Biomechanical model of the human face with a perspective of surgical assistance

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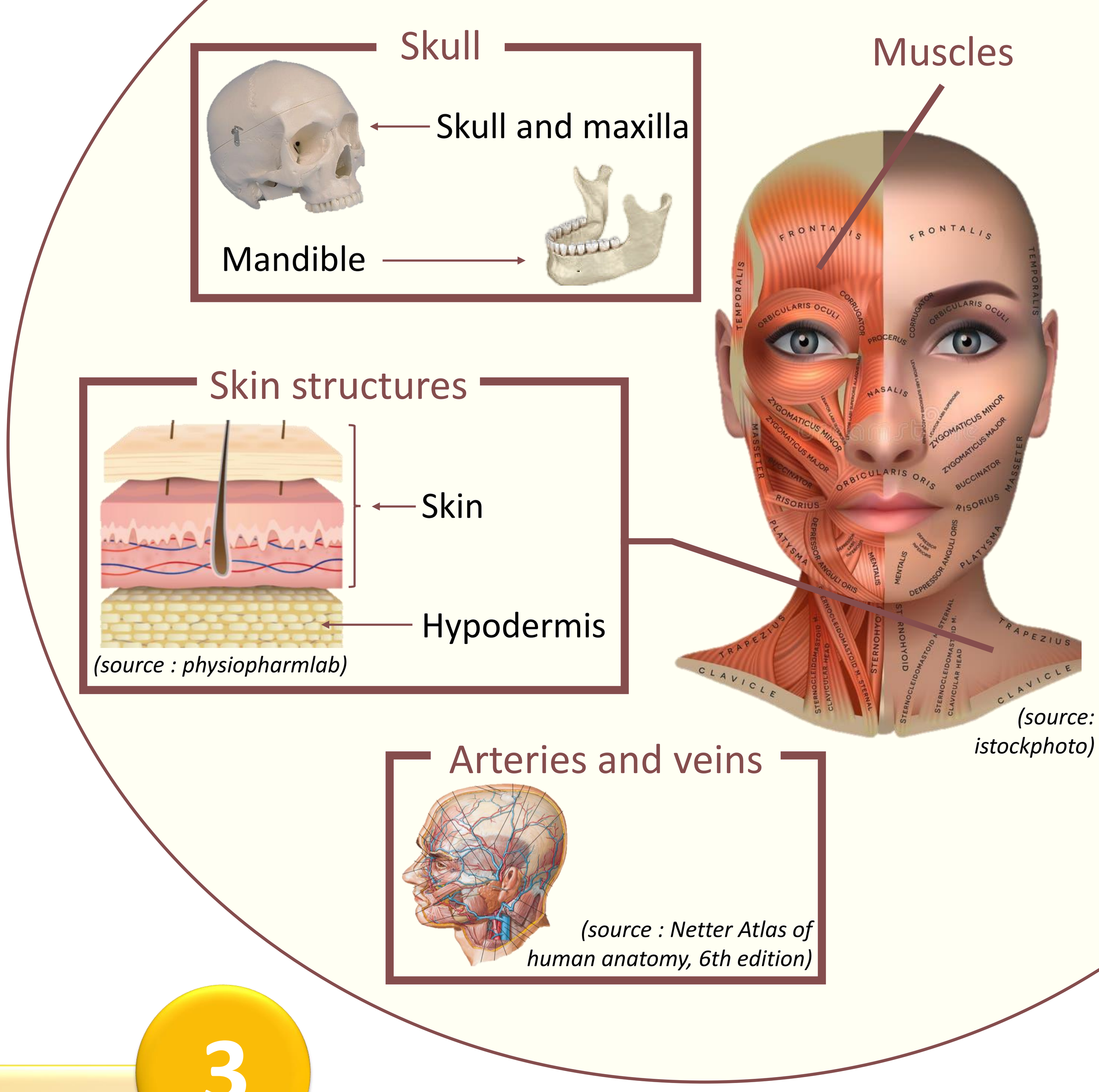
The human face



Context

- Orthognathic surgery aims to correct facial dysmorphoses by performing bony osteotomies.
- Commercial products propose modeling options for predicting passive face tissue deformations after bone repositioning, but these options are currently not used by surgeons who consider them as not sufficiently realistic.

Research goals

- Predict the aesthetic and functional consequences of bone repositioning in the context of maxillofacial surgery.
- Design a patient-specific face model including soft tissues, bones (maxilla and mandible) and muscles.

Methods

1 3D geometries extracted from CT-scan

- Soft tissues
- Bones: mandible and maxilla

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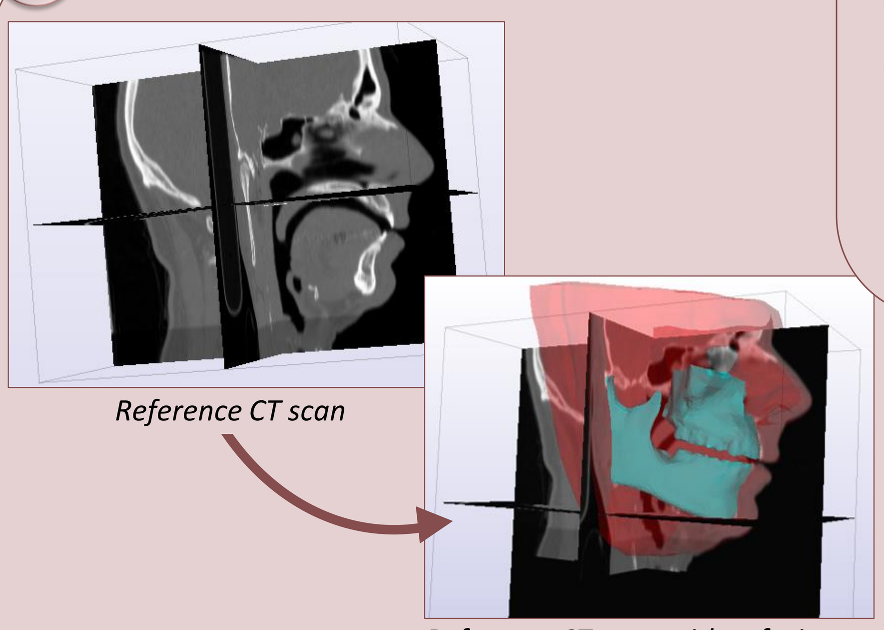


Reference CT scan

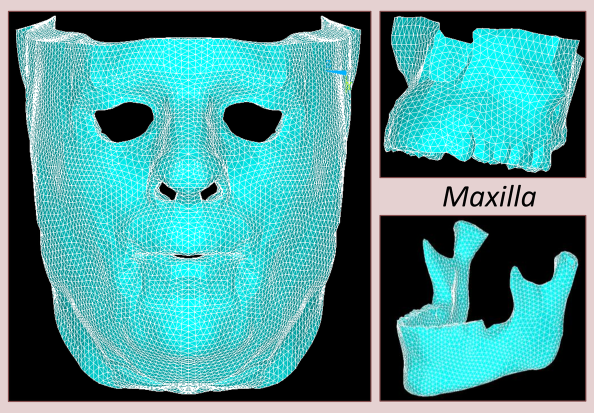
Reference CT-scan with soft tissues (red) and bones (blue) geometries

2 The Finite Element (FE) model

Meshing:
- **Soft tissues**: Tetrahedral (hypodermis) and shell (skin) elements
- **Bones**: Shell elements

2 FE meshes

Mesh convergence was performed to determine the size of the elements to be imposed on the model

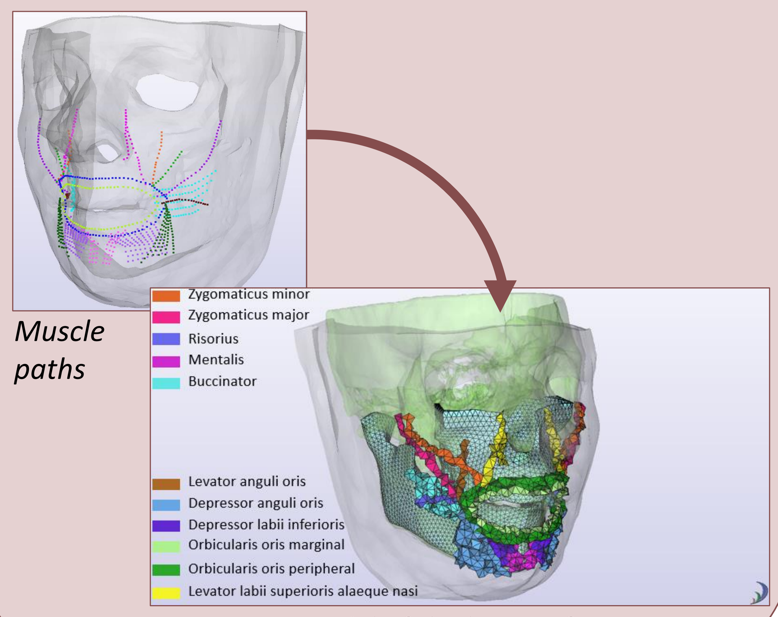


Face mesh (skin and hypodermis) — *Maxilla* — *Mandible*

3 Boundary conditions

1. Muscle paths definition
2. Automatic selection of elements and assignment of muscle fiber directions
3. Contact:
   - Bone/Soft tissues
   - Soft tissues/Softs tissues (lips)
4. Imposed displacements

3 Muscles definition



Muscle paths

Model of the human face

4 Material parameters from tensile tests

4 *Ex vivo* experimental tensile tests

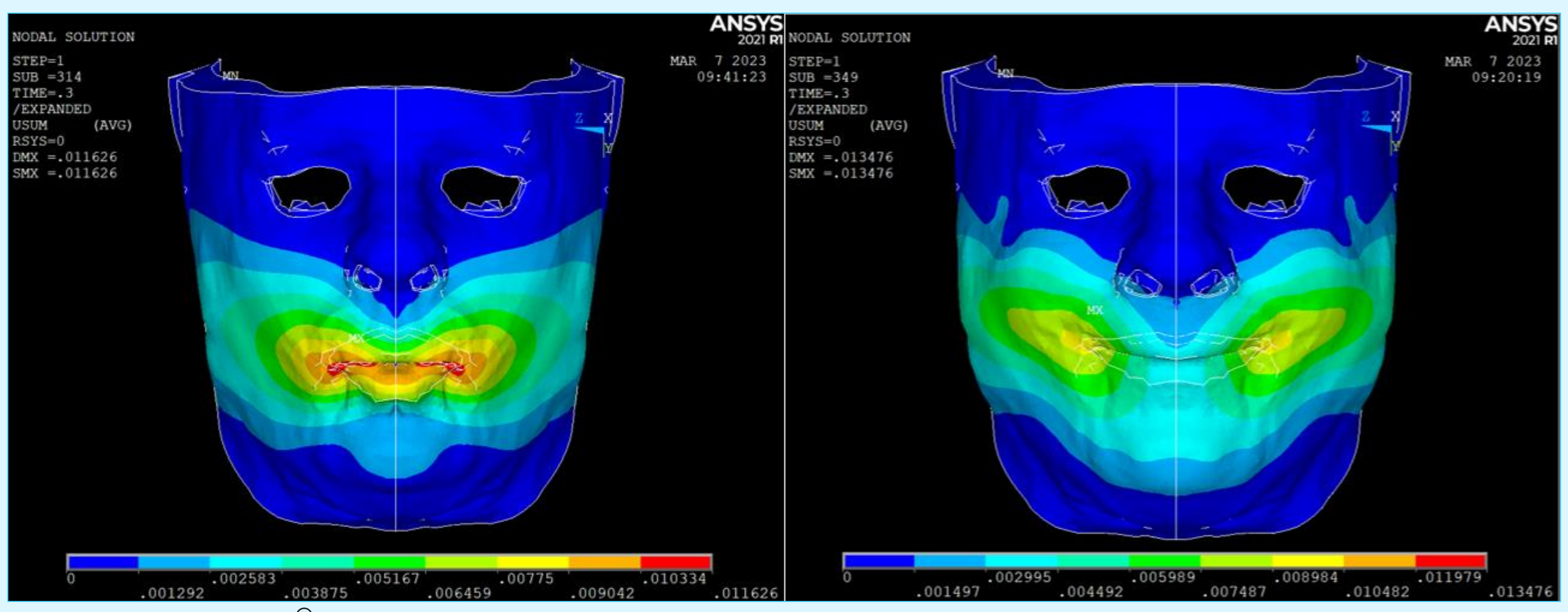
- The dissection of the fresh cadaver head occurred 36 hours after death.
- The samples :
  - Skin and hypodermis tissues
  - Zygomatic and masseter muscles

Skin tensile test

Results

1 Face deformations from muscles activation

Facial deformations observed after activation of the peripheral orbicularis oris (OOP, left), and the zygomaticus (ZYG, right). These deformations are consistent with the expected functions of these muscles, namely lip closure and protrusion by OOP, and a smile induced by ZYG *(Nazari et al. 2010)*

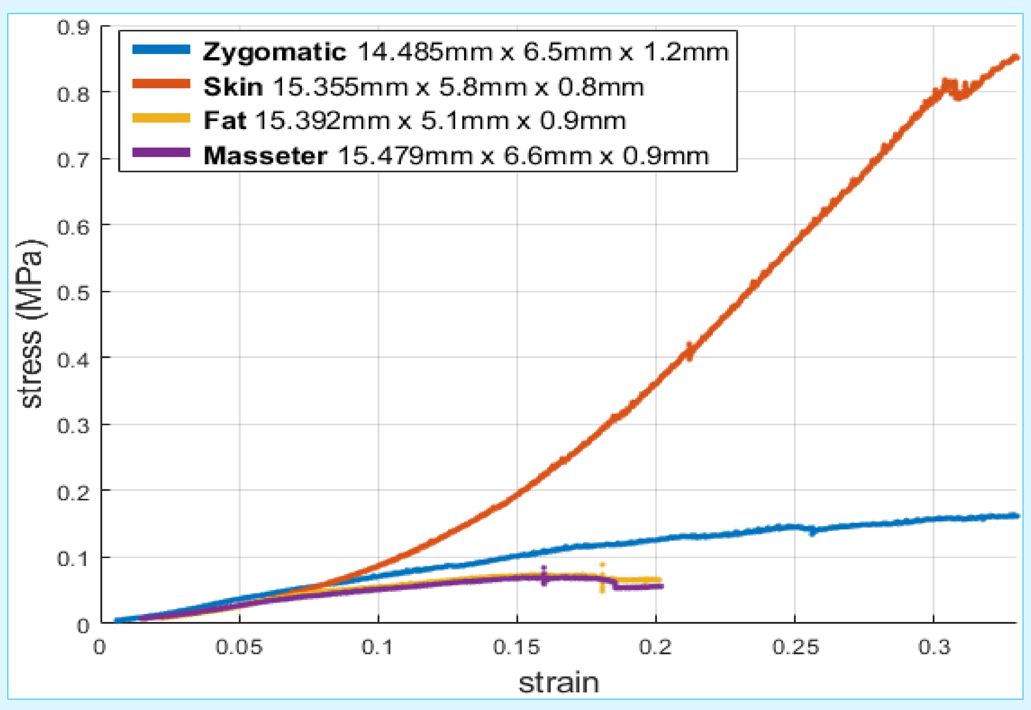


Simulations with ANSYS® software (material parameters of Barbarino et al. 2009)

2 Experimental tensile tests

Nominal stress-strain curves recorded for four tissue samples (skin, fat, zygomatic and masseter muscles), with a 10%/min strain rate.

As expected, *(Barbarino et al. 2009)*, skin appears stiffer in tension than fat and muscles.



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Perspectives

- Generating a patient-specific FE face models from our reference FE model using non-rigid image-based registration technique *(Bijar et al. 2016)*
- Evaluating differences between constitutive parameters measured on cadavers versus living tissues (using elastography and aspiration method, Connesson *et al. 2023*)