Titanium (Ti) alloy is the material of choice for the porous bone ingrowth materials for non-cemented total joint arthroplasty. Recent studies have shown the importance of controlling the macro, micro, and nano surface topographies on the bone apposition surfaces of these implants. Historically, much attention has been given to the designs of macro fixation features (millimeter scale), and the design of micro fixation porosity (micrometer scale). More recently, the importance of the nano-surface texture (nanometer scale) is being recognized as an integral component of the design. Nano-textures are being enhanced during implant processes to optimize the bond between implant and bone.

The ultra-hydrophilic nano-texture of an implant interacts with the corresponding nano-texture of the outer cell membranes to increase cell adhesion and differentiation. This speeds the osseointegration rate between Ti alloys, and the surrounding osteoblast tissues. Living cells sense and respond to surface texturing on the nanoscale which in turn direct stem cell and osteoblast differentiation. This has been recognized to improve the speed at which the implant interface bonds to bone with the end goal of ultimately allowing patients to weight bear on non-cemented arthroplasty implants sooner.[1]

One surface modification treatment technique of particular promise is nano-texturing via electrochemical anodization to form arrays of vertically aligned, laterally spaced titanium dioxide (TiO\textsubscript{2}) nanotubes on titanium implant surfaces in areas where enhanced implant-to-bone fixation is desired. Bio-mimicking TiO\textsubscript{2} nanotube arrays are superimposed onto existing porous surface micro-structures to further enhance the already known bone ingrowth properties of these porous structures. These nanotube arrays show an accelerated osseointegration. Foundational work has demonstrated that the TiO\textsubscript{2} nanotube surface architecture significantly accelerates osteoblast cell growth, improves bone-forming functionality, and even directs mesenchymal stem cell fate.[1] Current generation nano-surface modification technologies show improved osseointegration response between implant materials and surrounding tissue and also provide surfaces that resist microbial adhesion.[2]

Implant surfaces treated with and without TiO\textsubscript{2} nanotubes were compared to grit blasted Ti controls in-vitro and in-vivo. The samples were evaluated after exposure to human mesenchymal stem cell (hMSC). Additionally, implants have been evaluated in multiple animal models with and without TiO\textsubscript{2} nanotubes. The bones with implants were retrieved for mechanical testing and histology analysis. The average bond strength was significantly higher (150% to 600%, depending on the in-vivo animal model) for TiO\textsubscript{2} nanotube implants compared to the non-treated Ti control implants.[3] The histology confirms direct bonded growth of new bone onto the nanotubes with a significantly less trapped amorphous tissue at the implant-bone interface compared to the controls. Both in-vitro and in-vivo analysis indicates that TiO\textsubscript{2} nano-texturing enhances the speed and proliferation of osseointegration. This surface treatment technique can be applied to non-porous or porous surfaces on TJA implants where improved bone fixation is desired.
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