TISSUE REACTIONS OF TITANIUM AND ITS ALLOYS

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Introduction

The results of scanning electron microscope investigations and Auger analysis of the interface between hard tissue and titanium lead to different conclusions. Whereas ALBERGTSSON et al. (1) find the metal closely by osteocytes and other cells, and a titanium surface which is inert in the contact with the biological environment, MC QUEEN et al. (2) ascertain that titanium oxide appears to be a dynamic substance capable of interacting with bone. Both mechanisms, the inertness on the one and the infinite growth of the oxide layer on the other hand might be indicative of biological interactions.

Preliminary investigations

A preliminary hint on the interaction of a polarized surface of titanium or one of its alloys with biological macromolecules produces the current density/potential curve which is measured for pure titanium and TiAl5Fe 2,5 as well as for the cast CoCrMo-alloy in pure physiological saline solution as well as in solution completed by albumin as an important protein, contained in all body fluids, i.e. in the extracellular fluid in an amount of: 5g/100 ml.

![Graph](image)

Fig. 1: Current density - electrode potential plot of Titanium
Fig. 2: Current densities of various implant metals in an albumin solution with a concentration of 5 g/100 ml.

The main differences arise in the limiting current in the passive region. A prerequisite for the reproducibility of the present surface preparation, the surface of the metals under test is ground, rinsed in distilled water and afterwards dried. The polarization starts into the cathodic direction, returns if the activation potential is reached and goes into the passive region exhibiting the expected limiting current. Whereas the current for the cast CoCrMo-alloy is independent of the addition of albumin titanium and its alloy show a current diminution if albumin is present.

An explanation for that finding might be a physical adsorption of macromolecules which hinder the chemical dissolution of the oxide layer. In contrast to that and following the developed thought at surfaces of cast CoCrMo an adsorption of the protein does not take place.

Preparation techniques and tissue reactions

The specimens for implantation in grown-up rats with a body weight of 200 - 300 g having a length of 20 mm, a diameter of 3 mm are machined in a cylindrical shape with rounded front ends (3). This special shape has the advantage that the surface being in contact with the tissue has an identical curvature independent of the locus. In this way artefacts as described in the literature (4) are reliably excluded.

Fig. 3: Size of the implanted metallic specimens.
Fig. 4: Fixation of the implant.

To make sure that no biological factor complicates the interpretation of the experimental results, in each rat a sample made of titanium, one of TiAl6 V4 and TiAl5 Fe 2.5, and one of cast CoCrMo were implanted and safely fixed with a non-reabsorbable thread left and right into the muscular tissue close to the spine.

Tissue sections are fixed for approximately 24 hours in Schaffer solution. The specimens are subsequently put in muslin bags and submerged for 24 hours in each of the following: 80 per cent alcohol, 96 per cent alcohol, 100 per cent alcohol–acetone 1:1, acetone, 100 per cent alcohol–acetone 1:1, and 100 per cent alcohol. This alcohol–acetone sequence is necessary for fat extraction and dehydration of the specimens as bone tissue containing fat and water can easily upset the polymerization of the monomethylmethacrylate. Clouded solvents must be renewed. Acetone remaining in the bone specimens also gives poorer embedding results. The specimens are submerged in methacrylate solution under refrigeration for five days at + 4°C in order to saturate the bones with the embedding agent and eliminate released gases (5).

Preparation of tissue with the implant in situ requires embedding of the object in an artificial resin of similar hardness. Methylmethacrylate fulfills this requirement and is especially suited for grinding with a diamond disk without a softening additive.

After hardening, the methacrylate blocks are removed by breaking the jars. They are trimmed with a belt saw so that they fit the holding mechanisms of a universal slicing machine. With this machine the methacrylate blocks are cut into slices 500–1,000 μm thick. The tissue specimens are ground flat on a precision grinding machine and subsequently glued on plexiglass slides with cyano acrylate adhesive. The thickness after grinding is between 100 and 10 μm.

All metals were incorporated without any foreign body reaction after the healing period of 14 days. However, some differences in the interaction of the specimens with the tissue could be seen after explanation. Three months postoperatively and later on the samples made of titanium were closely connected with the tissue, so that the disconnection could only be done with the aid of a scalpel, whereas the cast CoCrMo came out of the connective tissue without problems after opening the surrounding capsule.
Histological findings

The whole surface of the implant material, which has more or less notches, is covered by a border of fibrillar scar. The border proliferates into the notches. In the region of the rounded ends of the implants the scar tissue shows larger thickness. Some separated solid particles and rough surface areas were found, which were accompanied by giant cells, being from the foreign body type. Immunological reactions could not be detected.

Fig. 5: CoCrMo in contact to a broad border of granulation tissue, rich in vessels and cells, 4 weeks after implantation.

Figs. 6: Typical result for Titanium implants with smooth surfaces, 4 weeks post operation. A small border of granulation tissue contact the metal.
Fig. 7: Picture 1-4 shows tissue in contact to 4 different implant materials after 3 months post operation.
1: CoCrMo (metal is seen as a dark structure on top of the picture); 2: pure Titanium; 3: TiAlFe and 4: TiAlV (there no metal can further be seen; at the white places on top of the pictures the metals are situated). The four implants show similar tissue reactions. A border of fibrillar scare tissue is observable.
Discussion

The implants were identified by the organism as foreign bodies and encapsulated by granulation tissue, being cell-rich and vascular within a period of 2 to 4 weeks. The granulation tissue varied in its extension and depends on surgical necroses and the surface state. Smooth areas were always surrounded by a border of granulation. After 3 months post operation all implants are covered substantially by a thin layer of fibrillar scar tissue. Smooth as well as rough, notched surface areas were encapsulated by a thin membrane-like structure. As a result of the formation of connective tissue, which encapsulates the implant, a strong fixation with the surrounding soft tissue is ensured. Relative movements of the implant were avoided.

The four tested implant materials always show similar tissue reactions. The observed differences in histology simply come from the various surface finish. The strong reaction of the granulation tissue, recognized shortly post implantation, can be diminished respectively avoided by a strong fixation and a smoother surface.

References


