Biomechanical Characterization of SMILE Lenticles

Background Laser refractive surgery is a popular treatment to correct the myopia, hyperopia, and astigmatism. This surgery uses a laser to permanently reshapes the cornea in order to correct the patient's visual acuity. The effect of laser surgeries is achieved by removing corneal tissue using an excimer laser. Although laser surgeries are well-established, there is still a ~10% chance of not achieving the desired correction. This leads to increased costs and potential adverse events. Moreover, laser surgeries can result in corneal ectasia or even permanent loss of vision (<1%). In clinics, planning of the surgery is mostly empirical based on nomogram tables, which don't explicitly account for the individual corneal biomechanics. Patient-specific finite element simulation of the refractive intervention should help improving the surgical outcome. However, personalized mechanical properties of the cornea are required.

Stromal lenticule extraction, such as SMILE or CLEAR, is a new technique to correct vision by reshaping the cornea. Unlike previous approaches, this technique produces a small lenticule that is removed from the patient's cornea. In this project, we plan to leverage this surgical waste to have an accurate characterization of the cornea biomechanics. This approach offers several benefits; availability of healthy specimens, tests can be performed immediately following surgery avoiding tissue modification associated with preservation techniques, and access to the pre-/post-surgical configuration of the same patient.

Aim The aim of the project is three-fold. First, establishing a protocol for the mechanical characterization of the extracted SMILE lenticule. Second, the identification of the mechanical properties of the specimens for constitutive mechanical models. Finally, simulating the refractive intervention with the identified properties and comparing its outcomes with the post-surgical clinical situation.

Materials and Methods First, the student will get familiar with the mechanical testing device (UStrech from CellScale) and determine the appropriate attachment system to mount the specimens. The testing protocol will be developed using porcine samples representing different amount of tissue ablation. Parameters such as the load rate, number of repetitions, quantification of the deformation from high-resolution CCD imaging, minimum sample thickness, or inter-clamp distance will be evaluated. After mechanical testing, the mechanical properties of the specimens will be performed using different constitutive hyperelastic models (isotopic & anisotropic). The final part of the project will deal with applying the protocol to human specimens. If time permits, this final characterization will be integrated within a patient-specific model of the cornea, and the simulated surgical outcome will be compared with the refractive correction observed on the patient.

Nature of the Thesis:
Biomechanical testing: 60%
Numerical modeling: 40%

Requirements:
Knowledge in continuum mechanics and FE simulation

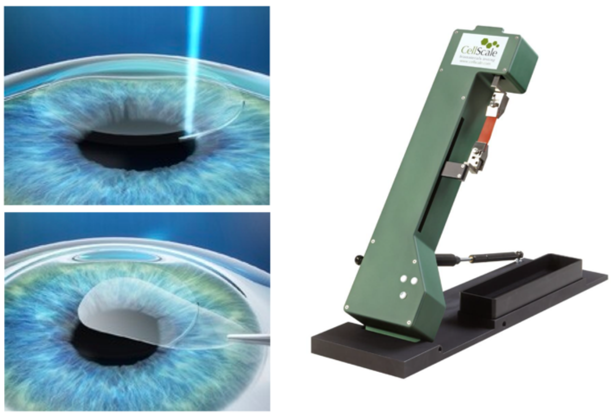
Skills acquired:
Python / Matlab / Abaqus
Experience with biomechanical testing
Knowledge in optics and ophthalmology

Supervisors:
Prof. Dr. Philippe Büchler
Malavika Nambiar

Location:
Experimental work conducted at IROC clinic in Zurich.
Data analysis / modeling at ARTORG Center in Bern

Institutes:
ARTORG Center, IROC clinic

Clinical Partners:
PD Dr. Theo G. Seiler



The SMILE lenticle cut out of the patient's cornea using a femtosecond laser is removed through a small lateral incision. The project will develop method to characterize this biological sample using uniaxial testing and identification of the parameters of a mechanical model.

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