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Lecture

Removal of fixation construct could mitigate adjacent segment stress after lumbosacral fusion: A finite element analysis

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ABSTRACT

Background data: Combined usage of posterior lumbar interbody fusion and transpedicular fixation has been extensively used to treat the various lumbar degenerative disc diseases. The transpedicular fixator aims to increase stability and enhance the fusion rate. However, how the fused disc and bridged vertebrae respectively affect adjacent-segment diseases progression is not yet clear.
Methods: Using a validated lumbosacral finite-element model, three variations at the L4–L5 segment were analyzed: 1) moderate disc degeneration, 2) instrumented with a stand-alone cage and pedicle screw fixators, and 3) with the cage only after fusion. The intersegmental angles, disc stresses, and facet loads were examined. Four motion tests, flexion, extension, bending, and twisting, were also simulated.
Findings: The adjacent-segment disease was more severe at the cephalic segment than the caudal segment. After solid fusion and fixation, the increase in intersegmental angles, disc stresses and facet loads of the adjacent segments were about 57.6%, 47.3%, and 59.6%, respectively. However, these changes were reduced to 30.1%, 22.7%, and 27.0% after removal of the fixators. This was attributed to the differences between the biomechanical characteristics of the fusion and fixation mechanisms.
Interpretation: Fixation superimposes a stiffer constraint on the mobility of the bridged segment than fusion. The current study suggested that the removal of spinal fixators after complete fusion could decrease the stress at adjacent segments. Through a minimally invasive procedure, we could reduce secondary damage to the paraspinal structures while removing the fixators, which is of utmost concern to surgeons.

1. Background

Posterior lumbar interbody fusion has gradually been used to immediately restore the dehydrated disc to its original height (Corniola et al., 2015; Hikata et al., 2014). A transpedicular fixator is instrumented to stabilize the anterior vertebrae and enhance the bony fusion, thus avoiding cage subsidence and back-out at the bone-cage interfaces (Lequin et al., 2014; Oh et al., 2016). However, the rigidity-raising effect, resulting from interbody fusion and transpedicular fixation, potentially induces adjacent segment disease (ASD) problems that accelerate the degeneration of the adjacent discs and facet joints (Kwon et al., 2013; Lawrence et al., 2012; Lee et al., 2014; Nakashima et al., 2015). Such an instrumentation-induced problem has been attributed to the fact that the constrained mobility and loads of the instrumented segments is compensated for by the adjacent segments (Lu et al., 2015; Okuda et al., 2014).

As an alternative, some dynamic fixators have been designed to provide the flexibility to limit both kinematic and kinetic constraints on the instrumented segments, thus mitigating the post-operative risk of ASD progression (Barrey et al., 2016; Galbusera et al., 2011; Hudson et al., 2011; Kim et al., 2011). There have been a great many attempts to design flexibility into the dynamic fixator, such as a rod-rod joint (*i.e.* ISOBAR), a rod-screw joint (*i.e.* Dynesys), a screw hinge type (*i.e.* COSMIC), and a flexible rod (*i.e.* BioFlex). Some clinical reports showed satisfactory results for achieving a good bony fusion rate while suppressing ASD progression (Hudson et al., 2011; Kim et al., 2011). However, there are still some studies that show fixator failure (screw loosening and component wear) and post-operative complications (Barrey et al., 2016; Galbusera et al., 2011). Consequently, static, rather than dynamic

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fixators, are still the principal method of treating such lumbosacral problems.

Recently, minimally invasive spine surgery (MISS) technique for interbody fusion and transpedicular fixation has been extensively adopted (Bourgeois et al., 2015; James and William, 2015; Niesche et al., 2014). Compared with the traditional technique, the screws and rods can be instrumented and assembled through small hole-like wounds which could cause less injury to the paraspinal soft tissue structures. Whether traditional or MISS technique is adopted, however, the metallic fixation inevitably induces kinematic and kinetic compensation from the instrumented to adjacent segments (Kwon et al., 2013; Lawrence et al., 2012; Lee et al., 2014; Lu et al., 2015; Nakashima et al., 2015; Okuda et al., 2014). Using static rather than dynamic fixation, the current authors have not yet found enough literature report to reveal an effective technique to mitigate the ASD progression. Intuitively, it seems that post-operative removal of the static fixator mitigates the stress on adjacent segments. However, removing the spinal fixator from the traditional midline approach has been a major concern, due to massive destruction of the posterior musculature again. For the spinal fixators used in MISS, however, a similar attempt to remove the static fixator *via* paramedian approach might be practical (Fig. 1). From the authors' experience, the size of an entry wound to remove the MISS fixator, through the previous surgical wound, may only be around 20–30 mm (Fig. 1D).

After complete solid fusion has occurred, the current authors have attempted to remove the screws and rods by MISS technique for disassembling the highly structural constraint of the static fixator on the fused segment (Fig. 1). If this could decrease stiffness of fusion segments and reduce the disc stress of adjacent segments, this attempt potentially provides a trade-off between ASD mitigation and musculature destruction. This study used the validated nonlinearly lumbosacral model to evaluate the biomechanical differences between the 'fusion-fixation' and 'fusion-only' models. Special effort was taken to illustrate the difference in the structural constraint between fusion and fixation. If the effects of the ASD mitigation are significant, the removal of the internal fixator by MISS technique can be recommended after posterior lumbar intervertebral fusion.

2. Methods

2.1. Lumbosacral models

The lumbosacral model from L1 to S1 segments has been developed and validated in the previous studies of the current authors (Chien et al., 2014; Chuang et al., 2012; Chuang et al., 2013). For a paired facet joint, the orientation and separation of the articulating surfaces were cautiously established to ensure a consistent unloaded neutral position within a range of around 0.5 mm. Other than the L4–L5 segment, the remaining segments were assumed healthy. The geometric size and material strength of the L4–L5 segment was simulated as 'moderate degeneration'. The contractions of the five muscle groups were simulated as distributed loads to stabilize the lumbosacral column (Fig. 2). The concentrated loads (*M*: moment and *C*: compression) were the result of body weight and the contractions of the abdominal muscles. The hybrid use of compression (= 150 N) and moment (= 10 Nm) was applied at the lumbosacral top to activate lumbosacral motion. The lumbosacral

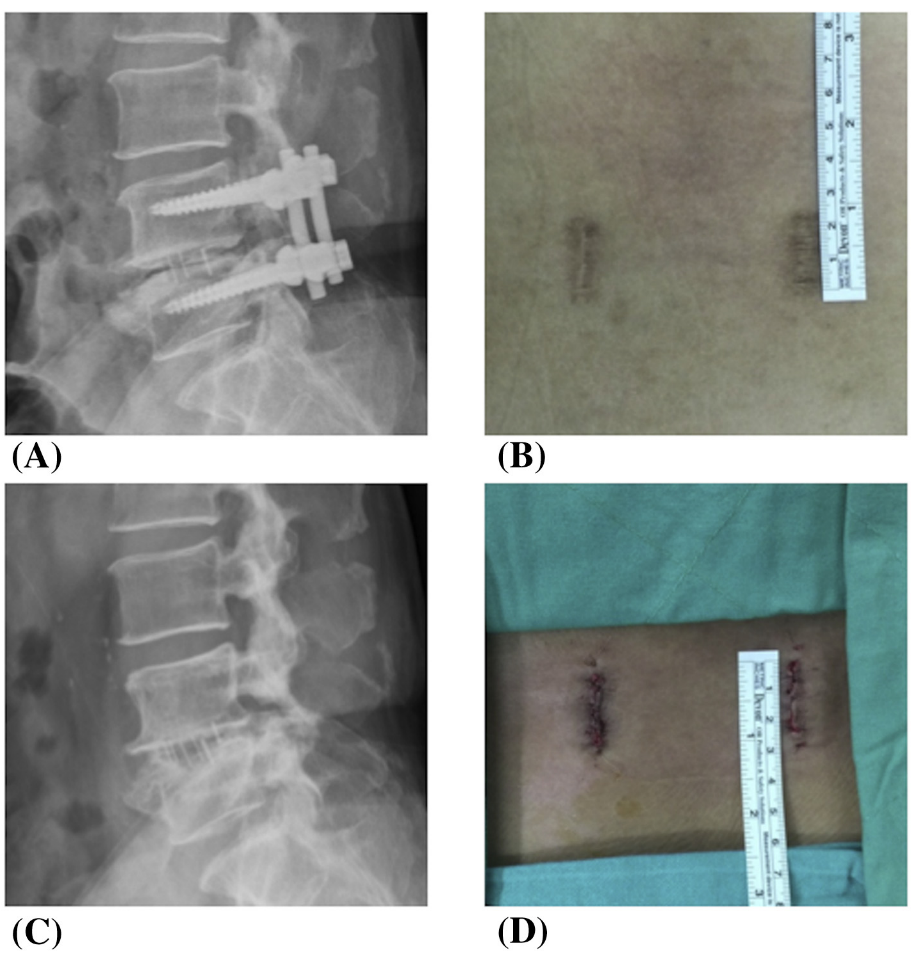

Fig. 1. The X-ray images and the operation wounds of the same patient subjected to interbody fusion and transpedicular fixation. (A) X-ray of fusion with MISS fixator. (B) The operation scars after the fusion surgery. (C) X-ray after removing the MISS fixator. (D) The new wounds after removing the MISS fixator.