Calcium Phosphate functionalisation of Ti6Al4V Scaffolds by Perfusion Electrodeposition

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Introduction: Functionalisation of titanium (Ti) implants with calcium phosphate (CaP) is a widely used approach in orthopaedic applications to obtain a mechanically strong system that is
Osteoconductive . In order to deposit CaP in a controlled way on complex 3D Ti surfaces, like scaffolds, this study applied a perfusion electrodeposition (P-ELD) system.

Materials and Methods: 3D Ti-scaffolds were fabricated by selective laser melting. A P-ELD system was developed to deposit CaP onto Ti-scaffolds (cathode) using a platinum ring as anode. A supersaturated calcium phosphate (SCP) solution was used as electrolyte. A full factorial (2^4) design was performed to analyse the effect of current density (***I***), temperature (***T***), deposition time (***t***) and flow rate (***f***) on the characteristics of the deposited CaP. The parameter ***I*** and ***t*** were optimised by performing P-ELD at: (a) varying ***I*** at constant ***t*** (12 hr) and (ii) varying ***t*** at constant ***I*** (3 mA/cm^2). The coating morphology, distribution, thickness, crystalinity and Ca/P ratio were characterised by scanning electron microscopy (SEM), X-ray diffraction (XRD) and electron probe micro- analysis (EPMA). The biocompatibility of CaP-coated Ti-scaffolds was tested by live-dead staining and SEM-analysis of human periosteum derived cells (HPDCs) seeded scaffolds after 7 days of culture.

Results and Discussion: CaP deposition increased with increasing ***t***, ***T*** and ***f***, whereas 20 & 40 mA/cm^2 of ***I*** were too high and disrupted CaP deposition. In fact, the effect of ***t*** and the ***t-f*** interaction on the CaP deposition were statistically significant (p=0.001 & p=0.019). 50 ^{o}C and 10 ml/min were selected for subsequent experiments. SEM analysis showed that P-ELD for ***t*** $\geq$ 6 hr with 2 – 10 mA/cm^2 resulted in a full coating of the scaffolds, up to a thickness of 40μm and with a Ca/P ratio of 1.41. Interestingly, P-ELD at 5 mA/cm^2 for 6 hr produced a cauli flower-like crystal structure of 28 μm thick with a Ca/P ratio of 1.45. XRD analysis indicated that the CaP coatings were carbonated synthetic hydroxyapatite. Live-dead staining of HPDCs cultured on coated Ti-scaffolds for 7 days showed high cell viability and biocompatibility. SEM imaging showed that the HPDCs had a fibroblastic phenotype and interacted with the CaP coating.
Conclusion: Perfusion electrodeposition (P-ELD) can become a useful tool to functionalise complex Ti structures (e.g. scaffolds) with CaP, in which the physiochemical properties of the CaP coating could be controlled and optimised for effective bone formation.