Abstract—Here we describe novel quantitative optical elastographic method based on shear wave imaging optical coherence tomography (SWI-OCT) for biomechanical characterization of ocular and cardiac muscle tissues through noncontact elasticity measurement. The SWI-OCT system employs a focused air-puff device for localized loading of the tissue and utilizes phase-sensitive OCT to monitor the induced tissue deformation. Phase information from the SWI-OCT is used to reconstruct 3-D depth-resolved shear wave propagation inside the tissues. Measurement of the shear wave group velocity allowed quantification of the Young’s modulus of thick tissues. The quantitative feature and measurement accuracy of this method is demonstrated from the experiments on tissue-mimicking phantoms with the verification using uniaxial compression test, and normal and pathological ocular and cardiac muscle tissues, both ex vivo and in vivo.

Keywords—Optical Coherence Tomography; elastography; shear wave; cornea; lens; muscle

I. INTRODUCTION

The biomechanical properties of many tissues can have a profound influence on the health, structure, and normal function of the organism. Recently, optical coherence elastography (OCE) has been established for qualitative and quantitative noninvasive imaging of tissue elasticity. Reinforced from the high spatial resolution of optical coherence tomography (OCT), OCE is able to provide microscale depth-resolved mapping of tissue elasticity. Quantitative assessment of the elastic modulus of tissue has been demonstrated based on the use of OCE to monitor the propagation of the induced elastic waves in cornea, skin and soft-tissue tumor. More recently, our group has developed shear wave imaging OCT (SWI-OCT), which enables noncontact depth-resolved imaging and visualization of the elastic wave propagation inside tissue at an ultra-high frame rate. In this report, we present further development of SWI-OCT with the ability to provide quantitative elasticity measurement for noncontact biomechanical characterization of ocular tissues and mouse cardiac muscle both in vitro and in vivo.

II. RESULTS AND CONCLUSIONS

The typical temporal displacement profiles from a particular depth in a 0.75% (w/w) agar phantom is shown in Fig. 1(a). The time delay can be clearly observed along the shear wave propagation. Fig. 1(b) indicates the plot of the data from cross-correlation of the signals in Fig. 1(a). The linear fit with a high R-square value (0.99) results in the group velocity of ~1.9 m/s. Fig. 1(c) clearly indicates the agreement of the results obtained from SWI-OCT and from Instron test, which demonstrates that SWI-OCT can be used for accurate measurement of the quantitative Young’s moduli of soft samples.

Fig. 2 shows a snapshot from typical results of shear wave propagation in rabbit cornea. The results demonstrate that SWI-OCT can clearly differentiate stiffness of the cornea from different age group of animals. All together, these data indicate that OCE has potential for quantifying Y.