INTRODUCTION:
The percutaneous application of a bone cement, specifically polymethylmethacrylate (PMMA), to vertebral defects associated with osteoporotic vertebral compression fracture has proven clinical success in alleviating back pain. However, as many as 20% of treated patients are expected to sustain further fractures, and the majority of new fractures (67%) are estimated to happen within just 30 days of the procedure, with approximately 67% of the new fractures occurring in the vertebra adjacent to the one that was treated [1]. 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, which may lead to additional fractures of the already treated vertebrae and adjacent untreated ones [3].

The elevated risk of adjacent bone fractures is still controversial, however, two theories have been hypothesized: 1) The elevated risk is attributed to the altered force distribution to the nearby vertebrae caused by a shift in the applied load, 2) the adjacent vertebrae are the next weak link along the spinal column to fail.

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 change in load-transfer along the spinal segment.

METHODS:
Twelve fresh-frozen cadaveric spinal segments (3VB+ 2Discs) from 6 human spines (6 T10-T12, 6 L1-L3 segments) were utilized in this study (mean age 73 ± 3 years). Specimens were stripped of soft tissue, while ligaments were left intact. Specimens were kept moist with saline soaked gauze at all times during testing. To reduce biological variability between donors and to increase statistical power the thoracic spinal segment was selected as control while the lumbar segment from the same spine was treated since the ultimate stress has been shown to vary only minimally along the spinal column [2]. To account for the difference in bone size between the 2 anatomic regions, we normalized the ultimate load by the cross sectional area of the middle vertebra determined at mid height through computed tomography imaging.

To simulate a worst-case scenario, the L1 and L3 vertebrae (treated group) were injected with PMMA with 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 cured for 24 hours with the specimens kept at 4°C.

The inferior and superior vertebral bodies were potted in bone cement in preparation for mechanical testing. Specimens were mounted to a 6DOF robotic arm with force feedback to apply pure compressive load while eliminating shear forces and bending moments, thereby following the path of minimum resistance (Figure 1). In contrast to uniaxial testing machines, the robotic system was programmed to find the weakest region within the specimen and follow its fracture pattern by adjusting its crosshead position in space.

The compressive load was increased in increments till the

Figure 1: Robotic testing system has 6 degrees of freedom (DOF) and was programmed to follow the path of minimum resistance in order to detect the weakest part of the specimen.

Figure 2: (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.

DISCUSSION:
The goal of this cadaveric study was to investigate the effect of vertebroplasty on adjacent vertebral levels. The lowered strength and the distinct failure at the endplates of the adjacent vertebrae after vertebroplasty, plus the strong correlation between ultimate stress reduction and cross sectional area supported the hypothesis that the presence of the PMMA cement within the vertebra prevented normal deformation of the vertebra upon compression, forcing an increased endplate bulge into the adjacent untreated vertebrae and hence lower their strength. Similar conclusions have been drawn in previous numerical studies [3,4]. New types of bone cements with different distribution patterns may be able to reduce adjacent bone failure.

REFERENCES: