PATIENT-SPECIFIC SIMULATION OF THE HUMAN RADIUS

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Introduction

Patient-specific finite element models (FEM) are standard tools for the analysis of the biomechanical behaviour of human bones. Patient-specific simulations mainly used computerized tomography (CT) images which may provide fairly accurate quantitative information on bone geometry that can be related to the mechanical properties of bone tissues. However, they greatly simplify the complex behaviour of bone. On the other hand, bone remodelling models have been extensively used providing important structural information, for example, bone anisotropy. The main goal of this study is to present both approaches, patient-specific FE modeling by CT data combined with a remodeling model to predict the bone density distribution of the human radius. A quantitative comparison computed from CT data against the one predicted by the bone remodeling model was also performed.

Methods

The human radius was scanned using a 64 slice multi-detector CT scanner (Philips Healthcare, The Netherlands) and the images used to reconstruct the joint geometry (Mimics). Then, the FE mesh and the analyses were performed in Abaqus v.6.9. (Fig. 1a). On the one hand, the FE mesh was imported into Mimics again and different material properties were assigned relating the bone mineral density with the Hounsfield Units (HU) (Fig. 1b) [Peng et al., 2007]. On the other hand, an anisotropic bone remodeling model [Perez et al., 2010] was used to predict the density distribution through the application of the corresponding loads and boundary conditions [Anderson et al., 2005]. Finally, a comparison between both approaches was computed.

Results

The cortical region in the radius and its corresponding trabecular area were qualitatively predicted (Fig. 1.c). The density obtained from the HU values was compared with the one predicted by the bone remodeling analysis and the relative error represented (Fig. 2a). The bone volume percentage over a certain error level was also computed for four density ranges (Fig. 2b). Low error in the predictions was found at the cortical regions. A higher error was obtained when the bone density decreased. The cortical bone region ($1.6 \leq \rho < 2.0$) is accurately predicted by the bone remodeling model.

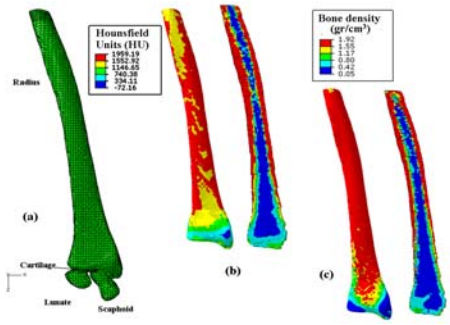

Figure 1:(a)FE mesh;(b) HU obtained from the CT scanning; (c)bone density distribution predicted using remodelling bone.

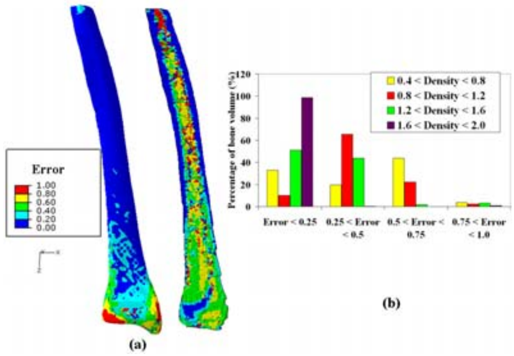

Figure 2: (a) Error computed between the CT data and bone remodeling prediction; (b) Percentage of bone volume with a certain error.

Discussion

A comparison between CT data and numerical predictions was performed. Good agreement was obtained (qualitatively and quantitatively). Despite, the limitations of the methodology we can summarize that bone remodeling models in combination with CT data are useful tools when the goal of the study needs to incorporate the complex behaviour of bone physiology (anisotropy, osteoporotic tissue, etc.).

References

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Acknowledgements:

The authors acknowledge the support through the Research project DPI2011-22413.