11th International Conference on Advanced Materials

Rio de Janeiro Brazil
September 20 - 25

ICAM2009

Pore structure study of powder metallurgy titanium for surgical implants

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Abstract – Porous titanium (Ti) have been used for bone-replacement implants since they induce new bone tissue formation inside the pores providing a better mechanical stability at the implant-bone interface. A high and interconnected porosity is required to enhance bone ingrowth and osseointegration. The porous Ti samples were manufactured by powder metallurgy (PM) with different Ti powder sizes and two different spacer materials, in order to evaluate the influence of these parameters on pore morphology. The results indicate that porosity morphology depends strongly on powder Ti and spacer sizes, as well as the spacer type used.

Evaluation of pore quantity and pore morphology is essential to optimize the processing parameters of porous materials [1]. In this study, porous Ti samples were manufactured by powder metallurgy (PM) with different Ti powder sizes and two different spacer materials, in order to evaluate the influence of these parameters on pore morphology. Pure Ti powder HDH grade 2 (Micron Metals/EUA) with acicular shape were used with large or small particle sizes, 149-177 µm, 125–149 µm, or < 67 µm. Urea and ammonium bicarbonate powders (ABC) were used as spacers, with 210–250 µm or 355–425 µm particle sizes ranges, respectively. The samples were prepared according to powder Ti sizes and spacer quantities (% weight) described in table 1. The powders were mixed and compacted by cold isostatic pressing at 300 MPa in cylindrical flexible moulds (3.0mm/height, 6.2mm/diameter). DSC analysis from Ti/urea and Ti/ABC compacts were used to define the elimination parameters. The treatment was conducted in air at 200°C/2h for urea and 170ºC/2 h for ABC. Sintering was performed at 1200ºC/2 h under vacuum (10^{-6} Torr). Mean porosity was measured by quantitative metallographic analysis (Image Pro-Plus 4.0). Pore morphology and surface topography were evaluated by optical metallographic and SEM/EDX analyses.

Chemical analysis did not reveal by-product formation as a result of Ti and spacers mixtures. Table 1 shows mean pore volume fraction. All samples presented small closed micropores and interconnected macropores (Fig. 1). Samples Ti/20%Urea (1), Ti/30%urea (2), Ti/30%ABC (3) and Ti/50%ABC (6) exhibited high porosity, high degree of interconnected pores and homogeneous pore distribution, achieving appropriate pore structure for use in surgical implants. The porosity of samples made with large Ti powders (1, 2, 3), as well as those made with small Ti powders (4, 5, 6), increased progressively with spacer quantity, as expected. Micro and macropores of samples 4, 5 and 6 were rounded (fig.1c, 1d), in contrast with the angular pore type of samples 1, 2 and 3 (fig. 1a,1b). These distinct pore morphologies were related to the Ti different particle size ranges used and may induce different integration with bone tissue. Ti/ABC samples made with small Ti powder size, presented reduced porosity than the Ti/Urea samples. These results indicate that porosity morphology depends strongly on powder Ti and spacer sizes, as well as the spacer type used.

In a previous in vivo research [2], plugs similar to Ti/30%Urea sample were inserted in rabbit tibias, resulting significant bone ingrowth eight weeks after surgery and a high shear strength displacement to bone. The other samples will also be evaluated to assess the influence of these different pore morphologies on *in vivo* osteogenesis.

Table 1: Sample data and porosity results.

(1) Ti /20%Urea	(2) Ti /30%Urea	(3) Ti/30%ABC	(4) Ti/30%ABC	(5) Ti/40%ABC	(6) Ti/50%ABC
64,29%	70,73%	69,69%	46,35%	55,78%	60,71%

(1) (2) Ti/149-177µm; (3) Ti/125-149µm; (4) (5) (6) Ti/< 67µm

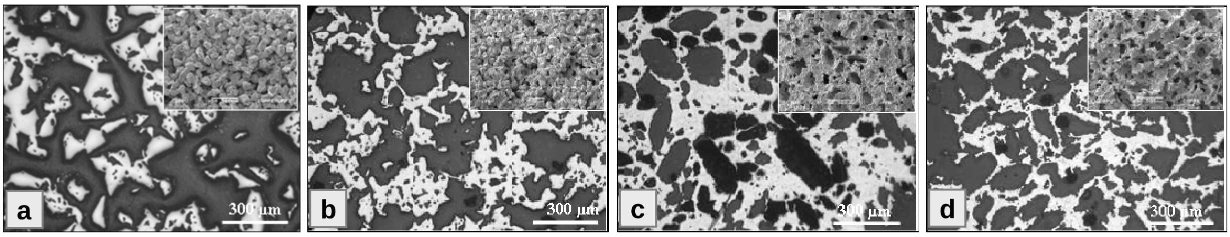

Figure 1: Optical and SEM (in detail) micrographs. Samples: 2-Ti/30%Urea (a); 3-Ti/30%ABC (b); 5-Ti/40%ABC (c); 6-Ti/50%ABC (d).

[1] V Karageorgiou, D Kaplan, Biomater. 26 (2005) 5474-5491.
[2] L.M.R. Vasconcellos, J. Mater. Sci.: Mater. Med. 19 (2008) 2851-2857.