Orientation of Pedicle Screw Bending Moments with Long Posterior Fixation Constructs

A.L. Freeman¹, L.A. Ferrara², G.D. Fleischer³

¹Excelen, Minneapolis, MN, United States, ²OrthoKinetic Technologies, LLC, Southport, NC, United States, ³Southern New Hampshire Medical Center, Nashua, NH, United States

Objective: The terminal screws in long posterior fixation constructs have an increased risk of failure due to excessive loads but there is a paucity of information describing the load magnitudes. Pedicle screw loads have been quantified previously but these studies have not attempted to determine the orientation of these loads. The objective of this study was to describe the orientation of bending moments acting on the S1 screws during simulated physiologic loading.

Methods: Six L2-pelvis lumbar spine specimens were obtained, carefully dissected and potted. Specimens were tested in four instrumentation states:
1) posterior fixation with pedicle screws from L2-S1 (PS),
2) iliac screws + PS,
3) AxiaLIF + PS and
4) ALIF + PS.

Pure moments were applied at ±7.5 Nm in each anatomic plane with no compressive preload. The S1 pedicle screws were instrumented to directly measure biplanar screw bending by positioning strain gages in two independent half bridge configurations. Screws were individually calibrated to measure bending in Nm. The orthogonal strain gaged surfaces of the S1 screws were carefully aligned with the anatomic planes of the spine by rotating the screws until an alignment pin was parallel to the spinous processes. The signs of the two strain channels were compared to determine the quadrant in the coordinate plane that the screw bending moment vector occupied and the angle was calculated using arctangent equations. Calculations were only performed at the peak applied moments.

Results: The S1 screw bending moment vectors were oriented in the cranial direction for flexion with small deviations from the vertical axis for pedicle screws and ALIF + PS (< 9°) and larger variations for AxiaLIF + PS and iliac screws + PS (up to 51°). Similar results were observed in extension but the bending direction vectors were oriented caudally. Screw bending moment vectors were highly variable in lateral bending due to small bending moment magnitudes. Axial torsion exhibited the most consistent orientation of the bending moment vectors. In right torsion, the left screw bending moment vector was oriented diagonally in the lateral/cephalad direction while the right screw vector was oriented in the caudal/medial direction. The directions of the vectors were consistent with high bending moment magnitudes (>0.4 Nm) but displayed a large degree of variability with small magnitudes.
Conclusion: Long posterior fixation is oriented parallel to the long axis of the spine, which may lead to the incorrect assumption that all forces also occur in this direction. While true for flexion-extension, the
spine is typically subjected to loads that are significantly more complex during the activities of daily living. These data therefore suggest that the loosening and potential failure of the caudal-most screws in a long fusion construct are the result of multi-planar loads being transferred to the screw via the fusion rods.