LUMBAR FUSION AFFECTS LOADING OF THE ADJACENT INTERVERTEBRAL JOINT

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Introduction
Pathological changes frequently occur in an intervertebral joint adjacent to a spinal fusion. Changes may involve accelerated degenerative disk disease, facet arthropathy and lumbar stenosis, acquired spondylolysis, traumatic fracture, or pain syndromes related to nerve compression (Lee 1987, Brunet et al., 1984, Drennan et al. 1978). The time course in which these changes develop may be measured in years and will generally occur long after other complications related to fusion procedures have become evident. The tremendous increase in the number of spinal fusions performed by spinal surgeons in the present day demands that these accelerated pathological changes be assessed and prevented if possible. Adjacent joint deterioration is likely due to changed mechanical demands on the segment. The changes to the mechanical loading environment of a segment adjacent to a fusion have not been quantified previously. Similarly, the severity of these changes as a function of fusion characteristics (i.e. fusion angle) has not been quantified.

Methods
Eight fresh-frozen human lumbosacral spines were instrumented with four custom FSR-based ultra-thin load cells (Hedman 1991) at two facet levels for direct measurement of facet forces while anterior column compressive and shear forces were acquired by a custom intra-vertebral load cell (IVLC) inserted into the L3 vertebra. This in vitro model provided direct time-dependent records of force transmission in an intervertebral joint immediately above an L4/L5 fusion. Each spine was tested intact and with flexed- (anterior collapse), neutral- and extended- (hyper-lordotic) fusions. Ten load cycles from 0N to 500N were applied in flexion-compression, straight-compression, and extension compression to each construct while force data were acquired. Sagittal-plane lumped-parameter models corresponding to each loading configuration were developed to further analyze the results. These models provided means for a determinate analysis of unknown component forces.

Results and Discussion
Spinal fusion was found to produce distinct changes to the adjacent segment loading environment. The most alarming finding of this study was that flexion loading with any of the three fusion types brought about 47—55% higher anterior column shear loading compared to the intact spine (Fig. 1). This result...
suggests that forward bending and other forms of loading in the flexed posture may lead to adjacent joint deterioration following fusion. Likewise, flexion loading produced 17—29% higher anterior column compressive loading with any of the three fusion types (Fig. 2).

![Figure 2. Mean maximum anterior column compression forces.](image2)

Load sharing between the anterior and posterior joint structures of the adjacent level was most disturbed by a kyphotic fusion. This is exemplified in Fig. 3. It shows a reduction in facet forces in all three loading profiles due to kyphotic fusion. A general trend of increasing mean maximum facet forces from kyphotic to neutral to lordotic fusion could be seen with the neutral fusion facet forces closest to the intact situation. Using an objective function to assess the overall severity of changes due to the three fusion types, differences from an intact spine were the largest with a kyphotic fusion and were minimized by neutral fusion. In addition, the sagittal plane models predicted other changes in component loading trends including changes to anterior longitudinal ligament, posterior amalgamated ligament and facet impingement forces.

As expected, removal of a spinal joint affects the load transmission at the level above the fusion. This study quantified the relationships between fusion type and anterior and posterior loading changes in the adjacent segment. The most dramatic change produced by all three fusion types was increased anterior column shear force under flexion-compression loading. Previous studies suggest that increased shear loading could be deleterious to the integrity of the intervertebral disc. This study has also documented the adverse effects that result from an anteriorly-collapsed lumbar fusion. In lieu of a perfectly neutral fusion, a slight lordotic lean may be safer than a comparable kyphosis. This experimental model is currently being used to compare disc replacement technologies with neutral-fusion.

![Figure 3. Mean maximum facet forces at the level above the fusion.](image3)
References

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