Can the decrease in failure strength due to augmentation of functional spine units be avoided using low modulus bone cement?

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Statement of Purpose: An increased fracture rate of the adjacent vertebrae has been observed after vertebroplasty [1]. Decreased failure load has been noted in a laboratory study of augmented functional spine units (FSUs), where the adjacent, non-augmented vertebral body consistently failed [2]. This may provide evidence that rigid cement augmentation may facilitate the subsequent collapse of adjacent vertebrae. The purpose of this study was to evaluate whether the decrease in failure strength of augmented FSUs can be avoided using a low modulus PMMA bone cement [3].

Methods: Thirty-three human FSUs (T9-L4) from ten specimens were prepared and assigned to three homogenous groups with respect to bone mineral density (BMD), spine level, FSU height, FSU cross section and disc height. First group comprised the untreated Control, second - for augmentation with a low-modulus cement (C_35) and third - with regular PMMA cement (C_0) (Vertecem, Synthes). Parameters were received from CT scans (Scanco, Xtreme CT), AP- and lateral radiographs (Fig.1).

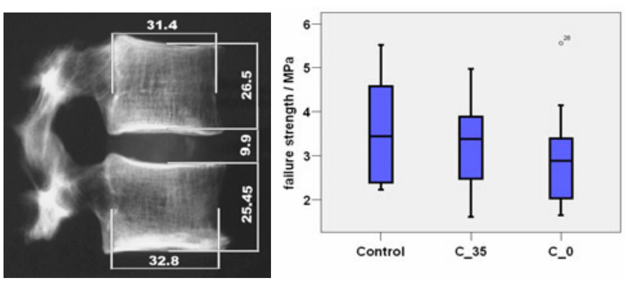

Figure 1. Radiograph with FSU dimensions (left). Failure strength of FSU groups (right).

FSUs assigned for vertebroplasty received bipedicular augmention to the caudal vertebral body. For mechanical testing each FSU was mounted in a servo-hydraulic machine. Following dynamic preconditioning, the FSU was axially compressed to failure at a constant displacement rate of 0.5 mm/s. Failure strength and overall stiffness were determined using force-displacement curves and specimen dimensions (Fig.1, left). Additionally, the individual stiffness of the caudal (stiffness VB_{caudal}) and cranial (stiffness $VB_{cranial}$) vertebral bodies was determined by measuring their displacements by an optical motion tracking system. During the destructive test, an x-ray video was taken using a C-arm image intensifier to determine which vertebral body failed first, failure mechanism and resulting fracture pattern. Failure strength, overall stiffness and stiffness $_{difference}$ (defined: stiffness VB_{caudal} – stiffness $VB_{cranial}$) were statistically analyzed by an ANOVA followed by post hoc testing ($p < 0.05$ for significance).

Results/Discussion: Volume of injected cement was approx. 37 ± 21% of the total volume of the vertebrae. There was a negative linear correlation between degree of filling and the BMD, i.e. a lower degree of vertebrae filling corresponds to denser bone in both groups (R^2 = 0.67). In the Control and C_35 group failure occurred in the cranial vertebrae in 5 of 11 and 7 of 11 cases. For the C_0 group 10 failures occurred in the non-augmented cranial, and one in the caudal vertebrae. The FSUs showed endplate and wedge-shaped fractures as seen clinically. The distribution of these fracture types was different for the three groups. The ratio of endplate to wedge-shaped fracture was 3:8; 4:7 and 10:1 for the Control, C_35 and C_0 groups, respectively. High similarity in fracture pattern for the C_35 and Control group demonstrates less alteration of the mechanical system after augmentation with a low-modulus cement rather than using regular cement. No significant difference in overall stiffness was found. The failure strength of the segments was 19.4% lower for C_0 group than in the Control group and 10% lower using low-modulus cement (C_35) (Fig.1, right). These differences were not statistically significant. Parameter $stiffness_{difference}$ was significantly higher for the C_0 group compared to the other groups (Control to C_0: p = 0.003; C_35 to C_0: p = 0.002).

Conclusions: These data strongly suggests that cement with mechanical properties similar to those of cancellous bone may be beneficial in terms of reducing the fracture risk of adjacent vertebrae after vertebroplasty. Interpretation based on clinically relevant fracture patterns seems to be more important than determining mechanical parameters like failure strength to obtain a better understanding of how to achieve improvement in human application. High resolution x-ray data acquisition might improve the specification and quantification of vertebral body fracture behavior.

References: [1] Grados F. Rheumatology 2000;39: 1410-1414. [2] Berlemann U. J.Bone Joint Surg.Br. 2002; 84:748-52. [3] Boger A. JBMR Part B. 2006 submitted.