SINGLE LEVEL FUSION IN A C27 CERVICAL SPINE FINITE ELEMENT MODEL

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INTRODUCTION

Spinal fusion is one of the most common procedures performed on the cervical spine. A fusion procedure consists of removing a degenerated intervertebral disc and inserting some form of graft material into the disc space to restore/maintain disc height and appropriate lordotic curvature of the cervical spine.

The long term goal of this procedure is to establish a completely fused and stable region across the space formally occupied by the intervertebral disc. Long term adjacent level degeneration after spinal fusion surgery has been documented in many clinical studies [1]; however, the etiology is not fully understood. A biomechanical hypothesis of the causes of adjacent level degeneration after fusion is that it is due to an altered stress environment and motion redistribution throughout the cervical column [2].

In vitro studies can be used to examine changes in axial stiffness and failure characteristics in an implanted spine, but are limited to studying the external responses. Finite element analysis has the ability to study internal changes (e.g. stress) in adjacent levels due to fusion, as well as the effects of the external response.

In this study, a single level C45 fusion was simulated within an intact C27 finite element model. The hybrid loading method was used to evaluate the effects of the fusion on the adjacent levels.

METHODS

The finite element model was developed using our previously reported meshing techniques for the cervical spine [3], and was validated using experimental data from the same specimen which was used for model development. The intact C27 model (Figure 1) of the cervical spine was analyzed in flexion-extension, lateral bending, and axial rotation moments up to ±1.0 Nm.

Fusion was simulated by making the C45 intervertebral disc properties similar to that of bone. The model was analyzed again in flexion-extension, lateral bending, and axial rotation by increasing the moment until the primary C27 motion matched that of the intact C27 motion.

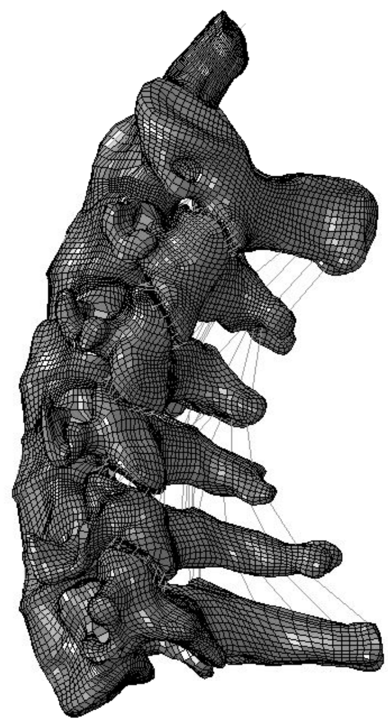

Figure 1. C27 finite element mesh.

Changes in motions, vertebral body stresses, and disc stresses were calculated at all levels in both cases to determine the relative effect of fusion on these parameters using the hybrid loading protocol.

RESULTS AND DISCUSSION

The fused model required moments greater than 1.0 Nm to obtain the same overall motion as the intact case for each mode of loading.

Increases in motion at each non-fused level varied from 15% at level C67 in right lateral bending, to 39% in level C67 in left axial rotation (Figure 2).

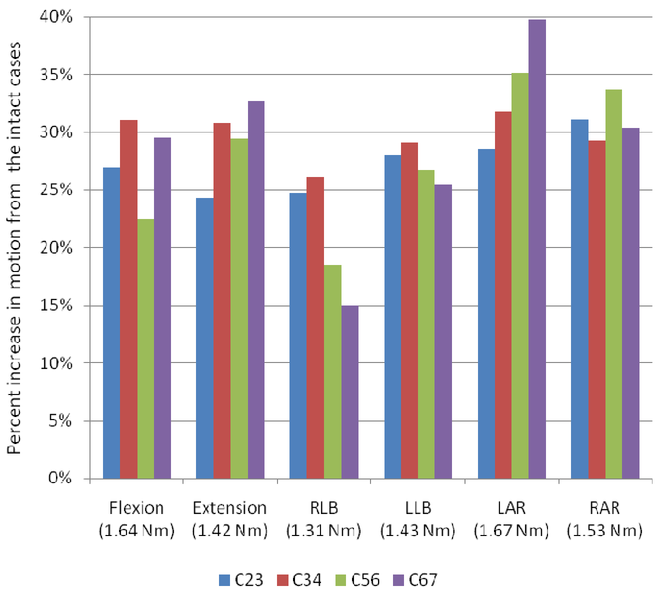

Figure 2. Percent increase in motion following C45 fusion.

Stresses in the vertebral bodies and intervertebral discs were compared for the fused and intact models. The von Mises stresses in the anterior regions of the vertebral bodies increased between 9 and 79% in all cases with the exception of C4 during extension and lateral bending, and for C5 in right lateral bending. In these cases, the stresses either remained the same or slightly decreased due to changes in load sharing within the fused C45 segment.

Stresses in the non-fused intervertebral discs were also compared (Figure 3). For flexion and extension, the von Mises stresses were analyzed in the anterior portion of the discs. In left lateral bending and left axial rotation, the left portion of the annulus was analyzed, and in right lateral bending and right axial rotation, the right portion of the annulus was considered.

CONCLUSIONS

This study examined the effects of simulated fusion on adjacent levels using the hybrid loading protocol. After fusion, adjacent levels in the spine experienced increases in intervertebral motions to compensate for the fused level. In addition, stresses in the vertebral bodies and discs of the non-fused levels also increased. Sustained changes such as those described have the potential to lead to degeneration and osteophyte growth. Increases in motions and stresses at adjacent levels (for all loading modes except extension) were found in another cervical spine multilevel (C37) finite element study of fusion [4]. Other fusion studies have quantified increases in adjacent level stresses for various surgical techniques and graft materials [5-6]. These findings may help to explain clinical observations of adjacent level degeneration following cervical spine fusion.

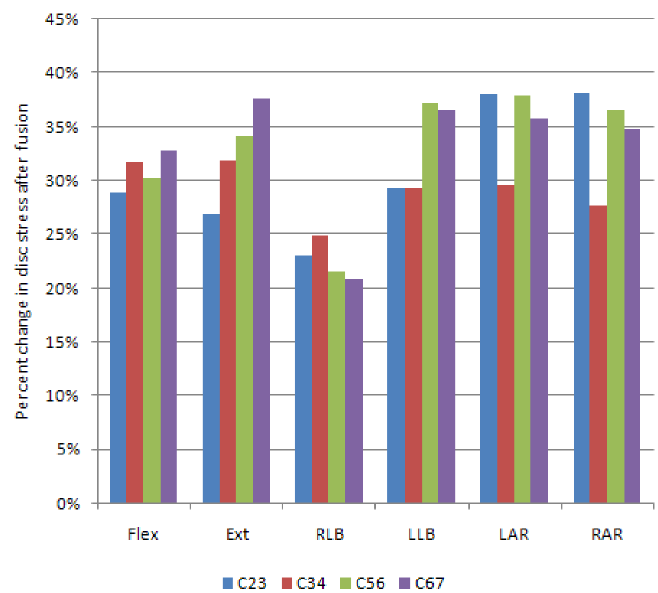

Figure 3. Percent increase in disc stresses after C45 fusion.

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