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AN ANISOTROPIC, VISCOELASTIC MODEL OF IN VIVO FACIAL SKIN

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INTRODUCTION

Accurate knowledge of the mechanical properties of facial skin can lead to better face models. These in turn can result in improved prediction of maxillofacial surgical outcome, enhanced artificial skin, and more realistic animations.

Flynn et al [1] conducted a series of tests where the facial skin of volunteers was subjected to a rich set of deformations. Briefly, a probe was attached to the facial skin and displaced in sixteen in-plane and out-of-plane directions. The reaction force on the probe was recorded for each displacement cycle. A finite element model simulated the experiment.

One shortcoming of the model was the use of the Ogden constitutive law to represent skin. Therefore, the material anisotropy characteristic of skin was ignored. It is hypothesised that using an anisotropic constitutive law will improve the fit between the model results and the experiment results.

The objective of the present work is to model the facial skin experiments of [1] using an anisotropic constitutive law to represent skin.

METHODS

A finite element model developed in FEBio [2] was used to simulate the *in vivo* facial skin experiments of Flynn et al. [1]. The model consisted of a single layer of shell elements.

The anisotropic Gasser et al. constitutive equation [3] represented the skin. Fibres were parallel to the skin surface and aligned along two directions ±θ to the x-axis [4], where the x-axis is specified in Figure 1. Similar to [1], a quasi-linear viscoelastic (QLV) model characterised the time–dependent properties of skin. To represent the *in vivo* tension, we applied a pre-stress to the model prior to simulating the full set of probe displacements. The reaction force due to the displaced probe was calculated.

The Matlab (The MathWorks, Inc., Natick, MA, USA) optimisation routine *fminsearchbnd* found the model parameters and *in vivo* tension that best fit the model reaction forces to the measured experimental reaction forces.

RESULTS AND DISCUSSION

The finite element model simulated the response of the facial skin under a rich set of deformations (two of the sixteen deformations tested are shown in Figure 1). Optimised sets of volunteer-specific material parameters and *in vivo* tensions were determined. The error between model and the experiment for the central cheek of one volunteer was 13% (Table 1). This compares to an error of 21% when using the isotropic Ogden law [1].

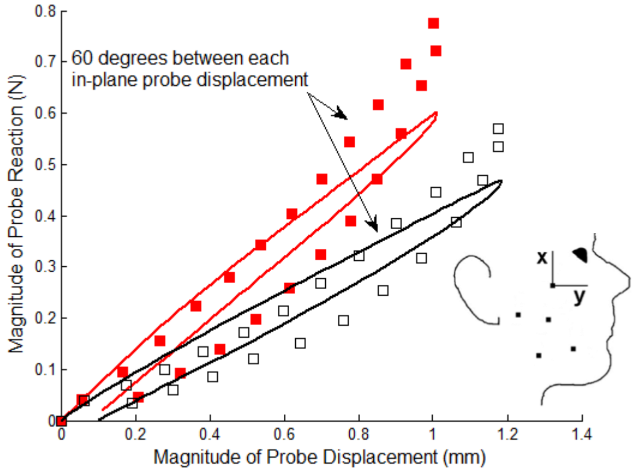

Figure 1: Experimental and model force–displacement response of zygomatic area. Symbols – experiment; lines – model. Inset shows facial test points and axes definition.

CONCLUSIONS

Using the Gasser et al [3] anisotropic material model results in an improved *in vivo* facial skin model (13% error) compared to using an isotropic material model (21% Error) [1]. Future work includes representation of subcutaneous tissues and sub-dermal attachments.

REFERENCES

[1] Flynn C et al. *J Mech Behav Biomed Mater,* **28**: 484-494, 2013.

[2] Mass S et al.*J Biomech Eng,* **134**: 011005, 2012.

[3] Gasser T et al. *J R Soc Interface,* **3**: 15-35, 2006.

[4] Ni Annaidh A et al. *Ann Biomed Eng,* **40**: 1666-1678, 2012.

Table 1: Optimised material (μ, k_1, k_2)and *in vivo* tension (σ_x, σ_y) parameters to fit a specific volunteer's deformation data from the central right cheek. The QLV parameters were set to $\bar{g}_1^p = 0.8$ and $\tau_1^G = 0.4$s

Constitutive Law [3]	μ (kPa)	k_1 (kPa)	k_2	θ (°)	σ_x (kPa)	σ_y (kPa)	Error (%)
$W = \mu/2\,(I_1 - 1) + k_1/k_2\,\{e^{k_2(I_n-1)^2} - 1\}$	3.65	66.78	0.26	41	31.20	23.67	13