

IN VIVO SUBJECT-SPECIFIC YOUNG'S MODULI OF HUMAN FOREHEAD BILAYER MATERIAL COMPONENTS VIA SUCTION

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1. Introduction

In vivo characterization of patient specific soft tissue is challenging, even under moderate quasi-static loading and small deformations. To be compatible with clinical environments, the data analysis should be performed almost in real time.

To achieve this goal, we developed an original suction-based device whose design enables the use of different suction aperture diameters from 6 to 30 mm [1]. This feature allows the identification of the Young's moduli under small deformation of the upper and lower layers of bilayers materials. A Finite Element (FE) database assuming an infinitely thick bilayer structure was developed to enable quasi real-time inverse identifications and to identify the identification indifference region.

This work questions the infinitely thick hypothesis previously implemented [1] when identifying in vivo Young's moduli on the human forehead.

2. Materials and Methods

A FE database has been computed with ANSYS for bi-layer materials, assuming Neo-Hookean constitutive laws to describe both layer behaviour under small deformation. The FE database chosen parameters are the upper layer thickness L , the total bilayer thickness H up to a clamped boundary conditions, and the Young's moduli stiffness ratio between the upper and lower layers.

Cyclic suction measurements on the forehead of a 26 yo healthy volunteer have been performed with aperture diameters from 6 to 25 mm.

The experimental suction data have then been analysed to extract the Pressure-tissue volume curves, normalized so that the results from each diameter can be compared to the others. The curve slopes dP/dS at a normalized volume of $S=0.05$ have been extracted and fitted with a model interpolated onto the database, letting the

identification procedure search the best fitting parameter H for a homogeneous soft tissue layer.

The total thickness of soft tissue above the forehead bone has also been estimated by ultrasound and is $H_{US}=2.89$ (Std of 0.2) mm.

3. Results dans discussion

The experimental apparent stiffness dP/dS increases significantly with the suction diameter, at a rate compatible with the soft tissue thickness measured by ultrasound H_{US} .

The optimal thickness value H_{sim} of the soft tissues identified by the model is of 3.0 mm with yet an unsatisfactory fitting for largest diameters (fig 1). The forehead of this subject appears as an almost homogeneous material which patient specific Young's Modulus is of 9.2 kPa.

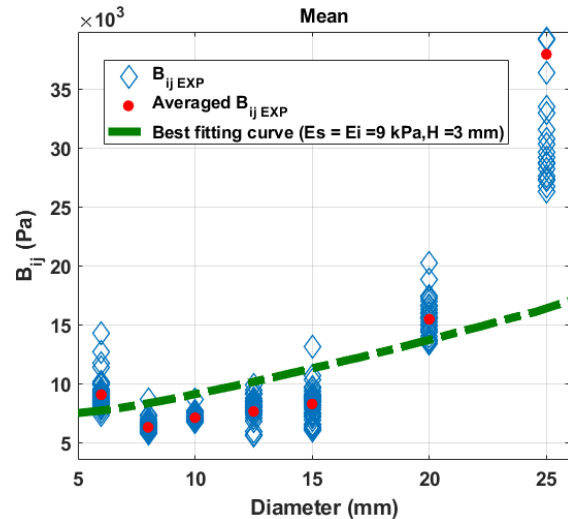


Fig 1. Normalized slopes dP/dS at shape $S=0.05$ for suction aperture diameter from 6 to 25 mm on a 26 yo female forehead and associated model identification.

5. References

1. Connesson N et al., Experimental Mechanics, 2023, 63(4), 715-742.