Phytic acid/calcium hydroxide composite coating on titanium implants promote early osseointegration

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Abstract

Titanium surfaces have been constantly modified to improve bioactivity and osseointegration. In this study, we modified titanium surfaces through hydrothermal treatment with a mixed solution of phytic acid and calcium hydroxide, then evaluated their bioactive and osteogenic activities. In vitro tests, calcium-decorated titanium surface enhanced the cell adhesion, proliferation and osteogenic differentiation of human bone marrow mesenchymal stem cells (hBMSCs). In vivo tests, Micro-CT and histological evaluations indicated that the modified implants promoted new bone formation and osseointegration between the implants and the host bone. These findings provided evidence that this simple modification would be promising solution to improve bioactivity and osseointegration, which would be beneficial not only for titanium implants but also other implanted biomaterials.

Results

Results: Phytic acid/calcium hydroxide composite coating with superior hydrophilicity were successfully prepared on titanium implants. The surface characteristics showed Ti-SLA-2/10 implants with multiple pits and craters can release calcium ions continuously. In vivo, the volume of new bone around the Ti-SLA-2/10 implants was significantly higher than that of the Ti-SLA implants, but more fibrous tissue was observed surround the Ti-SLA implants after 1 week of healing. The Ti-SLA-2/10 implants showed higher bone volume fraction (bone volume/total volume, BV/TV, %) than that of the Ti-SLA implants at each time points ($p < 0.05$). The bone implant contact ratio (BIC, %) of the Ti-SLA-2/10 implants was higher than the Ti-SLA implants after 4 weeks of healing, $94.71 \pm 2.31\%$ and $83.51 \pm 4.16\%$, respectively ($p < 0.05$).

Background and Aim

Background: Titanium (Ti) or titanium alloys coated with various bioactive calcium phosphates (CaPs), including hydroxyapatite (HA) and β -tricalcium phosphate (β -TCP), are considered as satisfactory implant materials (Dorozhkin, 2015; Park et al., 2018). CaP coatings provide nanostructural or microstructural characteristics on titanium or titanium alloys, thereby increasing the adhesion of osteoblasts, which enhance the osseointegration and shorten the healing time (Chen et al., 2014).

Aim: To prepare and evaluate the effect of calcium-containing chemical conversion coating on promoting new bone formation and early osseointegration in vivo.

Conclusion

Conclusion: The phytic acid/calcium hydroxide composite coating on the SLA surface promoted new bone formation and early osseointegration in vivo, which suggests that calcium-containing chemical conversion coated materials would have great potential for not only dental implants but also various other biomaterial applications.

Methods and Materials

Methods and Materials: We designed and prepared a phytic acid/calcium hydroxide composite coating on the pure titanium implant (Ti-SLA-2/10) through hydrothermal treatment with a mixed solution of phytic acid (PA) and saturated calcium hydroxide solution $[\text{Ca}(\text{OH})_2]$. The pure titanium implant with a sandblasted/acid-etched (SLA) surface was used as the control group (Ti-SLA). The surface morphology, elemental composition, surface roughness, wettability, and calcium ion release were investigated separately. Twenty-four SLA and calcium-containing SLA implants were immediately inserted into the mandibles of twelve New Zealand white rabbits. The biological effects were evaluated by Micro-computed tomography (Micro-CT) analysis and histological evaluation after 1, 2, and 4 weeks of healing.

References

- Chen, Z., Wu, C., Gu, W., Klein, T., Crawford, R., & Xiao, Y. (2014). Osteogenic differentiation of bone marrow MSCs by beta-tricalcium phosphate stimulating macrophages via BMP2 signalling pathway. *BIOMATERIALS*, 35(5), 1507-1518.
- Dorozhkin, S. V. (2015). Calcium orthophosphate deposits: Preparation, properties and biomedical applications. *Materials Science & Engineering C-Materials for Biological Applications*, 55, 272-326.
- Park, K. H., Kim, S. J., Jeong, Y. H., Moon, H. J., Song, H. J., & Park, Y. J. (2018). Fabrication and biological properties of calcium phosphate/chitosan composite coating on titanium in modified SBF. *Mater Sci Eng C Mater Biol Appl*, 90, 113-118.