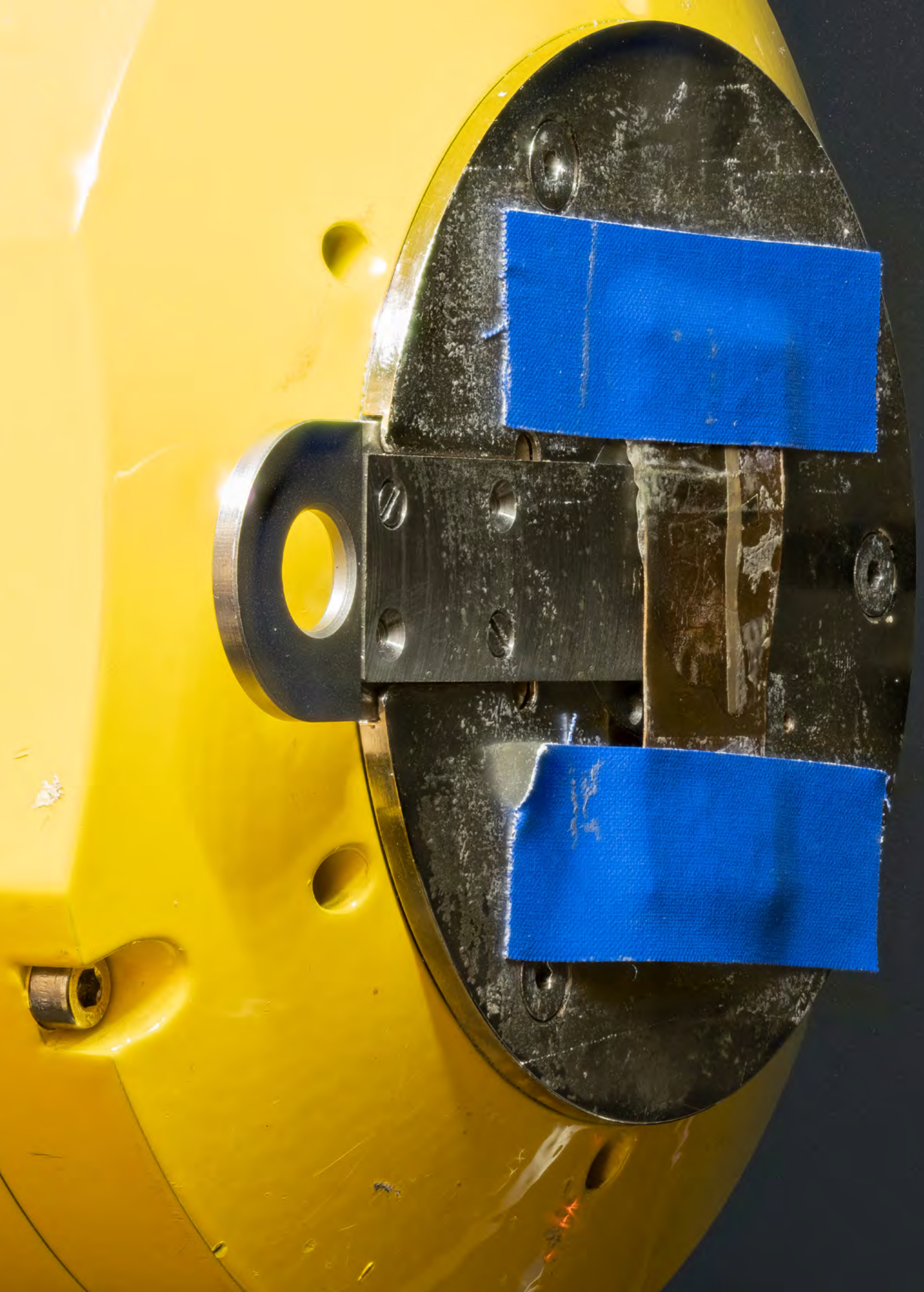
University of Basel

Department of Biomedical Engineering

Department of Biomedical Engineering

Annual Report 2021



Guiding Principles

Our Vision
We contribute to a world where health care needs are met by innovative biomedical research and engineering solutions.

Our Mission
We translate basic science and engineering into medical knowledge and healthcare innovations.
We provide high-quality education and capacity building for academics, clinicians, and industrial partners.

Our Values
We adhere to the Code of Conduct of the University of Basel and promote an interdisciplinary culture of dialog, appreciation, respect, honesty, and tolerance.
We are committed to scientific integrity, reliability, transparency, and good scientific practice.
We value and foster enthusiasm and passion for science

Our Main Goals in Four Fields of Action
1. **Research, Problem solving, Innovation & Translation:** The DBE provides practical innovative biomedical engineering solutions for clinical challenges and covers the whole translation process from bench to bedside by developing and validating clinical applications and supporting approval processes.

2. **Organization, Collaboration & Environment**: The DBE is a multidisciplinary network of research groups and clinicians and combines life sciences with complementary expertise. It is a research department that is embedded in the Medical Faculty, integrated in a clinical environment and part of an ecosystem of med-tech spin-offs, industry, and proximity to pharma and hospitals. In this constellation the DBE is a unique platform in Switzerland and the EU.

3. **Talents & Education:** The DBE's motivated faculty provides excellent education, capacity building, and integrates our interdisciplinary students directly into ongoing research activities.

4. **Finances & Structural Resources:** The DBE is secured by solid structural funding by the University, resp. the Medical Faculty covering the core facilities, research-IT, safety, and administration. To stabilize it in the future, at least one permanent University professorship in every research cluster will be needed. The DBE is an interesting partner for innovative research and able to secure substantial third-party funding exceeding the structural funding approximately three to four times.

The implementation of our mission relies on the support of our founding institutions:

University of Basel
Universitätsspital Basel
UKBB kompetent & menschlich

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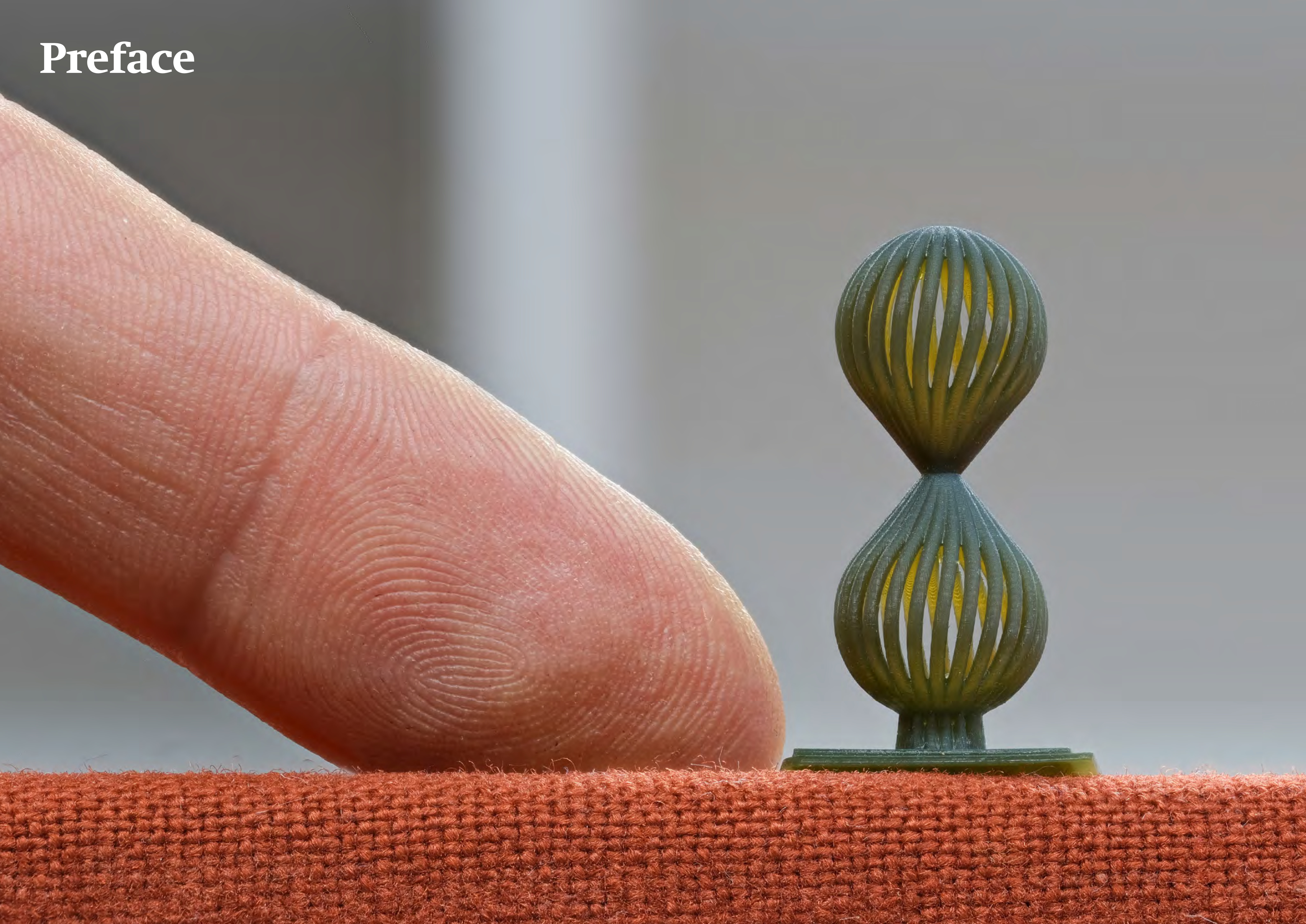
Preface



On Patience

The way of patience (picture: R. Wendler).

Much has been written about the patient's patience. Because there is more to be found here than just the similar sound of the two words. Etymologically speaking, the patient patient waits less for the doctor than for his or her recovery. In this sense, we are all patients more or less patiently waiting for the pandemic to finally release us from its pincer grip.

Both the patient and the patience, furthermore, have the same root as the word passivity. It is known, though, that the patient patient who passively awaits his or her cure will recover more slowly than the one who actively participates in the therapy. That is why we, too, have chosen the active path at the DBE.

No, we have not developed a new vaccine or a drug against Covid-19, that is beyond our capabilities. We just didn't let the virus stop us from working for the benefit of the patients. This is our therapy. And if we look at the successes we have achieved again this year, we can say that we have interpreted the role of the active patient with great ambition.

The Annual Report of 2021, which you are reading right now, offers you a comprehensive overview of these activities and successes of the past year. The fact that we lost Azhar Zam to New York University is probably a price of this success. But on the other hand, we also successfully retain excellent researchers such as Georg Rauter, whose professorship will be made permanent, and Pablo Sinues, who has now been tenured. This and other evidence of our success in the past year are presented here.

I invite you to browse through this annual report and see for yourself that the DBE is an impatient patient, a participative patient, and therefore well on its way.

Philippe Cattin

We are Growing. Fast.

Staircase at the GRID (picture: R. Wendler).

We proudly present you our Annual Report for 2021. We are proud not only because it provides a vivid image of a very busy and successful year, but also because it shows that the DBE is doing fine. In other words: we are growing fast in every aspect.

When I look back on last year, I especially remember the many planning meetings for the design of our future workshops and labs at GRID – a really big effort for everyone, which is not apparent anywhere in this annual report.

However, if we consider the growth of the DBE it quickly becomes clear why we have to move: The number of scientific staff at our department continues to rise since the DBE exists, notably the numbers of students in our master and PhD programs – a consequence of the increasing number of SNSF projects performed at the DBE.

Governmental funding now contributes a major part to our resources. 2021 particularly noteworthy are an SNSF R'Equip grant for the acquisition of a new Micro-CT for our Core Facility Micro- and Nano-Tomography as well as the NTN Innovation Booster "Robotics", based on a co-initiative from the DBE (Prof. Rauter).

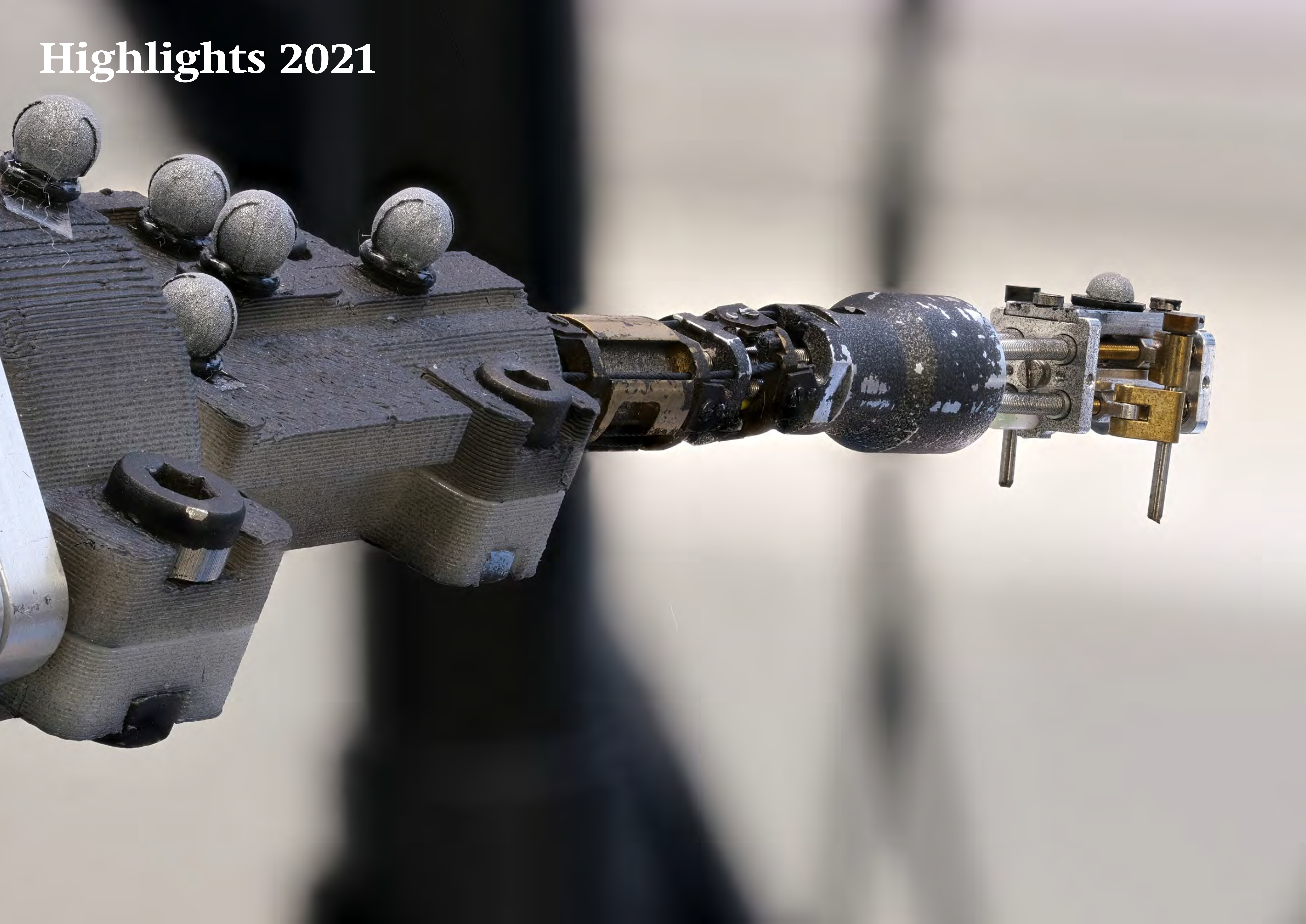
A benefit of the GRID planning are new co-operations that emerged within the DBE, e.g. "CADENCE" (for Clinical biomechAnics anD ErgoNomiCs Engineering) to name one on which you find further information in this report.

At the international level, the DBE was able to strengthen its reputation by holding the combined international conferences MESROB and AUTOMED 2021, which were already planned for 2020, and now held virtually, due to the Corona situation.

We would like to share these and other successes with you by means of this annual report and hope you enjoy reading it.

Daniela Vavrecka-Sidler

Highlights 2021



Medical Robotics Week 2021

Flyer of the Medical Robotics Week Conference.

The DBE was this year's host of the Medical Robotics Week (MRW2021). Planning took exceptionally long, as the changing Corona measures kept transforming the framework. The event has – finally – taken place from June 07–11, 2021 and was attended by more than 230 participants.

One-Week Fully Digital Conference

The one-week event consisted of two conferences (MESROB 2021 and AUTOMED 2021) with up to three parallel sessions on June 07–09, 2021, followed by three workshops on June 10–11, 2021.

A broadcast studio was set up in Allschwil, where four of our employees provided the entire live streaming into the conference platform. There, more than fifteen keynote speakers from the US and Europe gave exciting insights into the latest research results in the field of engineering sciences, including robotics, navigation and laser technology. If you want to know more, watch our videos about some of the DBE research groups and the conference's making-of on our YouTube channel.

Many thanks to the organizers: Prof. Georg Rauter, Prof. Philippe Cattin and Prof. Azhar Zam from DBE as well as Prof. Robert Riener from ETH Zurich!

After Conference Online-Event: From Industry to Medical Robotics

Few days after the Medical Robotics Week, Basel Area hosted a follow-up on-line event. In this context, Prof. Georg Rauter presented his research, followed by highlights of the Medical Robotics Week and chaired a round table discussion. There, the participants discussed the various opportunities for innovation that can arise when synergies are created between industrial and medical robotics.

Funding:

University of Basel, Department of Biomedical Engineering
Roche
ETH zürich
AOT
Stäubli
stryker

DBE Junior Faculty Mentoring Program

Dr. Manuela Eugster showing her Robotic System for Accurate Minimally Invasive Laser Osteotomy to Prof. Dr. Niklaus Friederich (picture: R. Wendler).

To steer the recruitment, support and coaching of talented researchers, the DBE implemented a "Junior Faculty Mentoring Program". For this purpose the DBE executive board elaborated a concept and guidelines of the program and appointed Prof. Bert Müller as head of the Mentoring Commission.

The aim of the Mentoring Program is to advise junior faculty during application for a career developing program such as SNSF Eccellenza and Ambizione or ERC starting grants, to assist them with establishing a translational network and to offer support in finding a permanent position in academia once the career development grant runs out.

Candidates interested in the DBE as host institution should seek support of at least one group leader at the DBE who works in a related field, before submitting an application to be hosted to the Mentoring Commission. The commission then starts the process by examining the application to ensure its quality and if necessary supports the applicant in finding suitable clinical partners. If the application is considered fit for the DBE, the Mentoring Commission presents it in the executive board which decides about its suitability in regard of the strategic strengthening of the DBE, before the candidate will be invited for a presentation.

Successful candidates in regard of the aquisition of a grant then get the benefit of two mentors at DBE – a clinician and an engineer or scientist – who will support the mentee through regular meetings and discussing topical research activities, career goals, and opportunities. The mentors assists the mentee in finding adequate partners, necessary infrastructure, and in the communication with the department, the faculty and the university. The concept of two mentors shoud ensure true translational research, coverig clinical as well as the scientific and engineering aspects equally.

All up-to-date documents regarding the program can be found on the DBE website.

Documentation:
https://dbe.unibas.ch/en/about-us/policies-guidelines/

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Awards & Prizes

Céline Berger won three awards for her work, including the Best DBE Master's Thesis Award. The award sponsored by the Zaeslin Teaching Grant, was presented to her at the 7th DBE Research Day by Prof. Niklaus Friederich (picture: T. Schürch).

This year again, many DBE members received awards and prizes. This definitely demonstrates how innovative DBE research is and how committed its scientists are. We congratulate our outstanding researchers and students:

Conference and Congress Awards

Dr. Corina Nüesch has been awarded for the best oral presentation at the annual meeting of the Swiss Society of Spinal Surgery for her work on "Differences in kinematics and electromyographic patterns during walking between patients with symptomatic lumbar spinal stenosis and healthy controls".

Dr. Stefan Stübinger, Dr. Srinivas Madduri and their colleagues won the Best Poster Award at the 10th World Congress of the International Academy of Ceramic Implantology in Las Vegas for their work on "Boosting osseointegration of ceramic dental implants with a novel surface topography designed for CIM".

Roya Afshari won a Magna cum Laude Award at the ISMRM & SMRT Annual Meeting for her work "Whole-brain B1-corrected quantitative MT imaging in less than 5 minutes".

Celine Berger won a Magna cum Laude Award at the ISMRM & SMRT Annual Meeting for her work "White matter fiber orientation dependent R2*: comparison between post mortem in situ and in vivo".

Linda Bühl won the 2nd price at the Young Investigator Award Competition at the Virtual Young Scientist Meeting of the German Society of Biomechanics for her presentation on "Comparison of knee biomechanics during walking between patients 2 years after primary ACL repair with InternalBrace and healthy controls".

Alexandra Migga won the Best Paper Award at the SPIE Conference "Developments in X-ray Tomography XIII" for her work: "Laboratory-based phase and absorption tomography for microimaging of annual layers in human tooth cementum, paraffin-embedded nerve and zebrafish embryo".

Alina Senst has been awarded the Gold Poster Award at the 7th DBE Research Day for her work "Optimizing Massive Parallel Sequencing Methods for challenging samples from decomposed human remains".

Manuela Monti has been awarded the Silver Poster Award at the 7th DBE Research Day for her work "Beyond THC and CBD – the potential of minor cannabinoid fingerprinting".

Massimiliano Filipozzi has been awarded the Bronze Poster Award at the 7th DBE Research Day or his work "Miniaturized absolute rotary encoder for endoscopic robot tracking system".

Yakub Bayhaqi won the Best Contribution Silver Award at AUTOMED 2021 for his paper "Kalman filtered depth prediction using optical coherence tomography for laser bone cutting".

Murali Karnam won the Best Research Paper Gold Award at MRW 2021 for his paper "Learned task space control to reduce the effort in controlling redundant surgical robots".

Michaela Maintz won the Best Poster Gold Award at MRW 2021 for her poster "Computational modeling for pre-operative guidance of mandibular fracture osteosynthesis".

Lorin Fasel won the Best Research Paper Silver Award at MRW 2021 for his paper "Tendon force control evaluation for an endoscope with series elastic actuation".

Cédric Duverney won the Best Student Paper Silver Award at MRW 2021 for his paper "Development and evaluation of a force-sensitive flexure-based micro-gripper concept".

Dr. Ferda Canbaz won the Best Application Paper Bronze Award at MRW 2021 for her paper "Laser-induced breakdown spectroscopy combined with artificial neural network for pre-carbonization detection in laserosteotomy".

Other Prizes

Smart Implants Group of the MIRACLE project has won the University Hospital of Basel's Sustainability Award for recycling old prototypes and test prints.

Bott Neuro AG, the latest DBE spin-off company, has won the Venture Kick, a philanthropic funding model initiated to support Swiss startups to kick-start their entrepreneurial success.

Celine Berger won the 3rd prize for the Best Master Thesis from the Medical Faculty for her work "Post mortem temperature and its effect on quantitative magnetic resonance imaging".

DBE Awards

Celine Berger has been awarded the prize for the Best DBE Master Thesis sponsored by the Zaeslin Teaching Grant for her work "Post mortem temperature and its effect on quantitative magnetic resonance imaging" (see page 76).

Carina Luchsinger Salinas, **Lucas Wey** and **Aleksandra Ivanovic** have been honored as well by the Zaeslin Teaching Grant for their respective master thesis (see page 76).

AMT Center won the DBE Best Lecture Award for its Lecture "Hands-on Magnetic Resonance Imaging" (see page 76).

Nominations, Honors & Dinstinctions

From top left to bottom right: Prof. Andreas Müller, Dr. Francessco Santini, Prof. Najat Salameh, Prof. Eva Scheurer, Prof. Pablo Sinues and Prof. Florian Thieringer (pictures: T. Schürch, R. Wendler and F. Santini)

In addition to the many awards that have been given to several DBE members, some of our researchers have also been appointed to positions of responsibility, received their Venia Docendi or have been honored with other distinctions. They include:

Committee Nominations

Prof. Niklaus Friederich has been appointed advisor to the Expert Screening Panel in the Field of Medical Devices of the European Union.

Prof. Andreas Müller has been honored by the Saveetha Institute of Medical and Technical Sciences (India) as visiting Professor in the Department of Plastic & Reconstructive Surgery.

Prof. Bert Müller has been appointed delegate for Switzerland of the European Academy of Science and Arts until end of December 2024.

Dr. Francesco Santini has been elected vice-president of the "Reproducible Research Study Group" of the International Society for Magnetic Resonance in Medicine ISMRM.

Prof. Najat Salameh has been elected vice-chair of the "MR Elastography Study Group" of the International Society for Magnetic Resonance in Medicine ISMRM.

Prof. Eva Scheurer has been elected President of the European Society for Magnetic Resonance in Medicine and Biology (ESMRMB).

Prof. Pablo Sinues has been been re-elected vice president of the Swiss Metabolomics Society.

Prof. Florian Thieringer has been appointed as an adjunct professor at the renowned SDM College Dental Sciences & Hospital in Dharwad (India).

Venia Docendi

Dr. Edgar Delgado-Eckert has been granted the Venia Docendi and the degree of Dr. habil. for Experimental Medicine.

Dr. Daniel Studer has been granted the Venia Docendi by the Medical Faculty for Pediatric Orthopedics.

Other Honors

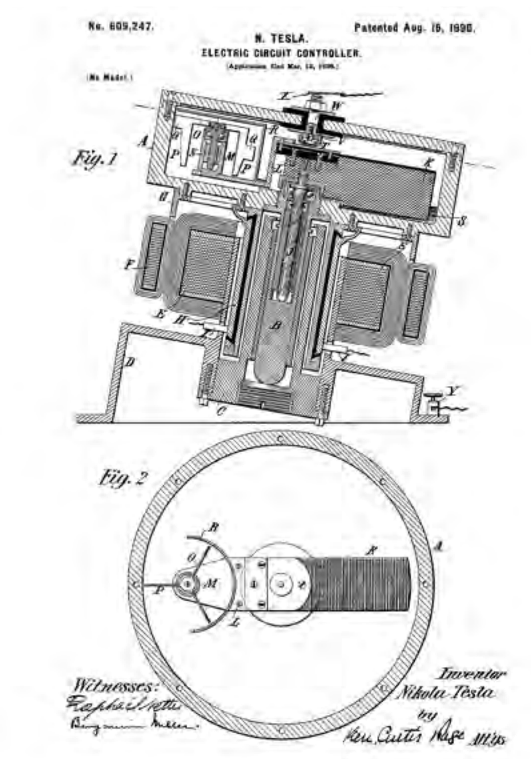
Prof. Bert Müller has been honored a SPIE Community Champion for his efforts on behalf of the optics and photonics community.

Prof. Niklaus Friederich has been honored a "Pillar of ESSKA" for having contributed largely to the foundation, structure and growth of European Society of Sport Traumatology, Knee Surgery and Arthroscopy.

From top left to bottom right: Dr. Edgar Delgado-Eckert, Dr. Daniel Studer, Prof. Niklaus Friederich, Prof. Bert Müller (pictures: UKBB, T. Schürch, and R. Wendler).

Spin-Offs & Patents

Bottneuro AG is the latest spin-off of the DBE.



Patent by Nikola Tesla, 1898 (picture: N. Tesla).

Considering the amount of innovative research taking place at the DBE, it is logical to witness the creation of new spin-offs and the application of new patents every year.

New Spin-Off

Bottneuro AG – under the leadership of Dr. Bekim Osmani – will facilitate early-stage diagnosis of Alzheimer's disease (AD) and aims to become a leading provider of fully personalized digital therapies for AD. Located at the Novartis Campus, Bottneuro will use digital biomarkers and establish brain clinics to diagnose AD at an early stage and use these data to deliver a fully personalized, patient-specific electrical stimulation therapy via 3D printed headsets with embedded electrodes. Bottneuro will advance its patented NENI® neuro-modulation platform technology to further develop and fine-tune stimulation protocols.

As a witness to its promising future, Bottneuro AG has not only attracted the attention of different media outlets (see page 40), but it also has been listed as one of the "Spin-Offs to Watch 2021" by the the Forbes Magazine, and won a 150 kSFR Venture Kick funding to support its entrepreneurial success.

Patent Applications

DBE members submitted three additional patents based on their research. Those are:

EP 21/172804.3 "Neural implant based on a cellulose thin film and corresponding fabrication process", Osmani et al.

EP 21/172809.2 "Tissue regeneration patch and corresponding fabrication process", Osmani et al.

EP 21/080722 "Endodevice – Federn in Endoskop-Zugsystem", Rauter et al.

Changes in Personnel & Organization

New Members in the DBE Executive Board

Prof. Ludwig Kappos and Prof. Bieri (pictures: USB).

Prof. Eva Scheurer and Prof. Cristina Granziera (pictures: Institut für Rechtsmedizin, and ThINk).

In November, the DBE Assembly voted for a change in the composition of the DBE Board to reflect the many female researchers at the DBE: Prof. Ludwig Kappos and Prof. Oliver Bieri stepped back and Prof. Eva Scheurer and Prof. Cristina Granziera were elected as new members of the DBE board which now has a gender parity.

Thank you to the Profs Kappos and Bieri

Prof. Ludwig Kappos and Prof. Oliver Bieri stepped down from the DBE Executive Board after two terms of service during which they contributed significantly to the rapid development of our department. We are grateful and thank them for their commitment to the DBE and their valuable input over the past years.

Welcome to the Profs Scheurer and Granziera

Prof. Eva Scheurer and Prof. Cristina Granziera were elected as new members of the executive board. These two highly qualified women are well suited to represent the diverse interests of the DBE members. Eva Scheurer is a medical doctor who aditionally did a master in physics. She is director of the Institute of Forensic Medicine at the Health Department of Basel Stadt. Cristina Granziera also combines the qualities of a medical doctor with those of a scientist: she works as a senior consultant for Neurology at the University Hospital and leads several research projects at the Department of Biomedical Engineering at the University of Basel.

Prof. Azhar Zam Joined New York University

Azhar Zam, former head of the Biomedical Laser and Optics Group (BLOG) at the MIRACLE project, during his farewell celebration (picture: T. Schürch).

Azhar Zam will start a new position as Associate Professor in Bioengineering at the Tandon School, New York University (NYU), USA as of January 2022, after a successful time at the Department of Biomedical Engineering.

An outstanding career at the DBE

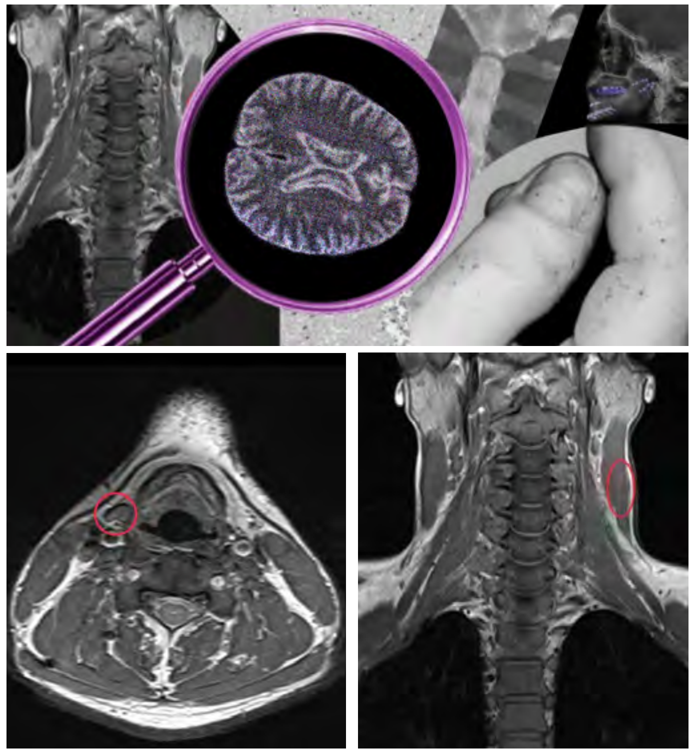
Azhar Zam came to the DBE in 2016 as assistant professor and founded the MIRACLE's Biomedical Laser and Optics Group (BLOG). He has built up BLOG from the ground and made it one of the pillars of the DBE's flagship project MIRACLE.

His research activities at the DBE included developing laser-based systems and optical sensors for biomedical applications. Until now three of his PhD students successfully graduated, he continues to supervise two more who are supposed to graduate in 2022. While Azhar Zam left end of December 2021, he will still act as PhD supervisor and project advisor until end of MIRACLE I (June 2022). Ferda Canbaz, one of his postdocs, will take over as the ad interim acting BLOG group leader.

We are sad to see Azhar Zam leave, but at the same time we are very happy for him that his research over the last years is bearing fruit – and that we will soon have another external collaboration partner at a prestigious institution in the field of biomedical engineering.

We wish him all the best for his future!

New Research Group "Forensic Medicine & Imaging" led by Claudia Lenz



Research example: Objectivation of strangulation findings using MRI of the neck in surviving victims (pictures: Institut für Rechtsmedizin)

The Forensic Medicine & Imaging Research Group of the Institute of Forensic Medicine in Basel supports the introduction of imaging into forensic routine by conducting research on the forensic use of CT, MRI and infrared photography mostly post mortem in situ, in the case of strangulation also in vivo.

Our main areas of research currently are:

- Identification of deceased using post mortem CT or infrared photography
- Detection of the causes of death based on CT data
- Temperature sensitivity of post mortem MRI
- Investigation of brain edema in deceased using CT and MRI
- Examination of surviving strangulation victims using MRI of the neck.

The team involves researchers from the disciplines medicine, physics and biomedical engineering. Our research group sees itself as a bridge between forensic services and biomedical research and tries to develop new standard procedures by collaborating closely with the physicians from forensic routine.

Funding:

University of Basel

Gesundheitsdepartement des Kantons Basel-Stadt
Institut für Rechtsmedizin der Universität Basel

Junior Group Leader:
Dr. phil. Claudia Lenz
claudia.lenz@unibas.ch

Group Members:
Dr. phil. Laura Egloff
Dr. med. Holger Wittig
MSc. Melanie Bauer
MSc. Celine Berger
MSc. Dominique Neuhaus
BSc. Andrea Zirn
Thomas Rost

https://dbe.unibas.ch/en/research/imaging-modelling-diagnosis/forensic-medicine-imaging-research-group/

New Research Group "Clinical Biomechanics & Ergonomics Engineering – Spine Biomechanics" led by Cordula Netzer

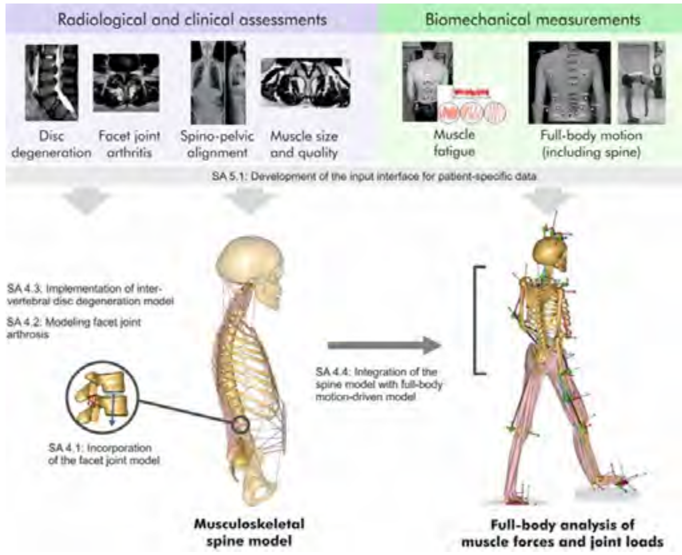


Figure 1: Overview RoLSSroice project (picture: D. Ignasiak, C. Netzer).

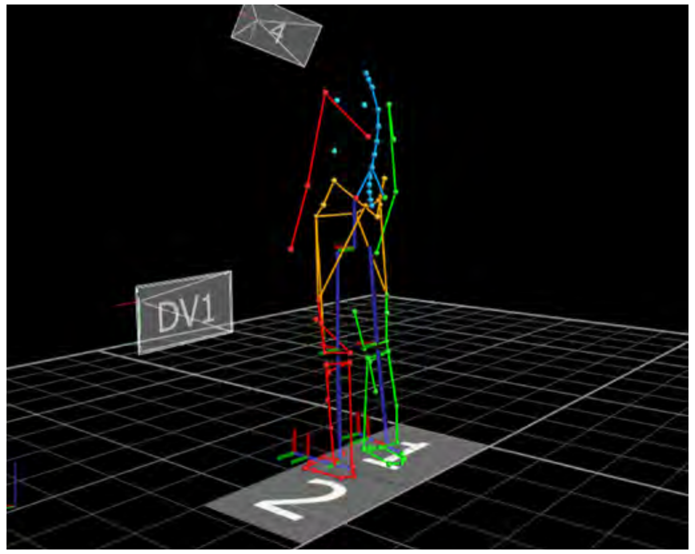


Figure 2: Person standing on the force plates in the biomechanics laboratory equipped with reflective markers including a detailed spine model (picture: D. Koch).

Role Of spinal load in the pathophysiology of Lumbar Spinal Stenosis: a translational approach combining clinical, functional, and radiological parameters, in vivo biomechanical experiments and advanced in silico musculoskeletal modelling (RoLSSroice).

This project addresses the pathophysiology of lumbar spinal stenosis, a narrowing of the spinal canal in the lower part of the spine. Using a translational approach, clinical, radiological, and functional and biomechanical parameters will be collected and matched to an innovative musculoskeletal in silico model. Modelling and in silico experiments with a patient-specific musculoskeletal model will also allow the systematic study of mechanical compensation of symptoms and degeneration to spinal anatomical structures such as the intervertebral discs, facet joints, ligaments and paraspinal musculature.

The combination of in vivo experiments with in silico experiments represents a unique opportunity to transfer clinical, biomechanical and radiological findings in patients to systematic in silico experiments back to the patient. Confirming the relationship between clinical, radiological, functional, and biomechanical factors and local loading will provide the evidence necessary to use the framework developed and employed in this project for diagnosis, treatment, and rehabilitation planning in patients with lumbar spinal stenosis and to predict the outcome of existing and new therapies. Recommendations based on the results will directly impact the treatment of patients in the clinic by identifying patient-specific parameters responsible for large local burdens. These parameters will be used to derive an evidence-based and ultimately individualized treatment approach with the ultimate goal of reducing the risk of symptoms and/or stenosis after surgery.

Funding:

Swiss National Science Foundation

Universitätsspital Basel

Group Leaders:
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Prof. Dr. Annegret Mündermann PhD
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Collaborators:
Prof. Stefan Schären (Spine Surgery, USB)
Dr. Corina Nüesch (Spine Surgery, USB)
Dr. med. Dorothee Harder (Radiology, USB)
Dr. med. Friederike Prüfer (Radiology, UKBB)
Prof. Stephen Ferguson (ETH Zürich)
Dr. Dominika Ignasiak (ETH Zürich)
Dr. Soheila Aghlmandi (Institute of clinical epidemiology and biostatistics, USB)

New Research Group "Basel Muscle MRI (BAMM)" led by Francesco Santini

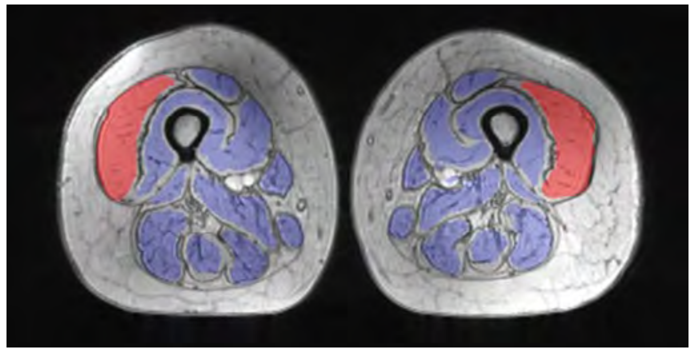

Figure 1: Muscle segmentation (picture: BAMM).

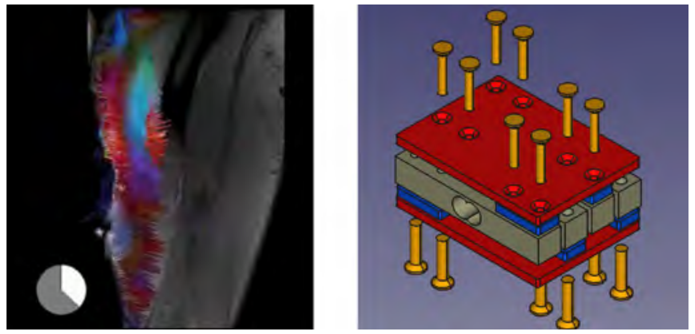

Figure 2: Muscle contraction (left) and hardware development (right) (picture: BAMM).

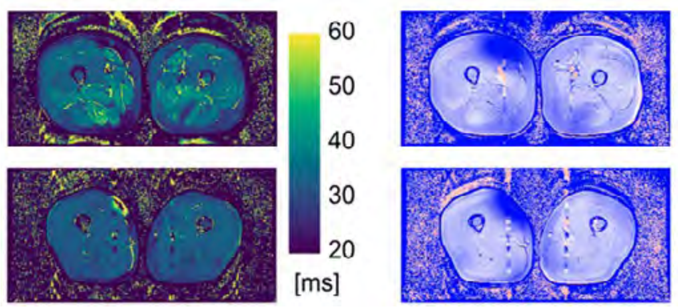

Figure 3: Quantitative Imaging (picture: BAMM).

The Basel Muscle MRI Group is dedicated to the development of innovative methods for the imaging of the muscular and musculoskeletal system. From the basic physics of imaging, to artificial intelligence in image analysis, we bring pioneering research to patient care.

Muscles are not only essential for body movement, but for life itself. To find the appropriate treatments for muscular disorders, we develop sensitive, and highly reproducible biomarkers to assess the subtle changes in the patients' conditions.

The Basel Muscle MRI Group addresses the challenge by developing novel imaging and image analysis methods ranging from MR acquisition techniques, to hardware development, to cutting-edge deep learning methods. We strongly support the idea of open science and open source, since this is the best way to secure success of research and development and effectively help patients. For the same reason we foster a number of close cooperation projects with radiologists and other clinicians to ensure translation of this research into real patient benefit.

Facts and Figures

- More than 10 peer-reviewed papers in the last 3 years.
- 2 running SNSF projects.
- 3 core members, 2 external.
- Numerous collaborations with research groups in:
  - Switzerland (Basel, Lausanne)
  - Italy (Pavia, Rome)
  - China (Beijing)
  - USA (Stanford)
- Our free segmentation software Dafne

Address:
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+41 61 55 65 417
https://bit.ly/bam_mri

Funding:
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fsrmm

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References:
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New "Acoustic and Vestibular Research Group" led by Christof Stieger

Figure 1: Cochlea and semicircular canals of the human ear (picture: R. Wendler).

Figure 2: Heiko Rust, Flurin Honneger, Lukas Graf, and Christof Stieger (picture: R. Wendler).

Malfunction of the acoustic and vestibular sensors of the human ear often results in social deprivation and are known as one of the most important risk factors for dementia. People with these malfunctions often isolate themselves because of the inability to participate in oral communication and suffer from a loss of balance control. Diseases of both sensory organs and their artificial restoration are the research subject of the Acoustic and Vestibular Research Group.

The group consists of two teams: Researchers led by Christof Stieger investigate acoustic peripheral pathways and clinical outcome of natural and artificially produced sound in the cochlea. Better understanding of these pathways improves efficient hearing implant development. Researchers around Flurin Honegger, Heiko Rust and John Allum are developing methods to measure malfunctioning vestibulo-occular and vestibulo-spinal reflexes underlying poor balance control, and track their central compensation. Additionally, training with sensory substitution devices is being used as one method to improve balance control. Exact measurement of responses of both sensory systems is needed to better understand and assess the impact of regressive disorders on daily life and to control the therapeutical measures needed to support the recovery processes from both types of human ear disorders.

The acoustics and vestibular Lab is located at the Campus of the University Hospital of Basel and bridges the gap between technical devices and its clinical application in collaboration with other Universities and Hearing Implant Industry.

Funding:
MED-EL
Cochlear™

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References:
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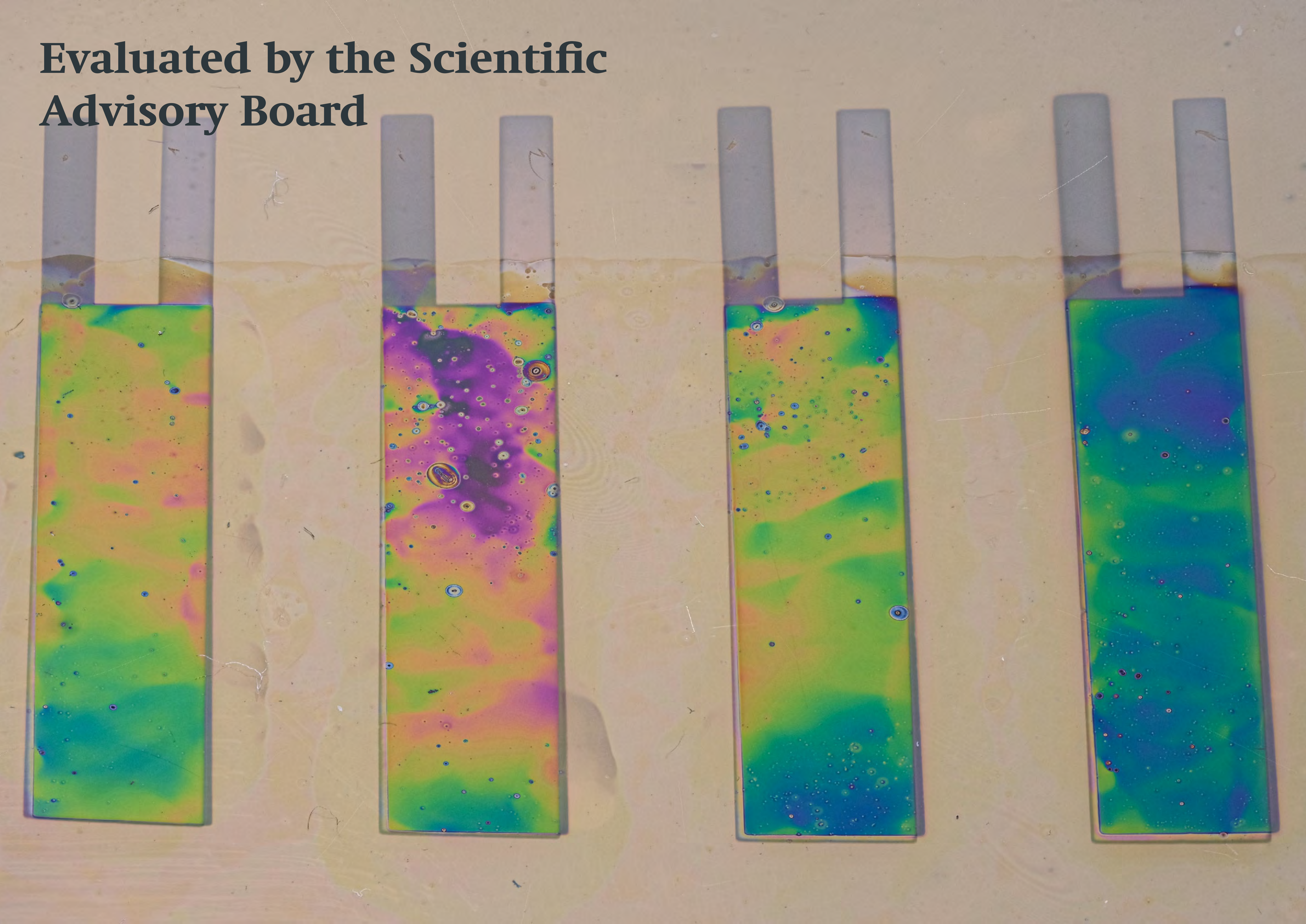
Evaluated by the Scientific Advisory Board



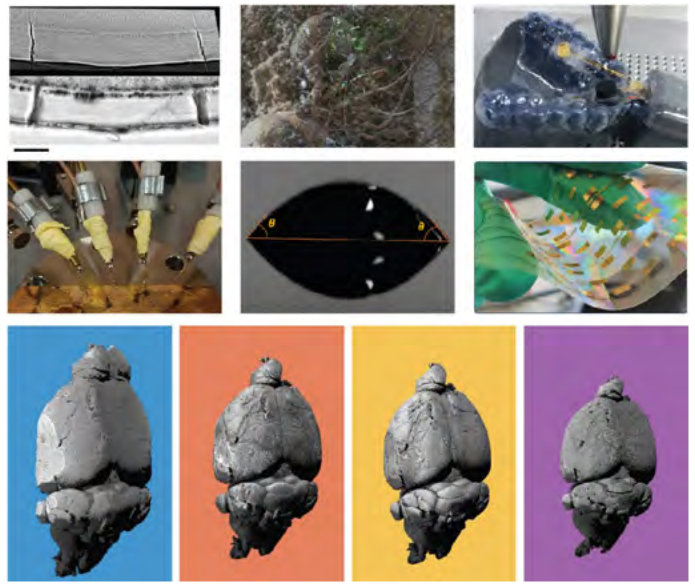


Figure 1: Thesis projects at the Biomaterials Science Center completed in 2021: top row – imaging annual layers in human tooth cementum, nanospheres in dental fillings for chameleon effect, prototype for tongue muscle training; middle row – conductivity of spinal cord implants after mechanical loading, water contact-angle on structured electrode, smart neural implants; bottom row – morphology changes during brain embedding for virtual histology, a tomography study at the ANATOMIX beamline of synchrotron SOLEIL, France. (pictures: BMC/BOTTmedical/BOTTneuro/acthera/SOLEIL).

Figure 2: Start-up companies of the Biomaterials Science Center founded in Basel between May 2019 and January 2021: Bottmedical AG, Acthera Therapeutics AG, and Bottneuro AG.

Employing physics: Benefitting patients. The interdisciplinary research team of the Biomaterials Science Center exploits physical principles to tackle main challenges in medicine of 21st century. In 2021, the research activities have spun over the fields of dentistry via neuroanatomy to the brain-computer interface, see fig. 1. Hard X-ray-based, three-dimensional imaging with micrometer resolution has played a major role (1, 2). Scientific results are directly transferred to the start-ups, see fig. 2.

The results have formed the foundation of the following theses completed in 2021.

- **Dr. phil. Griffin Rodgers**, Doctoral Thesis in Physics, University of Basel: "Hard X-ray microtomography for virtual histology of the brain with cellular resolution", SNSF-funded by project 185058;
- **Carina Luchsinger Salinas**, Master Thesis in Biomedical Engineering, University of Basel: "Dielectric elastomer sensors for the tongue-computer interface";
- **Abinaya Nallathambi**, Master Thesis in Biomedical Engineering, University of Basel: "Analysis of gold-silicone films for the electrical interface of soft neural implants";
- **Corinne Mattle**, Master Thesis in Biomedical Engineering, University of Basel: "Nano-structural characterization of a dental filling for wide color matching";
- **Mahyar Joodaki**, Master Thesis in Biomedical Engineering, University of Basel: "Fabrication and characterization of silk reinforced, micro-patterned cellulose films for soft neural implants";
- **Muriel Stiefel**, Semester Thesis in Physics at ETH Zurich: "Combining optical and hard X-ray images of annual layers in cementum of human teeth";
- **Simon Bucher**, Bachelor Thesis in Medical Technology, University of Applied Sciences Offenburg, Germany: "Cyclic loading of laser-perforated, thin-film implants for the spinal cord".

Funding:

Swiss National Science Foundation

WISSENSCHAFT. BEWEGEN
GEBERT RÜF STIFTUNG

SOLEIL SYNCHROTRON

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References:
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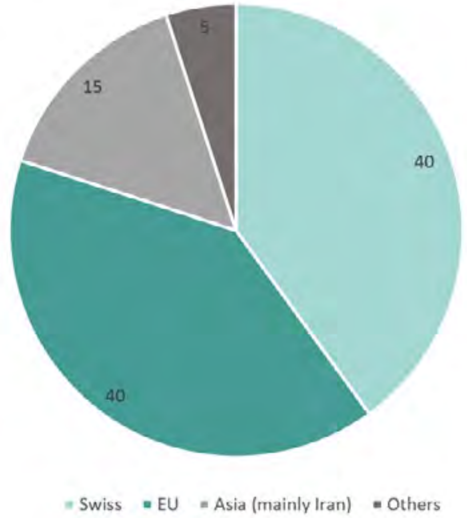

Figure 1: Geographical distribution of admitted students (in %).

Figure 2: Video to promote the Maser of Biomedical Engineering: https://tube.switch.ch/videos/edaa87f0 (Video: R. Wendler).

The Master's Program Biomedical Engineering (BME) is among the youngest study programs of the University of Basel and was initiated in 2018. After three years of operation, the Scientific Advisory Board (SAB) had the opportunity to evaluate the success of the program during its visit in September 2021.

The initial goal of recruiting 25 students has already been reached and with the constant increase in the number of applications, the DBE hopes to soon attract enough students to operate at maximum capacity (30-40 admissions/year). During its visit, the SAB also appreciated the diversity of the student body (with medical, engineering, or natural science background), its international character (60% of the students are from abroad – see fig. 1) and its focus on gender parity.

Thanks to the quality control system implemented at the end of each semester, the DBE is constantly improving its curriculum to better meet the needs of its students. The interviews that the SAB conducted with several students confirmed a high level of satisfaction with the program.

Finally, a discussion between the SAB and the teaching committee highlighted opportunities for further improvement. For example, the BME Master's program will soon be extended to 4 semesters (instead of 3) to allow students with different scientific education to acquire an even stronger common background. On this basis, the SAB has suggested to opening the program in the future to students with a Bachelor of Science degree in Biology. This recommendation is currently reviewed by the teaching committee.

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Scientific Advisory Board:
Prof. Christos Bergeles
Prof. Christian Enzinger (excused)
Prof. Andreas Maier
Prof. Markus Rudin
Prof. Regine Willumeit

Core Facilities

Core Facility Micro-Calorimetry

Figure 1: An isothermal microcalorimeter equipped with 48 measuring channels with a sensitivity of 200nW (picture: R. Wendler).

Figure 2: Calorimetry vials with catalytic beads. Only a few beads are necessary to have a good signal and measurement reproducibility (picture: R. Wendler).

The Micro-Calorimetry Core Facility provides services for researchers at the DBE, the Medical Faculty of the University of Basel, external research institutions and industry partners. In addition to services, the Core Facility performs its own research. Main fields of work in 2021 have been:

Measure of metabolic rates: metabolic heat release can be used in various fields of medicine and biotechnology. The information gained can be used for applied sciences but also for basic research. The Micro-Calorimetry team is particularly interested in biofilm metabolism and anti-biofilm compounds.

Rapid detection of contaminations and infections: The goal of this research area is to allow rapid determination of contamination of various medical and non-medical products such as blood products, fermented milk products or water, for example to increase patient and consumer safety.

Rapid drug susceptibility testing: here the researchers want to enhance evidence based patient specific treatment by providing rapid antibiogram to medical practitioners and thus allow faster action and recovery for patients.

Coatings of implants: as implant related infections are still a major issue in biomedical science, the team aims to provide evidence-based data on antimicrobial efficacy of implant coating materials with an emphasis on complex 3D shapes and materials difficult to investigate due to their porosity and opacity, for example.

Finally, over longer term the aim of the lab is to work with industrial partners on miniaturization of calorimeters allowing the development of "adaptable calorimetry", and possibly its combination with other non-invasive and label-free technologies such as laser spectroscopy.

Funding:

MERIAN ISELIN Klinik für Orthopädie und Chirurgie

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

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Core Facility Micro- and Nanotomography

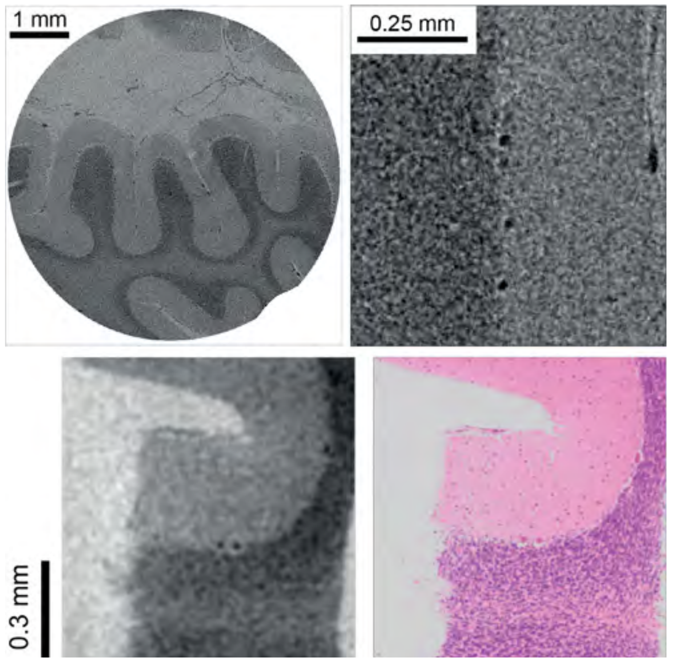

Figure 1: Virtual slice through a human cerebellum piece embedded in paraffin (top left) showing the three layers, i.e. white matter and the molecular and granular layers. The spatial resolution and contrast are sufficient to resolve individual Purkije cells (top right). The second row shows a comparison between the histological slice and the corresponding µCT slice (figure adapted from (1)).

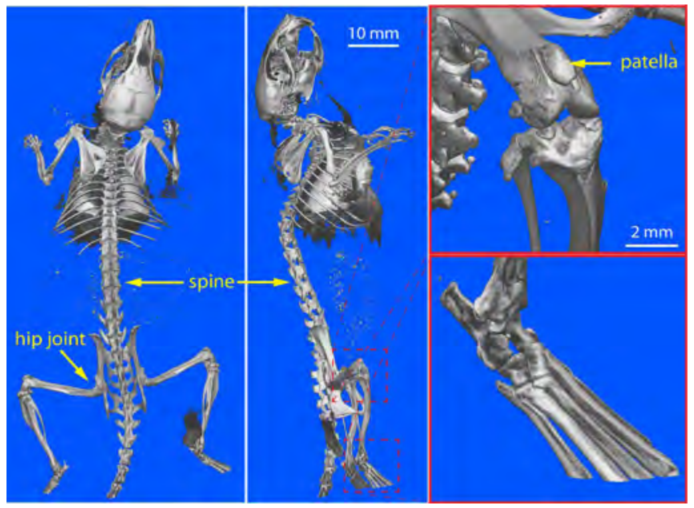

Figure 2: 3D rendering of a mouse skeleton. For the visualization, soft tissues and fur were made transparent (pocture: MiNa, DBE).

The Micro- and Nanotomography Core Facility (MiNa) provides support for non-destructive three-dimensional imaging, serving biomedical, engineering, environmental and archaeological sciences from internal and external research groups or industry. MiNa hosts two state-of-the-art X-ray microtomography systems: nanotom® m (phoenix|x-ray, Waygate Technologies, Wunstorf, Germany) and Skyscan 1275 (Bruker microCT, Kontich, Belgium). The current systems allow investigations with a spatial resolution down to the cellular level (1), see fig. 1. After successful R'Equip application in 2021, the Core Facility will be extended by a next-generation microtomography system (2) with an isotropic resolution on the sub-micrometer range.

Frequent users at the University of Basel are from Department of Biomedical Engineering (hard & soft tissues from humans and animals, implants), Department of Pharmaceutical Sciences (nanoparticles in zebrafish embryos) and Department of Biomedicine (tissue engineering, bone deformations (fig. 2), hearing devices). Bone regeneration was investigated with partners from French National Institute of Health and Medical Research in Strasbourg (3). Researchers from the Institute of Physiology at University of Zurich take advantage of microtomography for visualizing murine kidneys. The Natural History Museum Basel examines inner ear morphology of ruminants to investigate allometric and phylogenetic aspects (4). Recently, a project with the University of Wisconsin was established that will concentrate on incremental lines in the cementum of bovids to answer questions in human evolution. Other users of the Core Facility: University of Toulouse, Aarhus University, Malmö University, UZB, University of York, JURASSICA Museum, Medartis, Straumann, AOT, Roche.

Funding:

Swiss National Science Foundation

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References:
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Core Facility 3D Print Lab

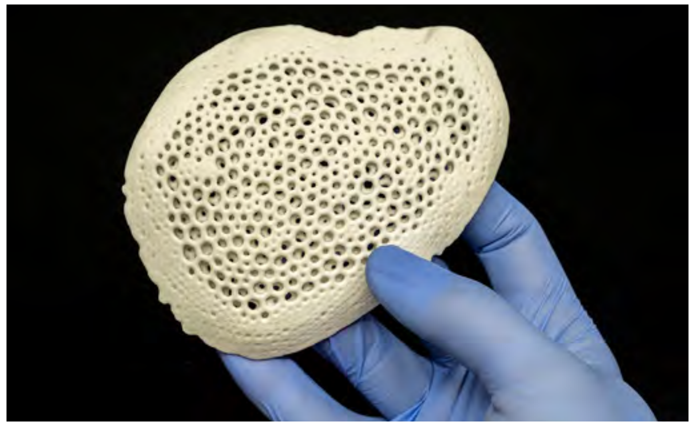

Figure 1: Biomimetic patient-specific cranial implant (picture: R. Wendler).

Figure 2: 3D printed titanium implant for orbital floor reconstruction (picture: M. Maintz).

Figure 3: The interdisciplinary Core Facility 3D Print Lab at the University of Basel (picture: M. Maintz).

3D printing is one of the great technological innovations of today and is becoming increasingly important in medicine. At the 3D Print Lab Core Facility, we design, print and post-process prototypes, anatomical 3D models (up to patient-specific implants), medical / surgical tools, and other devices used for diagnosis, (virtual) surgical planning, patient communication, training, and education. The 3D Print Lab Core Facility is associated with the Medical Additive Manufacturing (Swiss MAM) a research group at DBE and the 3D Print Lab at the University Hospital Basel.

We provide our broad national and international network, our expertise and services to various research groups at the University of Basel, the DBE, the research groups at DBM (Tissue Engineering Group), and at UZB (Department of Dentistry: Biomaterials & Technology). Our services are also available to other universities, hospitals, centers / institutes in Switzerland and abroad.

We can offer an extensive and growing portfolio of 3D printers (FFF, SLA, APF, Binder Jet, PolyJet, SLM, Bioprinting, …), software, and materials. The Core Facility 3D Print Lab includes a range of 3D printers with numerous technologies. Our range of 3D printing materials includes a wide range of polymers and high-performance (medical) materials such as PEEK and PEKK, ceramics, biodegradables, bio-inks, up to metals like medical-grade titanium in collaboration with our partners from the FHNW University of Applied Sciences Northwestern Switzerland. We have licenses for state-of-the-art 3D software and medical (certified) software versions.

Do you want to learn more about Virtual Surgical Planning and Medical 3D Printing? Visit us at www.swiss-mam.ch

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Outreach

Media Coverage

Figure 1: Visualizing medical datasets (picture: Werner Siemens Foundation).

The various research studies conducted at the DBE attracted the attention of numerous medias including websites, newspapers and magazines. This constantly growing interest demonstrates the innovative spirit of the DBE.

Prof. Sarracanie in on-line media

The benefits of low-field MRI have been evident for decades, only the path to clinical application seemed to be blocked. This is currently changing, also thanks to the efforts of AMT Center at DBE. In March 2021, Prof. Mathieu Sarracanie, co-head of the AMT Center, appeared in two articles published on Healthcare-in-europe.com and AuntMinniEurope.com discussing the advantages of adaptable MRI systems.

DBE in the Neue Zürcher Zeitung

An article about future of health published in NZZ (Neue Zürcher Zeitung) in April 2021 highlights developments in the Basel Area, which is characterized by a life science cluster that is unique worldwide. In this context, the DBE is mentioned as one of the main players in the innovation campus.

BIROMED-Lab in UNINOVA

In May 2021, Prof. Georg Rauter's BIROMED-Lab was presented in UNINOVA #137, the research magazine of the University of Basel. The feature is part of a series called "My Workspace", which presents labs and offices of different researchers of the University.

MIRACLE Project in USB Gazzetta

The MIRACLE project appeared in an article of the USB Gazzetta on-line magazine in June 2021. The article addresses the translational work conducted at DBE and how our researchers collaborate with the clinicians at the University Hospital Basel to develop applicable solutions for minimally invasive surgery.

Prof. Rauter in the Basler Zeitung

"Will robots soon replace nursing staff?" was the title of an article on a workshop led by Prof. Georg Rauter during the Medical Robotics week in Basel, which appeared in the Basler Zeitung in June 2021.

DBE and DKF Alliance in DKForum

As a joint effort, the DBE and DKF are making it possible to overcome the new regulatory hurdles for medical device development in academia and quickly make available the most innovative developments in biomedical engineering research. This subject has been developed in an article published in DKForum in June 2021.

BMC in UniNews

The research conducted by the Biomaterials Science Center (BMC) group was highlighted in the Uni News in July 2021. In this article, Prof. Bert Müller, head of the research group, comments on the results of their study where they used a three-dimensional imaging method to take high-resolution captures inside zebrafish embryos.

3D Print Lab in the Neue Zürcher Zeitung

The NZZ (Neue Zürcher Zeitung) published an article in November 2021 called "3-D printing instead of a chemical factory" reporting on the 3D Print Lab at the Unispital.

Swiss MAM in Medizin Aktuell

In November 2021, the magazine Medizin Aktuell reported on the work of PD Dr. med. Philipp Honigmann of Swiss MAM on organ modeling in the 3D printer.

Bottneuro AG in diverse media

Throughout 2021, the latest DBE spin-off attracted media's attention. In addition to being listed as a "Spin-Offs to Watch in 2021" by the Fordes magazin and winning the Venture Kick 2021, the Bottneuro AG was featured in Medinside and Switzerland Global Enterprise (S-GE).

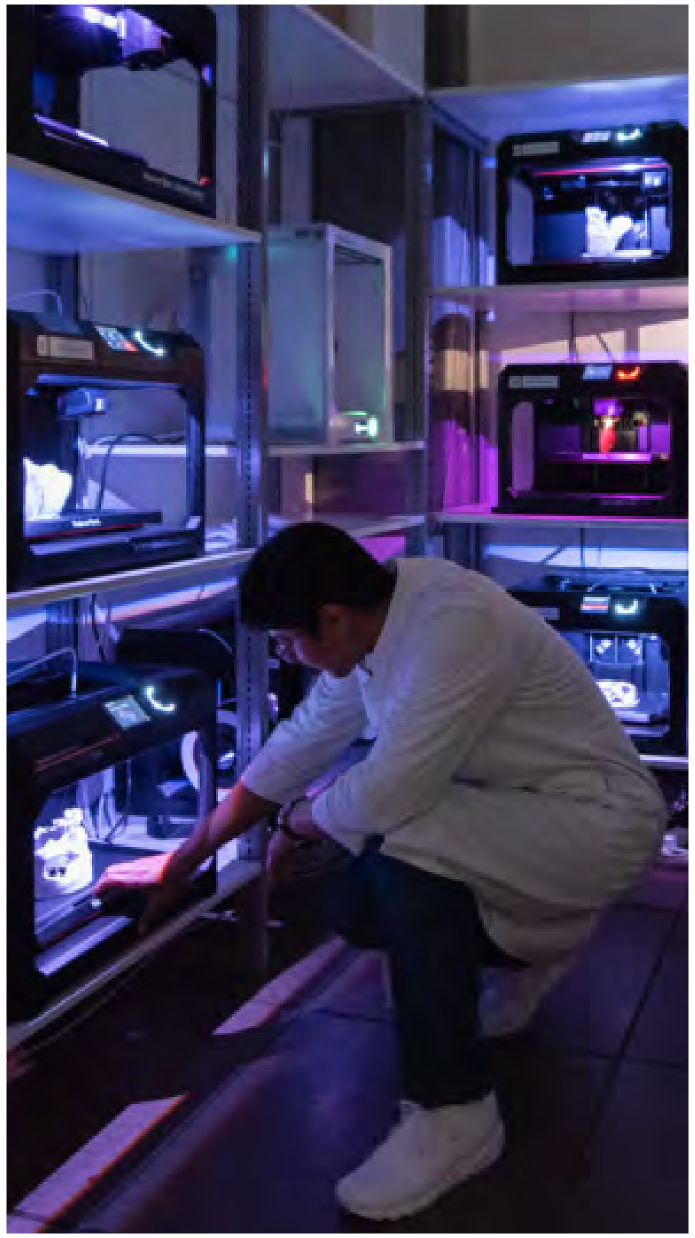

Figure 2: The 3D Print Lab Facilities at the University Hospital Basel (picture: C. Flierl, University of Basel).

Public Events & Outreach Activities

Figure 1: Presentation at the Open House at GRID (picture: R. Wendler).

In parallel to its research activities, the DBE is strongly involved in numerous communication activities for researchers and the general public and contributed to the following events and projects:

Exhibition at the Smart City Lab Basel

The DBE was invited to showcase two of its signature projects at the Going Live Exhibition in the Smart City Lab Basel taking place from March 16 to 24, 2021. At this event, high-end innovations of researchers and entrepreneurs from Basel Area were presented.

The University's Master's Info Evening

The DBE participated to the Master's Info Evening organized by the University of Basel on March 18, 2021. On this occasion,we were able to meet potential future students and present them our Master's program whose main interests have been wrapped up in this video teaser.

1st DBE PhD Day

On 19 March 2021, the first (virtual) DBE PhD Day took place, connecting almost 50 researchers through poster sessions, networking opportunities, and interactive lab tours. After these exciting exchanges, the event was concluded by about 30 DBE PhD and Master students engaging in an on-line murder mystery game.

Virtual Lab Tours

This year, in the context of organizing the digital conference MRW2021 in June 2021, the DBE has begun shooting a series of Virtual Lab Tours to allow the public to continue tours despite the Covid pandemic. Videos of these virtual visits are available on the DBE YouTube channel.

Open House at GRID

The DBE will soon move to the GRID (Grand Réseau d'Innovation et de Développement), a new building designed by Herzog & de Meuron currently under construction in Allschwil. While waiting for our new premises, we were on the building site on June 26, 2021 to present our research activities to the public. PhD student, Cédric Duverney, even had the opportunity to comment the advantages of this move in a news post of Telebasel.

CIAN at the exhibition Waves - Dive in

The exhibition Wave – Dive in (24 August 2021 – 5 March 2023) organized by focusTerra approaches the phenomenon of waves from very different disciplinary perspectives. CIAN contributed two exhibits, both based on the principle of ultrasound.

7th DBE Research Day

About 200 participants joined the 7th DBE Research Day on September 7, 2021. 25 speakers and 50 posters gave an insight into the lively and constantly growing research culture at the DBE. New this year, was a section called "Translational Tandems", in which a clinician and a researcher presented a joint project, thus exemplifying the translational activities of the DBE.

Swiss Robotics Day 2021

The MIRACLE project has been invited to the Swiss Robotics Day 2021 at the StageOne Event & Convention Hall in Zurich. Researchers from BIROMED-Lab and Smart Implants presented the project with various installations and objects ranging from the robotic endoscope with haptic feedback to 3D printed implants and videos. Also Prof. Georg Rauter, head of BIROMED-Lab, presented his research in a panel discussion.

FCA at Treffpunkt Science City

Members of the Facial and Cranial Anomalies (FCA) Group offered a demo at the ETH Zurich's public education event for all ages: Treffpunkt Science City. This demo about the digital production of palpate plates was part of the autumn program: "Rich and Poor".

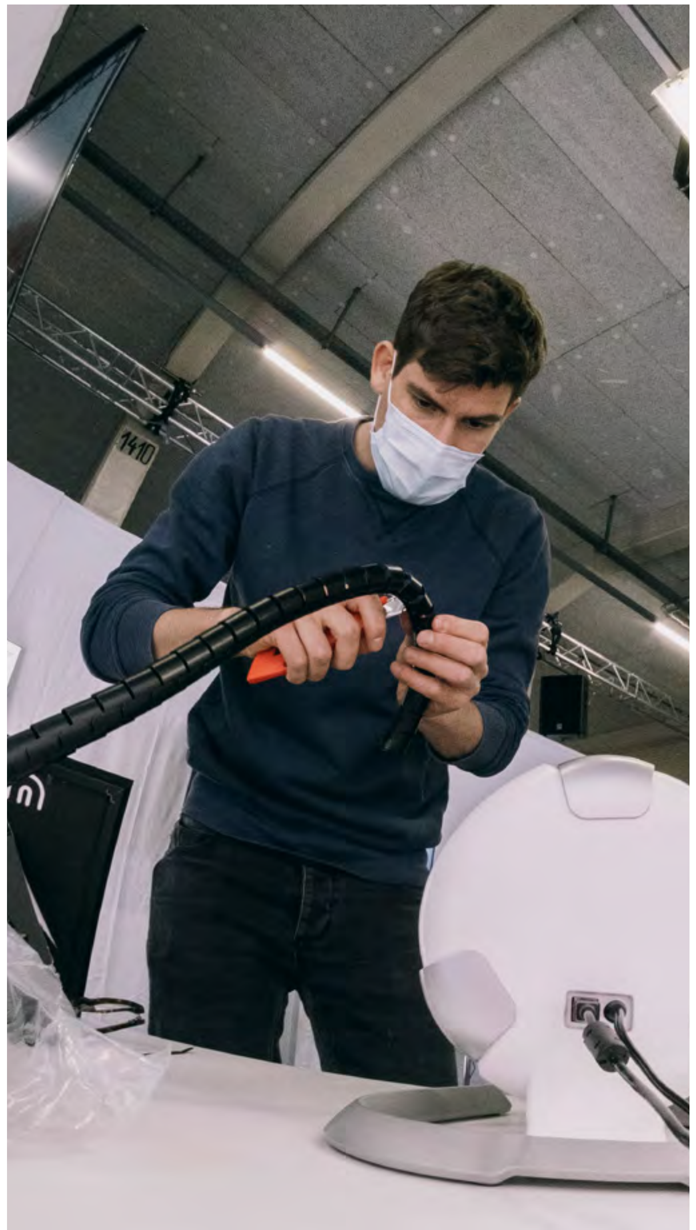

Figure 2: Installation of the Going Live Exhibition at the Smart City Lab Basel (picture: R. Wendler).

Selected Collaborations

Clinical Biomechanics & Ergonomics Engineering

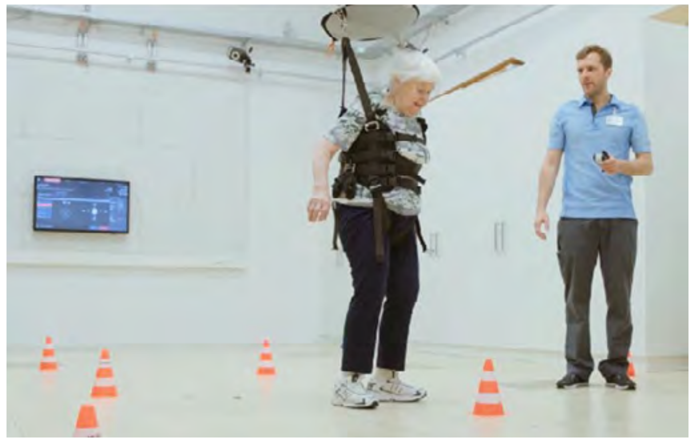

Figure 1: The FLOAT system developed by Prof. Georg Rauter

The CADENCE research area combines the expertise and disciplines of robotics, functional biomechanics, musculoskeletal modelling, virtual reality, orthopaedics and neuroorthopaedics, paediatrics, spine surgery, biochemistry, and radiology.

Principal Investigators are Prof. Annegret Mündermann (USB/DBE), Prof. Georg Rauter (DBE), Prof. Heide Elke Viehweger (UKBB/DBE), PD Cordula Netzer (USB/DBE) and PD Morgan Sangeux (UKBB). Together with their teams, they will develop novel systems, methods and outcomes for diagnosis, measurement, treatment, and rehabilitation of pathologies and conditions of the neuromusculoskeletal system.

The new laboratory facilities at the GRID building will allow the different groups within the CADENCE research area to focus on collaborative research projects by utilizing and combining the multidisciplinary expertise within the same research space, and to translate results directly to the clinic by partnering with the existing groups and facilities in the current clinically-based settings.

Facts and Figures

The research area is currently funded by the Department of Orthopaedics and Traumatology and the Department of Spine Surgery at USB, the Department of Neuroorthopaedics at UKBB, several SNSF grants, Toggenburger Stiftung, NCCR Robotics, Werner Siemens Foundation, Swiss Government Fund, Innosuisse, and other private foundations. The group comprises two Postdocs, nine PhD-students and several Master and Bachelor students.

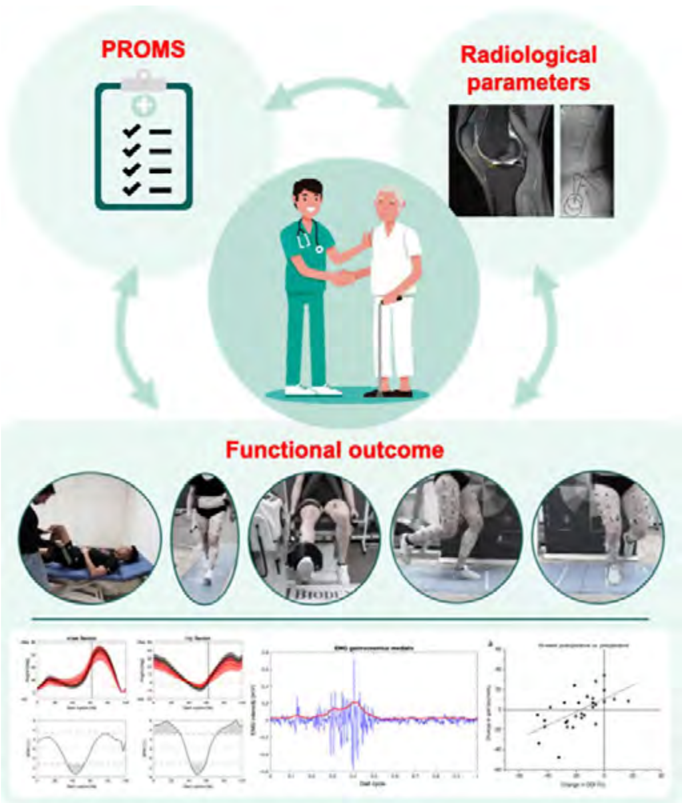

Figure 2: Motion analysis as performed by Annegret Mündermann (image: A Mündermann, L Bühl, C Nüesch, USB/DBE).

Funding:
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UKBB
Swiss National Science Foundation

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Dr. Dorothee Harder, Dr. Balazs Kovacs (Radiology, USB)
Dr. Friederike Prüfer (Radiology, UKBB)
Prof. Daniel Baumgartner (ZHAW)
Prof. Stephen Ferguson, Prof. William Taylor, Dr. Dominika Ignasiak, Dr. Navrag Singh (ETH Zürich)
Dr. Anna-Maria Liphardt (Universitätsklinikum Erlangen)

Bringing Translational Breath Research to the next level

Figure 1: Molecular breath analysis platform at the Translational Medicine Breath Research Lab (picture: TMBR).

Breath analysis holds a vast potential for non-invasive diagnosis and therapeutic monitoring. At the Translational Medicine Breath Research Lab, the next generation of clinical breath tests with a focus on pediatric patients are developed. These research activities lead to intellectual property generation, which was further licensed to Deep Breath Intelligence AG (DBI). DBI is a MedTech start-up uplifting such technology into what will be standard-of-care solutions.

"Please exhale through this mouthpiece". This simple request is exercised daily at the Translational Medicine Breath Research Lab, led by Prof. Sinues and located at the University Children's Hospital Basel (UKBB). Children with a variety of conditions, comfortably provide a breath specimen into a sophisticated instrument and leave the laboratory after a few minutes. The instrument is a high-resolution mass spectrometer that has been modified to allow capturing extremely information-rich breathprints. The children then leave the lab and move to the consultation room. During this short walk, the digital breathprint is being analyzed with machine learning algorithms. By the time the children enter the consultation room, a clinical report has been automatically generated and pushed to the referring physician, who uses this valuable information as guidance to decide the next steps to be taken. This vision is currently being developed jointly between the Translational Medicine Breath Research Lab and DBI to treat children suffering of epilepsy.

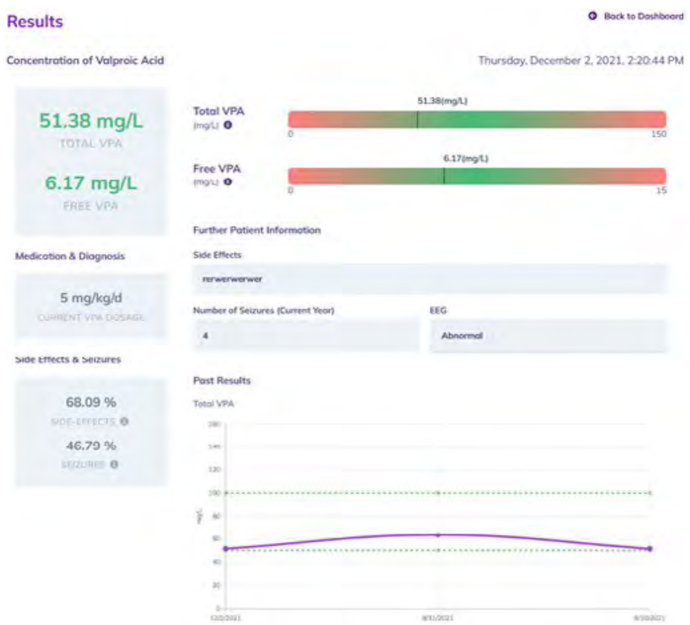

Figure 2: Report generated after the breath test to guide therapeutic management of epilepsy patients (picture: TMBR).

Facts and Figures

- The Translational Medicine Breath Research Lab was founded in June 2017 and is located at UKBB (Basel, Switzerland). The group employs 11 people whose main research foci are: Therapeutic Drug Monitoring | Pneumonia Diagnostics | Metabolomics.
- Deep Breath Intelligence AG was founded in Nov 2018, (Rotkreuz, Switzerland) and employs 6 people. The IP is filed with UKBB/UZH. The Spin-off has contracts with pharma research and the first CE/IVDD medical application is expected in May 2022.

Funding:
fondation BOTNAR
Swiss National Science Foundation

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References:
(1) Singh KD et al. Personalised therapeutic management of epileptic patients guided by pathway-driven breath metabolomics Communications Medicine 2021, 1 (1), 21

Figure 1: Digital future (picture: RC2NB).

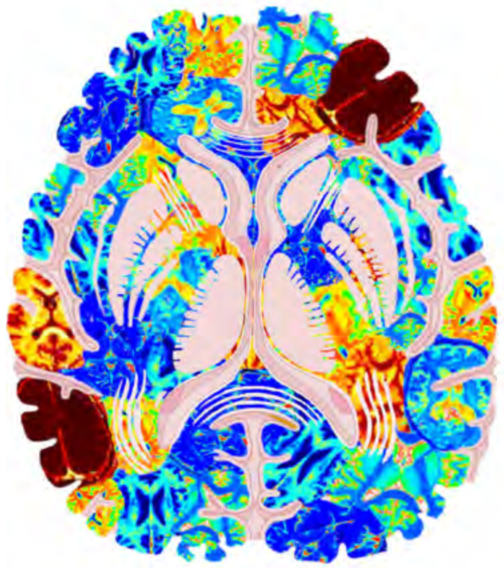

Figure 2: Innovative imaging (picture: C . Granziera).

The Research Center for Clinical Neuroimmunology and Neuroscience Basel (RC2NB) is run by a non-profit foundation of the University Hospital Basel (USB) with participation of the University of Basel.

RC2NB aims at sustainably strengthen the leading position of the University of Basel and the Department of Biomedical Engineering in the field of MS and neuroimmunology by catalyzing innovation in all fields, rendering it attractive to life science industry and research funding institutions.

Moreover, within RC2NB significant synergies are created with other central projects of the University/Medical Faculty and the USB, especially in the fields of personalized medicine and digitalization.

The activities at the RC2NB are divided into three workstreams, which drive different research areas in parallel but at the same time remain intensively networked with each other.

The Translational Imaging in Neurology (ThINk) Basel group of DBE and Neurology is a fundamental part of the second workstream of RC2NB.

Facts and Figures

- 3 Main workstreams: Digital future | Innovative Imaging and analysis of body fluids | Recording and understanding the malfunctioning of the immune system in the laboratory

- CEO: Prof. L. Kappos, Deputy : Prof. Jens Kuhle, COO: Dr. Yvonne Nägelin

Funding:

University of Basel

Universitätsspital Basel

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Prof. Jens Kuhle
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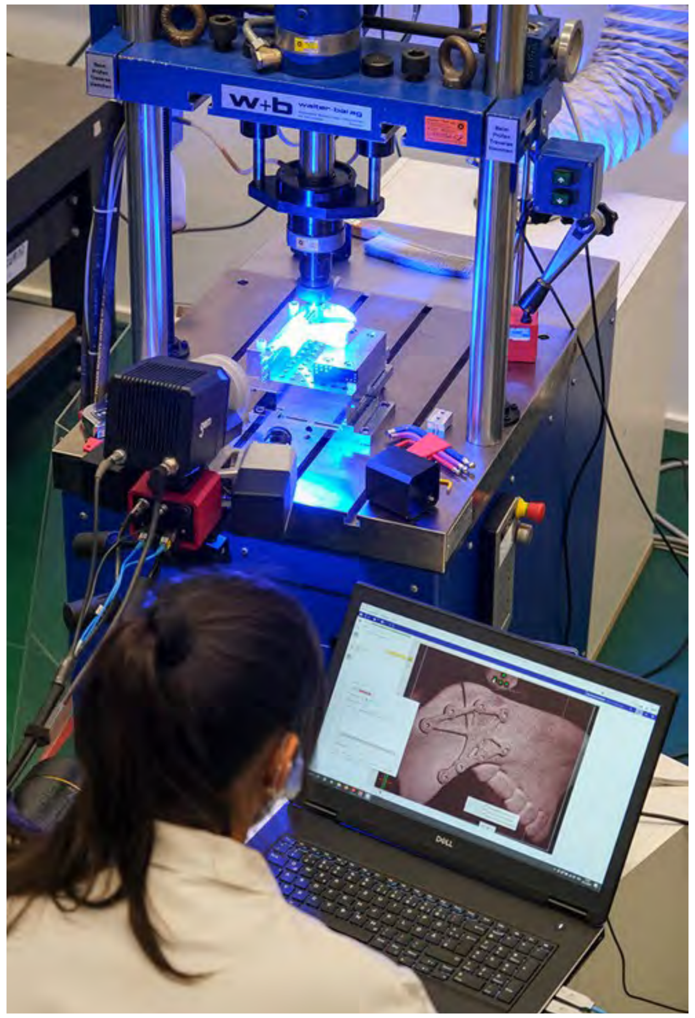

Michaela Maintz dynamically testing the 3D printed individualized metal scaffolds as part of the implant qualification (picture: SwissMAM).

This collaboration enables cranio-maxillo-facial surgeon PD Dr. mult. Florian Thieringer and his team to use patient-specific implants for the benefit of their patients at the University Hospital Basel. Thieringer's groups Swiss MAM, Smart Implants and the 3D Print Lab are collaborating with the Medical Additive Manufacturing Lab of the Institute for Medical Engineering and Medical Informatics IM2 at the Life Sciences Department of the University of Applied Sciences and Arts Northwestern Switzerland (FHNW).

Customized implants are planned, modelled, and simulated on the basis of CT and MRI data at the University Hospital Basel, the final designs are sent to the Medical Additive Manufacturing Lab of FHNW where Daniel Seiler and his teams produce the implants in a medically certified and validated process.

The tight collaboration aims at establishing point-of-care manufacturing of patient-specific "smart" implants at the University Hospital Basel and elsewhere.

Both groups co-supervise the PhD student Michaela Maintz, who appears as personalized link between the institutions and expertise.

The group heads participated in establishing the "3D Printing for Life Sciences" conference as new format for the promotion of Additive Manufacturing at the point of care. Both groups are also working closely together on a joint master's program in biomedical engineering.

Funding:

n|w Fachhochschule Nordwestschweiz

Universitätsspital Basel

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Dr. Neha Sharma, PhD
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Daniel Seiler
daniel.seiler@fhnw.ch

Prof. Dr. Michael de Wild
michael.dewildfhnw.ch

References:
(1) 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. doi: 10.3390/ijms22168521. PMID: 34445228; PMCID: PMC8395180.

(2) www.swiss-mam.ch

USB Innovation-Focus Regenerative Surgery

Figure 1: Engineered cartilage tissue (picture: DBM).

Figure 2: 3D-printed patient-specific cranial implant (PEEK) (picture: Swiss MAM/ Kumovis).

The Innovation-Focus Regenerative Surgery at the University Hospital Basel is about regenerating the structure and function of tissues that have been lost due to injury, disease, or aging processes. With innovative treatment strategies, we aim to permanently preserve our patients' mobility and increase their quality of life. Research and scientific advances at the DBE are closely interlinked with this new interdisciplinary platform, including the Department of Biomedicine (DBM) and several clinical / surgical partners at the USB.

In the IFRS we grow tissue and use pioneering techniques such as robotics, laser osteotomy, 3D printing and virtual surgical planning to offer individual therapies tailored to our patients. On the one hand, we want to improve the clinical outcomes that are possible with today's methods. On the other hand, we also want to treat diseases that we have not yet been able to cure, including osteoarthritis.

For example, we are currently working on cultivating cartilage that we want to use for (knee) osteoarthritis. There is still no generally recognized treatment strategy for this. Another example of our work: in the reconstruction of bone, we use advanced virtual surgical planning and imaging technologies and print at the point-of-care (in the hospital) individually adapted, precise implants in a 3D printer. Since many people suffer from back pain, we are also focusing on the regeneration of intervertebral discs with the help of cultured cells.

The team aims at cutting-edge scientific and technological achievements, their pioneering clinical translation and a cultural environment of interdisciplinary and innovation.

Project video:
https://player.vimeo.com/video/638686576?h=01d232607

Institutions:

Universitätsspital Basel
Departement Biomedizin Basel
University of Basel, Department of Biomedical Engineering

and collaborating clinics

Representative DBE:
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www.swiss-mam.ch

References:
(1) Wang F. et al. Polymers 2022, 14, 669.

(2) Shuaishuai C. et al. Materials 2020, 13, 3057.

(3) Honigmann P et al. Biomed Res Int, 2021.

(4) Sharma N et al. J Clin Med, 2020.

International and National Collaboration for a United Course

Figure 1: Dr. Benito Benitez (BRCCH-project-cooperation-lead in Warsaw), Dr. Lek. Zbigniew Surowiec (Deputy Head of Department for Treatment of Craniofacial Defects), Mr. Jürg Burr (Ambassador of Switzerland to Poland), Prof. Ewa Sawicka (Head of Clinic of Paediatric Surgery), MD Alicja Karney PhD (Deputy Director of Clinical Affairs Institute Mother and Child), Lek. Łukasz Wieprzowski, Dr. Andrzej Brudnicki (Assistant Professor, Institute Mother and Child) (picture: assistant to Mr. Burri, Embassy of Switzerland, Warsaw, Poland).

Figure 2: Dr. Prasad Nalabothu (BRCCH-project), PD Dr. Dr. med. Dr. mult. Andreas A. Müller (BRCCH-project), Monika Kapil Mohta (Indian Ambassador), Dr. Maren Roche (BRCCH-project), Dr. Charlotte Werthemann (USB, Lead External Affairs), Dr. Baran Gözcü (BRCCH-project), Mr. Deepak Bansal (Deputy to the Indian Ambassador) (picture: assistant to Mrs. Mohta, Embassy of India, Berne, Switzerland).

Our Burden-Reduced Cleft lip and palate Care and Healing Multi-Investigator Project (2020-2025) with the Botnar Research Center for Child Health, took a huge step forward in 2021. We, together with our national collaborators at ETHZ (computer graphics laboratory, Barbara Solenthaler, PhD) and Disney Research (Prof. Markus Gross), initiated our collaborations with: Assistant Prof. Andrzej Brudnicki at the Institute of Mother and Child in Warsaw/Poland; Prof. R.V.M. Surya Rao, Saveetha Medical College and Hospital, Chennai/ India and Prof. Syed Altaf Hussain, Sri Ramachandra Institute of Higher Education and Research Medical Center, Chennai/India.

To mark the initiation of these international collaborations, DBE members of the Facial and Cranial Anomalies (FCA) group of PD Dr. mult. Andreas Müller were invited, as part of a delegation, to the Swiss Embassy in Warsaw (fig. 1) and to the Indian Embassy in Bern (fig. 2).

These collaborations focus on knowledge exchange and aim at further improving the treatment regime for patients with cleft lip and palate, world-wide. As part of the project we will produce an individual shaped and automatically designed 3D printed palatal plate, without the need for plaster cast impression, and so avoiding the risk of airways obstruction. To achieve this ambitious goal, we are now also collecting intraoral scan data together with our international partners in Poland and India and we move forward, together.

Funding:

BRCCH Botnar Research Centre for Child Health
University of Basel
FAG Freiwillige Akademische Gesellschaft Basel seit 1835

Group Leader:
PD Dr. mult. Andreas Albert Müller
aa.mueller@unibas.ch

References:
(1) Benitez BK, Brudnicki A, Surowiec Z, Singh RK, Nalabothu P, Schumann D, Mueller AA, Continuous Circular Closure in Unilateral Cleft Lip and Plate Repair in One Surgery, Journal of Cranio-Maxillofacial Surgery, 2021

Leveraging International Collaboration for Innovative Research

Figure 1: Presenting DBE research in person at the International Symposium on Medical Robotics (ISMR) 2021 in Atlanta, GA, USA (picture: N. Friederich).

Figure 2: Attending the conference in Atlanta was combined with with a visit to research labs at Vanderbilt University in Nashville, TN, USA (picture: G. Rauter).

Figure 3: BIROMED-Lab PhD student Lorin Fasel joined Prof. Bob Webster's MED-Lab at Vanderbilt University for a month to work on a collaborative project (picture: L. Fasel).

International collaborations boost innovation in research by sharing knowledge and by giving new perspectives. Especially in times of home-office and virtual events, we have come to value meeting our collaborators in person. Thanks to funding by Dr. h.c. Hans-Heiner Zaeslin, three DBE members had the chance to travel to the USA in November 2021 to present their research at the International Symposium on Medical Robotics (ISMR) and to visit research labs at Vanderbilt University.

The cooperation with Vanderbilt University (Nashville, TN, U.S.A.) started in 2018, when Prof. Dr. Robert Webster III. visited the DBE site in Allschwil to give a lecture as "Erwin Morscher Visiting Professor". Prof. Webster and his lab (1) are distinguished researchers in the field of surgical robotics and thus share many common research interests with the DBE. Prof. Webster and his collaborators organized a very interesting and inspiring two-day tour of the Vanderbilt biomedical engineering research facilities for the DBE delegation.

The visit in Nashville was combined with the presentation of our research (2) at the International Symposium on Medical Robotics (ISMR) in Atlanta, GA, USA.

After the symposium, BIROMED-Lab PhD student Lorin Fasel joined Prof. Webster's MEDLab again for a month to start work on a collaborative project. The project aims at developing a soft robot for minimally invasive knee cartilage repair. During the visit, groundwork was laid for the registration of the robot, i.e., using sensor data to determine where the robot is with respect to the patient anatomy. This initial work opens the door for safer control of soft robots – and the continuation of a fruitful collaboration.

Funding:
Claudine und Hans-Heiner Zaeslin-Bustany-Stiftung

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Prof. Dr. Niklaus F. Friederich
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References:
(1) MEDLab at Vanderbilt University: http://research.vuse.vanderbilt.edu/MEDLab/

(2) L. Fasel, N. Gerig, P.C. Cattin, and Georg Rauter, "The SEAScop: Torque limited endoscopic joint control for telemanipulation or visual servoing through tendon force control with series elastic actuation", 2021 International Symposium on Medical Robotics (ISMR), Atlanta, GA, USA, 2021.

Collaborating Institutions & Partners

3devo
3D SYSTEMS
Ad Mirabiles – mesmerizing implants
additiveflow
AGA – Gesellschaft für Arthroskopie und Gelenkchirurgie
Amsterdam UMC – Universitair Medische Centra
AO CMF
AO Research Institute Davos
AOT
Apium – Additive Technologies GmbH
ARGODENTIS ZAHNMEDIZIN
axial3D – Patient data made real
BASEL AREA.SWISS
Departement Biomedizin Basel
bott MEDICAL
bott NEURO
BRUKER – Bruker microCT
Chinese Academy of Sciences
ceb
chondrometrics
CELLEC BIOTEK AG
CHARITÉ – UNIVERSITÄTSMEDIZIN BERLIN
CMX
COLGATE-PALMOLIVE
cost – EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY
credentis
csem – centre suisse d'électronique et de microtechnique
deep breath intelligence
DPU – DANUBE PRIVATE UNIVERSITY – Fakultät Medizin/Zahnmedizin
DESY.

University of Basel
Department of Environmental Sciences

Deutsche Arthrose-Hilfe e.V.
DAH

diamond

DISIOR

Drexel UNIVERSITY

ESRF

ETH zürich

CYBATHLON
ETH zürich

EVONIK

EXCISCOPE

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Universidad de Valladolid

n|w Fachhochschule Nordwestschweiz

FAU FRIEDRICH-ALEXANDER UNIVERSITÄT ERLANGEN-NÜRNBERG

山东大学齐鲁医院
QILU HOSPITAL OF SHANDONG UNIVERSITY

GLOOR INSTRUMENTS

HEIDELBERG ENGINEERING

HOCHSCHULE FURTWANGEN UNIVERSITY HFU

Les Hôpitaux Universitaires de STRASBOURG

HAAG-STREIT

Hochschule Offenburg
University of Applied Sciences

IFToMM

Inserm
La science pour la santé
From science to health

interreg
Oberrhein
Rhin Supérieur

INSTITUT de MATHEMATIQUES de TOULOUSE

The Interface Group

INSTITUT P'

IPAS

暨南大學
JINAN UNIVERSITY

Institute of Mother and Child

Kantonsspital Baselland

Kantonsspital Aarau

Kantonsspital Graubünden

KIT
Karlsruher Institut für Technologie

KIDNEY CONTROL OF HOMEOSTASIS
SWISS NATIONAL CENTRE OF COMPETENCE IN RESEARCH

KUMOVIS

LÖWENSTEIN medical technology

materialise
innovators you can count on

MIAC
Medical Image Analysis Center

FACULTATIS MEDICINAE BASILIENSIS 1460

naturhistorisches museum Basel
archive des lebens

PAUL SCHERRER INSTITUT
PSI

DEPARTMENT OF PHARMACEUTICAL SCIENCES

robotics
Swiss National Centre of Competence in Research

REGEMAT 3D

REHA STIM MEDTEC

REHABILITATION ENGINEERING SCIENCE

SAVEETHA
INSTITUTE OF MEDICAL AND TECHNICAL SCIENCES

SIEMENS Healthineers

SWISS LIGHT SOURCE
SLS

SWITZERLAND INNOVATION
PARK BASEL AREA

SOLEIL SYNCHROTRON

SNI
SWISS NANOSCIENCE INSTITUTE
EINE INITIATIVE DER UNIVERSITÄT BASEL UND DES KANTONS AARGAU

SPENTYS
REINVENTING ORTHOPEDICS

Stanford MEDICINE

stratasys

swiss orthopaedics

SYNOVA

UNIVERSITÄTS KLINIKUM FRANKFURT
GOETHE-UNIVERSITÄT

Unil
UNIL | Université de Lausanne

UNIST
ULSAN NATIONAL INSTITUTE OF SCIENCE AND TECHNOLOGY

THE UNIVERSITY OF AUCKLAND
Te Whare Wānanga o Tāmaki Makaurau
NEW ZEALAND

1495
UNIVERSITY OF ABERDEEN

Universitätsspital Basel

1431
Université de Poitiers

UNI FREIBURG

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

UNIVERSITY OF LEEDS

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND
SAPERE AUDE

UNIVERSITÉ DE GENÈVE

UPPSALA UNIVERSITET

UNIVERSITY OF Massachusetts Amherst

u^b UNIVERSITÄT BERN

université PARIS-SACLAY

Universitätsklinikum Erlangen

Université de Strasbourg

VNIVERSITAT DE VALÈNCIA

Universität Zürich[UZH]

THE UNIVERSITY of WISCONSIN MADISON

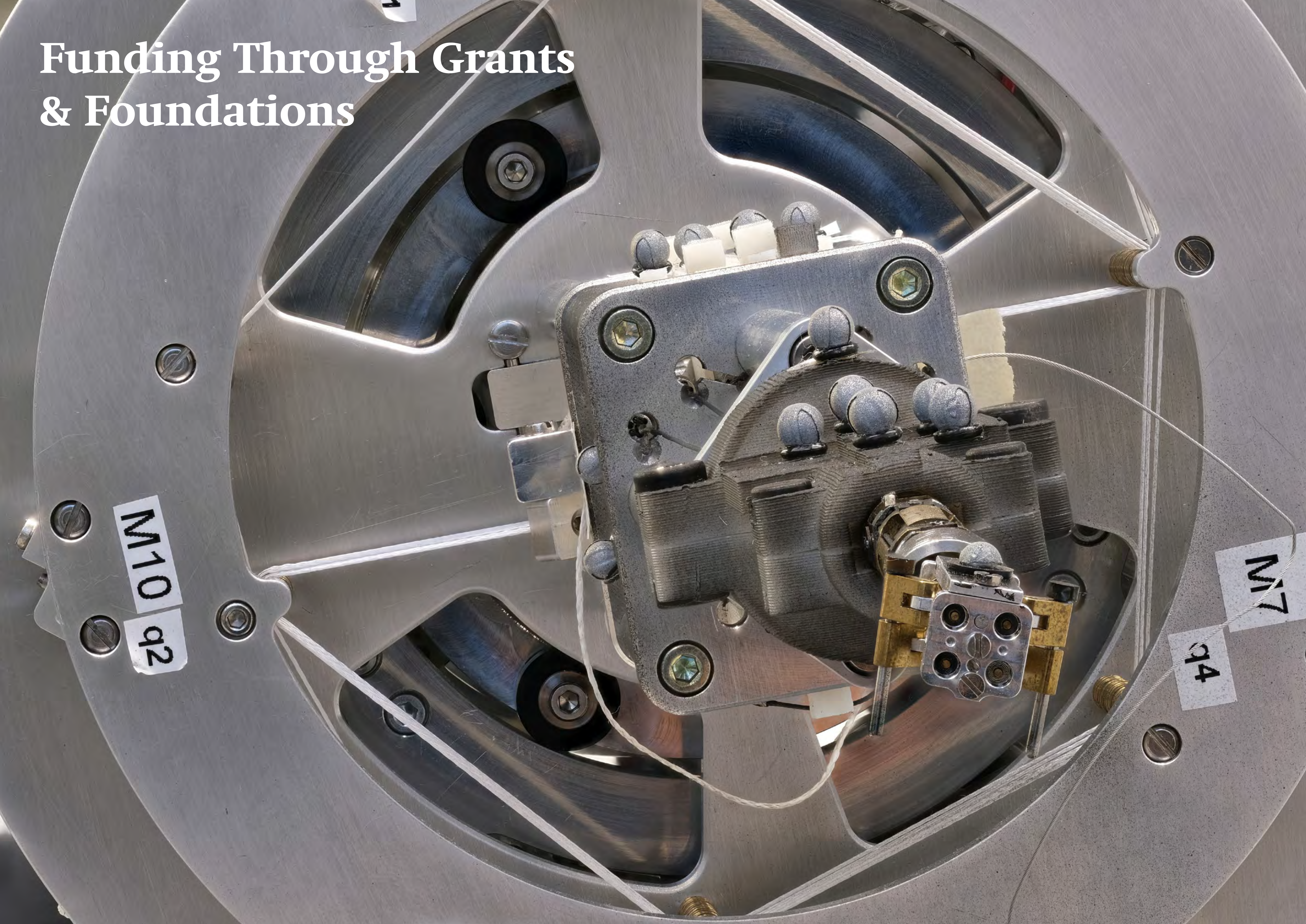
USZ Universitäts Spital Zürich

UZB Universitäres Zentrum für Zahnmedizin Basel

Zurich University of Applied Sciences
zhaw School of Engineering

ZEISS

Funding Through Grants & Foundations



Research Funding secured in 2021

Figure 1: Robotic endoscope for minimally invasive laser surgery developed by the team of Prof. Georg Rauter (picture: R. Wendler).

SNSF Grants

Prof. Cristina Granziera's main research project entitled "ImagiNg the Interplay between Axonal DamagE and Repair in Multiple Sclerosis – Remyelinating lesions And Pathways" will be supported with an additional 796 kSFR.

PD Dr. Cordula Netzer has been granted 900 kSFR for her project "Role of spinal load in the pathophysiology of lumbar spinal stenosis: a translational approach combining clinical, functional and radiological parameters, in vivo biomechanical experiments and advanced in silico musculoskeletal modeling" (RoLSSroice).

PD Dr. mult. Andreas Müller received funding for a 4-year project called "Learning-based 3D Infant Face and Head Model for Medical Applications".

Prof. Bert Müller and Consortium for the MiNa Core Facility have been granted an SNSF R'Equip Grant over 856 kSFR to purchase an innovative micro-CT to equip the Core Facility MiNA (Micro & Nano Tomography).

Prof. Najat Salameh has been granted an additional 800 kSFR for her on-going project "Interventional and susceptibility artefact free MRI".

Prof. Elke Viehweger and **Rosa Visscher** have been granted 429 kSFR for their project "Stop Tip-Toeing Around Toe-Walking".

Prof. Georg Rauter has been funded with 200 kSFR for the development of an "Origami-Based Human-Robot-Interface for Stabilizing Deployable Miniature Robots for Minimal-Invasive Laser Surgery".

Innousuisse Grants

Dr. Olivier Braissant has been granted 245 kSFR for the project "Natur-Aligner 2.0 – Body-friendly teeth alignment reinforced with natural oral care".

Beat Göpfert has been granted 23 kSFR for the project "MOWA 4.0".

Prof. Georg Rauter has been granted 15 kSFR for for their project "Virtuoso gloves".

European Funding

Prof. Georg Rauter has been funded with 18 kSFR for the project "The surgeon's eye: Structural intelligence and visual servoing to enable safe automated tracking of surgical tools in robot-assisted minimal invasive surgery".

Third Party Funding

Prof. Philippe Cattin has been granted 341 kSFR by Roche for his project "Invention and development of a cell and organoid instrument prototype".

Prof. Philippe Cattin and **Philippe Valmaggia** have been funded with 20 kSFR for their project "Time-resolved 3D Optical Coherence Tomography Angiography for novel biomarkers".

Dr. Christoph Jud has been granted 144 kSFR by Idorsia for his project "Accelerated Deep Learning".

PD Dr. mult. Andreas Müller and his team have been granted 25 kSFR by the Freiwillige Akademische Gesellschaft (FAG).

Prof. Georg Rauter has been granted the 100 kSFR Christian Toggenburger Award for the project "Spinebot2".

Dr. Georg Schulz and **Prof. Bert Müller** have been granted 32 kSFr by the Swiss Nanoscience Institute within the Nano-Argovia initiative for their project "Development of Achromatic X-ray Lenses for Laboratory Transmission X-ray Microscopy" (ACHROMATIX).

Research Fund for Junior Researchers

Dr. Reina Ayde has been granted 50 kSFR for her project "High fidelity deep learning reconstruction for fast low field MRI".

Dr. Ferda Canbaz received a 50 kSFR grant for a project seeking for the development of new an innovative laser sources.

Dr. Lukas Graf has been granted 14 kSFR for his project "Experimental Development of Implantable Microphones".

Figure 2: A vaccum chamber at the biomaterials science center headed by Prof. Bert Müller (picture: R. Wendler).

Funding Institutions

University of Basel

WSS
WERNER SIEMENS-STIFTUNG

Swiss National Science Foundation

Innosuisse - Swiss Innovation Agency
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Education, Research and Innovation SERI

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Eidgenössisches Departement des Innern EDI
Bundesamt für Gesundheit BAG

Jacobson-Goldschmidt Stiftung

WISSENSCHAFT. BEWEGEN
GEBERT RÜF STIFTUNG

fondation BOTNAR

BRC CH Botnar Research Centre for Child Health

Osteology Foundation

Horizon 2020
European Union Funding for Research & Innovation

HMZ

NOVARTIS

F H
Berner Fachhochschule
Haute école spécialisée bernoise
Bern University of Applied Sciences

AO Research Institute Davos

MERIAN ISELIN
Klinik für Orthopädie und Chirurgie

suva

propatient
Forschungsstiftung Universitätsspital Basel

FAG
Freiwillige Akademische Gesellschaft Basel
seit 1835

eurostars™

sgms

VELUX STIFTUNG

AGA
Gesellschaft für Arthroskopie und Gelenkchirurgie

swiss orthopaedics

Deutsche Arthrose-Hilfe e.V.
DAH

Education & Completed Student Theses

The PhD-Program in Biomedical Engineering

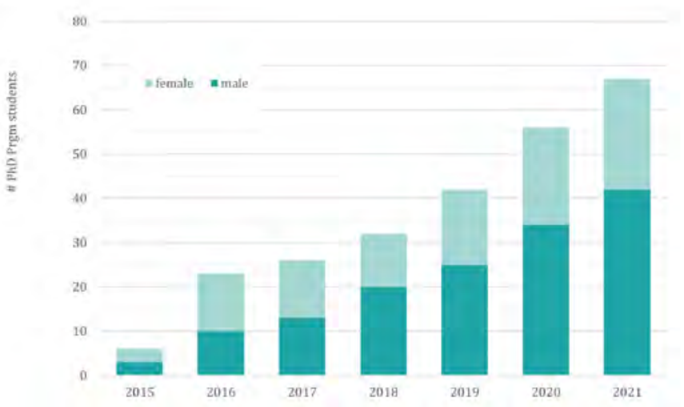


Figure 1: Number of participants in the PhD program in biomedical engineering, broken down by gender.

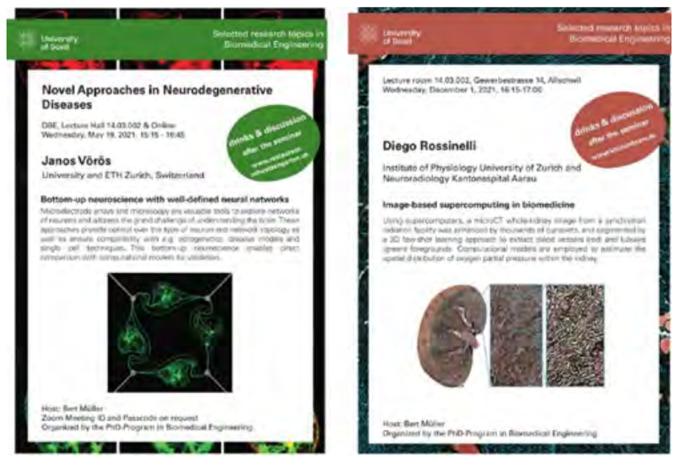


Figure 2: Two attractive posters of seminars announced in 2021. The audience appreciated the inspiring presentations and related scientific discussions with the high-ranking experts (picture: B. Müller, DBE).

The PhD-Program in Biomedical Engineering started in 2015 with very few students. Since then the number of participating students is constantly increasing, as shown in Figure 1. The figure further shows the gender balance between male and female doctoral students.

In 2021, 16 doctoral students started a thesis project among them four who previously completed the DBE's Master's of Science in Biomedical Engineering. The interdisciplinary program hosts students with a degree from the University of Basel (27%), a degree from other Swiss universities (21%) and about 50% who earned an international master degree.

The pandemic had greatly influenced the PhD-Program this year again. In spring, the seminar series entitled "Novel Approaches in Neurodegenerative Diseases" with virtual and life seminars was organized and advertized as shown in Figure 2 on the left. In autumn the uncertain travelling situation interfered with the seminar's schedule and we could only offer selected seminars, as for example the one advertised in figure 2 on the right.

The Summer School, planned to happen in the Black Forest, had to be reorganised into a modular fashion and shifted to a virtual format. This year the topic was "Applications of Machine Learning in the Medical Field". After the introduction into the subject, the students applied their knowledge in groups. Additionally, presentations from start-up (RetinAI), mid-sized (Idorsia) and established companies (Amazon Robotics, Sonova) showed the students how machine learning is implemented in medtech and pharma industries.

PhD Committee Director:
Prof. Dr. Bert Müller
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PhD Program Coordinator:
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Completed PhD Theses

Marek Zelechowski working on his PhD project dedicated AR visualization and control of surgical robot (picture: O. Lang, Werner Siemens Foundation).

Despite the pandemic, which again this year has created a demanding environment for research, several students completed their PhD thesis at the DBE:

- Lina M. Beltrán B (BLOG)...................................... 68
- Manuela Eugster (BIROMED-Lab) 69
- Lorenzo Iafolla (Planning & Navigation) 70
- Andrea Mainardi (Tissue Engineering) 71
- Prasad Nalabothu (Pediatric Oral Health)................ 72
- Griffin Rodgers (BMC)... 73
- Neha Sharma (Smart Implant)................................ 74

Laser and Wave-Guides System for Endoscopic/ Fiberscopic Laser Surgery

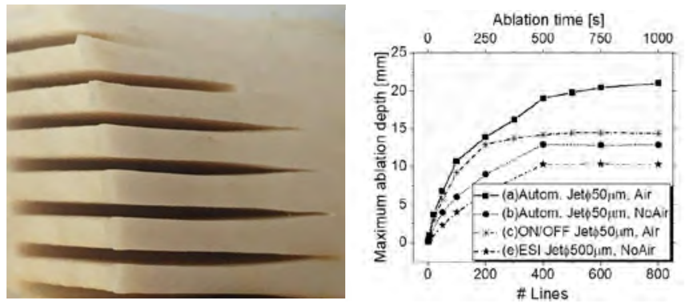

Figure 1: Left: photograph of a bone ablated in free space by the Er:YAG laser under optimized conditions. Right: ablation depth variation with the number of lines and time for line ablation of the bone shown in the left (picture: L. Beltrán).

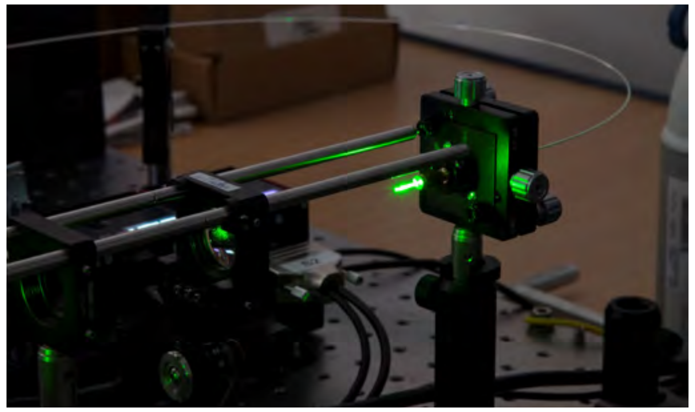

Figure 2: Photograph of the coupling setup with a green laser for visualization (picture: R. Wendler/DBE).

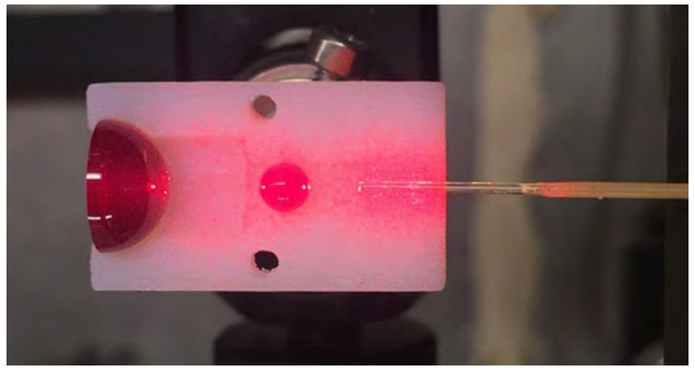

Figure 3: Photograph of the fiber end tip and the refocusing system, designed to obtain a focal plane at 10cm beyond the last lens (picture: L. Beltrán).

PhD Thesis by Lina M. Beltrán B (Department of Biomedical Engineering, University of Basel) at Biomedical Laser and Optics Group (BLOG).

Using lasers in surgery offers a great advantage over the conventional mechanical tools. Lasers allow for contactless cutting, free and flexible cutting shapes, and localized ablation that minimizes heat in the surrounding tissue. Due to the advantages lasers offer, laser technology has been also implemented in minimally invasive procedures. However, the use of lasers for ablating hard tissue is still very limited, especially for deep ablation.

This PhD thesis project has two main objectives. The first is to investigate and optimize a laser system for deep bone ablation (1). The second aim is to perform deep bone ablation using the laser coupled into an optical fiber. Here, the optimization methods obtained in the free space laser system were implemented (2).

The free space laser system consists of an Er:YAG laser working at a wavelength of λ=2.94µm. The optimization of the laser parameters for deep ablation was made possible by eliminating some of the factors that stop laser ablation deep in tissue, like the limitation of a spray system to reach deeper into the tissue, and the accumulation of water and debris acting as a shield against the laser energy. First, we used a novel thin water jet of 50µm diameter capable of reaching deeply into the bone while being ablated, together with a feedback system to obtain the superficial temperature of the bone and control the irrigation system. Additionally, pressurized air was used to reduce the debris and water excess. We found that deep bone ablation requires an understanding of the beam propagation within the tissue and a meticulous procedure to increase the average laser power. With this optimized system a maximum depth of 21mm was achieved in pig bone (1). The laser used in free space was coupled to various optical fibers from where a germanium oxide fiber was chosen to perform deep bone ablation together with a refocusing system (fig. 3). The maximum depth achieved was 10mm in pig bone at 450mJ and 7mm in sheep bone at 370mJ (2).

Funding:

WSS
WERNER SIEMENS-STIFTUNG

Supervision:
Prof. Dr. Ing. Azhar Zam
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Prof. Dr. Philippe C. Cattin
philippe.cattin@unibas.ch

Prof. Dr. Niklaus F. Friederich
niklaus-f.friederich@unibas.ch

References:
(1) Beltran, L.M., et al, 2020. Optimizing deep bone ablation by means of a microsecond Er:YAG laser and a novel water microjet irrigation system. Biomedical Optics Express, 11(12), pp.7253-7272.

(2) Beltran, L.M., et al, 2021. Optical fibers for endoscopic high-power Er:YAG laserosteotomy. Submitted to Journal of Biomedical Optics.

Robotic System for Accurate Minimally Invasive Laser Osteotomy

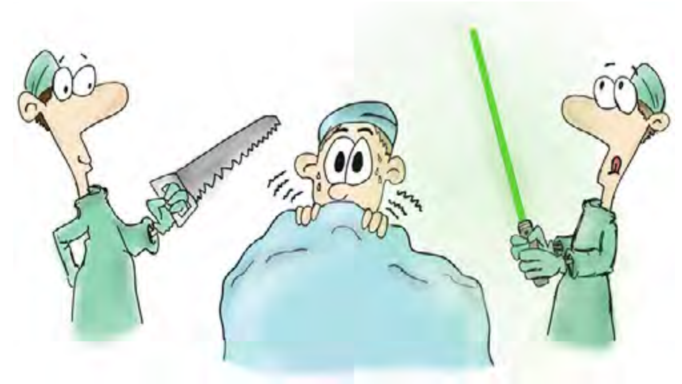

Figure 1: Have you decided whether you want conventional or laser surgery? (picture: M. Eugster).

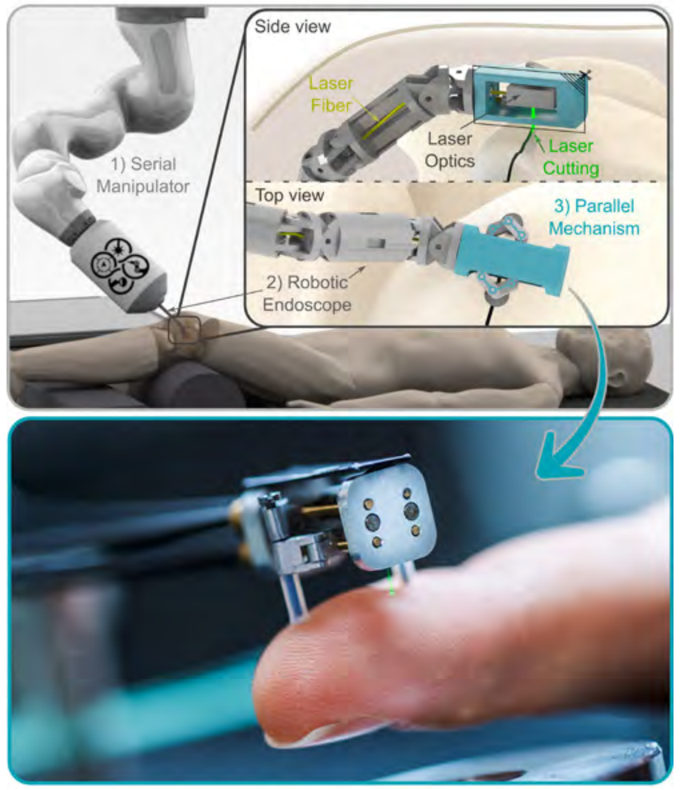

Figure 2: The developed robotic system for accurate minimally invasive laser osteotomy (Bottom photography: Werner Siemens-Stiftung, Frank Brüderli, other picture content: M. Eugster).

PhD Thesis by Manuela Eugster (Department of Biomedical Engineering, University of Base) at the BIROMED-Lab.

Bone cutting, so-called osteotomy, is an essential part of many surgical procedures. Nowadays, bone cutting is mainly performed using mechanical devices such as milling cutters, drills, and saws. Laser osteotomy is a novel alternative for cutting bone with several advantages compared to conventional methods. However, existing devices for cutting bone with laser require direct access to the entire bone, i.e., are not minimally invasive.

This PhD project is part of an overall project called Minimally Invasive Robot-Assisted Computer-guided LaserosteotomE (MIRACLE), aiming to make minimally invasive bone cutting possible. My PhD thesis (1) focused on the challenges in robotics in developing a system for minimally invasive insertion and accurate positioning of a laser for cutting bone in Unicompartmental Knee Arthroplasty (UKA) (2). One of the main challenges in developing such a system is to achieve the desired high positioning accuracy of the laser with a dexterous device with a small diameter suitable for minimally invasive interventions.

We developed and evaluated a concept and first prototype of a robotic system consisting of 1) a serial manipulator guiding 2) a robotic endoscope for minimally invasive insertion of the laser fiber, and 3) a bone-mounted parallel mechanism (3) integrated at the robotic endoscope's tip, which will allow accurate positioning of the laser optics, i.e., of the laser on the bone during cutting.

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References:
(1) M. Eugster, "Robotic System for Accurate Minimally Invasive Laser Osteotomy." PhD Thesis, University of Basel, 2021.

(2) M. Eugster et al., "Quantitative Evaluation of the Thickness of the Available Manipulation Volume Inside the Knee Joint Capsule for Minimally Invasive Robotic Unicondylar Knee Arthroplasty," in IEEE Transact. Biomed. Engineering.

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Development of an Angular Sensor for Shape Sensing of Medical Robots

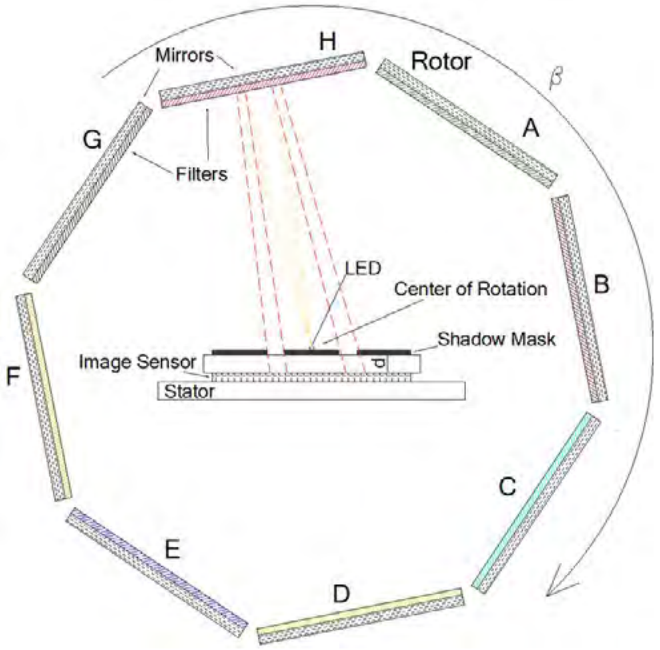

Figure 1: Schematic of ASTRAS360 (picture: L. Iaffola).

Figure 2: Picture of the first prototype of ASTRAS360 (picture: L. Iaffola).

PhD Thesis by Lorenzo Iafolla (Department of Biomedical Engineering, University of Basel) at Planning and Navigation Group.

Tracking is a crucial need to control an endoscopic surgical tool accurately. For this reason, this work aims to develop new solutions to track the pose and to sense the shape of robotic articulated endoscopes for minimally invasive surgery.

This thesis lays down the foundations for a new method based on a novel, miniaturizable, angular measuring system, called ASTRAS (Angular Sensor for TRAcking Systems). The tracking method involves measuring the joints bending angles of the articulated endoscope by placing one ASTRAS in each of them.

As ASTRAS is a novel concept, it was necessary to define and test the methods to achieve the required performance. For example, we demonstrated that ASTRAS is very precise (5arcsec) even when using miniaturized components (overall size ~1×1×1mm^3).

The result of this work is the know-how to design new versions of ASTRAS specifically for minimally invasive robotics. Furthermore, ASTRAS is prone to further developments, enabling further applications, such as tracking of continuum robots.

Facts and Figures

ASTRAS generates a shadow image with a one-to-one correspondence to an input angle. ASTRAS360 is a development of ASTRAS able to measure over the full rotation angle (360°). Figure 1 on the left shows the schematic of ASTRAS360. Figure 2 below represents its first prototype.

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Organs-on-Chip as Advanced Models of Osteoarthritis and Mechanically Active Body Districts

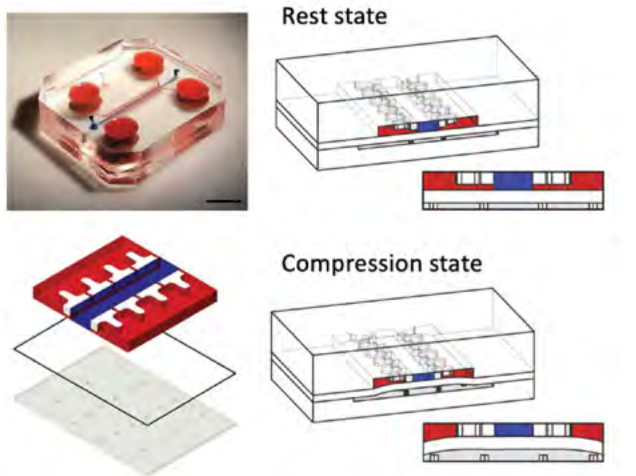

Figure 1: Schematization of the cartilage on chip device. Culture chamber and actuation chamber are divided by a thin PDMS membrane. A 3D cellular constructs (in blue) is subjected to defined levels of confined compression (picture: A. Mainardi).

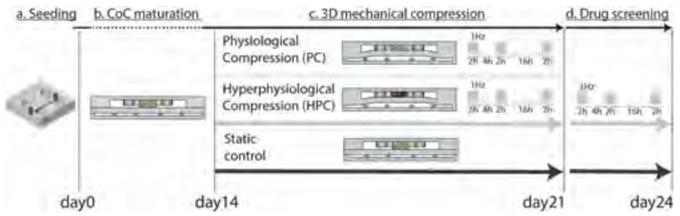

Figure 2: Experimental timeline. After 2 weeks of maturation a healthy cartilaginous construct can be obtained on chip. HPC is then used to induce OA traits in the constructs. The model was adopted to screen different anti OA compounds (picture: A. Mainardi).

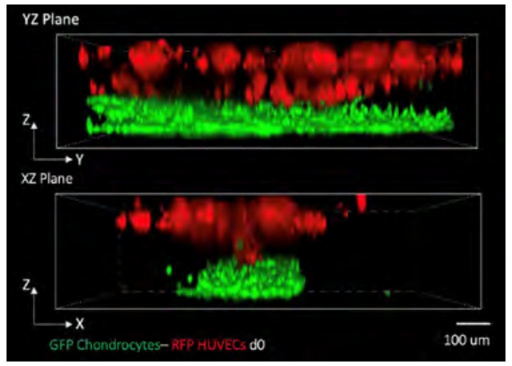

Figure 3: 3D confocal reconstruction of biphasic superimposed constructs (picture: A. Mainardi).

PhD Thesis by Andrea Mainardi at the Tissue Engineering Group of the University of Basel and at the MiMic Group of Politecnico di Milano (cotutelle de thèse).

Osteoarthritis (OA), the most diffused musculoskeletal pathology, is a degenerative whole joint disease correlated with mechanical risk factors (e.g. joint injury or misalignment, obesity). Most OA in vitro models, however, do not account for the multiplicity of tissues affected, nor for the mechanically active joint environment.

In this thesis the Organ-on-Chip (OoC) technology (i.e. the use of micro-fabricated devices aiming at replicating organ and tissue functions) was adopted to develop relevant in vitro OA models.

A mechanically active OoC (fig. 1) capable of providing 3D chondrocytes-based tissues with hyperphysiological compression (HPC) was developed. A cartilage on chip model that replicated OA traits such as unbalanced anabolic/catabolic processes, tissue inflammation and chondrocytes hypertrophy could thus be achieved. The model was adopted to screen possible anti-OA compounds (fig. 2) (1). Moreover, it was feasible to engineer a multi chamber version of the device increasing its overall experimental throughput (2).

OA has been described as a whole joint disease. To account for this fact the final aim of the thesis was that of engineering an OoC device capable of providing biphasic micro-constructs (fig. 3) with compartment specific compression levels. Osteochondral like micro-constructs featuring a cartilaginous layer and a mineralized/vascularized layer were achieved on chip. The proposed OoC models may enable the screening of disease-modifying OA drug candidates with innovative targets and help the dissection of OA onset mechanisms.

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(1) Occhetta P and Mainardi A, et al. Hyperphysiological compression of articular cartilage induces an osteoarthritic phenotype in a cartilage-on-a-chip model. Nat Biomed Eng 2019 37 3:545–557.

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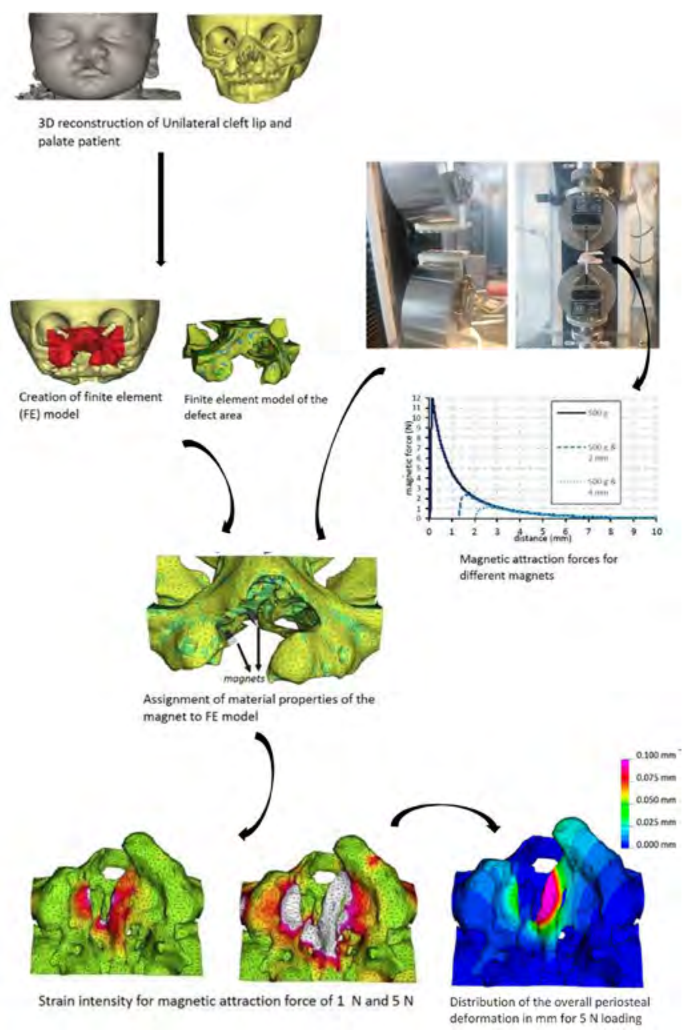
Smart Implants for Mucoperiosteal Tissue Expansion in Cleft Palate Defects



Measurement of the gap dependency of magnetic force was used to study the strain induced by dental magnets in a finite element model of defect area in unilateral cleft lip and palate. The periosteal deformation resulting from the strain in the model at 5 N is shown at bottom left (picture: adapted from ref (1) and (2)).

PhD Thesis by Prasad Nalabothu at Pediatric Oral Health and Orthodontics, UZB and Department of Oral and Craniomaxillofacial Surgery, USB.

Cleft lip and palate are the most craniofacial malformations, affecting one in every 500 to 700 live births. The surgery can solve the problems, but to determine a good surgical outcome, the surgeons have to be able to interpret the actual size of the cleft and have to be able to generate enough periosteal tissue to close the defect. The surgeons faced a challenge to measure the cleft size due to wide diversity in methodologies employed.

We have introduced the vomer edge for establishing a validated 3D measuring method for the width, area and height of the true cleft with reproducible landmarks for easy and accurate measurement of the outcomes in unilateral cleft lip and palate patients. The passive plate therapy provided to ULCP patients gave anatomical conditions for subsequent surgical palatal repair in patients by alleviating the problems of tissue deficiency to some extent. We therefore adopted periosteal tissue distraction osteogenesis as potential treatment strategy, to target the tissue deficiency while using the magnetic forces to exert necessary strain.

In our study, we have assessed whether the dental magnets have the potential to act as a device to generate mucoperiosteal tissue in UCLP. We have used in-silica approach in the form of 3D FE-model and found that strain levels in the palatal segments of the cleft for the load cases do reach 1500 μ strain limit, a requirement for bone formation, according to the mild overload window of the Mechanostat theory proposed by Harold Frost. We further examined the forces, which reach threshold for regeneration of the hard and soft tissue volumes along the cleft edges in both UCLP and BCLP by means of periosteal distraction. We found that 5N attraction force could initiate generation of soft and hard tissue along the cleft edges.

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(1) Nalabothu P, Verna C, Benitez BK, Dalstra M, Mueller AA. Load Transfer during Magnetic Mucoperiosteal Distraction in Newborns with Complete Unilateral and Bilateral Orofacial Clefts: A Three-Dimensional Finite Element Analysis. Appl. Sci. 2020; 10(21):7728.

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Hard X-ray Tomography for Virtual Histology of the Brain with Cellular Resolution

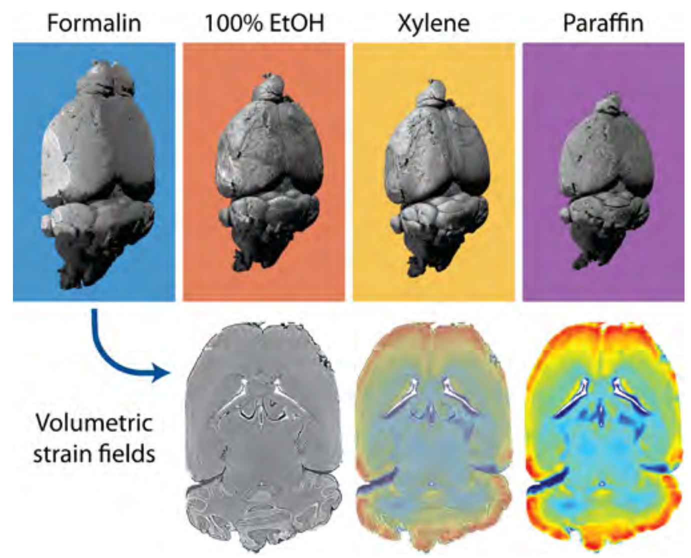

Figure 1: Virtual histology datasets of an entire mouse brain at each step towards paraffin embedding were non-rigidly registered to characterize volumetric strain fields and compare contrast of selected anatomical features. It forms a basis for next-generation brain atlases (pictures: G. Rodgers/BMC).

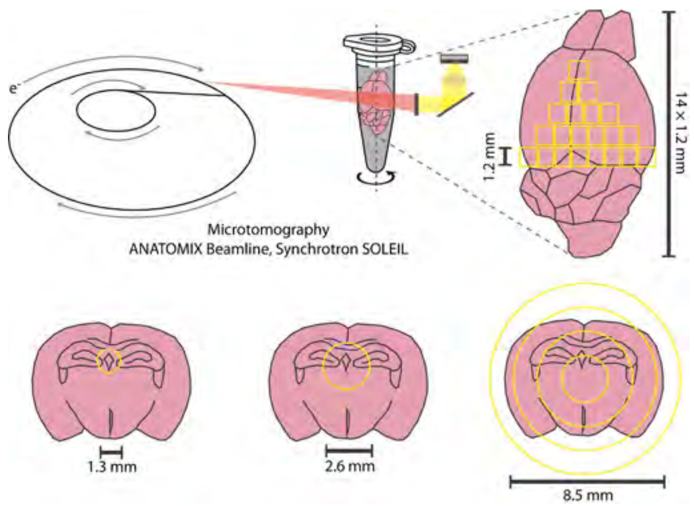

Figure 2: For synchrotron radiation-based microtomography with 0.65 µm pixel size, field-of-view (FOV) is typically limited to about 2 mm³. FOV must to be significantly extended for full brain mapping, e.g. to 450 mm³ for a mouse brain. Mosaic tiling of multiple FOVs has been demonstrated based on a dedicated pipeline to process these tera-voxel sized datasets (4). The obtained brain atlas will be made publicly available (pictures: G. Rodgers/BMC).

PhD Thesis by Griffin Rodgers at Biomaterials Science Center (BMC).

The brains of mammals, such as the murine brain, contain millions of neurons. Three-dimensionally mapping the brain's cytoarchitecture down to the sub-micrometer level is a key step towards understanding brain function. This thesis focused on neuroimaging with virtual histology based on hard X-ray tomography. This emerging technique holds promise for three-dimensional analysis of centimeter-sized brains with true micrometer resolution.

This work addresses four challenges in brain mapping with microtomography: first, optimizing contrast and spatial resolution for imaging physically soft tissue using synchrotron radiation. Here, an image quality metric was identified to compare phase-contrast imaging with conceptually simpler filtering known from image processing (1). Second, quantifying morphology and density chang-es within the brain towards paraffin embedding, see fig. 1 (2,3). Here, the tomography data were non-rigidly registered to correct the morphological changes. Third, the field-of-view for full brain mapping was extended to submicron pixel sizes stitching the radiographs (4), see fig. 2. Fourth, the power of tomography for studying neurological disorders has been demonstrated. Pathological changes associated with the onset of mesial temporal epilepsy in a mouse brain were detected based on the label-free, volumetric data.

During this thesis, the entire mouse brain was imaged with 0.65 µm-wide voxels. The datasets, each 6 TB in size at 16-bit depth, contain a wealth of anatomical information to be segmented. The human brain is about 3,000 times larger. Can we acquire and analyze such peta-byte data?

Funding:

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anatomix

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References:
(1) G. Rodgers et al. Appl. Phys. Lett. 116 (2020) 023702.

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Unveiling the Prospects of Point-of-Care 3D Printing of Polyetheretherketone (PEEK) Patient-Specific Implants

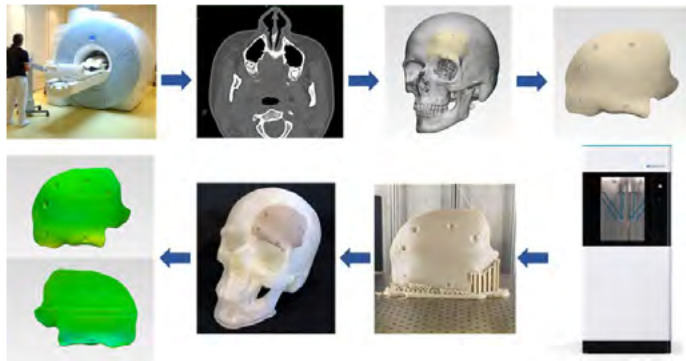

Figure 1: Schematic representation of a digital clinical workflow for point-of-care 3D printing of PEEK patient-specific implants (picture: N. Sharma).

Figure 2: Material extrusion-based 3D printed PEEK customized implants. Left top: Scaphoid prosthesis; left bottom: Orbital floor mesh implant; right: Cranial implant (picture: N. Sharma).

PhD Thesis by Neha Sharma (Department of Biomedical Engineering, University of Base) at Smart Implant group.

Additive manufacturing (AM) or three-dimensional (3D) printing is rapidly gaining acceptance in healthcare. Polyetheretherketone (PEEK), a high-performance thermoplastic polymer, has been used mainly in reconstructive surgeries as a reliable alternative to other alloplastic materials to fabricate customized implants. With advancements in AM systems, prospects for customized 3D printed surgical implants have emerged, increasing attention for point-of-care (POC) manufacturing.

In this work, the potential clinical application of material extrusion-based 3D printing for PEEK patient-specific implants (PSIs) at the POC was demonstrated (1). With a digital clinical workflow, we could illustrate a smoother integration and faster implant production (within two hours) for a complex-shaped, patented PEEK patient-specific scaphoid prosthesis (3). Furthermore, the quantitative assessment of geometric, morphological, and biomechanical characteristics of 3D printed PEEK cranial PSIs were in line with their clinical applicability (2,4). Lastly, it was demonstrated that compounding multi-design computational analysis with 3D printing of PEEK orbital mesh implants can be beneficial for the optimal restoration in orbital floor fractures (5). In conclusion, this work explored and described the variables that impede or enable AM in reconstructive surgery applications, laying the groundwork for the POC manufacturing of patient-specific or customized implants.

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References:

(1) Honigmann & Sharma et al. Biomed Res Int. 2018.

(2) Sharma et al. J Clin Med. 2020.

(3) Honigmann & Sharma et al. Biomed Res Int. 2021.

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Teaching in the Master's of Science in Biomedical Engineering in 2021

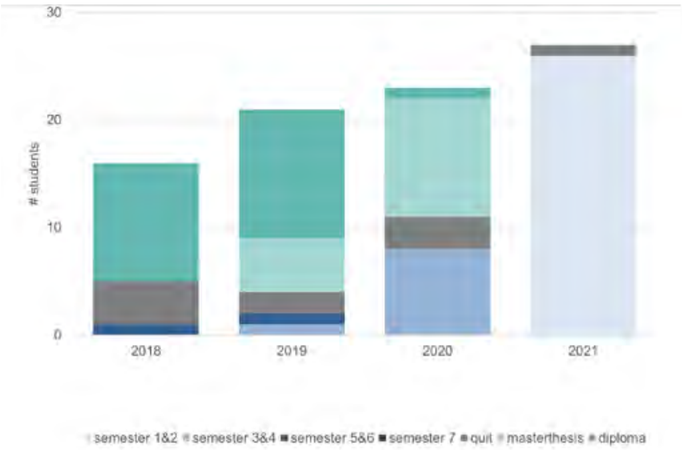

Figure 1: Progression of master students in the Master's Program in Biomedical Engineering.

Figure 2: Prof. Pablo Sinues (head teaching committee) with the course award winners: Prof. Najat Salameh and Prof. Mathieu Sarracanie for their course "Hands-on Magnetic Resonance Imaging" (picture: T. Schürch).

Four years after launching the new master program, we still observe a sustained increase in the number of students joining us. Up to date, 24 students graduated in our Master of Science in Biomedical Engineering. To further promote excellence in our master program, we launched the best course award and the prize for the best master thesis.

Currently, 57 students are matriculated in our master program. Figure 1 displays the progression of all master students throughout their studies. Importantly, 83% of the graduated students have already taken the next career step and continue with either a PhD (38%) or a position in industry (42%), indicating a favorable job prospect upon completion of our Master.

In September 2021, the distinction "Best Master Thesis" was awarded to Celine Berger, for her master thesis in the group of Forensic Medicine & Imaging, supervised by Dr. Claudia Lenz. This prize, awarded for the first time in 2021, is kindly sponsored by the Zaeslin Teaching Grant, which promotes excellence and stimulates master students to aspire and achieve high quality in their master thesis. Exceptionally, due to the extraordinary pandemic context in 2021, all nominated master thesis received prizes.

In 2021, our master program was supported by 62 lecturers delivering 27 courses. To also promote and strive for excellence in teaching, we introduced the first course award (Figure 2).

Our commitment to provide high quality education to our students is also reflected in the positive feedback from the Scientific Advisory Board (SAB) on the occasion of the evaluation of the Master's Program in Biomedical Engineering held in 2021 (see page 31).

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Completed Master Thesis

In the Master of Science in Biomedical Engineering curriculum, students work on their own project within a research group. This work is concretized by the writing of a Master Thesis (picture: D. Ettlin, University of Basel).

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Proprioception, Muscle Activity, and Tibial Translation During Heel Strike While Jogging in ACL Patients Compared to Controls

Figure 1: ACL repair and InternalBraceTM augmentation (left) and ACL reconstruction (right) (picture: courtesy of Arthrex GmbH).

Figure 2: Angle reproduction test (picture: N. Bleichner, L. Bühl, DBE/KIT/USB).

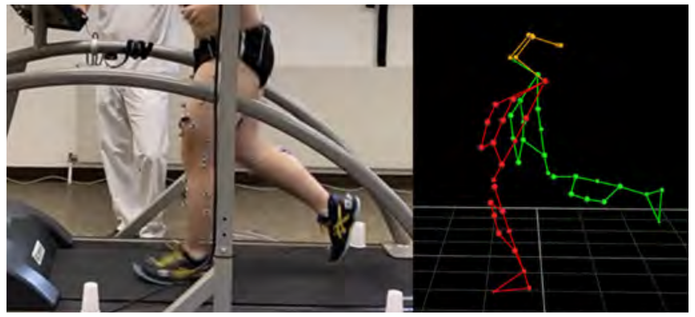

Figure 3: Running analysis on the treadmill with applied markers and electromyography electrodes (left); used marker model (point cluster technique; right) (picture: N. Bleichner, DBE/KIT/USB).

Master Thesis by Niklas Bleichner (Department of Biomedical Engineering, University Basel; Institute of Sports and Sports Science, Karlsruhe Institute of Technology) at the Functional Biomechanics Laboratory (University Hospital Basel).

Anterior cruciate ligament repair with InternalBrace augmentation (ACL-IB; Arthrex Inc., USA) is an alternative to gold-standard ACL reconstruction, yet the functional outcome of this surgical treatment is unknown.

Compared with ACL reconstruction, preservation of the native ACL in ACL-IB is considered to maintain neuromuscular integrity and provide more natural joint mechanics (1). In this study, knee proprioception, tibial translation (TT), and muscle activity around heel strike [-200; 100] ms during treadmill running were compared among three sex- and age-matched groups: ACL-IB, ACL-R, and healthy controls (N=19 each).

Group differences in an angle reproduction test (at 60° and 30° of knee flexion), range of motion and slope of anterior and posterior TT, as well as muscle activation in m. vastus medialis, vastus lateralis, and semitendinosus were analysed.

Compared with controls, no significant differences were found in both ACL groups. Between ACL groups, ACL-IB showed significantly smaller TT range (p=0.008, r=0.686) and slower posterior TT motion (p=0.038, r=0.572).

In terms of long-term outcomes and lower risk of osteoarthritis than ACL-R (2), further investigation is needed to determine which parameters of TT (range or slope) are of greater relevance for favourable patient.

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Patient Motion Compensation Using RGB-D Images and Deep Learning

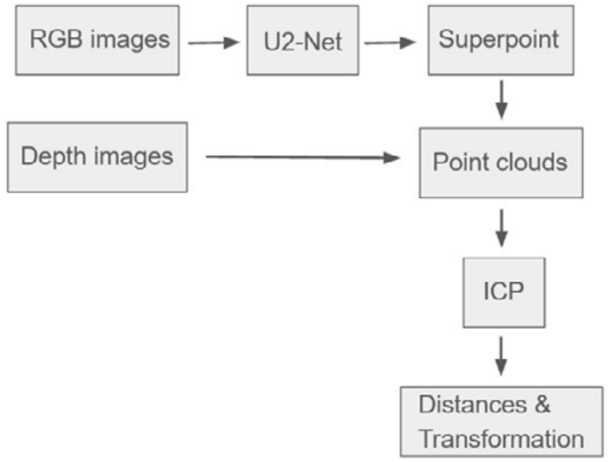

Figure 1: This graph shows the pipeline of our approach. The RGB images are fed into the U2-Net (1), which outputs the masks of the region-of-interest. The masked images are then fed into the SuperPoint (2) which identifies feature points, their descriptors, and point correspondences between consecutive frames. These are then combined with depth data to create point clouds. Lastly, with ICP the distances and transformations between point clouds of consecutive frames are computed (picture: A. Bojic, CIAN/ETH).

Figure 2: This figure shows the robotic endoscope of the MIRACLE project. The Azure Kinect (3) camera, which is outlined in red, will be mounted at the base of the endoscope and will have the surgical site in its field-of-view (picture: M. Zelechowski, CIAN).

Master Thesis by Aleksandra Bojic (Department of Information Technology and Electrical Engineering, ETH Zurich) at Center for medical Image Analysis & Navigation (CIAN)

As part of the MIRACLE project, this thesis introduces an approach for markerless patient pose tracking with RGB-D images and deep learning. Compared to traditional marker-based patient tracking, this approach reduces invasiveness and the risk for post-operative injuries and complications. Our system uses one neural network, the U2-Net (1), for segmenting the region-of-interest in RGB images and a second network, the SuperPoint (2), for finding feature points in those regions and matching them across consecutive frames. The resulting point clouds of consecutive frames are matched with the depth data, and the corresponding transformation matrix is calculated with the iterative closest point (ICP) method. We demonstrate the functionality of this approach with self-acquired data using a knee phantom. We reached a promising performance given the small amount of data used for fine-tuning. We believe that this approach offers a good foundation for future research toward non-invasive patient tracking during surgeries.

Facts and Figures

Segmentation error in less than 2% of the images

1. Average alignment error of 8.69 mm ± 10.36 mm and a median of 7.07 mm

2. Smoothing the depth data impairs the performance

3. Non-optimized runtime for both networks combined exceeds 1s per frame, according to literature a runtime of 38-48ms per frame can be reached

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References:
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(2) SuperPoint: Self-Supervised Interest Point Detection and Description (DeTone et al., 2018).

(3) Evaluation of the Azure Kinect and Its Comparison to Kinect V1 and Kinect V2 (Tölgyessy et al., 2021).

Development of a Mechanical Quick-Coupling for a Tendon-Driven Robotic Endoscope

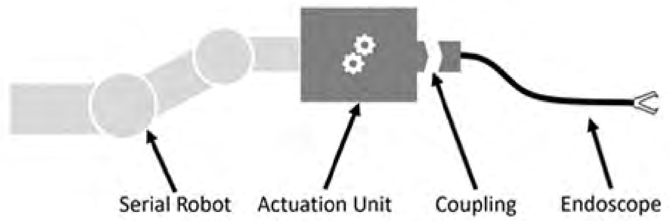

Figure 1: Schematic of a robotic endoscopy platform with an endoscope that is detachable from the actuation unit (picture: P. Butschle, BIROMED-Lab).

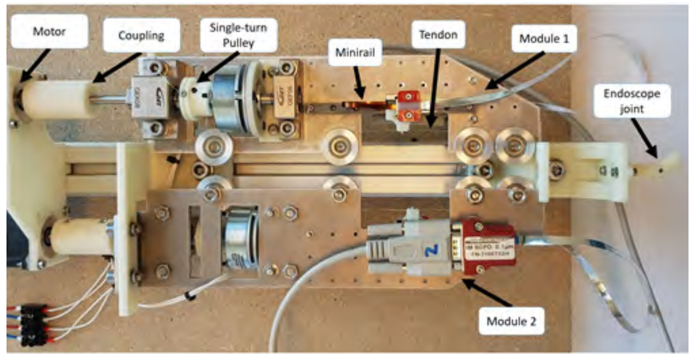

Figure 2: Two manufactured prototypes of the developed tendon module controlling a tendon-driven endoscope with one rotary joint (picture: P. Butschle, BIROMED-Lab).

Master Thesis by Philipp Butschle (Department of Mechanical and Process Engineering, Eidgenössische Technische Hochschule Zürich – ETHZ) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

One of the key features of many successful robotic surgical platforms, like the DaVinci System, by Intuitive Surgical Inc., is the ability to switch to a new surgical tool without exchanging the entire platform. This makes quick changes of tools during surgery possible and thus reduces the number of required robot arms. Furthermore, it also eases processes between surgeries as the detachable tools can be sterilized in an autoclave. The possibility to decouple the surgical tool also adds to the safety of the system: in case of emergency, the surgeon can remove the surgical tool from the patient's body manually.

The goal of this project was to develop a coupling for a tendon-driven robotic endoscope. Coupling mechanisms that are implemented in current surgical robotic systems are not able to couple many individual tendons at once. The proposed concept features modules, which enable individual control of tendons and provide information on the tendon dislocation with a position sensor. These tendon modules also include a brake to avoid slack when the endoscope is decoupled. Two prototypes of the tendon module design were manufactured, and experiments were conducted to evaluate the positioning accuracy and efficiency of the power transmission. The results of the experiment show that tendon modules with sufficient performance are possible but require further research.

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Performance and Knee Biomechanics of a Single Leg Hop 2 Years after Primary ACL Repair and InternalBrace™ Augmentation

Figure 1: ACL repair and InternalBrace™ Augmentation (picture: courtesy of Arthrex GmbH).

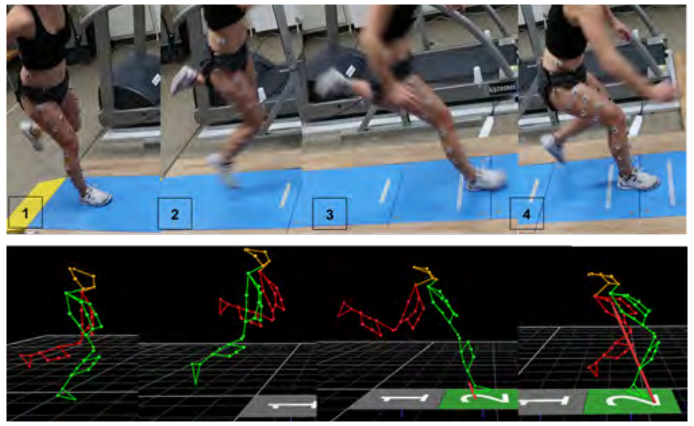

Figure 2: 3D motion capture of the single leg hop. Preparation (1), take-off (2), initial foot contact (3) and landing (4) in the measurement setting (picture: B. Coppers, L. Bühl, DBE/Uni Basel/KIT/USB).

Master Thesis by Birte Coppers (Department of Biomedical Engineering, University Basel; Institute of Sports and Sports Science, Karlsruhe Institute of Technology) at the Functional Biomechanics Laboratory (University Hospital Basel).

In recent years, the interest in alternative surgery of the anterior cruciate ligament (ACL) has increased. Advantages of ACL repair with ligament augmentation over the gold standard – ACL reconstruction – are seen in a less invasive surgery and preservation of the native ligament. Good clinical and patient-reported outcomes after ACL repair with ligament augmentation have been reported (1). However, information about the functional outcome in dynamic situations is scarce. Therefore, we aimed to compare performance and knee biomechanics during landing from a single leg hop between the knees of 30 patients after primary ACL repair with InternalBrace™ (Arthrex, USA) and 30 healthy controls. Maximal hop distance and knee biomechanics (using the point cluster technique) were recorded via a motion capture system (Vicon, UK). Patients achieved comparable hop distances and leg differences to healthy controls. A significantly lower flexion moment of the affected compared to the contra-lateral knee of the patients as well as a significantly smaller range of motion compared to the contra-lateral knee and the knee of healthy controls was found.

Two years after ACL repair, patients showed on average no relevant side-to-side differences (<10%) in hop performance. However, the results varied strongly between patients. Alterations in movement strategies may indicate existing deficits comparable to those previously reported in patients after ACL reconstruction (2). Compared to healthy, no relevant deficits were found indicating good functional outcome.

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Design of a Rotational Endoscope Joint with Integrated Joint Position Sensor

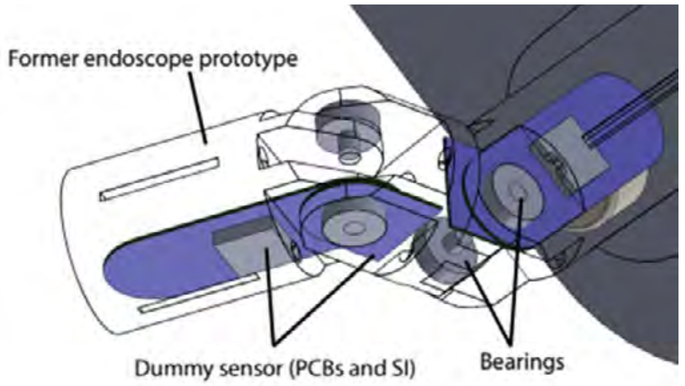

Figure 1: A dummy sensor has been placed into an articulated 8 mm diameter endoscope. The semi circular disk printed onto the PCB creates a change in capacitance when the joints rotate (picture: S. Drews, BIROMED-Lab).

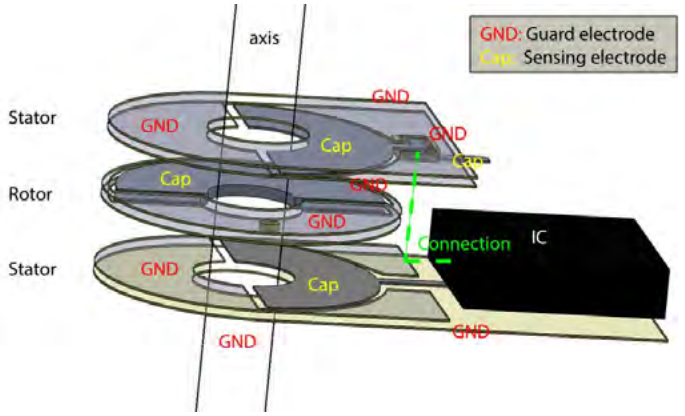

Figure 2: Improved concept of the sensor that introduces a third PCB as a rotor in-between. With this configuration the sensor performance is thought to greatly increase in comparison to the prototype produced in this work (picture: S. Drews, BIROMED-Lab).

Master Thesis by Saverio Drews (Department of Biomedical Engineering, University of Basel) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

Endoscopes have small diameters and often lack the space to integrate joint position sensors.

In this work, a concept to create cheap and compact rotary position sensors that allow implementation into current endoscope designs is presented. The sensor concept, based on the capacitance measurement principle, consists of ultra-thin printed circuit boards (PCBs) and a surface mount device (SMD) sensor interface (SI). The presented design is theoretically capable of resolving the endoscope joint angle down to 0.05 degrees.

A prototype was produced that achieves rotation angle measurement repeatability of 1 degree and has a non-linearity of about 5 degrees. The results seem promising, especially as design improvements proposed in this work will lead to higher repeatability and higher linearity.

The concept allows flexibility in design and quick adjustments, which may lead to fast iterations and improvements. For robotic endoscopes, the designed sensor can create new opportunities for feedback control. The presented sensor design also allows implementation into other devices where space is scarce, and miniature rotation sensors are required.

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Biomechanical Analysis of Stepping Up and Down a One-Step Stair

Figure 1: One-step stair used for the tasks stepping up and down, here stepping up is shown (picture: Courtesy of Laboratory for Movement Analysis, UKBB).

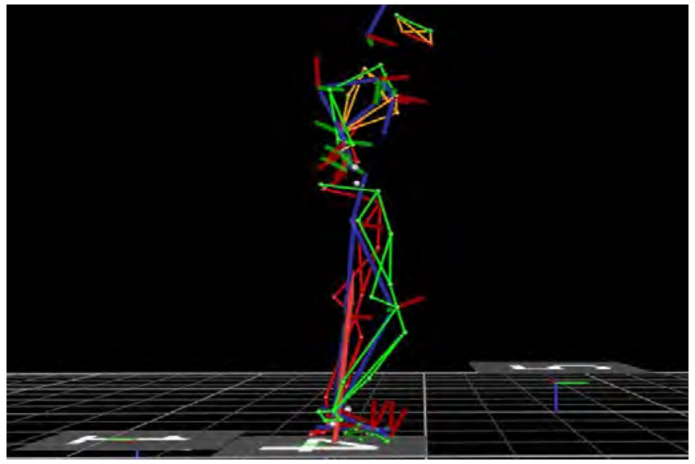

Figure 2: Visualization of reflective markers and corresponding segments in Vicon Nexus 2.5, here for stepping up the one-step stair (picture: A Durrer, DBE/UKBB).

Master Thesis by Alicia Durrer (Department of Biomedical Engineering, University of Basel) at the Laboratory for Movement Analysis, University of Basel Children's Hospital (UKBB).

This thesis aimed to develop an analysis routine for stepping up and down a one-step stair, which can be used in addition to level gait analysis. Furthermore, level gait and the one-step stair tasks were compared for healthy subjects. Retrospective data (kinematics, kinetics, surface electromyography) collected of 17 healthy adult subjects was used.

For stepping down, mostly the knee of the trailing leg was challenged in terms of range of motion. In addition, the maximum power that needed to be absorbed by the leading leg ankle was almost five times the maximum value during level walking. Stepping up required wider ranges of motion of the knee and hip of the leading leg, compared to the trailing leg and level gait. Moreover, the power that needed to be generated by the trailing leg ankle was 38 % higher than the power generated during level gait.

The findings suggest that the one-step stair tasks are a beneficial addition to the pre-existing level gait analysis routine. They require wider ranges of motion, higher internal moment generation, power absorption and power generation ability compared to level gait.

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Domain Transfer for Harmonization of MR Image Contrasts

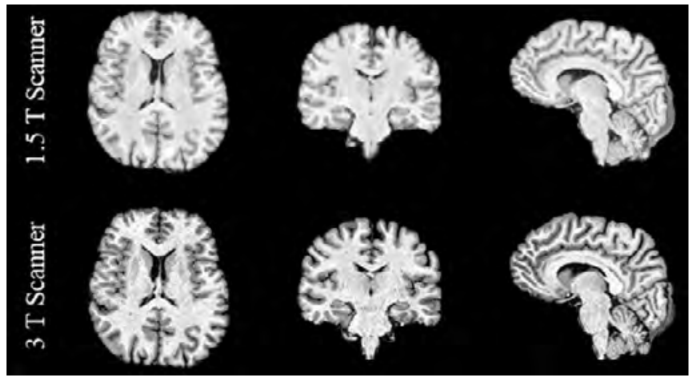

Figure 1: From left to right: Axial, coronal and sagittal slice of brain MR scan of the same subject acquired with the same imaging sequence, once acquired with a 1.5 T and once with a 3 T MR scanner (picture: S. Fluder, CIAN).

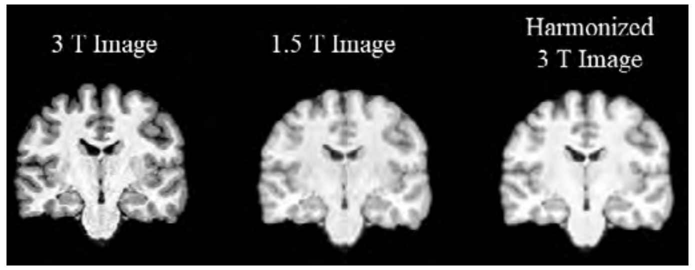

Figure 2: Same slice of same subject acquired with different scanners before and after contrast harmonization. From left to right: Brain scan acquired with the scanner working on a 3 T magnetic field before contrast harmonization (source contrast). Brain scan acquired with the scanner working on a 1.5 T magnetic field (target contrast). Brain scan acquired with scanner working on a 3 T magnetic field after contrast harmonization with the proposed network (picture: S. Fluder, CIAN).

Master Thesis by Simon Fluder (Department of Biomedical Engineering, University of Basel) at Center for medical Image Analysis & Navigation (CIAN).

In magnetic resonance imaging (MRI), various factors such as scanner model or acquisition protocol affect the resulting image contrast. This limits the application of MRI as imaging modality in long-term studies, where image consistency is required. Furthermore, the performance of deep-learning, which showed great success in various applications in the medical field, suffers in presence of a domain shift between training and test data introduced by different MR devices or protocols.

Image harmonization aims to reduce the domain gap between a source and a target image and would greatly improve the applicability of deep-learning networks in MRI (1-2).

In this thesis, a supervised harmonization network is proposed to harmonize the contrasts in MR images in a scanner change scenario, using a cohort of healthy subjects scanned in both MR scanners working with a 1.5 T and 3 T magnetic field, respectively. The harmonization network was trained to transform images acquired with the 3 T scanner so that they show the same image contrast as images acquired with a 1.5 T scanner.

The proposed network architecture was able to generate images, that showed increased image similarity after harmonization of source and target domain. Furthermore, the volumetric difference in segmented structures introduced by the scanner change was successfully reduced in the brainstem segments mesencephalon and pons. Additionally, volumetric bias in longitudinal data of Multiple Sclerosis patients could be reduced in mesencephalon and pons by harmonizing image contrasts across scanners.

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Optimization-Based Design of a Robotic Endoscope for Intraventricular Tumor Surgery

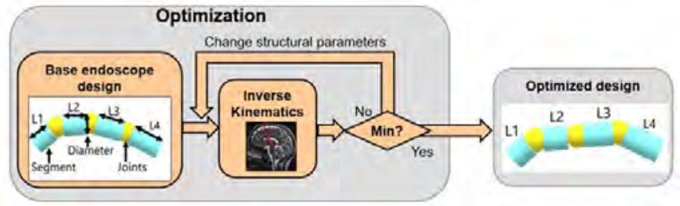

Figure 1: The optimization framework developed in this thesis: A base endoscope design was evaluated using the endoscope inverse kinematics by comparing the endoscope shape to the desired insertion path of the endoscope. The structural parameters (i.e., the segment lengths) were changed and the evaluation was repeated. The optimization was stopped when the termination criteria were met and the design was assumed to be optimal (picture: O. Garrido, BIROMED-Lab).

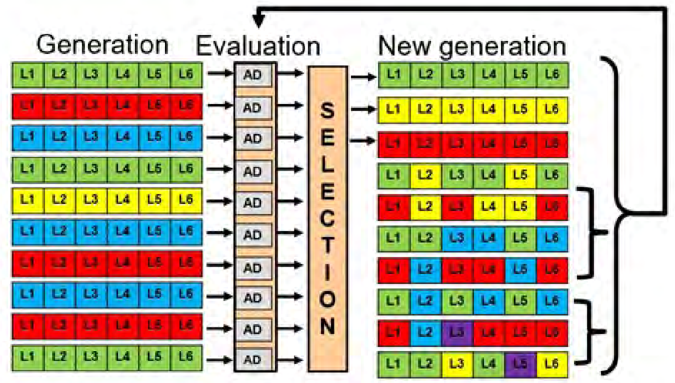

Figure 2: A genetic algorithm was used in the optimization. The genetic algorithm started with an initial population that went through an evaluation. Later, the best chromosomes were selected and passed to the next generation. The population of the next generation was filled with crossover and mutation (picture: O. Garrido, BIROMED-Lab).

Master Thesis by Omar Garrido (University of Basel) at the BIROMED-Lab.

Flexible robotic endoscopes can make it easier for the surgeon to reach challenging surgical locations within the human body. For example, reaching tumors in the posterior third brain ventricle could be possible with a single incision. However, choosing the design parameters of robotic endoscopes (e.g., number of joints, length of individual segments) is often based on a trial-and-error approach.

In this thesis, I optimized the endoscope's segment lengths such that the shape of the endoscope matches the desired insertion path of the endoscope as well as possible. The proposed optimization framework employed a genetic algorithm, and as cost function the area between the desired path and the endoscope's final configuration. An optimal design was found for articulated endoscopes with four, five, and six segments.

This optimization method could lead to a faster robotic endoscope development process and a reduced risk of tissue damage in robotic surgeries.

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Switching Tools on the Fly – Design and Fabrication of a Small-Scale Tool Changing System for a Miniature Robot Arm

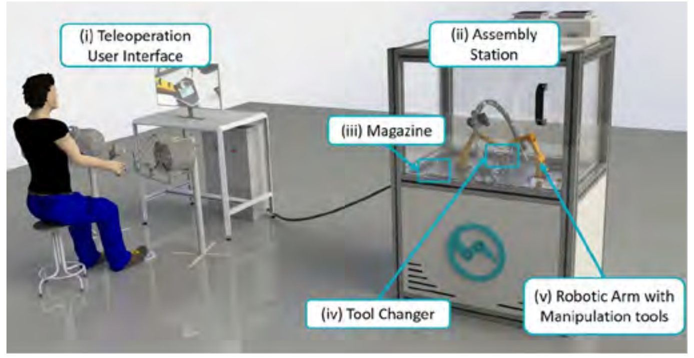

Figure 1: With the teleoperation interface (i) the user can execute an assembly process with robotic arms (v), the manipulation tools are switched with the tool changer (iv) and stored in the magazine (iii) (picture: C. Duverney, BIROMED-Lab).

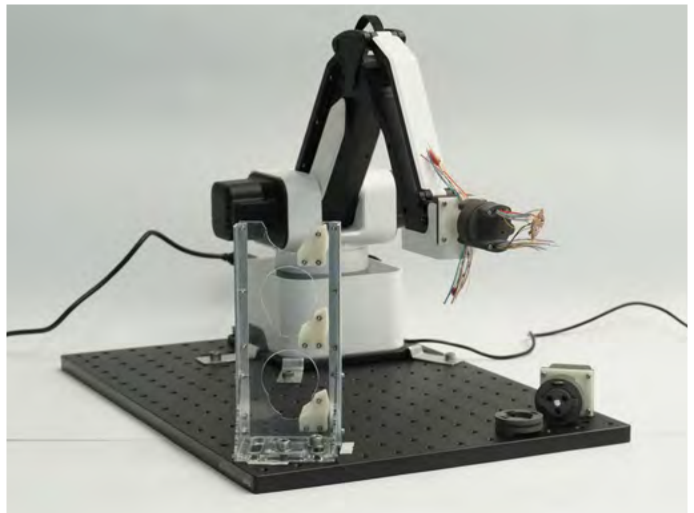

Figure 2: In front: magazine with three slots for the manipulation tools, back: robotic arm with one concept of tool changer attached, second concept placed on groundplate (picture: J. Glünkin, BIROMED-Lab).

Master Thesis by Josua Glünkin (Swiss Federal Institute of Technology Zürich – ETHZ) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

The overall project MIRACLE of the BIROMED-Lab requires devices in millimeter or sub-millimeter dimensions which must be assembled. Such a device can be assembled manually, automated, or teleoperated. The user can control with the teleoperated interface within an assembly station, robots which build the devices. This research investigates the use and benefits of a tool changing system for such an assembly station and focuses on the impact on the task completion time and task load (1).

Two concepts for the mechanical coupling mechanism were developed, one with magnets, the other with a spring-loaded lever that locks the tool changer units together. The evaluation has shown the usability and simplicity of the developed concepts and the promising task completion time reduction and task load reduction. It can be concluded that the use of the tool changer is straight-forward and quick for an untrained human compared to an everyday tool changing task. Furthermore, it could be demonstrated that a (semi-) automation with a robot is feasible. A high acceptance by the user was observed. The simplicity and speed of the tool changing task, the automation of the process, as well as the user acceptance, point to a promising integration into the overall micro-assembly system.

Finally, the developed tool changer can be adapted to different applications due to its expandable and simple design. With such a promising prospect, the system could be improved in mechanical and electrical reliability and implemented in the teleoperated micro-assembly system.

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Repeatability of a Treadmill Gait Stress Test to Understand the Serum Biomarker COMP in Young Healthy Adults

Figure 1: Walking stress test on day 1 and day 2 with the blood sampling time point t_{pre}, t_{post} and $t_{post+30}$ (marked in red). Physical activity was monitored for 24 hours before the stress test (blue) (picture: M. Hächler, DBE/Uni Basel/USB).

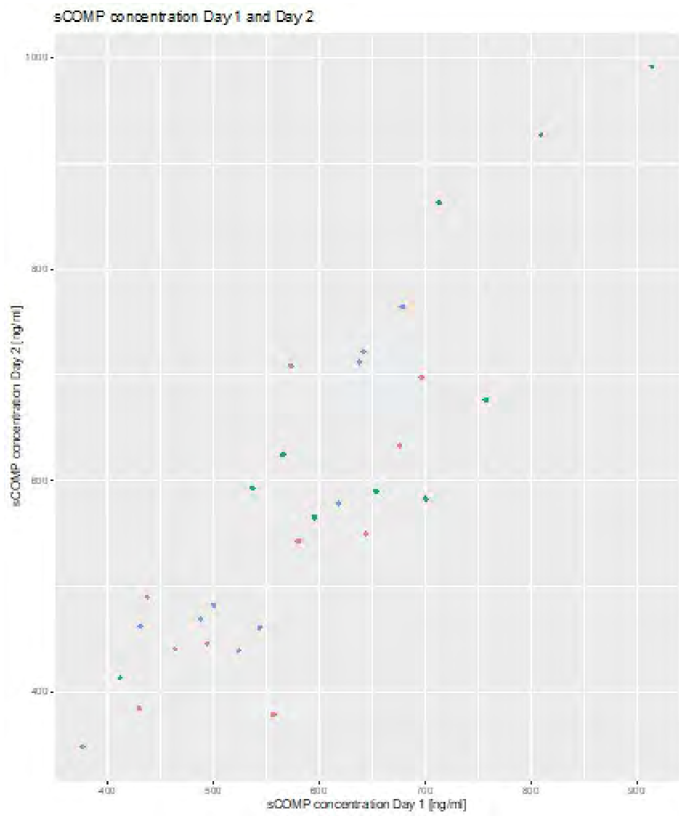

Figure 2: Sctterplott of sCOMP concentration for the timepoints t_{pre} (red), t_{post} (green), $t_{post+30}$ (blue) (picture: M. Hächler, DBE/Uni Basel/USB).

Master Thesis by Michael Hächler (Department of Biomedical Engineering, Department of Sport Exercise and Health, University of Basel) at the Functional Biomechanics Laboratory (University Hospital Basel).

Cartilage damage in the human body represents a relevant problem due to the lack of regenerative capacity (1). Currently, there is no diagnostic procedure to determine the underlying biological processes. Analyses of articular cartilage blood biomarkers are potential diagnostic methods for the early detection of cartilage damage (2). The aim of this study was to determine the repeatability of load-induced changes in serum marker cartilage oligomeric matrix protein (sCOMP) concentration.

In young healthy volunteers (n = 10), sCOMP concentration, spatiotemporal and vertical ground reaction force during treadmill walking were measured on two identical test days within 7 days (figure 1). sCOMP concentrations were collected immediately before (t_{pre}), immediately after (t_{post}) and 30 minutes after a walking stress test ($t_{post+30}$). Repeatability between test days was determined using intraclass correlation coefficients (ICC).

No significant differences of all sCOMP absolute concentrations were detected between test day 1 and 2, which is confirmed by moderate to good agreements (ICC ≥ 0.695, Figure 2). The spatiotemporal parameters as well as the ground reaction force parameters showed no difference and good agreement (ICC ≥ 0.847).

The agreements between both test days of the absolute sCOMP concentrations show reproducible load-induced concentration changes. In conclusion, the standardization protocol has proven suitable for testing repeatability with a framework that is as identical as possible, which could be helpful for further research.

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Development and Evaluation of a Visual Feature Recognition Framework for a Robotic Assembly System

Figure 1: Representation of the future intended teleoperated micro-assembly station and visual framework (picture: C. Duverney, BIROMED-Lab).

Figure 2: The users can complete the task with high accuracy by having visual information such as object type, object orientation, and object dimension (picture: C. Duverney, BIROMED-Lab).

Master Thesis by Farid Taji Heravi (Department of Biomedical Engineering, University of Basel) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

Today miniaturization has been become a major development factor in different industries such as electronics, medical technology, and watch making. The MIRACLE project of the University of Basel aims to develop robotic endoscope devices for minimally invasive surgery. The developed prototypes with dimensions in the millimeter or even micrometer scale need to be assembled. These small objects can get damaged when untrained humans assemble them by hand. The teleoperated robotic micro-assembly station also developed within the MIRACLE project is an assistance robot helping users to assemble fragile micro-parts (1). The users need to have visual information to recognize parts, part orientations, and dimensions. Knowing the parts' orientations is necessary, because when two objects are not aligned during insertion, they would get jammed. The parts list was collected as needs of target application and they were categorized into known parts, known shapes, and unknown shapes. The machine learning network was designed based on the human mind's structure to categorize parts and find parts orientations. When the human mind cannot recognize an object, they compared it with a similar simple shape object. Also, if it has an unknown shape like a pallet fork found in watches, the pose of a hole is estimated by human minds. The designed framework was evaluated in three steps: firstly, the calibration of cameras was evaluated by computing the reprojection error. Calibrating cameras was successful with reprojection errors of about 8 %. Then, the trained network can detect known parts and known shapes, but it was sensible to the light conditions. Finally, it was proven that the part orientation was computed successfully when all key-points were detected successfully. However, the trained network was not robust enough to detect all key-points in all test images. It was shown that increasing the number of datasets and improving light conditions can improve network robustness.

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Silk-Reinforced, Micro-Patterned Cellulose Film for Soft Neural Implants

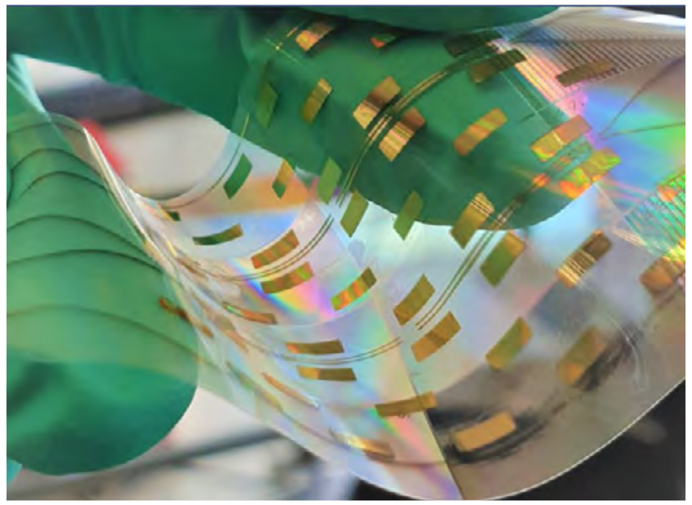

Figure 1: Prototype of cellulose base flexible micro-patterned electrodes for implantable devices. It softens by water uptake, stays stable for extended periods of time, and is easy to handle during surgical interventions (picture: M. Joodaki, BMC).

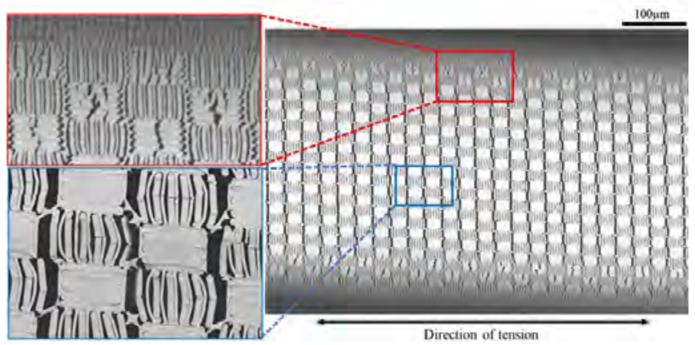

Figure 2: The flexible, micro-structured electrode, micro-patterned Au on cellulose, withstands up to 30 % strain. Electron micrographs after tensile testing (picture: M. Joodaki, BMC).

Master Thesis by Mahyar Joodaki (Department of Biomedical Engineering, University of Basel) at the Biomaterials Science Centre (BMC)

Neuromodulation therapy with MHz to GHz signals has attracted attention for progressive neurodegenerative diseases. For these treatments, the spatial proximity of the electrodes to the neural tissue must be guaranteed, requiring neural probes to be implanted into the human brain. Creating a glial scar-free neural-probe interface for extended periods of time is, however, challenging (1,2). Soft and flexible electrodes are therefore a key for next-generation probes (3).

This thesis dealt with the brain-probe interface. The cellulose films used soften in aqueous environments and therefore adapt to the tissue's curvature at the implantation site. The ratio of the bio-based polymer, plasticizer and solvent was optimized to create films with desired softness via blade coating. These films were reinforced using silk networks and reached an elastic modulus of 124 ± 7 MPa. The silk embedding improved the tear strength by a factor of seven, maintaining flexibility and softness, see fig. 1. The metal adhesion on these films was enhanced by micro-patterning with a determined height-to-width ratio. They were stable in phosphate buffer saline over 10,000 loading cycles. Contrary to flat electrodes, the two-directional micro-patterned Au remained conductive up to 30 % strain because of the framework behavior, see fig. 2.

The fabricated neural probes are considered to be compliant interfaces to the human brain and spinal cord. They adapt to the tissue's anatomy, withstand substantial bending without losing electrical conductivity, and provide long-term stability under physiological conditions. Our clinical partners proved the easy handling of the biocompatible implants during surgical interventions. Their effective fabrication can be adapted to large-scale production.

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Path Planning for Hyper-redundant Surgical Robots

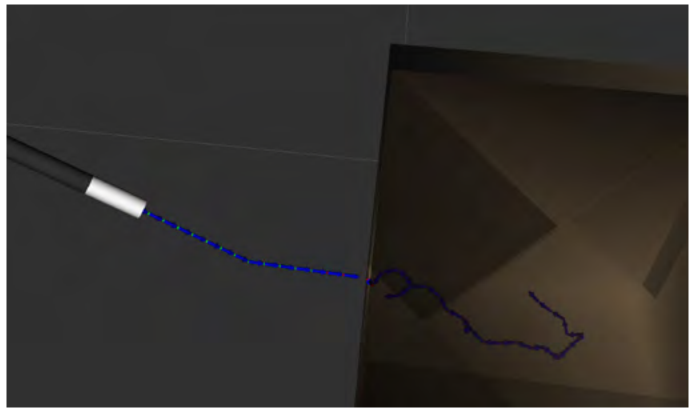

Figure 1: Solution created by TSRRT-biromed. Inside the obstacle (strong simplification of a human body) we see the sampled task space path for the robot. Outside of the obstacle we have the created task space path (picture: Zs. Kalotay, BIROMED-Lab).

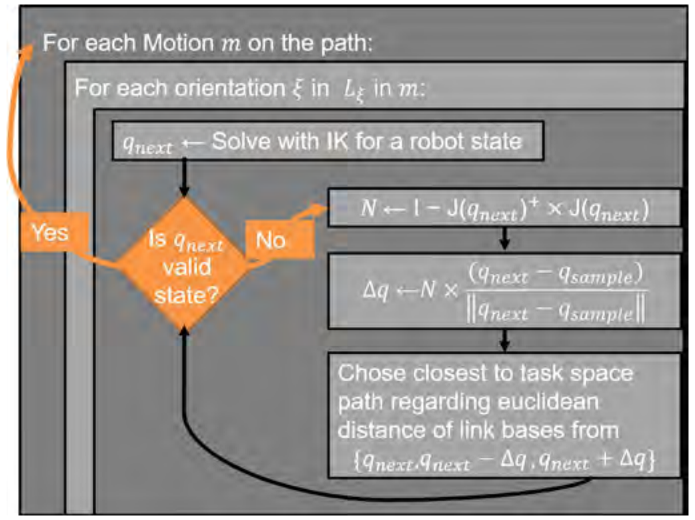

Figure 2: Flowchart of how the "Null Space Search" works (picture: Zs. Kalotay, BIROMED-Lab).

Master Thesis by Zsombor Kalotay (Eidgenössische Technische Hochschule Zürich – ETHZ) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

The goal of the thesis (1) was to create a general path planning framework for hyper-redundant actuated serial robotic manipulators with focus on minimal invasive surgical applications.

Based on findings from previous work (2) we decided to work with the Open Motion Planning Library (OMPL). OMPL implements many sampling-based path planners, which we aimed to test for feasibility. First experiments and results have shown us that the existing planners in OMPL are not sufficient for the defined surgical use case. The problem identified was the well known "Narrow Passage Problem" (3). Existing solutions to the problem do not work for our robotic setup. Therefore, we have decided to create our own four step path planning algorithm to solve the "Narrow Passage Problem", called TSRRT-biromed.

The TSRRT-biromed consists of following steps:

- Sample task space path inside human body, RRT-style (4).
- Create task space path outside of the human body.
- Smooth task space path and create for each point a set L_ξ of possible end-effector orientations.
- Iterate over full path and calculate robot states by performing a "Null Space Search" (See second picture).

We concluded that the algorithm has the potential of solving the problem. However, further work on the path-planner is required.

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Anomaly Detection in Magnetic Resonance Image Series of the Lung

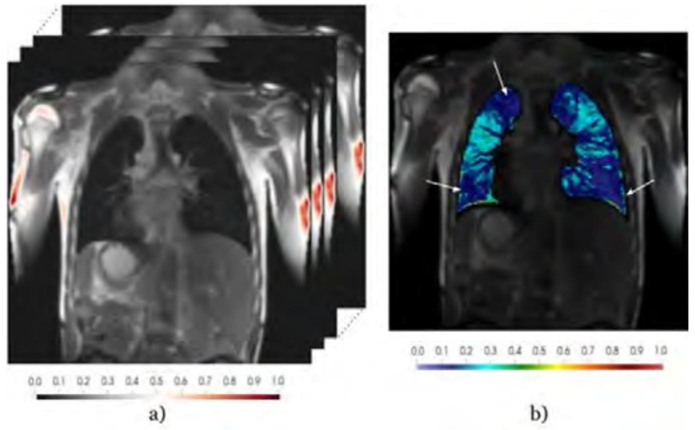

Figure 1: a) Time-resolved MR image series of a patient with cystic fibrosis, b) ventilation map computed from the image series (1). The arrows on the ventilation map indicate possible ventilation defects, which can be recognized by dark regions (picture: M. Kojanazarova, CIAN).

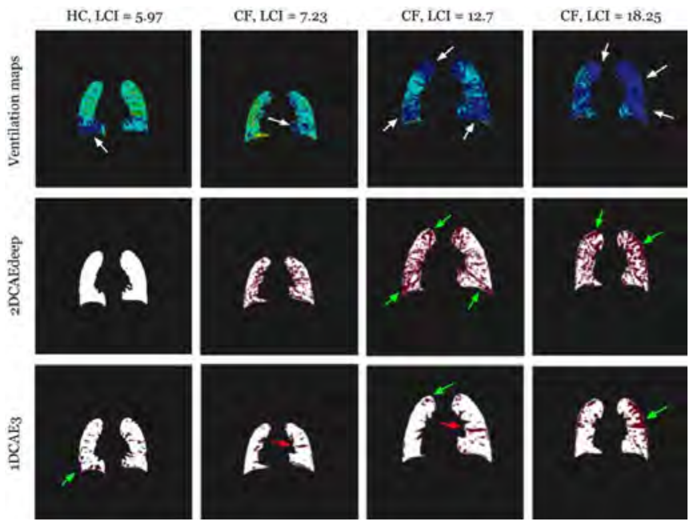

Figure 2: Anomaly segmentation results for 2D and 1D models compared with the ventilation maps of a healthy control (HC) and patients with CF, the white arrows showing the ventilation defects. Red regions in the anomaly maps indicate segmented anomalous regions, with green arrows showing the anomalies corresponding to the defects in the ventilation maps, and red arrows pointing out the anomalies not seen in the ventilation maps (picture: M. Kojanazarova, CIAN).

Master Thesis by Madina Kojanazarova (Department of Biomedical Engineering, University of Basel) at Center for medical Image Analysis & Navigation (CIAN)..

Anomaly detection using Artificial Neural Networks (ANN) has shown promising results in disease detection and localization in Magnetic Resonance (MR) images. New techniques in functional MR image acquisition (1) allow us to image the lungs with high tissue contrast and can be used to continually monitor patients with chronic lung diseases such as cystic fibrosis (CF). Early detection of disease progression and treatment is crucial for improvement of the life quality of the affected patients. Anomaly segmentation with ANNs in a supervised manner requires manually labeled training data which is difficult to obtain. Additionally, manually labeled data comes with a bias to the known defects. Auto-encoder (AE) networks can be used for anomaly detection in an unsupervised manner, where images from only healthy subjects are used for the training.

In this work, we train various AE networks for anomaly detection in time-resolved 2D MR image series of the lungs. We investigate the potential of 3D, 2D and 1D AE networks to reconstruct the images of patients with CF, expecting to find high reconstruction errors in defective regions of the lungs. We perform anomaly segmentation by thresholding the resulting error maps and compute the correlation between the results of the segmentation and the subjects' Lung Clearance Index (LCI). LCI is a global measure of lung ventilation inhomogeneities. We visually compare the error maps and the anomaly segmentation results with previously computed ventilation maps showing the ventilation defects in the lungs.

The results of our study show that the 1D and 2D convolutional AE networks are able to detect anomalies corresponding to the ventilation defects in the lungs and have moderate correlation when compared to the LCI values.

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Reference:
(1) G. Bauman & O. Bieri (2017), Matrix pencil decomposition of time-resolved proton MRI for robust and improved assessment of pulmonary ventilation and perfusion. Magnetic Resonance in Medicine, 77 (1), 336–342.

Validation of Estimated Orientation from Inertial Measurement Units with an Optical Tracking System

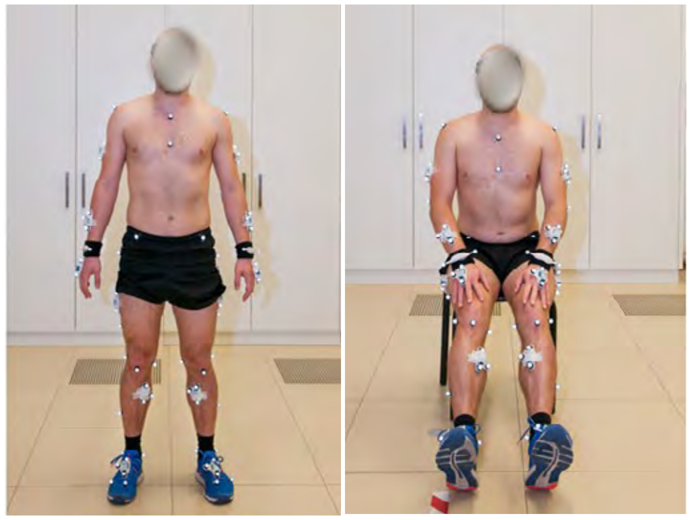

Figure 1: Measurement model with full body OMC, IMU set-up. Data acquired during treadmill and over ground walking trials (picture: R. Haji Hassani, BIROMED-Lab).

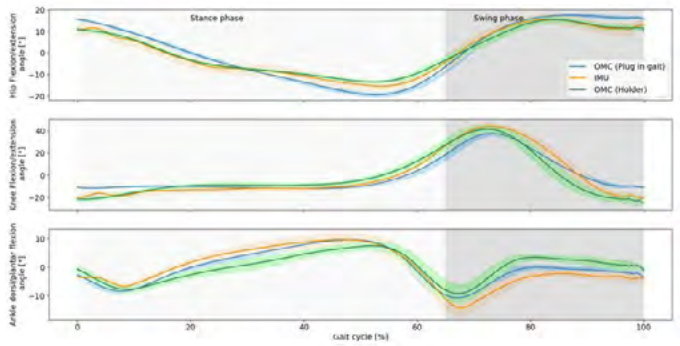

Figure 2: Joint angles estimated from OMC, IMU and 3D printed holders from treadmill walking from one participant (picture: V. Lakshmanan, BIROMED-Lab).

Master Thesis by Vidhya Lakshmanan (Department of Biomedical Engineering, University of Basel) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

Inertial measurement units are gaining importance in the field of gait analysis and human motion tracking. To enable studying gait kinematics in incomplete spinal cord injured (iSCI) patients, wearable sensors are found to be advantageous compared to optical motion capture systems (OMCs) which are the existing gold standard for gait analysis. OMCs involve the use of large hardware set ups which usually confine motion tracking to a laboratory environment. In order to reduce dependency on room-based hardware and therefore enable studying walking patterns of daily life activities in patients, inertial measurement systems (IMUs) seem to be an appropriate alternative. However, to understand the validity of results obtained by use of IMU systems, results need to be compared to those obtained from OMCs. There are various algorithms that are studied to analyze the kinematic gait parameters from IMUs. This thesis aims to validate an algorithm that do not use the magnetometer data and considers kinematic constraints in lower limb joints to obtain solutions more comparable to the OMC. This algorithm has been previously tested on mechanical hinge joints and proven to have a sensor-to-segment calibration accuracy around 2° compared to the angular deviation from the ground truth of the joint axis (1). In this thesis, a total of 15 individuals with no neurological disorders (control group) and 5 iSCI patients were recruited. Their walking patterns were recorded using IMUs and OMC based on a full body set up while the participants walked on a treadmill as well as on over ground (straight walking, walking with turn, walking in the shape of '8'). For the validation study, a set of sixteen 3D printed holder that can hold one IMU and 3 optical markers per holder for each segment were used. The lower limb joint angles calculated from the IMU data were compared with the plug-in gait model of OMC. Another set of validation is made with the optical markers in the 3D printed holder from which the orientation of the segments and the joint angles are calculated as well.

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(1) F. Olsson, M. Kok, T. Seel, and K. Halvorsen, "Robust plug-and-play joint axis estimation using inertial sensors," Sensors, vol. 20, p. 3534, 06 2020.

Simulation for Extraventricular Drain Placement Training using Virtual Reality with Haptic Feedback

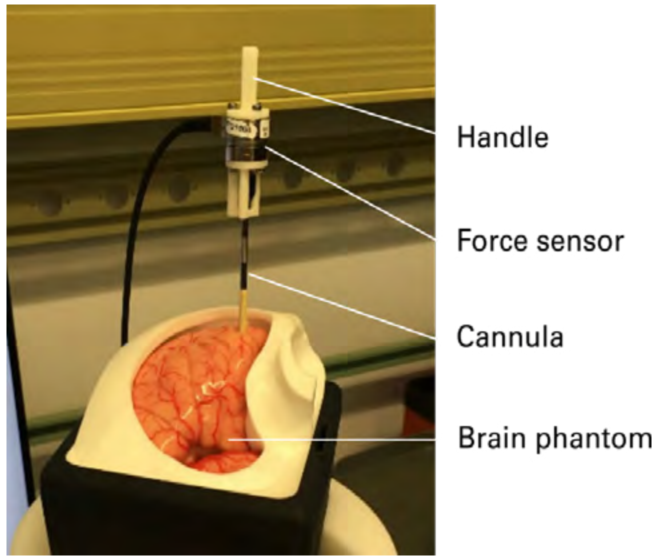

Figure 1: Cannula with mounted force sensor inserted in brain phantom (picture: J. Liechti, BIROMED-Lab).

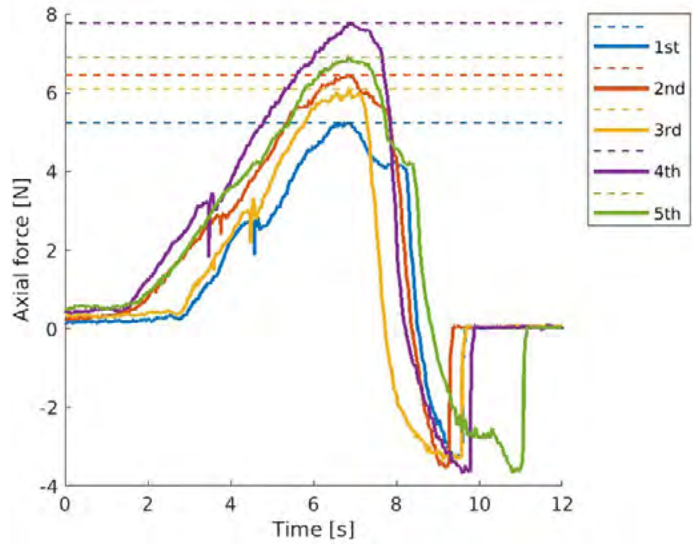

Figure 2: Force plot showing 5 trials with characteristic force development (picture: J. Liechti, BIROMED-Lab).

Master Thesis by Jan Liechti (University of Basel, Medical studies) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

For residents in neurosurgery, it is crucial to have regular access to training opportunities. Training phantoms allowing to showcase different pathologies are very limited, since modifications to a physical model are intricate.

Virtual Reality (VR) applied in neurosurgery planning and training has a big potential to increase efficiency and to improve surgery outcome (1). Combined with a haptic feedback device, VR training has the capability to further increase the immersive experience that help exploring individual anatomic features based on patients CT scan data (2).

Insertion of an extra ventricular drain (EVD) requires trained haptic perception and a dexterous linear insertion movement of the cannula. In order to realize VR training, the haptic features of cannula insertion must be adequately simulated. To develop the haptic feedback device, tissue properties and force ranges must be known. With this experiment we aim to characterize the axial forces occurring during the insertion of a cannula.

We instrumented a Cushing cannula with a force sensor, placing it with a centred z-axis between cannula and handle. Axial force over time were recorded in 5 trials and maximum values of up to 8N were determined.

The observed force ranges and slopes seem feasible for the implementation in a haptic simulation and we plan a continuation with more suitable models and additional participants.

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(1) Croci, D.M., Guzman, R., Netzer, C., Mariani, L., Schaeren, St., Cattin, Ph.C., Jost, G.F., "Novel patient-specific 3D virtual reality visualisation software (SpectoVR) for the planning of spine surgery: a case series of eight patients", BMJ Innovations 2020;6:215-219.

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Dielectric Elastomer Sensors for the Tongue-Computer Interface

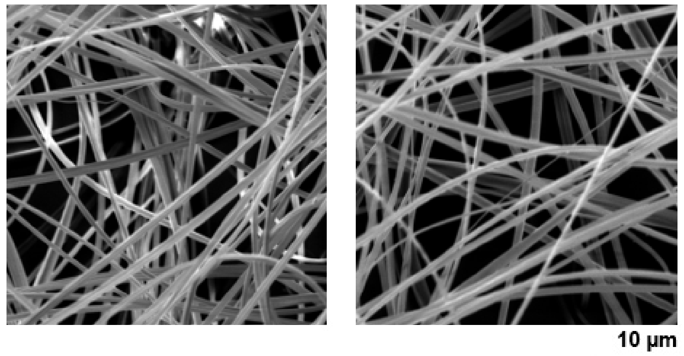

Figure 1: Electro-spun fiber network visualized by electron microscopy (picture: C. Luchsinger, BMC).

Figure 2: Two dielectric elastomer sensors embedded between two molded substrates for their integration/implementation into a personalized dental splint (picture: R. Wendler).

Master Thesis Carina Luchsinger Salinas (Department of Biomedical Engineering, University of Basel) at the Biomaterials Science Center (BMC).

This thesis project pursued the development and comprehensive characterization of a sensor prototype for the tongue-computer interface. These dielectric elastomer sensors are micrometer-thin and highly flexible and thus well suited for intra-oral tongue-machine interface applied for the treatment of sleep apnea and snoring problems through digitalized myofunctional therapy.

The elastically deformable pressure sensors consist of elastomer films sandwiched between compliant electrodes (1). The application of a force changes the capacitance of the device. Such sensors are attractive for a variety of applications in wearable electronic devices, soft robotics and touch-sensitive electronic products (2).

In order to guarantee softness and flexibility, the sensor prototype contains a non-woven porous network of polymer fibers. The micro- and nanometer-thin fibers were fabricated employing an electro-spinning technique (3).

The pressure sensors can operate in the range between 1 kPa and more than 10 MPa. Its sensitivity at the characteristic tongue pressure of 100 kPa reached about 0.15 pF/kPa. Therefore, the prototype was functioning in the oral cavity to detect the tongue forces at predefined locations. Partners at Empa provided the electronics and the Zurich University of the Arts contributed to the software for the demonstrator device.

Funding:

bott MEDICAL

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(1) B. Osmani et al.: Appl. Phys. Lett., 2017, 111, 093104

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Nanostructural Characterization of a Dental Composite for Wide Color Matching

Figure 1: The chameleon can adapt its color to the environment (picture: C. Mattle, BMC).

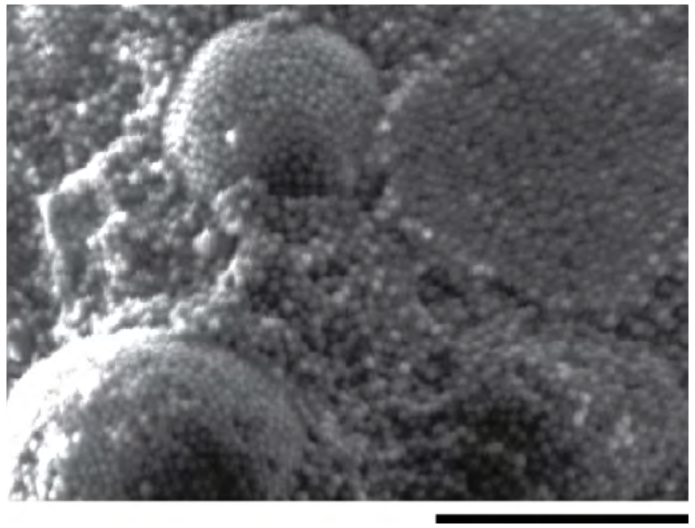

Figure 2: The composite contains ceramic spheres with a diameter of 260 nm, which are arranged in micrometer-sized domains, as clearly visible in the electron micrograph of the fractured surface. The bar corresponds to 5 µm (picture: I. Jerjen, Gloor Instruments, Kloten, Switzerland).

Master Thesis by Corinne Mattle (Department of Biomedical Engineering, University of Basel) at the Biomaterials Science Center (BMC).

Currently, dentists apply a series of resin-based composites in dental restoration to adapt the color and translucence of the natural crown (1). Now, the manufacturer Tokuyama Dental offers a product that covers the entire tooth color range. We term the color adaptation to the environment as chameleon effect, see fig. 1. Such a product not only reduces the costs of the dentists but can help to follow color changes of the natural crown.

The study aimed at a sound experimental basis to quantitatively understand the underlying chameleon effect. For this purpose, the structural properties of the composite material were evaluated by means of electron microscopy, see fig. 2, nanotomography at the beamline ANATOMIX of Synchrotron SOLEIL, France, small-angle X-ray scattering at the cSAXS beamline of the Swiss Light Source, Paul Scherrer Institute, Switzerland, and at the NANOSTAR system, and UV-Vis-IR absorption measurements. The obtained experimental results consistently showed that the composite contained spherical ceramics 260 nm in diameter (2), which are symmetrically arranged in spherical domains, see fig. 2.

Because the ex vivo restorations of numerous human crowns, that were prepared during the Master course "Digital Dentistry", showed clinically acceptable results but suboptimal color matching, one can reasonably assume room for improvement.

Funding:

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(1) de Abreu JLB, Sampaio CS, Benalcázar Jalkh EB, Hirata R. Analysis of the color matching of universal resin composites in anterior restorations. J Esthet Restor Dent. 33 (2021) 269-276. doi: 10.1111/jerd.12659.

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Navigated Knee Surgery

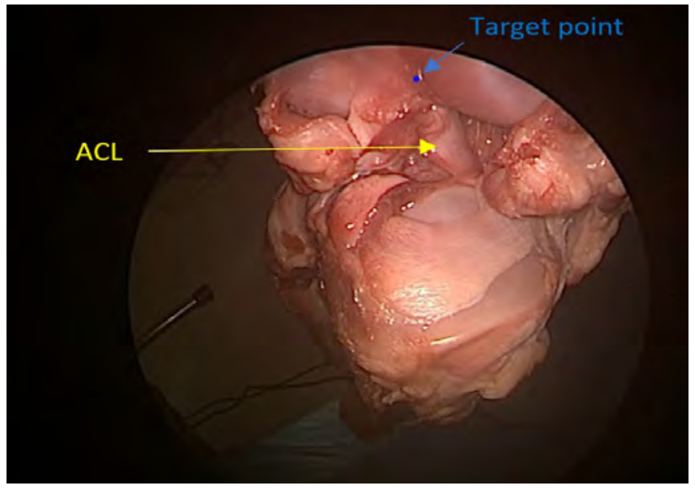

Figure 1: Arthroscopic image of a knee (picture: A. Mohler, CIAN).

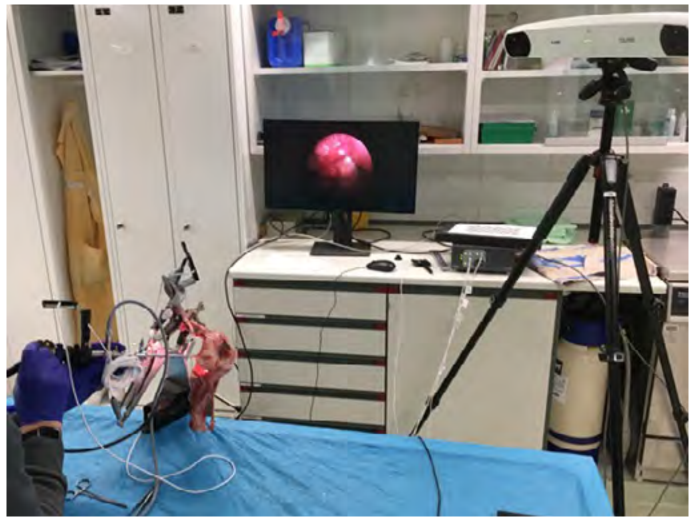

Figure 2: Setup of the navigation system (picture: A. Mohler, CIAN).

Master Thesis by Anton Mohler (Department of Biomedical Engineering, University of Basel) at Center for medical Image Analysis & Navigation (CIAN)..

In an anterior cruciate ligament (ACL) reconstruction it is very demanding for surgeons to see in arthroscopic images where the original ACL was attached to the tibia and to place the replacement (the graft) at this exact location inside the knee joint. However, it is relatively simple to locate the placement of a drilling tunnel for the graft in a magnetic resonance (MR) scan.

In this thesis a navigation system for the localization of the tibial tunnel placement during an ACL reconstruction is implemented. With the navigation system it is possible to track the position of the camera and the position of the patient. These two positions and the located position of the drilling tunnel in the MR scan are used to calculate where the drilling tunnel should be in arthroscopic images. To find the exact position of the drilling tunnel in the image, some calibration steps are required. These calibration steps consist of the tool-tip calibration, the camera calibration, the hand-eye calibration and the patient referencing.

To verify that a reasonable position in the arthroscopic images is shown the calibrations of the navigation system have been tested on its accuracy and different parameters are tried out. A deviation for the complete navigation system is determined too.

In further projects the navigation system can be further developed and used to record arthroscopic images and corresponding pixel coordinates of the drilling tunnel location. The next goal is a machine learning approach that could predict the placement at inference time without a navigation system.

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Reconstruction in Magnetic Resonance Elastography

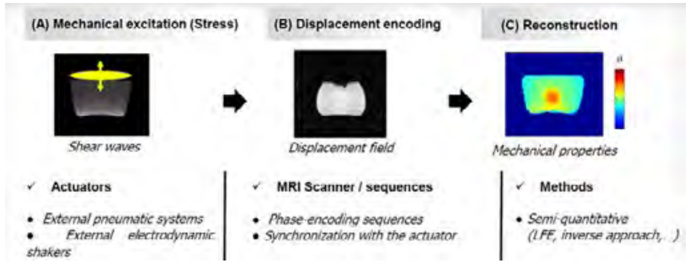

Figure 1: MR Elastography Pipeline (picture: S. Chatelin, Biomechanics and Rheology course, Télécom Physique Strasbourg, ICube).

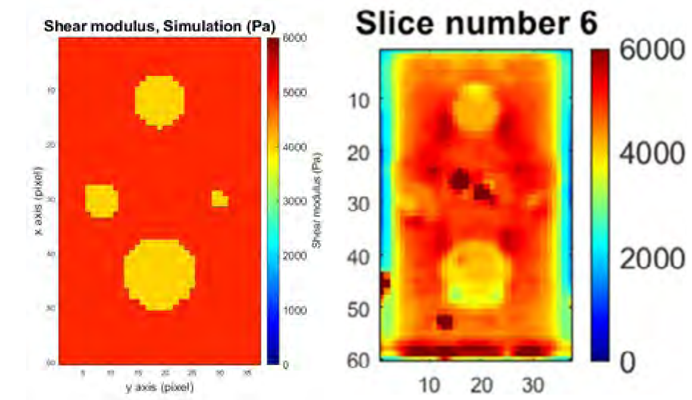

Figure 2: Elastogram of the shear modulus; left : ground truth; right: LFE results obtained during the Master Thesis (picture: A. Moreau, AMT-Center).

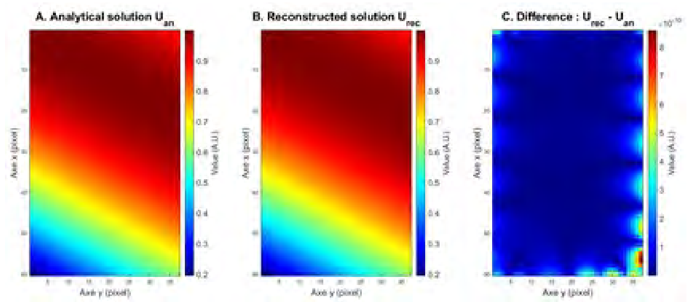

Figure 3: Analytical solution: reconstruction results with Fading Regularization (picture: A. Moreau, AMT-Center).

Master Thesis by Augustin Moreau (Télécom Physique Strasbourg / University of Strasbourg) at AMT Center.

MR Elastography (MRE) is an imaging technique that aims at mapping the mechanical properties of tissues, like their stiffness or viscosity. Changes in stiffness are often involved in pathophysiological processes, making elastography particularly effective in the diagnosis and staging of liver fibrosis. MRE relies on the following 3 steps (fig.1): 1- mechanical waves are generated and transmitted in the tissue; 2- MRI is used to capture the displacements of these shear waves; and 3- the mechanical properties called an elastograms are mapped using a reconstruction algorithm. This final step is usually done by solving an inverse problem, which comes with many technical challenges and is very sensitive to noise. My work during this project was to explore 2 tracks for MRE reconstructions: 1- the Local Frequency Estimation (LFE) providing a 2D-estimate of the stiffness; and 2- leveraging a mathematical approach called fading regularization to solve the inverse problem. My pipelines were tested on simulated noise-free displacements fields for validation purposes. LFE is frequently used in MRE and aims at estimating the spatial frequency of the waves that propagate in the tissue. In practice, our signal must be first pre-processed with specific filters. Then, from recombining these filtered outputs, we can compute the mechanical properties and elastograms. Fig. 2 shows our initial results in a simulated phantom (right) compared to the ground-truth elasticity (left). Two major findings need to be noted: 1- LFE enabled to identify the inclusions and background with values close to their ground-truth's; and 2- the elastograms lack homogeneity, especially at the inclusion/object interfaces. Fading regularization on the other hand was never implemented in MRE and by definition should offer greater stability, a low sensibility to noise and denoising abilities. Initial phases included solving the inverse problem on known analytical solutions. Fig. 3 shows good stability and indicates that the mathematical implementation works. Yet, the pipeline failed in our simulated data and required further investigations to be used with MRE data.

Funding:

Swiss National Science Foundation

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Analysis of Gold-Silicone Films for the Electrical Interface of Soft Neural Implants

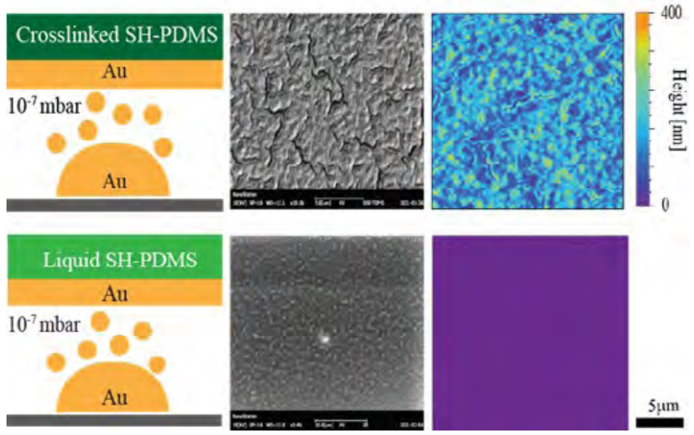

Figure 1: Schematic of Au deposited on cross-linked SH-PDMS, corresponding SEM image at 5'000X showing micro-cracks on surface and AFM topography image of amplitude 380 nm shown in the top row. Schematic of deposited on liquid SH-PDMS corresponding SEM image at 10'000X showing well embedded Au and AFM topography image of amplitude 30 nm shown in the bottom row (picture: A. Nallathambi, BMC).

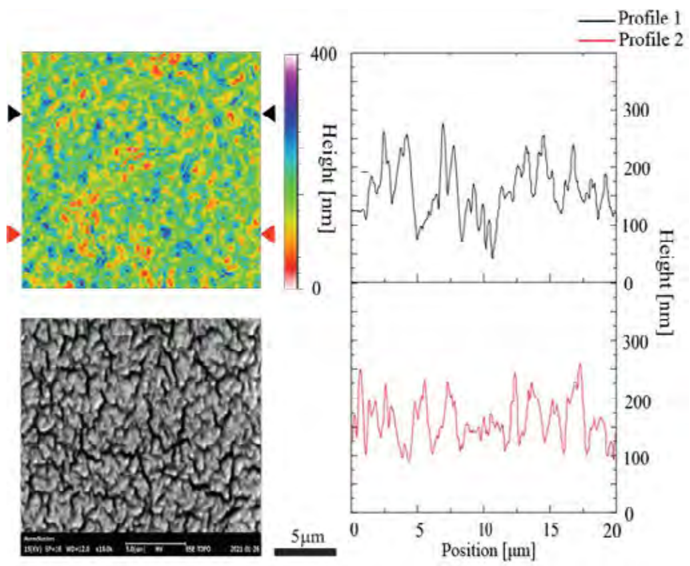

Figure 2: AFM Topography image presented with a color scale bar of 400 nm in the top row showing higher roughness, corresponding profile displayed in the right column showing the average height of the profile about (250 ± 50) nm. SEM of 240 nm – Au deposited on cross-linked SH-PDMS provided in the bottom row showing increased micro-cracks (picture: A. Nallathambi, BMC).

Master Thesis by Abinaya Nallathambi (Department of Biomedical Engineering, University of Basel) at Biomaterials Science Center (BMC).

Neuro-degenerative diseases such as Alzheimer's disease affect an increasing number of people in our aging population exceeding annual costs of 220 billion US$. Neuromodulation of glial cells is a promising approach to slow down or stop the progress of this disease. However, the treatment is limited by the lack of appropriate tools to probe the nervous system. Currently available electrodes differ by orders of magnitude from that of soft neural tissue leading to fibrosis at the tissue-implant interface. This effect could be overcome with a compliant electrode. Recent research has shown that soft gold/silicone electrodes remain conductive beyond 60% strain, which is not understood so far. For this purpose, we fabricated gold layers on cross-linked nanometer-thin silicone films using molecular beam deposition and analyzed their characteristics to prove the hypothesis that Au forms clusters bonding to the SH-groups of the cross-linked silicone. This hypothesis implies that electrical conductivity could only be reached at nominal Au layer thickness when the Au clusters form the percolation network.

Our analysis manifested linked gold clusters of nanometer size and a network of cracks evolving with increased gold deposition. It exhibit a percolation threshold at a nominal gold thickness of 60 nm. Nano-indentation studies revealed an inverse relation between the adhesion force and nominal gold thickness. Pull-off forces of (75 ± 8) and (70 ± 7) nN were found for 30 and 60 nm-thin gold, respectively. Contact-angle measurements revealed a hydrophobic behavior characterized by a Young's angle of (103 ± 3) degrees, as known from bare silicone. Therefore, we could conclude that the surface contained mostly silicone and gold migrated into the elastomer and, therefore forms a soft electrode/neural tissue interface.

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Automatic Assessment of the Hip Joint Geometry in Radiological Images

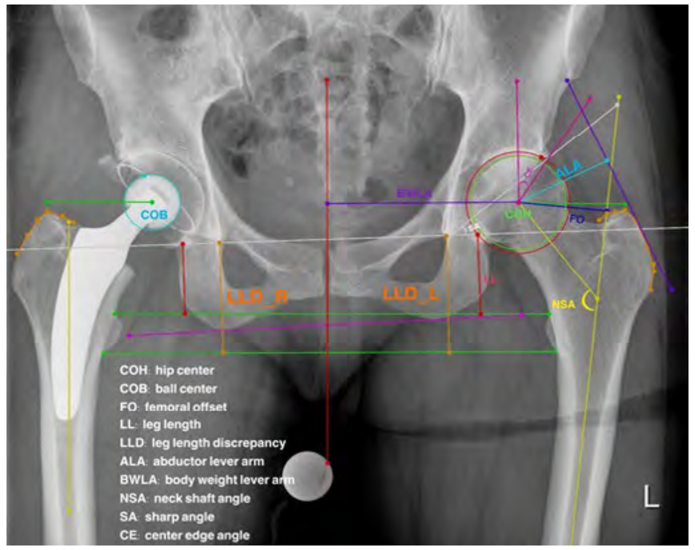

Figure 1: Radiographic assessment of the hip joint in order to restore the joint biomechanic parameters (picture: M. Salehi, CIAN).

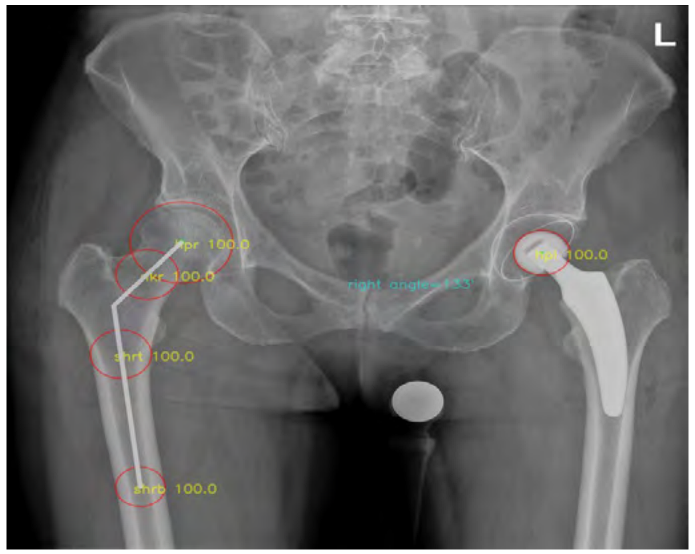

Figure 2: Automatic assessment of the hip joint in order to localize hip, ball, neck and shaft centers and measure NSA (picture: M. Salehi, CIAN).

Master Thesis by Seyede Matin Salehi (University of Basel) at Center for medical Image Analysis & Navigation (CIAN).

This project aims at automizing quantitative aspects of clinical image analysis while increasing the accuracy of measurements. An automated assessment can thereby support image analysis in clinical practice and scientific research.

Radiographic assessment is essential for both proper diagnosis and surgical planning. Traditionally, quantitative radiological outcomes have been assessed manually by the clinician. However, the manual assessment of radiological images is a time-consuming and error-prone task. For this reason, in order to reduce the burden of radiological assessments in clinical routine as well as in the context of clinical studies, automatic assessment has been introduced.

In this work, by using a dataset of real patient pelvic radiographs in Anterior Posterior (AP) view and applying supervised learning, we developed and implemented a deep learning based algorithm that is able to identify the landmarks of interest and measure Neck Shaft Angle (NSA) based on them.

Although lack of reliable landmarks, unclear acetabular and neck contours, and inaccurate patient positioning that can make the definition of these landmarks uncertain, the object detector trained in this project shows outstanding performance on the category of images used for training.

From the methodical point of view, this method is fast, accurate, and reliable and can be more reliable with a larger amount of data to ensure a clinically compliant method. As this model is capable of locating landmarks very well, it can be really helpful for clinical measurements.

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Deep Learning for Reconstruction of Subsampled Low-Field MRI

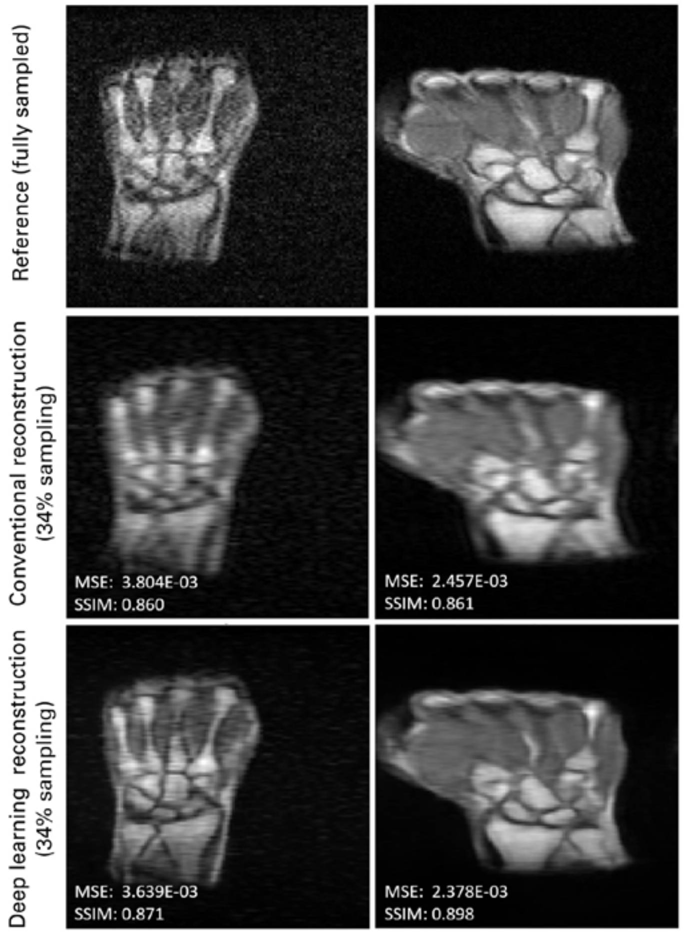

Figure 1: Two demonstrations of DL reconstruction. Top to bottom: Magnitude image of fully sampled acquisitions. Magnitude image of a corresponding acquired subsampled image using conventional Fourier Transform. DL Reconstruction of acquired subsampled image. The image reconstructed with the DL model is qualitatively equivalent to a fully sampled acquisition, while only requiring one-third of the acquisition time. Given are the reference metrics mean squared error (MSE) and the structural similarity index measure (SSIM), comparing the subsampled images to the fully sampled image (picture: T. Senft, AMT-Center).

Master 's Thesis by Tobias Senft (Department of Biomedical Engineering, University of Basel) at AMT-Center.

Low-Field (LF) MRI (field strength, $B_0 \leq 199$ mT) is getting more and more attention. Indeed, LF-MRI scanners are less expensive (purchase & maintenance) and offer more flexibility with regard to MR compatibility compared to conventional clinical scanners (field strength $B_0 \geq 1.5$ T). Yet its imaging capabilities are impacted by a lower NMR sensitivity, essentially leading to long acquisition times. In order to be deployed in clinic, acquisitions at LF have to be accelerated while maintaining fine spatial resolutions. This can be done by subsampling the acquisition, but at a cost of lower image quality using conventional Fourier Transforms for image reconstruction (i.e. aliasing, blurry contours, or similar).

This study aimed to create a DL-Model able to reconstruct subsampled LF-MR acquisitions without a loss in image quality. Further, the model should also apply to both simulated and prospectively acquired, subsampled data.

Different subsampling approaches and training methods, based on existing approaches (1), were tested despite the very low amount of low field data (~100 2D images) available for training purposes.

The model was trained using a transfer-learning approach (2): it was initially trained on the ImageNet data-base (3) before being fine-tuned using the LF-MRI data in combination with augmentation techniques. The approach providing the best results uses a simple, centered subsampling, which only samples the center 34% of k-space, leading to a 3-fold acceleration of acquisition time.

Figure 1 shows the reconstructions of two acquired sub-sampled images to a fully sampled acquisition of the same subject. The DL approach leads to a high-quality images with overall reduced noise, and shows promises in LF MRI. Further developments are now needed to improve its performances in preserving high-frequencies.

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References:
(1) Hyun et al. "Deep learning for undersampled MRI reconstruction".

(2) Salman Ul Hassan Dar et al. "A Transfer-Learning Approach for Accelerated MRI Using Deep Neural Networks".

(3) J. Deng et al. "ImageNet: A Large-Scale Hierarchical Image Database".

Initial Methods for the Engineering of Thick Vascularized Tissues

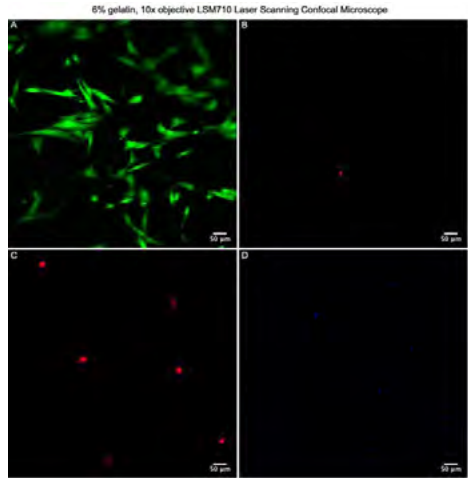

Figure 1: Live-green/dead-red/DAPI staining of ASCs inside a gelatin hydrogel (picture: J. Simeone, VBBG).

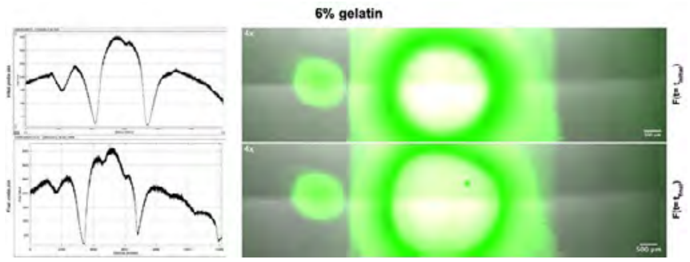

Figure 2: diffusion spectrum of FITC-dextran in a gelatin hydrogel (picture: J. Simeone, VBBG).

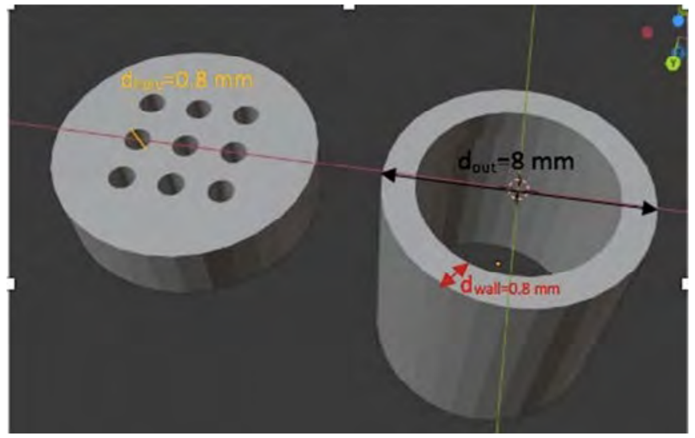

Figure 3: Perfusion chamber designed for 9 serial gelatin hydrogels (picture: J. Simeone, VBBG).

Master Thesis by Jessica Simeone, University Basel, Vascularized Bone Biofabrication Group.

Breast reconstruction is typically required after mastectomy in patients suffering from breast cancer. Standard methods comprise autologous grafting and allograft transplantation. However, due to donor site morbidity and immune response from these approaches, tissue engineering approaches are used.

The goal of an engineered tissue is, that after implantation in vivo it is able to maintain cell density and cell survival and to fulfill the required biological function of the tissue. For tissues bigger than 400 µm, a vasculature is needed to avoid graft necrosis by delivering nutrients and removing cell waste products. Thus, the challenge nowadays is to generate and engineered tissue in vitro with embedded vasculature which can then do anastomosis with the graft vascularization once implanted in the patient.

In this work, four different stiff gelatins enzymatically cross-linked with Transglutaminase were chosen as a scaffold for adipose derived stromal cells (ASCs) and it could be shown that every gelatin concentration is bio-compatible to the ASCs (figure 1) and that there is no change in morphology or migration of the cells depending on the gelatin stiffness. The diffusion capacities of the gelatins could be shown with the fluorophore FITC-dextran (figure 2) and a multichannel mold and a personalized perfusion set up for channel perfusion could be planned (figure 3).

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Pathological Maps Based on T1 Relaxometry: Robust Estimation and Clinical Validation

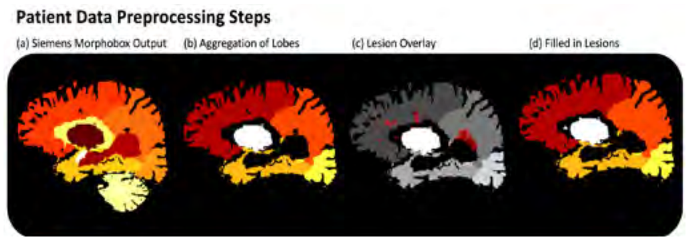

Figure 1: Output of the different preprocessing steps (a) Output of the brain segmentation into 51 different regions performed by the Siemens Morphobox (b) Aggregation of certain lobes to 5 brain regions (frontal lobe, parietal lobe, temporal lobe, occipital lobe and a region containing the deep grey matter) (c) The lesion map overlaying the aggregated lobes map to illustrate the missing regions for certain parts of the lesions (d) The final map after applying the k-nearest neighbor algorithm to identify the missing regions (picture: A. Smolinski, ThINk).

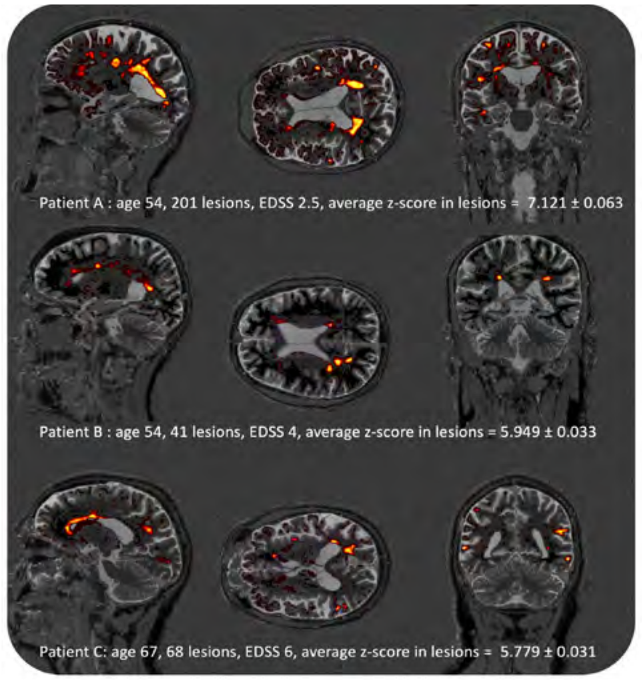

Figure 2: The T1 images of 3 patients (A, B and C) have been overlaid with the deviation map. The patients have been chosen due to their high average z-scores in lesions to give a qualitative impression of the deviation (picture: A. Smolinski, ThINk).

Master Thesis by Anna Smolinski (Department of Biomedical Engineering, University of Basel) at ThINk Group.

Quantitative MRI (qMRI) is an essential tool to quantify brain changes due to inflammation, degeneration and repair in multiple sclerosis (MS). However, how these quantified changes in the micro-structure of the brain affect the individual patient and if they are clinically relevant remains an open question. This master thesis attempts to answer this question by:

1. making the method developed by Bonnier et al., 2019 more robust,
2. correlate the measured changes in brain tissue with the Expanded Disability Status Scale (EDSS) to ascertain the statistical significance and clinical relevance,
3. making the method more lightweight and unified so it can be implemented to support clinical decisions.

To compute the reference distribution of qMRI metrics a group of 80 healthy cohort was used. To obtain the qMRI metrics, all subjects underwent 3T MRI examinations including T1 relaxation, Magnetization Prepared 2 Rapid Acquisition Gradient Echoes and High-Resolution 3D Fluid Attenuated Inversion Recovery imaging. The Siemens Morphobox was used for brain segmentation and for tissue probability estimation. The personal pathological map of 34 patients were computed. The selected parameters for the prediction of the EDSS score are: age, average z-score within the lesions and within the healthy brain tissue, number of lesions in total, and number of voxels within lesions. A generalized linear model with backwards selection was applied for the prediction of EDSS scores.

The average z-scores within MS lesions in all 34 patients is 4.14 ± 1.06 and the average z-scores outside of the lesions is 0.51 ± 0.40. The generalized linear model with backwards selection determined the most significant model. The parameters of this model are: age, average z-score and number of voxels within lesions. With a p-value of 0.000837, the resulting model has a is statistically significant.

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Reference:
(1) IG. Bonnier, E. Fischi-Gomez, R. A., et al. Personalized pathology maps to quantify diffuse and focal brain damage. Neuroimage Clin., 21:101607, 2019. doi: 10.1016/j.nicl.2018.11.017.

Digitalization of Requirement Analysis in Nursing Robotics

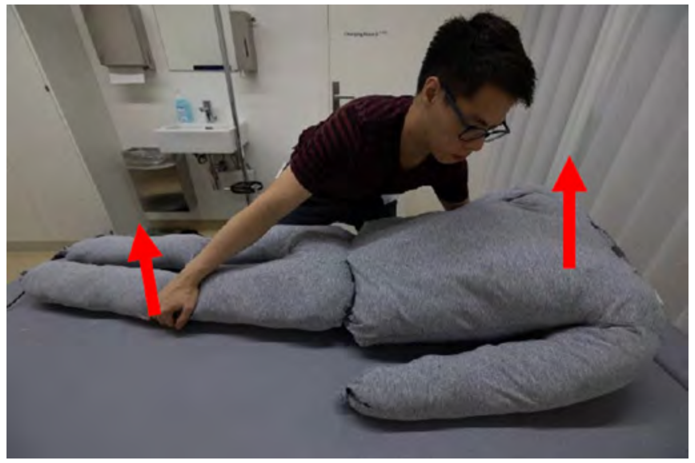

Figure 1: Bed to Wheelchair transfer of a dummy patient (picture: A. Stutz, BIROMED-Lab).

Accuracy: 69.47%

True Class \ Predicted Class	BedWheelchair	WheelchairBed	LegRearrangement	Mobilization	Sitting	Standing	Walking
BedWheelchair	37.8% 283	16.9% 155	0.1% 1	17.4% 160	4.7% 52	4.5% 45	0.0% 0
WheelchairBed	14.0% 105	49.9% 457	0.7% 6	4.2% 39	1.8% 20	2.0% 20	0.0% 0
LegRearrangement	3.1% 23	2.6% 24	95.1% 801	4.2% 39	1.0% 11	6.0% 60	0.0% 0
Mobilization	37.3% 279	24.7% 226	2.4% 20	68.8% 632	3.1% 34	8.9% 89	0.0% 0
Sitting	1.7% 13	1.5% 14	0.5% 4	0.5% 5	70.9% 789	16.1% 161	0.0% 0
Standing	6.0% 45	4.3% 39	0.8% 7	4.7% 43	13.0% 145	61.7% 616	0.0% 0
Walking	0.0% 0	0.0% 0	0.4% 3	0.0% 0	5.6% 62	0.8% 8	100.0% 876

Figure 2: Confusion matrix of the best performing CNN (picture: A. Stutz, BIROMED-Lab).

Master Thesis by Adrian Stutz (ETH Zürich) at the BIROMED-Lab.

Musculoskeletal diseases are one of the major problems in nursing. Despite efforts from industry and academia to find technical solutions, no satisfying solution has been found so far. We suspect a disconnect between perceived and actual needs of the nursing staff is a factor. To better understand the actual needs, determining the workload has a high priority. One way to look into that is by activity tracking of nursing specific tasks.

In this thesis, an IMU and CNN-based human activity recognition system has been evaluated. To ensure real-world application in nursing, the equipment used had to be held minimal. At the same time, it had to be capable to recognize complex movements. 10 low-profile IMUs were used for data recording. Data processing took advantage of the capabilities of CNN in image recognition, by converting the raw IMU signal into RGB images.

The CNN was evaluated by using leave-one-participant-out-cross-validation with data from 4 participants. The best performing network showed an accuracy of 69.47% for 7 classes.

Although the network is not robust enough to deliver reliable results, the whole approach shows promise. Due to its easy setup and data processing without needing any visual recordings, the approach shows potential to be used in a real-world environment. But before this approach can be taken into a real-world environment, further improvements have to be made. These range from including more tasks for classification, including more participants to generate a larger dataset, or adjusting model parameters.

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Reinforcement Learning for Automatic Dose Control in Proton Radiotherapy

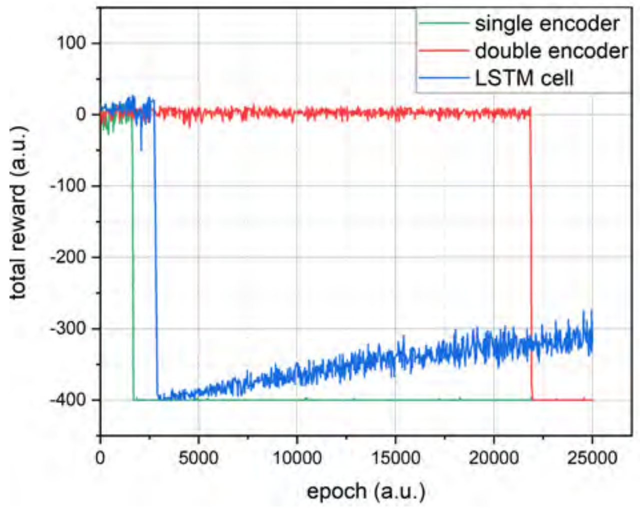

Figure 1: The total reward is plotted against the number of epochs. In green one can see the performance of the single encoder network, in red the double encoder networks and in blue the LSTM cell network (Plot: N. von Mühlenen, CIAN).

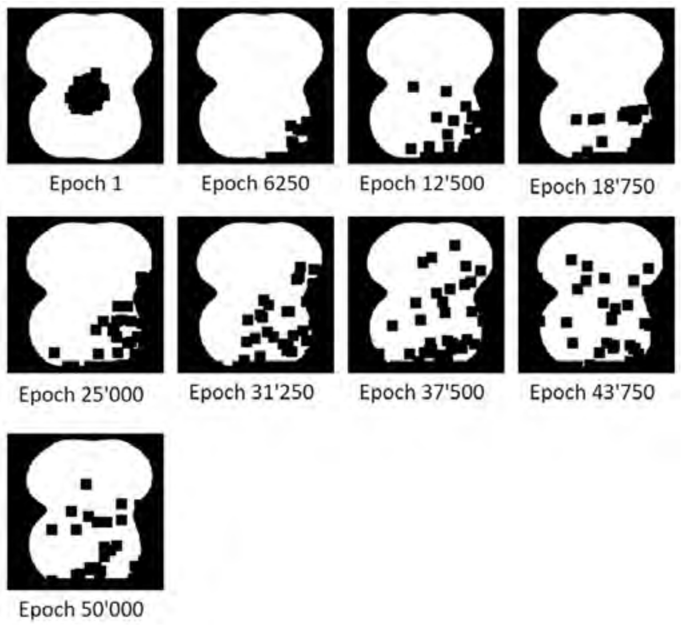

Figure 2: Images show the final result of the performance of the LSTM cell network on the environment, over the course of the training. It shows that for the first episode the agent is able to hit the tumor, but all the hits are clustered together. For the later epochs, the agent starts to spread out the hits over the tumor (picture: N. von Mühlenen, CIAN).

Master Thesis by Nair von Mühlenen (Department of Biomedical Engineering, University of Basel) at Center for medical Image Analysis & Navigation (CIAN)..

Proton therapy is a treatment method for various cancer types. One of the challenges found while performing proton therapy is motion management. Especially the breathing motion of the patient poses a challenge (1). We propose an artificial intelligence (AI) trained with reinforcement learning (RL) to control the delivery of proton therapy and actively adapting to the breathing motion of the patient.

The real-life environment of treatment delivery is simplified into a virtual 2D environment. The tumor is represented by a static target. An example environment is shown in fig. 2. We used an advantage actorcritic (A2C) (2) model in combination with three different neural networks (NN) to train with the virtual environment. The first NN is the here-called single encoder, a simple convolutional neural network (CNN), where the actor and critic NN share parameters. The second NN, here-called double encoder is also a CNN, where the actor and critic NN do not share parameters. The last NN is a CNN combined with a long-short term memory cell (LSTM cell) (3).

Figure 1 shows the performance of all three networks, plotting the total reward accumulated during one epoch against all epochs. It shows that all three networks experience a sudden fall in reward, with only the LSTM cell (blue) network being able to increase the reward afterwards. The double encoder (red) can maintain a higher reward count longer than the single encoder (green). But after the abrupt fall is not capable to recover. Fig. 2 depicts the final states of the environment during the training of the LSTM cell network. It shows that over time the agent is spreading the hits over the entire tumor, which coincides with the improvement of the reward seen in figure 1.

We were able to show that with an adequate network the agent can hit the target and that it can improve performance over time.

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References:
(1) Clinical Experience. Paul Scherrer Institut (PSI). URL: https://www.psi.ch/en/protontherapy/clinical-experience

(2) Policy Gradient Algorithms. Lil'Log. Apr. 8, 2018. URL: https://lilianweng.github.io/2018/04/08/policy-gradient-algorithms.html

(3) LSTMCell – PyTorch 1.7.0 documentation. URL: https://pytorch.org/docs/stable/genated/torch.nn.LSTMCell.html

Evaluation of Active Middle Ear Implant Using Acoustomechanical Middle Ear Model

Figure 1: Microscope picture of the Acoustomechanical Middle Ear Model with a Floating-Mass Transducer. White structure is the tympanic membrane. Yellow structures is the ossicular chain (malleus, incus, stapes). A FMT is coupled on the incus with a long process coupler (picture: L. Wey, USB).

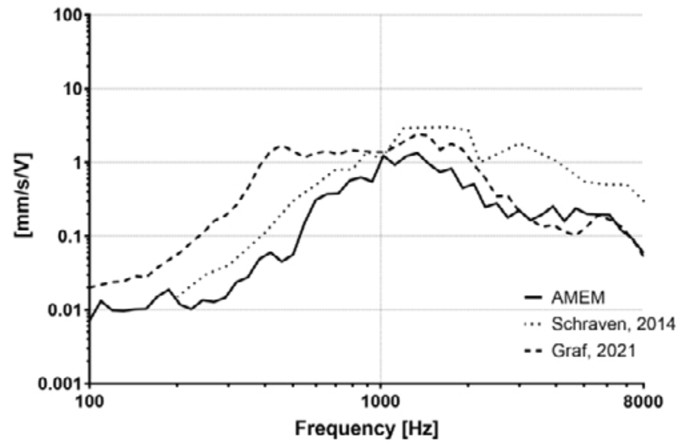

Figure 2: Comparison of transfer functions from the literature, for the LP-coupler, both three curves have generally the same shape and amplitude, except for Graf's curve which is approximately 15 to 20dB higher between 100Hz and 800Hz and Schraven's curves has an amplitude around 10dB higher for the higher frequency between 2'000Hz and 8'000Hz (Plot: L .Wey, USB).

Master Thesis by Lucas Wey (Audiology, University Hospital of Basel).

The middle ear is a complicated and subtle structure for the sense of hearing, which aims to transmit the sound information to the inner ear. Understanding and reproducing its functions is a critical topic for researchers, because it could lead to the innovation of active middle ear implant (AMEI), but not exclusively.

Actually, most of the studies are conducted with human temporal bones, which is not always the best solution, due to the anatomical inter-individuality and the post mortem changes inducing variation in the mechanical properties. Furthermore, there is limited access for such preparation. For these reasons, different groups have invented middle ear models to study the mechanical properties of the middle ear. The Acoustomechanical Middle Ear Model (AMEM) presented by Taschke et al. includes the real size and weight of the ossicle, a latex or silicon tympanic membrane, middle ear ligaments and 2cm^3 volume in front of the tympanic membrane (1). The LP and SP couplers where implanted sequentially. For each coupler, we measured the motion of the stapes head and the backside of the stapes using laser Doppler vibrometry (LDV) with electrical stimulation in a frequency range between 100 and 8'000Hz. For acoustical stimulation the motion of the stapes was in approximately 15 dB lower in the frequency range between 600 Hz and 3'000 Hz. The coupler placed on the short process of the incus provided a higher magnitude in the frequency range between 200 to 400 Hz and 1'600 to 8'000 Hz compared to the coupler on the long process of the incus. The AMEM has the advantage that couplings parameters can be easier changed than in temporal bones. There are no constraints in terms of availability and no biologic decay as it is the case for human temporal bones. The AMEM presents a useful model for relative comparison of different parameters in AMEIs. For absolute magnitude estimations human temporal bones are preferred.

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(1)Taschke, H., Weistenhöfer, C. and Hudde, H. "A Full-Size Physical Model of the Human Middle Ear", Acta Acustica united with Acustica, 2000.

(2) Stieger, C., et al. "Human temporal bones versus mechanical model to evaluate three middle ear transducers" J Rehabil Res Dev, 2007.

(3) Schraven, S. P., et al. "Alternative fixation of an active middle ear implant at the short incus process", Audiol Neurootol, 2014.

Magnetic Resonance Fingerprinting Reconstruction Using Methods from Multimedia Retrieval

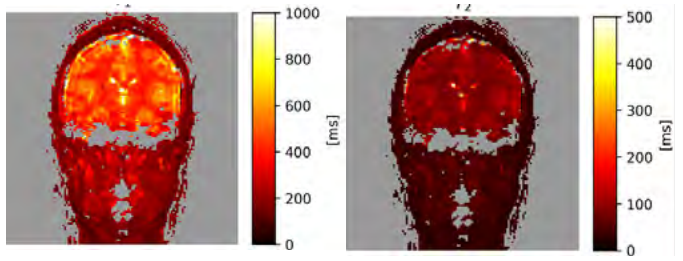

Figure 1: Magnetic resonance fingerprinting reconstructions of T1 and T2 of a healthy volunteer at 1.5 T. The reconstruction was performed with approximate dictionary matching using product quantization requiring 12 % of the time of the exact reconstruction (picture: G. Zihlmann, AMT-Center).

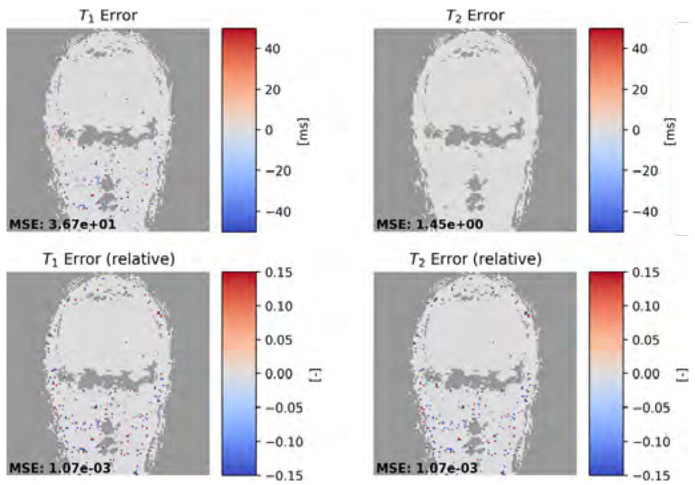

Figure 2: Absolute and relative error values incurred by the approximate nature of the reconstruction. 91 % of all points have the exact same values as the exact reconstruction (picture: G. Zihlmann, AMT-Center).

Master Thesis by Gabriel Zihlmann (Department of Mathematics and Computer Science, University of Basel) at AMT-Center.

Magnetic resonance fingerprinting (MRF) is a relatively new form of MRI with the capability of simultaneous quantitative mapping of multiple properties simultaneously. A relatively short, pseudo-random data acquisition is followed by a computationally expensive reconstruction step in which acquired signals are compared to a large dictionary of simulated signals to retrieve tissue parameters. The computational cost associated with fingerprint matching imposes constraints on dictionary size and ultimately on the number of measurable parameters and their resolution. We introduce concepts and methods from approximate nearest neighbor search to reduce the computational cost for MRF matching. Our main contribution consists of extending product quantization-based maximum inner product search to the complex domain. We achieved 91 % correctly matched fingerprints (recall) at 12 % the time required for the exhaustive search during the evaluation of our preliminary implementation with in vivo data at 1.5 T. Using phantom samples at low field (100 mT), we verified that the incurred error is low compared to the overall accuracy of the MRF method.

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References:

1) Dan Ma et al. Nature 495.7440 (2013), pp. 187–192.

(2) H Jégou, et al. IEEE Transactions on Pattern Analysis and Machine Intelligence 33.1 (2011), pp. 117–128.

(3) Ruiqi Guo et al. Artificial Intelligence and Statistics. PMLR (2016), pp. 482–490.

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Other Completed Student Projects

Angular Sensor for shape sensing of medical robots developped at the DBE (picture: R. Wendler).

Each year, in addition to the students who finish their Master or PhD, the DBE hosts many other student projects. This section contains a non-exhaustive list of projects conducted by interns or students who completed a bachelor or a semester thesis at DBE:

Semester Theses:

- Anna Louisa Cirtautas (BIROMED-Lab) 109
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Internship:

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A Concept Evaluation Method for an Actuation Unit of a Handheld Multi-functional Laparoscopic Instrument

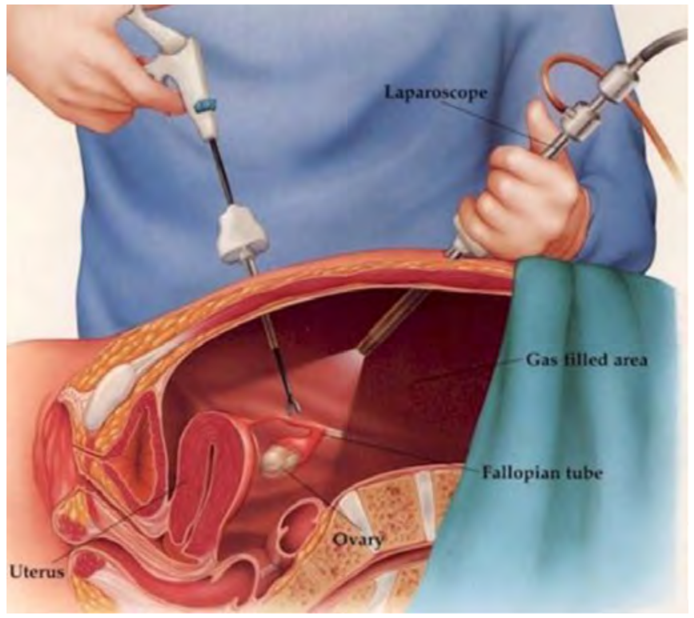

Figure 1: Example of laparoscopic surgery (source: F. S. Tsai et al. 2010, Journal of Biomedical Optics).

Figure 2: The Medusascope by Surgical Synergy is equipped with a rotating cylinder to choose between various tooltips during surgery (picture credit: Surgical Synergy).

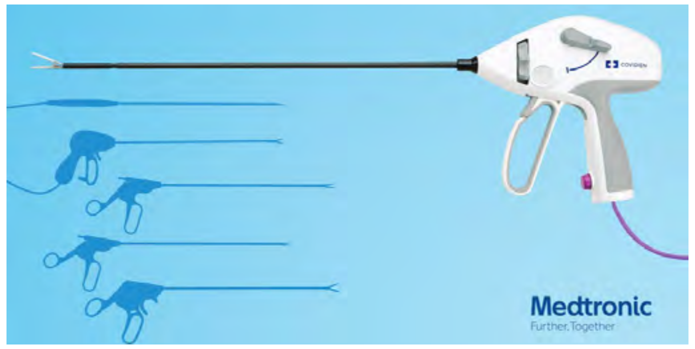

Figure 3: The multi-functional LigaSure Retractable L-hook by Medtronic with a retractable hook and grasping tip (picture credit: Medtronic).

Semester Thesis by Anna-Louisa Cirtautas (Eidgenössische Technische Hochschule Zürich – ETHZ) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

This semester thesis aims to help creating a device for laparoscopic surgery, the Multiscope system, which integrates the tool change in the device, considering the constraints of the surgical environment in the development process and the other key objectives. The overall goal of this system is strengthening the independence of the surgeon, reducing error sources and therefore complications and operation time. The actuation and drive unit (continued to be solely described as actuation unit) is the core of the system, enabling tool tip change and manipulation and therefore requires in depth pre-investigation for defining a suitable solution concept, as it has an interface to every other subsystem of the device. The development of the actuation unit is determining the functionality and usability of the complete system and plays an important role regarding fulfilling the expectations of the user.

The contribution of this report is to define a systematic strategy for a subsystem development with the necessary decisions. Which concept for the actuation unit should be pursed, being most promising fulfilling requirements for medical devices and user needs. The focus of this thesis is the prework for prototyping. Methodologically, a systems engineering approach is chosen, including the RFLP (Requirements engineering, Functional design, Logical design, Physical design) approach and the VDIs (German Engineering Association Guidelines) 2206 and 2221. To support decisions, an evaluation method for the solution concepts of the actuation unit is developed, which can be applied and adapted in every phase of the product development process.

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Virtual Simulation Environment for a Teleoperation User Console

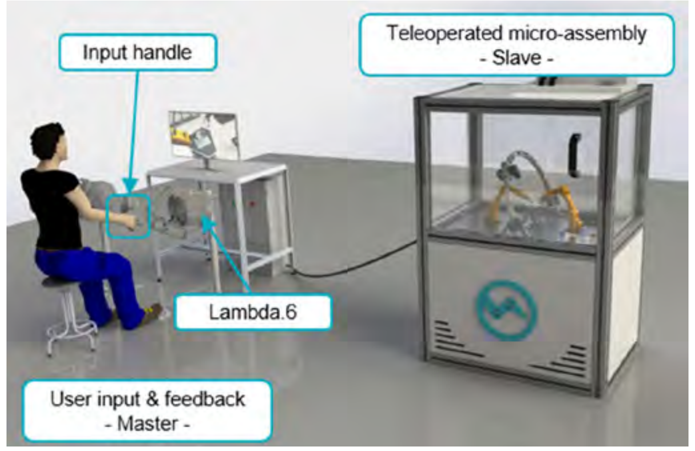

Figure 1: Representation of the future intended teleoperated micro-assembly station (picture: C. Duverney, BIROMED-Lab).

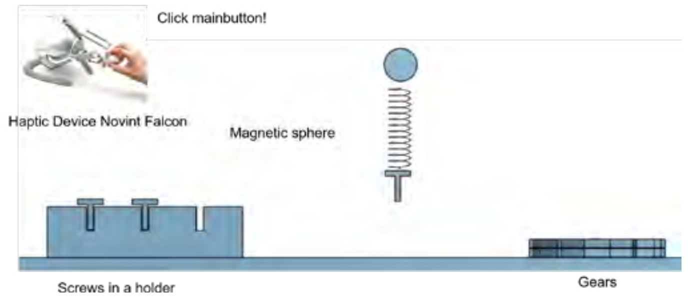

Figure 2: Proof-of-concept application to analyze if H3D was a suitable haptic framework for a future implementation of the virtual micro-assembly system (picture: Y. Koster, BIROMED-Lab).

Semester Thesis by Yannick Koster (Eidgenössische Technische Hochschule Zürich – ETHZ) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

Miniaturization of devices results in innovations in research and various industry sectors such as consumer electronics, medical technology, or watchmaking. One of the key challenges is the assembly of such miniature devices. To assemble those, we envision building a micro-assembly system for precision and flexibility. This system consists of a robotic assembly side that a user teleoperates with haptic interfaces for an intuitive and safe assembly process. We also want to use a haptic framework to implement a virtual micro-assembly system that helps to develop and test the micro-assembly system. Haptic frameworks facilitate developers to implement whole haptic applications.

The objective of this semester project was to find the most suitable haptic framework – a tool to implement the virtual micro-assembly system. In addition, we aimed to validate its applicability to the virtual micro-assembly with a simple proof-of-concept application and a small user study. Based on the virtual micro-assembly system concept, we defined requirements that a haptic framework had to fulfill to be suitable for the virtual micro-assembly system. We compared popular haptic frameworks identified in our literature research and selected the most suitable haptic framework, H3D, based on the defined requirements. Using H3D, we implemented a proof-of-concept application which was a simple pick-and-place task – a task of a micro-assembly process. We learned by implementing the proof-of-concept application that some physic functionalities fundamental for our virtual micro-assembly system were not yet implemented in the haptic framework H3D. In a small user study, we investigated how haptic force feedback can make an assembly task more intuitive for the user. We conclude that haptic frameworks are suitable for haptic applications with simple physic interactions and less suitable for haptic applications with complex physic interactions like our virtual micro-assembly system.

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Developing a Sterilisation Concept for an Innovative Multifunctional Laparoscopic Device

Figure 1: The Medusascope by Surgical Synergy is equipped with a rotating cylinder to choose between various tooltips during surgery (picture credit: Surgical Synergy).

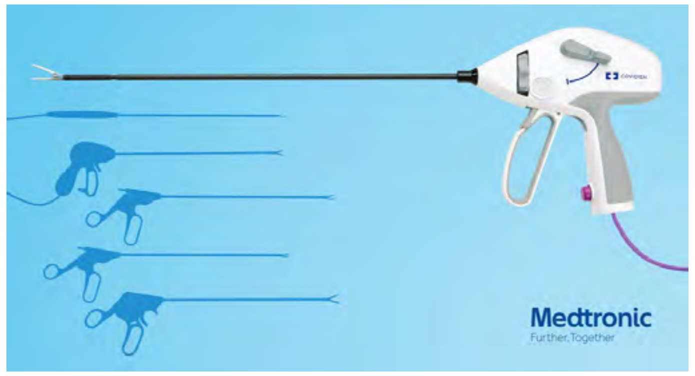

Figure 2: The multi-functional LigaSure Retractable L-hook by Medtronic with a retractable hook and grasping tip (picture credit: Medtronic).

Semester Thesis by Mira Cecilia Mahavadi (TU Munich) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

When developing a new medical device, novel and innovative technology is not sufficient. Additionally, the device must be desired by the user, the design must be feasible and the product must be viable. These three lenses of human centred design (HCD) are key factors for successful product design.

Early-stage start-ups often struggle to meet those requirements simultaneously while improving (medical) technology. To solve this challenge, the prototyping framework PETRA (Plan-Execute-Test-Reflect-Assimilate) was designed. PETRA provides a clear roadmap with various phases and milestones towards a minimum viable product (MVP). The framework and agile management tool is specifically designed for interdisciplinary teams working on novel hardware solutions. PETRA not only assists the development team in tracking their tasks, but also documents the progress with respect to the lenses of HCD. By leveraging a combination of different agile product development tools and computing a matrix of development, PETRA can thus provide suggestions for the project manager on where to set future focuses.

The aim of this thesis is to develop a sterilisation concept for an innovative multifunctional laparoscopic device in the framework of PETRA. During the case study, the research, requirement engineering and design recommendation for the reprocessing concept of the new device are tracked in the PETRA tool. Based on the generated data, challenges are to be identified and recommendations for the PETRA framework should be made. Additionally, a sterilisation concept for the laparoscopic instrument is to be defined.

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Combining Optical and µCT Images of Annual Layers in Human Tooth Cementum

Figure 1: The part of a stem's cross section of a woody plant displays annual layers, here from ash wood. The age of a tree can be determined by counting the number of annual layers at the base of the trunk. Fluctuations in layer thickness provide information about ancient climates. Variations of their thickness reveal compass direction (picture: B. Müller).

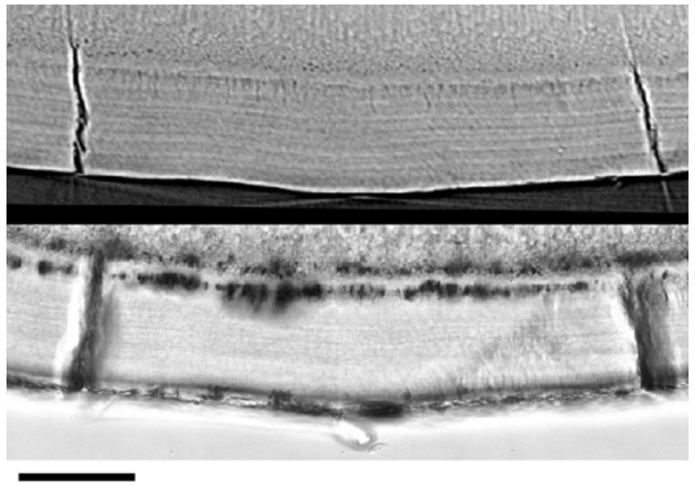

Figure 2: Registered micro computed tomography (top) and optical microscopy (bottom) images from human tooth cementum with annual layers running from left to right. From the expected 39 layers, one finds for this region 13 layers in the optical micro-graph and 15 layers within the CT data. The scale bar corresponds to 100 µm (picture: M. Stiefel, BMC/ETH).

Semester Thesis by Muriel Stiefel (Physics Department of ETH Zurich) at the Biomaterials Science Center (BMC).

Annual layers are best known from wood, see figure 1. Such layers are also found in human teeth. To visualize them, optical microscopy is applied to tooth sections a fraction of millimeter thick (1). The physical slicing of unique teeth, however, should be avoided. Recently, the annual layers of entire human teeth were made visible by computed tomography with micrometer resolution for local regions (2,3) and full cross-sections (4).

In this study, slices of human teeth were imaged using both approaches to identify the advantages of the individual techniques. For this purpose, four tooth sections were provided by the Natural History Museum in Basel. First, the optical data were acquired by means of the Panorama MIDI II scanner. Second, the hard X-ray data of the same sections were recorded in a stacked setup at the beamline ANATOMIX of synchrotron SOLEIL in France. Third, the tomography data were reconstructed and the individual sections extracted. Forth, the two-dimensional optical data were registered with tomographic data, which was enhanced by projecting along the layers (4). An example is shown in figure 2. One can clearly recognize the features in the tooth cementum including cracks. Visual inspection of the common area allows for the detection of the annual layers in both datasets with limited agreement, see figure 2. Therefore, one can count the layers; some of them are not resolved.

For a pixel-to-pixel correlation between the images, however, a more detailed data treatment has to be employed. Such a correspondence would enable us to generate bi-variant histograms to combine the information of the two complementary techniques (5).

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Real-Time Visual Feature Recognition and Metrology for Mechanical Micro-Parts

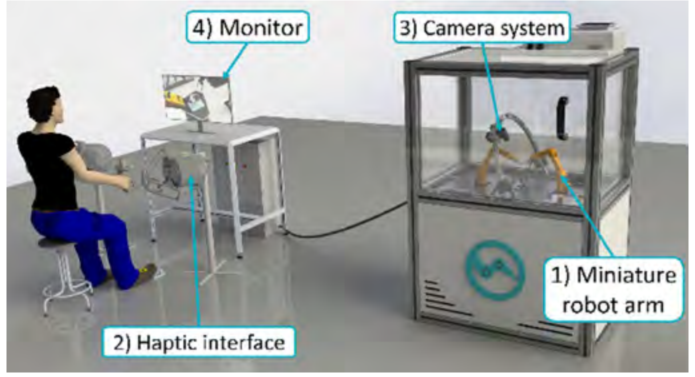

Figure 1: A 1) miniature robot arm is used to manipulate micro-parts and is controlled by the user through a 2) haptic interface. A 3) camera system provides a live video stream to the user via a 4) monitor. Image processing techniques can be applied to the video stream to provide the user with additional information such as part types and dimensions (picture: C. Duverney, BIROMED-Lab).

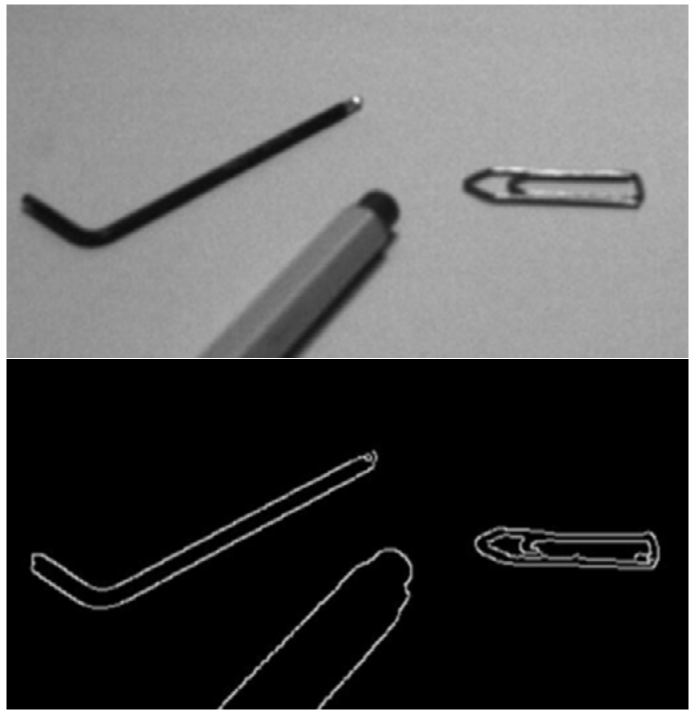

Figure 2: Top: Original black and white image of everyday objects. Bottom: Output of the edge detection framework. This output can be further processed for example with object recognition methods (picture: L. Gschwind, BIROMED-Lab/FHNW).

Bachelor Thesis by Lucien Gschwind (University of Applied Sciences and Arts Northwestern Switzerland – FHNW) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

A key challenge arising during the development of small-scale prototypes is the assembly of the miniature parts into functional devices. While large batches of devices can nowadays efficiently be assembled by automated assembly lines, unique prototype devices are typically still assembled by hand. Prototype developers are however not necessarily trained and experienced in manual micro-assembly. To support developers in micro-assembly and reduce the risk of parts being damaged, teleoperated micro-assembly systems can be used (1).

A key challenge in micro-assembly is the precise insertion of micro-parts into an overall assembly. The goal of this thesis was to develop a visual framework, which identifies the location and orientation of micro-parts, holes, and threads. This information can be provided to the user for a more intuitive assembly experience or fed to a visual servoing framework for automation of specific assembly steps.

Different feature recognition methods have been developed, implemented, and compared based on the specific needs of the micro-assembly application. Furthermore, different software and hardware architectures for the final framework have been compared. Several promising methods and architectures could be identified. Next steps will include the implementation and validation of these methods with a wider range of micro-parts, and the integration into the overall micro-assembly system.

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Influence of Age and Sex on Maximal Single Leg Hop for Distance in Knee Healthy Subjects

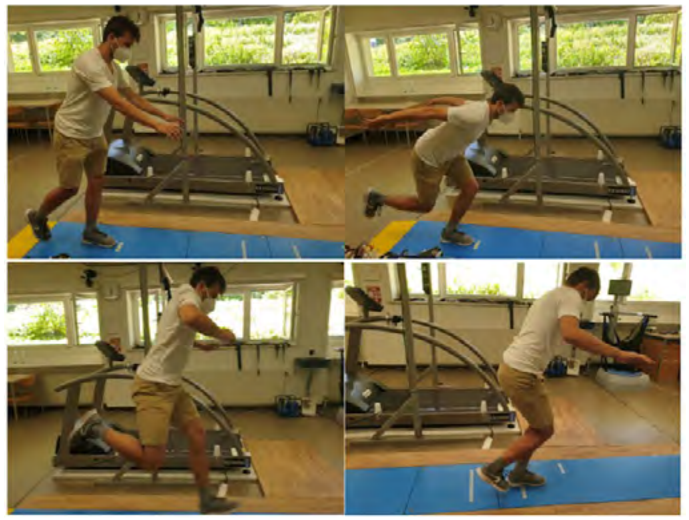

Figure 1: Serial picture of a single leg hop for distance (picture: N. Hügle, FBL/USB/Uni Freiburg).

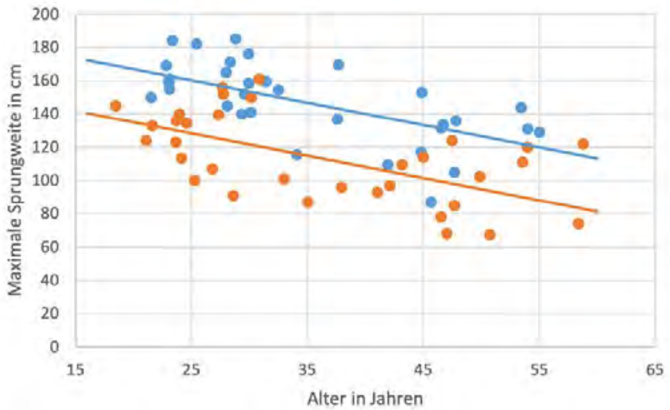

Figure 2: Scatterplott of age and maximal single leg hop distance for female (red) and male (blue) participants (picture: N. Hügle, FBL/USB/Uni Freiburg).

Bachelor Thesis by Nico Hügle (Department of Biomedical Engineering, University of Basel; Department of Sport Science, University of Freiburg, Germany) at the Functional Biomechanics Laboratory (University Hospital Basel).

The single leg hop (SLH) for distance reflects the functional capacity of the knee joint after a knee injury (1). For this purpose, a knee-healthy control group is often used as a reference, yet to date normal values from the literature predominantly referred to very athletic individuals between 18 and 45 years of age (2). The aim of this work was to investigate the influence of age and sex on single leg hop distance in knee-healthy participants with moderate activity between 18 and 60 years.

In the present work, the maximum single leg hop distances of 32 men (35.6 ± 10.6 years) and 33 women (36.6 ± 12.2 years) were determined. Each subject performed up to six single leg hops per leg side (figure 1). Linear models based on multiple linear regressions were used to investigate the influence of age and gender.

In the general linear model, a significant correlation of the maximum jump distance with age and gender was found (figure 2). In male participants (146.9 ± 23.5 cm) the jumped distance was significantly higher than in female participants (114.9 ± 25.6 cm; P<0.001). With increasing age, the maximum distance decreased regardless of sex (P<0.001). In addition to age and sex, activity level and body weight significantly influenced maximal jumping distance.

Based on these results, previous normative values for maximum jumping distance in men and women should be adjusted for older subjects. In future studies, matching control subjects for the SLH should be based on age and sex, and activity level and body weight should also be considered.

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Path Planning for Planar Hyper-Redundant Surgical Robots

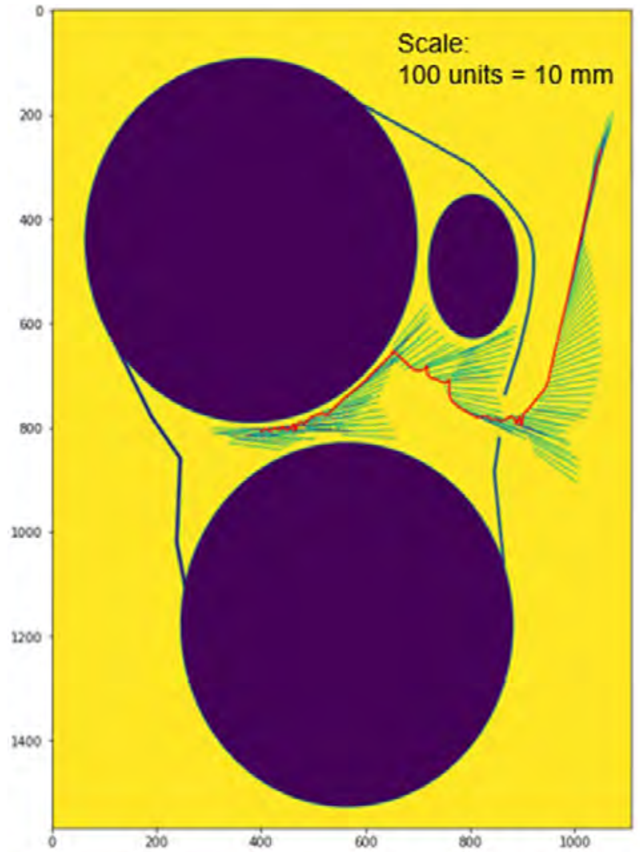

Figure 1: A 2D depiction of the path planning problem in human knee (picture: T. Prasad, BIROMED-Lab).

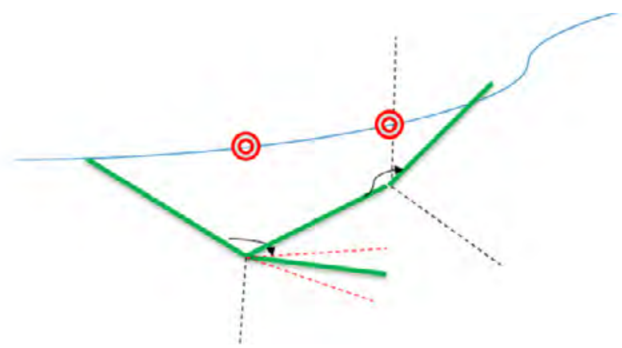

Figure 2: Fitting the configuration space solution to generated task space trajectory (picture: T. Prasad, BIROMED-Lab).

Internship by Tarun Prasad (Indian Institute of Technology Madras) at Bio-Inspired Robots for Medicine-Lab (BIROMED).

This project aims to perform path planning for an hyper redundant robotic endoscope addressing the narrow passage problem in human knees. The literature indicated that alternative approaches to sampling-based algorithms need to be developed. A previous work (1) served as the start point for this project as it showed the effectiveness of task space trajectory synthesis for the end-effector while also showing the complications in using top-down approaches such as IK and null space search in generating configuration space solutions. Here, the idea is to develop an intuitive bottom-up approach for the configuration space solution while leveraging the effectiveness of a RRT-based task space planner in generating the end-effector trajectory. A planar abstraction of the problem was adopted to intuitively visualise and analyse the various bottlenecks in configuration space planning. This 2D abstraction of the knee was the simulation environment and Python was the framework. A pixel-based collision checker was implemented. The task space trajectory planner from (1) was reconstructed for the 2D environment. For each end-effector task space solution along the trajectory the joint angles were chosen such that the links best fit the trajectory line. This was used as the initial configuration space planner with discretisation between consecutive instants for finer collision checking. Based on the solutions generated using this concept, the visuals suggested different methods to overcome collision bottlenecks. Some solutions involved pre-validating whether a given configuration space solution will face collision in the next consecutive instant and rejecting the ones which fail. Another method was to use different permutations of trajectory lines for configuration space planning to evaluate, which one better represented collision free zone. The task space planner had a success rate of 79% on 400 cases while the configuration space planner had only a success rate of 42%. A more sustainable solution would be to develop a configuration space planner which optimises between generating the instantaneous best fit to collision free zone and exploring collision free zone by sampling.

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Publications

Selected Publications 2021

***Peer-reviewed publications (116), where first author (30) or last author (96) is at DBE, impact factor >2.**

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