

Acrylic Vertebroplasty Alters Vertebral Load Distribution and Causes Reduction in Strength of Adjacent Vertebrae

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INTRODUCTION: Percutaneous vertebro-plasty, specifically polymethylmethacrylate (PMMA), to treat vertebral defects has proven clinical success in alleviating back pain. However, the compact distribution of PMMA within the vertebrae has been shown to cause stress concentrations in the bone tissue directly above and below the PMMA bolus. This in turn is believed to cause secondary fractures of the adjacent vertebrae [1, 2]. The overall goal of this study was to test the hypothesis that vertebral body augmentation through acrylic vertebroplasty reduces the ultimate stress in adjacent untreated vertebrae due to changes in load-transfer along the spinal column.

METHODS: Twelve fresh-frozen cadaveric spinal segments (3VB+ 2Discs) from 6 human spines were utilized in this study (mean age 73 ± 3 years). To simulate a worst-case scenario, the L1 and L3 vertebrae (treated group) were injected with PMMA using a transpedicular-bilateral approach with the middle vertebra left untreated. Through each pedicle 5 cc of PMMA (SimplexP, Stryker) was injected into the anterior 2/3 of the vertebral body. The cement was allowed to cure for 24 hours with the specimens kept at 4°C. Specimens were mounted to a 6DOF robotic arm in load control. Pure compressive load was applied while eliminating shear forces and bending moments, thereby following the path of least resistance. The compressive load was increased till the segment has fractured or compressed 20% of its initial height. The load-deformation curve was extracted from the load-cell data and cross-head coordinates. At each 600 N load increment, plane X-rays were taken to identify fractures. The ultimate stress of the control group was used to predict the failure stress of the treated group.

RESULTS: The average ultimate stress of the vertebroplasty treated spinal segments was 36% less compared to the ultimate stress of their counterparts in the control group. The bilateral vertebral body augmentation resulted in all but one specimen in a significant loss of strength of the middle vertebra ($p < 0.01$). A comparison in the fracture types by X-rays showed that the superior and inferior endplates of all L2s in the treatment group were fractured whereas in the control group,

the segment failure were mostly due to cancellous bone failure resulting in a wedge fracture pattern (Figure 1).

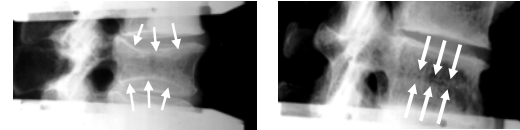


Figure 1: (Left) Spinal segment with top and bottom vertebrae treated with PMMA resulted in fractures at the endplates of the middle untreated vertebra upon compression. (Right) Compression of an untreated spinal segment resulted in a wedge fracture pattern.

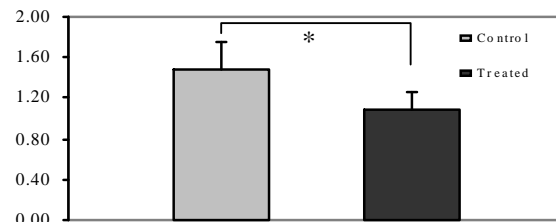


Figure 2: Ultimate Stress [MPa] of the treatment group is on average 36% lower than the ultimate stress of the control ($p < 0.01$; $n = 6$).

DISCUSSION & CONCLUSION: The goal of this cadaveric study was to investigate the effect of vertebroplasty on adjacent vertebral strength. The lowered strength and the distinct failure pattern at the endplates of the adjacent vertebrae after vertebroplasty indicate a change in load transfer along the spinal column due to the procedure. The results supported the hypothesis that the presence of the PMMA cement within the vertebra prevented normal deformation of the treated vertebra upon compression, forcing an increased endplate bulge into the adjacent untreated vertebrae and hence initiate premature tissue damage leading to catastrophic failure. Similar conclusions have been drawn in previous numerical studies [2,3]. New types of bone cements with different distribution patterns may be able to reduce adjacent bone failure.

REFERENCES: ¹Uppin AA, et al. (2003) *Radiology* **226**:119-24. ²Polikeit A, et al. (2003) *Spine* **28**: 991-996. ³Baroud, G, et al. (2003) *Eur Spine J.*, **12**: 421-6.