Published at the DWG 2012 (German Spine Congress) in Stuttgart, Germany (December 6-8, 2012)

Biomechanical investigation of dynamic topping-off in two-level posterior instrumentation

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Introduction:
Topping-off instrumented lumbar fusion with a dynamic implant has been suggested to avoid adjacent segment disease by creating a smoother transition zone from the instrumented segments to the untreated levels above. This study evaluates ex-vivo the range of motion (RoM) and intradiscal pressure to characterize the transition zones of two-level posterior instrumentation strategies for elucidating biomechanical differences between rigid fixation and the topping off approach with a pedicle screw-based dynamic implant.

Material and Methods:
Eight human lumbar spines (L1-5) were loaded in a spine tester with pure moments of 7.5Nm in lateral bending (LB), flexion/extension (FE) and axial rotation (AR) and with a hybrid loading protocol in lateral bending and flexion/extension. The following states were tested: (a) intact, (b) laminectomy L4 with rigid fixation of L4-5 and dynamic topping off L3-4 (HPS, Paradigm Spine, Wurmlingen, Germany). (c) laminectomy L4 with rigid fixation of L3-5. The RoM for all segments for both loading protocols was evaluated and normalized to the intact segmental RoM. The intradiscal pressure was measured in the segments L3-4 and L2-3.

Results:
For pure moment loading, RoMs of the segments cranial to both instrumentations (L1-2 and L2-3) were not affected by the type of instrumentation ($p>0.5$) in FE, LB and AR. The dynamic instrumentation in L3-4 reduced the RoM compared to intact ($p<0.05$) but allowed more motion than the rigid fixation of the same segment ($p<0.05$) in LB and FE. Under the hybrid loading protocol, the cranial segments (L1-2 and L2-3) had a significant higher RoM ($p<0.05$) for both instrumentations compared to the intact (ranging from 162%-227% of the intact RoM in FE and LB). Comparing the two instrumentation approaches with each other, the dynamic topping of showed a smaller increase of RoM than the rigid fixation (L1-2 Δ=15% and 26%; L2-3 Δ=8% and 11% for FE and LB, respectively). Under pure moment loading the intradiscal pressure for FE and LB showed comparable effects for the untreated segment L2-3 (fig. 1) and comparable pressure reductions for both instrumentations in L3-4 (fig. 2).

Conclusion:
Regardless of the approach, two-level posterior instrumentation was accompanied by a considerable amount of compensatory movement in the cranial untreated segments under the hybrid protocol. Dynamic topping-off, however, showed a significant reduction of this compensatory movement in comparison to rigid fixation along with more than 50% of movement preservation of the dynamically instrumented level.
The clinical relevance of these differences cannot be deduced from this model. From a biomechanical point of view, however, they could offer advantages for the dynamic topping- off because of a slightly smoother transition zone.

Figure 1:

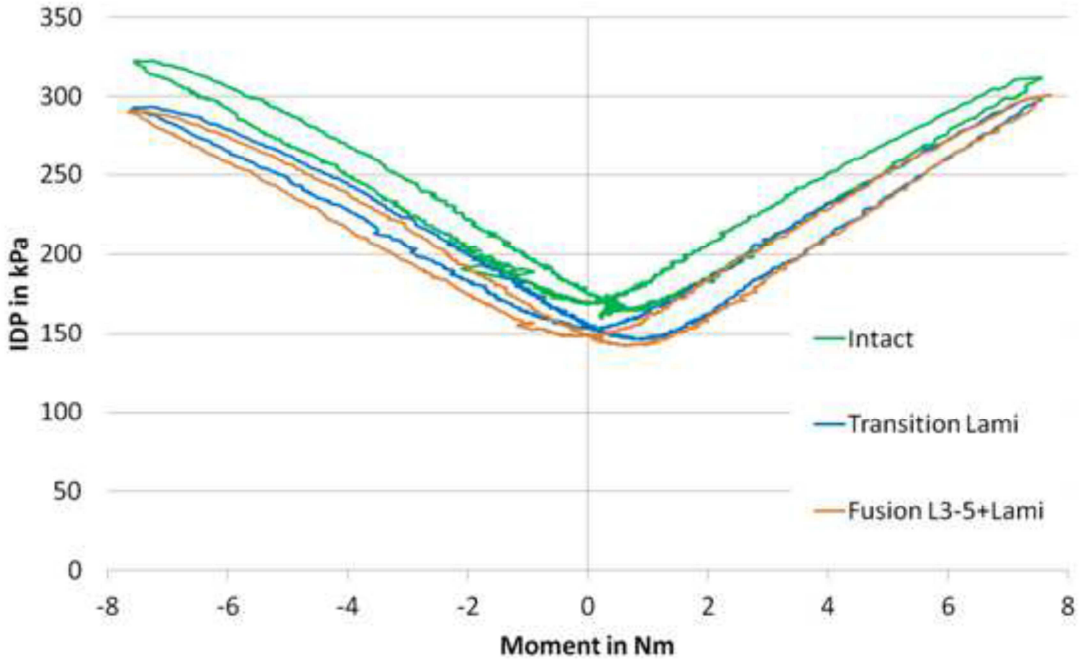

Figure 2: