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Basic Science

Biomechanical analysis of four- versus six-screw constructs for short-segment pedicle screw and rod instrumentation of unstable thoracolumbar fractures

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Abstract

BACKGROUND CONTEXT: Conventionally, short-segment fusion involves instrumentation of one healthy vertebra above and below the injured vertebra, skipping the injured level. This short-segment construct places less surgical burden on the patient compared with long-segment constructs, but is less stable biomechanically, and thus has resulted in clinical failures. The addition of two screws placed in the fractured vertebral body represents an attempt to improve the construct stiffness without sacrificing the benefits of short-segment fusion.

PURPOSE: To determine the biomechanical differences between four- and six-screw short-segment constructs for the operative management of an unstable L1 fracture.

STUDY DESIGN: Biomechanical study of instrumentation in vertebral body cadaveric models simulating an L1 axial load injury pattern.

METHODS: Thirteen intact spinal segments from T12 to L2 were prepared from fresh-frozen cadaver spines. An axial load fracture of at least 50% vertebral body height was produced at L1 and then instrumented with pedicle screws. Specimens were evaluated in terms of construct stiffness, motion, and rod strain. Two conditions were tested: a four-screw construct with no screws at the L1 fractured body (4S) and a six-screw construct with screws at all levels (6S). The two groups were compared statistically by paired Student *t* test.

FDA device/drug status: Approved (pedicle screws and rods).

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The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

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RESULTS: The mean stiffness in flexion-extension was increased 31% ($p<.03$) with the addition of the two pedicle screws in L1. Relative motion in terms of vertical and axial rotations was not significantly different between the two groups. The L1–L2 rod strain was significantly increased in the six-screw construct compared with the four-screw construct ($p<.001$).
CONCLUSIONS: In a cadaveric L1 axial load fracture model, a six-screw construct with screws in the fractured level is more rigid than a four-screw construct that skips the injured vertebral body.

Keywords: Short-segment fusion; Axial load fracture; Pedicle screw instrumentation; Spine fracture biomechanics; Spine fracture fixation; Thoracolumbar instrumentation

Introduction

Axial load injuries such as compression and burst fractures involving the thoracolumbar junction without associated neurologic injury are often managed nonoperatively with bracing and early mobilization. Operative intervention may be warranted in certain fractures, especially in those with associated neurologic injury and/or perceived mechanical instability. Patient factors such as multitrauma and inability to tolerate bracing may also lead to surgical treatment in cases that would otherwise be nonoperative. In these situations, operative intervention allows for neural element decompression when needed, restoration of sagittal alignment, and early patient mobilization. The appropriate surgical technique for unstable thoracolumbar compression and burst fractures remains controversial. Surgical options include vertebral column reconstruction and instrumentation via an anterior approach, posterior instrumented fusion, or a combination thereof. Anterior column reconstruction allows for direct restoration of the vertebral body height, but with associated morbidities and potential complications accompanying an anterior approach. The posterior approach may be used to reconstruct the anterior column, but is more often used for decompression and instrumentation rather than anterior column reconstruction. As pedicle screw instrumentation was introduced and popularized, the instrumented levels mimicked the historically used hook-and-rod constructs, incorporating two or three levels above and below the level of injury, which came to be called long-segment posterior instrumentation (LSPI). Although this produced mainly successful outcomes with respect to fracture reduction, maintenance of sagittal alignment, and fracture healing, there arose concern that fusion over five or more levels could significantly decrease spinal range of motion and hasten adjacent-segment degeneration [1]. Pedicle screws allow for instrumentation of vertebrae with fractured or absent lamina and potentially provide three-column fixation [1,2]. These biomechanical advantages over hook-and-rod or wiring constructs led to shortening of construct lengths from two or three levels above and below the fractured segment to one level above and below the fractured segment, the latter coming to be known as short-segment posterior instrumentation (SSPI) [3–7].

Short-segment instrumentation initially involved placing pedicle screws in the vertebra immediately above and below the level of injury, creating a four-screw construct connected by rods spanning, but not directly incorporating, the injured level. The idea was to reduce the extent of surgery and maintain as much native spine mobility as possible, thereby hopefully reducing morbidity and the risk of late adjacent-segment degeneration. Early clinical reports, however, showed a relatively high rate of instrumentation failure and progressive sagittal plane deformity with short-segment instrumentation [8–10]. Because axial loading is shared by all three columns of the spine, if the anterior and middle spinal columns are structurally disrupted, then the pedicle screws and rods of the SSPI will be exposed to large cantilever bending loads and will be at risk for implant failure [1].

Spine surgeons have subsequently modified their techniques and indications for the use of SSPI. Highly unstable injuries such as fracture dislocations and high-energy burst fractures with extensive comminution of the vertebral body are more reliably treated with LSPI. However, it is possible to treat other unstable injuries with SSPI. One of the technical modifications that allows for the successful use of SSPI involves placing pedicle screws in the fractured vertebra, provided the pedicles are not fractured and the screws can be safely inserted. This theoretically provides additional stiffness to the construct, thereby reducing the incidence of instrumentation failure, screw pullout, and progressive deformity. There is inherent concern and skepticism, however, as to whether the addition of screws into the injured vertebra adds any real biomechanical benefit. A few reports in the literature tout the improved stability seen with the inclusion of screws in the fractured vertebral segment of a burst fracture [11–13]. To our knowledge, there are no reports on the biomechanical effects of the addition of two pedicle screws placed within the injured vertebral body of an unstable compression fracture. This study seeks to examine this question by comparing a four- to six-screw short-segment construct spanning T12 to L2 in an unstable L1 vertebral compression fracture cadaveric model.

Materials and methods

Thirteen grossly and radiographically normal fresh-frozen human cadaveric spines (donor ages 20–60 years at time of death) were thawed and manually stripped of the paraspinal muscles, leaving the facet joints, capsules, and interspinous ligaments intact. The spines were separated at the T11/12 and L2/3 discs, leaving an intact segment from T12 to L2. Multiple holes were drilled in the L1