ACCELERATED BIORESORPTION AND ALTERED OSTEOCONDUCTIVITY OF CALCIUM SULFATE BASED BONE CEMENTS IN THE OSTEOPOROTIC RAT SPINE

Wang, M L; Massie, J; Lee, Y-P; Garfin, S R; Kim, C W
Veterans Affairs Medical Center of San Diego, San Diego, CA
Department of Orthopaedic Surgery, University of California, San Diego, San Diego, CA
chollkim@ucsd.edu

INTRODUCTION
The mounting prevalence of osteoporosis and the substantial morbidity and costs associated with osteoporotic fractures will have a dramatic impact on global healthcare. Previously, we have proposed the concept of the “local treatment of osteoporosis”, or osteoplasty, as a potential adjunctive treatment strategy for patients who, despite medical optimization, remain at risk for pathologic fracture due to osteoporosis. Previous work with the resorbable salt CaSO4 has suggested that its osteoconductive nature is among the material attributes advantageous to osteoplasty. However, these studies have been largely limited to animal models exhibiting non-osteoporotic bone biology. Mounting evidence has suggested that normal bone physiology is globally altered in the osteoporotic state. We hypothesize that such systemic alterations in physiology radically affects the interaction between biomaterial and osteoporotic bone, ultimately accelerating cement resorption and interfering with the cement-mediated bone augmentation reported in non-osteoporotic animal models. The purpose of this study is to test this hypothesis that CaSO4 based bone cements exhibit a heightened bioreactivity and altered osteoconductivity under osteoporotic conditions in a preclinical model; and evaluate the performance of an injectable form of CaSO4 and a novel CaSO4/CaPO4 (Hybrid) bone cement for potential use with osteoplasty.

MATERIALS AND METHODS
Ovariectomized (OVX) Female Sprague Dawley rats were maintained on a low calcium diet for 3 months, and Normal female rats (NL) of similar age and size were maintained on regular rodent feed. Following exposure of the caudal spine (proximal tail), vertebral defects were filled with either CaSO4 or CaSO4/Biphasic CaPO4 (Hybrid) cement (Wright Medical, Arlington, TN) for each animal. A randomized unfilled vertebral defect was left as a surgical sham internal control. Cement implantation was performed on both NL (n=4) and OS (n=4) groups. Cement resorption and cortical diaphyseal bone volume fraction (BVF) were analyzed by Micro-CT throughout the 8 week period.

RESULTS

At 8 weeks, NL vertebrae injected with either cement exhibited increased cortical bone and trabecular network density compared to NL sham vertebrae. This cement mediated bone augmentation was altered in osteoporotic vertebrae, which exhibited irregular porous cortical bone not noted in OS sham vertebrae.

DISCUSSION
We evaluate here the in vivo behavior of two CaSO4 based bone cements following implantation into the osteoporotic rat spine. The pro-inflammatory and pro-osteolytic bone environment associated with the OS rat may contribute to the accelerated resorption rate exhibited by both materials. The slower resorbing Hybrid cement may offer a more desirable resorption profile for the early stabilization of pathologic bone. Of interest, the cement-mediated bone augmentation observed in the normal caudal spine is altered under the osteoporotic conditions. Such disruption of new bone formation may adversely impact the biomechanical integrity of the cement-bone construct. These findings suggest that bone cement bioreactivity is dramatically heightened, and osteoconductivity may be limited, in the osteoporotic rat spine. The disparity between the resorption profiles of CaSO4 and Hybrid cement demonstrates the material-dependence of accelerated cement resorption within the OS rat. These findings may provide additional insight into the modification of common osteoconductive biomaterials designed for optimal performance within an aggressive bone microenvironment, such as that of the osteoporotic spine. Future study of potential biomaterials intended for use with osteoplasty will necessitate further exploration of the relationship between biomaterial performance and osteoporotic bone pathology. The rat OS model provides a consistent and cost-effective system to test such potential materials within the osteoporotic spine and may aid in future endeavors to identify ideal osteoplasty bone cements.

Fig. 1. Cement resorption profiles under NL and OS conditions demonstrated by Micro-CT 3-dimensional surface reconstructions. Both cements demonstrated accelerated cement resorption profiles under OS conditions compared to NL. Under both conditions, residual Hybrid cement was evident at 8 weeks, while CaSO4 exhibited no radiographic evidence of residual material by 8 weeks.

Fig. 2. Bone microarchitecture of caudal vertebrae following cement implantation analyzed by micro-CT. At 8 weeks, NL vertebrae injected with either cement exhibited increased cortical bone and trabecular network density compared to NL sham vertebrae. This cement mediated bone augmentation was altered in osteoporotic vertebrae, which exhibited irregular porous cortical bone not noted in OS sham vertebrae.

Fig. 3. Bone Volume Fraction analyzed by micro-CT radiomorphometry. At 8 weeks, OS vertebrae implanted with either cement exhibited decreased BVF compared OS sham vertebrae (*, p<0.05, **, p<0.01).