Measurements of the linear elastic properties of the face soft tissues using an aspiration device

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Abstract: Maxillo-facial surgeries have a direct impact on the face shape and appearance. The anatomical variations in the face soft tissues (skin thickness, skin or muscle material parameters…) make it hard to predict the face final shape accurately. Biomechanical modeling could help in this prediction by simulating the soft tissue displacement following the bone remodeling and therefore the patient's face visible outcome [1]. Measuring the variation of the skin properties across a range of subjects could help to build accurate patient-specific biomechanical simulations. In [2], the skin initial Young's modulus was evaluated to 22.8 kPa using a Mooney Rivlin model and measurements on different locations on the face of one subject. In this study, a specifically designed aspiration device, called LASTIC (Light Aspiration device for in vivo Soft TIssue Characterization), is used to characterize the elastic modulus of the face soft tissues at four different locations (cheek, cheekbone, forehead, and lower lip) on 16 subjects. LASTIC is sterilizable and could therefore be used in the operating room. It is a two-compartment 33 mm x 34 mm metal cylinder using the aspiration technique to estimate the elastic modulus [3]. The bottom compartment is an airtight chamber, opened at the bottom by a 12 mm diameter circular aperture lying on the soft tissues where a negative pressure can be applied to aspirate the tissues. The upper compartment holds a miniature digital camera which images the height of the deformation resulting from the aspiration. Measuring the deformation height corresponding to several steps of increasing negative pressures leads to an estimation of the behavior of the tissues using an inverse analysis based on a Neo Hookean model. To study the possible variations between subjects, LASTIC was used to estimate the elastic moduli of 16 healthy subjects, eight males and eight females, of different ages and body mass indexes (mean age = 29.2±6.3, mean BMI = 21.5±2.1). The initial Young's modulus of the cheek, cheekbone, forehead, and lower lip are respectively estimated to be in the range [31 kPa: 42kPa]. Significant intra-subject differences in tissue stiffnesses between the cheek and forehead and between the lower lip and forehead are highlighted by these estimations, and can be explained by the tissue thickness. They also show important inter-subject variabilities for some locations even when mean value stiffness show no statistical difference. This study stresses the importance of using a measurement device capable of evaluating the patient-specific tissue elastic moduli before and during an intervention in order to improve the accuracy of a surgery outcome.

References

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