Evaluation of Pedicle Screw Failure in Osteoporotic Vertebrae

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INTRODUCTION:
Modern spine surgical techniques encounter great difficulty in achieving and holding fixation of osteoporotic vertebrae in cases of fracture and/or deformity. Cement augmentation of pedicle screws can improve their pull-out performance. This study investigates the mechanisms under which solid core and two new types of fenestrated pedicle screws with/without cement augmentation fail under straight dorsal pullout. The objective of the study was to determine the comparative pullout strength of the EXPEDIUM Fully-Cannulated and Partially-Cannulated Fenestrated pedicle screws and standard EXPEDIUM “solid” polyaxial screws. Two different PMMA augmentation formulations were assessed as well. Screw removal torque testing helped to quantify the force needed to free these screws from the cement once in place.

MATERIALS AND METHODS:
All procedures were approved by MU Institutional Review Board (IRB). Fifty human osteoporotic (with average bone mineral density 0.581 g/cm$^3$) cadaveric thoracolumbar vertebrae were instrumented with pedicle screws from a single vendor according to usual surgical practice. Screw geometry varied by being solid-core (“Solid”), partially cannulated with multiple side fenestrations over the distal 1/3 of the screw (“Pfen”), or fully cannulated with multiple side fenestrations over the distal 1/3 of the screw (“Ffen”). Two (differing in viscosity) commercially available polymethylmethacrylate (PMMA) cements were tested for augmentation. Radiographs were taken to evaluate cement distribution and screw trajectory (fig 1).

Pullout testing was performed on all screws. A pushrod-yoke fixture was developed to apply pure dorsal pullout to the vertebral body (fig 2). Dorsal pullout was applied using displacement control on a servohydraulic Instron.

RESULTS:
Initial failure was significantly higher (P<0.05) for augmented compared to the non-augmented samples (fig 3). The partially fenestrated screws augmented with CONFIDENCE cement demonstrated significantly higher pullout strength than solid-core screws augmented with CONFIDENCE and fully-cannulated screws augmented with Vertebroplasty. Solid core screws augmented with CONFIDENCE required significantly higher extraction torque (p<0.05) but all failures occurred at the implant – cement interface leaving the cement mantle to remain in the bone.

DISCUSSION:
Based on the findings in this study, the use of cannulation and fenestrations in pedicle screws as a means of delivering augmentation cement in a controlled manner seems promising. There was a considerable observed difference in the location and dispersion of material in the screws with fenestrations (fig 1). It is believed that the fenestrations, whether partial or full, led to a more optimal distribution of cement inside the vertebrae when the CONFIDENCE cement was used. This distribution led to significantly (p<0.05) higher failure loads for the fenestrated screws used with CONFIDENCE. The viscosity of the Vertebroplasty was less than optimal for injecting down the screw cannula and thus less of an effect was seen in those samples.

ACKNOWLEDGEMENT:
Work funded by MU Grant # 00023145, from Depuy Spine.