Evaluating the Effects of Spinal Treatments on the Kinematics of Spine Using a Robotic Simulator

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Introduction

Low back pain and other common spinal disorders are ubiquitous in all industrialized nations with an estimated 70 million Americans affected.

Anecdotal evidence suggests that surgical treatment at one level of the spine may be a stimulus for degeneration at adjacent levels. New dynamic spinal stabilization techniques purport to eliminate this problem.

However, the effects of intervention at one level of the spine on adjacent levels has not been quantitatively characterized.

(A) (B)

Figure 1 – (A) A radiograph of a rigid five level (L2 to sacrum) instrumented fusion. Yellow dots are placed on the thickened and sclerotic end plates of the degenerated segment adjacent to the fusion. (B) Sagittal magnetic resonance image revealing previous C6-7 fusion with development of new adjacent level disease above the fused segment [1].

Adjacent level disease is defined as the development of a new radiculopathy or myelopathy referable to a segment adjacent to a previously fused level in the spine [2]. Identifying the factors that play a role in the pathogenesis of adjacent level disease will foster the development of novel treatments to minimize the risk of accelerated degeneration and at the same time effectively treat patients presenting with adjacent segment disease [1].

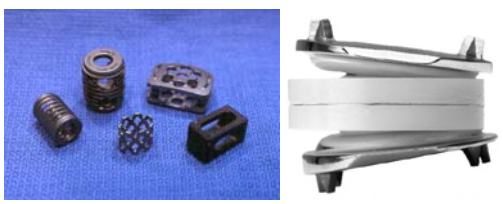

Figure 2: Interbody fusion implants (left) and Charite Artificial Disc (right) [3].

Purpose

The purpose of this ongoing study is to characterize the effects of single level spinal intervention on the kinematics of the whole spine using a robotic spine motion simulator.

Materials and Methods

1. Collect voluntary motion data from 15 healthy volunteers to map workspace volume via Flock of Birds 3D position and orientation sensors & plain radiographs.

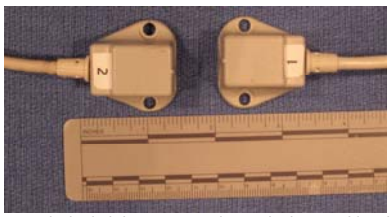

Figure 3: Flock of Bird sensors used as a six-degree of freedom electromagnetic tracking device.

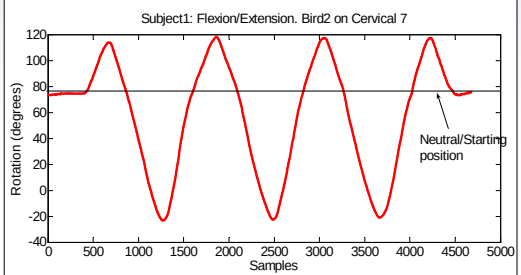

Figure 4: ROM data collected via Flock of Birds system of a subject moving through flexion and extension.

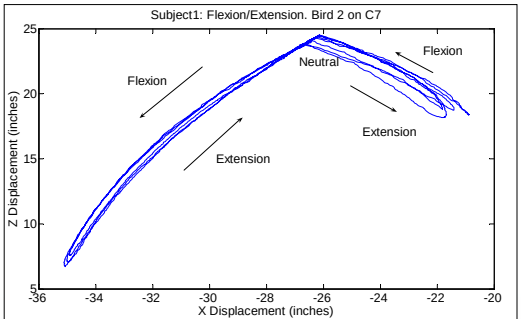

Figure 5: ROM data collected via Flock of Birds system of a subject moving through flexion and extension.

2. Use ROM data collected from subjects to drive a PUMA robot to move excised cadaveric spines through the same motions.

Figure 6: The PUMA 6 DOF robot replicates active voluntary motion of the entire thoracolumbar spine from data collected *in vivo*. Neutral and right lateral bending of an intact specimen are shown.

3. Compare motion in live subjects to robot controlled excised spine & validate.
4. Mount excised spine in robot and replicate the motion collected with the volunteers in the validation phase.
   - Photograph in multidirectional positions to facilitate ROM analysis
   - Mount bird sensors on each level of the vertebrae and track individual kinematics.
5. Perform clinical procedure on cadaveric spines.
   - Discectomy
   - Single Level Fusion
   - Multi Level Fusion
   - Motion Preserving Anterior Stabilization
   - Motion Preserving Posterior Stabilization

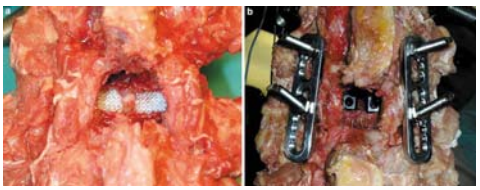

Figure 7: Posterior reconstructions at L2-3 level. a Subtotal 3DF posterior disc replacement (two implants). b Posterior interbody fusion cages (Brantigan cage) and VSP pedicle screw fixation.

6. Mount excised spine after alteration in robot and replicate the motion collected with the volunteers in the validation phase.
   - Photograph in multidirectional positions to facilitate ROM analysis.
   - Mount bird sensor on each level of the vertebrae and track individual kinematics.
7. Observe the comparative changes before and after intervention at the non-operative spinal levels.

Discussion

A better understanding of adjacent level effects following surgical intervention of the lumbar spine helps to guide the surgeon in selecting the most appropriate treatment for patients in jeopardy of developing spine pathology at levels adjacent to a surgical intervention. While fusion procedures are likely to exacerbate or accelerate degeneration at adjacent levels, new motion preserving technologies such as total disc replacement or posterior dynamic stabilization are thought to preserve adjacent level kinematics and normal tissue strain. Quantitative comparison of the effects of each technique will provide new insights into the effects of each treatment.

References

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