Comparison of different soft tissue modeling methods with post-operative CT scan in maxillofacial surgery

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Abstract :
A comparison between different soft tissue modeling methods is proposed in the context of the simulation of the morphological outcomes of maxillofacial surgery.

The face soft tissues are modeled using two different approaches: Finite-Element Method (FEM) and Discrete Particle Method (DPM). For the FEM approach, three hypothesis are compared: a linear elastic model with small and large deformation hypothesis, and an hyperelastic Mooney-Rivlin model. For the DPM approach, two models are considered: a simple mass-spring network and a more sophisticated physically-based particle system. This last model improves the classical mass-spring network method by guarantying the tissue incompressibility and by offering a better numerical stability.

An evaluation procedure based on a qualitative and quantitative comparison of the simulations with a post-operative CT scan is proposed. A patient specific facial mesh is built from pre-operative CT scan including the inner nodes (attached to the bones) and the outer nodes (modeling the skin surface). All methods use this same initial mesh. The rheological parameters are either extracted from experimental measurements or are those classically used in the literature. Boundary conditions are extracted from the pre- and post-operative CT scans and used by all methods as imposed bone displacements (inner nodes). The resulting facial surfaces (outer nodes) obtained by the different methods are evaluated relatively to one real clinical post-operative surface (also segmented from the CT scan).

Performance comparisons focus on accuracy, realism, simulation time and prediction in comparison with the real data. Clinically, the simulations are of good quality and quite coherent with the actual outcome of the surgery. The results of this study allows us to determine which types of methods are appropriate for a given patient, operative mode and medical situation (e.g. pre-operative or per-operative computer assisted medical interventions).