IN-VIVO BILAYER MATERIAL YOUNG MODULI IDENTIFICATION UNDER SMALL DEFORMATION USING ONLY SUCTION

Nathanael Connesson (1), Yohan Payan (1), Noemie Briot (1), Pierre-Alain Barraud (1)

1. Univ. Grenoble Alpes, CNRS, UMR 5525, VetAgro Sup, Grenoble INP, TIMC, 38000 Grenoble, France

Email: nathanael.connesson@univ-grenoble-alpes.fr

1. Introduction

In vivo, patient specific and non-invasive mechanical characterisation of biological soft tissue is challenging, even under moderate quasi-static loading and small deformations. Among other technical solutions, suction-based devices enable the acquisition of experimental data under relatively well controlled boundary and loading situations. However, (i) the usual aspiration head design constraints drastically limit the number of used aspiration aperture diameter [1], (ii) the underlying tissues are often assumed to be homogeneous during inverse identification, and (iii) inverse identifications usually imply time-consuming postprocessing that hinders any clinical application. An original suction system and method is implemented as a step toward dealing with these limitations.

2. Materials and Methods

An original suction system is proposed based on volume measurements [2], which enable extreme customisation of the suction aperture shape and diameter. Cyclic partial vacuum (repeatability) was applied under small deformation using 9 suction cups of aperture diameters ranging from 4 to 30 mm both on silicone reference phantoms (with different upper layer thicknesses) and *in vivo* on the abdominal tissue of a healthy volunteer. Each cup extract tissue mechanical behaviour information integrated over about one diameter depth [3]. The tissue in-depth heterogeneity thus differently affects the pressure-tissue volume curves depending on the suction diameter.

A cost function was built to minimize the squared distance between the 9 experimental pressure-tissue volume curves with their simulated counterparts assuming a bilayer structure (two Neo Hookean layers) defined by three main parameters: the upper and lower layer Young's Moduli and the upper layer thickness. A real time evaluation of the simulated pressure volume curves was implemented by interpolating a Finite Elements database so that these three parameters, including the upper layer thickness, minimizing the cost function were identified in less than one minute. The parameter identifiability was also evaluated.

The silicone reference mechanical properties were characterized during classical tensile tests. The silicone upper layers thicknesses were measured by annexe destructive measurement. The reference skin thickness of abdomen was measured using Bmode ultrasound imaging (natural contrast between the epidermis and fat).

3. Results

On a bilayer controlled silicone phantoms with superficial upper layer thickness of 3 mm, Young's moduli identified by suction and uniaxial tension presented a relative difference lower than 10%. Preliminary tests on in vivo abdomen tissue provided the skin and underlying adipose tissue Young's Moduli at 54±1 kPa and 4.8±0.1 kPa respectively. The skin upper thickness was of 2.21±0.033 mm using Bmode ultrasound and 2.15±0.05 mm using only suction data.

4. Discussion and Conclusions

The whole process results on controlled silicone phantoms were considered fully satisfactory. The identified Young moduli of skin and fat are in good accordance with literature data.

5. References

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