7th World Congress of Biomechanics

BONE REMODELING SIMULATIONS: CHALLENGES, PROBLEMS AND APPLICATIONS

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Bone remodeling is the mechanism that regulates the relationship between bone morphology and its external mechanical loads. It is based on the fact that bone adapts itself to the mechanical conditions to which it is exposed. Several mechanical and biochemical factors may regulate the final bone remodelling response [1]. In fact, bone remodeling is hypothesized to achieve several mechanical objectives: repair damage to reduce the risk of fracture and optimize stiffness and strength with minimum weight. During recent decades, a great number of numerically implemented mathematical laws have been proposed, but most of them present different problems as stability, convergence or dependence of the initial conditions. Several works have studied these issues trying to overcome the numerical problems. In [1] it was hypothesized that the reference homeostatic stimulus is not constant, but it is locally dependent on the loading history that each local point is effectively supporting. As a direct consequence of this assumption, we demonstrate that the numerical instabilities that all these algorithms normally present can be solved, clearly improving the final results. This contribution improves the convergence of the solution, leading to its numerical stability in the long-term. However, it is worth noting that the initial conditions still remain an influential factor in these models.

Additionally, it must be stressed that these numerical models are not really affordable for the simulation of realistic bone remodelling. One of the most challenges facing the computer simulation is to solve realistic conditions. It needs to get adapted to patient specific models, i.e., applying computer models in the evolution of bone density for studying the most suitable prosthesis for each particular patient. Moreover, these models can be combined with other mathematical techniques as neural networks, extrapolation techniques that can reduce the computational cost for obtaining the best solution for each case. Finally, we remark that these computational models should be considered as a predicting tool which helps to estimate individual loads, to design prosthesis for each patient and to simulate which is the behaviour.

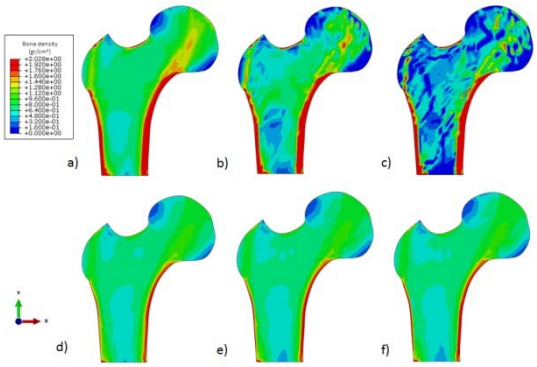

Figure 1: The density distribution resulting from a bone remodeling simulation carried out using bone remodeling simulations for (a) 300 days, (b) 1000 days, and (c) 4000 days; and the modified model for (d) 300 days, (e) 1000 days and (f) 4000 days.

N. Garijo, J.R. Fernández, M.A. Pérez, J.M. García-Aznar, Numerical Stability and Convergence Analysis of Bone Remodeling Model, Computer Methods in Applied Mechanics and Engineering, ISSN 0045-7825, http://dx.doi.org/10.1016/j.cma.2013.12.014.

Acknowledgements
The research leading to these results has received funding from the (European Commission) Seventh Framework Programme (FP7/2007–2013) under grant agreement n286179 and the Spanish Ministry of Economy and Competitiveness through research project DPI 2011–22413