Abstract

Development of Injectable and In Situ Solidifying Biomaterials for Vertebral Body Repair—Synthesis, Characterization, and Application †

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Presently, kyphoplasty constitutes one of the most advanced methods to treat and repair fractured vertebrae. This is a minimally invasive surgical technique that consists in the percutaneous injection of a bone cement inside the collapsed vertebral body, after restoration of its height with an inflatable balloon tamp. After being injected, the bone cement becomes solid, thus increasing the mechanical strength of the repaired vertebra. Typically, the bone cements used in kyphoplasty are based in poly (methyl methacrylate) (PMMA), or other acrylate-based compositions, in which polymerization reaction enables the production of an injectable and in situ solidifying paste. Its composition needs to contain radiologic contrast materials to monitor surgery in real time. Although conventional bone cements are taken as efficient and safe to apply in kyphoplasty, several risk factors and limitations remain, motivating the search for alternative biomaterials.

The main objective of this study has been the development of a new injectable biomaterial for kyphoplasty that would be able to repair a fractured vertebra and, ideally, enable new bone formation. This involved the synthesis of a composite material that replicates some characteristics of natural bone. Natural hydroxyapatite was selected as the fundamental mineral in the intended composition. Detailed studies involving the calcination of human, bovine and porcine bone at diverse temperatures (600, 900 and 1200 °C) were performed in order to obtain advantageous properties. Barium sulphate was added to the solid phase. The ratio of minerals was studied to obtain adequate radiocontrast. These components were combined with a polymeric system based on poly (vinyl alcohol) and other reagents, so that the concentration of solids in the polymeric solution could provide an adequate initial viscosity for injection of the mixture. A chemical reaction between hydroxyapatite and a carbodiimide lead to the formation of a hybrid intermediate that, after addition of the other reagents, originated a new biomaterial that could solidify at the physiological conditions existing inside a vertebral body. The introduction of controlled porosity in the solidified material was achieved using microcapsules based on poly (lactic acid), modified with specific borax contents. The composite materials obtained along this work were thoroughly characterized relative to chemical, structural and mechanical properties. The formulations that better fulfilled the desired material requirements were further tested regarding biocompatibility with blood and with osteoblasts. Moreover, a preliminary in vivo study was conducted using one selected solid formulation, which was implanted in an animal model. This essay showed promising results relative to osteoinductive properties of the tested new biomaterial.
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