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Engineering Osteophilic and Osteoinductive Surfaces on Metallic Implant Scaffolds

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Surfaces of medicinal implant metals like cp titanium, 316L steel or cobalt chromium alloys (CoCr29Mo), generally possess contact angles of 60-80°, thus displaying effective hydrophobic surfaces (for review see [1]). In 1972 Baier [2] suggested a model, in which a correlation exists between biocompatibiltiy, bioadhesion and the critical surface tension of solids. In this model Baier postulated a good bioadhesion on hydrophilic surfaces. Several years ago we discovered a novel wet chemical etching method with chromosulfuric acid (CSA) at 200-240 °C for the preparation of extremely hydrophilic surfaces on transition metals like titanium, steel (316L) [3] and cobalt chromium (CoCrMo) alloys [4]. It was demonstrated that these metals with surface roughness values of Ra > 1 µm were nano-structured and exhibited ultra-hydrophilic properties i.e. dynamic contact angles < 10° with absent contact angle hysteresis [5], a phenomenon which we have called "Inverse Lotus Effect" [6]. The development of ultra-hydrophilicity on titanium surfaces follows a typical time course. The advancing and receding contact angles respectively decrease from ca. 70°/60° at zero time to 1°/1° at 60 minutes and then increase again to 15°/3° or more at 120 minutes of heating in chromosulfuric acid. This typical minimum-function behavior of the dynamic contact angle was found for electropolished, anodically oxidized, SLA- (sand-blasted surface etched) and PVD- (plasma vapor deposited) titanium surfaces, inspite of the fact that the surface roughness (Ra value) varied between 1 µm (electropolished) and ~ 40 µm (PVD-surface). In pilot animal experiments such ultra-hydrophilic surfaces show an enhanced bone growth (osteophilicity) versus controls.

Based on the above CSA-surface as a priming coat, we have developed a method for immobilizing bone morphogenetic protein 2 (rhBMP-2) on metal surfaces [3-6]. In this way chemotactic-juxtacrine surfaces may be produced: chemotactic by way of a slow controlled release of rhBMP-2 and juxtacrine by simulating juxtacrine secretion in the form of a 2-dimensional layer of immobilized rhBMP-2 for solid phase interactions with the receptors of osteoprogenitor cells. 125I-rhBMP-2 can be immobilized in amounts between 0.1-5 µg/cm2 on different titanium surfaces in clinical use. The half-life of rhBMP-2 released from such surfaces is in the order of bone growth depending on the immobilization procedure and varies between 30 and 100 days [4]. In vivo and in vitro experimenters show that the immobilized BMP-2 is biologically active, thus opening the possibility of rationally engineering osteoinductive implant surfaces.

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