The Spine Journal 14 (2014) 3018–3024

Basic Science

Positional effects of transforaminal interbody spacer placement at the L5–S1 intervertebral disc space: a biomechanical study

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Received 19 February 2014; revised 7 May 2014; accepted 30 June 2014

Abstract

BACKGROUND CONTEXT: Transforaminal lumbar interbody fusion (TLIF) is an increasingly used alternative fusion method over anterior and posterior lumbar interbody fusions. There are conflicting results on the optimal positioning of interbody devices. No study has addressed the lumbosacral segment, L5–S1, where the lordotic configuration presents unique challenges.

PURPOSE: To determine if there are biomechanical and/or anatomical advantages related to the positioning of an interbody device at L5–S1, either anterior or posterior to the neutral axis.

STUDY DESIGN: An in vitro biomechanical study using human cadaveric lumbar specimens.

METHODS: Lumbar specimens were biomechanically tested using pure moments with and without compressive axial loading. Testing was performed in intact and after TLIF with the implant posterior (TLIF-post) and anterior (TLIF-ant) to neutral axis. Segmental range of motion (ROM) and stiffness were analyzed at the L5–S1 surgical level and the adjacent L4–L5 level. Neuroforaminal height measurements of L5–S1 were analyzed in neutral and end range positions.

RESULTS: Compared with the intact condition, ROM decreased more than 75% at L5–S1 and stiffness increased up to 270% with TLIF. There was no significant difference between anterior or posterior placement for ROM and stiffness. There was a change in L5–S1 neuroforaminal height based on the placement, with posterior placement showing a significant increase compared with anterior placement. There were no relative changes in neuroforaminal height under loading after TLIF. Compressive load did not affect the magnitudes or resulting significance of outcome measures at L5–S1 after either TLIFs.

CONCLUSIONS: An interbody spacer with the addition of posterior instrumentation significantly enhances the mechanical stability of L5–S1 regardless of interbody position. There were noticeable increases in terms of construct stability and stiffness after both TLIF-ant and TLIF-post in comparison with the intact condition. A posteriorly placed interbody implant did result in the distraction of the neuroforamin. Positioning an interbody implant at L5–S1 for TLIF with posterior instrumentation should be at the discretion of the surgeon without consequence to biomechanical stability.

Keywords: Lumbar spine; Fusion; PEEK; Pedicle screw; Range of motion; Posterior fixation

FDA device/drug status: Approved (Stryker AVS, PEEK intervertebral spacer), (Stryker XIA, pedicle screw and rods).

Author disclosures: ***RAT:*** Speaking and/or Teaching Arrangements: Stryker Spine (C). ***WFL:*** Grant: Depuy Spine (C, Paid directly to institution). ***AJB:*** Nothing to disclose. ***JLT:*** Nothing to disclose. ***NRO:*** Grant: Depuy Spine (C, Paid directly to institution).

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

There were no conflicts of interest or research funds received for this study.

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http://dx.doi.org/10.1016/j.spinee.2014.06.023

Introduction

Currently, there are a variety of interbody fusion techniques and devices to aid in spinal reconstruction. Transforaminal lumbar interbody fusion (TLIF) has been increasingly used as an alternative fusion method and has gained favor over conventional techniques, such as anterior lumbar interbody fusion and posterior lumbar interbody fusion (PLIF). The advantage of posterior-based interbody procedures, such as TLIF and PLIF, is the provision anterior column support and stabilization while achieving direct nerve root decompression through a posterior approach [1]. Transforaminal lumbar interbody fusion procedures offer additional potential benefits that include minimizing dural retraction, decreasing risk of traversing nerve root injury, and decreased epidural bleeding and potential for scarring, along with avoidance of complications and morbidities associated with the anterior retroperitoneal approach [2–8].

The TLIF procedure was first described by Harms and Jeszenszky in the late 1990s [9]. They suggested placing interbody devices in the middle or posterior third of the disc space behind the bone graft placed behind the anterior longitudinal ligament occupying the anterior third of the interspace [9]. Since this study, the literature has shown conflicting results on the optimal positioning of these devices. Subsequent biomechanical and finite element studies have suggested that placing the spacer anteriorly results in better load sharing between the interbody device and the posterior pedicle screw construct, thereby enhancing stability and successful bony fusion [10,11]. However, other in vitro biomechanical studies have suggested that the spacer should interface with the posterolateral aspect of the end plates, where resistance to axial compression is the highest [12]. Most recently, a biomechanical cadaveric model investigating anterior versus posterior placement of a TLIF cage showed no statistically significant difference in terms of three-dimensional stability or segmental lordosis in the lumbar spine [13].

The anatomical considerations when placing an interbody device via TLIF approach are distinct at the L5–S1 level. The L5–S1 level is elliptical in cross-section in comparison with a kidney-bean shape at other levels. The coronal to sagittal diameter of the end plates are large compared with other spinal levels and result in the largest cross-sectional area [14]. The lordosis at L5–S1 is due to a dorsally tapered L5 vertebra [15] and a 10 to 15 mm anterior disc height [16]. These characteristics along with a unique facet orientation result in the most flexion/extension motion [17] and least lateral bending and axial rotation motion [18] of the lumbar levels. In addition, the foraminal area at L5–S1 has been shown to behave differently from the other lumbar levels when moving from flexion to extension [19]. Although biomechanical studies have looked at anterior versus posterior cage placement in the lower lumbar levels, none have addressed this consideration at the lumbosacral junction [10,12,13,20].

Many surgeons consider the L5–S1 interspace to be the level where interbody support would be most often justified. This belief is based on the lumbosacral junction portending a higher rate of pseudoarthrosis and instrumentation failure when compared with any of the superjacent motion segments. For fusion at L5/S1, there are additional anatomical and biomechanical variations that are unique. These variations include the ''uncinate-like'' lateral processes of the sacrum, a more concave end plate and the additional stabilization offered by the iliolumbar ligament. These factors call into question the placement of an interbody device when attempting circumferential arthrodesis across the lumbosacral junction. To our knowledge, there have been no reports of the optimal positioning of a TLIF device, specifically at the L5–S1 intervertebral disc space, although the lower lumbar levels are the most common level for fusion surgery in the lumbar spine. This study was designed to determine if positioning of a TLIF spacer in an anterior or posterior position relative to the neutral axis of the vertebral body at the L5–S1 interspace has biomechanical and/or neuroanatomical advantages.

Materials and methods

Specimen preparation

Lumbar spine specimens (L2–S1) were dissected en bloc from six fresh frozen cadavers. The average height and weight was 176±8 cm and 102±12 kg, respectively. The average age of the specimens was 57±14 years (three women, three men). Specimens were screened with radiographs (anteroposterior and lateral), dual-energy x-ray absorptiometry (DEXA), and gross examination after removal of soft tissue (preserving the intervertebral discs and all ligamentous structures). DEXA was performed on a Lunar DPX-IQ Pencil Beam Densitometer (General Electric, Louisville, KY, USA), and bone mineral density measurements were acquired using a lumbar protocol. Specimens were chosen based on the following inclusion criteria: no prior spinal surgery or instrumentation, free of osteophytes, significant degeneration (disc height collapse), spinal deformity, and osteoporosis.

Each specimen was prepared for biomechanical testing. Metal screws were driven into the L2 and S1 vertebral bodies and specimens were potted in Z-grip lightweight filler (Fibre Glass-Evercoat, Cincinnati, OH, USA) to provide attachment to the test fixtures. The specimens were potted in a neutral anatomical position. Specimens were kept moist with saline-soaked gauze during the preparation and testing.

Experimental testing

Mechanical testing was performed using an MTS Bionix 858 spine simulator (MTS Systems Corporation, Minneapolis, MN, USA) with custom spine test fixtures (Model