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Evaluation of the exophthalmia reduction with a finite element model

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1. Introduction

The exophthalmia is a pathology defined by an excessive forward protrusion of the ocular globe [1]. For disthyroidy exophthalmia, a surgery is usually needed, once the endocrinal situation has been stabilized. A classical surgical technique consists in decompressing the orbit [2] by opening the walls, and pushing the ocular globe in order to evacuate some of the fat tissues inside the sinuses. This work aims at proposing a biomechanical model of the complete orbit in order to help the clinician in the definition of his surgical planning.

2. Methods

In order to provide a precise and patient-specific modelling, our method is based on:

(1) A generic biomechanical model manually elaborated: CT data are used for the extraction of the orbital cavity, fat tissues, ocular muscles and nerve. From this segmentation, a volumetric mesh is manually built and a Finite Element (FE) poro-elastic model is introduced to model the orbital soft tissues. The simulation of the wall orbit osteotomy and of the pressure applied to the globe, is modelled with specific boundary conditions: nodes located in the osteotomy hole region are fixed, while pressure forces are applied to the nodes that are in contact with the ocular globe.

(2) Patient data acquisition, through segmentation of CT images.

(3) Local elastic deformations of the generic FE mesh to fit each patient morphology. The Mesh Matching algorithm [3] is used to automatically generate patient FE models.

3. Results

This study aims to assist the surgical planning by estimating (1) the influence of the hole size and location onto the backward globe displacement, and (2) the mechanical behavior of orbital soft tissues, especially in the hole region. Four FE models corresponding to four patients geometries were generated. For each patient, four different holes were simulated, assuming two locations and two sizes for the degree of osteotomy. Our simulations provided heterogeneous results: (1) for the same hole size, different levels of globe backward displacement are observed depending on the location of the hole, and (2) for a given hole size and location, different globe backward displacements and different soft tissues volumes evacuated through the hole are observed according to patient geometries.

References

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