Methods for evaluation of early bone healing at titanium implants

Akademisk avhandling

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Av

KARIN HEDERSTIERNA
legitimerad läkare

Fakultetsopponent: Professor Timo Närhi, Department of Prosthetic Dentistry and Biomaterials Science, Institute of Dentistry, University of Turku, Finland

Avhandlingen baseras på följande delarbeten:

I. C. Eriksson, H. Nygren and K. Ohlson
Implantation of hydrophilic and hydrophobic titanium discs in rat tibia: cellular reactions on the surfaces during the first 3 weeks in bone
Biomaterials 25(2004) 4759-4766

II. C. Eriksson, K. Börner, H. Nygren, K. Ohlson, U. Bexell, N. Billerdahl, M. Johansson
Studies by imaging TOF-SIMS of bone mineralization on porous titanium implants after 1 week in bone
Applied Surface Sciences 252(2006) 6757-6760

III. C. Eriksson, K. Ohlson, K. Richter, N. Billerdahl, M. Johansson, H. Nygren
Callus formation and remodelling at titanium implants
Journal of Biomedical Materials Research Part A, 2007 Dec 15;83(4):1062-9

IV. H. Nygren, C. Eriksson, K. Hederstierna, P. Malmberg,
TOF-SIMS analysis of the interface between bone and titanium implants – effect of porosity and magnesium coating
Applied Surface Sciences, in press, doi: 10.1016/j.apsusc.2008.05.143

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Karin Hederstierna
Institute of Biomedicine, Department of Medical Biochemistry and Cell Biology, The Sahlgrenska Academy, University of Göteborg, Box 420, SE 40530 Göteborg, Sweden

ABSTRACT

Titanium has for a long time been the implant material of choice when in need for abilities as strength, biocompatibility and stability. Although numbers of studies have been made, little is known about the early events in implant healing.

The primary aim in this thesis was to develop methods for evaluating bone healing around implants. We used common histological methods but also time-of-flight secondary mass spectrometry (TOF-SIMS) to evaluate the implant healing. This method has previously been used for inorganic materials but can, thanks to new ion sources, be efficiently utilized for analysis of biological compounds. With the Bi_3^+ cluster ion source used, it is possible to detect high mass fragments of hydroxyapatite (HA) which was applied in the last paper. HA within an area of 40µm from the implant was measured and a correlation between histology and TOF-SIMS was found. We think that TOF-SIMS as a method may be suitable for studying high mass HA fragments. The interface zone was another area we wanted to elucidate using TOF-SIMS technique.

Bone formation and resorption and the relationship between those two during the first weeks have been of interest in this thesis. Our hypothesis is that understanding of the bone resorption phase could be a crucial step in influencing the bone healing around implants. After 7 days bone was in close contact with the implant but from this day and evident after 14 days resorption was seen. The initially formed bone was then resorbed and replaced by mature lamellar bone. Our findings indicate that healing around implants starts primarily in the periphery growing toward the implant. Early callus formation and resorption are crucial steps in these early phases and possibly the net bone production is influenced by these factors. Findings in the fourth paper indicate that magnesium coatings decrease resorption and increase net bone production.

Porosity together with Magnesium coating seems to positively influence bone growth. We detected formation of adhering bone around all the implants after 7 days through measuring HA. After 4 days there was a zone at the interface without mineralization despite light microscopy (LM) detected bone formation. This has not been reported before. Decalcification and sectioning were used in one paper which gave an opportunity to study the relation between bone and the titanium implant in thin sections giving a good LM resolution. The most porous surface only had the third highest HA coating which indicated that other factors influences implant healing except porosity. TOF-SIMS was used pre implantation to characterize the surfaces. It was then possible to see that during the oxidation process different compounds, like sulphur, phosphor and fluoride, are built into the oxide.

Keywords: TOF-SIMS, titanium, porosity, Magnesium, hydroxyapatite, implant surface, bone resorption, bone formation,

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