INTRODUCTION:
Cervical spinal stenosis is a medical condition caused by the narrowing of the spinal canal, possibly leading to the compression of the spinal cord or other nerve roots [1]. Surgical options include an anterior approach involving decompression and fusion or a posterior approach involving laminectomy and fusion or laminoplasty. Laminoplasty, considered an alternative to laminectomy, is a procedure intended to relieve pressure on the spinal cord while maintaining the stabilizing effects of the posterior elements of the vertebrae.

A single hinge laminoplasty procedure involves “hinging” one side of the lamina and cutting the other side to form a door. Once the lamina is opened, preventing restenosis is a primary concern. Several modifications to Hirabayashi’s original methods have been developed [4]. The use of titanium miniplates and screws to stabilize the lamina in an open position has been well accepted. Our earlier studies on single-level laminoplasty have shown increased sagittal diameter using this technique [6]. The finite element method is an ideal tool to assess the biomechanical efficacy of surgical treatments while supplementing in vitro studies. The current study is a finite element approach of looking at the effect of multi-level laminoplasty on the biomechanics of cervical spine.

METHODS:
In this study, a detailed subject-specific 3D finite element model of the cervical spine (C2-C7) was used. The intact finite element model was validated under flexion/extension, lateral bending and axial rotation at a load of 1Nm by comparing the results with specimen-specific experimental data [3]. The intact mesh was modified to simulate a laminoplasty procedure at levels C3-C6 (Figure 1).

A cut was made along the junction of the lamina and the lateral mass of the intact vertebral mesh by removing the bicortical layer completely. Then a hinge of approximately 3-4mm was created along the contralateral junction of the lamina and lateral mass by removing elements representing the unicortical layer. The lamina of each vertebrae, C3-C6, was opened towards the hinge by applying a uniform load.

Two holes in the lateral mass and one hole in the lamina were made based on the desired plate position. Care was taken to angle the screws away from the facet joints. In order to ensure proper contact between the plate and screw, the plate was bent as is often performed during surgery. The titanium plate and screws were meshed with hexahedral elements using IA-FEMesh [2] and were assigned an elastic modulus of 116GPa and poissons ratio of 0.3. Small sliding contact was formulated at the interface between the bone and the laminoplasty constructs (plate, screws). Additionally, the surfaces of the bone/screw and the screw/plate were tied during the analysis.

The model was tested under a pure moment of 1 Nm under physiologic flexion/extension, right/left lateral bending, and right/left axial rotation modes. The inferior nodes of C7 vertebra were fixed in all directions while a moment of 1Nm was applied to the superior surface of C2. The analysis was performed using ABAQUS 6.8. Ranges of motion, stresses in the cortical regions of the vertebral bodies and laminoplasty constructs (screws and plate) were analyzed.

RESULTS:
Figure 2 shows the ranges of motion of intact and laminoplasty models under different loading directions. When compared with the intact model, the percent increase in the ranges of motion was 3.4%, 1.8%, 1.6%, 0.65% for flexion, extension, left axial rotation and left lateral bending, respectively. A decrease of 3.8% and 4.6% was observed during right lateral bending and right axial rotation, respectively. The maximum von Mises stresses in the laminoplasty constructs were less than the yield strength of the implants. A significant increase in stress was observed in the cortical regions of the vertebral bodies post laminoplasty. Furthermore, a greater increase of the cortical stresses in the posterior region of vertebral bodies was observed when compared to the anterior regions at the altered levels for all loading modes. During flexion, a moderate increase in the disc stresses was observed at the unaltered levels (C23 and C67) while a slight decrease in stress was observed at the altered levels. No notable changes were observed in other loading modes.

DISCUSSION:
Numerous clinical studies have addressed the influence of multi-level laminoplasty on the kinematics of spine. To our knowledge, this is the first finite element study; thereby enabling changes in both the external and internal biomechanical responses of the spine to be considered. In an in vitro study, Wang et al.[7] showed the preservation of range of motion in all directions after multi-level laminoplasty. These findings are consistent with our results, where minimal changes were observed in the angular rotations of the spine. The moderate increase in the disc stresses during flexion at the unaltered levels may be due to the greater stability added by the plates [5]. Though no profound increase in the disc stresses was observed in other loading modes of the laminoplasty model, the significant increase in the cortical stresses of the vertebral body may be clinically correlated to the degenerative process. The present model is being refined to simulate the ligament resection as done during the clinical procedure. Additionally, in vitro studies will be conducted to augment/validate the finite element studies.

REFERENCES: