Ca^{++} release behavior and biological responses to sol-gel calcium polyphosphate surfaces

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Introduction

Pure titanium (Ti) and Ti alloys are widely used for dental and orthopedic implants because of their high mechanical properties, chemical stability, and biocompatibility. The biocompatibility of Ti is closely related to the properties of the surface oxide layer. Hydroxyapatite (HA) coating on metallic implants has been used in dental and medical fields to improve the cell responses and osteoconductivity because it has chemical and crystallographic similarity to the inorganic component of hard tissue[1]. However, concern has arisen recently about the long-term stability of the HA-coated implants due to the weak interfacial bonding between HA layers and a metallic substrates.[1] In an attempt to eliminate the problems associated with long-term stability and the induction of direct bonding between bone and metallic implant after gradual degradation of the calcium phosphate (CaP) coating layers, the coating of biodegradable CaP on metallic substrates was investigated in this study. One of the condensed CaP, calcium polyphosphate (CPP, $[Ca(PO_3)_2]n$) can be a good candidate which represents a polymeric structure consisting of phosphate (PO_4^{3-}) chains, thus resulting in faster degradation compared to other CaP materials due to hydrolytic degradation of PO_4^{3-} groups.[2] In this study, the sol-gel derived synthesis of CPP and spin coating technique were used to obtain a homogeneous and smooth CPP coated layer. The technique also facilitates easy coating on complex-shaped implants. The coating properties and dissolution behavior were also investigated.

Materials and Methods

The CPP sol was prepared by reacting $Ca(NO_3)_2{\cdot}4H_2O$ with $P(OC_2H_5)_3$ in methyl alcohol using correct amounts to obtain the stoichiometric Ca/P ratio of 0.5. The prepared CPP sol was then aged at 40°C for 48 hrs. The prepared CPP sol was coated onto the grit-blasted Ti disks by spin coating at 5000 rpm for 50 seconds, immediately drying at 70°C for 12 hours and followed by heat treatment at 600°C for 3 hours. The surface morphology was observed with SEM and the phase was identified with XRD. For the Ca^{++} release study, coated specimens were immersed in vials containing 30 ml of simulated body fluid (SBF) having pH 7.4, and maintained at 37°C with shaking at 80 rpm in an incubator for 1, 3, 7, and 21 days. *In vitro* cell attachment and differentiation on CPP coated and non-coated Ti disks were examined using human bone marrow stromal cells (HBMSCs) for 3 and 7 days.

Results and Discussion

Homogeneous and transparent stable CPP sol was obtained after 48 hrs aging at 40°C. The surface morphology of the coated CPP layer was smooth and uniform with fine grains (about 100nm). The phase of the fine grains was identified with δ-CPP (JCPDS #9-363) from XRD study. The Ca^{++} ion concentration was decreased on the CPP sol-gel coated surface after soaking in the SBF and the Ca^{++} ion concentration in the SBF was increased. *In vitro* studies indicated attachment of HBMSCs on both coated CPP layer and non-coated Ti surfaces, with CCP-coated surfaces exhibiting significantly higher cell numbers at days 3 and 7 when compared to the non-coated Ti surfaces. However, no significant change in cell numbers was observed within each treatment between 3 and 7 days. The lack of cell proliferation at days 3 and 7 within each treatment was suggested to be attributed to cell differentiation on days 3 and 7, with more differentiation observed on days 7 when compared to days 3 of culture (Fig 1).

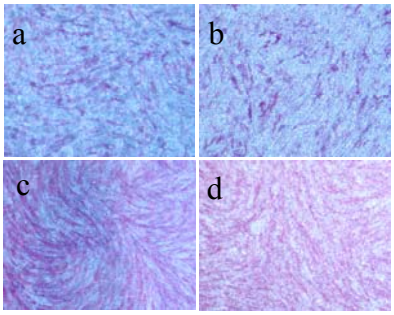

Fig 1. Micrograph of ALP staining differentiating HMBSCs on a) CPP-coated surface after 3 days culture, b) grit-blasted surface-right after 3 days culture, c) CPP-coated surface after 7 days culture, and d) grit-blasted surface-right after 7 days culture.

Conclusions

Since *in vitro* studies indicated biocompatibility, significantly higher cell number and differentiation of cells on CPP-coated surfaces, it was concluded that the CPP can be used as an alternative coating on dental and orthopaedic implant surfaces for enhancing osteoblast responses.

References

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