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An elastomer-based Skin-on-a-chip microfluidic as validation tool for translational studies in multi-modal angiographies

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An integration of multiple working principles into one angiography device brings correspondingly the need of one microfluidic-based tissue model with combined tissue equivalences to validate the anatomy and functional imaging performance. However, the state of the art shows that none of the established microfluidic chips has become an all-in-one artificial tissue model. The limitations derive from the selection of chip matrices, by which, either the optical transparency or mechanical rigidity is there by default, thus causing problems during translational studies. For instance, using a transparent PDMS based microfluidic as the test chart for spectroscopic Optical Coherence Tomography (sOCT) imaging brings challenges on validating the recovery of optical absorbance of the melanocytes in the melanoma lesion, because they are not reflected in the transparent microfluidic matrix [1].

To address such problems during the translational studies of multi-modal angiographies, we aim to investigate a totally new optofluidic chip-based resolution test chart out of turbid elastomer with a wide range in the tunability of optical/mechanical/acoustical parameters. The microfluidic network is located in the first 200 µm of chip device. The vasculature mimicking structure includes 12 separate microchannels (sized from 200 µm to 100 µm), which imitate the artery, venous and capillary network. A rhombus-shaped resolution test target is placed in the center of a 1 mm x 1 mm square. The in-/outlets have a width of 2 mm to accommodate the incoming flow. We use a Spectral-Domain OCT (SD-OCT Telesto-II-SP1, Thorlabs GmbH, Germany) to see through the turbid microfluidic matrices (see Fig.1).

We measure the optical parameters, namely the absorption coefficient μ_a and the reduced scattering coefficient μ_s', at the wavelengths of 540, 570, 630, 700, 800, 900 nm by using a spectrophotometer. The plotted results of μ_a mostly cover those of ex-vivo tissues, ranging from 0.05 to 1.3 mm^{-1} at the mentioned wavelengths. Similarity in μ_s' can also be found at these wavelengths (see Fig.1). The Young's modulus range from a minimum of 0.28 MPa over an average of 0.57 MPa to a maximum of 0.81 MPa, rather linearly decrease with the softener concentration. Compared to the results from ex-vivo tissues (ranging between 0.5 and 0.8 MPa [2], our PVCp matrices possess a broader band in the mechanical elasticity. The speed of sound in soft tissues rates a mean value of 1540 m/s[2]. A speed of sound of 1350 to 1500 m/s is recorded from the PVCp matrices of our microfluidic, which matches that of the ex-vivo tissue.

As the conclusion, we find a significant similarity between the optical/mechanical/acoustical properties of PVCp matrices and those of the extracellular matrix of ex-vivo skin tissue.

Meanwhile, the vascular anatomy in the superficial skin is replicated by the hollow microfluidic structure.

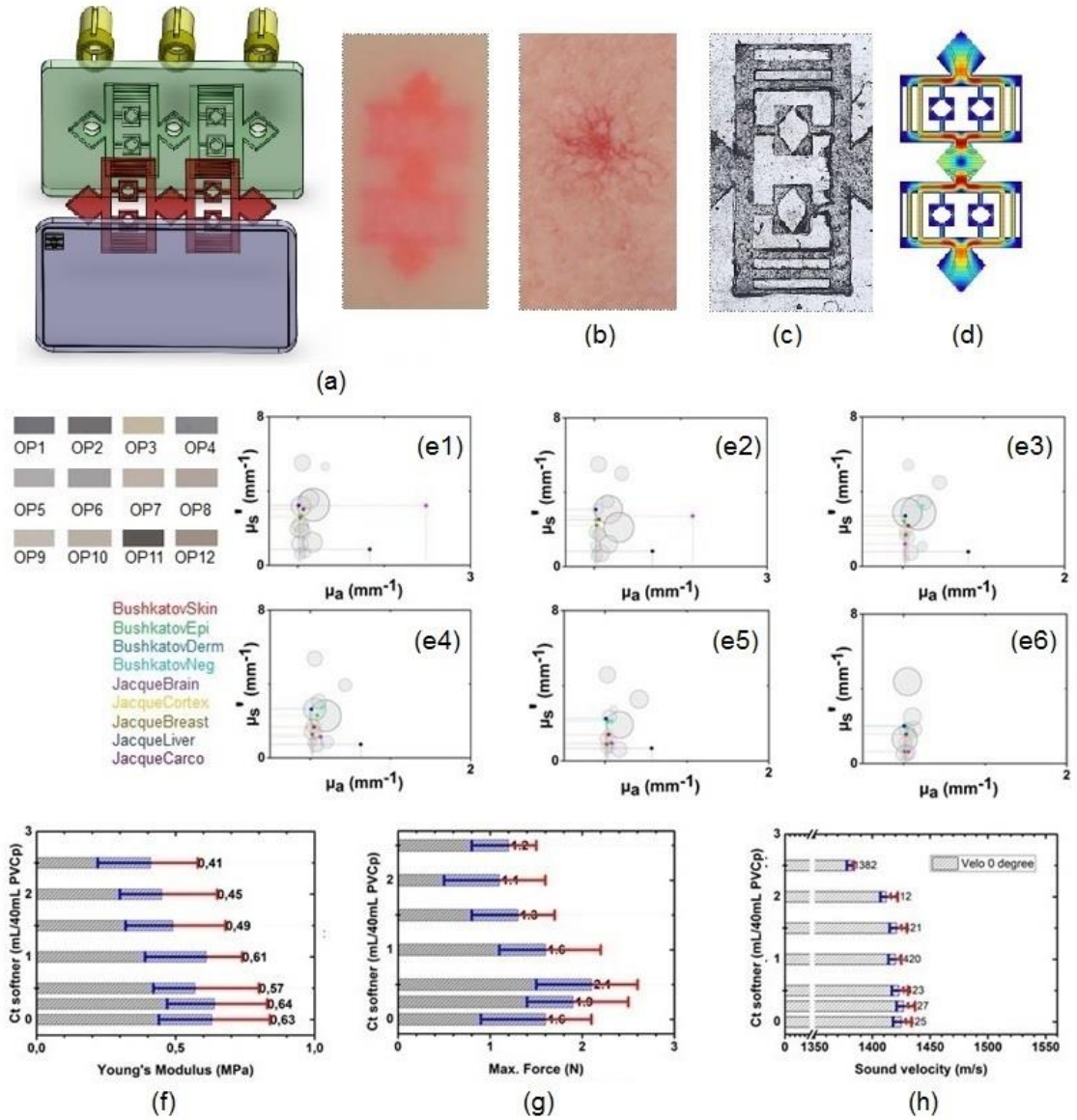

Fig. 1. (a) A 3D drawing of the microfluidic chip and a top view camera picture upon the region of microfluidic structure, compared to (b) a picture of spider angioma lesion, are given. (c) A sharp picture of the generated microfluidics structure is reconstructed by using LSM, and (d) the flow velocity field in the microfluidic is simulated based on Navier-Stoke equation. The absorption coefficient and reduced scattering coefficient of the PVCp matrices at the wavelengths of (e1) 540 nm, (e2) 570 nm, (e3) 600 nm, (e4) 700 nm, (e5) 800 nm, and (e6) 900 nm are shown. (f) The Youngs modulus of the PVCp matrices against the concentration of softener, and (g) the max. force performed on the PVCp matrices during the tensile test against the concentration of softener, are plotted.. (h) The sound wave velocity in the PVCp matrices against the concentration of softener is measured by TOF method.

References

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