THE STABILITY OF THE ANTERIOR CERVICAL INTERBODY FUSION CONSTRUCTS USING CAGE VS. BONE GRAFT: A FINITE ELEMENT MODEL STUDY

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INTRODUCTION:

Over the past several years, some investigators as alternative to bone graft for anterior cervical fusion have advocated interbody fusion cages. This device is relatively new development and is somewhat controversial because of unknown long-term clinical outcome. It is not clear how other factors such as multi-level fusion affect the stability of the cage constructs as compared to the conventional bone graft constructs. The purpose of this study is to investigate the stability achieved with cages and Smith-Robinson type bone graft construct for one or two level cervical fusion, and to determine the stresses generated by various constructs using a validated finite-element-model (FEM).

MATERIALS AND METHOD:

A three-dimensional finite element model of C3 to T1, which was previously validated, was used in the study. Cortical and cancellous bone in each vertebra was modeled by three-dimensional finite elements. The annulus of the disc was modeled with annular fibers embedded in a matrix. Contact between facets surfaces were modeled by sliding three-dimensional contact elements. The model includes five ligaments spanning each motion segment. Fusion with bone graft or with cage was simulated at C5-6 level or at both C5-6 and C6-7 levels. The Smith-Robinson technique was simulated for the bone graft constructs. A graft of mean cross-sectional area equal to 65% of endplate area was used. The cage was modeled as a hollow cylinder and was filled with cancellous bone. To simulate discectomy and fusion, the disc material was removed down to the posterior longitudinal ligament and laterally to the margin of the uncinate process and substituted with either graft bone or cage filled with bone. Arthrodesis or fusion was modeled by rigidly connecting the end plates to the graft or cage. Motions at various levels of the cervical spine were calculated for flexion, extension and torsion moment loads of 1.0 Nm. Finally, the Von Mises stresses generated in the bone grafts and vertebrae were analyzed and compared among different constructs.

RESULTS:

For all loading modes, both graft and cage constructs decreased the motion in the fused segments as compared to the intact or unfused motion segment (Figure 1). For the single-level C5-6 fusion constructs, the bone graft produced a 80% reduction in motion, while the cage reduced the motion by 70%. This difference of reduction in motion between graft and cage was more pronounced for the two-level fusion constructs, particularly at C6-7 level (80% vs. 70% at C5-6 and 80% vs. 28% at C6-7).

The graft compressive stresses in a single level fusion varied between 5.8 MPa and 6.6 MPa for the three different loading modes considered (Figure 2). This was well below the iliac crest graft failure stress level reported in the literature (9.6 MPa). In the case of two level graft fusion, compressive stresses in the C5-6 level varied from 6.1 MPa to 7.0 MPa, but stresses at C6-7 level were 9.7 MPa under flexion/extension and 6.7 MPa under torsion.

In the two level fusion constructs, the stresses in the intermediate vertebra (C6) were higher than the corresponding values in C5 and C7 (Figure 3). The stresses in the C6 vertebra were higher in the cage construct (14 MPa, 14 MPa, and 8.7MPa) as compared to the bone graft fusion construct (5.2 MPa, 6.7 MPa, and 3.0 MPa) for flexion, extension, and torsion moment loadings, respectively.

DISCUSSIONS AND CONCLUSIONS:

This study was performed to assess the biomechanical properties of the anterior cervical cage fusion constructs, as compared to bone graft fusion constructs. It was interesting to note that the caudad fusion level at C6-7 gave a relatively high stress in the bone graft, which is indeed observed clinically. The cage constructs provided inferior stability as compared to the bone graft constructs, especially for the two-level construct. In the two level fusion constructs, the intermediate vertebra (C6) showed higher stresses than the vertebrae superior and inferior to the fusion (C5 and C7) under all moment loads. This stress levels were much higher in the cage construct, which implies susceptibility of the subsidence or bone collapse in the cage construct.

This study has limitations, which are inherent to all FEM studies, in that results need to be validated experimentally. This study has shown that the stability of the cage fusion construct is similar to graft fusion constructs for the single level cases, but it is inferior for the multi-level fusion cases. Other observation such as vulnerability of the graft in the caudad motion segment for multi-level fusion constructs are consistent with clinical observation. The multi-level cage fusion construct may increase the susceptibility of subsidence from the increased stresses in the intermediate vertebra.

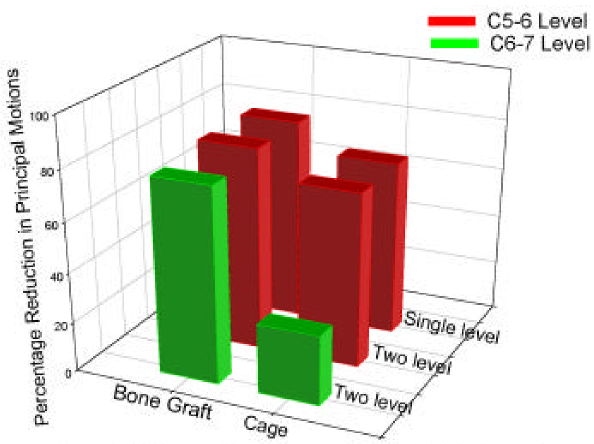

Figure 1. Comparison of percentage reduction in motion with fusion simulated with cages and bone graft

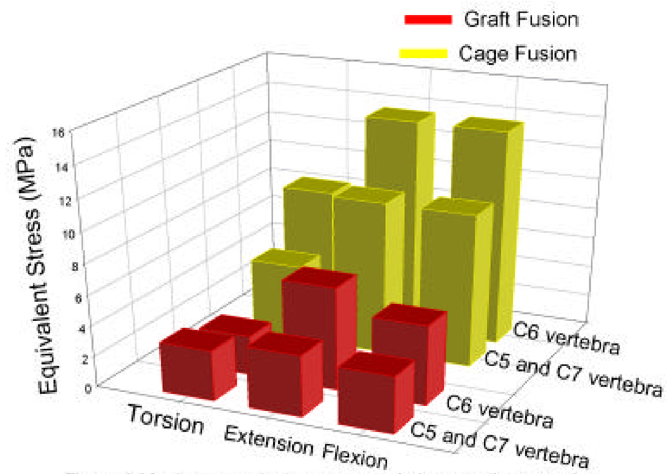

Figure 3:Maximum equivalent stresses in intermediate vertebra

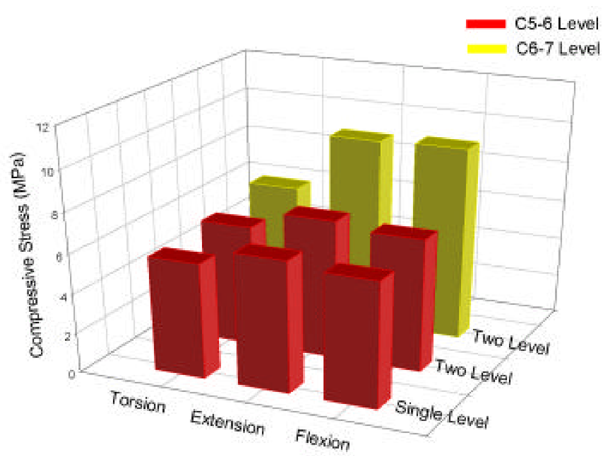

Figure 2. Comparison of compressive stresses in the graft for the two constructs with normal and osteoporatic models