INTRODUCTION

Dynamic stabilization has been introduced as an alternative to spinal fusion in order to mitigate complications associated with spinal fusion such as transition syndrome [1]. Past research has indicated that the outcome of dynamic stabilization surgery depends heavily on the combination of spinal segment mobility and implant rigidity [2]. However, spinal mobility is generally measured in whole body range-of-motion studies performed before and after surgery. The objective of this study was to evaluate a novel method to determine spinal stability quantitatively. Our long-term goal is to provide physicians with a non-invasive diagnostic tool for tailoring spinal implants and evaluating implant loosening over time.

METHOD

Five human lumbar spinal segments (mean age: 58.2, 3 females and 2 males) from L3 to sacrum were harvested. The fresh specimens were stripped of muscles with care taken to preserve spinal ligaments and facet joints. The L3 and S1 vertebrae were mounted with PMMA in the potting fixtures of a robotic testing system that consisted of a 6-DOF robotic arm (KR150, KUKA Robotics Corp., Clinton Township, MI) and a 6-DOF force/torque transducer (Omega160, ATI, Apex, NC).

Pedicle screws (DePuy Spine, Inc., MA) were implanted in the L4 and L5 vertebrae of each specimen and their position verified with X-rays (Bowie MFG, Inc. Lake City, Iowa). Four different materials (Rubber, Low-density Polyethylene (LDPE), Aluminum (Al), and Titanium (Ti)) to connect the pedicle screws were tested including one experiment representing the “no device” case. The robotic testing system was used to prescribe an oscillating bending moment for ROM measurements, with parameters based on pre-surgical radiographic image sets of fifty-five patients suffering from L4-L5 disc degeneration, stenosis and/or spondylolisthesis. For each implant rigidity case, segmental ROM and disc pressure at each level were measured.

RESULTS

As the rigidity of the implant rod increased, both the ROM and disc pressure at the treated levels decreased while those values increased at the adjacent levels. Flexion and extension showed similar tendencies and patterns in the tests of ROM and disc pressure. Implant stiffness saturation was evident as the ROM and disc pressure were only marginally increased beyond an implant stiffness of Aluminum (E = 70Mpa). Even though the stiffness of the implant increased, ROM and pressure were not significantly increased for the Ti case. The magnitude of ROM of the untreated spinal segments at 0 and 400 N axial loads did not show significant differences. As expected, the disc pressure difference between the 0 N and 400 N axial loading case was independent of implant rigidity.

Dynamic spinal stiffness varied with implant rigidity and correlated well (p < 0.05). The dynamic stiffness values measured with the impulse device increased as the rigidity of the implant rod increased (Figure 3).

DISCUSSION

This study demonstrated the ability of a point impedance analysis to capture the spinal stability and its change with surgery on a quantitative basis. As expected, more rigid dynamic stabilization devices further limited mobility at the degenerated level, the dynamic stiffness of the spinal segment also increased. This relationship was highly correlated.

In addition, as the more rigid implants shared more of the applied compressive loading, the significant difference in L4-L5 disc pressure between 0 and 400 N axial load diminished. The same phenomenon was evident in the dynamic stiffness measurements, however, to a lesser extend as the segmental stiffness was dominated by the implant.

Future studies may include clinical trials on patients scheduled for fusion or dynamic stabilization surgery.

SIGNIFICANCE

Intra-operative joint stability assessment of the spine is currently not possible. Clinical outcome of dynamic stabilization may be improved through measuring dynamic stiffness during the procedure and adjusting implant rigidity accordingly.

REFERENCES


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