Diagnostic Parameters that Predict Spinal Shear Strength and Stiffness following Lumbar Laminectomy: A Human Cadaver Study

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Significance
Spondyloysis and spondylolysis are well-known complications of lumbar laminectomy without the use of instrumentation. Being able to predict residual shear strength and stiffness of the lumbar spine after laminectomy can lead to better criteria to establish if patients need additional spinal stabilization.

Introduction
The effect of facet sparing lumbar laminectomy on shear biomechanics of human cadaveric segments has previously been elucidated. Laminectomy was found to have a substantial effect on shear strength and stiffness, while bone mineral density was recognized as an important co-determinant. To be able to predict such biomechanical characteristics may provide valuable information and aid surgical decision-making. Our hypothesis is that shear strength and stiffness of lumbar spinal segments can be estimated from spinal characteristics as measured by standard diagnostic tools.

Therefore, the aim of this study was to determine relationships between a broad range of spinal and degenerative characteristics and in vitro shear strength and stiffness of human lumbar spinal segments. In addition, we assess whether residual strength and stiffness after laminectomy can also be accurately predicted.

Methods
Ten human cadaveric lumbar spines were obtained (mean age 72.1 years, range 53–89 years). Facet sparing laminectomy was performed either on L2 or L4, equally divided within the group of ten spines. The lumbar spines were subjected to standard imaging techniques (MRI, X-ray, and DXA) and further assessed with commonly used classifications of degeneration. In addition, segmental geometry, facet joint angles (both MRI), and bone characteristics (DXA) were assessed. Spinal motion segments were dissected (L2-L3 and L4-L5) and tested in shear, while simultaneously loaded with 1600N axial compression (Fig. 1). Shear stiffness (SS), yield force (YF) and shear force to failure (SFF) were determined from load-displacement curves (Fig. 2).

Correlations between independent and dependent variables (YF, SS and SFF) were calculated for each individual variable. For dichotomized independent variables independent-sample t-tests were used while bivariate correlations were determined for continuous and ordinal values. When independent variables were associated with a dependent variable, here defined as independent-sample t-test: p < 0.05 or as a bivariate correlation with a significance level of: p < 0.05, they were used for the combined statistical models. Before final analysis was performed, all independent variables were checked for correlations with each other. In case a correlation > 0.7 with a p-value < 0.05 was found, the independent variable with the strongest effect on the specific dependent variable was included in the model. Finally, backward linear regression techniques were used to create final statistical models per dependent variable per treatment group.

Results
Lumbar laminectomy had a substantial effect on SS, YF and SFF, with differences ranging from 23.9% to 44.2%.

Geometrical parameters
YF after laminectomy depended on parameters of intervertebral disc geometry (length: p = 0.039; surface: p = 0.037 and volume: p = 0.032), while SFF depended only on length (p = 0.016). YF of untreated segments was strongly affected by pedicle geometry (p = 0.003). SS depended on facet joint orientation (p = 0.022).

Bone characteristics
Bone characteristics determined both treated and untreated segments. In untreated segments SFF depended on bone mineral content (BMC) (p = 0.002) and bone mineral density (BMD) (p = 0.013). YF (p = 0.041) and SFF (p = 0.005) of treated segments depended only on BMC.

Degeneration
Disc and other parameters of degeneration (Pfirrmann: p = 0.045; Lane: p = 0.017; Pathria: p = 0.044 and Griffith: p = 0.026) only affected SS after laminectomy.

Regression
SS, YF and SFF could be predicted with reasonable accuracy (R²-value respectively: 0.528, 0.811 and 0.766) and without laminectomy (R²-value respectively: 0.500, 0.828 and 0.825). Bone geometry and characteristics are the most important factors in the model predicting biomechanics of the untreated segment, whereas parameters of disc geometry and degeneration are important for predicting biomechanics after treatment.

Discussion
Bone characteristics were important for strength parameters of both treated and untreated segments. In treated segments YF and SFF were best predicted by intervertebral disc geometry. Intervertebral disc and facet joint degeneration were important predicting parameters for SS. Shear behavior of untreated segments depended primarily on pedicle geometry (YF) and facet joint orientation (SS).

DXA outcomes, intervertebral disc geometry and degenerative parameters are indicative for biomechanical shear characteristics of lumbar spinal segments. They may provide additional tools to support surgical decision-making.

Figure 1. Lumbar spinal segment placed in the materials testing apparatus

Figure 2. Load-displacement curve of two motion segments from one human cadaver. In this case segment L2-L3 was with laminectomy, while L4-L5 was untreated.

Reference