

Volumetric Bone Density Measurements on Computed Tomography Scans Predicts Pedicle Screw Pullout

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Introduction: Spinal bone mineral density (BMD) is an important factor to consider prior to instrumentation with pedicle screws. Low bone mineral density has previously been correlated with higher rates of instrumentation-related complications. This study aims to assess the correlation between spinal BMD measurement techniques and pedicle screw pullout strength.

Methods: A biomechanical assessment of pedicle pullout strength was performed on human cadaveric thoracolumbar spines. Pullout strength, pullout energy, and pullout stiffness were measured and then correlated to various 2D and 3D methods of assessing spinal bone density on CT scans in Hounsfield units (HU). In total, 11 human cadaveric thoracolumbar spine segments were obtained, of which 7 were subjected to 30,000 cycles and cyclic fatigue using a coming flexion-compression-anterior shear moment and 5 were not. The average age of the donors was 67 years old (range: 60 to 77 years old). All specimens were instrumented with 6.5 mm diameter and 45 mm length pedicle screws. A total of 30 pullout tests were performed. Pullout testing was performed on each pedicle screw by subjecting them to a continuous vertical load oriented along the principal axis of the pedicle at a rate of 5mm/minute using a servohydraulic testing frame. In total, 8 measurements were performed: 3D vertebral body, 2D axial vertebral body, 2D sagittal vertebral body, 3D pedicle, 2D AP pedicle, 2D axial pedicle, and pedicle width.

Results: With regards to pullout strength, the volumetric body ($R=0.65$, $p=0.006$) and volumetric pedicle ($R=0.63$, $p=0.009$) had the strongest correlation in the non-fatigue cohort. There were no significant correlations to pullout strength in the fatigue cohort. With regards to pullout energy, the volumetric body, axial body, sagittal body, and volumetric pedicle measurements had the strongest correlations in the non-fatigue cohort ($R=0.78$, $p<0.001$). In the fatigue cohort, only the volumetric pedicle, axial pedicle, and AP pedicle measurements correlated to pullout energy ($p<0.05$). There were no significant correlations for the pullout stiffness.

Discussion: We found that 3D measurements of bone density of the pedicle had strong correlations to pedicle screw pullout strength and energy. These measurement techniques should be considered preoperatively to predict pullout strength more accurately. An improved understanding of possible pedicle screw failure may help facilitate alternatives to traditional pedicle screw placement techniques.

Significance/Clinical Relevance: Our results suggest that the 3D measuring technique of bone density of the pedicle on CT scans in Hounsfield unit should be considered preoperatively prior to pedicle screw instrumentation due its strong correlation to screw pullout strength for energy.