Restoration of Lumbar Spine Stability with an Interspinous Implant: An in vivo Biomechanical Study

R. Gunzburg, M. Szpalski, C.J. Colloca, V. Kosmopoulos, M. Afifi, R.J. Moore

1Eeuwfeestkliniek Hospital, Department of Orthopaedic Surgery, Antwerpen, Belgium, 2Hôpitaux Iris Sud/IRIS South Teaching Hospitals, Department of Orthopedics, Brussels, Belgium, 3Arizona State University, Department of Kinesiology, Tempe, AZ, United States, 4University of North Texas Health Science Center, Bone and Joint Research Center, Department of Orthopaedic Surgery, Fort Worth, TX, United States, 5University of Calgary, Faculty of Kinesiology, Calgary, AB, Canada, 6The Adelaide Centre for Spinal Research, Adelaide, SA, Australia

Introduction: Interspinous implants are used in non-fusion surgical techniques to treat lumbar spinal disorders. Little research has investigated their effect on lumbar spinal stability and stiffness. The objective of this in vivo biomechanical animal study was to determine the effect of an interspinous implant on lumbar spine stability and stiffness during exposure to posteroanterior (PA) loading.

Methods: Merino lambs (n=12, 6-8 months old, 25 kg) were mechanically tested in vivo using a validated computer controlled force application apparatus designed to quantify PA stiffness. Load and displacement at L2 were collected at a sampling rate 2500 Hz. To quantify intersegmental displacements, tri-axial accelerometers were attached to intraosseous pins rigidly fixed to the L3 and L4 lumbar spinous processes under fluoroscopic guidance and general anesthesia. Oscillatory (2 Hz) loads (~5% of body weight) were applied to the L2 spinous process under load control and with the animals lying prone on an operating table. PA Lumbar spine stiffness (load/deformation, N/mm) at L2 were determined over six trials of 20 cycles of loading, and averaged. PA and Axial (AX) acceleration responses at L3 and L4 were recorded at 5000 Hz. Peak-peak segmental accelerations at L3, L4 and L3-L4 were computed from the acceleration-time recordings and displacements subsequently calculated.

Four spinal conditions were examined:
1) the initial intact condition,
2) following a destabilisation procedure at the L3-L4 level simulating a stenotic degenerative spondylolisthesis,
3) following the insertion of an 8 mm InSwing® interspinous device at L3-L4, and
4) again with the implant secured by means of a tension band tightened to 1 N/m around the L3 and L4 spinous processes.

Stiffness and displacement comparisons for each condition were performed using a one-way analysis of variance (ANOVA) with repeated measures. Post-hoc analysis with Bonferroni correction was used when significant differences were observed.

Results: The mean stiffness (± standard deviation) for the intact, destabilization, InSwing®, and InSwing® with tension band conditions were 4.20 (±0.94) N/mm, 4.07 (±0.92) N/mm, 4.10 (±1.04) N/mm, and 4.25 (±1.16) N/mm, respectively. Compared to the intact condition, the destabilization condition significantly decreased L2 stiffness (P=.000) which was only recovered by the InSwing® with tension band intervention. AX Displacements of L4 significantly increased from 4.09 (±1.73) mm in the intact condition to 4.47 (±1.40) mm in the destabilized condition (P=.038). L4 AX displacements were significantly reduced by the InSwing® and InSwing® with tension band to 3.70 (±1.15) mm (P=.038) and 3.12 (±0.96) mm (P=.001), respectively. The addition of the tension band to the InSwing® condition significantly reduced L4 AX displacements (P=.005). Likewise, intersegmental AX displacements of L3-L4 were significantly reduced by both InSwing® (P=.01) and InSwing® with tension band (P=.001) interventions.

Conclusions: The ovine model used in the current study provided objective biomechanical evidence of restoration of lumbar stability and stiffness by means of an interspinous device during PA spinal loading. The addition of a tension band had a marked effect on stability in several biomechanical outcomes. To our knowledge, this is the first in vivo biomechanical study showing the advantage of using an interspinous device to stabilize the spine in response to PA forces. These results may be useful when considering non-fusion devices for unstable degenerative spondylolisthesis patients.