The initial fixation strength of pedicle screws is commonly tested using a standard pull-out test, with load applied at a constant rate. This method overlooks the cyclic nature of in-situ loading responsible for clinical failure. This study was undertaken to determine the effects of stress relaxation properties at the bone-screw interface on screw fixation strength. Pedicle screws were inserted into calf lumbar vertebrae, using a paired testing array. After embedding and mounting in a custom fixture, axial pull-out tests were performed at the rates of 1mm/min, 5mm/min, and 25mm/min. For each vertebra, one screw was pulled at a continuous rate. The other screw was pulled at increments of 0.5mm, at the same rate, with 1,000 seconds pause between increments. Peak load, energy-to-failure, displacement-to-failure, and stiffness were calculated for each screw pull-out test. Two-way ANOVA showed that the standard pull-out method yielded significantly higher peak loads (p<0.05) at faster pull-out rates, and higher stiffnesses (p<0.05) at all rates compared to the stress relaxation pull-out model. These results suggest that the stress relaxation properties of bone significantly affect the pull-out behavior of pedicle screws, reducing the peak load and stiffness values observed during testing. This mode of testing may provide a better biomechanical model of screw pull-out failure, and a more accurate estimate of initial fixation strength.

Our study of microCT morphometry showed that the trabeculae in the pedicle are plate-like and isotropic. Anisotropy in the trabecular network is mainly derived by a particular direction of loading in the bone. Considering the combined bending moments caused by facet orientations in the spine, it is not surprising to observe an absence of anisotropy in the pedicular trabeculae.

The correlation analysis between BV/TV and Tb.Th and Tb.Sp showed weak interrelations, and negligible correlations between BV/TV and Conn. D. and Tb.N were observed. These findings can be interpreted such that thinning but not loss of trabeculae causes the change in the bone volume in pedicle cancellous bone. Mathematical models showed that the loss in strength by trabecular thinning was recoverable by therapeutical treatments.

Some studies in the literature documented the morphometric properties of vertebral trabeculae, ie, BV/TV (0.138 and 0.17), Tb.Th (0.156-0.217 mm and 0.17 mm), Tb.Sp (0.500-1.500 mm and 1.11 mm), and Tb.N (0.95). Our results indicated that pedicular trabeculae have somewhat different architectural properties than vertebral trabeculae. Trabeculae in pedicle were larger in thickness and number and had less spacing in the network. Moreover, the cancellous bone in vertebral body was anisotropic and consisted of mainly rod-like trabeculae whereas trabeculae in pedicle were more isotropic and plate-like. This suggests that pedicle screw fixation, because of better fixation strength within the pedicle, compares favorably to anterior screw fixation where the screws are inserted transversely through the vertebral body.