Biomechanical Microscopy of Tissue and Biomaterials
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Purpose: The mechanical properties of biological tissues and biomaterials are closely related to their functional abilities, and thus play significant roles in many areas of medicine. For example, hardened coronary arteries by calcification can cause heart problems; changes in the elasticity of crystalline lens and cornea are thought to be central in the development of ocular disorders such as cataracts, presbyopia and corneal ectasia; biomechanical compatibility is crucial in tissue engineering procedures; and, the stiffness of extra-cellular matrix influences drug delivery and cell motility. However, measuring such biomechanical properties remains a significant challenge due to a dearth of non-invasive technologies. Our goal is to develop a novel diagnostic technique, Brillouin confocal microscopy[1], to probe the biomechanical properties of tissue in vivo without contact, quantitatively, and with high spatial resolution.

Materials & Methods: Brillouin light scattering arises from the interaction between light and sound waves inside material. Such interaction induces a small frequency shift in the scattered light that is directly related to the viscosity and elasticity of samples. We have developed a high-resolution optical spectrometer that is able to measure such tiny frequency shift with unprecedented detection efficiency and we integrated it with a home-built confocal microscope.

Results: Using Brillouin microscopy, we have obtained the first 3D images that use elasticity as contrast mechanism (Fig.1a); we monitored fast dynamic changes in elastic modulus during polymer cross-linking (Fig.1c); and we performed the first in vivo measurement of crystalline lens in the mouse eye (Fig.1b). We have also obtained the first in vivo demonstration of age-related stiffening of lenses (not shown).

Conclusion: Brillouin confocal microscopy can indeed characterize in vivo the biomechanics of tissue and biomaterials non-invasively and with micron-scale resolution. The first areas of biomedical applications we are exploring are in ophthalmology where Brillouin microscopy may enable measuring changes in corneal and lens elasticity by aging, by the progression of disease, or in response to treatment and drugs; and in tissue engineering for the optimization of procedures by mapping and monitoring in situ and in real time the micromechanical properties of host and implanted tissue.