TOWARDS THE CREATION OF FE PATIENT-SPECIFIC BIOMECHANICAL MODELS

Noelia Garijo (1), Steven Walscharts (2), José Manuel García-Aznar (1), Mª Ángeles Pérez (1), Lara Vigneron (3), G. Harry van Lenthe (2), Jos Vander Sloten (2)

1. Multiscale in Mechanical and Biological Engineering (M2BE) - Aragón Institute of Engineering Research (I3A), University of Zaragoza, Spain; 2. Biomechanics section, KU Leuven, Leuven, Belgium; 3. Biomedical engineering department, Materialise NV, Leuven, Belgium;

Introduction

Patient-specific finite element models (FEM) are standard tools for the analysis of the biomechanical behaviour of human bones. Specifically, bone remodeling simulations seek to predict bone density patterns. These simulations mainly use computerized tomography (CT) images, which provide fairly accurate quantitative information on bone geometry, and are validated by comparing the predicted mechanical properties of bone tissues with the CT-based material properties (Garcia-Aznar et al., 2005). Although these simulations are based on patient-specific geometry of the bones, additional density variations can be found between individuals that are due to physiological differences. Another aspect very relevant for the creation of patient-specific models is thus the determination of the specific load that the bone is really supporting. Therefore, the main objective of this work is to perform a multidisciplinary research to develop patient specific simulations integrating, musculoskeletal loading and simulation of adaptive bone remodeling to simulate functional outcome of patient treatments. Specifically, it is to combine the bone remodeling scheme with a subject-specific musculoskeletal model for estimating the loads, and to determine the model parameters.

Methods

CT data were segmented using Mimics (Materialise NV) with a remodeling model to predict the bone density distribution of certain human bones. We used this geometry for muscle attachment regions and forces will be identified through musculoskeletal modelling methodology developed. In this methodology, contact forces on the surface were chosen pointing towards the hip joint center, with amplitudes proportional to the projected vertex surface area, diminishing in amplitude away from a pole. The magnitude and location of this pole was determined iteratively starting from the direction of the total contact force until the required total contact force was acquired. It was found a level of uncertainty in the estimation of these loads and boundary conditions that it has been solved with the bone remodelling algorithms. Finally, it has been compare the simulated result with the bone density estimate from CT.

Results

Different specific musculoskeletal model parameters were varied and the resulting bone density distributions were compared with CT data (Figure 1).

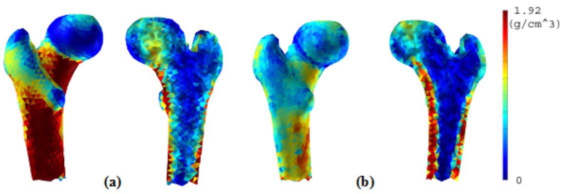

Figure 1: Bone density results (a) for the specific musculoskeletal model and (b) HU obtained from the CT scanning.

Discussion

Good agreement was obtained (qualitatively and quantitatively) between approaches. The average apparent density, derived from the CT-image, was 636 kg/m³ while the simulation results showed an average density of 657 kg/m³. Then, the combination of both methodologies allow evaluating if the loads and boundary conditions estimated are able to reproduce a realistic bone density distribution.

Acknowledgements

The authors acknowledge the support through the CAD-BONE project 286179 of the European Commission and the Spanish Ministry of Science and Technology through research project DPI2011-22413.

References

García-Aznar et al, Biomech Model Mechanobiol, 4: 147-67.