Effects of Lumbar Pedicle Screw Insertion Depth on Screw Loosening and Fulcrum Location: A Biomechanical Study of the Human Lumbar Spine

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Introduction

Pedicle screw fixation in the osteoporotic spine carries increased risk of loosening and failure. Increased screw insertion depth enhances pull-out strength. Yet, better guidelines for optimal screw depth in relation to screw-bone interface biomechanics and the resulting loosening risk are needed.

Purpose

To evaluate effects of screw depth on pedicle screw loosening risk.

Pedicle Length Measurement

Figure 1: Pedicle length was measured and fulcrum point was calculated in relation to the pedicle/vertebral body junction.

Methods

Specimens:

Fifty osteoporotic vertebrae L1-L5 from ten specimens
T-Score=-3.5±0.8

irLED Marker Array

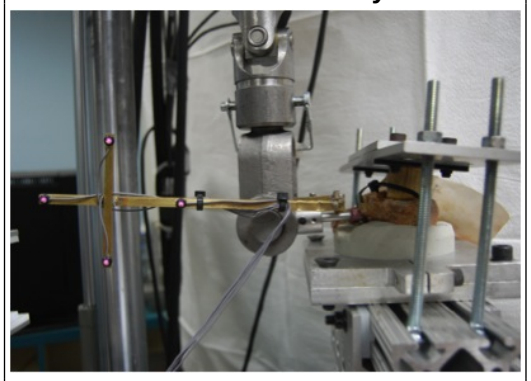

Figure 2: Four irLED markers were attached to an array and attached to the screw to measure motion.

Methods (Cont.)

Instrumentation:

Pedicle screw insertion depths of DePuy Synthes Dual Core - Matrix screws:
-Halfway through the vertebral body (mid-body)
-Up to the anterior cortex (pericortical)
-Through the anterior cortex (bicortical)

Testing:

5000 load cycles at ±2 Nm in flexion-extension to simulate post-operative activity. A 4 irLED marker array was attached to the pedicle screws to track motion (Figure 2). The screw fulcrum point (about which the screw pivots) was calculated and identified within the vertebra in terms of anatomical landmarks (Figure 1). A t-Test evaluated differences between groups ($p=0.05$).

Fulcrum Location in Flexion-extension

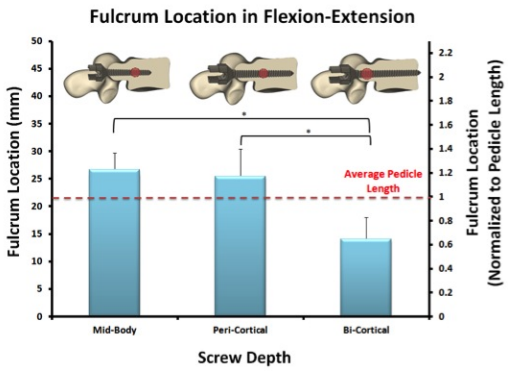

Figure 3: The location of the fulcrum point (with respect to the screw insertion point) for each testing group.

Results

Cyclic loading produced screw loosening in all groups ($p<0.001$).

Stiffness of the screw-bone interface for mid-body and pericortical screws decreased more than that of bicortical screws, with mid-body screws being significantly less than bicortical screws ($p<0.05$).

The screw fulcrum point was anterior of the insertion point (Figure 3):
-Mid-body pedicle screw: 25.8±3.8mm
-Pericortical pedicle screw: 25.3±5.2mm
-Bicortical pedicle screw: 13.8±4.2mm
Average pedicle length: 21.5±2.7mm

Conclusions

Increased screw depth substantially enhanced screw purchase. Bicortical screws had a fulcrum point about the mid-length of the pedicle benefitting from the strong cortical shell of the pedicle associated with enhanced screw purchase. Mid-body and pericortical screws had a fulcrum point anterior to the pedicle within the traebecular region of the vertebral body, which was associated with reduced screw purchase as demonstrated by pullout tests, suggesting a weaker screw-bone interface. Data suggest that bicortical screw placement significantly enhances screw purchase and decreases post-operative screw loosening leading to improved fusion and clinical outcome.

Learning Objectives

By the conclusion of this session, participants should be able to:
1) Describe the importance of pedicle screw depth in regard to loosening
2) Discuss, in small groups, the effect of pedicle screw depth on fulcrum location and loosening
3) Understand principles underlying the selection of screw depth in lumbar posterior fixation.