Simulation of Lumbar Spine Biomechanics Using Abaqus

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Abstract: Biomechanics testing of the lumbar spine, using cadaveric specimens, has the advantage of using actual tissue, but has several disadvantages including variability between specimens and difficultly acquiring measures such as disc pressure, bone strain, and facet joint contact pressure. A simulation model addresses all of these disadvantages. The objective of this work is to develop a method to simulate the biomechanics of the lumbar spine.

A process is currently being used to convert a CT scan of a lumbar spine into a simulation model. The process includes converting the CT scan to a geometry file, creating a mesh of the bone and soft tissue, and assigning material properties to each element of the bone based on the bone density. Finally, the model is solved using Abaqus Explicit. Optimization techniques are used to tune uncertain material properties to match the kinematics of the simulation model to actual cadaveric test results.

In addition, techniques have been explored to greatly reduce the computational time for the model. The soft tissue, discs, and ligaments were replaced with simplified mechanical constrains (ball-in-socket joints and non-linear, 3 dimensional torsional springs) and the vertebrae are rigid. This technique can be used for all or a portion of the spine.Further efforts are being pursued to simplify the workflow from CT scan to simulation model.

This model can be used to simulate the performance of implants including total disc replacement and fusion techniques such as interbody spacers with rods and pedicle screws.

Keywords: Spine, Biomechanics, Explicit, Kinematics, Disc, Vertebrae, Vertebral Body, Lumbar, CT Scan, Experimental Validation, Motion Tracking

1. Introduction

Biomechanics testing of the spine is currently used to evaluate the performance of spine implants such as total disc replacements and fusion systems. This is typically done by applying loads such as compression and moments to multi-segmental spine or a functional spinal unit (FSU). The intact condition is tested first, and then the spine is instrumented with implants and tested again. Kinematic measures such at rotation and translation are measured for each level of the spine using a motion tracking system. Axial, shear and moment loads are measured with a six degree of freedom load cell. Other metrics can be calculated from these measures such as the instant center