Biomimetic coatings for a new generation of advanced implants

Recubrimientos biomiméticos para una nueva generación de implantes avanzados

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Abstract

Introduction: Calcium Phosphates (CaPs) are the best substitutes for human bones and as such a primary candidate for the manufacturing of medical implants. Unfortunately, they do not withstand stress in bulk and break when subjected to mechanical pressure. A new generation of biomimetic implants are developed which combine the high stress resistance of metals with excellent biocompatibility, bioactivity, and resorbability provided by thin CaP coatings. New materials such as bioglasses were intensively studied due to their behavior in prolonged contact with the extracellular fluid. Through bioglasses degradation inside the human body and due to ions exchange between glass and extracellular fluid, a new carbonated bioapatite layer is naturally synthesized, replacing the initial coating material. ***Material and Methods:*** We pulsed laser deposited (PLD) simple or doped CaPs or bioglasses on different substrates using a KrF* (λ = 248 nm, $\tau \sim$ 25 ns) UV laser source in controlled atmospheres of oxygen or water. Hybrid organic-inorganic nanocomposites obtained from soluble salts of calcium, phosphorus, and polymer were deposited by matrix assisted pulsed laser evaporation (MAPLE). Human plasma proteins (e.g. fibronectine, colagen) were applied by MAPLE for biomaterial activation by increasing both protein adsorption and cell adhesion at the biointerface. A key advantage of the MAPLE technique is that it allows the deposition of high molecular mass compounds at very low temperatures thus preventing organic phase decomposition. ***Results and Discussion:*** All synthesized nanostructured layers were optimized following investigations by complementary physicochemical techniques (SEM, TEM, SAED, XTEM, GIXRD, XPS and FTIR). Biocompatibility, bioactivity and biodegradability were evaluated by *in vitro* and *in vivo* tests. *In-vivo* pull out tests of different doped CaPs clearly showed that these coatings have strongly activated and enhanced the bone repairing. Both types of bioglass thin films of 6P57 and 6P61 proved to be appropriate media for cell survival and proliferation. Strong bonds between the materials and cells were found. According to our observations, the 6P57 glass films were superior with respect to viability and proliferation performances. We proved that the presence of strontium ranelate in the CaP coatings enhances osteoblast activity and differentiation, while it inhibits osteoclast production and proliferation, preventing undesirable bone resorption. Our data demonstrate that it is possible to use MAPLE to synthesize coatings of alendronate-doped hydroxyapatite with different bisphosphonate content which couple the bioactivity of HA with the local availability of alendronate. They proved suitable to promote bone formation and prevent bone resorption. ***Conclusion:*** We demonstrated that human osteoblasts proliferate faster, reach a normal morphology and remain viable when cultured on PLD and MAPLE coatings as osteoblast pseudopodes penetrated deep into the material.