Measurements of Biomechanics by Dynamic Optical Coherence Elastography

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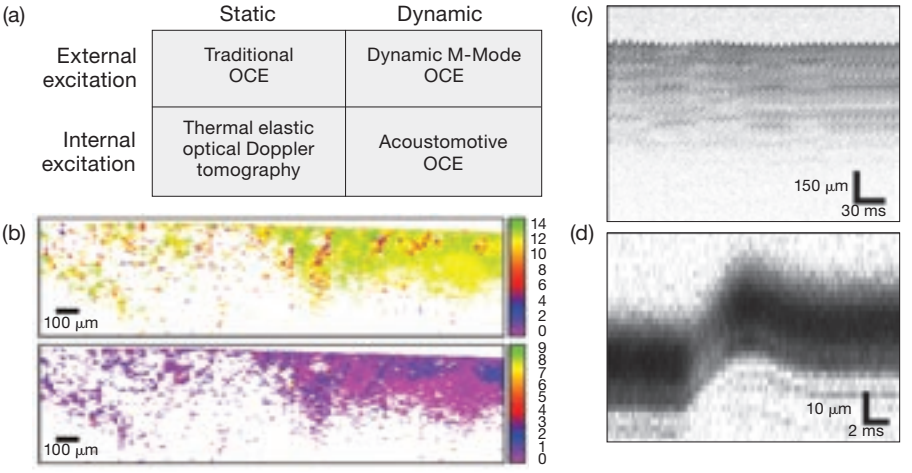
Optical coherence elastography (OCE) is a novel elastography technique that can measure tissue biomechanical properties using mechanical excitations and *in vivo* optical coherence tomography (OCT). This technique has great potential for detecting mechanical property changes in the tissue microstructure—such as tumor invasion—due to its high resolution, high speed and non-invasive features.

OCE techniques can be classified as static or dynamic depending on the mechanical excitation approach used. Static methods are commonly used in conventional OCE studies, and they are based on cross-correlation algorithms.[1] We concentrated on dynamic OCE techniques in which the sample is excited by mechanical waves. The biomechanical properties can subsequently be obtained by solving wave equations. In addition to being static or dynamic, OCE excitation can also be classified as internal or external based on the spatial characteristics of the excitation. Internal excitation OCE techniques benefit from remote excitation and the ability to maintain a sterile *in vivo* environment.[2]

M-mode (motion-mode) OCE, a dynamic and external excitation OCE method, was first studied to measure and map biomechanical properties of samples.[3] We used a mechanical wave driver as the external mechanical excitation and a spectral-domain OCT system for detection. Low-frequency sinusoidal waveforms were used in the OCE experiments and Voigt bodies served as mechanical models for the mechanical driver and samples. Normal and neoplastic *ex vivo* human breast tissues were investigated using dynamic M-mode OCE. The measured elastic moduli were 10.68 ± 0.86 and 0.42 ± 0.17 kPa for tumor and adipose tissue, respectively.



(a) Classification of optical coherence elastography. (b) Elasticity and error maps obtained with sinusoidally driven phase-resolved M-mode OCE. Unit for color bar is kPa. (c) OCE image indicating wave propagation on human skin *in vivo*. (d) AM-OCE image on gelatin tissue phantom showing inclusion motion.

Using the phase-resolved M-mode OCE method and transverse scanning, we derived an elasticity map of tissue containing both tumor and normal adipose material. The elasticity map allows for the differentiation of the tumor from the normal adipose on the microscale, and even minor changes within the tumor tissue that cannot be differentiated on the OCT structural image alone. This dynamic and external OCE method was also used to determine *in vivo* skin biomechanical properties based on mechanical surface wave propagation. Quantitative Young's moduli are measured on human skin from different sites, orientations and frequencies.[4]

We also reported acoustomotive OCE (AM-OCE), a dynamic and internal excitation OCE technique.[5] We used acoustic radiation force for internal mechanical excitation and spectral-domain OCT for detection. We measured mechanical properties of gelatin tissue phantoms by AM-OCE and verified them using rheometry results. Measured mechanical properties, including shear moduli and shear damping parameters of the gelatin samples, were found to double when their polymer concentration increased from 3 to 4 percent.

Novel dynamic OCE imaging techniques, including external and internal excitation methods, have been applied quantitatively for measuring and mapping biomechanical properties of tissue phantoms and biological tissues. With features of micron-scale resolution and non-invasive measurement, these novel OCE technologies have the potential to be used to identify and quantify mechanical tissue properties in various biomedical applications such as early-stage tumor detection. ◭

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References

1. J. M. Schmitt. Opt. Express **3**, 199-211 (1998).
2. Q. Wang et al. Proc. SPIE 68471B (2008).
3. X. Liang et al. Opt. Express **16**, 11052-65 (2008).
4. X. Liang and S.A. Boppart. IEEE Trans. Biomed. Engr. In press (2009).
5. X. Liang et al. Opt. Lett. **34**, 2894-6 (2009).