Calcium Based Fillers Promote Bone Defect Healing Around Porous Titanium Implants

Lim, L Z; 1 Bobyn, J D; 2 Ökuye, M J; 1 Barralet, J E; 2 Bobyn, K M; 1 Tanzer, M
1Division of 1 Experimental Medicine and 2 Orthopaedics, Faculty of Medicine, 3 Faculty of Dentistry, McGill University, Montreal, Canada
john.bobyn@mcgill.ca

Introduction:
Revision arthroplasty surgery often involves loss of bone stock and cavity defects that result in suboptimal implant fit, reduced initial stability, and reduced potential for biologic fixation of porous implants. Several types of biomaterials have been proposed for defect filling as substitutes for autogenous bone graft; these include calcium phosphate (CaP) and calcium sulfate (CaS) compounds. Medical grade formulations of Ca-based biomaterials have been developed with porosity and bio-degradation characteristics that encourage invasion of cellular blood supply and osteoclastic activity, all of which are necessary for bone regeneration. The purpose of this study was to investigate the gap healing potential of two different Ca-based materials in a canine implant model using porous titanium implants.

Materials and Methods:
Gap-type intramedullary implants were fabricated from commercially pure titanium with a 5mm diameter central porous rod and 11mm diameter solid end and central spacers to create two separate 3mm gap regions between host bone and porous metal implant (Fig 1). The titanium foam core was 55% porous with an average pore size of 400µm. One gap filling material was a commercial formulation of nanocrystalline apatitic CaP (Etex Corp, MA). The CaS material was in the form of small granules ranging between 20-400 µm in diameter. Adding sterile saline to the materials at the time of surgery produced compounds with handling characteristics conducive to molding and shaping into the implant gap regions. Prior to setting, the CaS compound was relatively soft and paste-like while the CaP compound was harder and more putty-like. The proximal 3mm implant gap was manually filled with either CaP or CaS, leaving the distal gaps empty as controls. Six dogs underwent bilateral surgery, each dog receiving one implant containing each material into the left or right proximal humerus. After 12 weeks, the humeri were harvested to yield 6 sets of paired data from each animal comparing CaP with CaS. The humeri were scanned with a high voltage, high resolution microCT (µCT) scanner to obtain 18µm thick serial images of the complete bone-implant construct. The resulting 1000 serial CT images of each gap were used to quantify the extent of resorption of the Ca-based materials and bone formation within the implant gaps, expressed as a volume percentage of the gap. Specimens were subsequently embedded in acrylic and undecalcified transverse serial sections were visualized by backscattered scanning electron microscopy (BSEM) to enable analysis of bone growth within the 3mm gaps as well as within the porous implant regions. Statistical comparisons were made using paired and unpaired Student’s t-tests and multiple two-level hierarchical models, with p<0.05.

Results:
MicroCT quantified both native bone and residual CaS or CaP within the gaps, without discriminating one material from the other. Compared with time zero, the total material within CaP-filled gaps diminished by a mean volume of 25%±13% (Fig 2). Compared with time zero, the total material within CaS-filled gaps diminished by a greater mean volume of 49%±7% (p=0.001).

Discussion:
Previous studies have shown that CaP-filled gaps remained predominantly filled by the material, with some new bone formation in and around the material pores (Fig 5). In contrast, BSEM revealed that most of the CaS had resorbed by 12 weeks, with most of the gaps filled with dense bony trabeculae connecting the porous implant core with surrounding host bone (Fig 5). CaP-filled implants showed more bone apposition at the porous implant perimeter than the CaS group (p=0.06) although the latter was associated with a greater mean extent of bone ingrowth (p=0.04).

Significance:
While possessing different properties and resorption characteristics, both Ca-based materials demonstrated potential for use in gap healing within a clinically relevant time frame.

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