New cosurface capacitive stimulators for the development of active osseointegrative implantable devices

Marco P. Soares dos Santos[1], Ana Marote[2], T. Santos[1,3], João Torrão[1], António Ramos[1], José A. O. Simões[1], Odete A. B. da Cruz e Silva[2], Edward Furlani[4], Sandra I. Vieira[2], Jorge A. F. Ferreira[1]

1 — Department of Mechanical Engineering & TEMA, University of Aveiro
2 — Department of Medical Sciences & iBiMED, University of Aveiro
3 — Department of Physics, University of Aveiro
4 — Department of Chemical and Biological Engineering, of Electrical Engineering, University at Buffalo, USA

Osteoarthritis is a disorder with a global prevalence around 4% and the most common indication for total hip replacement (THR) and total knee replacement (TKR). An increasing trend in the incidence of primary and revision THRs and TKRs has been observed throughout the last decades, mainly among patients under 65 years old. These patients account for approximately 30% of the overall patients, and sustained increases exceeding 50% are expected by 2030. Even today, the number of revisions can exceed 10% of these joint replacements.

Current methodologies used to improve the performance of these bone implants have been focused on:
(1) the optimization of their geometry and materials;
(2) design of custom-made geometries, nanometer-scale textured surfaces and porous structures;
(3) design of therapeutic actuators based on chemical and biochemical modifications of the implants' surfaces;
(4) design of instrumented implants.

However, these implant technologies have been not able to significantly reduce the implant failure rates. Our proposal is to design instrumented active implants with ability to deliver personalized biophysical stimuli, controlled by clinicians, to target regions in the bone-implant interface throughout the patients' lifetime. This work is focused on designing innovative biophysical actuators for instrumented implants to control the bone-implant integration. In this study, the novel concept of cosurface capacitive stimulation was analyzed. It comprises a set of electrodes in the same surface, prohibiting cell-electrode contacts, such that electric fields can be delivered as required by extracorporeal commands. Electrodes were driven by two excitations, only differing by their frequency (LF: 14 Hz; HF: 60 kHz; 10 V amplitude). Tests were conducted by using anodes always surrounded by cathodes. Successful results were achieved for proliferation and differentiation of osteoblastic MC3T3-E1 cells *in vitro*. Besides, numerical simulations have shown that different stimuli (varying waveform, strength, frequency, etc.) can be delivered to bone cells. These results provide a solid basis to a paradigmatic change in the design of bone implants. A huge societal impact is expected if these novel active implants are fully implemented and successfully tested *in vivo*.