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Healing of complement activating Ti implants compared with non-activating Ti in rat tibia

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ABSTRACT

Recent studies have revealed that ozone ultraviolet (UVO) illumination of titanium (Ti) implants improves bone–implant anchorage by altering the physico-chemical and immune activating properties of the titanium dioxide (TiO_2) layer. In the present rat tibia model, the authors compared the early events of inflammation and bone formation around UVO-treated Ti and complement activating immunoglobin g (IgG)-coated Ti. Machined Ti and machined Ti coated with a physical vapour-deposited Ti layer were used as references. Screw-shaped test and reference implants were implanted into rat tibia and harvested after 1, 7 and 28 days. Messenger RNA expression of implant adhered cells and peri-implant tissue ~250 μm from the surface were subsequently analysed with regard to IL-1β, TNF-α, osteocalcin, cathepsin K, BMP-2 and PDGF. Separate implants were retrieved after 7 and 28 days for removal torque measurements, and histological staining and histomorphometric analysis of bone area and bone-to-implant contact. While enhanced expression of inflammatory markers, TNF-α and IL-1β, was observed on IgG-coated surfaces throughout the observation time, UVO-treated surfaces indicated a significantly lower early inflammatory response. In the early phases (1 and 7 days), the UVO-treated surfaces displayed a significantly higher expression of osteoblast markers BMP-2 and osteocalcin. In summary, complement activating Ti implants elicited a stronger inflammatory response than UVO-treated Ti, with low complement activation during the first week of healing. In spite of this, the UVO-treated Ti induced only marginally more bone growth outside the implants.

1. Introduction

Photocatalytic reactions on TiO_2 have been explored in various contexts, and the superhydrophilic Ti oxide is of interest in biomaterials science, since it may improve integration to bone [1]. The surfaces were made superhydrophilic by pitching in acids or by extended UV-illumination (UVA, wavelength = 352 nm). The effects of the hydrophilicity on stem cell behaviour were evaluated by measurements of pluripotent mesenchymal precursor C2C12 cell attachment, proliferation and morphology [1]. Histomorphometry revealed improved bone formation around the superhydrophilic implants upon insertion in rabbit tibia, and the implants already displayed enhanced osseointegration 2 weeks after implantation. The tissue cell morphology at the hydrophilic disk was extremely flattened, with elongation of lamellipodia, whereas round/spherical morphology was observed on control discs without UV illumination. The superhydrophilic implant significantly enhanced the bone-mineral content after 2 weeks of healing: 28% compared with 18% for the control.

In a later study with similar UV treatment of TiO_2, however, no improved bone-to-metal contact was shown after 4 weeks of implantation in the rabbit [2]. A plausible explanation for this was that the material in use did not possess high enough hydrophilicity, owing to a lower percentage of anatase crystallites in the oxide. This was based on the suggestion by Wang et al. [3] that photoinduced superhydrophilicity is an attribute of anatase type TiO_2 crystallites in the oxide [3].

Yet another study compared machined and acid-etched TiO_2 surfaces, both exposed to UV illumination (UVA and UVB, 360 nm and 250 nm, respectively). The in vitro results indicated that UV increased the rat bone marrow derived osteoblast attachment, spreading, proliferation, differentiation and protein adsorption (model proteins; bovine serum albumin and plasma fibronectin). The UV-treated surfaces then showed almost 100% bone-to-implant contact (BIC) and four times higher implant push in force after 4 weeks of implantation in the flat part of the rat distal femur [4].

Protein adsorption to differently treated Ti was investigated by others, and one study reported that protein adsorption is indeed

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