Implant surfaces in fracture fixation: *In vitro* & *In Vivo*

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When inserting an implant into the body, protein adsorption occurs within seconds and usually cell adhesion within minutes, followed by either soft-tissue adhesion or matrix adhesion and mineralization. Early soft tissue integration with vascularisation at the tissue-implant interface, without liquid filled capsule formation is desirable, especially for deterrence of infection. Some osteosynthesis applications require that neighbouring tissues can freely glide over the implant. Such instances include orbital fractures with connective tissues and distal radius fractures where tendons have to glide over internal fixation plates. In both cases tissue adhesion is undesirable since this prevents normal tissue motion. The intrusion of a plate can produce friction for the gliding tissue and is liable to become a site for tissue adhesion and inflammation. These applications require the development of surfaces that prevent soft tissue attachment and irritation, allow tissue gliding, but maintain their biocompatible properties. One way to reduce the tissue adhesion is to reduce surface roughness of the implant.

With long term or permanent CMF or spine implants osseointegration is vital to their success. In other cases such as plating in paediatric tissue, or areas where aesthetics are important, minimal bone bonding to implants is desirable for the least traumatic explantation. In femoral nailing, minimal bone bonding to implants is desirable for ease of removal. Internal fixation screws require a stable bone-implant interface for transmission of forces, and their success is related to both design and surface structure. Bony integration is increased on implant surfaces with higher amounts of microroughness. Strong bony integration between the bone and screw is a disadvantage when considering removal of screws, and the surface microstructure is the major determinant of this. Bony integration is minimized by using surfaces with minimal microstructure reducing the forces required to remove screws. Recent work with polished titanium and titanium alloys has shown the surfaces to be favourable for such areas. The microstructure of the implant surface of these metals has been shown to be more important than the implant surface chemistry, which usually is similar from the final anodisation process (which both protects the implant with a thicker oxide layer and gives the implant its final colour).

Our work also found that polishing TAN surfaces significantly decreased the amount of *S. aureus* adhesion compared to the standard TAN (which has surface micro-protrusions). The standard TAN had a higher affinity to the bacteria compared to titanium (polished or rough).

Our *in vivo* studies show that surface polishing of titanium and titanium alloy internal fixation plates can minimise soft-tissue adhesion. Therefore polished plates could also avoid tendon irritation and associated problems. Our *in vivo* work with bone demonstrates that polishing can reduce removal torque and percentage bone contact and thereby improve the ease of removal of TAN and titanium implants placed into cortical and cancellous bone. Surface polishing appears to exert its affect on bone by reducing extraosseous formation from a cellular level. This is by inhibiting osteoblast ability to mineralise and produce mature matrix therefore preventing subsequent bone formation. The cells behave in a fibroblast like manner upon the smooth polished surfaces.

In situations with either hard or soft tissue interactions with biocompatible bulk materials, the ‘implant biocompatibility’ is determined more by the design and surface characteristics. Without surface modification an implant may be biocompatible in one anatomical situation, yet not in another. There is no ‘One Surface’ for all applications and surfaces even on one implant interacting with different tissues need to be considered as separate entities.

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