

# Exploring Lumbar Spine Flexibility vs. Stability: A Biomechanical Study on Stand-Alone Cages vs. Unilateral and Bilateral Pedicle Screw Fixation in Multilevel Lateral Lumbar Interbody Fusion

Ishani Patel, MPH<sup>1</sup>, Roberto Leonardo Diaz, PhD<sup>1</sup>, Joe Mekhail, BS<sup>1</sup>, James M Mok, MD<sup>3</sup>, Craig Forsthoefel, MD<sup>1</sup>, Farid Amirouche, PhD<sup>1,2</sup>

<sup>1</sup>University of Illinois Chicago, Chicago, IL, <sup>2</sup>Northshore University Health System, Skokie, IL

<sup>3</sup>Stanford University School of Medicine, Palo Alto, CA

Email of Presenting Author: amirouch@uic.edu

**INTRODUCTION:** Lateral lumbar interbody fusion (LLIF) is a surgical method for achieving spinal fusion in diverse lumbar conditions. While conventional LLIF involves supplemental internal fixation through pedicle screws and rods to enhance fusion stability, this approach carries potential risks, such as adjacent facet joint violation and guidewire migration, which can result in vascular complications. Conversely, stand-alone LLIF, devoid of rods and screws, presents a minimally invasive alternative that mitigates tissue trauma, postoperative discomfort, and recovery duration.<sup>1</sup> While prior research reveals a direct relationship between the extent of instrumentation and subsequent reduction in spinal flexibility, it also prompts a vital question: To what extent should flexibility be sacrificed for successful spinal fusion? This query considers whether it's necessary to completely restrict the spine's natural motion by employing more extensive instrumentation or if an optimal equilibrium exists, achieving stability while retaining a certain level of physiological mobility. This study aimed to assess the biomechanical flexibility of 26 mm lateral cages for multilevel fusion (L1 to L5), considering various spinal motions. Our hypothesis suggests that 26 mm wide interbody cages could offer comparable biomechanical flexibility to traditional rod-based methods, potentially challenging the necessity of additional instrumentation.

**METHODS:** Using custom fixtures, eight human cadaveric L1-L5 specimens underwent biomechanical assessment in a universal testing machine (MTS 30/G) (Fig 1A). An optical motion-tracking system (Optotrak, Northern Digital Inc.) recorded three-dimensional motion during varied spinal movements. Testing involved four conditions: intact, 26 mm lateral interbody stand-alone cages (stand-alone LLIF), 26 mm lateral interbody cages with unilateral rod fixation (LLIF + unilateral rod), and 26 mm lateral interbody cages with bilateral rod fixation (LLIF + bilateral rods). A physiological preload mimicking lumbar spine alignment was applied via bilateral cables, with added forces generating flexion, extension, and lateral bending movements. ROM changes were expressed as numerical and percentage decreases from the intact specimen. The slope alterations assessed ROM by comparing vertical change (rise) to horizontal difference (run) between L1 and L5 positions before and after spinal motion. L1 was chosen for its central lumbar location and alignment significance, representing overall spinal alignment changes (Fig 1B). Statistical analyses, including paired t-tests ( $p < 0.05$ ), were performed in Microsoft Excel Version 2023 to compare ROM among instrumentation conditions while accounting for potential specimen variations.

**RESULTS:** Compared to the intact state, stand-alone LLIF induced reductions in the slope of flexion by 0.29, extension by 0.89, left lateral bending by 0.93, and right lateral bending by 0.18. The variations were statistically significant for all four scenarios ( $P < 0.05$ ) (Fig 2). When compared to the stand-alone cages, LLIF with unilateral rod and pedicle screw fixation yielded additional decreases in the slope of flexion by 0.04, extension by 0.08, left lateral bending by 0.30, and right lateral bending by 0.25, with statistical significance observed for left and right lateral bending. The introduction of bilateral rods and pedicle screw fixation further amplified these reductions, showing an additional 0.29 decrease in flexion, 0.24 decrease in extension, 0.29 decrease in left lateral bending, and 0.42 decrease in right lateral bending compared to stand-alone LLIF. This difference was statistically significant across all four conditions.

**DISCUSSION:** This study revealed that adding a unilateral rod with pedicle screws reduced spine ROM by 0.08-0.30 compared to stand-alone cages, while bilateral rods and pedicle screws led to an additional 0.24-0.42 decrease. These findings echo our earlier research, which found a mere 1.1-degree difference in flexion-extension alteration between bilateral instrumentation and stand-alone cages and a similarly minimal variance of 1.42 degrees in lateral bending change.<sup>2</sup> Although a substantial 38.16% decrease in flexion appears advantageous when employing bilateral rods and pedicle screws, its quantitative effect corresponds to only a 0.29 reduction in ROM during flexion. These findings underscore the importance of evaluating absolute numerical changes alongside percentages to comprehend biomechanical alterations fully. This prompts a crucial inquiry: Is extensive incorporation of such instrumentation essential, especially when the observed differences in slope amount to fractions below 1? Does the marginal 1-2 degree decrease in ROM by implementing bilateral rods and screws justify their use in spinal interventions? Moreover, incorporating increased spinal instrumentation during fusion procedures restricts essential spinal movements, affecting patients' daily activities, work, recreational pursuits, posture, and overall well-being. Conversely, the stand-alone LLIF technique preserves natural spinal movement, facilitating a more active and fulfilling post-surgery life. A limitation of this study is its focus on an immediate post-surgery snapshot without considering healing dynamics over time. Future investigations should incorporate these dynamics to understand the necessity of extensive instrumentation for spine stabilization.

**SIGNIFICANCE/CLINICAL RELEVANCE:** The findings challenge the assumption that increased instrumentation leads to superior results, emphasizing the importance of a well-rounded strategy that accounts for stability and spinal flexibility. This insight aids in enhancing surgical decision-making and patient care.

## REFERENCES:

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Fig. 1. Experimental configuration illustrating the load cell application (A). Optical motion sensors were strategically positioned from L1 to L5, enabling the motion slope (B) computation.

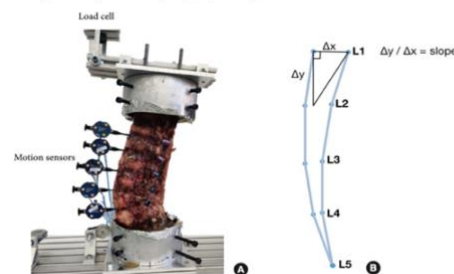


Fig 2. Bar graphs illustrate the ROM achieved by the intact spinal specimen and the specimens treated with various interventions, including LLIF with stand-alone cages and unilateral and bilateral pedicle screw and rod fixation.

