On the role of surface properties for implant fixation

From finite element modeling to in vivo studies

Akademisk avhandling

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av

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Avhandling baseras på följande delarbeten:

I. Stenlund P, Kurosu S, Koizumi Y, Suska F, Matsumoto H, Chiba A, Palmquist A. Osseointegration Enhancement by Zr doping of Co-Cr-Mo Implants Fabricated by Electron Beam Melting.
Additive Manufacturing. 2015;6:6-15.

II. Stenlund P, Omar O, Brohede U, Norgren S, Norlindh B, Johansson A, Lausmaa J, Thomsen P, Palmquist A. Bone response to a novel Ti–Ta–Nb–Zr alloy.
Acta Biomaterialia 2015, *In press,* http://dx.doi.org/10.1016/j.actbio.2015.03.038

III. Stenlund P, Murase K, Stålhandske C, Lausmaa J, Palmquist A. Understanding mechanisms and factors related to implant fixation; a model study of removal torque.
J Mech Behav Biomed Mater 2014;34C:83-92.

IV. Murase K,[*] Stenlund P,[*] Nakata A, Takayanagi K, Thomsen P, Lausmaa J, Palmquist A. 3D modeling of surface geometries and fracture progression at the implant interface.
In manuscript. [*] Equal contribution

V. Stenlund P, Trobos M, Lausmaa J, Brånemark R, Thomsen P, Palmquist A. The effect of loading on the bone around bone-anchored amputation prostheses.
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ABSTRACT

The aim of this thesis was to gain a deeper understanding of the factors contributing to the fixation of bone-anchored implants, especially with regard to surface chemistry, surface topography and implant loading. The methodology used in the thesis ranges from systematic bench studies, computer simulations, experimental in vivo studies, to load cell measurements on patients treated with bone-anchored amputation prostheses.

The bone response to the surface chemistry was the main factor of interest in paper I and II. It was evaluated by adding a low amount of Zr to electron beam melted Co–Cr–Mo implants in vivo using a rabbit model, and a novel Ti–Ta–Nb–Zr alloy was compared to cp–Ti in vivo using a rat model, respectively. Surface roughness parameters and factors related to the removal torque technique were identified in a systematic experimental study (Paper III). Finite element analysis was used to study the effect of surface topography and geometry on mechanical retention and fracture progression at the implant interface (Paper IV). In the last paper, site-specific loading of the bone-implant interface was measured on patients treated with bone-anchored amputation prosthesis. The effect of typical every-day loading for the bone-implant system was simulated by finite element analysis. Evaluation of retrieved tissue samples from a patient undergoing implant revision was conducted to determine the interfacial condition after long-term usage (Paper V).

It was concluded that the surface topography, the surface chemistry and the medium surrounding the implant were all found to influence the stability of the implant. A model of interfacial retention and fracture progression around an implant was proposed. Observations of bone resorption around an amputation abutment can partly be explained by the long-term effect of daily loading.

In summary, the implant surface properties can be tailored for improved biomechanical anchorage and optimal load transfer, thus reducing the risk of implant failures and complications in patients.

Keywords: Implant stability, removal torque, surface roughness, surface chemistry, finite element analysis, experimental, in vivo, osseointegration, mechanical loading, bone regeneration.

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