ELECTRON WORK FUNCTION AS A DIRECT PARAMETER FOR BACTERIAL INFECTION RISK OF IMPLANT SURFACES

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Introduction

The risk of biomaterial centred infection (BCI) is the main drawback limiting their use. To prevent bacteria colonization of the metal implants surface, several approaches which require precise engineering of their surface architecture and properties can be considered e.g. changing surface chemistry and functional groups and/or introducing topographical features on the surface (micro– and nanopores). All of the mentioned practises aim in favouring osseointegration over hazardous bacteria attack [1]. Since the bacteria exhibit the charge on the surface (partial charges accumulated on wall teichoic acids functional groups) it is expected that the electrostatic potential between implant surface and bacteria can play a crucial role in their adhesion.

The aim of the study was to evaluate if there is any correlation between electrodonor properties of the implant surface and bacterial adhesion. To address this problem, a series of implant material were prepared with the same chemical and structural composition while their nanotopography and thus, the work function values, varied. The second stage of the study involved evaluation of the prepared surfaces for bacteria adhesion.

Materials and Methods

Nanoporous anodic titanium oxide (ATO) layers were prepared by three-step anodization in a standard two-electrode electrochemical cell with a platinum plate as the cathode and the titanium foil as the anode. An ATO layer formed on a Ti substrate has several advantages like nontoxicity, biocompatibility and osseointegration. The anodization experiments were carried out at a constant potential of 30-100V in an ethylene glycol with NH_4F and H_2O [2].

The contact potential difference (V_{CPD}) measurements were carried out by the Kelvin method with KP6500 (McAllister Technical Services). For bacteria adhesion test *S. aureus* 24167 DSM with net negative surface charge was selected.

Microbiological tests were performed for three independent series in triplicates according to the procedure described elsewhere [3]. Area occupied by *S. aureus* was determined with the use of fluorescence microscopy. Prior observations, bacteria cells were fixed and stained with propidium iodide.

Results and Discussion

The series of ATO samples differed substantially in terms of surface electronic properties gauged by the work function. The highest work function was found to be 4.23 eV for the samples anodized at 30 V, whereas the lowest value of 3.98 eV for 100 V. For various anodization potentials the samples exhibit different pores diameters and also the titania wall thickness. As a result, work function changes in non-linear way. Such changes substantially modify the bacteria adhesion to the titania surfaces. The adhesion was quantified by the area occupied by bacteria on the investigated ATO surfaces. The profile exactly follows the non-linear trend observed for work function measurements with the highest occupied area of 12%, observed for the highest work function values. The general revealed trend is schematically presented in FIG. 1.

The obtained results can be interpreted in terms of microbial adhesion to implant surfaces as primarily mediated by non–specific interaction forces which include Lifshitz–Van der Waals forces and electrostatic forces, which both operate over a long range, as well as hydrophobic and acid-base interactions that act over a shorter range. After approaching the implant surface, microorganisms are attracted or repelled by the biomaterial surface, depending on the resultant interaction forces. It should also be noticed, that this situation takes place immediately after implant placement in the environment of body fluids before the surface is conditioned (adsorption of proteins and peptides). This stage is critical in the ‘race for the surface’ between bacteria and osteoblasts and decisive for the appropriate host response after surgery. Winning the competition between bacteria and osteoblasts is the ultimate goal of surface implant engineering.

The obtained results clearly indicate the infection-reducing strategy based on the concept of implant surface work function lowering. Since the repulsion electrostatic forces between surface and bacteria play a key role in the weakening of irreversible adhesion, which is an initial step in biofilm formation, favouring osseointegration.

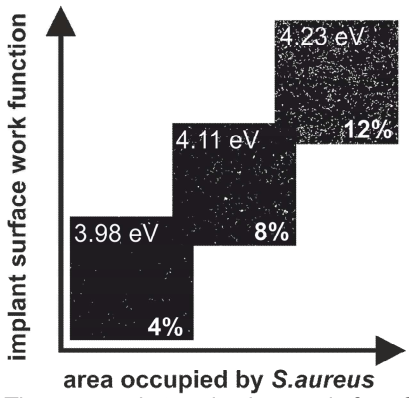

FIG. 1. The general trend observed for *S. aureus* adhesion to titania implant surfaces.

Conclusions

Strong correlation between *S. aureus* adhesion on the ATO surfaces and the electron work function of this implantable material was discovered. The conducted study proved that the work function can be applied as a direct parameter for evaluation of surfaces against bacteria adhesion.

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