Studying the Effects of Facial Muscles Activations to Investigate the Optimum Positioning of Subcutaneous Suspension Sutures

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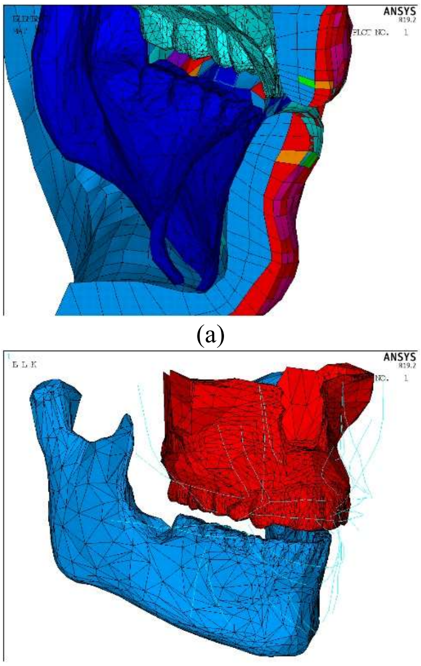
1. Introduction

Subcutaneous biodegradable sutures are used to produce lifting effects on face and neck (Few et al. 2020). The benefit of these sutures lies in their minimally invasive insertion by a clinician. The suture material (Poly-L-Lactic Acid) stimulates the collagen fibre generation around the suture path. These collagen fibres will build up during the degradation period of the suture material (around three months). One of the challenging aspects of suture insertion is suture positioning: for an optimal collagen fibre generation, the suture should move as little as possible. One of the main sources of suture movement is facial deformations induced by muscle contractions. In order to investigate these deformations, an "atlas" face model (Nazari, et al., 2010) has been morphed to match the face of an elderly person. Using the three-dimensional muscle modelling developed by Nazari et al. (2013) the effect of different muscle activations (single or multiple) on the face deformations can be simulated. We have used this approach to identify the locations that are appropriate for suture insertions.

2. Methods

2.1 FE Model

The finite element of the face model, developped in the ANSYS software environment, consists of three layers totalling of 6342 hexahedral linear elements (with 8720 nodes). The outer layer corresponds to the dermis layer and the two other sublayers up to bony structure represent the hypodermis tissue of the face (Fig. 1a). On the outer surface a thin membrane layer (0.1mm thick) has been added to account for the epidermis layer. The material properties of the dermis and hypodermis layer are modelled with a Yeoh 2nd order model. Since skin stiffens exponentially when stretch ratio exceeds a limiting value, a Gent material, which well accounts for this behaviour, has been used. The material parameters of these layers are given in Table 1. The inner surface of the deepest face layer is in contact with mandible and maxilla. Contacts between upper and lower lip have also been modelled. Global muscle fibre directions have been defined (Fig. 1b) in order to generate muscle elements around these directions. These muscle elements also include an active material part based on a Hill-Type model to generate forces.



(b)

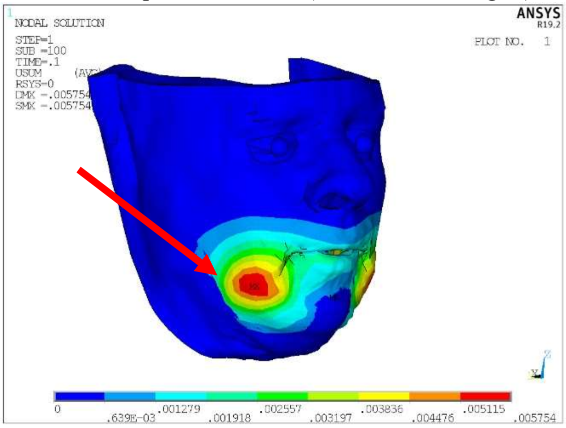
Figure 1. (a) Cross section of the face model (b) the muscle directions (in cyan color)

Skin Layer	Model	$C_{10}\ (Pa)$	$C_{20}\ (Pa)$	$d_1\ (kPa^{-1})$	$d_2\ (kPa^{-1})$
Hypodermis	Yeoh	400	1400	50	50
Dermis	Yeoh	4000	14000	50	50
		$\mu\ (Pa)$	j_m	$d\ (kPa^{-1})$	
Epidermis	Gent	4000	1.2	50	

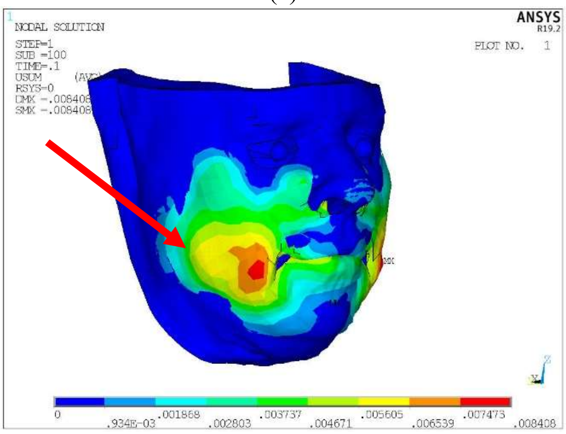
Table Coefficients of the Hyperelastic Models

3. Results and discussion

As shown by the EMG study of Root & Stephens (2003) the natural use of facial muscles in daily life shows co-activation patterns, sometimes due to common synaptic drives. Figure 2a displays the face deformation in the lip corner region, which is very frequently the object of cosmetic treatments, due to the co-activation of muscles. In this work though, which focuses on muscles' influences on facial deformation, it is also interesting to study single muscle activation, since it can induce larger and/or localized deformations with stronger possible impacts on inserted sutures. Fig. 2b displays such a strong effect of a single muscle activation in the lip corner region. It provides a good estimation of the pattern of maximal face deformations in this region. Such a pattern can be used by clinicians to determine the suited place for suture insertion, which will efficiently reshape the face while reducing the impact of muscle activations on suture mobility. Since the displacement damps very fast, the best strategy should be to position the extremity of the suture just at the boundaries of the maximum displacement area (red arrows on Fig. 2):



(a)



(b)

Figure 2 Displacement contours due to (a) the co-contraction of the Depressor and Levator facial muscles (max displacement 6mm) (b) the activation of Depressor Muscle only (Max displacement 8mm)

4. Conclusions

Lifting sutures are often used to compensate for tissue deformations induced by recurrent and strong muscle activation, as for example in the lip corner region affected by smiling, wincing and speaking. Our modelling based approach enables to determine in a subject-specific manner the distribution of the deformations in the regions of interest, in order to find a location for the insertion of the suture which preserves the efficiency of the lifting while reducing the strength of the deformation that the suture undergoes due to natural muscle activations. Our results suggest that it is thus possible to avoid the region of the maximum displacement in the face by positioning the extremities of the suture just at the boundaries of this region. This action boosts the final purpose of these sutures which relies on the best possible collagen fibre generation. Doing so minimizes the suture mobility during daily facial movements and should provide the best possible effect. A weakness of the model though is the absence of a model for the neck and the platysma muscle. This feature is under development.

Acknowledgments

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References

Few, J.W., Vachon, G., Pintas, S. and Smith, J.R., 2020. Nonsurgical Tissue Repositioning: Analysis of Long-Term Results and Patient Satisfaction From 100 Absorbable Suture Suspension Cases, Aesthetic Surgery Journal Open Forum. 2 (1): 1-13.

Nazari MA, Perrier P, Chabanas M, Payan Y. 2010. Simulation of dynamic orofacial movements using a constitutive law varying with muscle activation, *Comput. Methods Biomech. Biomed. Eng.*, 13(4): 469 – 482.

Nazari, M.A., Perrier, P. and Payan, Y., 2013. The Distributed Lambda (λ) Model (DLM): A 3-D, Finite-Element Muscle Model Based on Feldman's λ Model; Assessment of Orofacial Gestures. *Journal of speech, language, and hearing research*.

Root, A.A. and Stephens, J.A., 2003. Organization of the central control of muscles of facial expression in man. *The Journal of physiology*, *549*(1), pp.289-298

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