SPINAL FUSION EFFECTS ON ADJACENT SEGMENTS: A COMPARISON OF DEFLECTION AND STIFFNESS

+*Haher T; **Ottaviano D; ***Lennox A; ***Wei V; **Gencarella C; **Errico C; *Valdevit A
*Lutheran Medical Center, Brooklyn, NY, **St. Vincent's Medical Center, New York, NY, ***The Cooper Union, Dept. of Engineering, New York, NY

Introduction: Spinal fusion is routinely achieved through the implantation of anterior devices. However, the effect of the inter-vertebral fusion on adjacent segments is not well documented. It would not be unfounded to hypothesize that upon the onset of solid fusion, the effect of loading is altered in both the involved and surrounding vertebra. Degeneracy of the adjacent levels is observed, and often results in expansion of the fusion to include additional segments. Radially deflecting displacement transducers mounted on the anterior and posterior surfaces of cadaveric models were utilized to investigate the deflection and stiffness of the intact and fused spines.

Materials and Methods: Five thoracic (T7-T12) cadaveric spines were embedded in Cerrobend (Cerrometals, Belefonte, PA) using aluminum sleeves and aligned with a positioning frame. In order to quantify the effects of implantation on adjacent levels, the displacements recorded during the testing modalities were utilized to infer to local and global effects of fusion.

![Image](https://example.com/image1.png)

Figure 1. A) The ACUSPAN™ radially deflecting transducer. B) Testing apparatus for multi-axial loading.

Each spine was instrumented with ACUSPAN™ (Dept. of Biomedical Engineering, The Cleveland Clinic Foundation, Cleveland, OH) radially deflecting transducers. These devices display excellent linearity. ACUSPAN™ transducers were situated posteriorly, spanning from the facets of T10 to T11, as well as anteriorly and laterally on the anterior column of T9 to T10. Non-destructive loads were applied at a rate of 1Nm/s using a materials testing machine (Model 858 Mini-Bionix, MTS Systems, Eden Prairie, MN) and fixture. The fixture permits proximal translation of the specimen in the plane of loading. Both the proximal and distal ends on the specimen can freely rotate about the axis perpendicular to the loading plane. The fixture allows manual axial rotation of the specimen to simulate the loading modes including flexion (7.5 Nm), extension (7.5 Nm), and lateral bending (7.5 Nm) loading modes. Fusion was simulated by the insertion of a stainless steel (SS) Harm’s cage (Deputy AcroMed, Raynham, MA) and rod system (T9-T10). Under each surgical condition, two loading cycles were applied for each loading modality with the data from the last cycle extracted for analysis. The output voltages from the transducers were converted to displacements using transducer-specific calibration curves.

The maximum local deflection from each transducer was compared to the global deflection, recorded by the materials testing machine. Stiffness and deflection data from the intact specimen, and the comparison of the intact and fused specimens were analyzed. Local stiffness was computed from a linear regression of the load versus deformation curve in the elastic region (obtained from the output of the ACUSPAN™ transducers). The data was analyzed using a repeated measures Analysis of Variance (ANOVA) and a Newman-Keuls Multiple Comparison Test for comparison between groups.

Results: In the intact specimen, flexural stiffness was not statistically significant between the anterior and posterior locations (P>0.05). Local stiffnesses increased 35% and 37% respectively for the anterior and posterior locations following fusion. A comparison between the fused and intact specimens revealed no statistically significant differences in anterior flexural stiffness (P>0.05). Similarly, no significant differences in posterior flexural stiffnesses were found (P>0.05). Contrasting from the intact specimen, under a fused surgical condition, a statistically significant difference was found when comparing the anterior flexural stiffness to the posterior flexural stiffness (P<0.05). (Figure 2)

![Image](https://example.com/image2.png)

Figure 2. Under a fused condition, statistically significant difference was detected between the anterior and posterior flexural stiffness.

In the intact specimen, flexural deflections between the global and local anterior and local posterior deflections differed significantly (P<0.05 for both). No disparity in maximum deflection was detected between the anterior and posterior locations, regardless of surgical condition.

In extension, the intact specimen displayed no statistically significant differences between the anterior and posterior stiffness (P>0.05). Unlike flexion, in extension, statistically significant differences were detected between the intact and fused anterior extension stiffness (P<0.05). Local anterior stiffness increased 69% and posterior stiffness increased 41% over intact levels. As was evident in flexion, a fused specimen displayed a statistically significant difference in stiffness between anterior and posterior extension (P<0.01).

In extension the deflection results were more dramatic. As with flexion, the global deflection was significantly different from both the local anterior and posterior deflections (P<0.05 for both). While no difference in deflection between the intact anterior and posterior locations were detected. Anterior deflection decreased to 62% below intact levels while posterior deflection displayed a decrease of 10% below intact levels. Under the fused condition, the anterior and posterior deflections were significantly different (P<0.05). Similar to flexion and extension conditions, the global deflection was significantly different from both the anterior and posterior local deflections (P<0.001 for both).

In lateral bending no statistically significant differences between the anterior and posterior deflections were detected. (Figure 3)

![Image](https://example.com/image3.png)

Figure 3. A statistically significant difference was found between anterior and posterior extension deflections for a fused specimen.

Discussion: Spinal fusion for the reduction of pain has proven to be successful. However, this study demonstrates that following fusion, the relationship between anterior and posterior local mechanics of adjacent segments is altered. Under fused conditions, local variations in both anterior-posterior stiffness and deflections were statistically significant. The global stiffness of the osteoporotic specimens was unchanged. The dominant motions of flexion and extension in this study provided evidence of altered anterior and posterior balance in spinal deflections. When considering fusion, the local effects of the instrumentation on the adjacent segments must be considered.