INTRODUCTION

Spinal fusion with instrumentation is an essential component in the management of degenerative conditions in the spinal motion segment. However, solid fixation often induces adjacent segment degeneration (ASD) above or below the site of fusion. Biomechanical changes of the segment due to fusion increase the intradiscal pressure (IDP), facet loading, and mobility, each contributing to ASD. To avoid the adverse effects of spinal fusion, dynamic stabilization (DS) has been advocated as an alternative to fusion surgery (Gardner ADH 1992, Graf H 1992).

DS systems are based on a concept to allow spinal motion, but to restrict excessive motion. The NNC (Natural Neutral Concept) -flexus system (previously the Graf system) is a popular method for DS. To be stabilized, the bands are pretensioned upon application to place the motion segments into lordosis and to lock the facet joints. Kanayama et al. (2002, 2005) reported that radiographic evidence of adjacent disc deterioration was observed more frequently in patients with posterolateral fusion (PF) than in those with the NNC-flexus system, and they concluded that the system decreased the risk of ASD compared to PF with instrumentation.

The objective of this study was to assess the biomechanical influence on the adjacent segment by DS with the NNC-flexus system and instrumented spinal fusion.

MATERIALS AND METHODS

The in vitro experiments were performed with 15 fresh-frozen porcine lumbar spines. Each specimen was dissected into an L3-L6 spinal column consisting of four adjacent vertebral bodies, including posterior elements and intervertebral discs. The spines were first tested intact, and then they were tested after bilateral medial facetectomy (MF), augmented by the NNC-flexus system (DS), and instrumented spinal fusion (MF). The measurements were performed at L4-5.

The spinal columns were tested using a spinal motion tester designed to apply displacement to the cranial vertebra to simulate sequential flexion-extension movement of the spine. During testing, an axial compressive load of 70 N was applied to the column. The actuator generated a speed of 5.0 mm/sec with a displacement of ±20 mm to bend the vertebral column. Three cycles of flexion-extension motion were applied from a neutral position to approximately 8 degrees of extension and flexion. The angular motion and IDP of each segment were recorded on the third cycle for each testing state.

To determine the segmental motion of each vertebra, three sets of markers were mounted on the cranial vertebral body, L4 vertebral body, and L5. As the motion was applied to the spine, the location of these markers was traced with a CCD camera. Based on the location of these markers, angular motion at the sagittal plane of each segment and whole specimen was calculated. For the measurement of IDP, a miniature fiber optic pressure sensor was directed into the central region of the nucleus pulposus of each disc from a 45 degrees right-anterior approach.

RESULTS

The angular deformity in each segment increased linearly in intact spines. After MF, the angular deformity in each segment increased similar to the intact spines in both positions. In DS, although the angular deformity of L4-5 was suppressed until 4 degrees of deformation, the deformity gradually increased after 4 degrees of deformation and then finally became equal to the intact spine. During the change of L4-5 deformation in DS, the caudal L5-6 segment decreased, compared to fusion when the spine was flexed more than 4 degrees (Fig. 1).

The range of motion (ROM) of the each segment was defined as an angular deformation during 8 degrees of extension and flexion from the neutral position. The ROM at the superior adjacent segment (L3-4) was increased significantly compared to the intact spine, with 54% in DS and 46% in spinal fusion in flexion, and 30% in the DS and 75% in spinal fusion in extension. In L5-6, the ROM was increased significantly, with 18% in spinal fusion in flexion, 117% in DS, and 74% in spinal fusion in extension (Fig. 2).

IDP in MF remained equal to the intact spine with no significant differences at each segment at the neutral position. IDP increased by 47% at L4-5 and 33% at L5-6 in DS, and decreased by 46% at L4-5 in spinal fusion. The maximal value of IDP in MF remained equal to the intact spine with no significant difference. The maximal value of IDP increased significantly in DS, by 96% at L3-4, 90% at L4-5, and 67% at L5-6. In spinal fusion, the maximal value of IDP was significantly increased by 54% at L3-4 and 67% at L5-6 (Fig. 3).

DISCUSSION

While ROM of the segment stabilized by the DS system was suppressed until 4 degrees of flexion of the whole unit, the ROM gradually increased after 4 degrees of deformation, and then finally became equal to the intact spine. This characteristic segmental motion reduced the motion of adjacent segments up to 4 degrees. However, the fusion group showed continuous increase of L5/6 segmental motion. These results suggest that DS reduces the adjacent segment motion in flexion.

IDP in DS was increased by 45% at L4-5 and 33% at L5-6 compared to the intact spine. Application of DS bands to the screws forces the disc into compression, producing high IDP and stability in extended alignment. While flexion was applied to the specimen where L4-5 was stabilized by the DS system, excessive flexion may be loaded to the adjacent segments, increasing IDP. In this study, bending moment was applied using displacement control methods. Although displacement control methods can adjust the maximum angle, they cannot adjust the maximum load to bend the specimen. This may be one explanation for the increased IDP of the adjacent segment in the DS series. In conclusion, the dynamic stabilization system can reduce the adjacent segment motion compared to the fusion group. However, the relationship between ASD and increments of IDP remains controversial.