Implant surface modification by a controlled biomimetic approach

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INTRODUCTION: Titanium and its alloys are the most frequently used biocompatible materials in medical engineering. Accelerated osseointegration can be achieved by modifying the Ti surface with a layer of calcium phosphate (CaP). Current processes typically generate a relatively thick CaP (e.g., by plasma spray) and only a few thin coatings are available [1, 2]. We developed a cost-effective protocol for Ti surface modification with a thin CaP layer using a wet biomimetic route [3].

METHODS: A sand-blasted and acid-etched Ti grade 4 material is used as starting substrate. The surface topography is similar to that of commercially available dental implants. The novel surface treatments consist of two steps. In the first step (a modified version of the Kokubo method [4]), the formation of a highly porous layer of hydrogen sodium titanate ceramics is promoted. This layer is strongly joined to metal and renders the implant surface able to accelerate the formation of apatite (grafting layer, Figure 1A). In a second step, a thin layer of synthetic bone (CaP) is grown by a wet chemistry technique. The physicochemical parameters which allow the controlled growth of the synthetic bone are calculated by means of an accurate thermodynamic-kinetic model of the aqueous system [5]. The CaP deposition occurs in the porosity of the grafting layer and on top of it (Figure 1B). During the whole process pH, ionic strength, temperature, and saturation level of the system are controlled on-line and in-situ ensuring the steady state conditions and the reproducibility of the process. Therefore, careful control over thickness, chemical phase, and morphology of the deposited synthetic bone is achieved.

RESULTS: A thin bioactive synthetic bone layer on Ti implant surface is attained. The layer does not alter the roughness induced by blasting or acid-etching and the implant surface results to be homogenously modified, regardless of its micro- and macroscopic shape. The synthetic bone layer is firmly grafted to the metal. Mechanical tests demonstrate that the modified surface is preserved upon implantation and the layer does not delaminate. The mechanic stability is obtained thanks to the optimized metal-ceramic joining of the grafting layer, whereas the modified surface with synthetic bone offers an ideal substrate for natural bone growth after implantation.

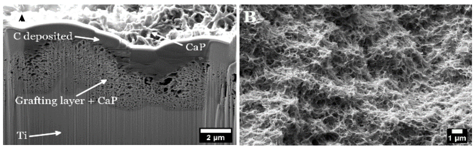

Fig. 1: Modified surfaces: (A) FIB cross-section; (B) surface after step 2.

Thanks to the control over the process, a <100 nm layer hydroxyapatite (HA) or octacalcium phosphate (OCP) can be deposited. In particular, OCP is considered the most bioactive CaP phase, being the precursor of natural bone in the osteogenesis. Reduced healing time and faster transition between primary and secondary stability of the implant can be expected. Moreover, the synthetic bone layer has a solubility higher than that of mature hydroxyapatite, which could promote remodelling to natural bone.

DISCUSSION & CONCLUSIONS: Ti implant prototypes with biomimetically modified surface have been produced and show promising chemical and mechanical in-vitro properties.

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