Applications of the *ImTOPScanner* for the investigation of ocular biomechanical parameters

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Ocular biomechanics have gained increased interest in recent years. The material properties of the cornea and the sclera determine the eye´s shape and play an important role in several ocular pathologies. In keratoconus (KC), a progressive, non-inflammatory disorder that results in thinning and protrusion of the cornea into a conical shape[1], corneal alterations are usually detected when the vision is already irreversibly affected, but changes in the corneal biomechanical properties take place before these morphological features occur[2]. For the more common eye condition myopia, which results from a mismatch between the focal length of the ocular components and the axial length of the eye, studies have shown an alteration of the scleral biomechanical properties in the equatorial and posterior regions[3]. In both cases, the ability to quantify biomechanical changes in the ocular tissue could enable earlier detection of disease progression, more individualized treatment options, and avoid irreversible vision loss, corneal transplants, or retinal detachment. Non-contact approaches that quantify biomechanical properties *in vivo* include Optical Coherence Elastography (OCE)[4-7], Brillouin microscopy[8, 9], and air-puff deformation Scheimpflug imaging[10, 11]. Recently, Optical Coherence Tomography (OCT) devices have been coupled to air-puff excitation sources to capture the deformation event at the corneal apex or on the horizontal meridian[12-14].

We have recently presented the *ImTOPScanner*, a customised swept-source optical coherence tomography system coupled with a quasi-collinear air-puff excitation, capable of acquiring dynamic corneal deformation on multiple meridians[15]. One advantage of the additional scanning meridian is that corneal deformation asymmetries that are due to softer corneal regions below the corneal apex (typical in KC patients) can be detected more easily. In addition, the proposed system is highly flexible in terms of customizing the air-puff parameter and ocular alignment, so that it can be used additionally for analysing scleral biomechanics[16]. In both cases, the resulting deformation parameters provide advanced input data for Finite Element (FE) modeling inverse analyses to estimate a set of ocular material properties[17]. The system also functions in phase sensitive mode (PSOCT), which allows detection of nanometer scale displacements on the cornea. Using PSOCT mode, we have implemented an advanced form of an OCT Vibrography[18] technique (closely related to Optical Coherence Elastography[19]) utilizing co-axial acoustic stimulation and OCT measurement with pre-compensation of acoustic frequency content and signal reconstruction in the Fourier domain.

Within this presentation, we will give an overview of the most recent results from the ImTOPScanner on corneal biomechanics that include KC patients and healthy subjects. We quantified deformation asymmetries (average asymmetries in displaced area, ADA) on two meridians and compared them to healthy subjects, and present estimations of patient-specific corneal material properties from FE modeling. We will then present first results of scleral deformation imaging, and discuss scleral deformation parameters and the estimated elastic modulus of different locations on the sclera. Finally, we will demonstrate the feasibility and reliability of the presented co-axial and acoustic pre-compensation approach for OCT Vibrography studies of the cornea by measurement of the mechanical resonance modes of contact lenses and porcine corneas.

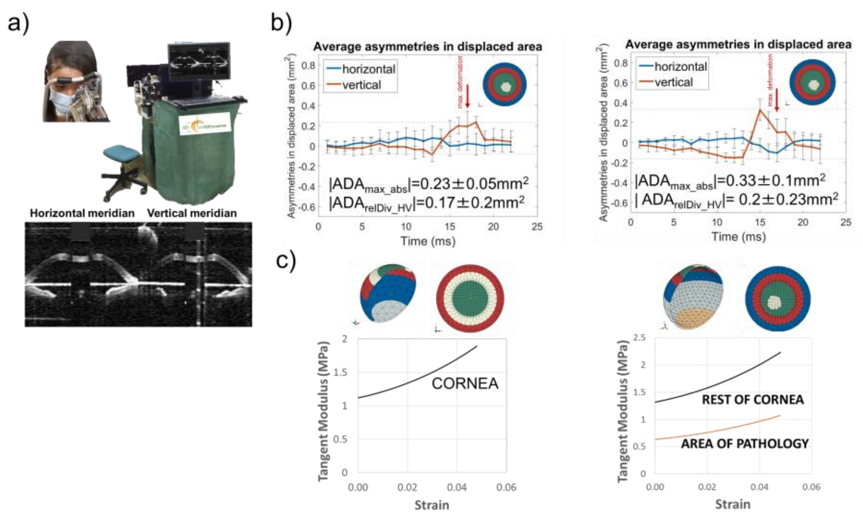

Figure 1. a) Set-up of the IMTopScanner device for patient use (corneal air-puff deformation imaging). Below an example-OCT image, showing the horizontal (left) and vertical (right) meridian during air-puff deformation b) The average average asymmetries in displaced area for a KC patient. c) Results of the FE modeling inverse analysis for a healthy (left) and moderate KC (right) subject.

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