Concept of a Bioactive Implant with Functional Gradient Structure

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Statement of Purpose: Materials such as polymethylmethacrylate (PMMA), Hirata (2005) combined with hydroxyapatite (HAp),Ono (1999) are coming closer in approaching the qualities of an ideal implant material its low satisfactory mechanical strength and stiffness associated with biological interaction, Eppley (2005). Searching for a material that can reaches properties to satisfy bone reconstructions mostly, this work aimed the development of a material able to be used as a bone implant for specific applications. A bioactive material composite with high mechanical strength designed with a PMMA functional structure gradient having a dense core enveloped by a porous bioactive surface is proposed for such applications. The proposed solution establishes that all implant surfaces should be bioactive; that porous surfaces in contact with bone are extremely necessary for bone adhesion; that the porous surfaces are necessary for interaction with the available periosteal tissue used in the surgical technique to eventually wrap the implant in order to prevent any accidental implant exposure and contamination. The effective interaction between the periosteal tissue and the implant avoids contamination as bone tissues recover by themselves.

Methods: The concept of functional gradient bioactive structure is based in two formulations, the first one called porous bioactive part, and the second is called dense part.

The porous bioactive part composite was produced with HAp and PMMA by mixing HAp granules (4.1 wt%), PMMA (14.0 wt%), MMA (42.0 wt%), Carboxymethylcellulose powder (CMC) (1.9 wt%), Soken Chemical & Engineering Co., Ltd., Tokyo, Japan and water (38 wt%).

The manufacturing process involves four stages. The first stage involves the porous bioactive part processing, when the PMMA spherical powder (∅ 8.0μm) was mixed with HAp granules and CMC powder (∅equivalent 3.0μm); then, the water is added to the mixture and in that stage the CMC change to gel linked like a rosary making a three-dimensional net; finally, the MMA monomer is added and mixed to start the crosslink. The plastic behavior of the composition allows the mixture be manually transferred to the mold surface, if not exceeding five minutes in time. In the second stage the dense part is prepared with a mixture of PMMA powder (33.3 wt%) and MMA monomer (66.7 wt%). In third stage, the porous bioactive part is handled and deposited inside the mold surfaces. The gradient structure is obtained spreading the mixture using a spatula. Thicknesses close to 0.5 mm is obtained, immediately after the deposition of the porous bioactive part. The core of the mold is then filled with dense casted PMMA. In the fourth stage, the mold is sealed and wet isostatic pressed at 0.2 MPa during 40.0 minutes and after, boiled in water for the totally polymerization and monomer/CMC gel removal. The mold used is made of a cylindrical silicon rubber with a hole and cap.

Results: The implant porous bioactive part was analyzed *in vitro*, and showed no toxicity; tests *in vivo* showed remarkable biocompatibility.

The EDX and the SEM tests showed a fair hydroxyapatite distribution in the implant pores surface as much a little part which was retained inside the PMMA inner porous. The average pores size obtained was approximately 250.0μm. The diameter shrinkage of 4.0% was observed in all samples.

Conclusions: In this study one can conclude that the method of manufacturing of a porous PMMA structures using CMC allowed the formation of a uniform hydroxyapatite distribution in the pores surfaces as well inside the porous matrix which improved considerably the morphological characteristics of the pores and allowed the totally removing of the CMC. The initial characterization of the PMMA porous matrix showed biomimetic trabecular features; the surface of the porous matrix impregnated with HAp has identified the presence of induced porosity with round oblong interconnected pores.

References:

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