Castability of Biocompatible TNZT in Investment Shell Moulds

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ABSTRACT

Beta-titanium alloys are capable materials for load-bearing orthopaedic implants due to their outstanding corrosion resistance and biocompatibility, low elastic modulus and moderate strength. The most commonly used is Ti-6Al-4V alloy that belongs to α+β Ti-alloys. The main drawback of this alloy is toxic nature of vanadium. In addition, a high amount of aluminum interferes with cell viability, besides having a long-term cytotoxic effect in-vitro and in-vivo. In vitro refers to the technique of performing a given procedure in a controlled environment outside of a living organism. In microbiology in vivo is often used to refer to experimentation done in live isolated cells rather than in a whole organism, for example, cultured cells derived from biopsies. The α+β Ti-6Al-7Nb alloy has been developed to avoid the bad effect of vanadium. Another adverse property is too high elastic modulus (115 GPa of Ti-6Al-4V and Ti-6Al-7Nb alloys) that is higher than that of cortical bone (20 GPa). Too high elastic modulus causes stress shielding and consequent osteoporosis that results in decreased life-time of orthopaedics implant. In spite of reducing the elasticity modulus of titanium alloys without causing cytotoxic effects, new promising alloys that add niobium, tantalum, zirconium and molybdenum to titanium have been developed. These alloys represent a new class of titanium-based alloys, which are free of aluminum and vanadium, while exhibiting low values of the Young’s modulus. Ti-35Nb-7Zr-5Ta (TNZT) alloy was developed in 1990s in USA and patented in 1999. The biggest current interest is focused on metastable β-titanium alloys with increased biocompatibility and decreased elastic modulus to avoid stress shielding and increase of life-time of an implant. The elastic modulus of TNZT alloy is 55 GPa. The mechanical properties of titanium-based alloys are directly related to their microstructure [5]. In fact, the strength and toughness of many β alloys are improved by the presence of the ω phase. The reason was attributed to the fact that α forms in a compositionally invariant way, having no long-range effect on the β matrix.

The purpose of this investigation was microstructural assessment of TNZT alloy cast by counter-gravity in Yttria-doped Titania investment shell moulds. The mechanical
properties with loading and unloading conditions, porosity levels and metal-mould reactions were also investigated.

Figure 1: Investment shell moulds: (a) gravity poured and (b) counter-gravity poured.

Figure 2: Optical microstructures of TNZT alloy: gravity poured and (b) counter-gravity poured.

The counter-gravity pouring of TNZT alloy in investment shell moulds has yielded fine grain structure in the castings. Also, the mechanical properties of TNZT alloy are superior with counter-gravity pouring. The tensile curves of TNZT alloys exhibit double yielding phenomenon. Gravity and counter-gravity poured TNZT alloy exhibited the modulus of elasticity 53.52 GPa and 55.96 GPa, respectively.

References: