Initial Experience with Synthetic Spinal Motion Segments: Biomechanical Assessment of High Cycle and Implant Performance

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Introduction: Laboratory tests of spinal biomechanics allow the evaluation of hypotheses that are not possible in vivo, however these tests have their limitations. Cadaveric tissues carry with them the potential for disease transmission, and cost as well as availability, variability and quality issues. Animal tissues may be used in place of human cadaveric tissues; however they may not perfectly simulate the human anatomy and biomechanics. Fresh tissues also suffer from decay and fatigue over large number of repeated tests. Therefore, a synthetic biomimetic spine model may be a suitable replacement.

The goal of this study is to evaluate the properties of a synthetic biomimetic spine model, namely comparative anatomy, comparative biomechanics, variability, performance in high cycle tests and the influence of spinal implants; also to assess the mechanical performance of lateral plating following lateral interbody fusion.

Methods: Three L3/4 synthetic spinal motion segments, recently developed by SawBones (Vashon, WA, USA) were examined using a validated pure moment testing system. Moments (±7.5Nm) were applied in flexion-extension (FE), lateral bending (LB) and axial rotation (AR) at 1Hz for total 10000 cycles. An additional test was performed 12 hours after 10000 cycles. A ±10Nm cycle was also performed to allow provide comparison to the literature. For implantation evaluation, each model was tested in the 4 following conditions: 1) intact spine, 2) lateral cage alone, 3) lateral cage and plate 4) anterior cage and plate. A near infrared 3D motion tracking system with retro-reflective markers (Osprey, Motion-Analysis, Santa Rosa, CA) and post processing was performed with an in-house written script MATLAB (MathWorks, Natick, MA). Results were analysed using ANOVA with post-hoc Tukey’s HSD test. Anatomy parameters of sample were measured from computed tomography scan data.

Results: The synthetic model anatomy showed a close match to the human. Range of motion (ROM) exhibited logarithmic growth with cycle number (increases of 16%, 37.5% and 24.3% in AR, FE and LB respectively).

No signification differences (p>0.1) were detected between 4 cycles, 10000 cycles and 12 hour rest stages. All measured parameters were comparable to that of reported cadaveric values. The ROM for a lateral cage and plate construct was not significantly different to the anterior lumbar interbody construct for FE (p = 1.00), LB (p = 0.995) and AR (p = 0.837). Compared to the intact state, a lateral cage alone reduced ROM for lateral bending by 68% (p = 0.010), for flexion-extension by 51% (p = 0.065) but did not significantly affect axial rotation.

Discussion: Based on the anatomy and biomechanical similarities, the synthetic spine tested here provides a reasonable model to represent the human lumbar spine. Repeated testing did not dramatically alter biomechanics which may allow non-destructive testing between many different procedures and devices without the worry of carry over effects. Small intra-specimen variability and lack of biohazard makes this an attractive alternative for in vitro spine biomechanical testing. It also proved an acceptable surrogate for biomechanical testing, confirming that a lateral lumbar interbody cage and plate constructs reduce ROM to a similar degree as anterior lumbar interbody cage and plate constructs.

Significance: The synthetic biomimetic model evaluated in the current study simulates the primary anatomical components of the human spine including; nucleus pulposus, annulus fibrosus, vertebral body and posterior bony aspects as well as ligamentous structures. This paper evaluated anatomy, biomechanical performance in high cycle tests and the influence of spinal implants within the current model. This model could be a suitable alternative for the cadaveric spines for some biomechanical evaluations.

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References:

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