AUTOMATIC ORTHOGNATHIC SURGERY PROCESS: FROM MESH GENERATION TO FINITE ELEMENT SIMULATION OF BONE CUTS

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Introduction

Our group works on biomechanical modeling of the human face, with the main objectives of surgical assistance and speech production modeling. In this project, we plan to predict the aesthetic and functional results of bone repositioning in maxillofacial surgery. Some commercial solutions already incorporate modeling approaches to predict facial soft-tissue deformations following bone repositioning. However, in the clinical setting, these modeling solutions are not much used, due for some of them to an insufficiently realistic account. Our work aims to address this limitation, by (1) automatically generating a patient-specific biomechanical face model, focusing on the accuracy of the geometry of the Finite Element (FE) mesh, which includes both bone and soft tissue (skin, hypodermis, muscles) and (2) numerically simulating bone repositioning using Ansys® APDL software.

Materials and Methods

A FE mesh of the face was accurately designed for a male subject who does not suffer from any disorder in the orofacial region. This subject is called “reference” subject henceforth. The mesh, which is adapted from a former model (Nazari et al., 2010), includes an account of the maxilla and the mandible, represented by shell elements, together with the soft tissues, which are heterogeneous due to a multilayer structure that describes hypodermis, skin and muscles, represented by tetrahedral elements. Bone structures follow a linear and isotropic elastic behavior, while soft tissues are modeled with a hyperelastic Yeoh constitutive law of order 2 (Barbarino et al., 2009). Muscles apply stress to the mesh along an automatically calculated fiber direction.
A procedure was set up to automatically generate:

- Patient's FE meshes, using the Elastix library (*elastix.lumc.nl*) to register the CT-scan of the reference subject with that of each patient, preserving geometries, soft tissues and bones, as well as muscles’ implementation and fiber directions.
- Boundary conditions including fixed nodes to prevent rigid solid displacement, and contacts between soft tissue and bones, as well as at the lip junction.

To simulate bone cutting and repositioning during orthognathic surgery, meshes are automatically cut using CamiTK software (*camitk.imag.fr*) as specified by the surgeon. Bone displacements are then simulated using displacement of boundary conditions on Ansys APDL software.

Results

In figure 1, the patient's preoperative FE mesh is shown on the left, while on the right, the results of soft tissue deformations following mandibular advancement are plotted (Bilateral Sagittal Division Osteotomy (BSSO)). The lips tend to close as the mandible moves forward.

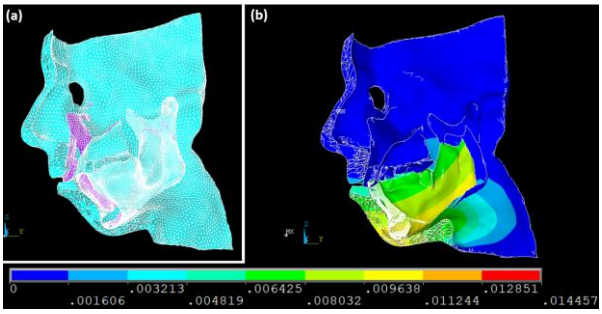

Figure 1: (a) Half FE mesh of the preoperative patient, including mandible, maxilla and soft tissues, (b) Facial changes after BSSO (displacements in meters).

Discussion and Conclusions

We have set up a full automatic process from the generation of the patient's FE model to the simulation of orthognathic surgery. The next step in this project will concern a quantitative comparison of the simulations provided by the model with the surgical outcome.

References

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