

# Ultrasonic micro-elastography on assessing corneal biomechanics

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## Abstract

The cornea, the window of the eye, provides approximately two-thirds of the total refractive power. The unique set of corneal biomechanical properties determined by its complex structure plays an important role in maintaining corneal function and human vision system [1]. Many factors, like ageing, trauma, diseases or clinical refractive surgery would affect the corneal biomechanics and finally cause changes to vision. In recent decades, there has been increased interest to investigate the importance of corneal biomechanics for disease diagnosis such as keratoconus [2], glaucoma, and the improvement of ocular treatments including LASIK surgery and crosslinking [3].

The commercial devices such as ocular response analyzer (ORA) and Corvis ST tonometry, are the only clinical available devices to measure the corneal biomechanical properties [4]. However, these devices don't have the ability to provide the point-to-point stiffness mapping which increase the possibility of missing local abnormalities. Thus, a high resolution modality to fully disclose corneal stiffness distribution is essential needed in ophthalmology.

Elastography, using either external force or acoustic radiation force (ARF) for excitation, is an imaging modality capable of mapping the biomechanical properties of soft tissues. Specifically, Zhou et al. used a shaker to generate vibrations on the surface of the eye and tracked the shear wave propagation using low frequency array system [5]. ARF-based ultrasonic elastography methods, such as acoustic radiation force impulse (ARFI) imaging, shear wave elasticity imaging (SWEI) and supersonic shear imaging (SSI), capitalizing on the advantage of synchronization of ARF excitation and ultrasonic detection, have been used to quantify the mechanical properties of soft tissue in a more effective and accurate manner. In 2009, Tanter et al. implemented SSI with an ultrafast imaging system to provide corneal stiffness distribution [6]. Later, Urs et al. utilized a 25 MHz transducer to monitor corneal biomechanical changing under UVA-crosslinking therapy using ARFI [7]. However, most of these ultrasonic elastography studies, carried out in the standard clinical frequency range, could only provide spatial resolution ranging from sub-millimeter to several millimeters and significantly narrows its translational to ophthalmologic applications that require micro-scale level visualization. It is notable that ultrasound biomicroscopy (UBM) has become an indispensable technique for ophthalmic imaging owing to its natural advantage of visualizing some ocular structure such as ciliary body and

zonules through the use high frequency ultrasound [8]. Therefore, high frequency ultrasound based elastography may be a routine method in the future.

It was well documented that ARFI has a high imaging resolution with relative stiffness distribution, while SWEI provides the absolute Young's modulus. Due to boundary conditions of shear wave propagation, the resolution of SWEI is much worse than that in ARFI. The goal of our work is to develop multi-functional ultrasonic micro-elastography technology to observe biomechanics of ocular tissues in a tiny scale [9]. In this method, the region of interest (ROI) will be first detected by high resolution ARFI imaging and then shear wave propagation was tracked at that specific region, finally the elasticity and viscosity of ocular tissues within ROI can be reconstructed using SWEI technology and some advance models such as lamb wave model. In the future, the high resolution elasticity mapping with a labeled absolute Young's modulus would be an optimal scenario for physician to make a decision in either diagnosis or treatment purpose.

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