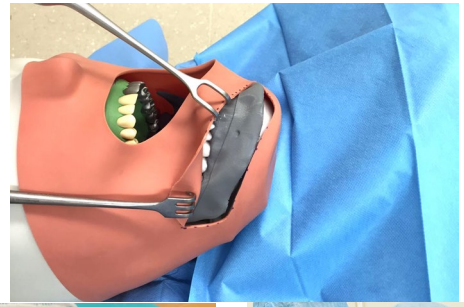
2020/21

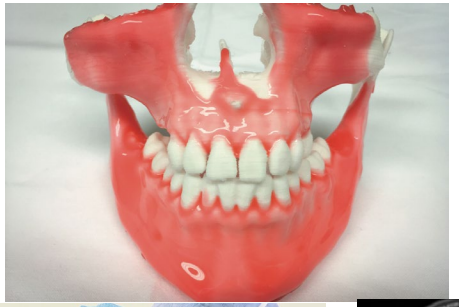
2024

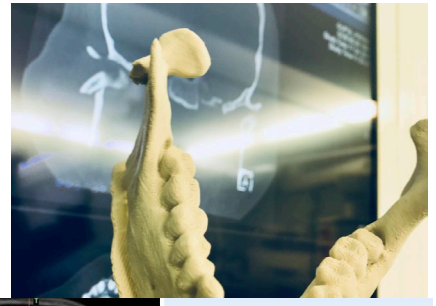
Thieringer FM, Sharma N and team…

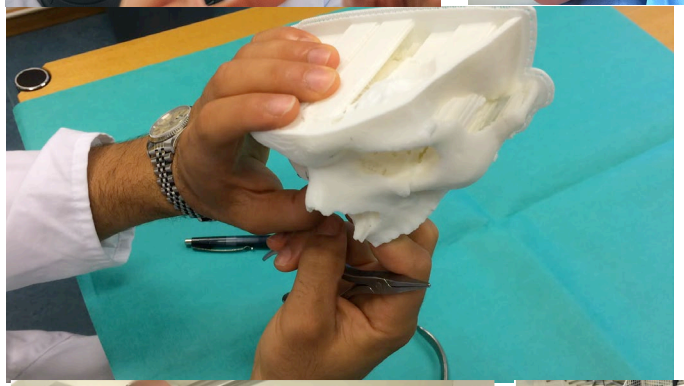
Education & Training > Skills Lab

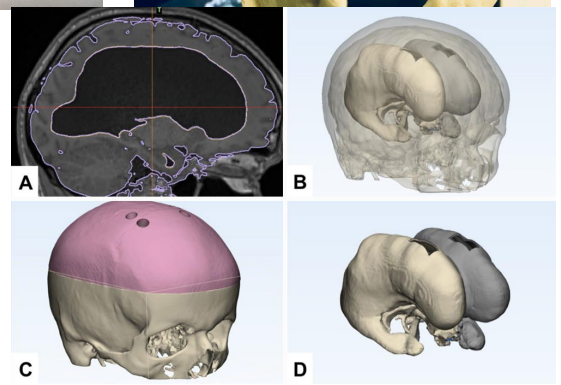
MEDICAL ADDITIVE MANUFACTURING

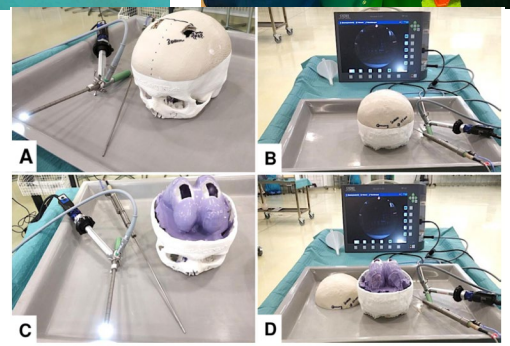


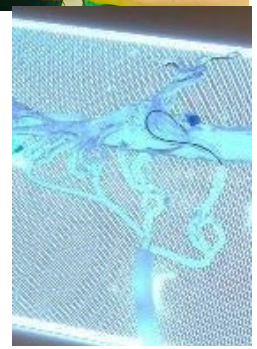


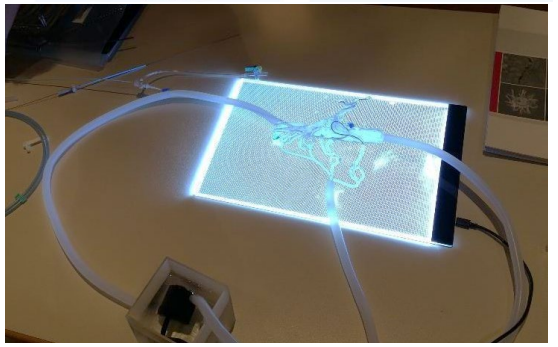


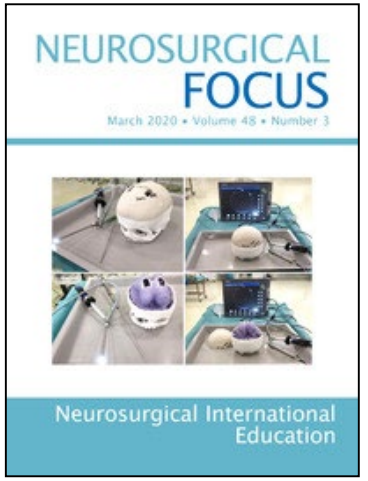




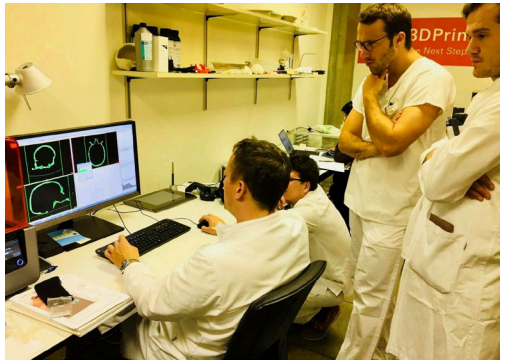


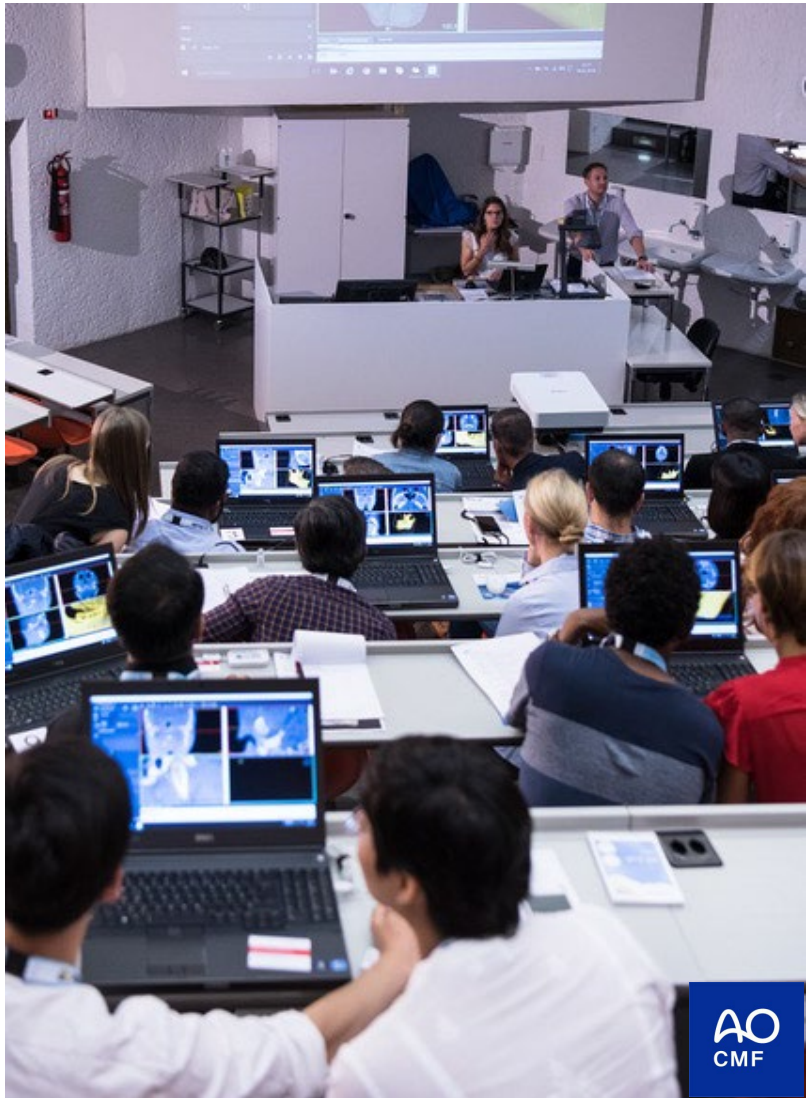


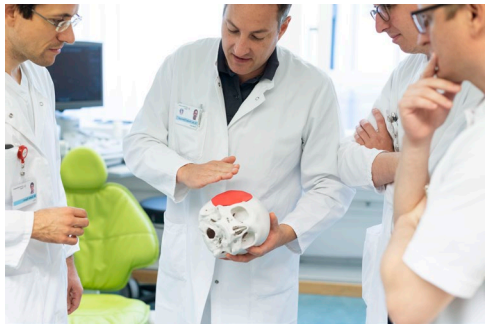




Education & Training > Skills Lab



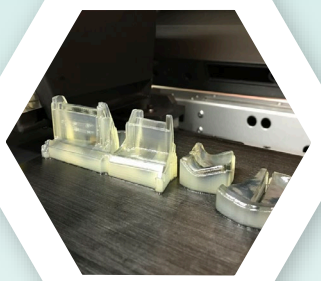




- Unibas courses, DBE / DBM Lectures, int. fellowship and internship programs Basel CMF
- Bernd Spiessl Symposium for Innovative & Visionary Technologies in CMF Surgery
- First AO 3D Printing Course—Advances in Medical 3D Planning & 3D Printing, 2018 / 2022
- AO CMF Master Courses Davos and international F2F and online courses
- Swiss Military dentist training program 2021
- 5th Symposium on 3D Printing for Life Sciences 2023, in collaboration with FHNW

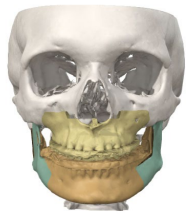
Key benefits of Medical 3D Printing

MEDICAL ADDITIVE MANUFACTURING

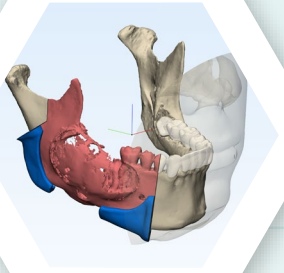


Highend Solutions
Personalized Medicine
Innovation & Research

Increase patient safety, reduce length of stay, improved accuracy



Reduce time, costs & complications



Optimally prepared in the operating room

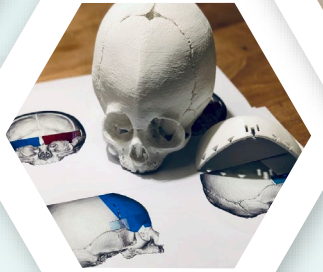
Improve patient consent, treatment adherence

Simulation
Prototyping
Bio-Printing
Spare Parts
Informed Consent
Anatomical Models
Pre-Bending
Patient-specific Implants
Surgical Planning
3D
Skills Lab
Drill & Cutting Guide
Education
Quality Control

Patient-specific treatment

Vivid interprofessional communication

Better Education & Training –
Med. Skills Labs



3D PRINT LAB, USB

regional

University of Basel
Department of Biomedical Engineering

EMPA
Materials Science & Technology

Kantonsspital Baselland
ganz nah

ETH zürich

Universitäres Zentrum für Zahnmedizin Basel
UZB

industry

n|w University of Applied Sciences and Arts Northwestern Switzerland
School of Life Sciences

national

SWITZERLAND INNOVATION
PARK BASEL AREA

csem centre suisse d'électroniq et de microtechnique

spinoffs

University of Basel

UKBB
kompetent & menschlich

University of Basel
Innovation Office

BASEL AREA. SWISS

IBAN

Kantonsspital Aarau

international

Complexity in CMF Surgery

MEDICAL ADDITIVE MANUFACTURING

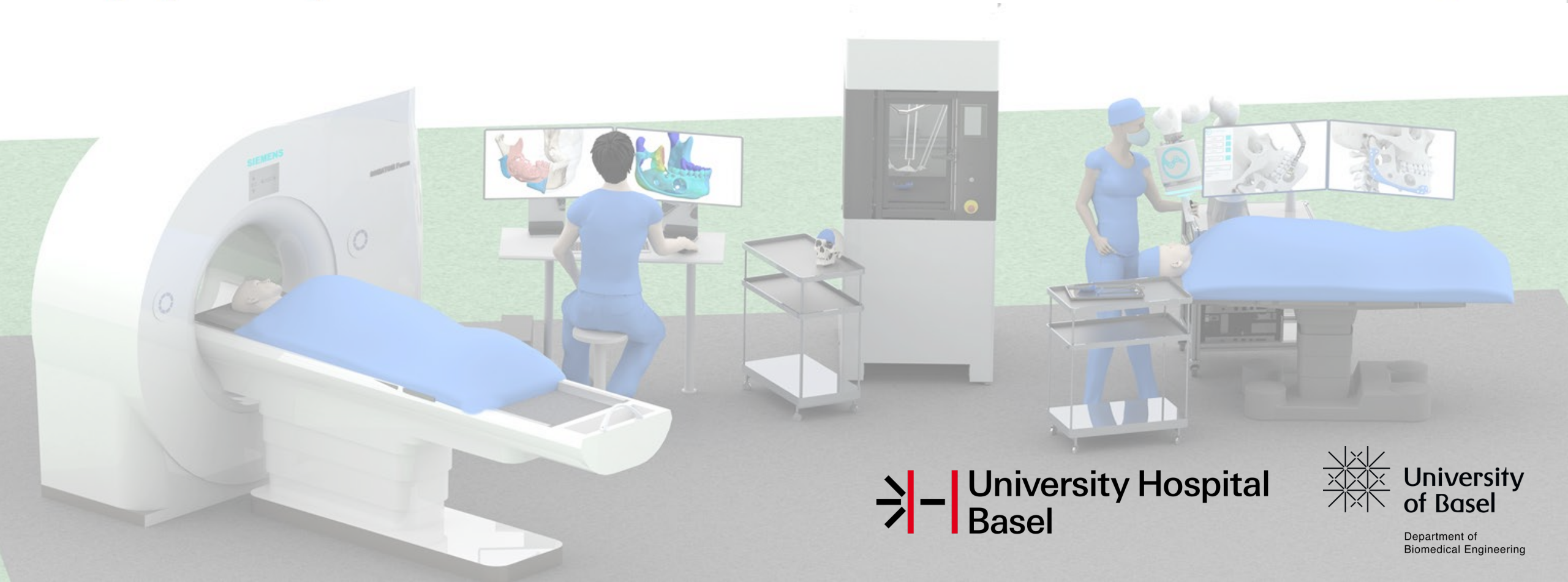
- Personalized Implants
- Personalized Tools
- Intraoperative Guidance
- Predictive Planning
- Virtual Surgical Planning

Need for 3D Printing

Digital Workflow in Cranio-Maxillo-Facial Surgery

AI-based diagnostics Implant design 3D-printing / TE Navigation

Imaging Segmentation VR/AR/MR Biomaterials Robotics / Laser PROM

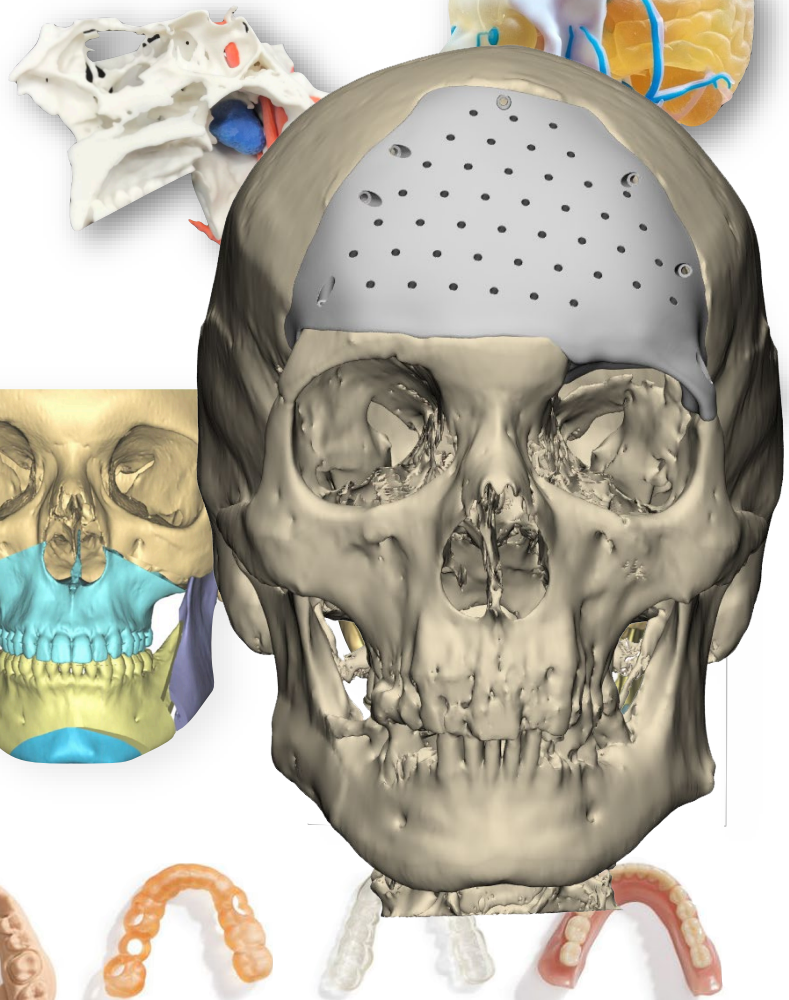
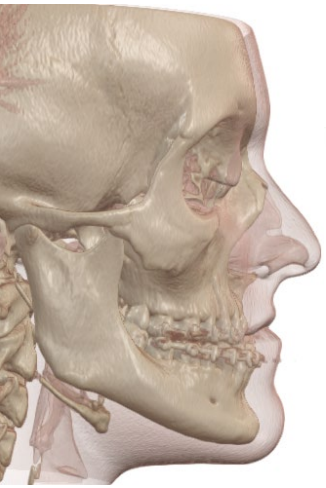
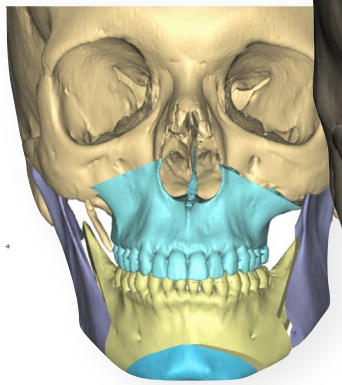


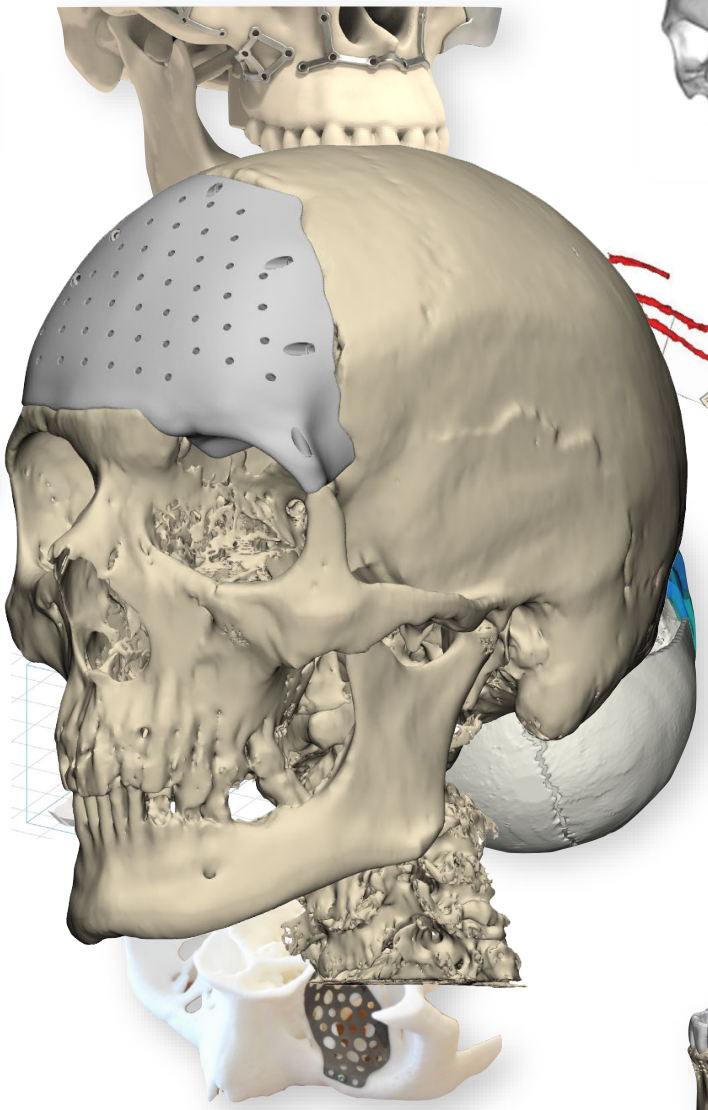
University Hospital Basel

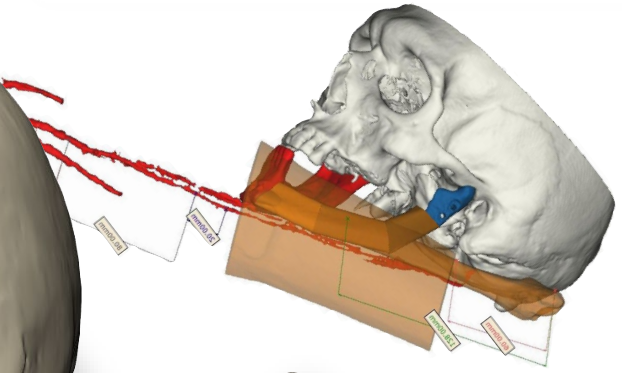
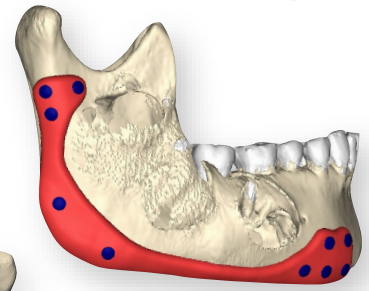
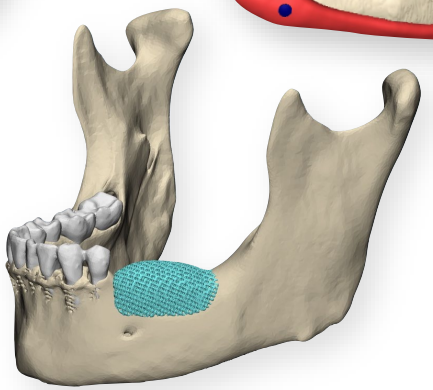
University of Basel

Department of Biomedical Engineering

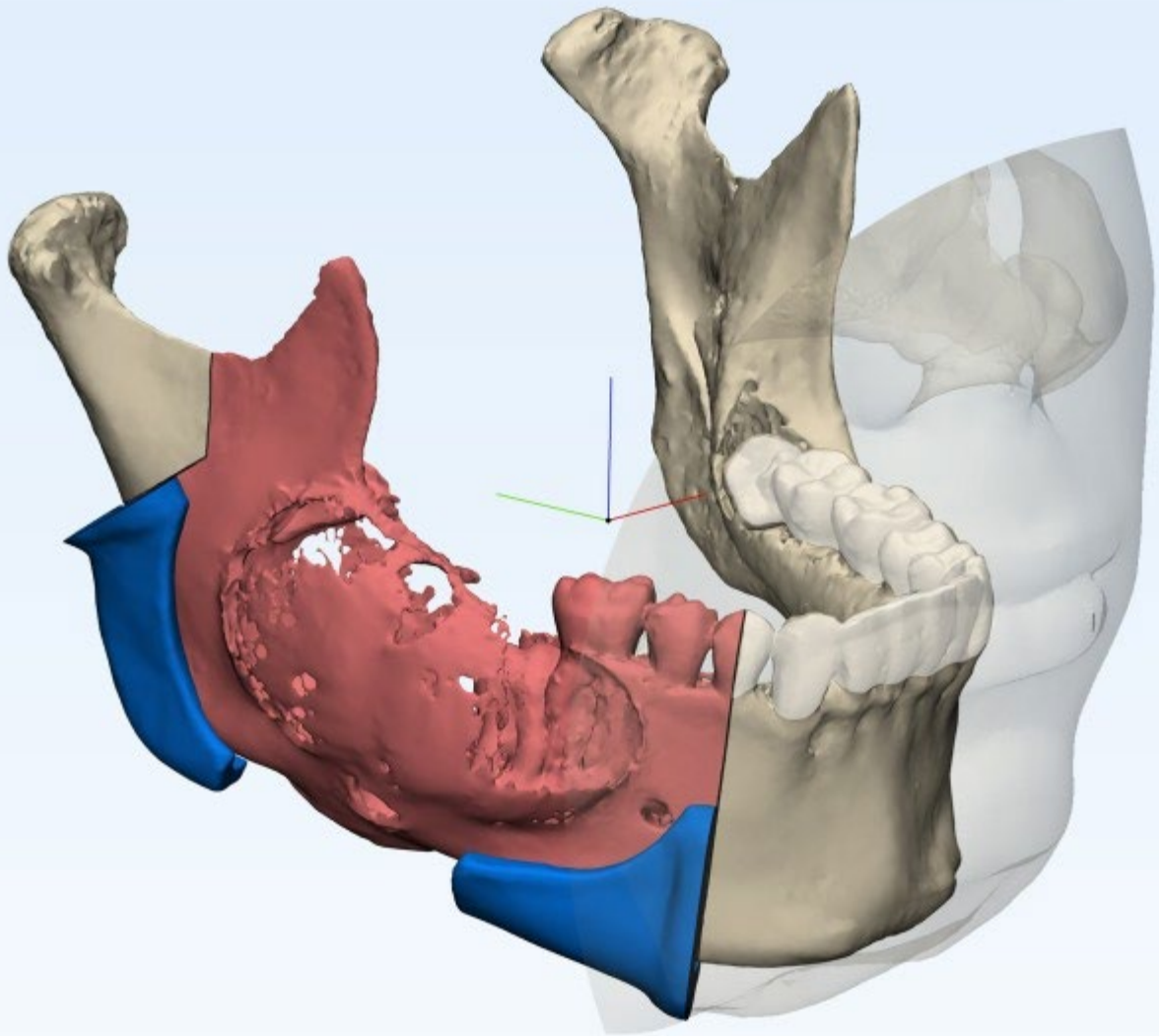
Applications in CMF Surgery



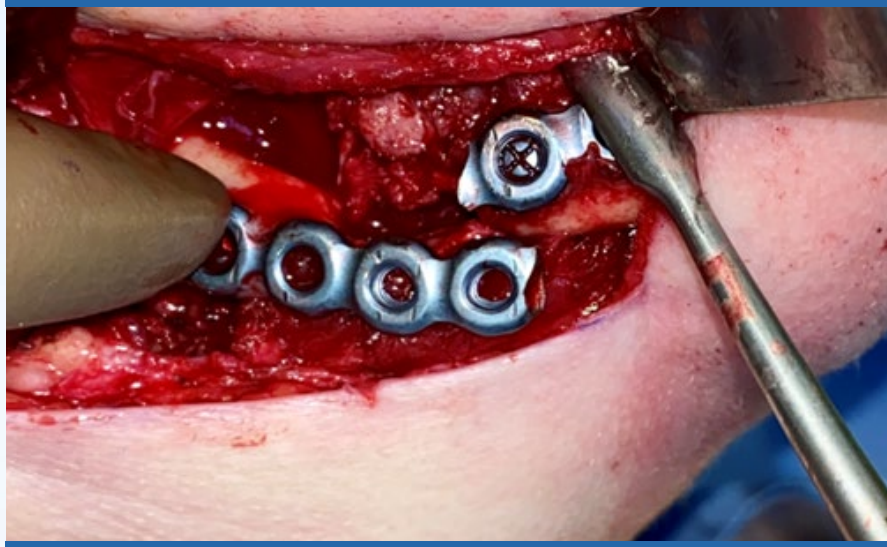






Innovation
invites new perspectives
Focus



Mandibular tumor / reconstruction

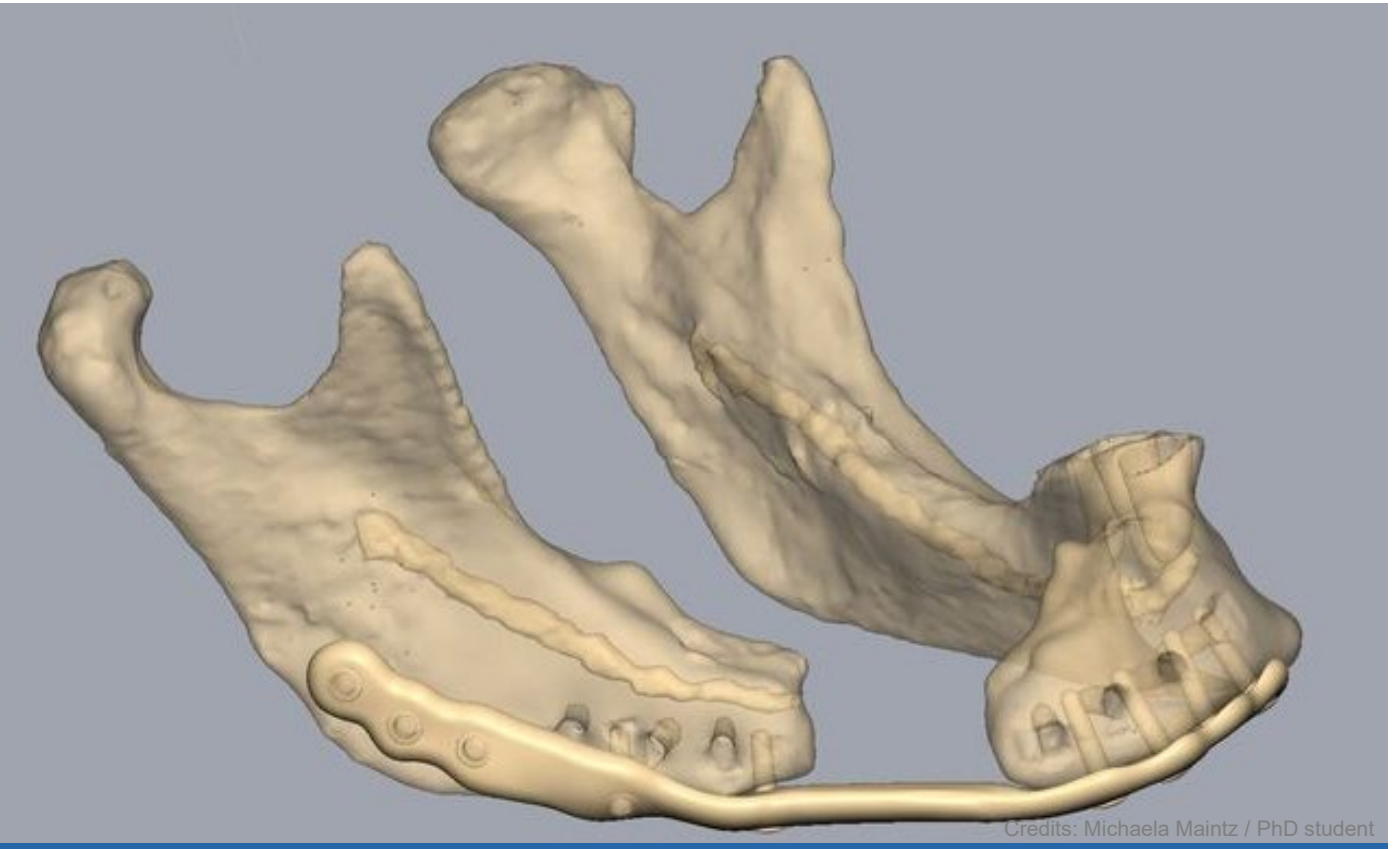
Standard recon plate



Recon plate fracture

Customized 3DP Titanium Implant

MEDICAL ADDITIVE MANUFACTURING



CAD customized implant

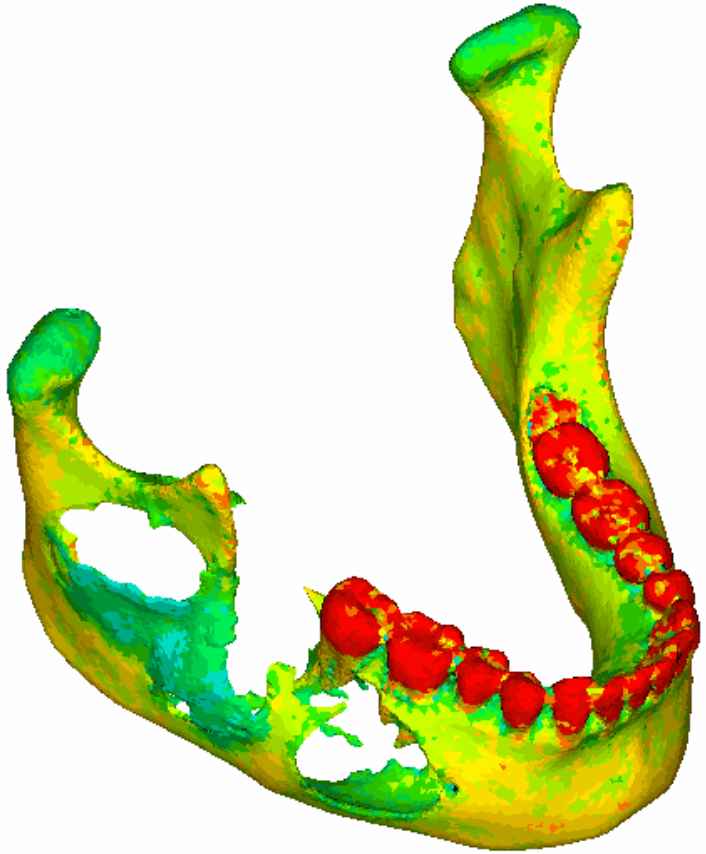
3D printed customized Titanium implant

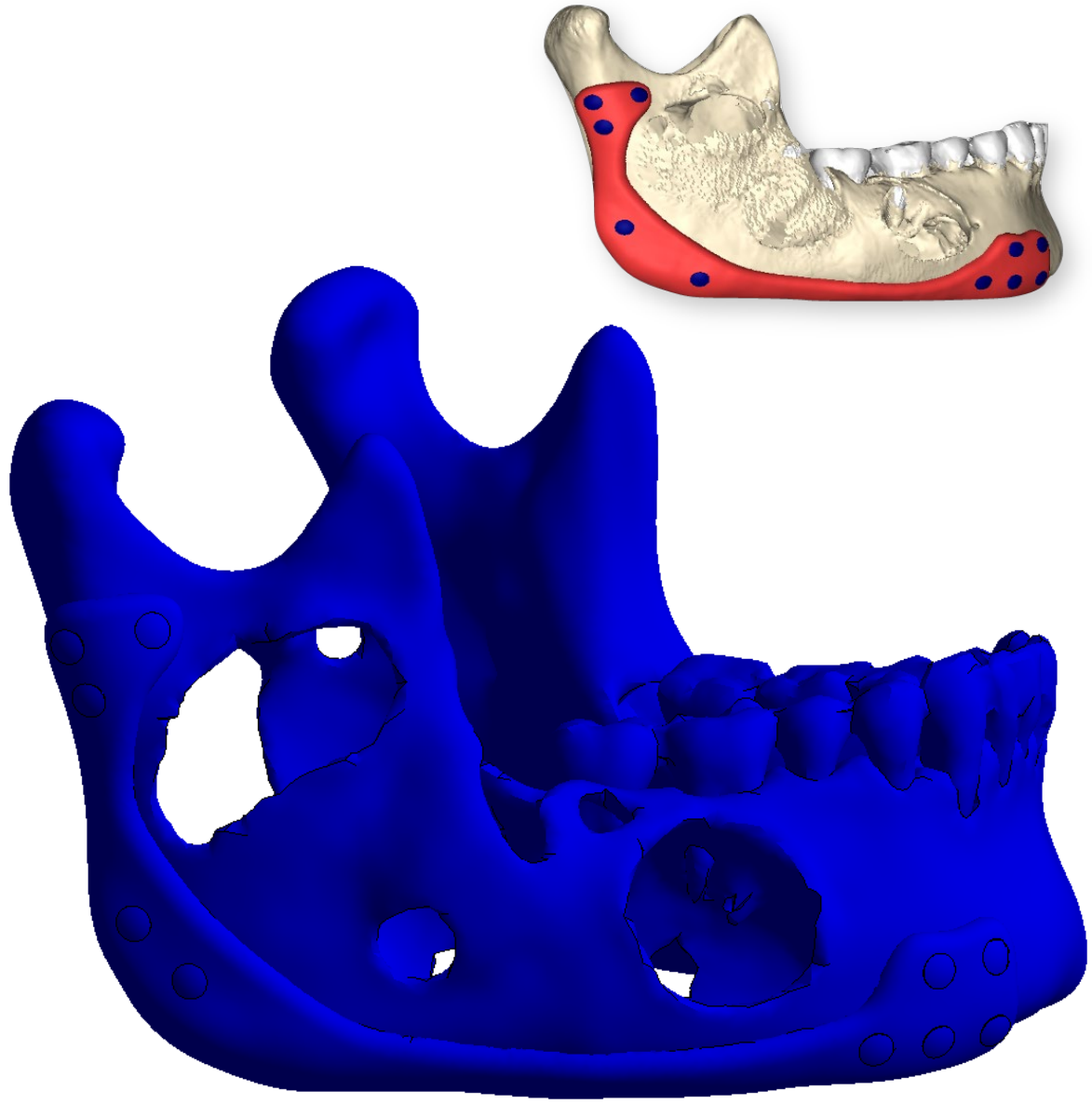
- In collaboration with the University of Applied Sciences / FHNW (Daniel Seiler).

Customized Reconstruction Plates

MEDICAL ADDITIVE MANUFACTURING

FEA HU- Based Material Property Acquisition





Credits: Michaela Maintz / DBE

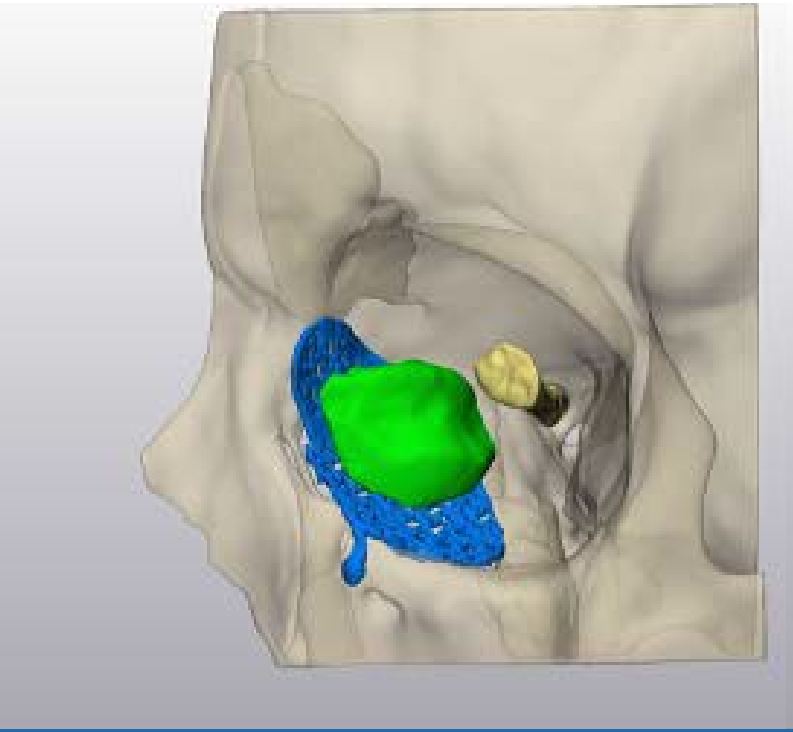
- In collaboration with the University of Applied Sciences / FHNW (Daniel Seiler).

MEDICAL ADDITIVE MANUFACTURING

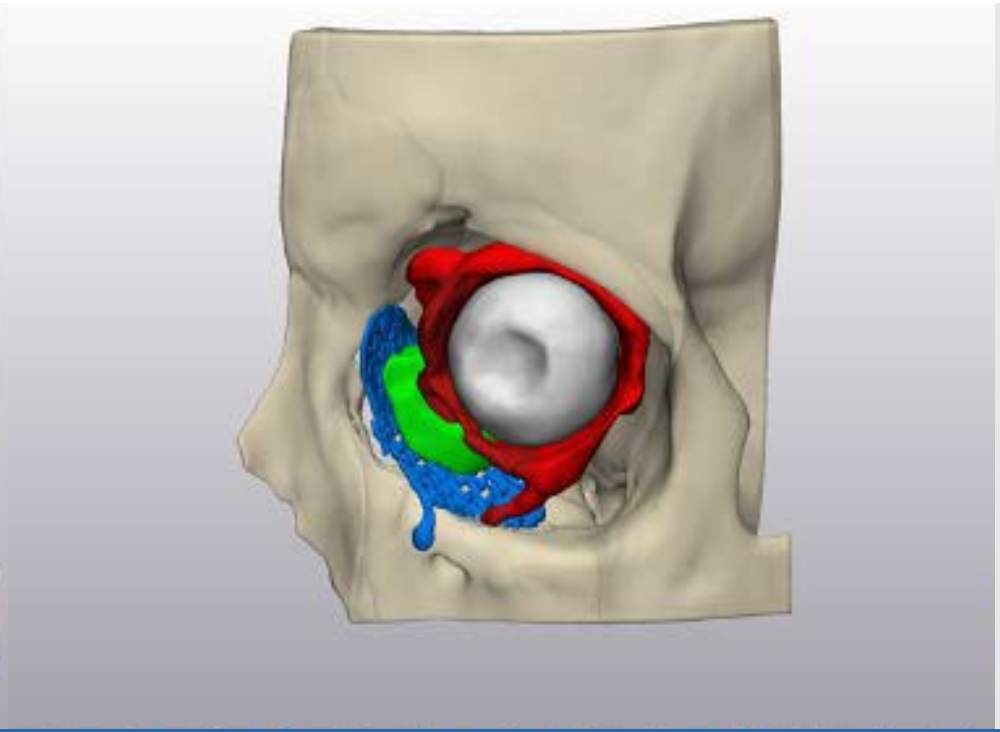
3D Printed Ti Implant

VSP & Customized Implants

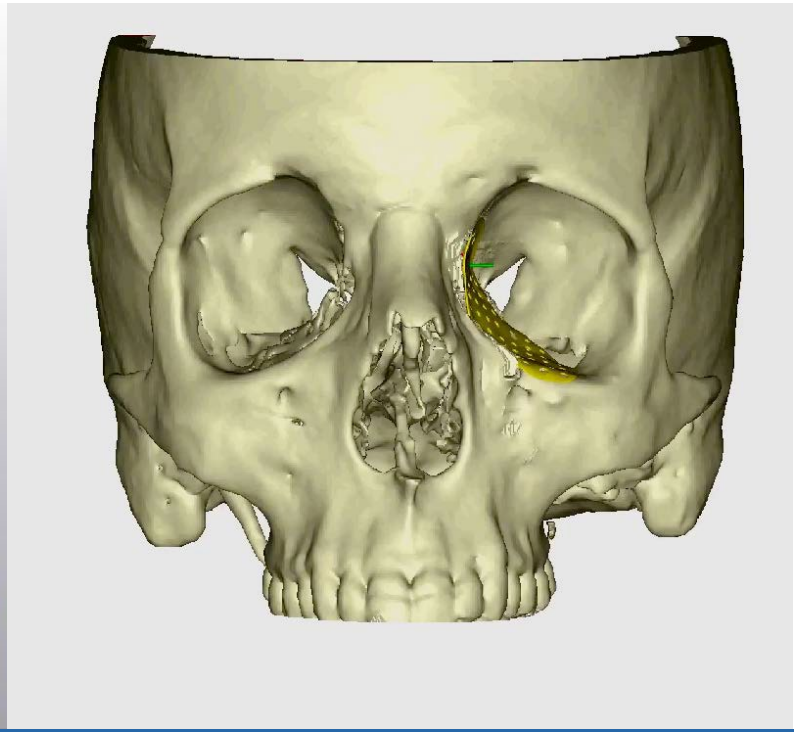
MEDICAL ADDITIVE MANUFACTURING



Mucocele impregnating Standard Ti. Orbital implant



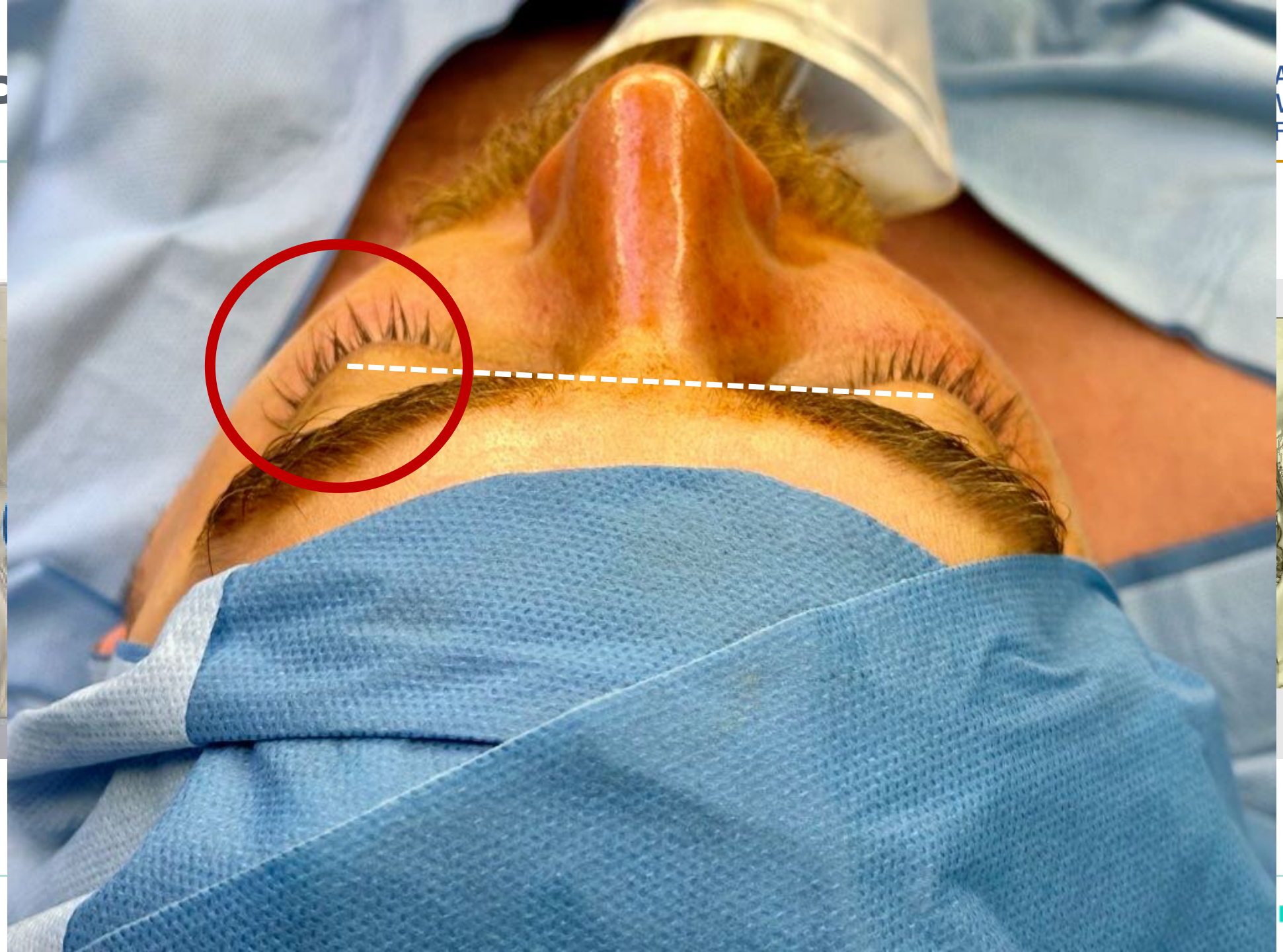
Protrusion of the eyeball



Reconstruction with 3DP customized Ti. implant

VSP

AL
VE
FACTURING



rabiles

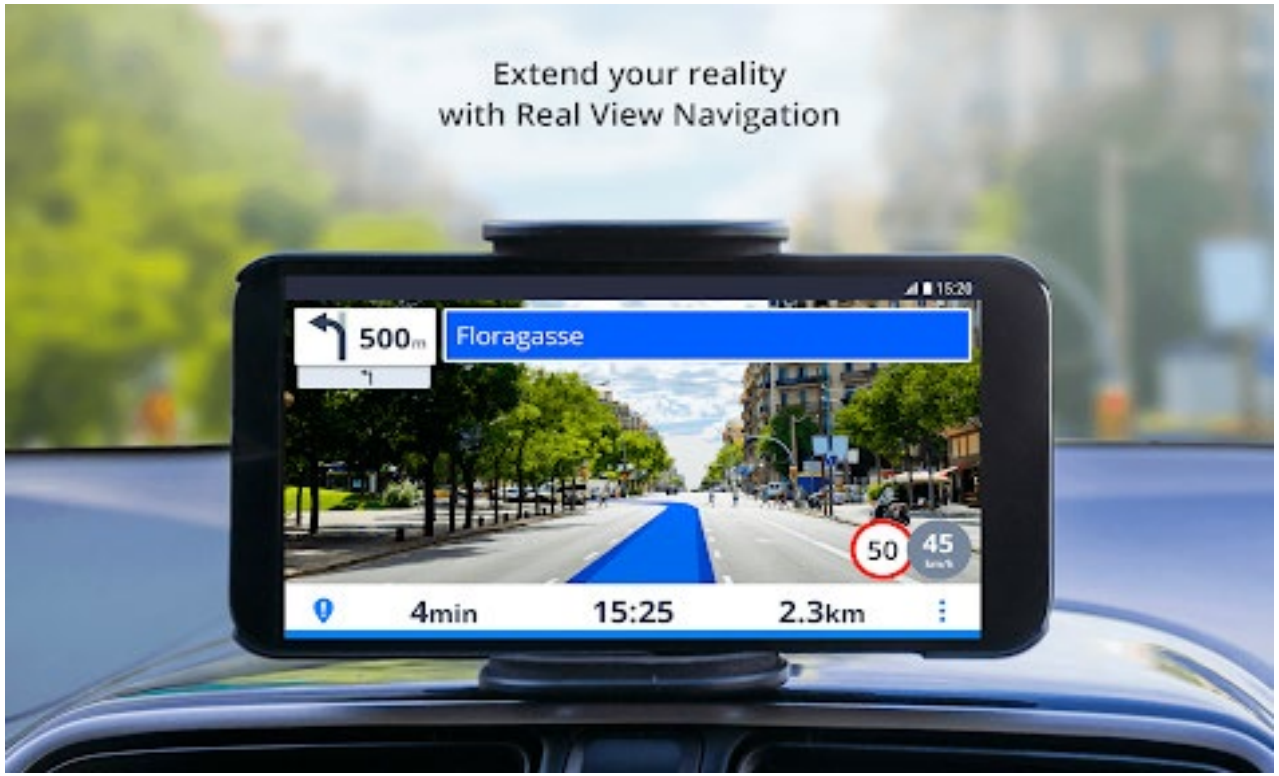
VSI

AL
VE
FACTURING

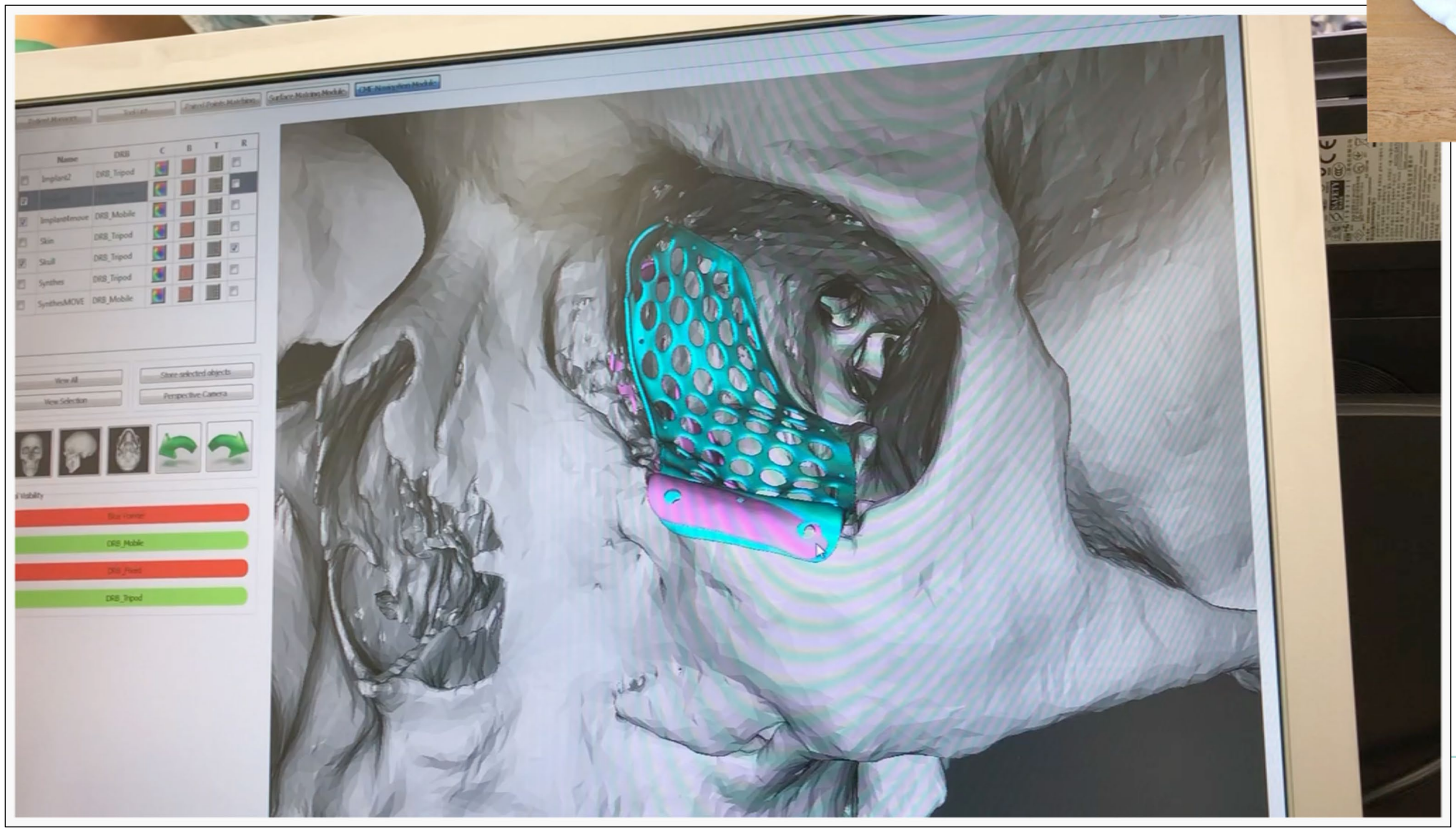
rabiles

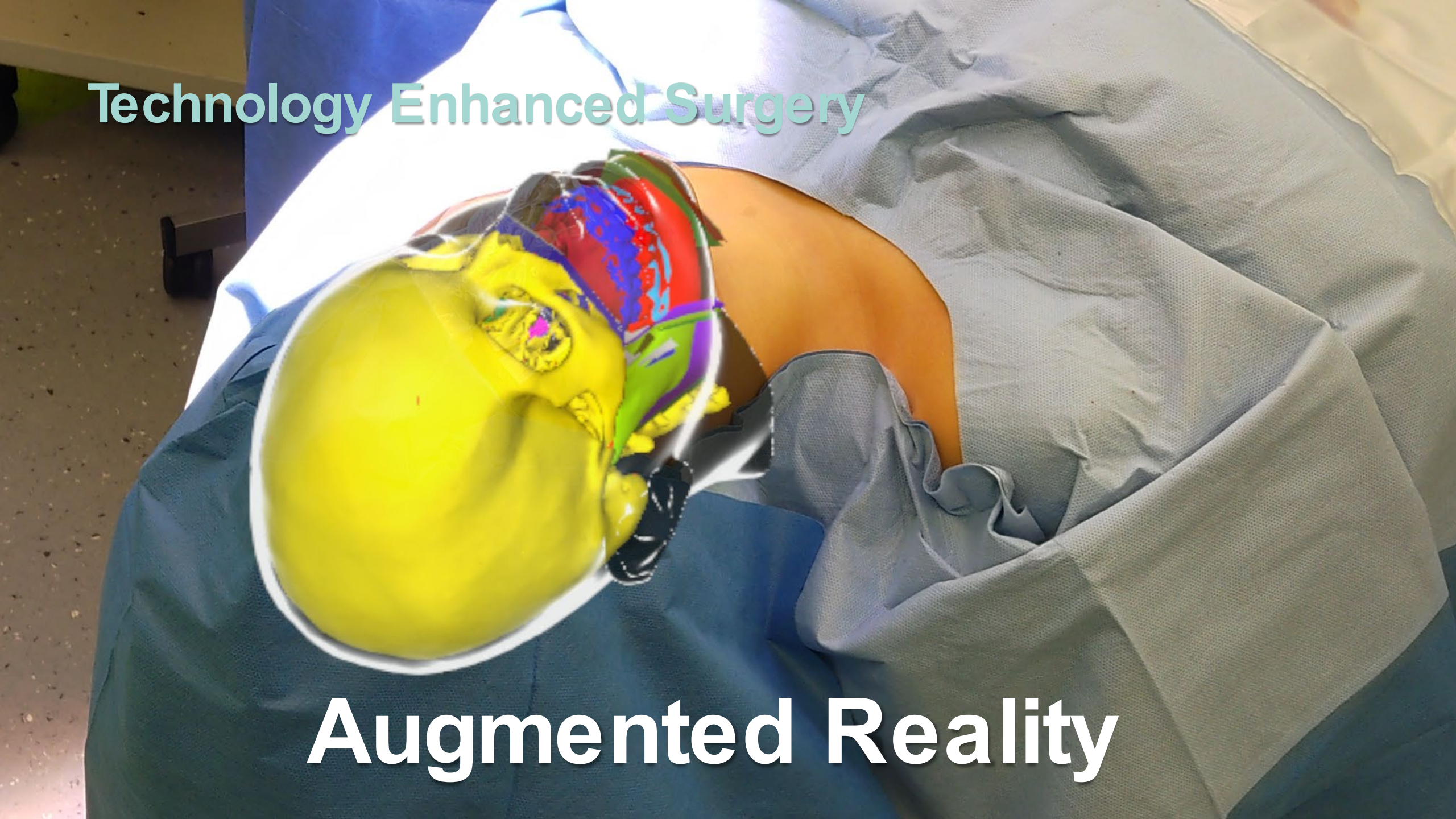
Realtime Navigation Assisted Surgery

MEDICAL ADDITIVE MANUFACTURING



3D Printed customized orbital implant (Ti)

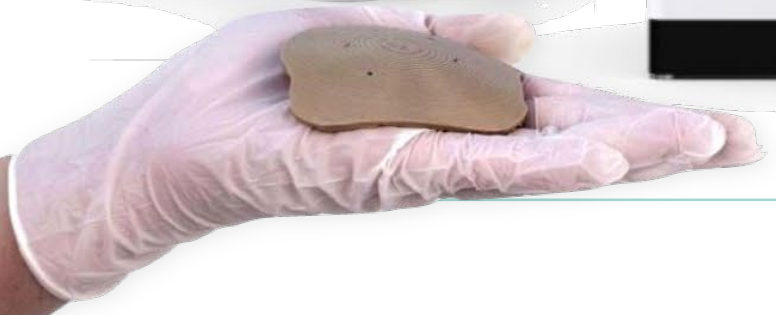


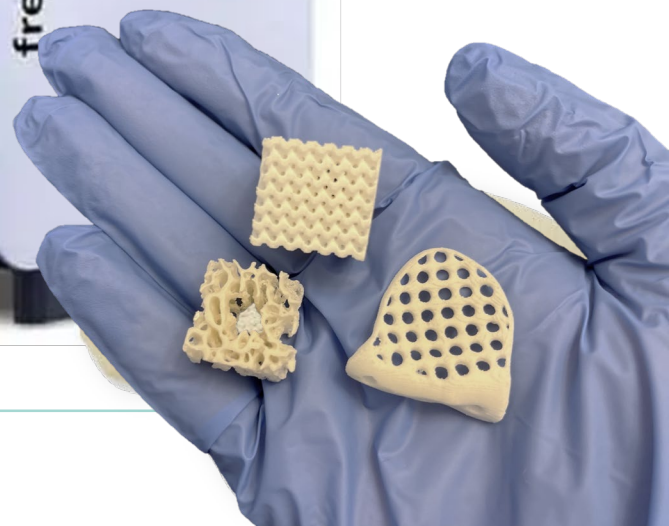

Technology Enhanced Surgery
Augmented Reality

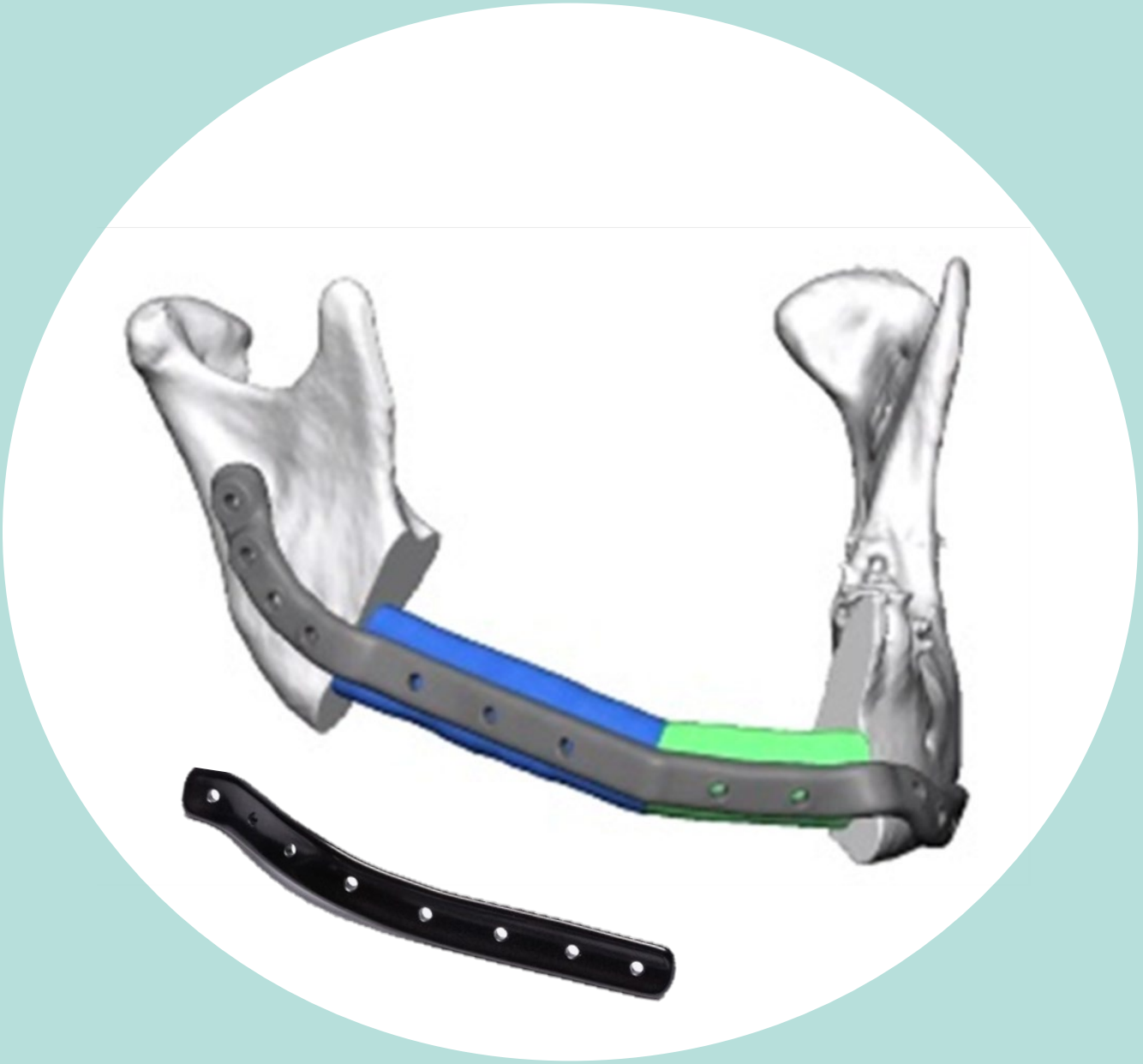
SMART IMPLANTS / PEEK / PEKK / BIO-RESORBABLE POLYMERS

MEDICAL ADDITIVE MANUFACTURING

Source: Ryortho.com

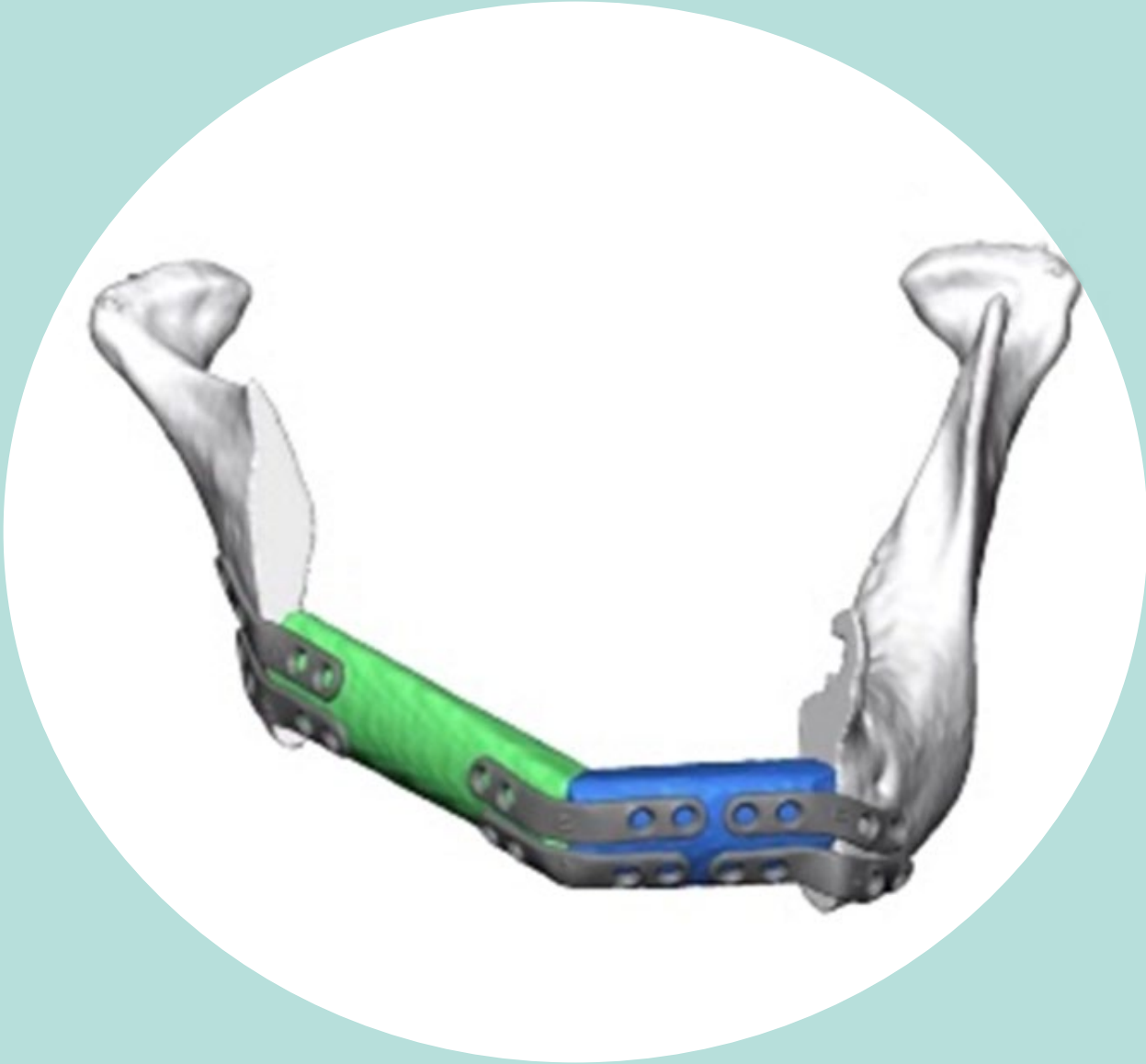


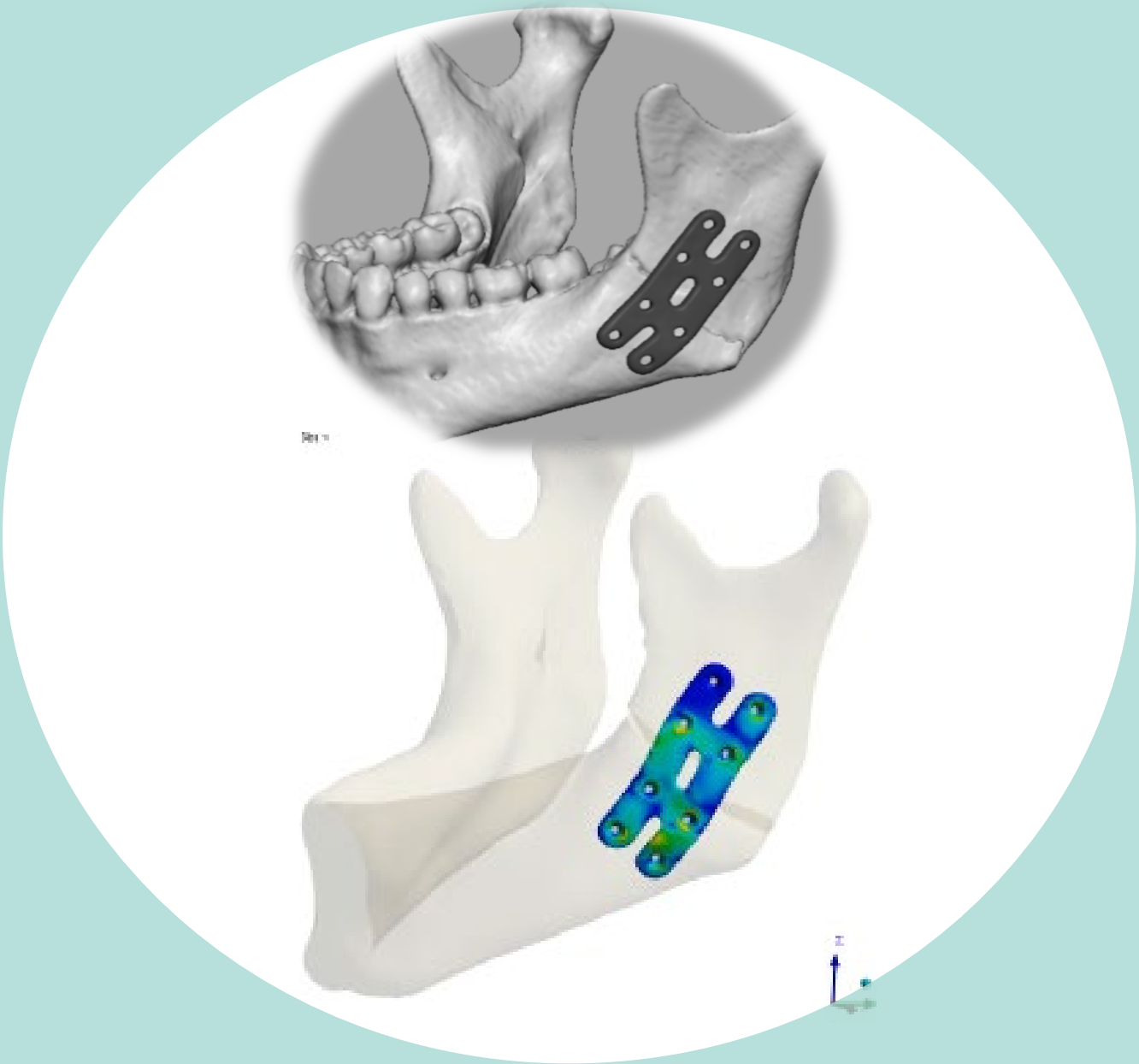




Personalized 3D Printed Carbon-reinforced PEEK Reconstruction Plate Solution

Personalized 3D Printed Carbon-reinforced PEEK Mini-plates Solution





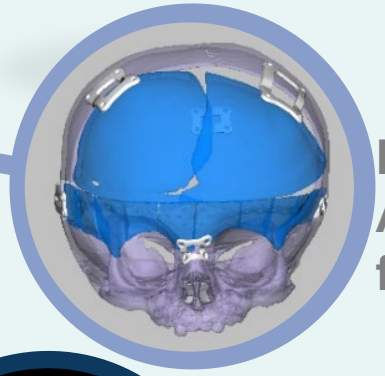
Personalized 3D Printed Carbon-reinforced PEEK Osteosynthesis Solution

University Hospital Basel

MEDICAL ADDITIVE MANUFACTURING

Application potential

Orbital Reconstruction

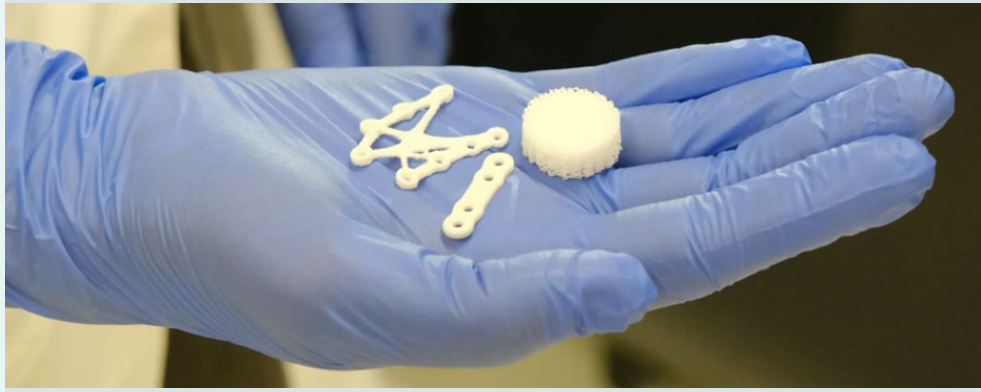


Fronto- Orbital Advancement fixation plates

Alveolar Ridge Reconstruction and Bone Grafts

Bone Plates for Fractures

Corrective Wedge Osteotomies for Distal Radius



Personalized Bioresorbable Implant solutions

- Maintz et al. Patient-Specific Implants Made of 3D Printed Bioresorbable Polymers at the Point of Care: Material, Technology, and Scope of Surgical Application (manuscript accepted)).

Advanced Osteotomy tools & Robotics

University Hospital Basel

NO SPLINTS / NO GUIDES!

University of Basel

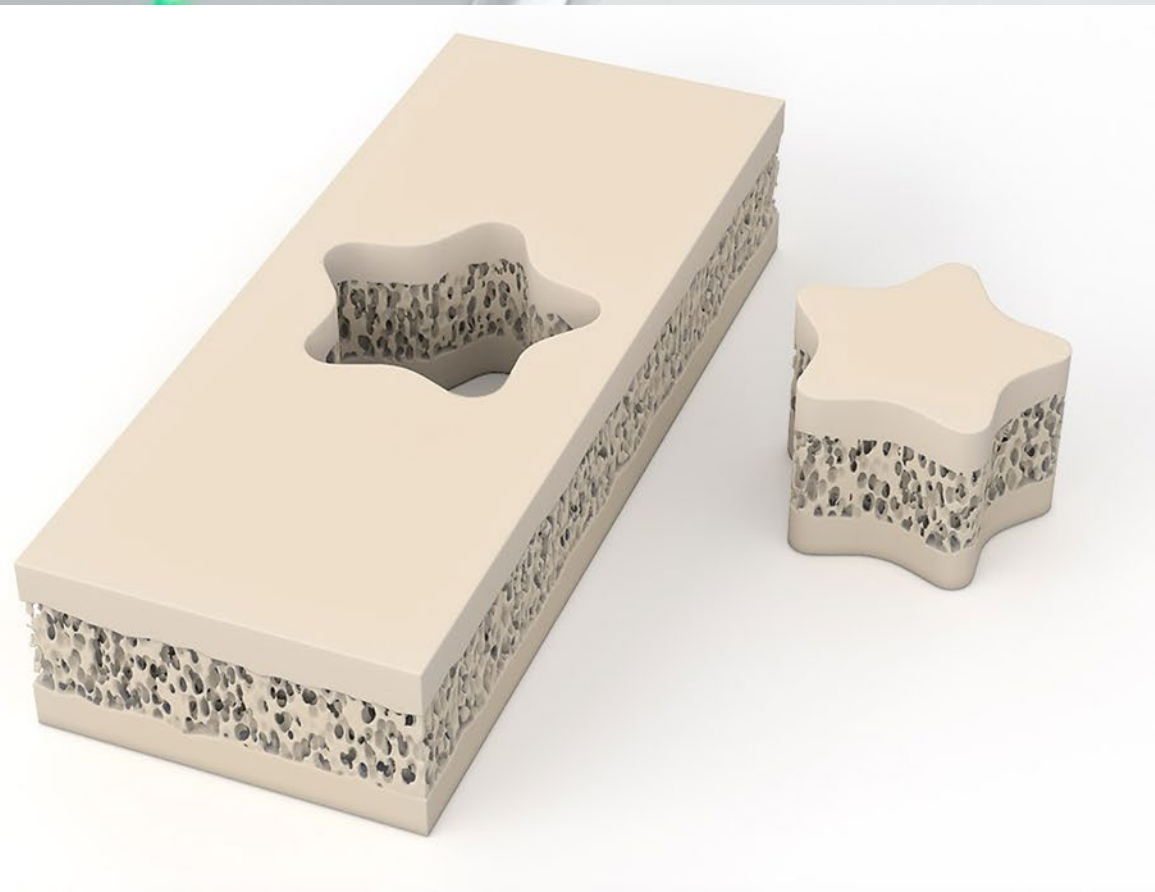
Department of Biomedical Engineering

AOT

Advanced Osteotomy Tools

Advanced Osteotomy tools & Robotics

University Hospital Basel



University of Basel

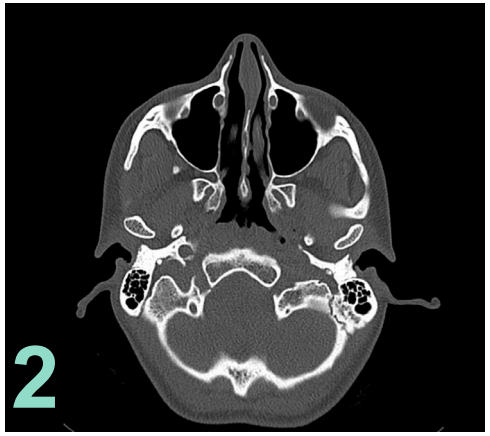
Department of Biomedical Engineering

AOT

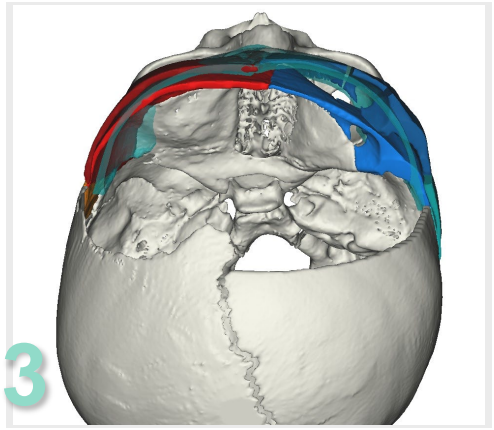
Advanced Osteotomy Tools

Digital FOA workflow (Basel)

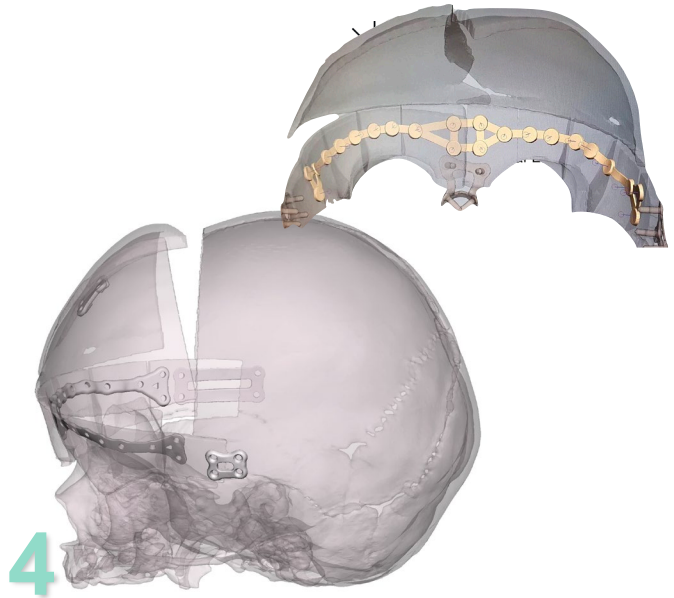
Imaging – CT



Segmentation

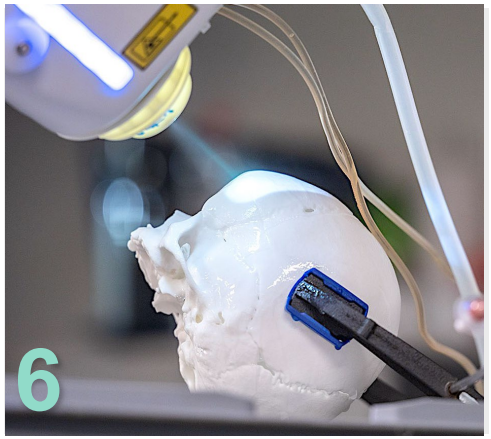


Virtual Surgical Planning



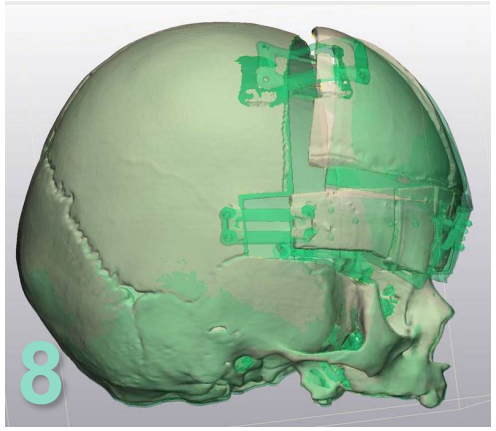
3D Backward-Planning Implants

3D Printing of patient-specific osteosynthesis plates (Poly(L-lactide-co-D,L-lactide))



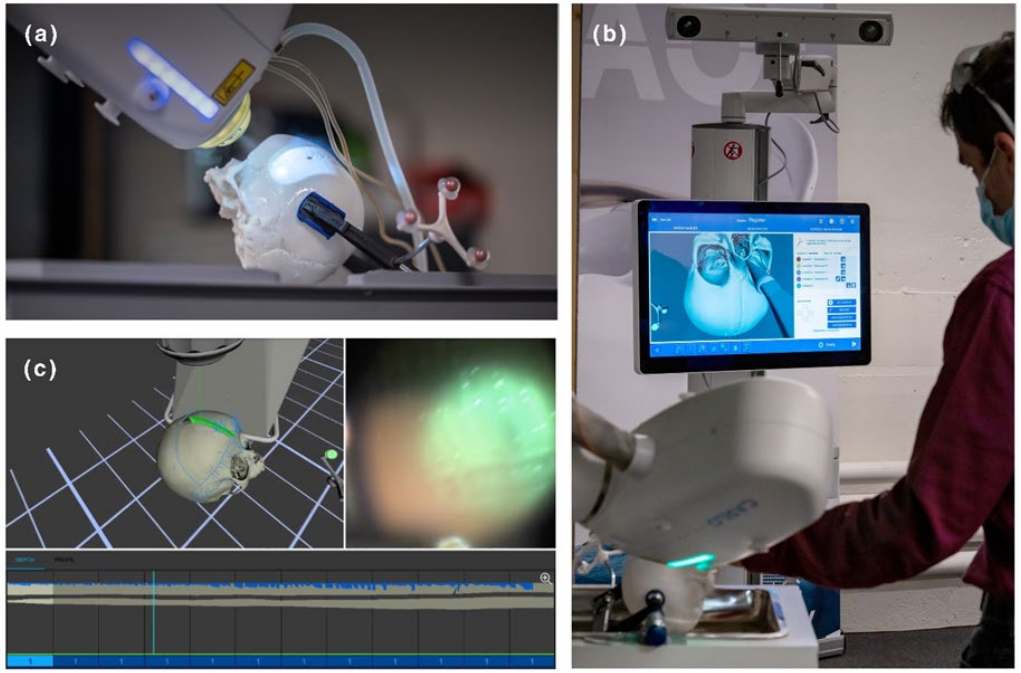
Robotic laser surgery (CARLO)

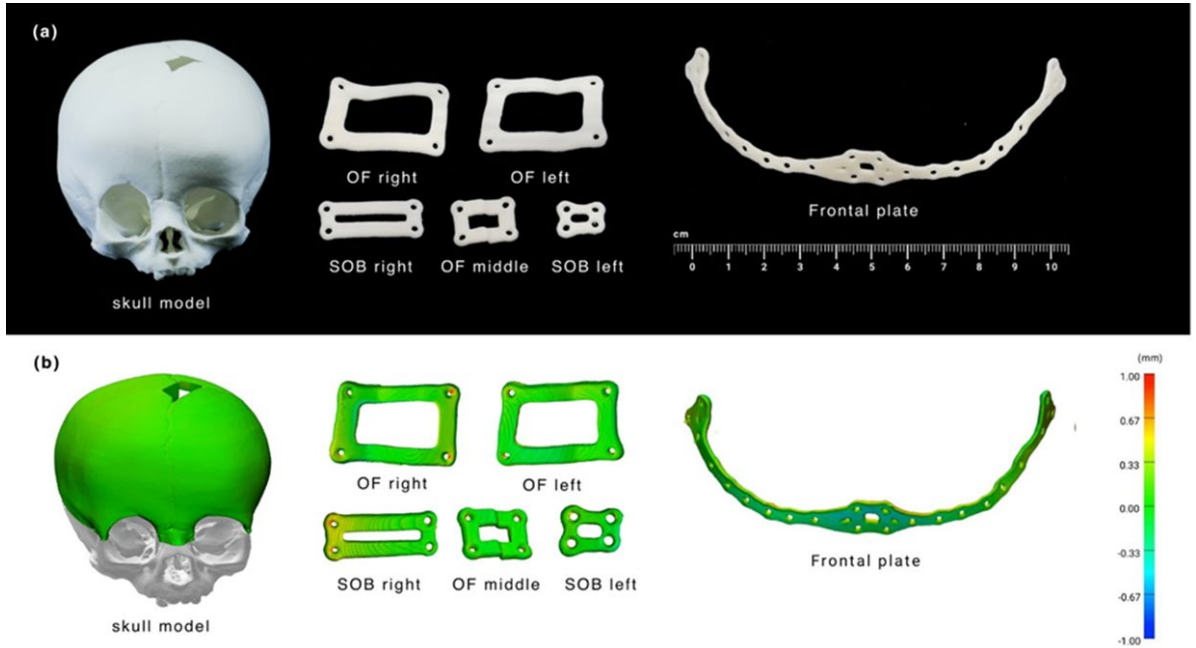
“Guided“ Osteosynthesis with resorbable 3D-printed PSI

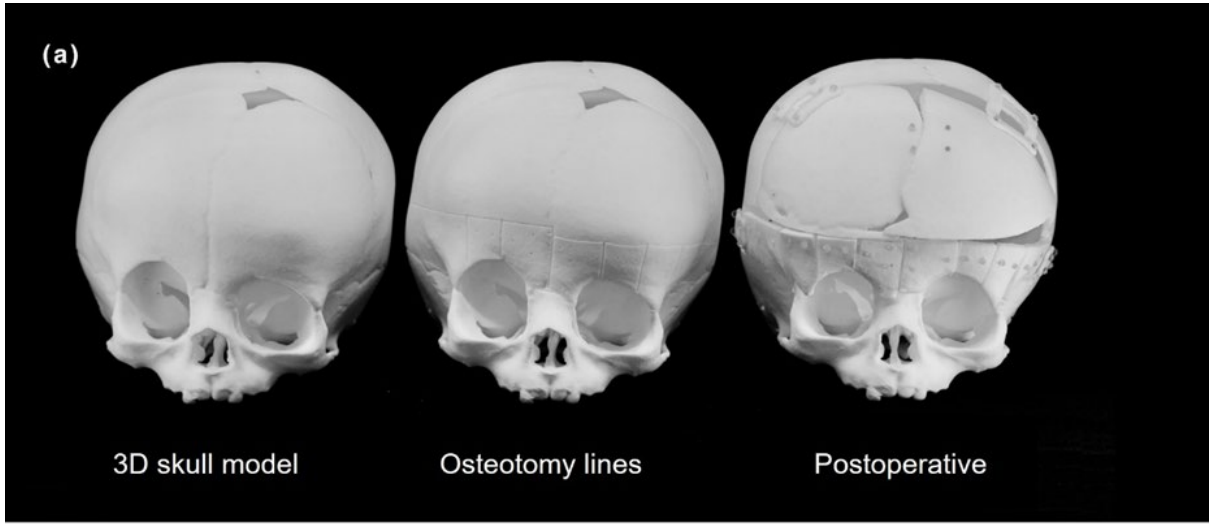


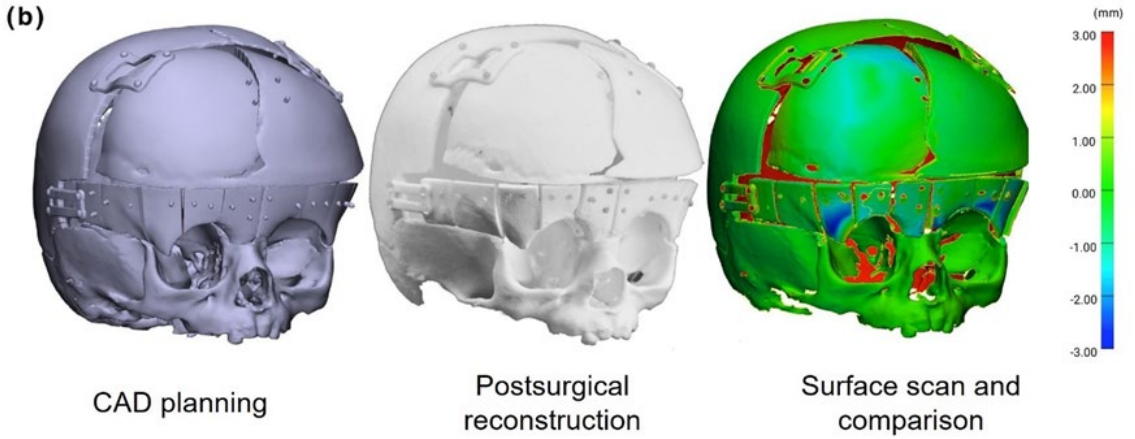
Postoperative 3D surface scan

- Maintz et al. Fronto-orbital advancement with patient-specific 3D-printed implants and robot-guided laser osteotomy – An in vitro accuracy assessment (manuscript under review).





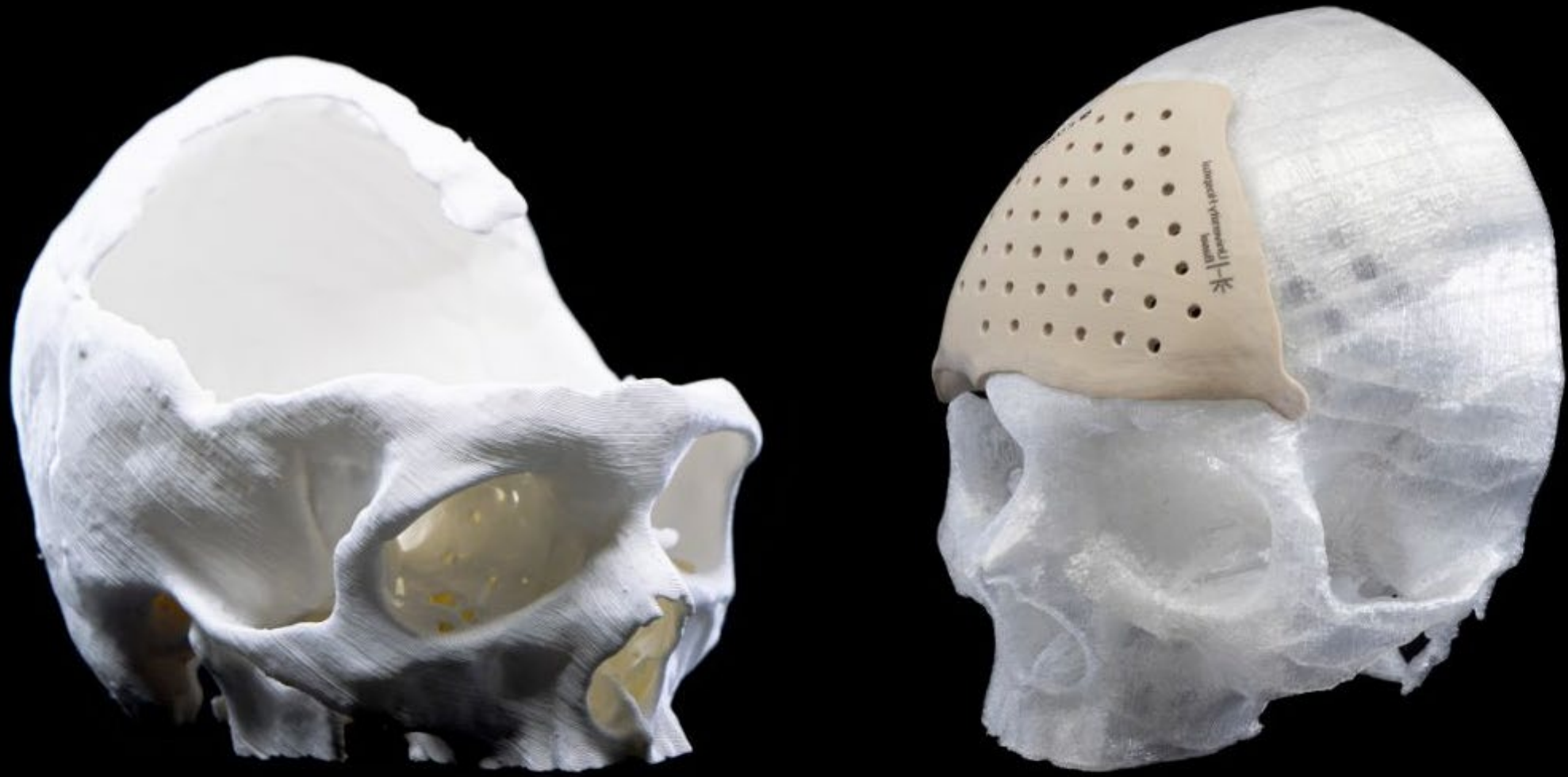




Personalized 3D Printed Bioresorbable Implant Solutions

The next step in personalized medicine

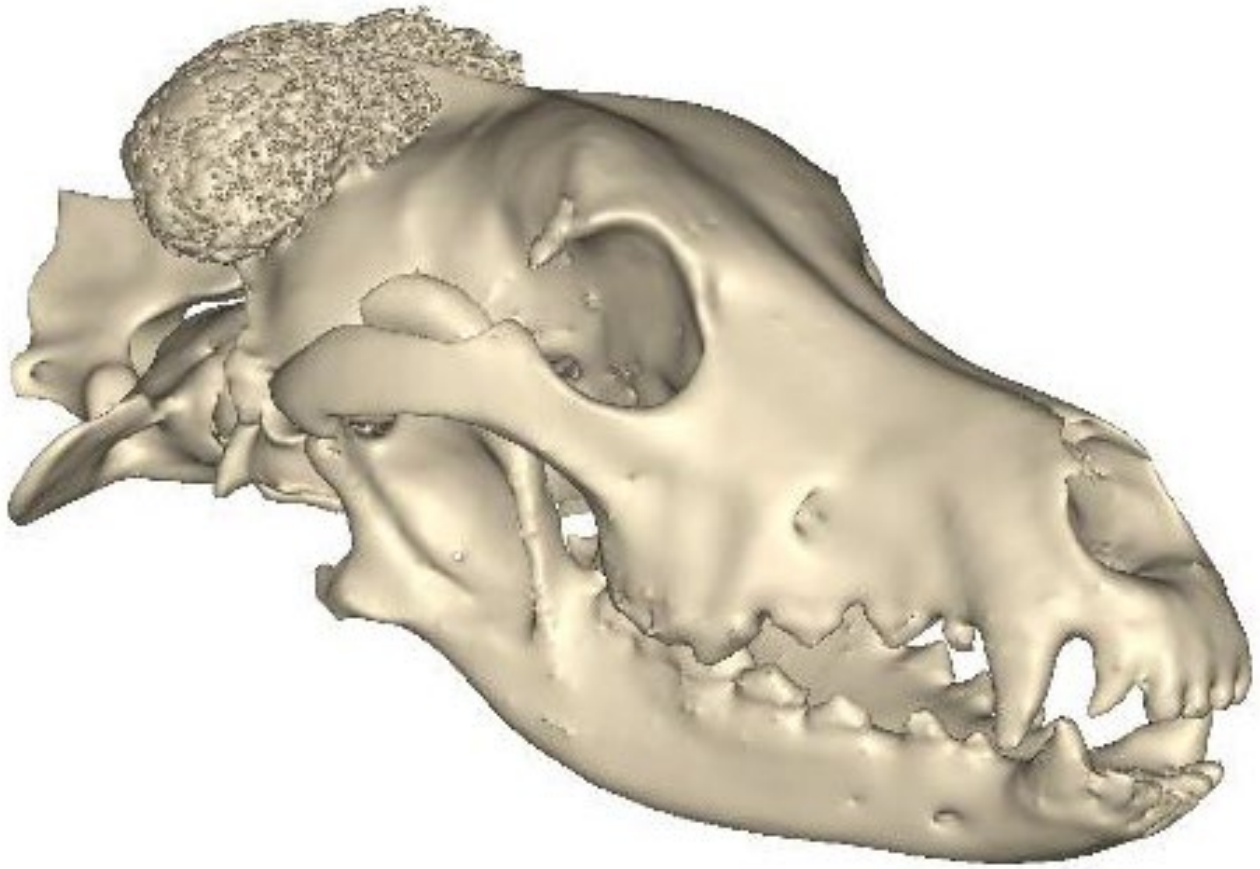
MEDICAL
ADDITIVE
MANUFACTURING



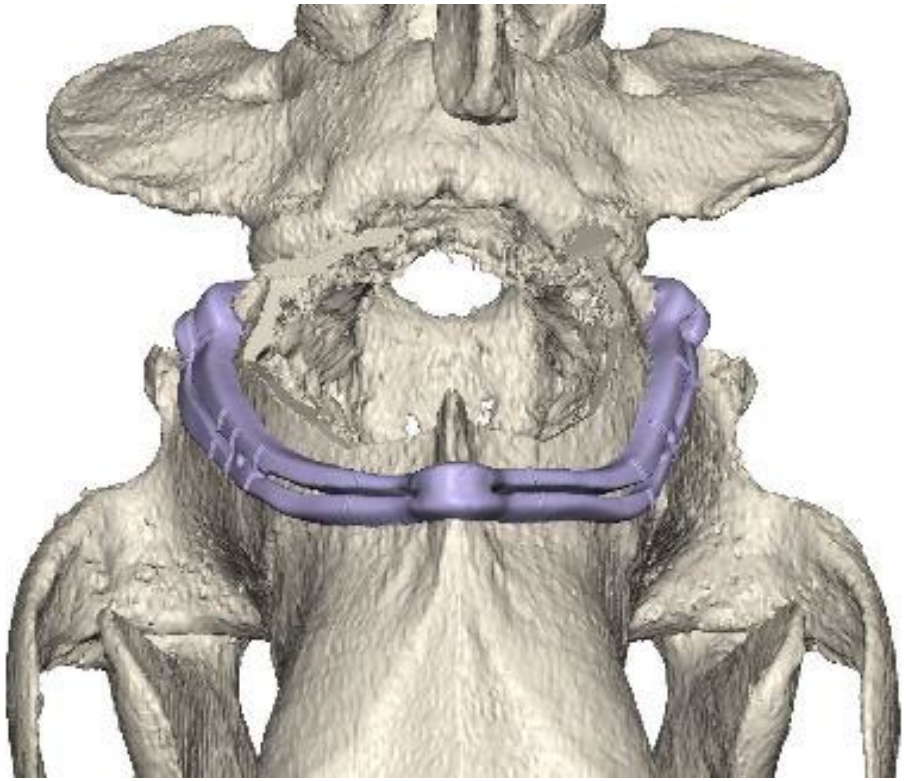
In-house 3D Printed Patient-Matched PEEK Cranial Implants

Canine (Osteosarcoma) – skull tumor

MEDICAL ADDITIVE MANUFACTURING

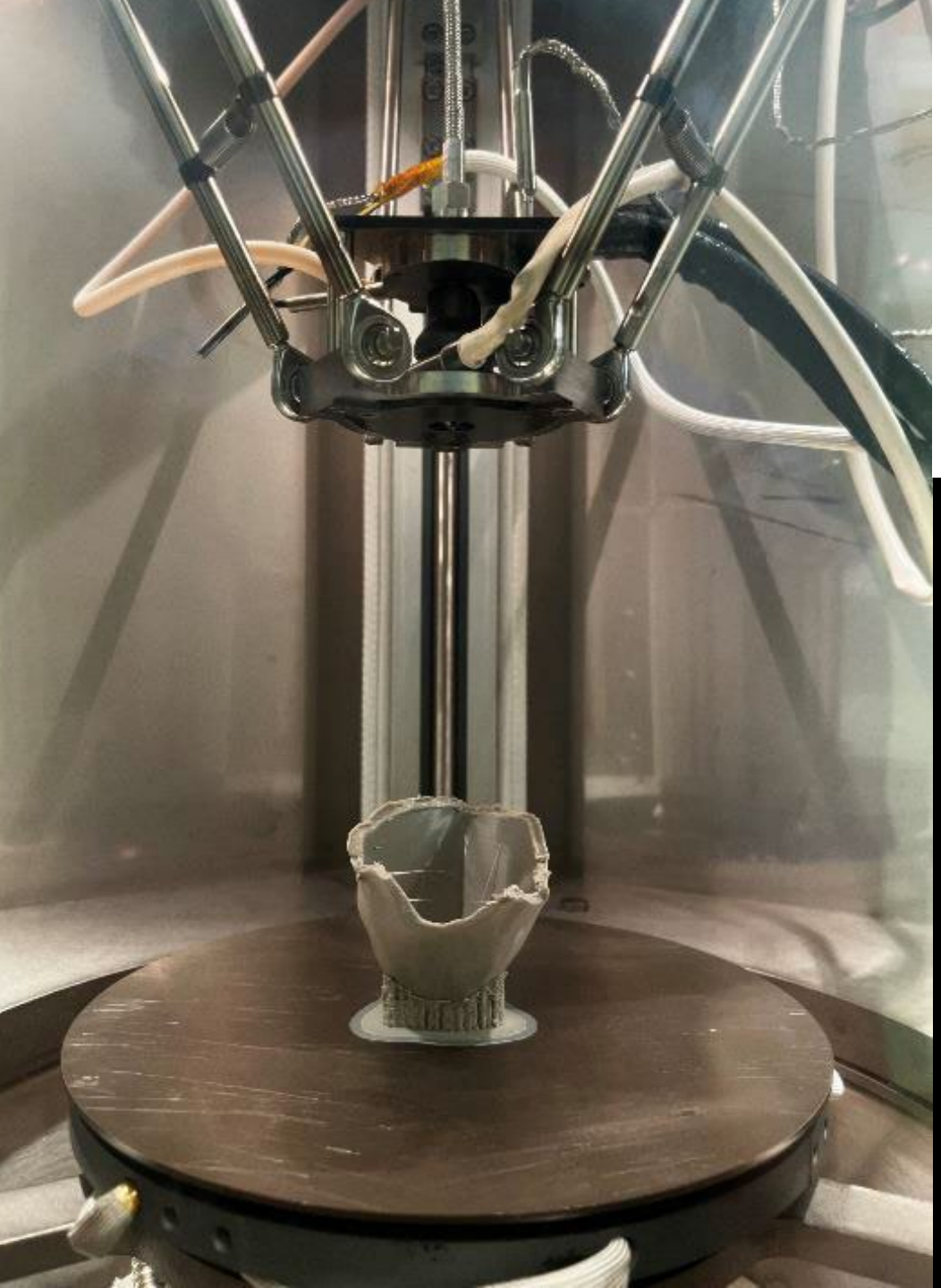


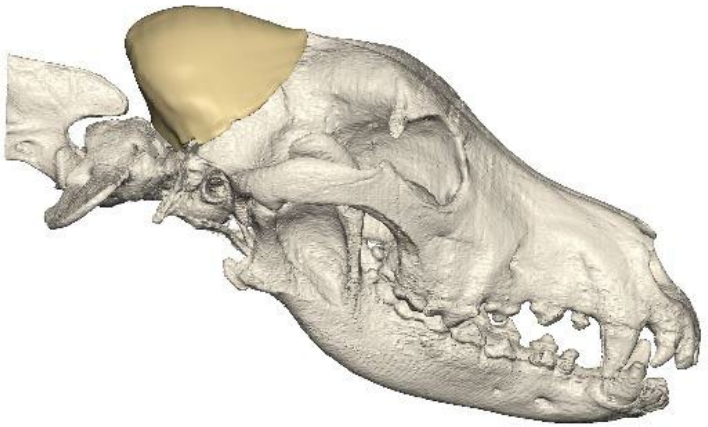
Canine skull tumor



Virtual surgical planning

- In collaboration with Vet hospital, University of Bern (Dr. Julien Guevar) and Kumovis / 3DS





MEDICAL
ADDITIVE
MANUFACTURING

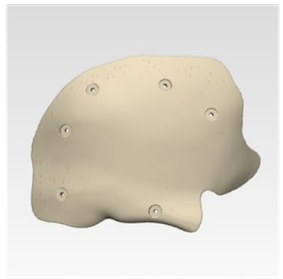
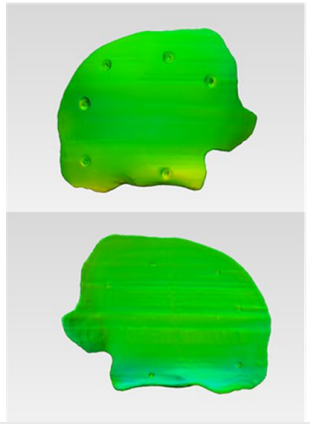
In-house 3D printed PEEK implant

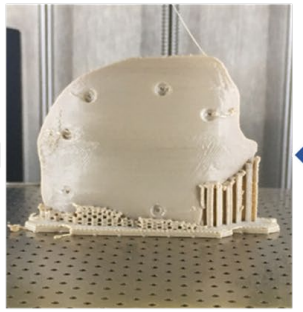
(Credits: J. Guevar)

POC 3DP PEEK Cranial Implant

MEDICAL ADDITIVE MANUFACTURING






- Han X, **Sharma N**, Spintzyk S, Zhou Y, Xu Z, Thieringer FM, Rupp F. Tailoring the biologic responses of 3D printed PEEK medical implants by plasma functionalization. Dental Materials. 2022.
- **Sharma N**, Welker D, Aghlmandi S, Maintz M, Zeilhofer HF, Honigmann P, Seifert T, Thieringer FM. A Multi-Criteria Assessment Strategy for 3D Printed Porous Polyetheretherketone (PEEK) Patient-Specific Implants for Orbital Wall Reconstruction. J Clin Med. 2021 Aug 13;10(16):3563.
- **Sharma N**, Aghlmandi S, Dalcanale F, Seiler D, Zeilhofer HF, Honigmann P, Thieringer FM. Quantitative Assessment of Point-of-Care 3D-Printed Patient-Specific Polyetheretherketone (PEEK) Cranial Implants. Int J Mol Sci. 2021 Aug 7;22(16):8521.
- **Sharma N**, Ostas D, Rotar H, Brantner P, Thieringer FM. Design and Additive Manufacturing of a Biomimetic Customized Cranial Implant Based on Voronoi Diagram. Front Physiol. 2021, 12, 647923.
- **Sharma N*,** Honigmann P*, Schumacher R, Rueegg J, Haefeli M, Thieringer F. In-Hospital 3D Printed Scaphoid Prosthesis Using Medical-Grade Polyetheretherketone (PEEK) Biomaterial. Biomed Res Int. 2021, 2021, 1301028.
- **Sharma N,** Honigmann P, Cao S, Thieringer F. (2020). Dimensional characteristics of FDM 3D printed PEEK implant for craniofacial reconstructions. Transactions on Additive Manufacturing Meets Medicine, 2(1).
- **Sharma N,** Aghlmandi S, Cao S, Kunz C, Honigmann P, Thieringer FM. Quality Characteristics and Clinical Relevance of In-House 3D-Printed Customized Polyetheretherketone (PEEK) Implants for Craniofacial Reconstruction. J Clin Med. 2020 Aug 31;9(9):2818.
- Han X, **Sharma N**, Xu Z, Scheideler L, Geis-Gerstorfer J, Rupp F, Thieringer FM, Spintzyk S. An In Vitro Study of Osteoblast Response on Fused-Filament Fabrication 3D Printed PEEK for Dental and Cranio-Maxillofacial Implants. J Clin Med. 2019 May 31;8(6):771.
- **Sharma N*,** Honigmann P*, Okolo B, Popp U, Msallem B, Thieringer FM. Patient-Specific Surgical Implants Made of 3D Printed PEEK: Material, Technology, and Scope of Surgical Application. Biomed Res Int. 2018 Mar 19;2018:4520636.

MDR Complaint Digital Fabrication Workflow

POC APP

3D SYSTEMS
KUMOVIS


MEDICAL
ADDITIVE
MANUFACTURING
University Hospital
Basel

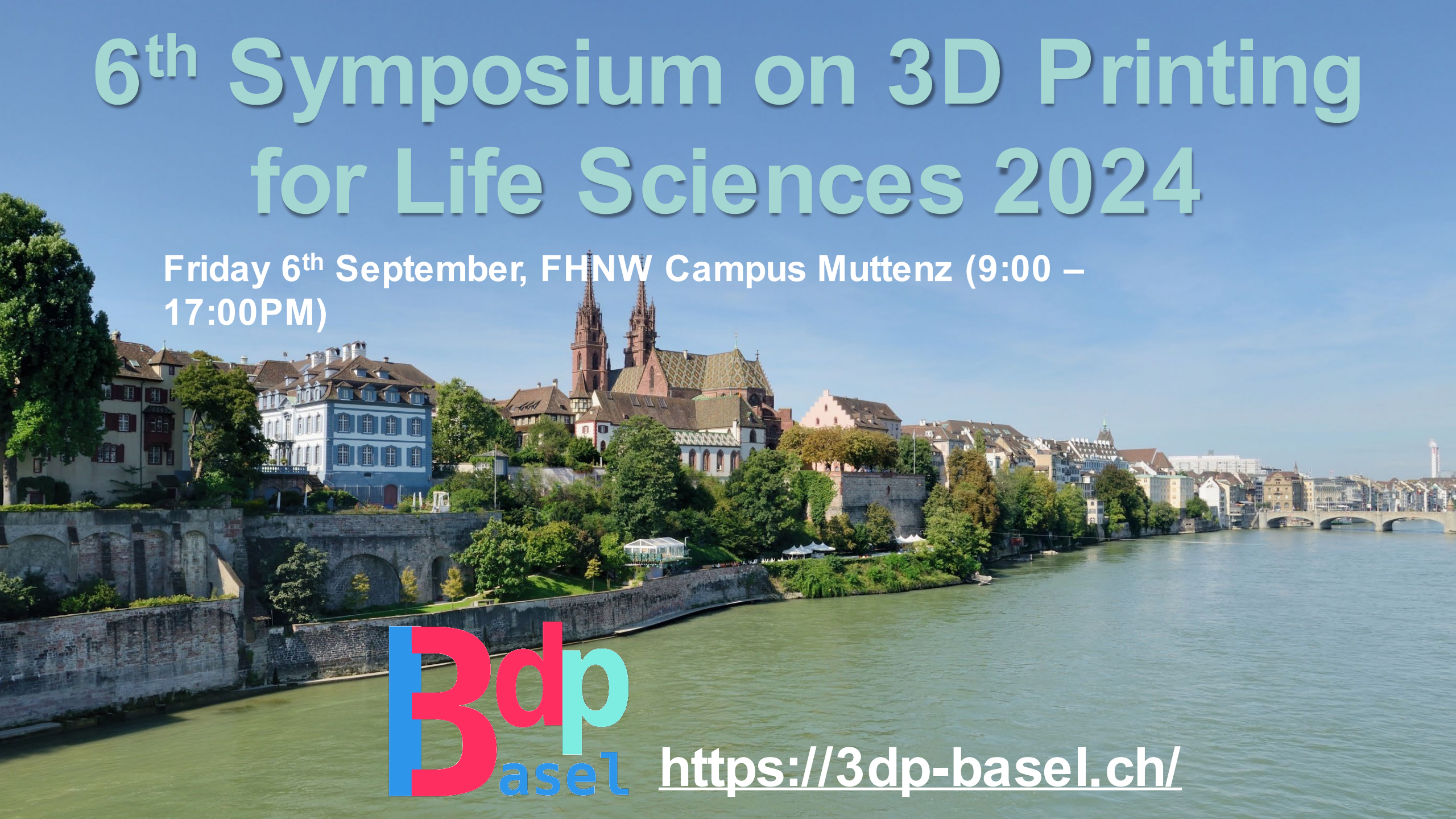
Take-home message

MEDICAL ADDITIVE MANUFACTURING

- **In CMF surgery: Patient-centered, patient-specific approach, interdisciplinarity, excellence in surgery, innovation at the point of care**
- Point of care platforms for technology transfer and innovation translation:
  “From Lab to Fab” > Life Sciences Cluster Basel
- Team of surgeons, radiologists, biomedical engineers and other health professionals
- Capacity building, education & training > skills labs
- Medical 3D printing is a key technology for innovation in cranio-maxillofacial surgery and other medical disciplines
- Evidence reporting – Publications, clinical trials/registries, PROMs, MDR compliance

6th Symposium on 3D Printing for Life Sciences 2024

Friday 6th September, FHNW Campus Muttenz (9:00 – 17:00PM)



https://3dp-basel.ch/

MEDICAL ADDITIVE MANUFACTURING

www.swiss-mam.ch

Neha Sharma, MDS; DMD; PhD

Deputy Head 3D Print Lab / Clinic of Oral and Cranio-Maxillofacial Surgery, University Hospital Basel

Deputy Head Swiss MAM Research Group / Department of Biomedical Engineering, University of Basel

neha.sharma@usb.ch