Multifunctional smart bone implants: fiction or future? – A New Perspective

Inês Peres[1], Pedro Rolo[1], Marco PS Santos[1, 2]

1 – Department of Mechanical Engineering & TEMA, University of Aveiro.
2 – LASI – Intelligent Systems Associate Laboratory, Portugal.

Even though bone replacements are among the most performed surgeries worldwide, implant failure rates can still exceed 10%. Controversial positions multiply in the scientific community about the potential of each implant concept to minimize the burden related to implant failures. (Bio)chemical and modifications of the implants' surfaces have been considered the most effective methodology to design the next generation of implants. However, (i) their delivery dynamics does not consider the bone-implant states; (ii) osteoconductivity and osteoinductivity cannot be changed after implant insertion; and (iii) the ability to deliver different stimulations to target tissue peri-implant regions will most likely be quite difficult to attain.

The concept of Instrumented Implant is a disruptive approach that aims to engineer new types of implants incorporating inner electronics and instrumentation to perform sensing and therapeutic actuations along the bone-implant interface. By designing them embedding wireless communication, monitoring and non-autonomous powering systems (Figure 1A), several biomechanical quantities were already measured *in vivo*. These instrumented implants strongly contributed to the development of smart implants, but they did not bring about a technological revolution. Currently, bioelectronic implant technologies has emerged as a leading research topic that aims to design implants comprising biophysical therapeutic actuation, bone-implant interface sensing, implant-clinician communication and self-powering ability (Figure 1B). We argue that the next technological revolution will most likely emerge with instrumented active implants as multifunctional smart devices extracorporeally controlled by clinicians/surgeons. The true essence of instrumented implants is to enclose a hybrid architecture, in which optimal implant performances require smart instrumentation, smart coatings, and optimized geometries and materials (Figure 2).

FIGURE 1
(A) Architecture used to design instrumented passive implants; (B) Architecture used to design instrumented active implants as multifunctional smart devices.

FIGURE 2
Multifunctional smart implants as hybrid technologies framing non-instrumented passive, non-instrumented active and instrumented passive implant technologies.