Additively Manufactured Tantalum Parts for Orthopedic Applications

This paper provides a brief summary of findings in the scientific and medical literature regarding the benefits of using tantalum materials in orthopedic applications including use of additive manufacturing processes. Samples of some of these references are provided below for the reader.

Tantalum has been in use in certain medical applications since the 1940's and increased in recorded use through the latter half of the 20 century to the present. For example, numerous articles have been published that reviewed the use of tantalum in staples[i] for ligation; wire for Stents[ii]; coatings for medical devices[iii] and for orthopedic applications.[iv] These articles also review the reported attributes in these applications such as Tantalum's inert bioactivity;[v] antithrombotic property; enhancement of macrophage response;[vi] bactericidal properties.[vii]

Over the last 25 years, in orthopedic implants, various Stainless steels, Titanium and CoCrMo alloys have been diffusion bonded or simply sintered into near net shape or thermally sprayed onto mass-produced forms, in order to improve fixation of an orthopedic implant.[viii] These articles also review the attributes of these materials and techniques in these applications.[ix]

By comparison, the literature referenced below has discussed inert *in vivo* and *in vitro* properties of porous Tantalum and address osseointegration as compared to certain other metals and alloys, and address the elastic modulus being similar to subchondral and trabecular bone, and attributes related to stress shielding,[x] as well as possessing a high coefficient of friction for biomaterials which can result in initial stabilization of an implant immediately after surgery.[xi] Specific studies have noted the porous Tantalum morphology as a framework for bone growth and osteoblast interaction.[xii] Additional evidence have indicated that human osteoblasts (cell line hFOB) exhibit potentially six time higher living cell density on Tantalum as compared to Titanium.[xiii] Researchers have also discovered that the elastic modulus of porous Tantalum can be modified over an order of magnitude by changing the porosity between 27 and 55%.[xiii] Indeed, as further noted in these articles, some commercial applications have been developed with porous tantalum implants that indicate, both *in vitro* and *in vivo*, osseointegration, secure mechanical attachment, biocompatibility, and minimal metal wear, yet providing friction.[xiv]

Recently there have been reports of using Additive Manufacturing techniques to produce fully dense open-celled structures for load bearing implants.[xv] Selective Laser Melting (SLM) specifically has been shown capable of making structures with high range interconnected porosity. SLM produced tantalum porous-structure also demonstrated mechanical properties relatively similar to human bone and osseointegration as compared to similar porous Ti-6Al-4V structures. One conclusion reached from this work was that "laser-melted tantalum shows excellent osteoconductive properties, has higher normalized fatigue strength and allows for more plastic deformation due to its high ductility."[xvi]

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