Characterization of mechanical properties of human dermis in vivo

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Characterization of Mechanical Properties of Human Dermis in vivo

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Introduction

Human skin is a complex tissue consisting of several distinct layers, each consisting of their own components and structure.

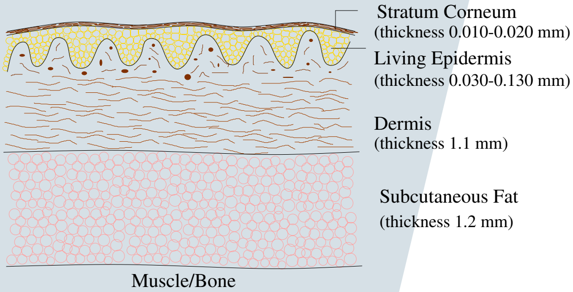

Figure 1 *Schematic view of cross-section of human skin, showing 4 layers (thicknesses for volar forearm).*

To gain a better insight into the overall skin behaviour during shaving, the mechanical behaviour of the different layers will be studied. This work is focussed at the dermis.

Objective

Development of numerical-experimental method to evaluate and simulate the mechanical properties of human dermis in vivo.

Material and methods

Suction measurements are performed at the volar forearm skin of 10 subjects. Deformations are measured with ultrasound. The experiment is simulated with a FEM model exhibiting extended (non-linear) Mooney material behaviour. An identification method which compares numerical and experimental results is used to identify the parameters of the material model.

Experimental Setup

A 20 MHz ultrasound system (DUB 20, TPM, Germany) is coupled to a pressure chamber with an aperture size of 6mm. The chamber is attached to the skin with double adhesive tape and filled with water. Application of an underpressure (suction) in the chamber with a syringe causes an uplift of the skin. Applied pressures are measured using a pressure sensor. Resulting displacements are obtained from the ultrasound images.

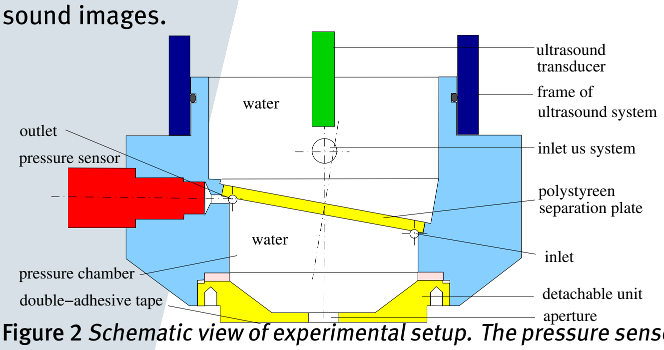

Figure 2 *Schematic view of experimental setup. The pressure sensor is located behind the water outlet.*

Results

26 mbar underpressure results in a fat thickness increase from 0.81 to 1.41 mm, dermal thickness is unchanged at 1.48 mm and the skin surface displacement is 0.55 mm.

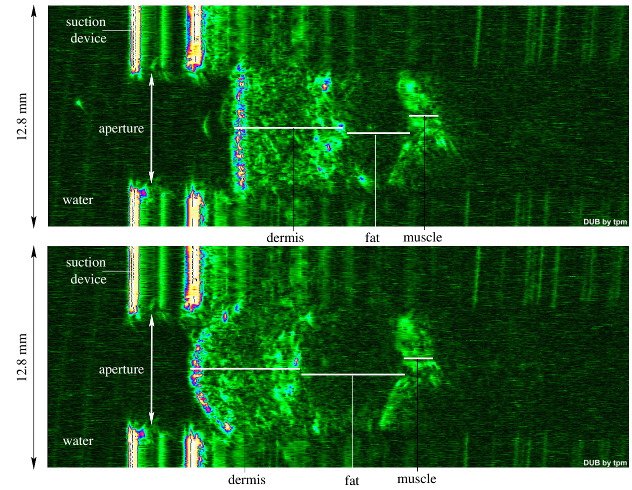

Figure 3 *Forearm skin and fat at atmospheric pressure (upper) and at 26 mbar underpressure (lower).*

Due to the ultrasound system's resolution (79 μm), the epidermis cannot be distinguished from the dermis.
Parameter identification for all subjects results in $C_{10} = 9.4 \pm 3.6$ kPa and $C_{11} = 82 \pm 60$ kPa.

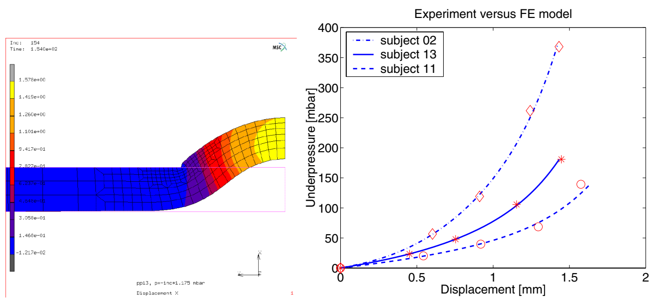

Figure 1 *Left: Enlarged part of axisymmetric FEM model showing x-displacements at 26 mbar suction for subject 13. Right: Experimentally obtained and simulated pressure-displacement curves for 3 subjects. Lines: simulation; symbols: experiments.*

Conclusions

The applied material model is able to describe the non-linear behaviour of the dermis. The obtained material parameters (for small strains) are consistent with results from earlier suction experiments where Young's moduli were obtained [1].

References:

[1] DIRIDOLLOU, S. *et al*: *In vivo model of the mechanical properties of the human skin under suction.* Skin Research and Technology, 2000:6:214-221.

[2] HENDRIKS, F.M. *et al*: *A numerical-experimental method to characterize the non-linear mechanical behaviour of human skin.* Submitted to Skin Research and Technology.

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