INTRODUCTION

Adjacent segment deterioration (ASD) is a serious sequela of spinal fusion surgery that has recently become much more widespread due to an increasing number of spinal fusions performed [1]. Moreover, previous studies [2] of potential risk factors for ASD have found that instrumentation, posterior lumbar interbody fusion, injury to the facet joint of the adjacent segment, fusion length, age, and sagittal alignment, are all risk factors for ASD. However, the actual significance of these risk factors remains controversial, possibly due to differing patient populations and methodologies [2]. Even though fusion probably affects motion and causes stress to adjacent segments, the following questions remain: to what extent does each risk factor impact ASD? What is the most decisive factor among the many risk factors for ASD? And, are there interactions between risk factors for ASD? In order to search for the answers to these questions, we planned to investigate the stress and the range of motion (ROM) at adjacent segments after fusion, using finite element (FE) model of lumbar spine. Two important risk factors were chosen such as instrumentation (pedicle screws) or the ablation of continuity of proximal ligament complex (PLC) among many risk factors. Therefore, the purpose of this study is to investigate changes of the range of motion (ROM) at adjacent segments after lumbar fusion according to whether or not pedicle screws is removed and whether or not the continuity of proximal ligament complex (PLC) is preserved.

MATERIALS AND METHODS

A three-dimensional, non-linear finite element model of the lumbar spine that consisted of three lumbar vertebrae, intervertebral discs and associated spinal ligaments have been developed. Geometrical details of the human lumbosacral spine (L2-L5) were obtained form high-resolution computed tomography CT images of a 46-years old male subject who had no spine deformities. Digital CT data were imported to softwares (Mimics, Materialise Inc., Leuven, Belgium), and three-dimensional geometrical surface of the lumbosacral spine was generated. The FE method was analyzed with commercial software (ABAQUS 6.6-1; Hibbitt, Karlsson and Sorenson, Inc.; Providence, RI). Material properties were validated in our laboratory, as reported in our prior publications [3]. In order to simulate the decompression state, a supraspinous ligament and interspinous ligament between L3 and L4 spinous processes were removed along with partial removal of L3 and L4 spinous processes. Furthermore, the inferior portion of L3 lamina, and ligamentum flavum of L3-4 were removed. Pp model has the continuity of PLC between L2 spinous process and remained L3 spinous process, while the L3 spinous process and PLC between L2 and L3 were totally removed in the Sp model. This model simulated the scenario of the instrumented PLF. First, PLF was represented as bilateral rectangular columns of fusion mass between the posterior surfaces of the transverse processes of L3 and L4. The screws were inserted into the pedicles of L3 and L4. This model simulated the scenario of PLF state with removal of pedicle screws. Therefore, this model was made by removal of pedicle screws in the WiP model. Combined with each models, 4 scenarios were simulated, that is, the preservation of the continuity of PLC with pedicle screws (Pp WiP), the preservation of continuity of PLC without pedicle screws (Pp WoP), the sacrifice of PLC with pedicle screws (Sp WiP), the sacrifice of PLC without pedicle screws (Sp WoP) Fig.1. To validate the model, the same loading conditions used in Yamamoto et al’s study were applied [4]. Therefore, 10 Nm flexion, 10 Nm extension, 10 Nm torsion, and 10 Nm lateral bending moment under the 150 N preload were imposed on the L2 vertebral body, respectively. To reach 10 Nm moments, the five load steps were applied to four models.
RESULTS & DISCUSSION

The intact L3-L5 model was validated in our laboratory, as reported in our prior publications [3].

3.1 Comparison of range of motion between models

The range of motion at each corresponding level was compared among three models (the intact and four models) under each moment (Fig. 2). Under flexion moment, the largest difference of motion at the L2-3 segment (proximal adjacent segment) was observed between Sp WiP model and Pp WoP model (7.6° and 6.4°, respectively), and the range of motion at distal adjacent segment (L4-L5 segment) was less influenced by the variance of fusion models than at proximal adjacent segment (Fig. 2). Relatively larger motion at fusion segment was shown in Sp WoP and Pp WoP models, which lead to less increased motion at the superior adjacent segment (L2-3), compared to the WiP models, and vice versa, in the WiP model (Fig. 2). L3-4 fusion also produced increased motion at both adjacent segments under extension moment. Changes of proximal adjacent segment motion model became most pronounced in the Sp WiP (4.8°), and least changes was noted in Wop models (4.3°), which is similar trend to flexion moment applied. However, compared to flexion moment, distal adjacent segments (L4-5) had similar differences of motion to proximal adjacent segment (L2-3). Fusion segment (L3-4) of the WiP models, on the contrary, had less motion than the WoP models (Fig. 2).

Similar patterns of changes of motion were also shown under torsion (axial rotation) and lateral bending moment. The changes became more prominent in the Sp WiP model (Fig. 2). As expected, the ablation of PLC with disruption of continuity of proximal segment in both Sp WiP and Sp WoP models caused increase of range of motion at proximal adjacent segments, compared to each corresponding Pp model. This study also demonstrated that the pedicle screw augmented more mechanical stress at adjacent segments after fusion. Conversely, in the Pp WoP and Sp WoP models, which simulated the scenario of removal of pedicle screws, relatively more motion was allowed at the fusion segment (L3-4) under 4 pure moments, and simultaneously compensatory motion at the adjacent segments reduced compared to each corresponding WiP model. This phenomenon became especially more pronounced at the superior adjacent segment under flexion moment. This is explained by the decrease of stiffness of fusion segments resulting from the removal of pedicle screws. Accordingly, Sp WiP shown the most increase of range of motion at proximal adjacent segments, and Pp WoP exhibited the least increase of range of motion at proximal adjacent segments among current FE models.

CONCLUSIONS

From many previous studies, fusion itself seems to lead to increased stress at adjacent segments, and be a main factor of ASD. However, the current study suggest that only fusion does not cause ASD, but decompression procedure, that is removal of PLC, is also a significant factor leading to increased stress at a proximal adjacent segment, and the combined effect of these risk factors would make the adjacent segments overstressed significantly.

REFERENCES