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A MECHANOBIOLOGICAL MODEL FOR BONE INGROWTH ON DENTAL IMPLANTS

***Pedro Moreo, José Manuel García-Aznar and Manuel Doblaré**

University of Zaragoza. Group of Structural
Mechanics and Materials Modelling
María de Luna 7, 50018 Zaragoza, Spain
{pmoreo,jmgaraz,mdoblare}@unizar.es
http://gemm.unizar.es

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ABSTRACT

Dental implantology is an increasingly treatment modality due to its convincing data of long-term clinical success rates. However, this very success has led to the use of implants in more challenging situations, usually involving the insertion of implants in abnormal positions or their almost immediate loading after placement. Therefore, continuing refinements in implant design are still needed and mathematical modelling can be a useful tool for this purpose.

Some phenomenological models have been proposed for the study of the osseointegration of bone implants (see [1] and references therein). These models, however, neglect the underlying biological phenomena taking place at the interface and therefore are not able to reproduce some important features of peri-implant bone healing. In particular, the crucial influence of the surface microtopography and the typology of the host bone on the process of osteogenesis [2] cannot be studied with such phenomenological models.

Hence the goal of this contribution, that is to propose a new mechanobiological model for the study of bone ingrowth on bone implants that, by means of considering the main biological interactions occurring at the surface of implants, is able to reproduce the above mentioned biological features of the osseointegration phenomenon.

Formally, the mathematical model is composed of a set of reaction-diffusion equations describing the evolution of the concentration of cells and growth factors coupled with the equation of balance of linear momentum for the matrix. Three types of cells, platelets, osteoprogenitor cells and osteoblasts, and two generic growth factors have been considered in the model. The main interactions between them are depicted in Fig. 1-(a). The influence of the mechanical state of the matrix on the behaviour of cells has also been taken into account and the reader is referred to [3] for more details.

Numerical solutions for this mathematical model in different geometries have been obtained by use of the finite element method. Specifically, simulations of the osteogenic process for different surface finishes have been performed and some results are shown in Fig. 1-(b) and (c). As it is known from the experiments [2] and reproduced by our model, a high surface microtopography tends to favour contact osteogenesis (bone forms first on the implant surface and from them growths towards the rest of the peri-implant site) whereas polished surfaces lead to distance osteogenesis (new bone forms first on the surface of old bone).

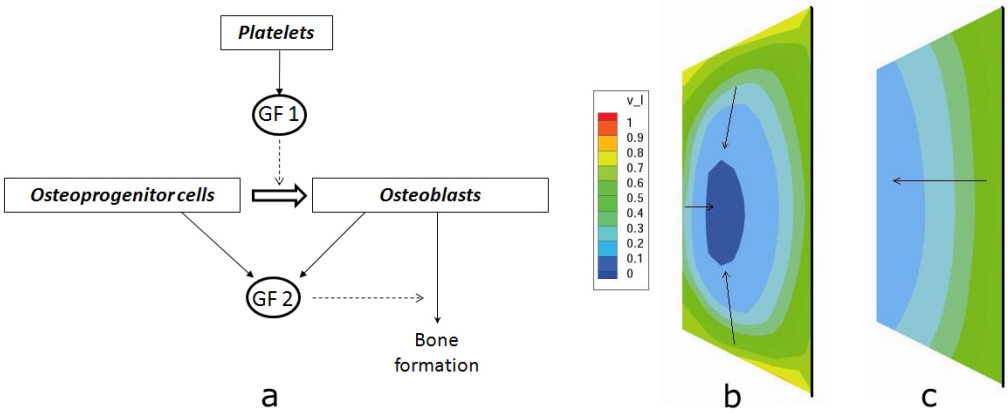

Figure 1. (a) Simplified schematic representation of the main interactions taking place between the three types of cells considered in the model and the generic growth factors *GF1* and *GF2*. Continuous arrows must be interpreted as "production of" whereas dashed arrows as "influence on". (b)-(c) Volume fraction of lamellar bone at the interface between the surface of old bone (highlighted in both pictures with a thick black line) and the surface of a dental implant at a certain stage of healing in the case of (b) a high microtopography surface implant and (c) a low roughness surface implant. Arrows indicate the direction of osteogenesis.

Summarizing, a new mechanobiological model for the study of bone ingrowth on dental implants has been presented and successfully shown to reproduce some important features of bone formation around implants. We hope that it constitutes a useful tool for a better design of bone implants.

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