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Overall, regarding all types of loading scenarios except torsion, extrapedicular technique offered at least as much stiffness as intrapedicular technique did. This study identified increased thoracic spinal stability with the use of extrapedicular pedicle screws, in comparison to that of intrapedicular pedicle screws, in flexion, extension, lateral bending and axial compression.

#3 THE EFFECTS OF INSTRUMENTATION ON LUMBAR VERTEBRAL COMPRESSIVE STRENGTH: A BIOMECHANICAL ANALYSIS

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Although the stability and pull-out strength of spinal constructs have been studied, to our knowledge no studies have investigated the effect of implants on vertebral body compressive strength. Decreases in cross-sectional area and trabecular volume may significantly decrease vertebral body compressive strength and increase the risk of pathological fracture. This study quantitatively compares the compressive strength of lumbar vertebral bodies after insertion and then removal of pedicle screws and anterior body screws. Seven human cadaveric lumbar spines were harvested shortly after necropsy and stored at -20°C. Prior to testing, each spine was thawed and vertebrae were separated and dissected free from all soft tissue. Vertebrae exhibited no evidence of space-occupying lesions or trauma. Vertebral bodies were individually potted into liquid epoxy and then compressed to failure in a MTS (Eden Prairie, MN) materials testing device. Failure was defined as the first 10% decrease in load with increasing deformation. Each spine was tested as follows: (L1) intact control with no instrumentation, (L2) instrumented with pedicle screws, (L3) pedicle screws inserted and removed, (L4) instrumented with anterior vertebral body screws, (L5) anterior vertebral body screws inserted and removed. The compressive strength was normalized as ultimate load per unit volume and data were statistically analyzed. The average compressive strength of intact control lumbar vertebral bodies was 194 N/cc (approximately 5000 N). With pedicle screw insertion, the average compressive strength was 195 N/cc. The average compressive strength after pedicle screw removal was 168 N/cc, corresponding to a -13% decrease compared to intact controls and a -14% decrease compared to vertebral bodies instrumented with pedicle screws. The average compressive strength with anterior body screws was 181 N/cc, corresponding to a -7% decrease compared to intact controls. Following anterior body screw removal, the compressive strength was 165 N/cc, corresponding to a -15% decrease compared to intact controls and a -9% decrease compared to vertebral bodies instrumented with anterior body screws. Differences in compressive strength between all groups were statistically insignificant ($p > .05$). The average compressive strength for intact control lumbar vertebral bodies was in agreement with previous studies. Decreases in cross-sectional area and trabecular volume after spinal instrumentation decrease vertebral compressive strength and increase the likelihood of pathological fracture. With either insertion or removal of pedicle screws or anterior body screws, however, it does not appear that this effect is significant.

#4 THE INVERSE EFFECTS OF LOAD TRANSFER AND LOAD SHARING ON AXIAL COMPRESSIVE SPINAL STIFFNESS: A MECHANICAL MODEL

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The goal of spinal instrumentation is to stabilize involved motion segments until fusion occurs. As per Wolff's Law, axial load sharing is necessary for fusion to occur in situ. The purpose of this study is to utilize a well-accepted and highly comparatively mechanical model to create a mathematical relationship between stress shielding and load transfer in the spine. Forty-eight standard 62 mm diameter x 35 mm depth ultra high molecular weight polyethylene (UHMWPE) cylinders were used to represent the lumbar vertebral

elements of an 85 kg human male. Each pair of superior and inferior blocks was instrumented with either an anterior plate, an anterior rod construct or a posterior rod construct in order to produce twenty-four different one above/one below corpectomy models. Axial compression stiffnesses were determined by collecting and plotting load vs axial deformation data utilizing an MTS Bionix servo-hydraulic materials testing apparatus to apply eleven cycles of axial compressive load. Each implant was tested with and without the addition of a titanium Harms (Depuy) load-sharing cage, and the relative increase in axial stiffness realized with the addition of the Harms cage was determined. On average, the axial compressive stiffness of a system with the addition of the load-sharing device was eight and a half times greater than without it. The stiffnesses of the constructs investigated (without the addition of a Harms cage) ranged from 36 N/mm to 2,096 N/mm. All construct stiffnesses increased with the addition of the load-sharing device. However, an inverse relationship exists between the axial compressive stiffness of the implant construct and the relative increase in axial compressive stiffness achieved with the addition of the load-sharing device. The equation for the inverse relationship was found to be: (% increase w/load-sharing device) X (stiffness of the system w/o load-sharing device)$^{1.32}$ = 293,240. In addition, the compressive stiffness of the system with the addition of the load-sharing device approaches that of the load-sharing device itself as the system flexibility increases.

Conclusions: Stiffer systems allow a larger amount of the load to be transferred away from the fusion mass, thereby reducing load sharing and theoretically decreasing the efficiency of the body's reconstructive processes via Wolff's law. A fixation method must be stiff enough to effectively stabilize the spine, but not so stiff that excessive stress shielding occurs. The technique and result of this study enable the clinician and manufacturer to design, select, and use instrumentation based on the ability of the implant to load share or load transfer.

#5 IN VITRO STUDY OF LOAD TRANSFER AND LOAD SHARING WITH RESPECT TO THE MATERIAL PROPERTIES OF AN ANTERIOR DEVICE: A MECHANICAL MODEL

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The purpose of internal spinal fixation is to provide immediate stability for bony fusion to occur. Extremely stiff constructs tend to stress shield, increasing the likelihood of device-related osteopenia. The material type used in load-sharing devices has not been extensively investigated. The goal of this study was to determine the significance of material type in load-sharing devices and to compare load transfer/load-sharing properties of stainless steel, aluminum, and titanium load-sharing devices. ASTM standard UHMWPE blocks were used to simulate an 85kg-male lumbar spinal motion segment. Each pair of superior and inferior blocks was instrumented with a *Depuy Motech* anterior fixation plate to construct a uniform one above/one below corpectomy model. A 60 mm separation was maintained between blocks, 40 mm for the missing vertebra and 20 mm for both missing discs. Stainless steel, titanium, and aluminum cylinders were uniformly manufactured (19 mm x 60 mm, 1.6 mm thick) and used as load-sharing devices. Each load-sharing device was tested in five different corpectomy models, and with and without load-sharing devices. Each load-sharing device was equipped with two Micro-Strain (Measurements Group, Inc., Raleigh, N.C.) strain gauges that were placed in the same transverse and sagittal planes to detect and minimize any unwanted bending motion. The construct was mounted in an MTS 858 Bionix servo-hydraulic material-testing machine (MTS Systems Inc., Minneapolis, MN) and a strain gauge conditioner (2120A Vishay Measurements Group, Raleigh, N.C.) was used to interface with the data collected via the MTS. A compressive preload of 10N was applied at 1 N/sec, followed by a compressive force oscillating between 10N and 110N at 0.25Hz for 10 cycles. Global and local strain data were recorded and statistically analyzed.

Material	Average percent increase in global axial stiffness	Average local stiffness measured via strain gauges (N/mm)
Aluminum	1925%	8×10^5
Titanium	2896%	1×10^6
Stainless Steel	2925%	2×10^6