University of Basel
Department of
Biomedical Engineering

Department of Biomedical Engineering
PhD & Master’s Thesis 2023

Completed PhD Thesis

Dr. Eva Schnider celebrating after her PhD Defence (picture:CIAN)

Since 2021, the number of students enrolled in the DBE doctoral program has stabilized at around 65. In 2023 they have been particularly sucessful, with 9 of them winning a total of 13 prizes and awards for their reserach work. In addition, 14 of these PhD students have defended their theses and started new careers. They include:

Rapid Magnetization Transfer Magnetic Resonance Imaging

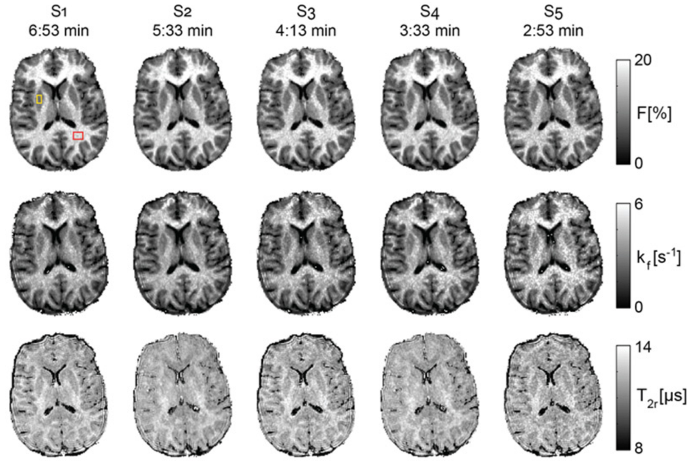

Figure 1: B_1-corrected quantitative MT parameter estimates acquired from different number of sampling points at 3T. S1 to S5 contain 18, 14, 10, 8 and 6 sampling points respectively (Figure from (3) published under a CC-BY license).

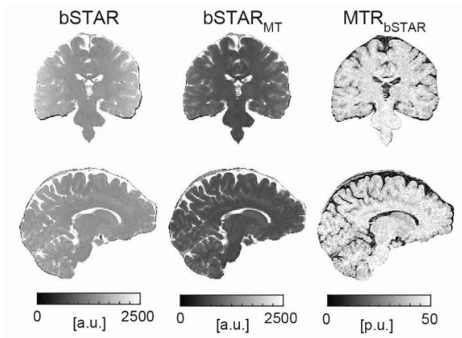

Figure 2: Exemplary coronal and sagittal view of non-MT-weighted, MT-weighted, and MTR images from bSTAR sequence reconstructed with 0.87 mm resolution at 0.55T (Picture: R. Afshari)

PhD Thesis by Roya Afshari at Radiology Physics, University Hospital of Basel.

Magnetization transfer (MT) (1) imaging provides a contrast reflecting the properties of hydrogen atoms bound to macromolecules in the tissue. These components, which are short-lived in nature, cannot be captured by conventional MRI methods. However, by saturating the magnetization of macromolecules using an off-resonance radio-frequency pulse, a signal intensity drop is induced, enabling the generation of MT contrast.

MT can be expressed by quantitative parameters (two-pool model parameters, see Figure 1), or as a semi-quantitative measure (MTR, see Figure 2). Both methods are useful in diagnosing and prognosing pathologies like multiple sclerosis. Integrating MT into clinical practice is challenging due to long acquisition times, B_1 field nonuniformities at high field, and limited signal-to-noise at low fields. This thesis addresses these issues by developing fast and robust MT imaging methodologies.

To this end, a fast spiral multi-slice spoiled gradient echo sequence, combined with a low-resolution B_1-mapping for accurate MTR imaging in less than one minute was implemented. The same method was further developed to obtain whole-brain quantitative MT maps in 5 minutes. Moreover, the feasibility of MTR imaging at low field was investigated with a highly efficient balanced steady-state free precession sequence, termed bSTAR (2), yielding submillimetre isotropic resolution within the clinically acceptable scan time.

The techniques presented in this thesis facilitate a wider use of MT imaging in clinics for the diagnosis and prognosis of various diseases.

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(1) Henkelman RM, Stanisz GJ, Graham SJ. Magnetization trans-fer in MRI: a review. NMR Biomed. 2001;14(2):57–64

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In vitro and in vivo Metabolomics: Tapping the Potential of Secondary Electrospray Ionization – High Resolution Mass Spectrometry

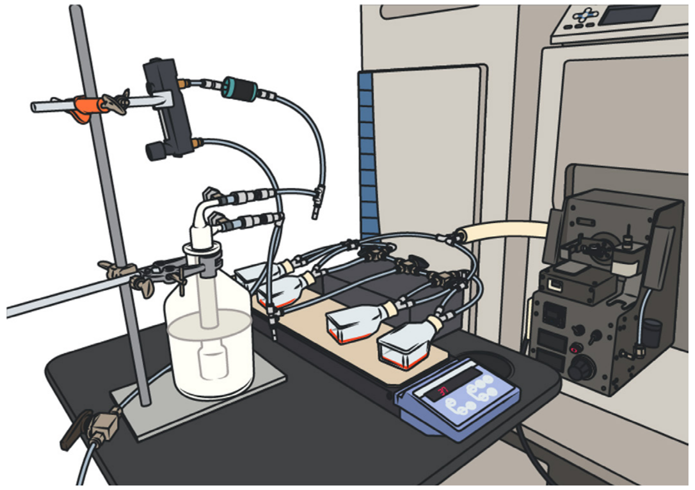

Figure 1: Experimental setup for DC headspace measurement by SESI-HRMS (picture: K. Arnold and A. Budiawan).

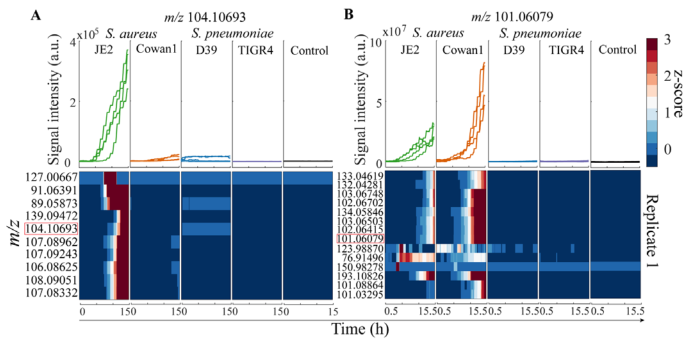

Figure 2: Specific time-dependent features detected during bacterial growth. (A) Time trace of the positive ion at m/z 104.10693 unique to S. aureus JE2. (B) Time trace of the negative ion at m/z 101.06079 unique to the species S. aureus (picture: K. Arnold).

PhD Thesis by Kim Arnold, Department Biomedical Engineering, University of Basel at the Translational Medicine Breath Research Group.

This thesis aimed to develop a rapid screening method to detect biomarkers of early bacterial infections from clinical specimens.

We developed an experimental and computational framework based on SESI-HRMS to detect in real time volatile biomolecules emitted during bacterial proliferation as well as from mammalian dendritic cells challenged by bacteria.

The results showed that volatile metabolic signatures could be monitored non-invasively and in real-time with high consistency and minimal sample preparation. The method was able to differentiate between immature and activated DCs (1), detect isotopic incorporation in volatile metabolites (1,2), and identify bacterial pathogens at the species and strain level (3). Clinical samples could be fingerprinted to differentiate between samples containing living or dead bacteria (3). Distinct volatile metabolites were found before and after bacterial inoculation in mice infection models.

Overall, we contributed towards the development of a diagnostic platform aiming to flag bacterial infections at early stages, thus contributing to initiate timely and tailored antibiotic treatment.

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References:
(1) Arnold K, Dehio P, Lotscher J, et al. Real-Time Volatile Metabolomics Analysis of Dendritic Cells. Anal Chem 2023;95:9415-1421.

(2) Arnold K, Chen X, Zhang H, et al. In vivo detection of 2H-incorporation upon ingestion of 2H2O. Journal of Bio-X Research 2022;5:81-89.

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Breath Pharma-cometabolomics on Type-1 Diabetes and Epilepsy

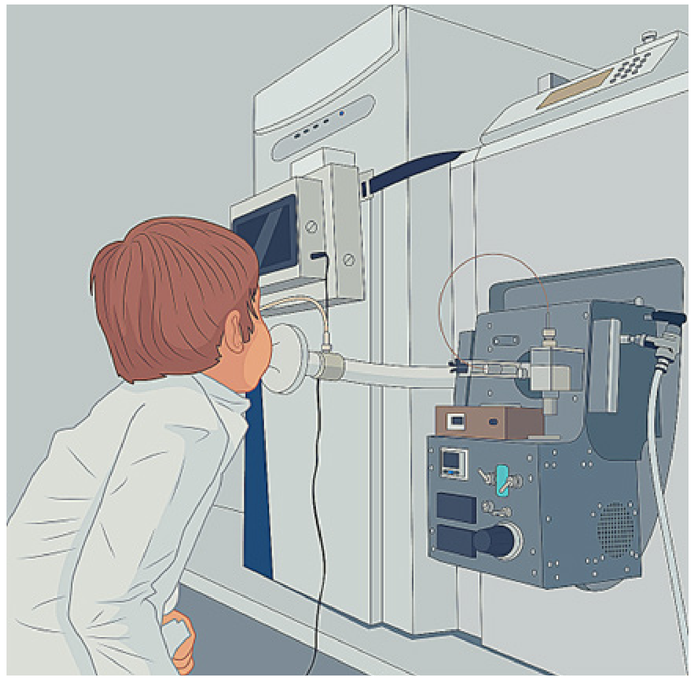

Figure 1: Real-time exhalation maneuver into a secondary electrospray ionization high-resolution mass spectrometer platform (SESI-HRMS) (picture: Sinueslab).

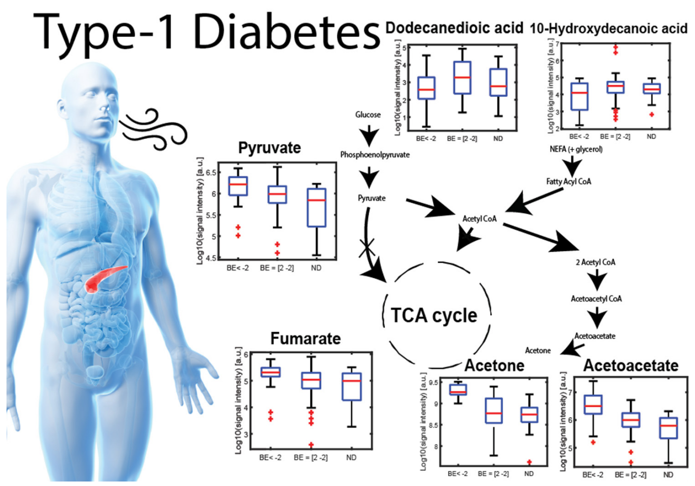

Figure 2: Breath analysis promptly reveals altered metabolism in diabetic ketoacidosis (DKA) patients after insulin onset (picture: Sinueslab)

PhD Thesis by Mo Awchi at the Translational Medicine Breath Research group.

Pharmacometabolomics investigates how drugs influence metabolites, contributing to the progress of personalized medicine. Breath analysis is a real-time and non-invasive approach (Fig.1). This PhD thesis concentrated on applications related to epilepsy and type-1 diabetes. Both conditions incur significant medical expenses and often require invasive monitoring.

We measured breath metabolites of anti-seizure medication (ASM) responses and side effects and exploring breath analysis for Type-1 Diabetes. SESI-HRMS was employed, analysing breath in real-time and off-line, followed by statistical and machine learning analyses.

This thesis revealed breath analysis potential in clinical pharmacometabolomics. Firstly, we identified relevant amino acids linked to ASM responses and side effects (1), enabling future metabolite interpretation. Secondly, we demonstrated offline SESI-HRMS ability to measure free and total valproic acid (2), facilitating bedside monitoring, including for cognitively impaired individuals. Additionally, we proposed a disease monitoring framework that holds the potential to be used bedside in the intensive care units and deepened our understanding of DKA pathophysiology (Figure 2).

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References:
(1) Awchi M. et al, UHPLC-MS/MS-Based Identity Confirmation of Amino Acids Involved in Response to and Side Effects from Antiseizure Medications. Journal of Proteome Research 2023

(2) Awchi M. et al, Prediction of systemic free and total valproic acid by off-line analysis of exhaled breath in epileptic children and adolescents. Journal of Breath Research 2023

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Automatic Tissue Characterization from Optical Coherence Tomography Images for Smart Laser Osteotomy

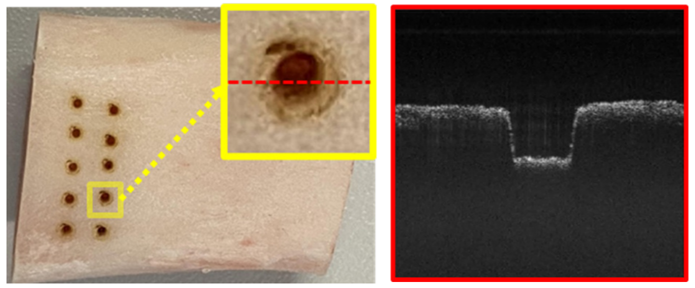

Figure 1: Holes made on a bone sample using the deep-learning-based OCT-guided laser osteotomy in real-time (Left). An OCT image was taken during the cutting process for real-time feedback (Right) (picture: Y. Bayhaqi).

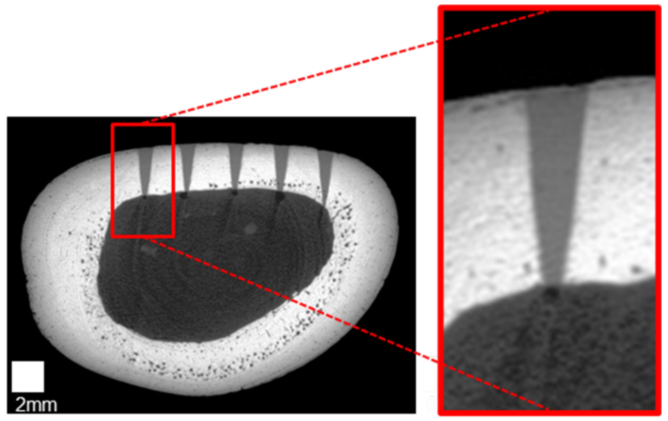

Figure 2: Micro-CT image of the bone sample in Figure 1 (Left). A zoomed version of the hole made using the deep-learning-based OCT-guided laser osteotomy (Right). The deep-learning-based setup stopped the ablation laser when bone marrow was detected. The average maximum depth of bone marrow perforation was only 216 μm (picture: Y. Bayhaqi).

PhD Thesis by Yakub Bayhaqi at the Biomedical Laser and Optics Group (BLOG), Department of Biomedical Engineering, University of Basel.

Laser osteotomy overcomes mechanical tools' shortcomings, with less damage to surrounding tissue, lower risk of viral and bacterial infections, and faster wound healing. Furthermore, the current development of artificial intelligence has pushed the direction of research toward smart laser osteotomy. This thesis aimed to advance smart laser osteotomy by introducing an image-based automatic tissue characterization or feedback system. The Optical Coherence Tomography (OCT) imaging system was selected because it could provide a high-resolution subsurface image slice over the laser ablation site.

This thesis presents the basic framework and result of applying the deep-learning-based OCT-guided laser osteotomy in real-time. The feedback system was evaluated based on its ability to stop bone cutting when bone marrow was detected. The results show that the deep-learning-based setup successfully stopped the ablation laser when bone marrow was detected. The average maximum depth of bone marrow perforation was only 216 μm.

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(1) Y. A. Bayhaqi, et al.," Deep learning models comparison for tissue classification using OCT images: toward smart laser oste-otomy", OSA Cont., Vol. 4, No. 9, pp. 2615-2628 (2021).

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Post Mortem Temperature and its Effect on Quantitative Magnetic Resonance Imaging

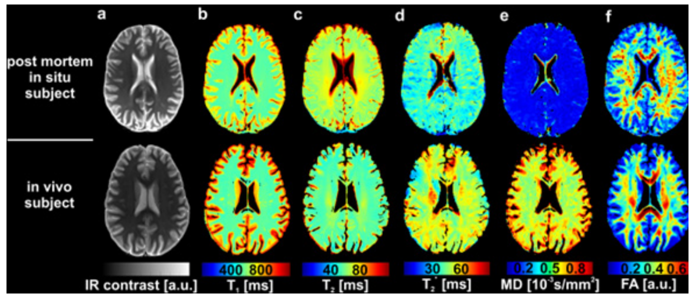

Figure 1: Representative inversion recovery contrast (TI= 200 ms) (A), T1(B), T2 (C), T2* (D), MD (E), FA (F) maps of one post mortem subject with a brain temperature of 5.6°C (top row) and one in vivo subject (bottom row).

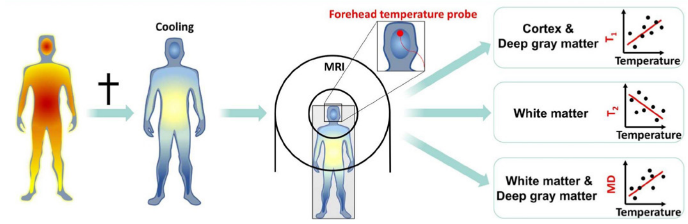

Figure 2: Real-time temperature correction of the temperature dependent MRI parameters using the forehead temperature during the MRI scan.

PhD Thesis by Celine Berger at the research group Forensic Medicine and Imaging of the Institute of Forensic Medicine, University of Basel.

Post mortem magnetic resonance imaging (PMMRI) enhances forensic death investigations by its high soft tissue contrast and facilitates the validation and development of in vivo MRI. To account for the post mortem temperature cooling effect on quantitative MRI, this research aimed to develop temperature correction methods for PMMRI of the brain.

This thesis discovered linear brain temperature effects on relaxation (T1, T2, T2*, TInull) and diffusion (MD, FA) parame-ters (1,2). Further, it explored non invasive re-al-time brain temperature measurement via the forehead (3). Subsequently, a real-time temperature correction mod-el during the MRI scan was developed using the forehead temperature for T1, T2 and MD (see Figure 2) (4). Additionally, this thesis observed that lower brain temperatures reduced R2* fiber orientation dependency in post mortem com-pared to in vivo subjects (5).

In conclusion, these findings provide temperature correction models for PMMRI based on the brain or the real-time assessed forehead temperature.

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(1) C. Berger et al. MAGMA, 35, 2022.

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Clinical and Functional Outcomes 2 Years after InternalBrace-Augmented ACL Repair vs. ACL Reconstruction and Healthy Controls

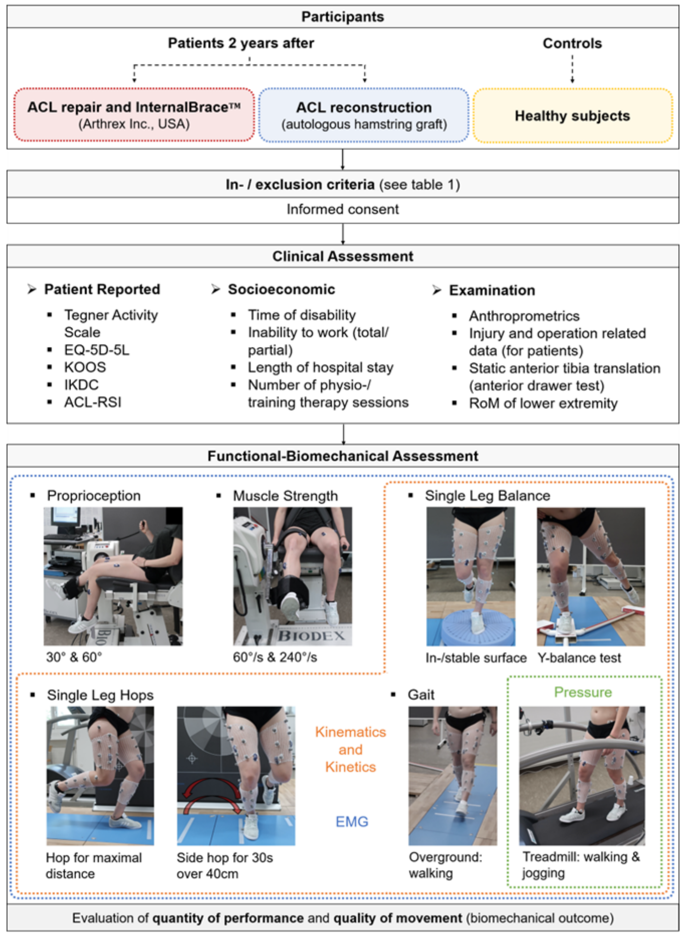

Figure 1: Overview of the RetroBRACE study protocol and clinical and functional-biomechanical assessments (picture: retrieved from Müller et al. (1))

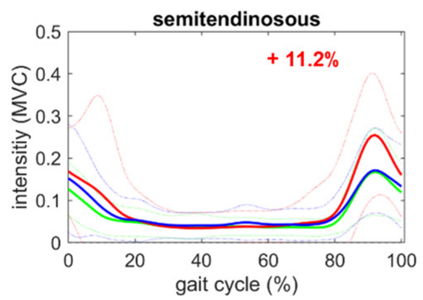

Figure 2: Mean trajectory (solid) and one standard deviation (dashed) semitendinosus muscle activation in ACL-IB (blue), ACL-R(red) and Controls (green). MVC, maximum voluntary contraction (picture: L. Bühl).

PhD Thesis by Linda Bühl at the Functional Biomechanics Laboratory (University Hospital Basel).

Although early studies in patients after anterior cruciate ligament repair with additional augmentation (ACL-IB, InternalBrace) show promising patient-reported and clinical outcomes similar to ACL reconstruction (ACL-R), evidence on functional and biomechanical benefits is lacking.

We investigated these outcomes two years after ACL-IB (N = 29) and compared them with ACL-R using hamstring tendon autografts (N = 27) and healthy controls (N = 29). Participants were assessed by clinical leg examination (clinical outcomes), functional testing of leg performance (Fig. 1), and analysis of leg movement and muscle activation during walking and single-leg forward hop landing (functional-biomechanical outcomes, Fig.1). Results were compared between groups and between the involved (operated) leg in patients and the non-dominant leg in controls.

All outcomes were comparable between ACL-IB and ACL-R. Both patient groups did not return to healthy levels and had subjective functional impairments, reduced quadriceps strength and altered leg biomechanics during walking. Only ACL-IB had different knee mechanics during hop landing and only ACL-R had different semitendinosus muscle activation during walking compared to controls (Fig. 2).

Overall, 2 years after surgery, patients undergoing less invasive ACL-IB can expect a comparable clinical and functional biomechanical outcome to patients after ACL-R, without the risk of comorbidities or changes in hamstring function. The initial ACL rupture causes changes that cannot be restored by surgery (repair or reconstruction) alone.

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References:
(1) Müller S, Bühl L, Nüesch C, Pagenstert G, Mündermann A, Egloff C. RetroBRACE: clinical, socioeconomic and functional-biomechanical outcomes 2 years after ACL repair and InternalBrace augmentation in comparison to ACL reconstruction and healthy controls: experimental protocol of a non-randomised single-centre comparative study. BMJ Open. 2022;12(2):e054709. doi:10.1136/bmjopen-2021-054709

Influence of Additional Weight Carrying on Load-Induced Changes in Shoulder Kinematics after Rotator Cuff Tears – An in Vivo Study

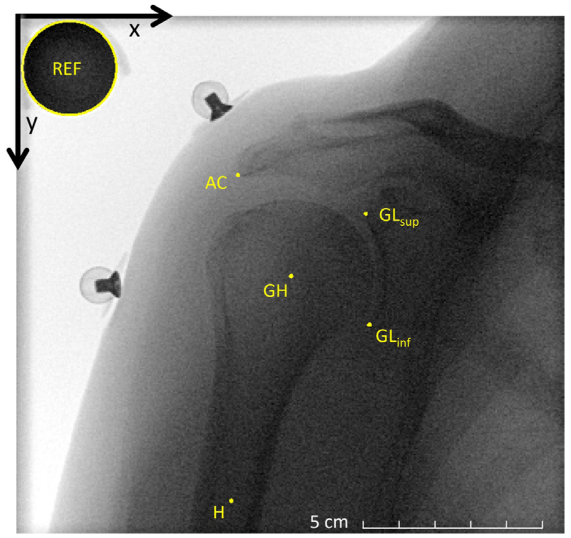

Figure 1: Example of a fluoroscopic image with the anatomical landmarks and the reference sphere. GH: glenohumeral joint centre, H: humeral shaft midpoint, GLsup: superior edge of glenoid, GLinf: inferior edge of glenoid, AC: most lateral point of the acromion, REF: reference sphere (Picture: Functional Biomechanics Lab).

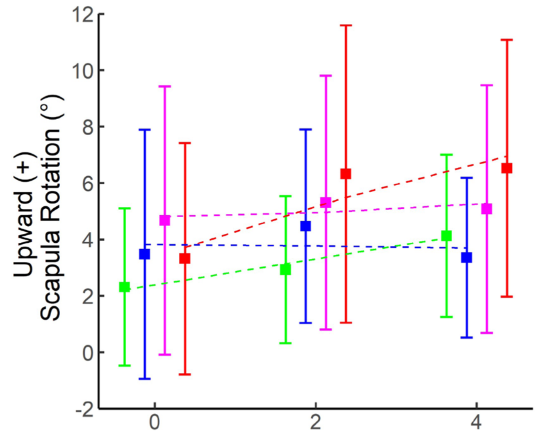

Figure 2: Mean and standard deviation of the scapular rotations and during abduction for the different shoulder types with regr ession lines (dashed) (Picture: Functional Biomechanics Lab).

PhD Thesis by Eleonora Croci at the Functional Biomechanics Laboratory (University Hospital Basel)

Rotator cuff tears are a very common age-related shoulder injury. A thorough understanding of the glenohumeral motion is still lacking and inconsistent patterns of shoulder kinematics have been reported.

This thesis presents the protocol of our in vivo study in patients with unilateral rotator cuff tears and control subjects (1), together with an assessment method for shoulder kinematics using single-plane fluoroscopy (2), and the associated kinematic results of a 30° loaded and unloaded arm abduction test in the scapular plane (3). Load-induced changes in muscle activity during the same abduction test are also presented (4).

All images (Figure 1) were labelled using an automatic landmark detection algorithm (5). Upward-downward scapular rotation and superior-inferior glenohumeral translation of all shoulders were examined. Load-induced kinematic changes occurred in scapular rotation (Figure 2), but not in glenohumeral translation in shoulders with rotator cuff tears. Scapular motion may therefore play an important role in compensating for rotator cuff tears. Associated load-induced changes in muscle activity were observed in all muscles analysed and differences between healthy and pathological shoulders were assessed.

Overall, this study shows that shoulder kinematics are load dependent. Implementation of this 30° loaded abduction test in the clinic could provide important insight into the functional status of the shoulder and be used to guide treatment decision.

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References:
(1) Croci et al. JMIR Res. Protoc. 2022;11(12):1–14.

(2) Croci et al. Biomechanics. 2022 May 19;2(2):255–263.

(3) Croci et al. J. Orthop. Trau-matol. Under review

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Load-Induced Biomechanical Changes in Shoulders with Rotator Cuff Tear – An Experimental Simulator Study

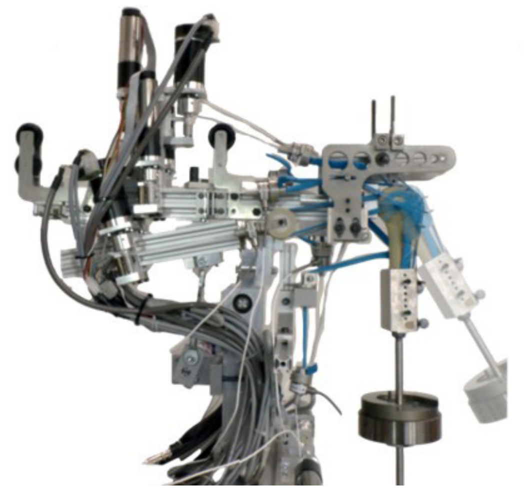

Figure 1: Potograph of the newly developed shoulder simulator; the abducted humerus is highlighted in opacity for clarity (Picture: Institute for Mechanical Systems, ZHAW).

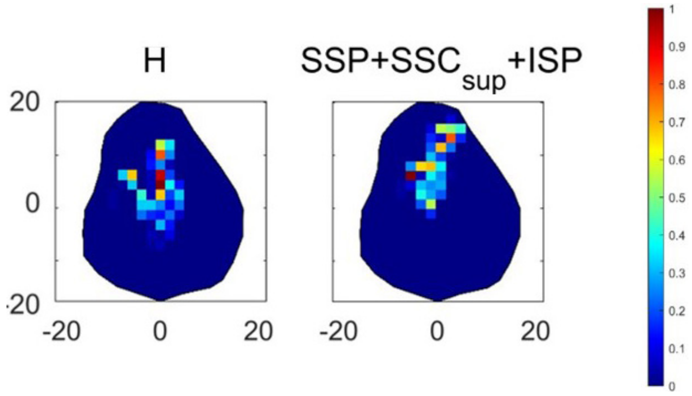

Figure 2: Illustration of the predominant location of the glenohumeral force center projected onto the glenoid (Picture: Institute for Mechanical Systems, ZHAW).

PhD Thesis by Jeremy Genter at the Functional Biomechanics Research Group, University Hospital Basel and ZHAW, IMES, BME.

This thesis focused on the biomechanics of the glenohumeral joint with rotator cuff tears, a common shoulder pathology (1). This thesis highlights the importance of the rotator cuff muscles in maintaining shoulder stability during movement. The purpose of this study was to develop a control strategy for a glenohumeral simulator to simulate the abduction motion of shoulders with rotator cuff tears and to investigate the biomechanics of weight-bearing shoulders with rotator cuff tears.

The research includes a review of existing glenohumeral simulators and their limitations, leading to the development of a musculoskeletal model-based simulator (Figure 1). Ex vivo (cadaveric specimens) and in situ (synthetic speciemns) experiments showed that the simulator reproduces glenohumeral translations and joint forces similar to in vivo measurements (2,3). Key findings include the effects of increased weight bearing and critical shoulder angle, which resulted in increased glenohumeral translations. The experiments also demonstrated the compensation of the remaining muscles with intact tendons in the presence of rotator cuff tears, which resulted in a superior shift in the location of the glenohumeral force center following multiple tendon tears (Figure 2). This shift in the force location suggests that patients with multiple rotator cuff tears may be at risk for secondary osteoarthritis, highlighting the potential benefits of strengthening the remaining intact rotator cuff muscles.

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References:
(1) K. Yamaguchi, A. M. Tetro, O. Blam et al. Natural history of asymptomatic rotator cuff tears: a longitudinal analysis of asympto-matic tears detected sonograph-ically. J Shoulder Elbow Surg, 2001.

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Development of Miniaturized Long-Range Optical Coherence Tomography for Smart Laser Surgery System

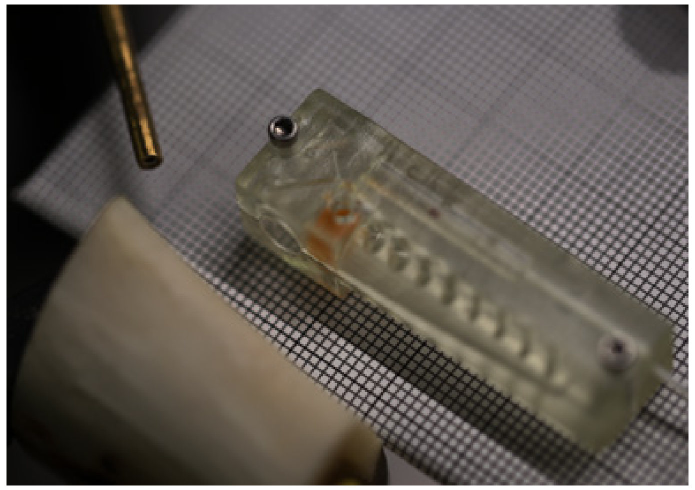

Figure 1: First prototype of the miniaturized long-range OCT integrated with a fiber-based Er:YAG laser (picture: A. Hamidi).

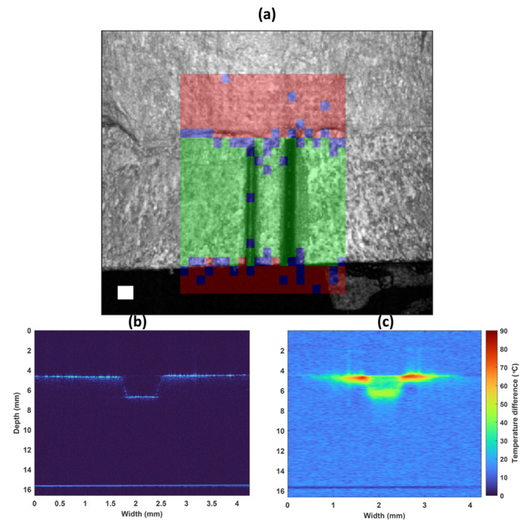

Figure 2: (a) Developed tissue-specific laser osteotomy, (b) real-time monitoring the depth and shape of laser-induced cut, and (c) calibrated phase-sensitive OCT system to detect temperature rise of tissue (picture: A. Hamidi).

PhD Thesis by Arsham Hamidi, University of Basel, at Biomedical Laser and Optics Group (BLOG).

Laser technology offers advantages in bone surgery (osteotomy) by enabling precise and nonlinear cuts while preserving bone structure, but certain challenges must be addressed. In laser surgery, it is crucial to improve accuracy and safety by providing feedback and control for depth and shape of cuts, temperature changes, and tissue type detection.

This PhD project was part of a project MIRACLE (Minimally Invasive Robot-Assisted Computer-guided LaserosteotomE), which aims to develop a laser-assisted robotic endoscope to perform deep bone ablation. In the framework of this thesis, a multimodal feedback system is developed to provide required feedback for the surgeon during laser osteotomy.

First, a long-range Bessel-like beam OCT is developed with the imaging range of 26.2 mm and extended depth of focus of 28.7 mm, capable to monitor/control the depth of cut in real-time (1). In addition, to prevent the thermal damage during laser osteotomy, we investigated the potential of the phase-sensitive OCT system to measure temperature rise of tissue during ablation (2). Furthermore, tissue-specific laser osteotomy is achieved by integration of a LIBS system to differentiate the type of tissue before surgery (3). Finally, the first miniaturized prototype of the fibre-based integration of the OCT and Er:YAG laser is developed (4).

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(2) Hamidi, A. et al. Submitted to Laser in Medical Science, Springer.

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(4) Hamidi, A., et al. Submitted to OSA continuum, Optica.

Dose-response Relationship of in vivo Ambulatory Load & Mechanosensitive Cartilage Biomarkers: The Role of Age & Tissue Health

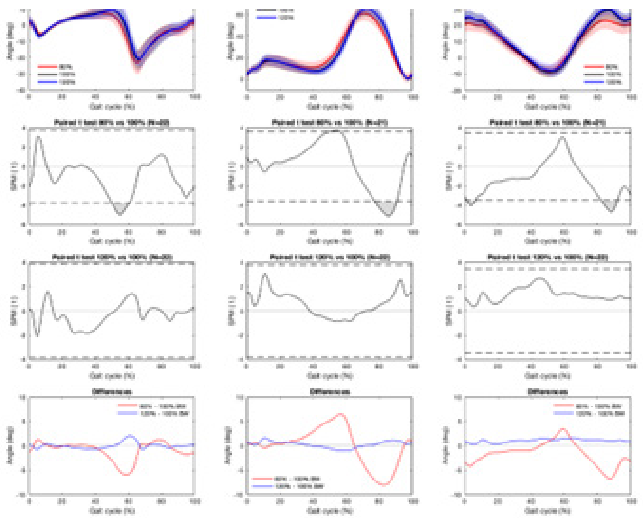

Figure 1: Mean (1 standard deviation) joint angle for the ankle, knee and hip (top; left to right), results of SPM paired t-test for the 80% and 120% vs. 100% BW conditions (1st and 2nd middle), and absolute difference in joint angle for the 80% and 120% vs. 100% BW conditions grey areas indicate statistical differences between conditions (p<0.025) (picture: S. Herger).

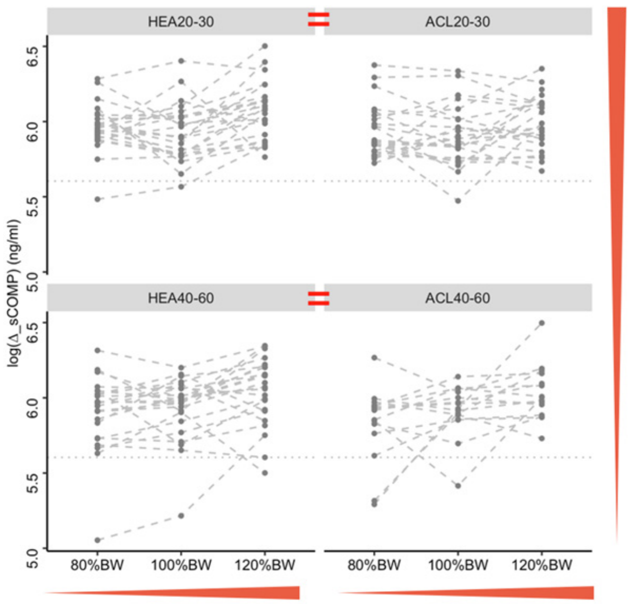

Figure 2: Visualization of the immediate load-induced increase in sCOMP (log(Δ_ sCOMP(tpost))) immediately after the walking stress with loading conditions reduced load (80%BW), normal load (100%BW), and increased load (120%BW). BW – body-weight, ACL – anterior cruciate ligament (picture: S. Herger).

PhD Thesis by Simon Herger at the Functional Biome-chanics Laboratory, University of Basel and University Hospital Basel.

In osteoarthritis (OA) research systemic articular cartilage biomarkers measured in blood have been proposed as surrogate measure of in vivo articular cartilage metabolism. As chondrocytes can respond metabolically to physical load, and normal joint loading contributes to joint health, whereas increased joint loading promotes cartilage degeneration, load-induced changes in cartilage biomarker concentrations were investigated in healthy, joint injured and OA participants to understand the underlying pathologic processes that initi-ate early or post-traumatic OA.

This thesis presents data from pilot studies and results of clinical, biomechanical biological data collection of the MechSens project (1). Younger and older healthy and ACL-injured participants underwent magnetic resonance imaging of both knees and completed a walking stress test on three different days. During this stress test, blood samples were taken before and after walking with either 80%, 100% or 120% body weight. First we validated that the used load modification framework allows us to systematically modulate load magnitude without changing joint kinematics or spatiotemporal parameters (2). We identified serum cartilage oligomeric matrix protein (sCOMP) and matrix metalloproteinase-3 as articular cartilage biomarkers that respond to the magnitude of ambulatory load with an increase in concentration (3). With the completion of the MechSens baseline data collection, we showed that the cartilage composition observed in our ACL-injured participants differs from uninjured knees and confirmed that ACL-injured subjects in the MechSens project have altered cartilage composition. Finally, we showed that the load-induced change in concentration sCOMP is sensitive to mechanical loading in healthy and ACL-injured subjects and that the immediate load-induced change in sCOMP is affected by age but not by ACL injury.

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(1) Herger et al. PLOS ONE 2022; 17: e0272694.

(2) Herger et al. Osteoarthritis and Cartilage Open 2020; 2: 100108.

(3) Herger et al. F1000Research 2022; 10.

Methodological Advances in Electrical Properties Tomography

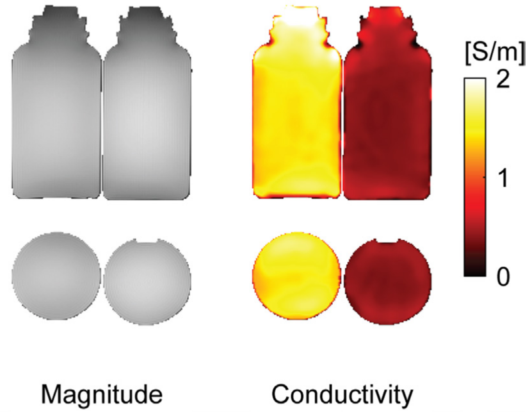

Figure 1: Exemplary slices of two salt water phantoms. A conventional MRI magnitude image does not show a difference between the phantoms, whereas a conductivity map is able to distinguish between the two phantoms with different salt concentrations (picture: Santhosh Iyyakkunnel, adapted from (1)).

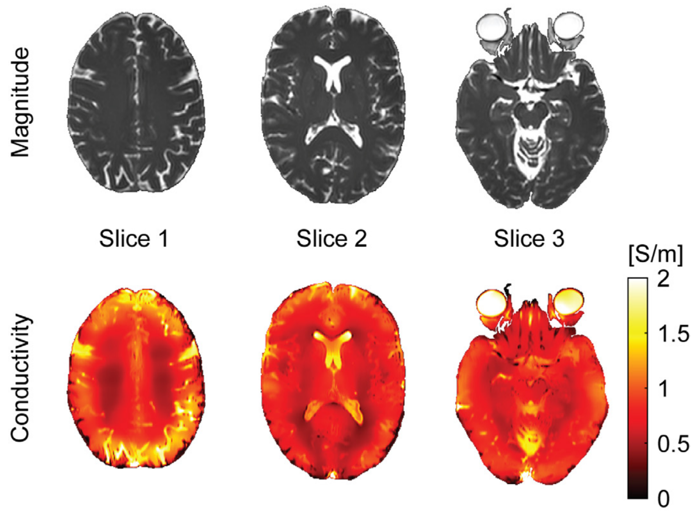

Figure 2: Conventional MRI magnitude images and conductivity images of the brain of a healthy volunteer (picture: Santhosh Iyyakkunnel, adapted from (1)).

PhD Thesis by Santhosh Iyyakkunnel at the Magnetic Resonance Physics and Methodology Group of the University of Basel.

Electrical properties tomography (EPT) aims to non-invasively measure the electrical properties (EPs), conductivity and permittivity, of biological tissues using conventional magnetic resonance imaging (MRI). EPT has gained increased interest over the last decade thanks to its potential in various applications, including cancer diagnosis.

In MRI, the EPs of the tissue distort the RF magnetic field used for spin excitation. Thus, local changes in the spatial distribution of this field, commonly known as B_1^+, allow the reconstruction of the EPs. However, obtaining the required high-resolution measurement of B_1^+ often results in extended acquisition times, which are impractical for clinical use.

This thesis investigated different strategies to increase the efficiency for B_1^+ mapping methods, maintaining a high signal-to-noise ratio and high precision. The proposed methods (1,2) showed promising results in healthy volunteers, laying a solid foundation for the potential clinical application of EPT.

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References:
(1) Santhosh Iyyakkunnel et al., "Configuration-based electrical properties tomography", Magn Reson Med. 2021;85:1855-1864.

(2) Santhosh Iyyakkunnel et al., "Complex B_1^+ mapping with Carr-Purcell spin echoes and its application to electrical properties tomography", Magn Reson Med. 2022;87:1250-1260.

Distinct Bone Segmentation from CT Images using Deep Learning

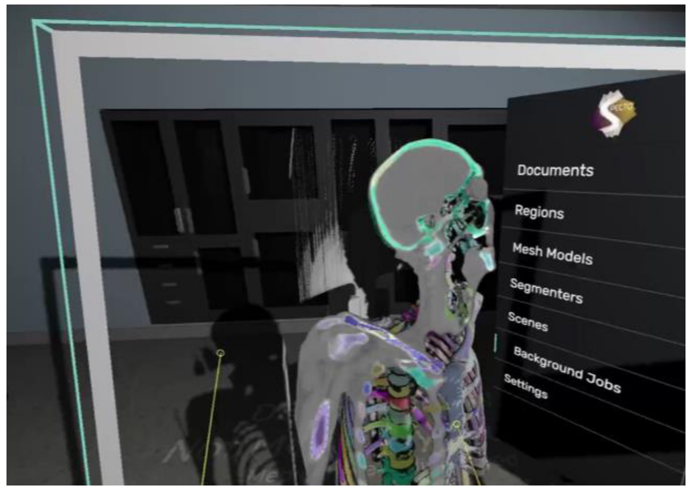

Figure 1: A glimpse into the Specto VR visualisation software with an overlaying bone segmentation. Different bones are displayed with individual colours (picture: N. Zentai, E. Schnider).

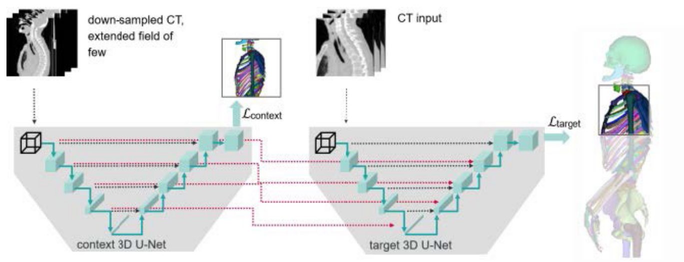

Figure 2: Multi-resolution neural network used to segment bones in upper bodies. The context networks supply additional spatial information at lower resolution to improve to localization capabilities of the target network (picture: E. Schnider).

PhD Thesis by Eva Schnider at MIRACLE Planning & Navigation group.

CT scans are ubiquitous in medical practice. Their analysis frequently involves surgeons, or radiologists who must manually or semi-automatically annotate bones. Their annotation labour can be decreased by automating segmentation and bone detection.

In this project, we have examined the use of deep learning to automate the segmentation of all individual bones in upper-body CT scans. This automation of distinct bone segmentation has the potential to not only speed up current workflows, but also to open up new avenues for processing and displaying medical data for planning, navigation, and education. We have based our network architecture on 3D-UNet architectures and proposed new modifications to handle the specific challenges of this large segmentation task with a plethora of segmentation classes. We have worked on a new inference procedure, which decouples background from distinct-class predictions and worked on a multi-resolution approach. Extending the network's field of view using additional low-resolution inputs improves the availability of spatial context within model input windows and increases the segmentation accuracy.

The resulting segmentation models have been integrated into the DBE's Specto VR visualization software and can be used to quickly segment new CT scans without leaving the Specto application.

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(1) E. Schnider, Automated Distinct Bone Segmentation from Computed Tomography Images using Deep Learning. Doctoral Thesis, University of Basel, 2023.
(2) E. Schnider et al. 3d segmentation networks for excessive numbers of classes: distinct bone segmentation in upper bodies. Machine Learning in Medical Imaging workshop: Held in Conjunction with MICCAI 2020.
(3) E. Schnider et al. Improved distinct bone segmentation from upper-body CT using binary-prediction-enhanced multi-class inference Int. J. Comput. Assist. Radiol. Surg, 2022.

Solving Inverse Problems for Medical Applications

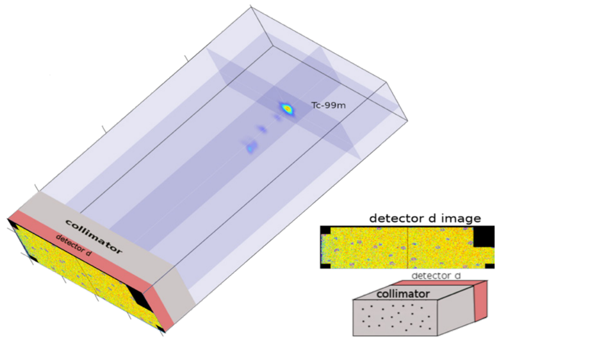

Figure 1: (MOONSTAR) Visualization of the 3D reconstruction of the Tc-99m source from a single measurement (picture C. Seppi).

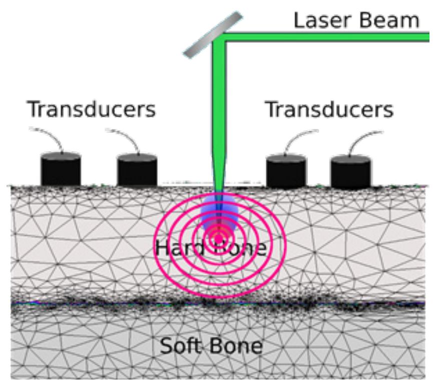

Figure 2: (MIRACLE) Illustration of the ablation of tissue with an Er:YAG laser (picture C. Seppi).

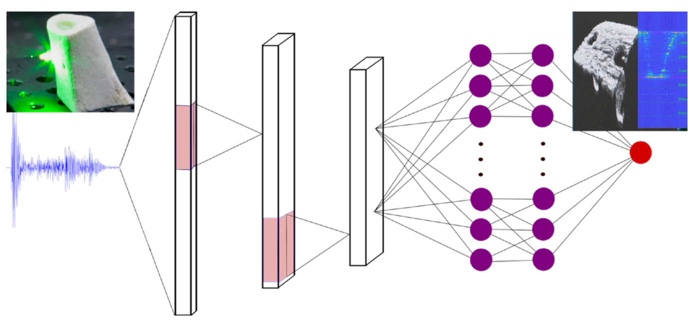

Figure 3: (MIRACLE) The acoustic wave emitted during laser ablation is used as an input to a Convolutional Neural Network (CNN) to estimate the depth of the cut (picture C. Seppi).

PhD Thesis by Carlo Seppi University of Basel at Center for medical Image Analysis & Navigation (CIAN).

MOONSTAR (Mobile Optical Navigated SPECT Camera with Augmented Reality) aims to revolutionize the visualization of Sentinel Lymph Nodes (SLN) through Augmented Reality (AR), enabling surgeons to perform minimally invasive removal of the SLN. This technique involves the injection of a Tc-99m tracer near the tumor, which accumulates in the SLN. In our study (1), we performed ex vivo experiments with Tc-99m sources. These sources were measured with our gamma detector and we successfully reconstructed their positions in a 3D subspace (Figure 1). In our work, we improved the design of the collimator and developed an algorithm capable of accurately locating the Tc-99m sources.

The MIRACLE (Minimally Invasive Robot-Assisted Computer-guided LaserosteotomE) project is dedicated to the development of a robotic endoscope capable of performing minimally invasive laserosteotomy. An acoustic wave is emitted during the tissue ablation process when employing an Er:YAG laser, which is subsequently measured by the transducers (Figure 2). Our primary goal is to extract valuable information from this acoustic wave. First, we used a simulation based on the Helmholtz equation to simultaneously reconstruct the position of the source and the velocity of the medium (2). In a second approach (3), we used the acoustic wave as input to a convolutional neural network (CNN) to estimate the depth of the cut (Figure 3).

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Project MIRACLE
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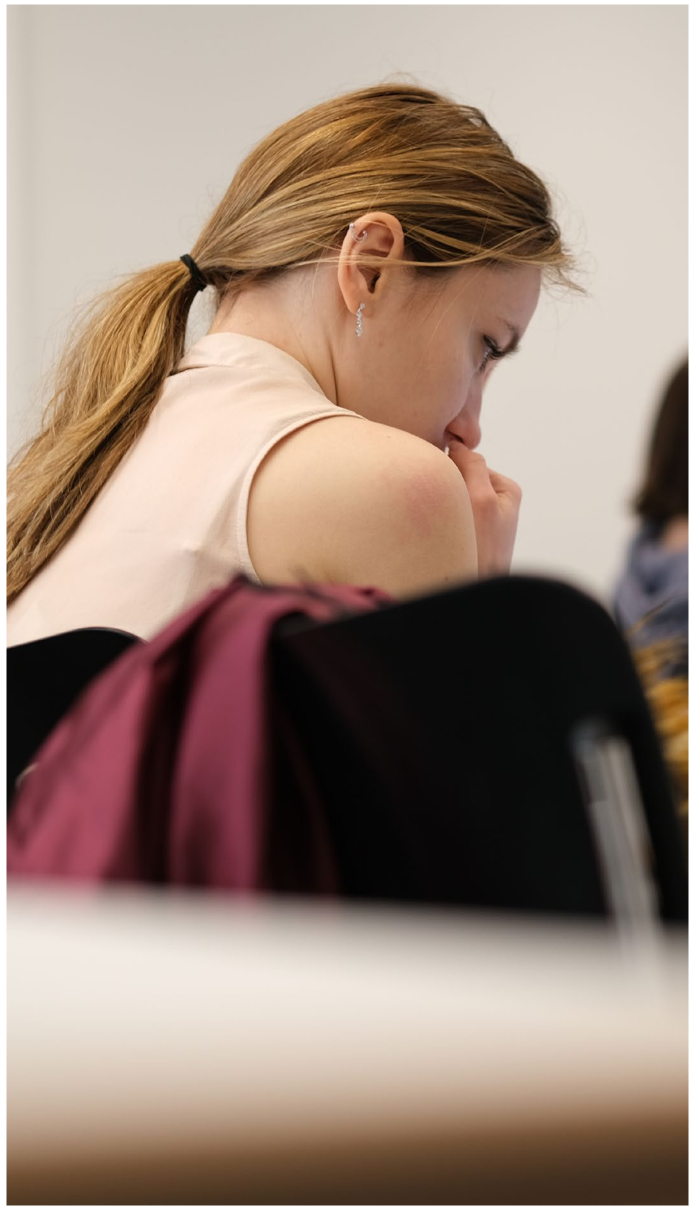
(1) U. Nahum, C. Seppi, et al. "Sentinel lymph node finger-printing" Physics in Medicine & Biology (2019)

(2) U. Nahum, C. Seppi, et al. "Joint inverse medium and optimal control problem for acoustic waves" PASC (2019)

(3) C. Seppi, et al. "Bone Ablation Depth Estimation from Er:YAG Laser-Generated Acoustic Waves" IEEE Access (2022)

Completed Master's Thesis



Studying Biomedical Engineering (picture: R. Wendler).

In 2023, numerous Master's students were involved in DBE's research projects. They include:

Supersampling and Denoising of Volume-Rendered Medical Images using a Deep Learning Method

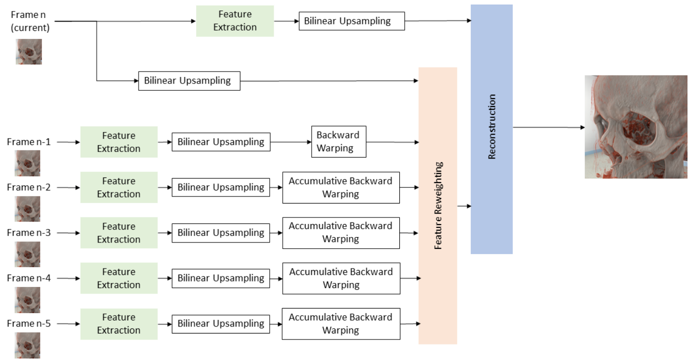


Figure 1: Network architecture. The network architecture is mostly based on the description in (1). Up to 5 previous frames are used to add temporal stability to the network and to give more background information beyond the kernel of the convolutions (picture: Z. Arslan)

	PSNR [dB]	SSIM	Average Time [ms]
Original Size (2160 x 2160)	38.43	0.9448	1399.671
Split Image (1080 x 1080)	36.94	0.9288	238.956
Specto (2160 x 2160)	-	-	123.911

Figure 2: Results of the network compared to the reference image using peak signal-to-noise ratio (PSNR) and structural similarity index measurement. The average time needed to compute the high-resolution images is comapred to the rendering time of the visualisation tool Specto. The network outputs good image quality. The long runtime is not usable for any real-time application with an update rate of 90Hz. (picture: Z. Arslan)

Master's Thesis by Zinar Arslan (Department of Biomedical Engineering, University of Basel) at Center of Medical Image Analysis & Navigation (CIAN).

Volume rendering at high quality is computationally expensive. Since the required computational power is high, further optimisation was needed for rendering and visualising medical data in virtual reality (VR).

This need for optimisation led to the introduction of foveated rendering, a method where computational power is focused on areas the user is looking at. But foveated rendering introduced new problems. Focusing computational resources opened doors for noise and flickering in non-focused areas, worsening the user experience in VR. The aim of this master's thesis was to find a deep learning-based approach to improve the quality and resolution for the visualisation of volumetric medical data sets in VR and test it for possible implementation in an ongoing research project.

The network was trained with pairs of images using a supervised learning method. To build a data set, ground truth images were rendered in Unity without any time constraints. The output was then compared to the reference image using the structural similarity index measurement (SSIM) and peak signal-to-noise ratio (PSNR). On one hand, we verified the drawbacks mentioned by Xiao et al. (1) and by Thomas et al. (2) in terms of needed computational power and runtime. On the other hand, we verified the advantages of this approach too: excellent image quality can be delivered, which is crucial for detailed high-resolution medical data.

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(1) Lei Xiao Salah Nouri et al. "Neural Supersampling for Real-time Render-ing". In: ACM Trans. Graph. 39.4 (2020).https://dl.acm.org/doi/10.1145/3386569.3392376.

(2) Manu Mathew Thomas et al. "Tem-porally Stable Real-Time Joint Neural Denoising and Supersampling". In: Proc. ACM Comput. Graph. Interact. Tech. 5.3 (2022). https://doi.org/10.1145/3543870

Relationship between Patient-Reported, Clinical, and Functional Outcomes in Patients 2 years after ACL Surgery

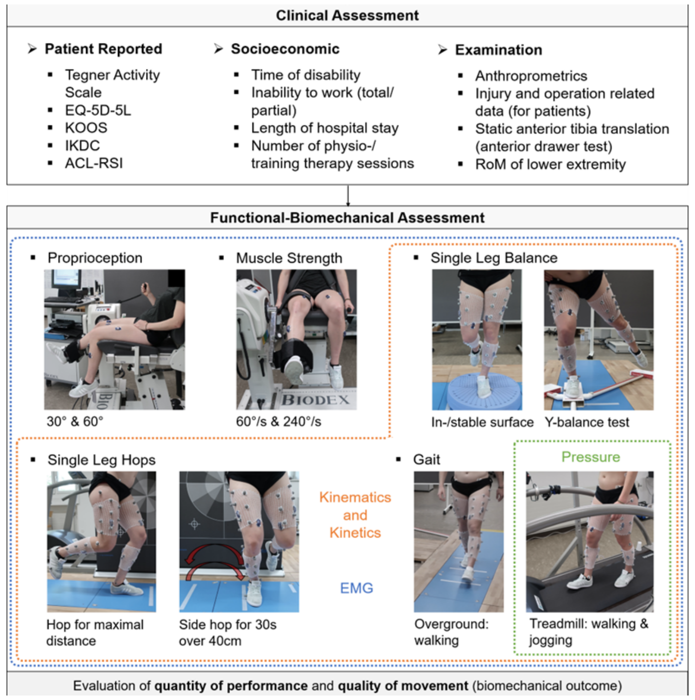

Figure 1: Overview of clinical and functional assessments including patient-reported outcomes, clinical outcomes (leg examination) and functional outcomes (performance tests and movement and muscle activity analyses) (picture: Retrieved from the RetroBRACE study protocol (1)).

Master's Thesis by Annika Bill at ETH Zürich and Functional Biomechanics Laboratory (DBE & University Hospital Basel)

In addition to anterior cruciate ligament reconstruction (ACL-R), augmented ACL repair with InternalBrace (ACL-IB) has been introduced as a surgical treatment option for proximal ACL tears.

We investigated the association between patient-reported outcome measures (PROMs) and clinical and functional outcomes in these two groups of patients and in healthy controls (N; 29 ACL-IB, 27 ACL-R, 29 controls). Outcome parameters included standardised questionnaires on activity level, health, knee function and knee confidence (PROMs), a leg examination (clinical outcome), performance tests and movement and muscle activity analyses of walking, running, balance, muscle strength and single-leg hop (functional outcome, Fig. 1). The association between the PROMs and the other outcomes was tested using beta regression, and the influence and interaction between the groups was tested using the likelihood ratio test.

Subjective knee function was associated with most clinical and functional performance outcomes, and subjective knee confidence and activity level with movement and muscle activity analyses. Higher slopes for ACL-IB than for ACL-R were observed for most of these associations.

Overall, subjective knee function (as assessed by PROMs) is associated with objective knee function after ACL surgery, and patients after ACL-IB may perceive better subjective improvements than patients after ACL-R when comparable improvements in leg performance (e.g. muscle strength) are present.

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(1) Müller S, Bühl L, Nüesch C, Pagenstert G, Mündermann A, Egloff C. RetroBRACE: clinical, socioeconomic and functional-biomechanical outcomes 2 years after ACL repair and InternalBrace augmentation in comparison to ACL reconstruction and healthy controls: experimental protocol of a non-randomised single-centre comparative study. BMJ Open. 2022;12(2):e054709. doi:10.1136/bmjopen-2021-054709

Optimization of Bone Ablation with a Ho:YAG Laser for Endoscop-ic/Fiberscopic Laser

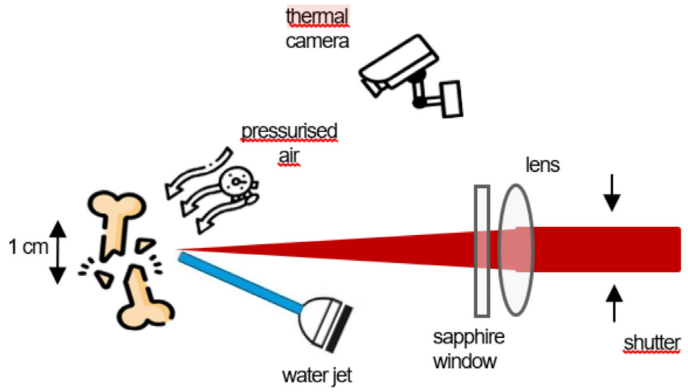

Figure 1: A schematic of the ablation setup after the laser output is aligned with two metallic mirrors. The lens (f=10 cm) was used to focus the laser beam on bone samples (picture: C.Cetin).

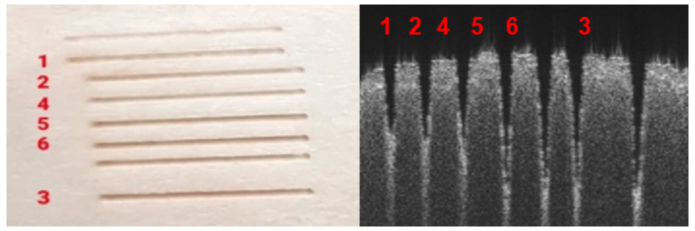

Figure 2: Picture of the line cuts generated using the Ho:YAG laser (left) and the corresponding OCT image of the cuts (right). Only the cust with numbers were considered in the experiments. (picture: BLOG).

Master's Thesis by Cigdem Cetin at Biomedical Laser and Optics Group (BLOG)

Contactless interventions performed with laser are associated with low collateral damage to the tissue, faster healing, and higher accuracy (1). Water absorbs light in a wavelength spectrum of around 2.1 µm, so Ho:YAG (Holmium Yttrium Aluminum Garnet) lasers, which produce light can be coupled into flexible and low-cost fibers (2). During laser ablation, particularly thermal ablation, tissue needs to be hydrated using an irrigation system and monitored to avoid any unwanted side effects while monitoring the surface temperature of the bone with a thermal camera. Hence, we used different irrigation systems to obtain an efficient ablation without carbonization. Furthermore, a pressurized air nozzle was used to clear the laser path and remove the excessive water and debris accumulated on the surface of the bone sample. The setup can be seen in Fig. 1. During the ablation experiments, laser energy was fixed to 550 mJ considering fiber delivery and the later use in minimally invasive bone surgeries. At this energy level, we then compared continuous and feedback-driven irrigation systems. After determining the ablation duration and repetition rate, the depth of ablation was optimized to be 1 mm by using continuous water irrigation. The obtained cuts can be seen in Fig. 2. These experiments were performed to avoid excessively long laser expo-sure of the tissue

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(1) K.F. Ginson and W.G.Kernohant," Lasers in medicine-a review" Journal of Medical Engineering and Techno-lo-gy,17(2),51-57,(1993).

(2) R. M. Verdaasdonk and C. F. P. van-Swol, "Laser light delivery systems for medical applications," Phys Med Biol 42, 869-894, (1997).

Automatic Curvature Measurement of the Left Atrium from Cardiac Magnetic Resonance Imaging

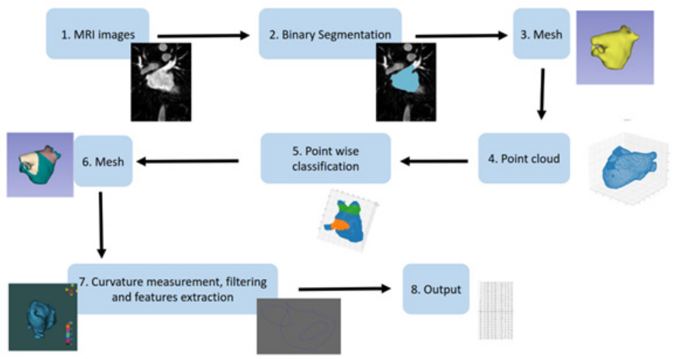

Figure 1: The proposed pipeline for curvature measurements: the inputs of the pipeline image are cardiac MRI (1). A binary segmentation is performed to create a mask of the atrium (2). A mesh is then reconstructed (3), and a point cloud is created from the mesh's vertices (4). Point cloud segmentation is performed with a point-wise classification to segment the left and right pulmonary veins (5). The mesh is then labeled according to the point cloud segmentation (6). The curvatures are measured on the original and the segmented mesh. Other features related to the shape are also extracted (7) (picture: H. Corbaz, CIAN).

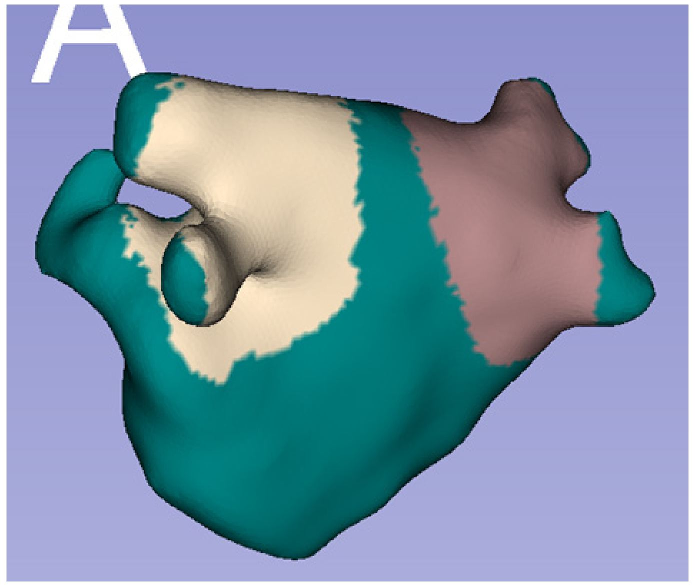

Figure 2: Example of the inference of the points cloud segmentation on meshes generated by the inference (picture: H. Corbaz, CIAN).

Master's Thesis by Hélène Corbaz (Department of Biomedical Engineering, University of Basel) at Cen-ter for medical Image Analysis & Navigation (CIAN).

Atrial fibrillation (AF) is caused by anarchic electrical signals within the atrium. It is the most common fibrillation and affects about 1-2% of the general population (1). This pathology can cause uncomfortable symptoms for the patient and lead to severe complications. Several approaches exist to treat AF, and one of the most important is pulmonary vein isolation (PVI) (2). PVI is an invasive procedure realized by catheter ablation. Even if this intervention is safe and efficient, some patients still have recurring AF after the procedure. Previous studies showed that the shape of the atrium impacts the success of the PVI intervention and the recurrence of AF, among many other clinical factors (3). Nevertheless, these studies were performed on small patient datasets and did not include a complete investigation of the shape features of the atrium. Studies on more extensive datasets need to be performed, including more shape features, such as curvature, to determine whether they could be interesting clinical biomarkers and predictors of the recurrence of AF. However, the manual segmentation of the atrium and the feature measurements is time-consuming, operator-dependent, and non-realistic on such an extensive dataset.

For this, we aim to develop a pipeline that automatically segments the atrium and extracts the investigated features. The result of this project shows that such a pipeline is achievable. In the field of this thesis, the main focus was on point cloud segmentation and feature extraction. The point cloud segmentation resulted in an accuracy of 85%. Further work is needed to rework the binary segmentation, and clinicians must perform investigations to decide which extracted features have a clinical interest.

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(1) P. Zimetbaum, "Atrial fibrillation," Annals of Internal Medicine, vol. 166(5), pp. 313–330, 2017.
(2) R. Parameswaran, A. M. Al-Kaisey, and J. M. Kalman, "Catheter ablation for atrial fibrillation: current indications and evolving technologies," Nature Reviews Cardiology, vol. 18, pp. 210–225, 2021.
(3) S. Knecht et al., "Left atrial anatomy, atrial fibrillation burden, and p-wave duration—relationships and predictors for single-procedure success after pulmonary vein isolation," EP Europace, vol. 20(2),

Registration of a Surgical Tool Based on CT Data and Optical Tracking

Figure 1: Optical tracking system (Qualisys) setup in veterinary OR (picture: A. Ivanova)

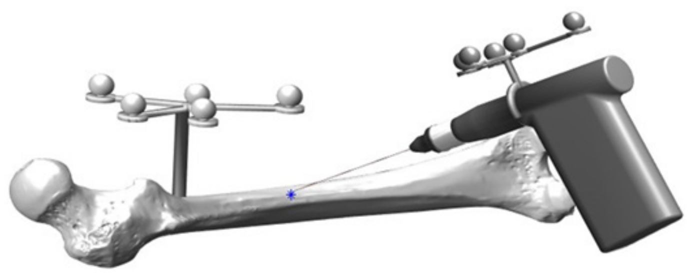

Figure 2: Live 3D visualisation of tool and anatomical target in a software GUI (picture: A. Ivanova)

Master's Thesis by Aleksandra Ivanova (University of Glasgow) at BIROMED-Lab.

Animal orthopaedic surgeries are performed routinely, however without surgical guidance involved and solely according to the surgeon's judgement. Therefore, the motivation behind the project was the need to assess the feasibility and accuracy of integrating a navigation system in the vet OR and to create a simple, intuitive guidance tool for surgeons to perform interventions with better precision and minimal invasiveness. The final product created was a software with a graphical user interface, relying on pre-operative CT-based registration and intraoperative optical tracking of the surgical instrument and patient's anatomy in 6 DOF to help the surgeon target and navigate the site of procedure accurately and confidently.

After carrying out accuracy tests with and without camera occlusions, it was evident that the optical tracking system was able to achieve a very high positional and angular accuracy of less than 0.5mm and less than 0.5° error with 4 or 5 non-occluded cameras. With fewer cameras, the accuracy was compromised. The software tool managed to provide real-time visual feedback and 6 DOF information of the instrument's pose relative to the anatomical target. Furthermore, the tracking system was set up in a vet OR to determine the optimal hardware arrangement and prove that it is feasible to integrate in the OR. Finally, a list of guidelines was provided on how to implement it for optimal results. With the promising accuracy results and some future improvements, the guidance system could find application in real animal surgeries and potentially be beneficial in robot-assisted surgeries as well.

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Bioresorbable Implants for Corrective Osteotomies of The Distal Radius

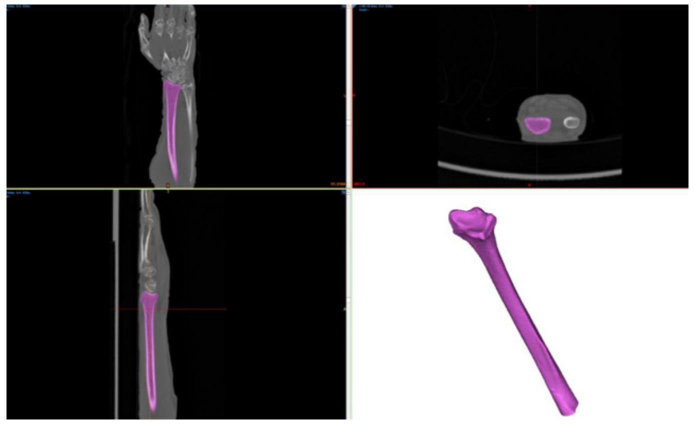

Figure 1: Virtual planning, segmentation of DICOM data and creation of 3D models of the bones of interest. (picture: Swiss MAM)

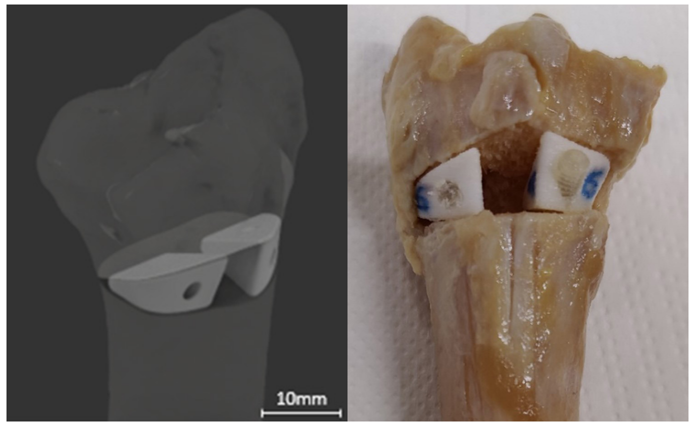

Figure 2: (left) Virtual design of implants using CAD software (right) 3D printed implants implanted into a cadaver bone (picture: Swiss MAM)

Master's Thesis by Adam Jakimiuk (Department of Biomedical Engineering) at Medical Additive Manu-facturing Research Group.

The distal radius fracture constitutes 8% to 17% of all bone fractures and up to 72% of all forearm fractures. It is thus the most commonly fractured bone in the human body. Despite many different techniques of treatment post-treatment complications can still occur. The most common complication is the malunion of distal radius fracture which can cause symptoms such as pain, limited mobility, hand weakness, dysfunction, or arthritis. (1,2)

The most common surgical procedure to manage the malunion of the bones is called corrective osteotomy. The current gold standard for securing the bone parts after osteotomy cut is with the use of titanium plates and allografts which has disadvantages such as possible allergic reaction, additional operations such as extraction of the graft from other site and removal operation. (3)

In this thesis, the viability of using synthetic, 3D-printed, patient specific implants (Fig. 2) consisting of 70% poly (L-lactide-co-D, L-lactide) (PLDLLA), and 30% β-TCP has been investigated as an alternative. Following a virtual planning (Fig. 1) mechanical tests have been performed for material characterisation, biomechanical tests with the use of cadaver bones have been performed to assess the stability of the connection and degradation tests in phosphate buffer solution to assess the viability of the construct in short and long term by means of degradation and surface chemistry. All PLDLLA/ β-TCP implants withstood a compressive force of at least 1'211 N which exceeds the maximum force reported in literature in case of a fall from the height of 1 m. measurements. Furthermore, the results showed a consistent surface chemistry and slow degradation rate.

The explored technique appears to hold great promise for numerous patients who are not suitable candidates for traditional titanium plate implants.

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Predicting Remyelination in Multiple Sclerosis Patients using Deep Learning

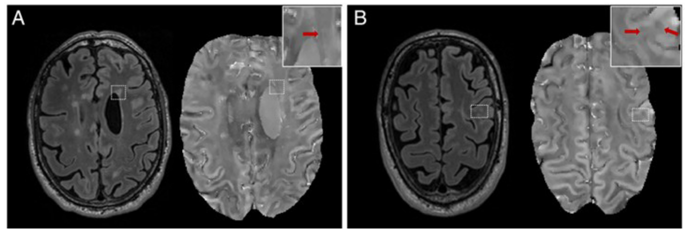

Figure 1: QSM lesion types classified as remyelinated lesions. A = iso-intense, B = hypo-intense. (R. Rahmenzadeh)

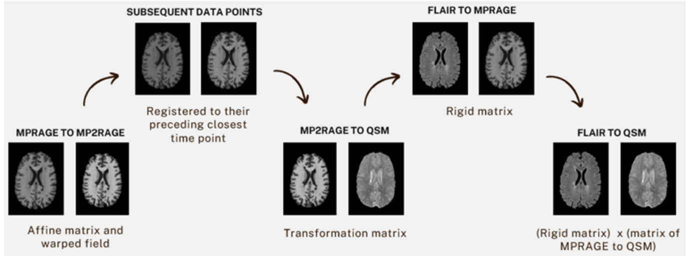

Figure 2: The registration pipeline used to register images from different time points for longitudianl data analysis. (T. Jayakumar)

Master's Thesis by Tejeswini Jayakumar (Department of Biomedical Engineering, University of Basel) at Translational Imaging in Neurology (ThINk) Basel group.

Multiple Sclerosis (MS) is a chronic inflammatory disease that targets the Central Nervous System whose effects can be seen as demyelination and axonal/neuronal damage. Previous studies by Rahmanzadeh et al. (1) have demonstrated that remyelination can be detected on Quantitative Susceptibility Mapping (QSM) and that monitoring remyelinated lesions might serve as a biomarker for disease progression.

Therefore, the aim of this Master's thesis was to distinguish between remyelinated lesions and non-remyelinated lesions in patients affected by MS with the help of deep learning (DL). The objective extended beyond mere differentiation; it sought to predict if a lesion would undergo remyelination in the future. This objective was achieved by using retrospective advanced MRI in Imaging the Interplay Between Axonal Damage and Repair in Multiple Sclerosis (INsIDER) dataset (2) and clinical MRI in the Swiss Multiple Sclerosis Cohort (SMSC) dataset (3). The ground truth remyelinated masks were segmented on the QSM from the advanced MRI. Data from the two closest time points in the SMSC dataset separated by 5-17 months were utilized to help the network detect remyelination over time.

The DL method developed in this study was based on UNEt TRansformers (UNETR) (4). Upon validating the results of the lesion segmentation, it became evident that using UNETR in its original segmentation configuration was not optimal for our specific needs. Consequently, we adapted the network for binary classification to distinguish between remyelinated and non-remyelinated lesions. This modified classification approach proved to be more effective than the original method.

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(1) Reza Rahmanzadeh et al. In: Annals of Neurology 92.3 (2022) pp. 486–502.

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Preconditioning of Adipose-Derived Stromal Cells for Chondrogenesis

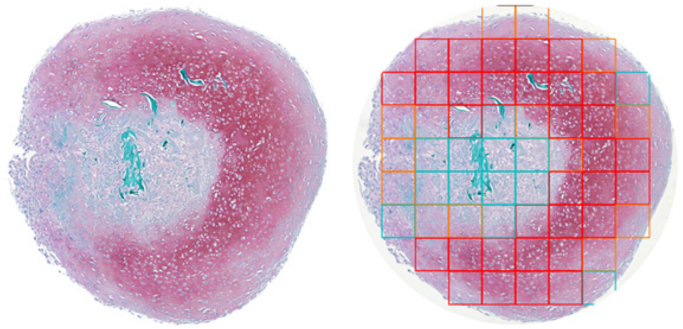

Figure 1: Safranin-O stained histological section of sample collected after 4 weeks of chondrogenic differentiation (left) and the same sample after segmentation for quantification of chondrogenic quality with the AI driven Automated Modified Bern Score method (right) (Picture: C. Jolérus, VBBG).

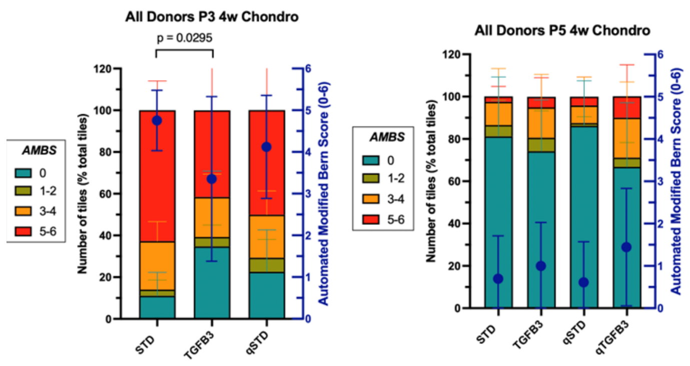

Figure 2: Evaluation of chondrogenesis of samples generated at passage 3 (left) and passage 5 (right) with the Automatic Modified Bern Score. The images show that there is no significant improvement in chondrogenic differentiation potential when preconditioning cells compared to standard conditions. Additionally, the images illustrate a clear drop in chondrogenic differentiation potential between the two passages. (picture: C. Jolérus, VBBG)

Master's Thesis by Claes Jolérus (Department of Biomedical Engineering, University of Basel) at the Vascularized Bone Biofabrication Group.

Severe or large bone defects can impaire the natural regeneration process of bones. Defects develop from infection (Osteomyelitis) or congenital diseases (Symbrachydactyly). Currently, these conditions are treated by autologous bone grafts. However, despite the good regeneration capacity, this method has disadvantages such as donor site morbidity and potential for complications from surgery. A tissue engineering approach can been used for treating bone defects. Isolated Human adipose-derived mesenchymal stromal cells (ASCs) could be used to produce in vitro cartilage tissue to form bone tissue after implantation at the defect site. If successful, this innovative approach could overcome the disadvantages of autologous bone grafts while achieving a similar regeneration potential. The main limitations of this therapy is the inherent inter-donor variability in the monolayer expanded stromal cells chondrogenic differentiation potential. But cell preconditioning can be used to counteract this limitation.

This master thesis aimed at providing insights into the necessity of bone morphogenetic protein 6 (BMP6) and potential benefits of cell preconditioning on chondrogenic differentiation in ASCs. Chondrogenesis in cells was evaluated from passage 0 to 5 through various techniques, such as the evaluation of released glycosaminoglycan concentration in cell culture supernatant, volumetric analyses and AI driven quantification of Safranin-O stained histological section of the in vitro generated cartilage tissues. We demonstrated that BMP6 was not needed after 2 weeks of chondrogenic differentiation to ensure proper chondrogenesis in ASCs at passage 0. We showed that none of the tested preconditioning leads to significant improvement of the chondrogenic differentiation at passage 3 where chondrogenesis was achieved and passage 5 where it was impaired. These findings may have practical implications for improving the efficiency and cost-effectiveness of chondrogenic differentiation protocols. Further investigations are required to identify potential targets for improving chondrogenic potential of expanded ASCs.

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Fabrication of Functional Muscular Thin Films for Biohybrid Soft Robotics

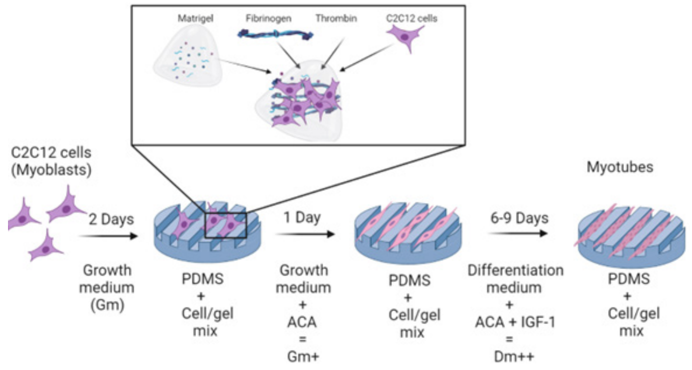

Figure 1: Scheme showing the tissue culture process: Using skeletal muscle cells (C2C12) after 2 days of tissue culture, seeding the cells with a hydrogel containing Matrigel, Fibrinogen, and thrombin, keeping culture 1 day in GM+, switching the next day for DM++. After 6-9 days a thin mature muscular tissue was obtained (picture: B. Lheimeur).

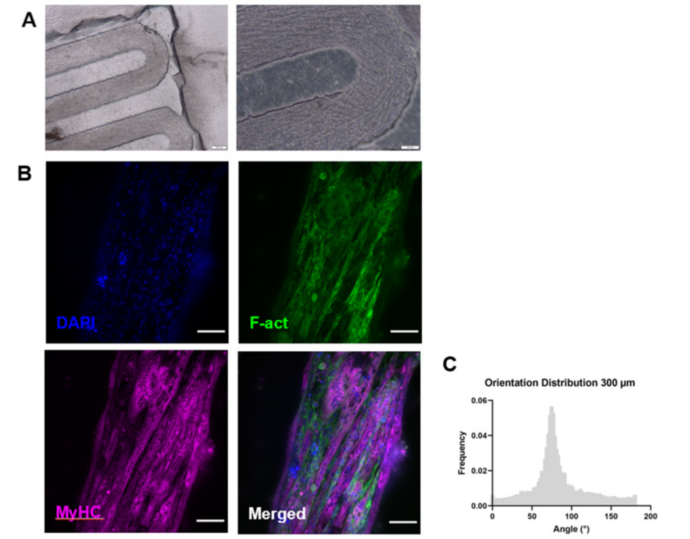

Figure 2: A- Inverted microscopy image of myoblast cultured on microgrooved 250 µm thick thin film (1:20 PDMS) on day 6 in DM++. The microgroove parameters: 300 µm width, and 100 µm depth. B- Fluorescent imaging of myoblasts stained with F-actin, DAPI, and MyHC after 10 days in DM++ (green, F-actin; blue, nuclei; magenta, MyHC), 300 µm-wide channels and a channel depth of 100 µm coated with Fibronectin. Scale bars: 100 µm. C- X-Y plot showing the orientation distribution of myotubes; 48% oriented at 75.06°(picture B. Lheimeur, A. Balciunaite)..

Master's Thesis by Bassma Lheimeur (Department of Biomedical Engineering, University of Basel) at the Soft Robotics Laboratory (ETH, Zürich).

The combination of biology and robotics in a working unit aims to create soft and controllable living systems that have unique functionalities (e.g., environmental adapta-tion and self-healing). Planar structures are good designs for biohybrid scaffolds as they can be efficiently perfused by liquid media during cell culture. It is important to have good cell alignment as it translates to great force generation. Additionally, providing a rich extracellular matrix (ECM) environment to the cells is important for determining their differentiation fate. In this study, a thin PDMS film was actuated with skeletal muscle cells. The PDMS surface contained topographical cues to align cells and improve the differentiation and maturation process. A new hydrogel formulation containing Matrigel, which has shown good results in previous studies was tested (1).

The study findings suggest that PDMS-based micro-grooved thin films have the potential to align cells effectively in tissue engineering. The addition of Matrigel to the hydrogel formulation also enhances cell differentiation and maturation. The resulting flexible thin scaffolds hold promise for utilization in biohybrid robotics, with particular success observed in the locomotion of the developed constructs under electrical stimulation.

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Effects of Sterilization on the Accuracy and the Mechanical Performance of 3D-Printed Surgical Guides Materials

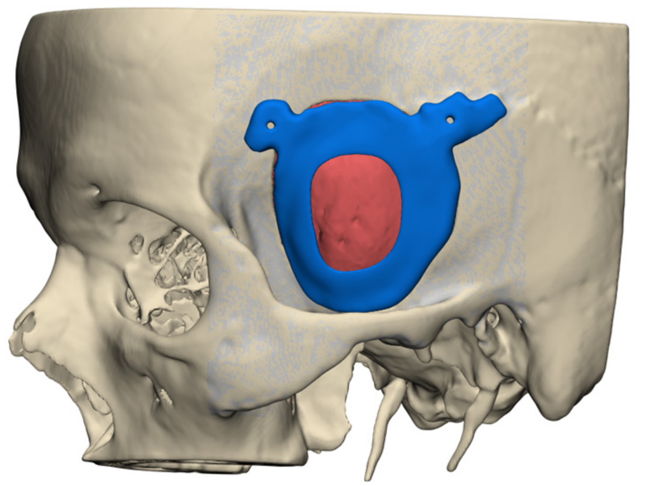

Figure 1: Resection surgical guide used in a cranial surgery (picture: Swiss MAM).

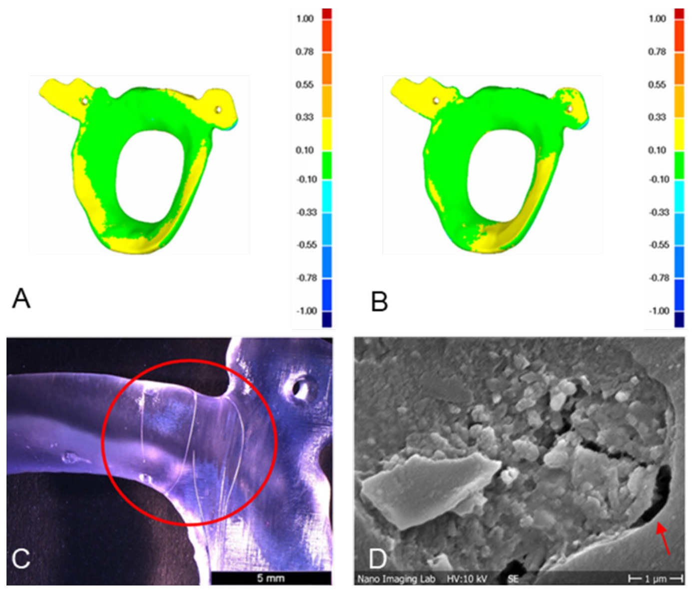

Figure 2: Assessment of sterilization effects: (A) color-coded deviation map of steam sterilized cranial surgical guide with a threshold set between ±0.1mm, (B) color-coded deviation map of plasma sterilized cranial surgical guide with a threshold set between ±0.1mm, (C) crack propagation of steam sterilized cranial surgical guide, and (D) SEM image indicating surface degradation of the 3D-printed surgical guide material (picture: A. Manea).

Master Thesis by Adriana Manea (Department of Biomedical Engineering) at Swiss Medical Additive Manufacturing (Swiss MAM) Research Group.

Surgical guides are three dimensional (3D)-printed customized medical devices a surgeon uses to guide a surgical procedure (Figure 1). The use of surgical guides yields more accurate results than free-hand surgery, reduces the overall duration of a medical procedure, as well as increase the safety of the procedure (1,2).

The objective of this thesis was to investigate the impact of steam and plasma sterilization on materials for Stereo-lithography (SLA) 3D-printed surgical guides, employing two distinct resin materials (BioMed Clear and BioMed Amber). To achieve this, a comprehensive study was conducted, encompassing dimensional accuracy and an examination of mechanical properties, with a specific emphasis on flexural properties. Subsequently, a fractographic analysis was carried out to identify the failure mode, and a surface analysis was performed to assess surface degradation.

The findings indicated the absence of accuracy concerns (Figure 2A, 2B); however, mechanical and structural alterations were observed. Following steam sterilization, the clinically applicable 3D-printed surgical guide designed for cranial applications exhibited cracks, rendering them unsuitable for practical surgical use (Figure 2C, 2D). In contrast, no such adverse effects were noted with plasma sterilization.

In conclusion, considering the study's limitations, it is evident that plasma sterilization proves to be a more dependable method compared to steam sterilization when applied to the specified 3D printed resin materials.

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References:

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Emergency Department 2.0: Improving Medical Care with Machine Learning

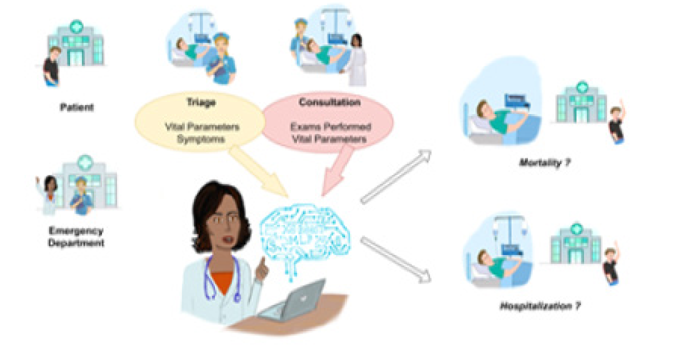

Figure 1: Experimental setup. Objective parameters measured at triage and during the consultation are used to predict hospitalization and mortality. (image: J. Cutuli and A. Mettler)

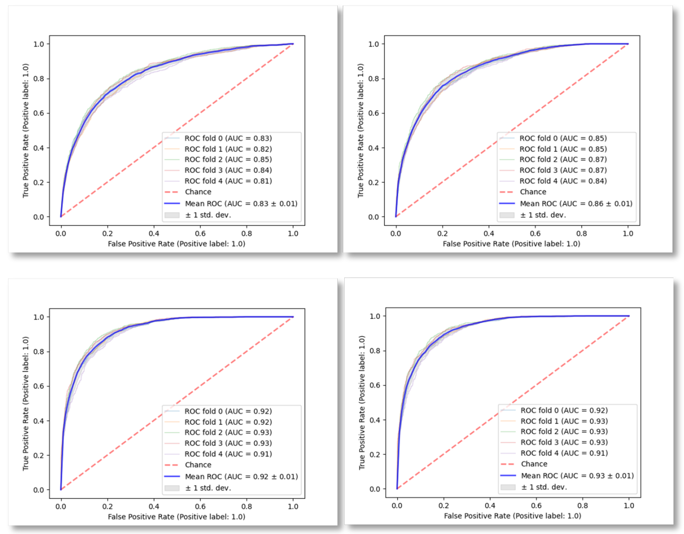

Figure 2: AUC measures using XGBoost for Hospitalization prediction based on nine vital parameters obtained at triage (on the upper left), an extended set of triage parameters (upper right), information including examps performed (lower left), and additional vital parameters at discharge (lower right). (graph: A. Mettler)

Master's Thesis by Annette Mettler (Department of Biomedical Engineering University of Basel) at Center for medical Image Analysis & Navigation (CIAN)

The aim of this Master thesis was to find a machine learning (ML) algorithm that allows prediction of the need for hospitalization as well as mortality within 30 days after emergency department (ED) presentation. Herewith, a baseline should be laid for implementation of artificial intelligence in different time steps of the ED presentation.

The medical dataset was obtained in the setting of the EMERGE study at the Basel University Hospital ED (1). It contains data of the ED presentation, such as for example vital parameters, various scores, text data, and information about exams performed.

With the prediction of Hospitalization, we aim to ameliorate patient flow in the ED by allowing early planning for the need of hospital beds. By predicting which patient has a high risk of Mortality, the patients who need most attention can be identified as early as at triage, and thus patient safety might be improved.

The algorithm should use objective values such as vital parameters, which are registered during the ED presentation, and predict whether the patient needs to be hospitalized or might not survive the 30 days following the ED presentation. Different ways of dealing with missing input values were considered, as not all vital parameters are reported for every patient. We tested a scalable tree boosting system called XGBoost (2), and a multilayer perceptron (MLP) with different sizes of inputs.

From a clinical perspective, the performance of XGBoost on predicting the need for hospitalization based on few inputs is surprisingly good. The MLP performed well for the rare outcome mortality.

Assuring a safe implementation of ML in daily clinical routine to the best patients' benefit is an important task that healthcare professionals face in the near future.

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(1) Roland Bingisser et al. "Physi-cians' Disease Severity Ratings are Non-Inferior to the Emergency Severity Index". In: Journal of Clinical Medicine 9.3 (2020).

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Letting Bio-bots Roam Free: Wireless Actuation of Skeletal Muscle Constructs

Figure 1: Bio-actuated robot composed of a contractile hydrogel-based C2C12 skeletal muscle ring and an elastic and conductive carbon black enriched PDMS skeleton (picture: D. Milone).

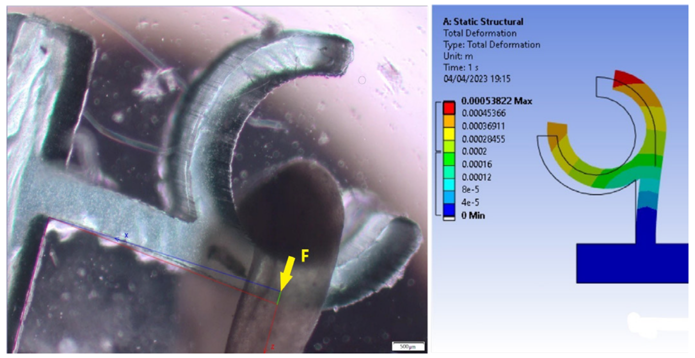

Figure 2: Calculation of passive and active contraction force: (a) Deflection calculation with ImageJ, (b) Passive deformation simulation with Ansys (picture: D. Milone).

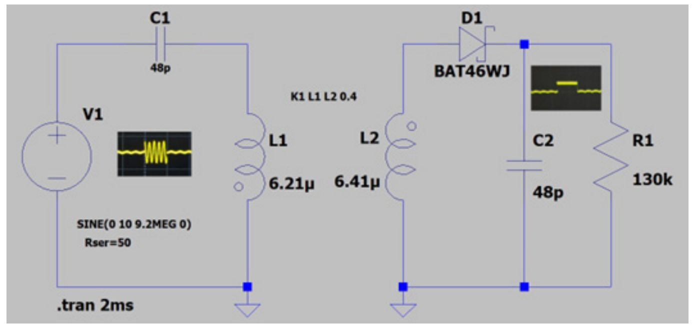

Figure 3: LT-spice RLC circuital simulation of the wireless power system and burst-mode signals used for triggering contraction in muscle cell constructs (picture: D. Milone).

Master's Thesis by Davide Milone (Department of Biomedical engineering, University of Basel) at the Soft Robotics Lab, ETH Zürich.

Biological skeletal muscle tissue actuators could produce controllable motion in response to electrical stimuli. It was proved that pulsed direct current (DC) can induce contraction in cell cultures and constructs, however, the dynamic state of the tissue was strictly dependent on the morphology of the cells and the electrical parameters provided. An optimal cell maturation and differentiation was crucial for a strong contraction capability and can be improved by mechanical and electrical training during the cell growth. In vitro electrical stimulation was usually induced by direct coupling of the electrodes to the cell medium (1) or pulsed light stimulation (2). Even though these approaches were efficient in terms of ES delivering, their cytotoxic and mutagenic effects interfere with the cellular health and nature (3).

The aim of this project was to induce the contraction of a hydrogel based C2C12 skeletal muscle ring by electromagnetic field. The coupling of the ring and a PDMS compliant skeleton constituted a bio-hybrid robot able to contract and spring back to the original position in response to each muscle twitch. A wireless petridish-sized magnetic induction set-up was built and adapted to the bio-bot needs aiming to deliver the most suitable electrical parameter configuration for contraction through a non-harmful conduction system. In order to create a flexible and conductive interface between the ring and the skeleton, the pillars were enriched with conductive carbon black particles. The circuital and magnetic induction settings were simulated before assembling the electrical components. Finite Element Analysis (FEA) was performed on the skeleton, so that, the ideal stiffness and compliance of the PDMS could be estimated. The capability to remotely control the contraction has always been a challenge for the bio-hybrid robotics field and with this project we were trying to overcome it.

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(3) S. Meng et al. "Electrical stimulation and cellular behaviors in electric field in biomedical research," vol. 15, no. 1, p. 165, number: 1 Publisher: Multidisciplinary Digital Publishing Institute.

Quantitative Evaluation of Shared Surgeon-Robot Workspace for Robot-Assisted Knee Surgery and Training

Figure 1: Set up of three (out of five) Qualysis cameras (red) capturing the tools and arms which have markers attached (green) during the simulated surgeries. The camera (orange) video captures the entire procedures (picture: F. Neumüller).

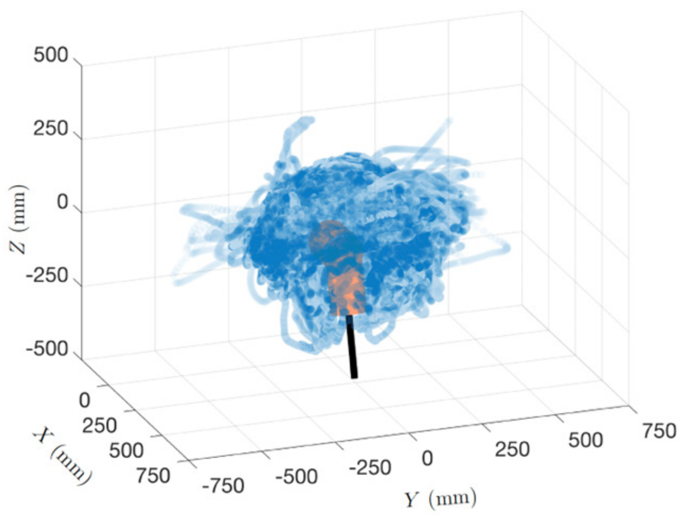

Figure 2: Aggregating all data points of the four tools leads to the total volume covered by the tools. The volume of the highest density can be approximately bound from 300mm left of the knee to 300mm right of the knee. The space from 100mm below the knee to 300mm above the knee and 200mm beyond the knee to 200mm in front of the knee is densely frequented (picture: F. Neumüller).

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

To be familiar with the medical procedures and the technology used during surgery, various training regimes have been developed for trainee surgeons, such as virtual simulators for knee surgeries. We aim to enable the use of robotic assistance in endoscopic knee surgery and training by assisting the trainee using a robot-mounted surgery tool. Thus, the shared surgeon-robot workspace which is the volume in which the surgeon moves the surgical tools during the procedure, needs to be quantified.

A user study with eight surgeons was conducted. The motion of the surgical tools and arms while performing multiple procedures on the VirtaMed ArthoS knee simulator were tracked (Figure 1). The 3D positions and the orientation were captured with a Qualysis tracking system. The user study resulted in a defined workspace volume for the surgical tools (Figure 2) and an occupied volume of the surgeon's arms as obstructions. Observations in the operating theatre highlighted regular knee motions by the surgeon, which are not reflected in the user study results.

The results quantify the workspace required for a robot that can potentially hold the tool for assistance in training and a workspace that the robot cannot occupy in order not to obstruct the surgeon.

Facts and Figures

The surgical tools occupy a volume of [632mm x 441mm x 450mm] . The arms covered a volume of [888mm x 1186mm x 618mm] during the simulated procedures.

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Total Human DNA Sampling

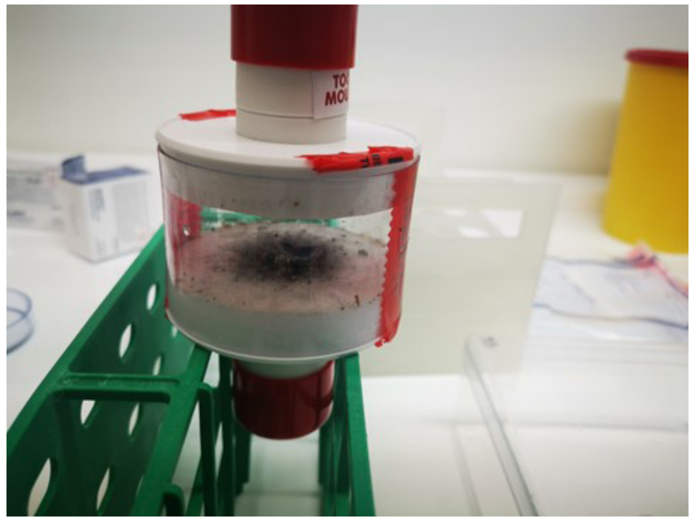

Figure 1: Filter-Unit after sampling traces and before processing in the lab. This shows the traces after sampling a 4.5 m² carpet (picture: C. Neves).

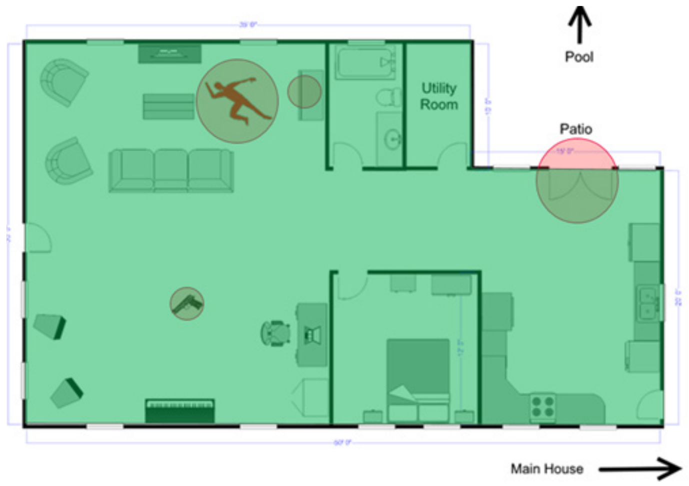

Figure 2: The red circles show what traces are currently possible to cover when the CSI arrives at the crime scene. The green field shows what is possible to cover with "Total Human DNA Sampling"(picture: https://www.measurepoint.de/crime-scene/, modified by: C. Neves).

Master's Thesis by Colino Neves (Department of Biomedical Engineering, University of Basel), at Department for Forensic Molecular Biology, Institute for Forensic Medicine Bern.

The objective of this research was to develop a method for efficient large-area DNA sampling and to address the challenge of dealing with DNA mixtures in forensic science. A technique utilizing a vacuum cleaner and filter was developed for collecting samples from a large surface area. The subsequent filter fragmentation and parallel processing significantly reduced the complexity of the dust mixture, allowing for interpretable DNA profiles to be obtained from individuals present on the sampled surface. The method was validated in a controlled laboratory setting and applied in a simulated crime scene containing resident background DNA, resulting in the creation of database-compatible DNA profiles from the "perpetrator" who was present at the simulated crime scene for less than a minute. Overall, at least 40% of the created DNA profiles on all sampled places had the potential to be submitted to the Swiss DNA database. These findings have the potential to provide additional investigative leads for law enforcement, particularly in cases where all other avenues of investigation have been exhausted.

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Additive Manufacturing of Patient-Specific Bone Grafts at the Point of Care

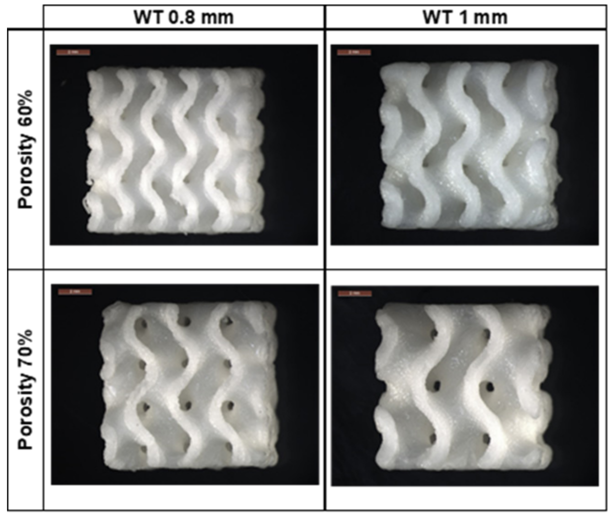

Figure 1: The top surface of 3D printed scaffolds with different porosity and wall thickness (picture: Swiss MAM).

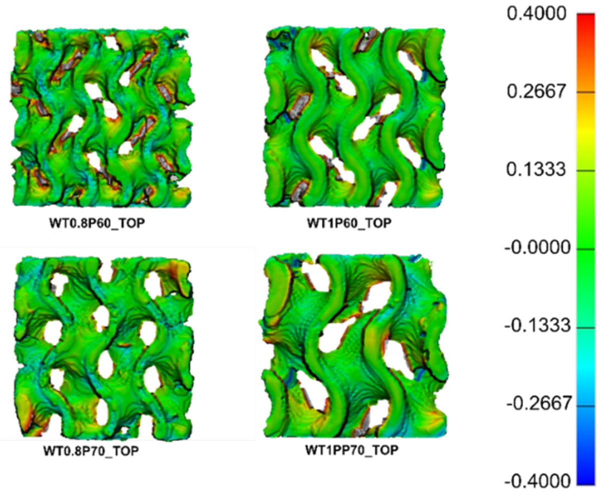

Figure 2: CAD comparison of original models and scanned models of 3D printed scaffolds. The color bar indicates a threshold set between ±0.4mm (picture: Swiss MAM).

Master's Thesis by Isabella Ortiz (Department of Biomedical Engineering) at Medical Additive Manufacturing Research Group.

Craniomaxillofacial (CMF) bone defects occur due to congenital abnormalities or are acquired through trauma, cancer, or infection (1). Autologous bone grafts are the gold standard for the treatment of large bone defects that use bone from a secondary site to replace the missing bone. Two surgeries, nerve and vascular injury, and bone site morbidity are drawbacks of this procedure (2).

An alternative treatment that uses bioresorbable polymer composite scaffolds has emerged as a promising solution to repair CMF bone. Fabricating scaffolds with a complex architecture resembling bone morphology is possible with additive manufacturing.

In this thesis, four scaffolds (Fig. 1) based on gyroid unit cells were designed to exhibit biological characteristics like those of trabecular bone. A biocompatible and biodegradable polymer composite, containing 70% poly (L-lactide-co-D, L-lactide), and 30% β-TCP were used to fabricate the scaffolds. According to the trabecular bone porosity, scaffolds were designed to have 60 and 70% porosity values. For each porosity wall thicknesses of 0.8 mm and 1.0 mm were selected. Build accuracy (Fig. 2) and mechanical properties of the scaffolds were investigated.

The results of this study show that the volume fraction, or porosity, has an important influence on the mechanical characteristics of the scaffold and that walls as thin as 0.8 mm meet the necessary mechanical requirements for the scaffolds to be comparable to mandibular trabecular bone.

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References:
(1) C. K. Mayfield, M. Ayad, E. Lechtholz-Zey, Y. Chen, and J. R. Lieberman, "3D-Printing for Critical Sized Bone Defects: Current Concepts and Future Directions," Bioengineering, vol. 9, no. 11, p. 680, Nov. 2022, doi: 10.3390/bioengineering9110680.

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Robot-Assisted Laser-Ablation of Engineered Human Cartilage

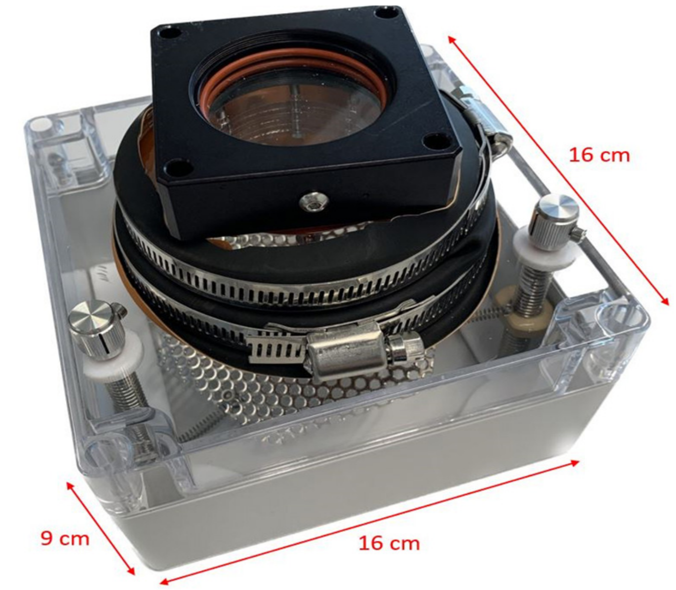

Figure 1: Container for sterile cartilage ablation (picture: N. Porciani)

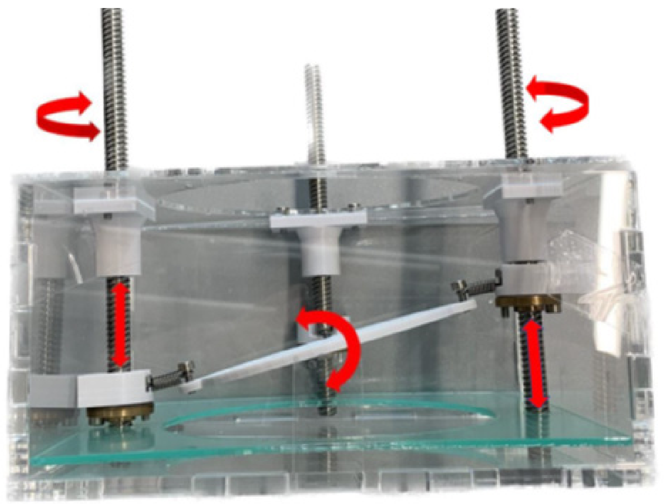

Figure 2: Adaptation of sample position and orientation using externally accessible leadscrews. (picture: N. Porciani).

Master's Thesis by Porciani Niccolò (Universität Basel) at BIROMED-Lab.

The ability to spontaneously heal articular cartilage injuries is extremely limited. This aspect is even more evident in full-thickness lesions. Healthy knee joint chondrocytes are difficult to harvest without further damage to the articular surface. The autologous grafts based on them have shown many drawbacks after being implanted. A new kind of autologous graft, using nasal chondro-cytes as a more appropriate source of cells, has been developed. However, for the transplant to be successful, the dimension and the shape of the graft must fit the articular defect. Previous studies have demonstrated how refreshing cartilage defects or reshaping the graft using surgical tools might be highly harmful, reducing the probability of success of the implant. On the other hand, promising results have been noted when these procedures are performed through laser ablation. Further investigation is required to better understand the actual benefits of using lasers in place of standard tools. The aim of this work was to develop a container that allows to perform laser-based experiments without contamination or damage to biological samples. The design must guarantee flexibility during the experiments and the possibility of using the container in any environment, even in unsterile ones. The developed device is a compact, autoclavable and biocompatible box that is suitable to be used in different experimental setups involving sterile samples. The 3 DoF inner platform and the movable laser transparent sapphire window enable the user to focus the laser light on different parts of the sample, with the possibility to change its inclination and distance from the laser source. Besides, custom-made airtight junctions are meant to ensure sterility during the experiments. It could be demonstrated through laser ablation experiments on human cartilage samples that the proposed device complies with all fundamental requirements. Thus, this device can in the future be used to further investigate laser-cartilage interactions.

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Optimization of Fibrin-based Hydrogels for Cardiac Tissue Engineering

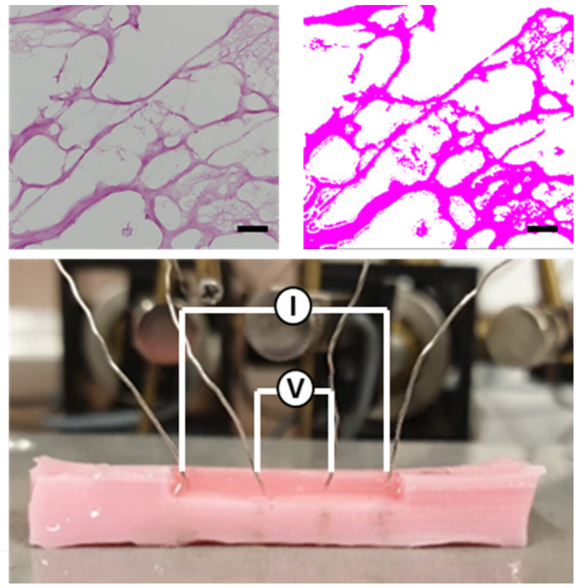

Figure 1: top) Hematoxylin and eosin stained cryosections and corresponding assignments of tissue and void area used to calculate the porosity. Scale bar represents 50 µm. bottom) Four-point probe system to measure the sheet conductivity. (picture: M.Puschmann, CSE).

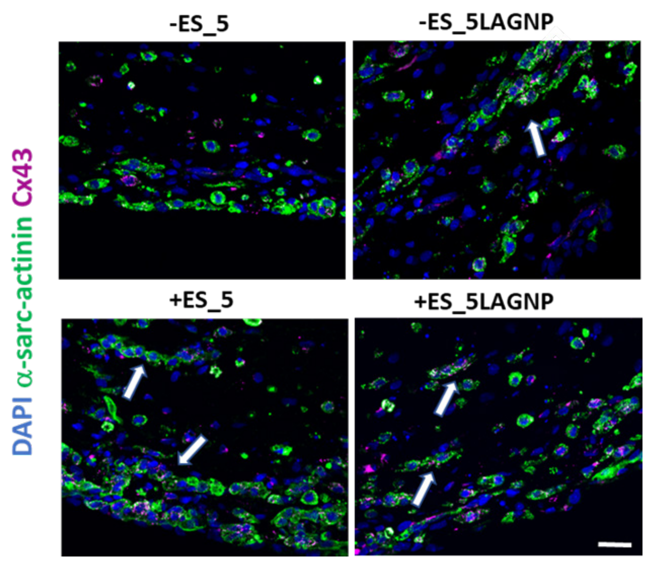

Figure 2: CImmunofluorescence staining of α-sarcomeric actinin (green) and connexin 43 (red). Cell nuclei were stained with DAPI (blue). White arrows indicate elongated and/or interconnected cardiomyocytes. Scale bar represents 50 µm.
-ES = not stimulated, +ES = electrically stimulated, GNP = graphene nanoplatelets, LA = laminin (picture: M.Puschmann, CSE).

Master's Thesis by Marc Puschmann (University of Basel) at Cardiac Surgery and Engineering (CSE)

The aim of this project was to investigate the effects of hydrogel formulation and electrical stimulation on tissue remodeling properties and cardiac cell maturation in vitro. For this purpose, acellular and cell-laden fibrin–based hydrogels supplemented with or without laminin and graphene nanoplatelets were prepared. Cell-laden con-structs were cultured for seven days with or without elec-trical stimulation. Acellular hydrogels were characterized by porosity and conductivity (Figure 1), cellular constructs were assessed by electrical pacing tests and extended histological readout.

Characterization of acellular constructs demonstrated an inverse relationship between fibrinogen concentration and porosity, and no increased conductivity upon supplementation with 0.04 wt% graphene nanoplatelets. Functionality and contractility analyses showed not only an increased maximum capture rate for electrically stimulated constructs, but also an increase in contraction am-plitude. Histological findings suggested a superior cardiomyocyte maturation in terms of cell elongation and sarcomeric organization upon application of electrical stimulation during culture or solely by dual supplementation with laminin and graphene nanoplatelets (Figure 2). Overall, this study emphasizes the importance of electrical stimulation towards the development of a functional syncytium and implies a positive effect of laminin and graphene nanoplatelets on cardiac maturation at the cellular level.

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Establishing Forensic Body Fluid Identification by RNA Profiling into the Routine DNA Extraction Workflow

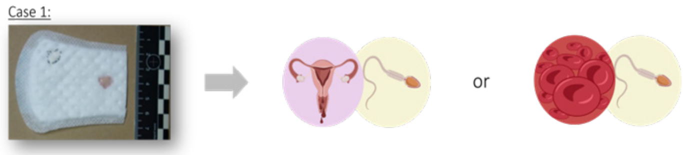

Figure 1: An exemplarly scenario highlighting the potential of body fluid identification through RNA profiling. The example shows a mixture of sperm and menstrual or venous blood, with the presence of the latter indicating a possible injury as commonly observed in sexual assaults (photo/graphic: Institute of Forensic Medicine Basel, Biorender.com.)

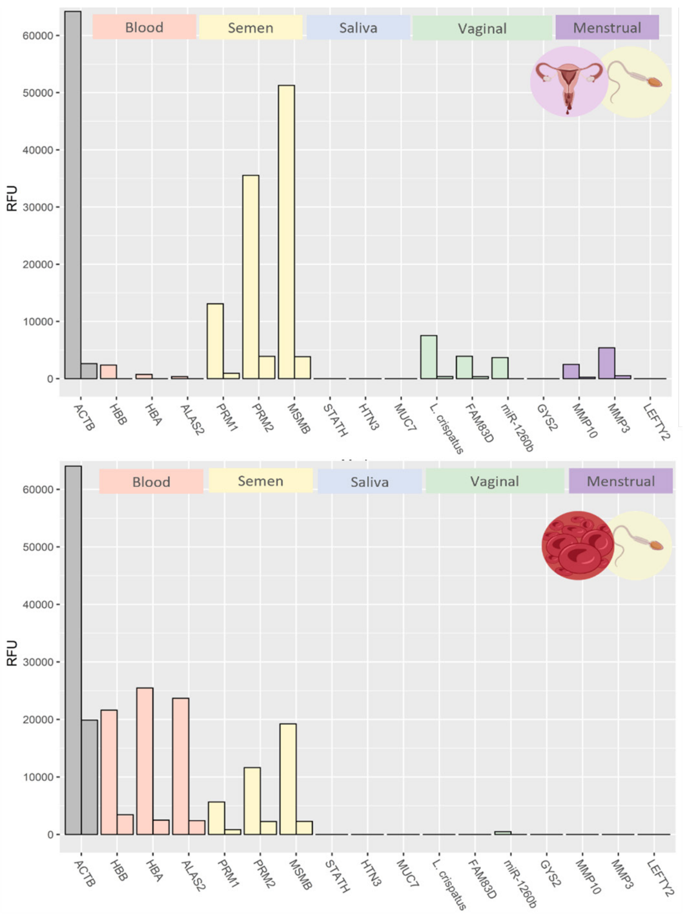

Figure 2: RNA analysis output from the example (Fig. 1) with corresponding body fluids reliably identified: sperm and menstrual blood (top), sperm and venuous blood (bottom) (picture: Institute of Forensic Medicine.)

Master's Thesis by Nicole Rittiner at the Department of Forensic Genetics, DBE, Institute of Forensic Medicine, University of Basel & Biozentrum, University of Basel.

DNA analysis in forensic casework matches crime-scene samples with an individual's DNA profile to identify a person of interest. However, no information on the type or origin of the sample is provided, which may help in reconstructing a crime scene (1). For this, RNA analysis has gained significant attention for forensic body fluid identification through extraction of mRNA or miRNA along with DNA, enabling the identification of body fluids and their respective origin (Fig. 1) and the contributor's genetic DNA profile (2,3,4).

A combined RNA/DNA co-extraction protocol has been successfully developed, including a novel biomarker for improved vaginal fluid detection. The designed RNA multiplex assay combines fifteen mRNA and three miRNA biomarkers to detect five relevant body fluids: peripheral blood, semen, saliva, vaginal fluid, and menstrual blood. The m/miRNA multiplex was validated for specificity, sensibility and repeatability. The assay is compatible with endpoint PCR and capillary electrophoresis that now will be integrated into the routine workflow of the forensic laboratory.

By incorporating the established procedure into routine casework, complex forensic questions will be resolved in a manner that benefits society and justice. As shown in the exemplary scenario and its results, we can now clarify whether the bloodstain in the mixture with sperm was caused by menstruation or an injury (Fig. 2), with the latter indicating a potential sexual assault.

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References:
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(4) Y. Li et al., Forensic Sci Int Genet. 2014, 12

Minimally Invasive 3D Bioprinting (MI3DB) for Articular Cartilage Resto-ration in the Knee

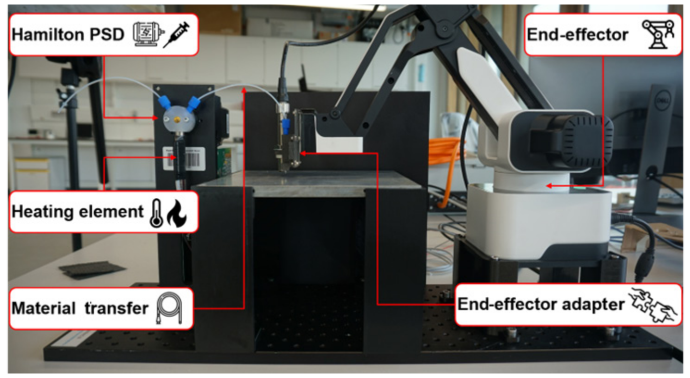

Figure 1: Final prototype setup (picture: D. Spothelfer).

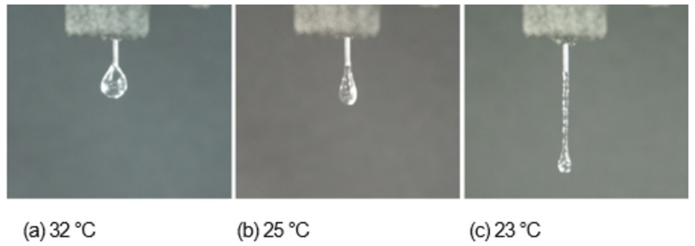

Figure 2: Extrusion of GelMA through tube of length 200mm and inner diameter of 337μm (picture: D. Spothelfer).

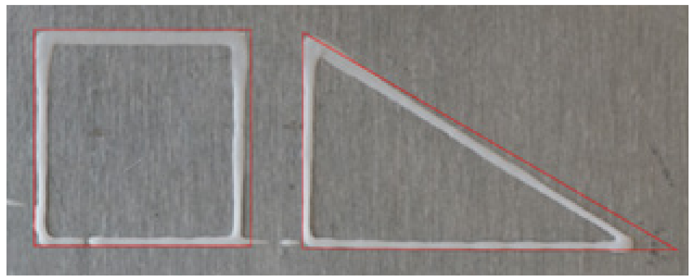

Figure 3: Printed shapes with designed shape overlayed in red (picture: D. Spothelfer).

Master's Thesis by Dominic Spothelfer (Swiss Federal Institute of Technology Zürich - ETHZ) at the BIROMED-Lab.

Articular cartilage defects in the knee are a common problem that can lead to pain, inflammation, and reduced mobility. Bioprinting has emerged as a promising technology for the treatment of such defects and using a minimally invasive approach is expected to reduce complications associated with the surgery and improve recovery time. However, to our best knowledge, there are no examples of minimally invasive bioprinting for articular cartilage defect repair. Therefore, this project's objective was to develop a prototype test bench to evaluate the feasibility of using minimally invasive 3D bioprinting (MI3DB) to treat articular cartilage defects in the knee.

A comprehensive literature review of in situ bioprinting devices for cartilage repair was carried out to find an appropriate bioprinting mechanism and material for MI3DB. Based on results from prior literature review, the prototype test bench was conceptualized using extrusion-based bi-oprinting of Gelatin methacryloyl (GelMa). The prototype was designed and developed to incorporate the components necessary to assess the feasibility of minimally invasive bioprinting. A pre-iminary feasibility assessment was carried out to investigate the impact of temperature and nozzle geometry on the printability of biomaterial. The results showed that it is feasible to form a continuous filament and print 3D structures. The precise control of temperature and appropriate choice of nozzle geometry are critical for the consistent deposition of biomaterial using the developed platform.

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Integration of Sensing Elements in Engineered Muscle for Proprioception in Bio-hybrid Robots

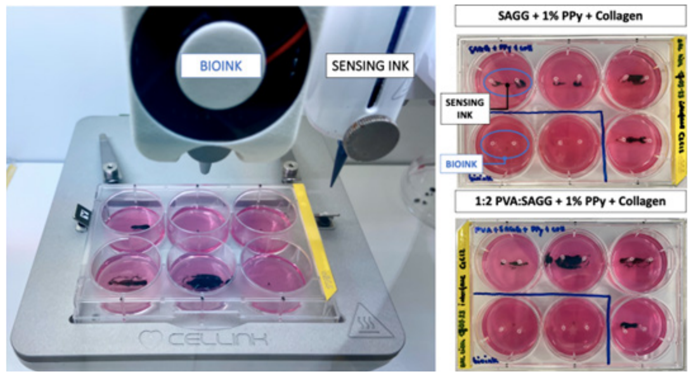

Figure 1: The picture on the left shows the multi-material printing on the 6-well plate containing the agar bed. The temperature-controlled extruder contained the bioink and the second extruder contained the sensing ink, here the PVA + SAGG + 1% w/v PPy + Collagen (1.6mg/mL). The pictures on the right are the well plates containing both printed interfaces. The upper one with the SAGG + 1% w/v PPy + Collagen (1.6mg/mL) sensing ink and the bottom one with the PVA + SAGG + 1% w/v PPy + Collagen (1.6mg/mL) sensing ink (figure: L. Stefani).

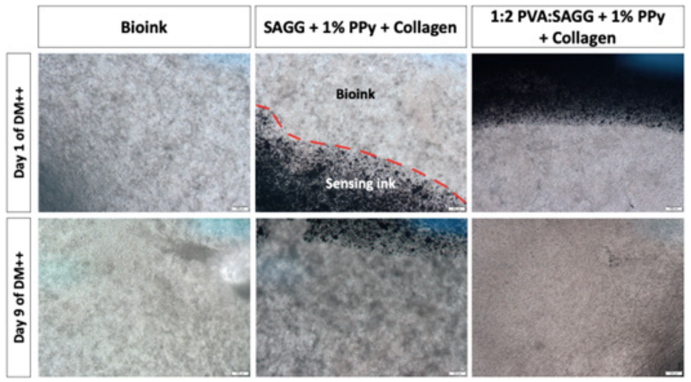

Figure 2: Optical microscope images of the bioprinted interfaces. Control of the myoblasts' maturation in the bioink and in both interfaces in DM++ on day 1 and 9. On day 9, myotubes formation was clearly visible in each sample, especially in the 1:2 PVA:SAGG + 1% w/v PPy + Collagen (1.6 mg/mL) interface The objective x2.5 shows that there was no change in the shape of the sensing ink from day 1 to day 9. Scale bars: 200 µm (figure: L. Stefani).

Master's Thesis by Lisa Stefani (Department of Biomedical engineering, University of Basel) at the Soft Robotics Lab (ETH, Zürich).

The field of soft biohybrid robotics is rapidly growing, with scientists developing various types of actuators that respond to external stimuli (1). However, one major aspect missing to improve the movement of bio-hybrid robots is proprioception, which requires bio-robots to sense their own contractions.

To achieve this, a biocompatible, conductive, and printable hydrogel that can deform upon the contraction of skeletal muscle cells within it is needed. The resulting composite must be soft and functional to avoid hindering the motion of the actuator and have good affinity to the growing tissue. Therefore, synthetic hydrogel will be mixed with sodium alginate, gellan gum, and conductive fillers (e.g. polypyrrole, carbon black) to create an optimal material that meets all the criteria. Once the synthesized scaffold can synchronize and conduct the contraction, sensing will be possible using the piezoresistive proper-ties of the material. The change in the material's shape will cause variations in the resistivity value read with a source measure unit, connected to the sensing material.

In this project, a biocompatible and sensing interface was developed to enable the growth of a muscle bioactuator in contact with a piezoresistive sensor. However, testing of the sensors in a biohybrid robotic demonstration was not successfully achieved.

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(1) M. Craddock, E. Augustine, S. Konerman, et M. Shin, « Biorobot-ics: An Overview of Recent Inno-vations in Artificial Muscles », Actuators, vol. 11, p. 168, juin 2022, doi: 10.3390/act11060168.

Simulating Fatal Fall from Height Cases: Evaluating Biomechanical Analysis Possibilities

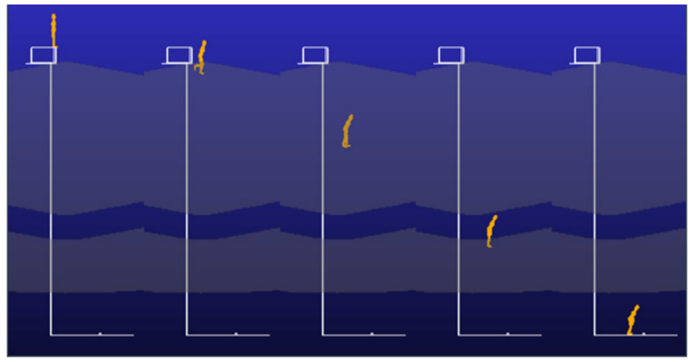

Figure 1: Case #1: Simulated fall from height showing initial contact with the feet approximately 1.62 sec. after initial takeoff. Simulation predicted 91% of injuries correctly (picture: V.Towianski).

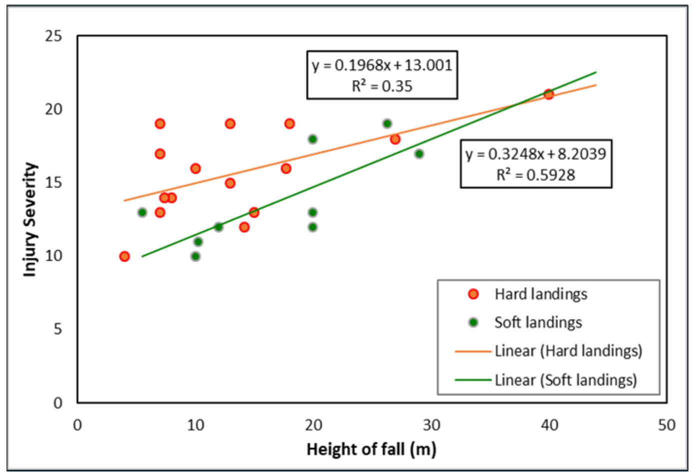

Figure 2: Number of injuries as related to ground gonditions (Hard vs. Soft) at the site of impact (picture: V.Towianski).

Master's Thesis by Veronica Towianski (Department of Biomedical Engineering, University of Basel), at the Forensic Medicine and Imaging Group.

Falls from a height are a frequent cause of injury and death, second behind only traffic accidents in terms of injury-related mortality [1]. The issue most often faced when in-vestigating these types of cases is that most individuals leave behind unanswered questions regarding the motive behind these deaths. In many of these cases, the only defi-nitive information available to investigators is the fall height, found position, and injuries sustained. Using these variab-les as inputs, the aim of this research was to utilize biome-chanical models to obtain more information as to the man-ner of the fall. To do this, we analyzed 39 fall from height cases (defined as a fall from height greater than 2 meters) provided by the Institute of Forensic Medicine in Basel, Switzerland. MSC Adams simulation software was then used to simulate four of these cases, based on what was known about the height of the fall and found position, to predict injury patterns. The simulated injuries were then validated based on their concurrence with the actual injuries identified by CT and autopsy results. When comparing the predicted (based on the simulation) and actual injuries, it was found that the simulation predicted 83% of the injuries in case #1 correctly, 91 % in case #2, 87% in case #3, and 67% in case #4. However, none of the cases exhibited initial segment velocities that were high or low enough to definitively speak to the presence of a push based on the simulation results alone [2]. In terms of influencing factors, the data showed an almost-significant linear correlation ($R2 = 0.5928$, $p-value = 0.08$) between the height of the fall and the injury severity for soft landing surfaces. While the trend was less emphasized for hard surface landings, a trend was still visible ($R2 = 0.35$, $p - value = 0.19$). In light of this research, it was shown that biomechanical models do have the potential to aid in forensic investigations. However, due to limitations in current simulation software development, these models should serve only as a guide in forensic in-vestigations and not as a standard until further research can be completed.

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References:
[1] Turgut, K. et al. Falls from height: A retrospective analysis. World journal of emergency medicine 9, 46 (2018).

[2] Cross, R. Forensic Physics 101: Falls from a Height. American Journal of Physics 76, 833–837. issn: 0002-9505, 1943-2909. http://aapt.scitation.org/doi/10.1119/1.2919736 (2022) (Sept. 2008).

Organoids Microscopic Image Analysis Using Convolutional Neural Network

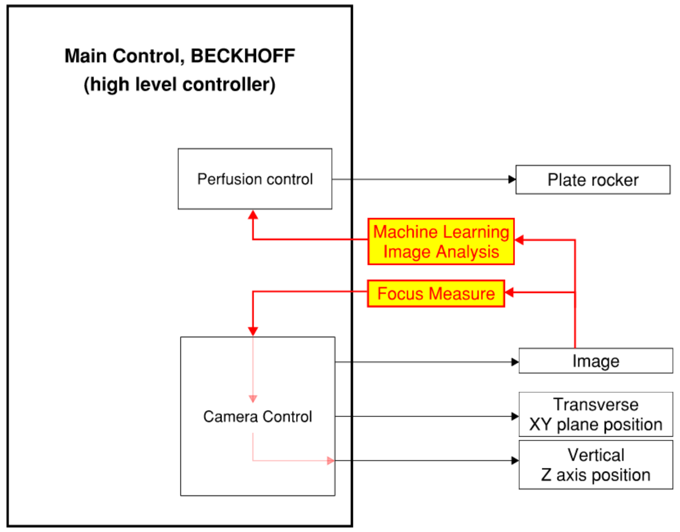

Figure 1: A control diagram (image analysis part only) of the robotic organoids incubator. Machine Learning Image Analysis and Focus Measure are constructed to be offered to the control system as feedback (picture: W. Yang).

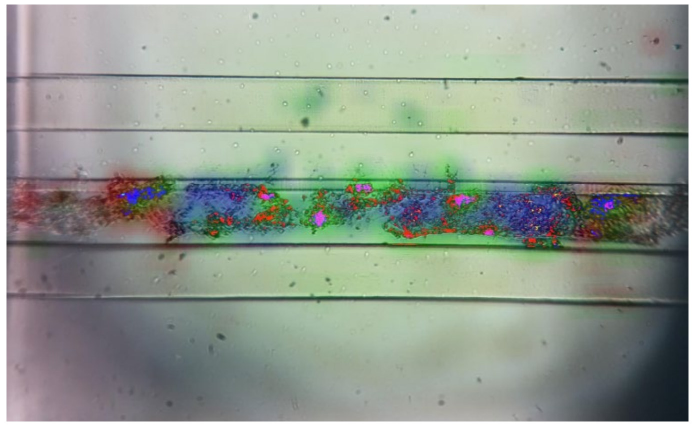

Figure 2: Classified organoids in Red (0 day), Green (1 ~ 3 days old), and Blue (+4 days) by the convolutional neural network model. Each color represents a growth level of organoids (picture: W. Yang).

Master's Thesis by Woosik Yang (Department of Biomedical Engineering, University of Basel) at BIROMED-Lab.

This project proposed how to develop two feedback loops to control an automated robotic organoids incubator. First, the focus measure method was adapted to enable the incubator to select good-quality microscopic image data among a mass dataset on its own. The methodology, also, offered feedback to the control system of a camera robotic arm to adjust the camera position and capture a well-focused microscopic image. Then Convolutional Neural Network, CNN, models were constructed to analyse the acquired images and make feedback for the perfusion control which could stimulate the vascularization of organoids in the incubator. One of the CNN models classified the development stages of organoids and identified the locations of the organoids. A segmentation model was also built to measure the volumetric growth of capillaries which were sprouted from the fully grown organoids vascular tube. In short, the purpose of this project was to construct feedback for fully automated microscopic image capturing and processing the image with a help of machine learning. Therefore, the robotic organoids incubator can produce organoids without any human intervention.

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Automated Detection of Tiger Mosquito Traps with Deep Learning

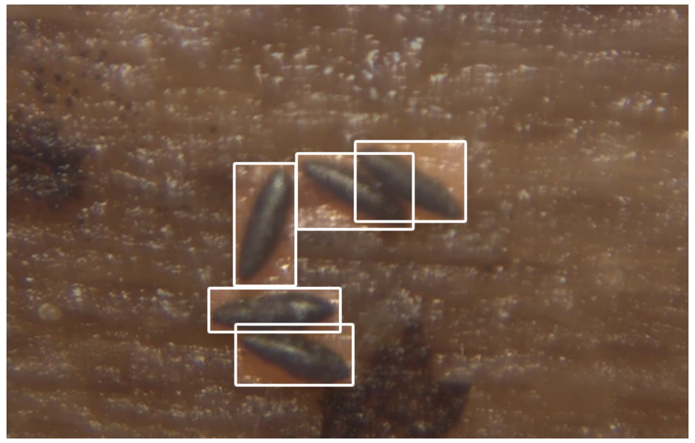

Figure 1: A control diagram (image analysis part only) of the robotic organoids incubator. Machine Learning Image Analysis and Focus Measure are constructed to be offered to the control system as feedback (picture: M. Zuber).

(a) *Ae. albopictus* (b) *Ae. geniculatus* (c) *Ae. japonicus*

Figure 2: An Inception Resnet v2 is trained to distinguish the three mosquito species Ae. albopictus, Ae. geniculatus and Ae. japonicus based on shape, size and texture (pictures: Vector Control Group, Swiss TPH).

Master's Thesis by Moira Zuber (Department of Biomedical Engineering, University Basel) at the Center of Medical Imaging and Navigation (CIAN).

This Master thesis aims to develop a Machine Learning tool for automatic detection and identification of eggs of the invasive Asian tiger mosquito. As part of the Swiss National Surveillance Program organized by the Swiss TPH, egg traps are laid out across Switzerland. The two main tasks performed by the entomologists are counting of the number of eggs as well as classification of the mosquito eggs into one of three possible species.

A tool was designed that solves the counting and classification tasks using Deep Learning. An iPhone X camera is used for image acquisition, equipped with a macro lens for magnification boost. The mos-quito eggs are detected using YOLOv8, a popular object detection tool. Classification of detected eggs into the possible mosquito species is performed by an Inception Resnet v2. The developed models are incorporated in a user-friendly iPhone application, which is designed to accelerate the workflow of the entomologists when analyzing the mosquito traps.

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