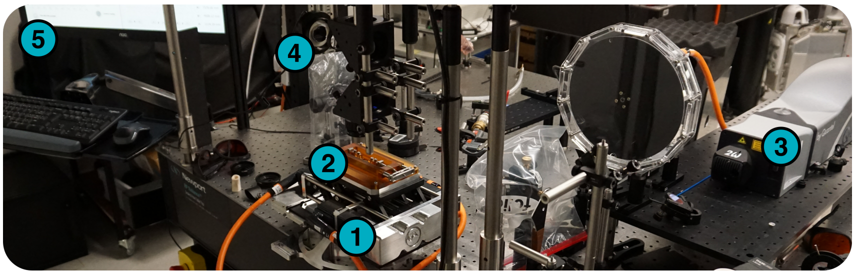
University of Basel
Department of Biomedical Engineering

BIROMED-Lab
Medical Robotics and Mechatronics

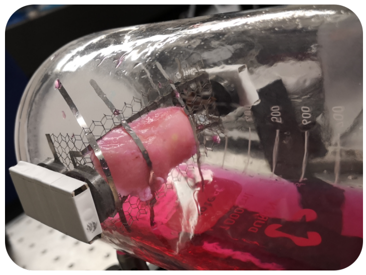
Master Thesis:
Robot-Assisted Laser Ablation of Engineered Cartilage Tissue - Implementation of Custom Ablation Shapes and Evaluation of Chondrocyte Viability

Context: Cartilage damage in the knee joint caused by aging or repetitive actions can be treated by surgically removing the damaged cartilage tissue and filling the generated defect with a precisely shaped, healthy cartilage graft [1]. Nowadays, removing defected cartilage and shaping the regenerative grafts is done manually using biopsy punches or scalpels. This approach is simple and quick, but only provides limited cutting accuracy. Moreover, removing defected cartilage exactly down to subchondral bone is not possible by hand. However, regenerative grafts will only reintegrate and survive if placed in the correct layer without leaving defective cartilage behind. Thus, we are developing a system (**a**) leveraging robotic positioning and laser light for precise, controlled, and contactless (**b**) tissue ablation [2, 3].

Task description: As of now, our system is able to ablate tissue along straight lines. Your task will be to develop a motion and ablation control framework for automatic ablation along simple shapes such as circles. After validating your framework with engineered cartilage samples, you will prepare and execute cellular stainings of these samples to investigate chondrocyte viability after laser ablation. Optionally, your framework should finally be extended to allow for the input of arbitrary ablation shapes by the user via the graphical interface and the automatic execution thereof.



(a) The developed tissue preparation system with (1) robotic stage, (2) biological sample, (3) ablation laser, (4) camera, and (5) graphical user interface.



(b) A cartilage sample fixed in the developed sterile ablation container.

Work packages:

- Review the relevant literature on (robot-assisted) laser ablation of soft tissue.
- Detail the requirements for your control framework and GUI based on the given cartilage regeneration application.
- Implement a basic framework and GUI, interface it with the existing robot-assisted laser ablation system.
- Evaluate the performance of your framework by preparing engineered cartilage samples for viability analyses.
- Prepare and execute suitable stainings of the prepared tissue to investigate chondrocyte viability.
- (Optional) Extend your framework and GUI to allow for the input and execution of arbitrary shapes.

Benefits:

- Gain practical experience with design and implementation of motion control frameworks and GUIs.
- Learn to use a state-of-the-art PLC (programmable logic controller) system (TwinCAT 3, Beckhoff).
- Apply cellular stainings and gain experience with interpreting their results.
- Work in a highly interdisciplinary team of robot engineers, laser physicists, and biologists.

Requirements:

- Solid background in medicine, biology, or a closely related field.
- Basic knowledge of mechanics, kinematics, and programming (Matlab Simulink, MathWorks).
- Prior experience with programming of PLC applications and GUIs is a plus, but not strictly required.

References:

[1] M. Mumme et al. "Nasal chondrocyte-based engineered autologous cartilage tissue for repair of articular cartilage defects: an observational first-in-human trial." *The Lancet*, 388(10055), pp. 1985-1994, Oct. 2016. doi.org/10.1016/S0140-6736(16)31658-0

[2] C. Duverney et al. "Sterile Tissue Ablation Using Laser Light - System Design, Experimental Validation, and Outlook on Clinical Applicability." *J. Med. Devices*, 15(1), pp. 11104/1-11104/12, Mar. 2021. doi.org/10.1115/1.4049396

[3] L. Beltrán Bernal et al. "Laser in Bone Surgery." In: S. Stübinger et al. (eds), *Lasers in Oral and Maxillofacial Surgery*, pp. 99-109, Springer, Cham, Mar. 2020. doi.org/10.1007/978-3-030-29604-9_9

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