INTRODUCTION: Self-setting calcium phosphate (CaP) bone cement has been used to restore the mechanical properties of vertebral bodies during treatment by kyphoplasty or vertebroplasty [1,2] and to augment the anterior column in traumatic thoracolumbar burst fractures [3]. Most previous studies have used limited ex vivo biomechanical tests to characterize the mechanical response post-treatment. Although in vivo ovine [4] and goat [5] models have been used to evaluate post-augmentation histological changes, they have not been used to examine the biomechanical effects of treatment. We compared the bone-bioceramic integration characteristics and compressive mechanical integrity of two CaP cements used to fill defects in ovine vertebral specimens created ex vivo and in vivo.

METHODS: As part of a broader in vivo study with skeletally mature sheep (approved by an Institutional Animal Care and Use Committee), ossous defects (~500 mm³ in vol.; 0.5 mm dia.) were created adjacent to the cranial endplate in ten vertebrae of four sheep (two vertebrae per animal). Defects were then filled with one of two CaP cements (KyphOs or KyphOs R). KyphOs and KyphOs R are self-setting CaP cements, but KyphOs R has added barium sulfate for enhanced radiopacity (Kyphon Inc., Sunnyvale, CA). The animals were sacrificed four months post-op and the treated vertebrae were dissected. For the ex vivo ovine model, defects were created at similar vertebral levels in ten specimens from five animals and were filled with the two CaP cements. The vertebrae treated ex vivo were placed in a 37°C water bath for 24 hours to allow the cements to cure before testing. Bone mineral density (BMD) measurements were taken using DEXA. µCT scans were also performed pre- and post- mechanical testing to characterize the extent of bioceramic integration and to assess cement fractures or discontinuities.

Compression testing was performed on an Instron system (Model 4505, Intron, Canton, MA) with a lockable ball joint fixture. Each specimen was: (1) preconditioned for 5 cycles (100 N to 500 N); (2) loaded to 500 N and held at the corresponding displacement for 3 minutes to reduce viscoelastic effects; and (3) compressed past its failure point to an endpoint of 70% to 80% of its initial peak load. Mechanical testing was performed at a strain rate of 0.1%/sec (~0.04 mm/sec) [6-8]. Ultimate compressive strength (at initial force peak), ultimate strain, and structural modulus (bottom left) for four specimen groups. The compressive properties measured in this study are consistent with previous findings [7,8]. Both in vivo and ex vivo ovine models provide reliable and consistent assessment of the effects of CaP on the compressive properties of vertebrae. The in vivo model is a more realistic model to be used with complimentary histological evaluations. Extensive osseointegration and adaptive peri-implant bone remodeling after four months in vivo appear to have increased whole vertebral structural integrity and reduced the incidence of implant fractures during whole bone compressive loading.

Fig. 1: Ultimate strength (top left), ultimate strain (top right), and structural modulus (bottom left) for four specimen groups.

Fig. 2: Representative 2-D µCT slices: thicker trabeculae adjacent (~300 μm above CaP) to CaP (A), pre-test discontinuities in CaP (B), and ex vivo bone-CaP interface disruption (C).


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