In vivo breast stiffness measured by aspiration assuming a bi-layer material

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1 Introduction

The aim of this study is to experimentally characterise *in vivo* and *in situ* local Young's moduli of the human breast material constituents using an improved version of an aspiration device described in Kappert et al. (2021). In the literature, *in vivo* characterisations are usually based on elastography or tomography using expensive resources; inexpensive methods based on indentation, torsion or aspiration usually provide only an apparent Young's modulus assuming the tested material is homogeneous and isotropic.

In this work, breast soft tissue was assumed as a bilayer homogeneous isotropic material; an upper superficial 'skin' layer (dermis + epidermis) spread over a thick lower 'fat' material composed of adipose tissue and the mammary gland. Local aspiration data were used to evaluate the apparent Young moduli of the two layers as well as the upper layer thickness.

2 Methods

Aspiration tests consist of applying a partial vacuum through an aperture placed on the tested soft tissue and measuring the associated material deformation. In this work, the tissue deformation was estimated by cyclically changing the system volume ($\Delta V = 0.1mL$) using a syringe and knowing the measurement system stiffness through a calibration step. This method does not require the presence of mirrors, cameras or sensors close to the suction opening, allowing the use of custom 3D printed cups with various opening diameters.

This peculiar feature was used to extract mechanical behaviour information over different loaded tissue volumes. By performing the same test with different sized cups (4 to 30 mm aperture diameter), the Young's moduli of both layers and the upper layer thickness were determined by inverting a non-linear model (Principal Component Analysis over a Finite Element model database). A sensitivity analysis was used to determine the confidence intervals.

3 Results

Nine cups with various diameters were used on four healthy subjects. Three breast anatomical positions (high, medium and low) were tested on each subject. The estimated Young's moduli of the skin and fat were in good accordance with literature (i.e. around 3kPa for fat and 60kPa for skin). On two subjects, an independent skin thickness measurement was performed using ultrasounds, showing a good agreement with the thicknesses estimated by our aspiration method.

4 Discussion

The tests conducted confirm the procedure to be comfortable and non-invasive for subjects. The results obtained were, however, subjects-specific and considered promising. The main limits of this work are related to the different assumptions obviously not fully met in reality : bilayer structure, homogeneity and isotropy versus non-homogeneity of the materials composing the breast, presence of fascia, muscle, ligaments...

References

Kappert, K., Connesson, N., Elahi, S., Boonstra, S., Balm, A., van der Heijden, F., and Payan, Y. (2021). In-vivo tongue stiffness measured by aspiration: Resting vs general anesthesia. *Journal of biomechanics*, 114:110147.