MECHANICAL INSTABILITY ON LUMBAR SPINE AT THE ADJACENT AND SUBJACENT SEGMENT AFTER RIGID FIXATION

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ABSTRACT

To investigate the effect of PLIF and after rigid fixation on adjacent segment and subjacent mechanical instability moreover under loading adjacent and subjacent segment mechanical behavior. Eleven fresh-frozen lamb lumbar spines (Sacrum-T12) were loaded, in axial, flexion-extension, right-left bending directions. All specimens were tested intact and after implantation with posterior pedicle screws and rod fixation. All specimens were fixed in a biomechanical test frame. The biomechanical tests were performed by using the axial compression testing machine. The displacements between S1 and L5 of markers were measured superior-inferior displacement and anterior-posterior displacement with two non-contact CCD cameras. The axial compression was applied to each specimen with testing machine was used to generate an increasing moment up to 8400 Nmm in flexion and extension right left bending and axial compression. The load was applied to each specimen consecutively before and after intact spine and implanted rigid fixation. In all direction after rigid fixation of spine adjacent and subjacent segment (S1-L5, L5-L4) vertical (superior-inferior) displacements were lower but anterior-posterior displacements were higher. Displacement values were evaluated and compared statistically. When we checked the statistical data, there were numerical differences and there was significant change between the intact spine and the spine implanted pedicular screws and rods. Biomechanical alterations likely play a primary role in causing adjacent and subjacent segment disease. After rigid fixation adjacent and subjacent mobile segment (anterior-posterior) displacement of the lumbar spine was significantly greater than intact spine. Rigid fixation of lumbar spine alters adjacent and subjacent segment level ROM. Therefore abnormal stress and hyper mobility on adjacent and subjacent segment may cause spinal instability, which may develop facet joint degeneration and low back pain.

Keywords: Adjacent and subjacent segment instability, Lumbar spine, Facet joint, Inter vertebral disc

1. INTRODUCTION

Instrumented lumbar spinal fusion is a common surgical procedure indication comprises degenerative disorders and lytic spondilolisthesis.[1,2,3] As a vertebral body become anteriority displaced due to an isthmus defect, spondilolytic spondilolisthesis and degenerative disorders have been created vertebral stenosis. This situation cause mechanical induced low back pain or it compresses the neural structures and causes neurological symtoms.[3,4,5,6,7] When instability of lumbar spine cause persistent pain or neurological impairment, it is usually treated using spinal fusion among the various fusion techniques (PLIF) with instrumentation is one option. The technique has the advantage of both 360 degree decompression and fusion and it has satisfactory clinical result and high fusion rates.[5,8,9] The initial good results following a posterior spinal fusion degrade over time as adjacent mobile segments proximal and distal to the fusion degenerate over time.[9] A higher fusion rate can be obtained in cases in which rigid fixation is performed using a pedicle screw segment next to spinal fusion is referred to as adjacent and subjacent segment disease and include disc degeneration, facet joint hypertrophy, spinal stenosis an even acquired spondilolisthesis.[10,11] After an

artrodesis at L3- L4-L5 (the most common level) of fusion the incidence of adjacent disc disease require additional surgery has been estimated to be 15%.[1,3,5] Degeneration that develops at mobile segments above or below a fused spinal segment is known as adjacent segment disease (ASD) with the dramatic increase in spinal fusions performed in recent years, ASD, subjacent segment disease will become much more widespread.[11,12]

One of the most difficult dilemmas in considering long posterior instrumented fusion of the thoracolumbar spine involves the extent to which to carry the fusion distally. The fate of the L5–S1 disc space has been analyzed by a number of authors, with a lack of consensus on whether or not to include this level in the fusion.[13] The etiology of the degeneration adjacent segment to fusion has not been clarified. There are two theories about adjacent segment disease; first theory, In-vitro investigation has suggested that fusion increase the intradiscal pressure of adjacent segment and also that situation of relative hypermobility is induced. Both observations would mean increased load on the segment. Another theory that claims that degeneration of the adjacent segment rather reflects genetic and the natural degenerative course of the aging disc.[1,4,7,8,10,14] The long level spinal fusion stopping fusion at L4 offers the preservation of the L4-L5, L5-S1 motion segment, and has the advantages of a smaller surgery and a decreased likelihood of pseudarthrosis. The disadvantage of fusion to L4 is subsequent disc degeneration at L4-L5 L5-S1. Subsequent disc degeneration is associated with the loss of sagittal balance and the need for revision surgery. Few studies evaluating how many these biomechanical changes contribute to adjacent segment and subjacent segment.

The purpose of this study is to clarify, after rigid fixation what is the mechanical effect on adjacent segment and subjacent segment under compression load.

2. MATERIALS AND METHODS

2.1 Specimens

Eleven fresh-frozen lamb spines were used for this study. The ages of lambs were six-twelve months. The specimens have not macroscopic and radiological diseases. Sacrum from T12 parts of the spine of each specimen was dissected. All of the specimens were frozen and thawed before tests during one night at room temperature. All of the specimens were potted with cement at the T12 vertebra and sacrum part.

2.2 The Biomechanical Tests

The current study was conducted in three groups. The spines were load tested in the following sequence: 1) Load testing of the intact spine before any manipulation. 2) Load testing after transpedicular screws (30 x 4.5 mm, mono axial Titanium screws) implanted to the L5, L4, L3 (Figure 1 a). Vertebras and fixed with two rods (6 x 100 mm, Titanium, Tıpsan-Tıbbi Aletler San. A.S.) at adjacent segments. 3) Load testing after transpedicular screws were implanted to the L4, L3, L2 (Figure 1 b) vertebras and fixed with two rods at subjacent segments.
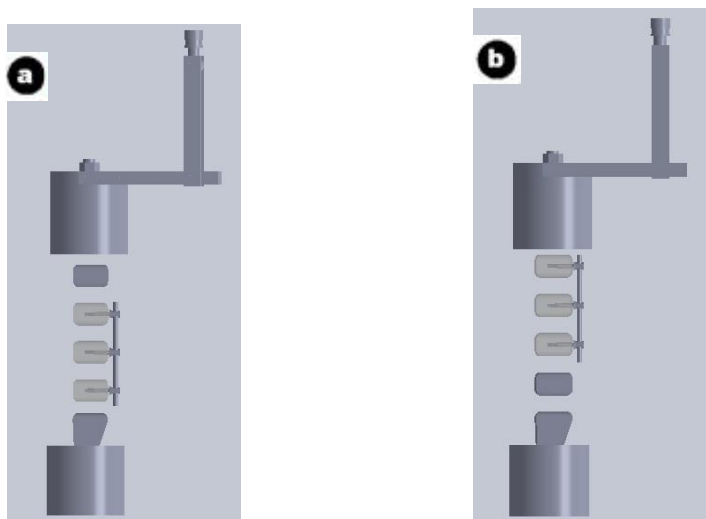

Figure 1. A specially designed fixture device used for loading test; implanted to L5, L4, L3 (a) and L4, L3, L2 (b)

A specially designed fixture used to increase moment up to 8400 Nmm generated through the axial movement of the actuator was applied to each specimen to achieve the flexion and extension motions, right and left bending, respectively.[15] In the axial neutral position 400N were applied to axial neutral compression (AG-I 10 kN, Shimadzu, Japanese) (Figure 2).
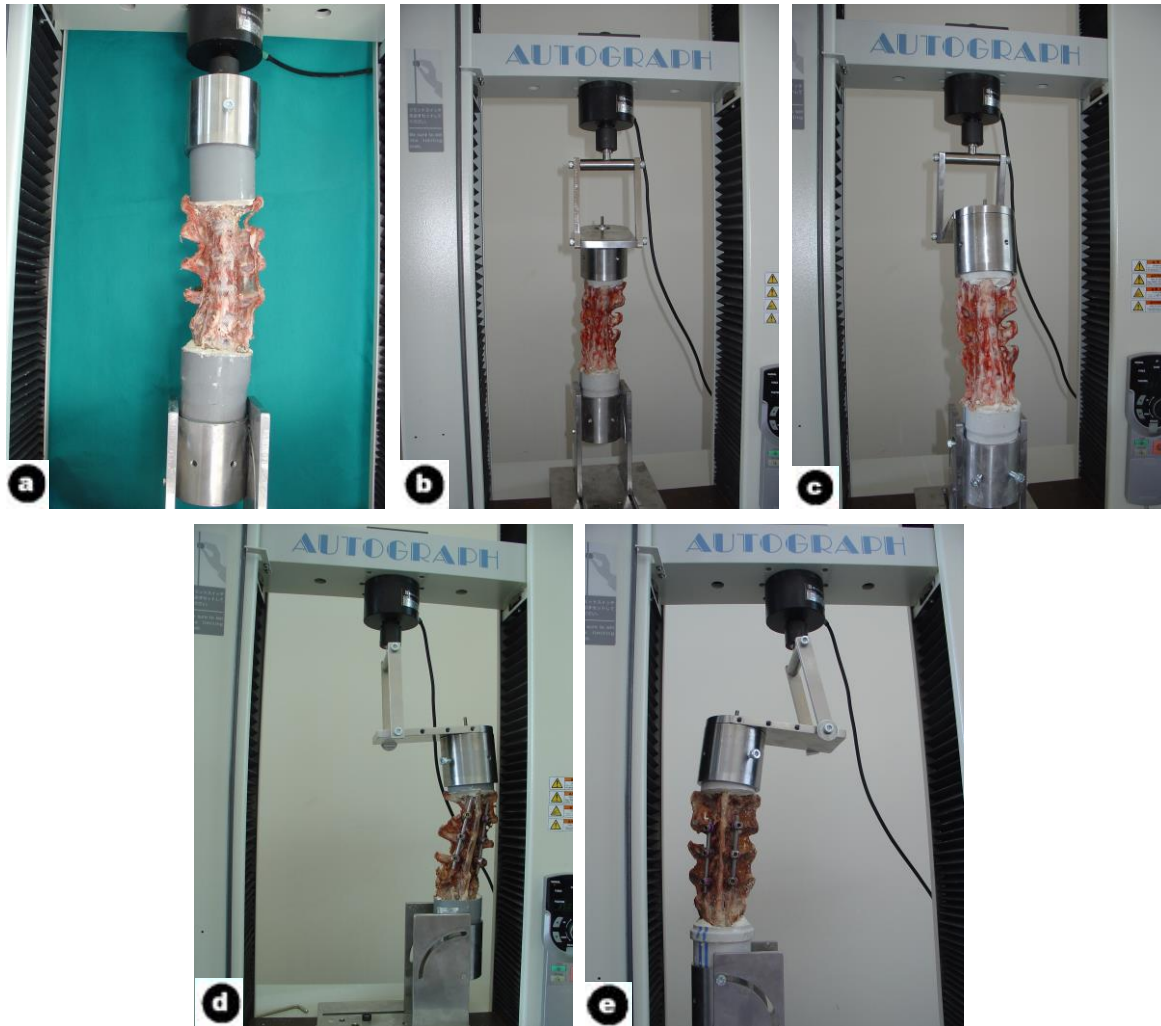

Figure 2. The axial compression tests which were applied to specimens; axial neutral compression (a), flexion (b) and extension (c), right (d) and left bending positions (e), respectively.

During testing, intervertebral displacement at decompression levels L5-S1 was recorded continuously by extensometer (Non-contact Video Extensometer DVE-101/201, Shimadzu, Japanese). While preparing test specimens, suitable gauge marks (diamond mark for high accuracy) were selected for the test specimen. Gauge marks were applied to test specimen with pins due to sliding surface of the specimen. Gauge marks were attached to L5 and S1 to measure the superior-inferior and anterior-posterior displacement. The two non-contact cameras grabbed image of the gauge marks. Personal computer processed the gray-scale image and measured displacement of the gauge marks of each camera image to measure the elongation of the test specimens. The gauge mark displacement on the CCD screen was converted into actual displacement. The elongation between two gauge marks was calculated by subtracting the lower mark displacement from the upper mark displacement. The displacement values were recorded on personal computer connected with test machine and two non-contact cameras. The data of displacement was evaluated with Mann-Whitney U test using SPSS 11.0 for Windows.

3. RESULTS

Results of the positions at neutral axial (inferior-posterior) displacements are presented in Figure 6 and anterior-posterior displacements are shown in Figure 7. When the neutral axial displacement values of the positions were compared, generally intact spine groups have demonstrated the highest displacement. There was a significant difference between the intact spine and adjacent segment of axial neutral compression position (p<0.027). Intact spines have exhibited the highest displacement and statistical difference at extension position (p<0.015).

However, no statistically significant differences were observed for displacement when comparing the intact spine and the implanted spine groups at left bending. There was a significant difference between the intact spine and subjacent segment in axial neutral compression position (p<0.003). In addition, there was a significant difference between the intact spine and the subjacent segment in extension position (p<0.011).

It was found that in anterior-posterior direction there was an increased displacement in adjacent segment. Implanted rod spine adjacent segment group showed highest displacement at flexion but it was insignificant. Displacement values in extension, right and left bending positions were again not significantly different. When the implanted rod spine adjacent segment and subjacent segment groups were compared at axial neutral compression, there was a statistically significant positions differences (p<0.042).

When the stiffness values of the groups were compared in axial direction, left bending have demonstrated the highest values in intact spine group. It can be seen that the effect of stiffness decreased in intact spine group in axial neutral compression position. On the other hand, right bending has demonstrated the highest stiffness values among all positions in adjacent segment. Similarly, right bending position has demonstrated the highest stiffness values in subjacent segment; nevertheless, flexion position has shown lowest stiffness values.

It was noted that the stiffness of the anterior-posterior values at the intact spine groups showed highest values in left bending position. Right bending stiffness seemed lowest value among all models. Axial neutral compression had higher stiffness values than the others in adjacent segment. Axial neutral compression had also highest stiffness values in subjacent segment.

4. DISCUSSION

Degeneration that develops at mobile segments above or below a fused spinal segment is known as adjacent segment disease (ASD). One of the most common findings next to a fused segment was disc degeneration.[3,4,5,8,11,12] The vertebral body between adjacent and subjacent intervertebral disk collapse associated with central spine canal stenosis. The vertebral body between adjacent and subjacent collapsed intervertebral disks may undergo radial expansion remodeling circumferentially in the horizontal plane. At the same time, there will be a superoinferior narrowing of the vertebral body producing a bony flat remodeling, or pancaking of the vertebra. This results in anteroposterior narrowing of the central spinal canal and its lateral recesses.[11] Listhesis, instability, hypertrophic facet joint arthritis, herniated nucleus pulposus, and stenosis were also reported frequently.[5,10,12]

Much rigid instrumentation are in use including pedicle screw systems which have gained broad support because of greater initial stability, increased fusion rates, decreased requirements for external immobilization and an earlier return to work.[1,4,5,6,9,10] The absence of controlled motion is also considered to be one of contributing factors in implant failure and outcome adjacent segment disease.[1,2,3,4,5,10,14] Biomechanical studies using both human and animal specimens demonstrated increase the mobility, mechanical stress and intradiscal pressure in motion adjacent segments and subjacent segments to arthrodesis.[1,2,11,14] Increase intervertebral stress may include interspinous ligament sprain this may include tears of the fibers of the adjacent and subjacent interspinous ligament.[11]

This study reports on the displacement changes of the lamp spine to examine the adjacent and subjacent segments instability and rigid fixation. Under laboratory conditions, we used lamb lumbar spines instead of human cadaveric spines. Although physiological structure such as spinal alignment number of lumbar segments of the lamb spines are somewhat different from those of human cadaveric spines, animal spines are most convenient choice to perform the experiment with long spinal segment for the reason that human cadaveric spines cannot be accessed.[1,15]

The present experiment focused on adjacent segment and subjacent segment instability. Few studies have reported on

the subjacent segment biomechanics kinematics in vitro. With the Increase in the adjacent segment mobility, the anterior and posterior structures protect the stability and show resistance to instability. The authors demonstrate that subjacent segment mobility and instability increase facet joint arthrosis. Anterolisthesis and rotolisthesis may occur at the adjacent vertebral body on the subjacent one. This may result in central spinal canal and lateral recess stenosis.[11,12]

Although there was a significant variation in intact spine and adjacent segment of axial neutral compression position, the displacement changes in intact spine groups were observed more than the other groups in axialvertical position. Additionally, there was a statistically significant increase in displacement at extension. Our testing protocol constantly tested the intact spine first followed by the L5, L4, L3 vertebras and then by the L4, L3, L2 vertebras. One of the findings showed a statistical difference between intact spine and subjacent segment in axial neutral compression position. Furthermore, there was an increased displacement of subjacent segment compared to the intact spine in extension position.

In the current experiment, adjacent and subjacent segment displacements and instability were analyzed under axial compression in intact spines and in spines following rigid fixation. Adjacent and subjacent data in axial displacement showed similar results. According to the mean of axial data, adjacent segment showed higher displacements than subjacent segment in all positions. Our data indicated significant differences in vertical neutral compression displacements evaluated for intact spine, adjacent and subjacent segments. Furthermore, the measurements showed significant differences in the vertical extension displacements assessed for intact spine adjacent and intact spine subjacent segments and   also adjacent and subjacent segments.

This is the first numerical study to compare the effects of adjacent segment and subjacent segment for different positions of spine with and without rod implant. We noticed a significant increase in the transverse displacement in axial neutral compression of the adjacent and subjacent segments. We also examined the effect of the stiffness values in the specimens. In the study presented here, the average stiffness data assessed that the left bending positions in intact spine, the right bending positions in the adjacent and subjacent segments showed higher values. In transverse displacement, the results indicated an increase in stiffness of left bending positions in intact spine group. There was an increase in stiffness in axial neutral compression both in adjacent and subjacent segments.

The present results illustrated that in the intact spine displacements were higher than the rigid fixation spine displacements because the rigid fixation increased the stability of spine. The rigid fixation decreases the ROM of spine. Therefore, excessive motion and degeneration occurs in adjacent and subjacent segments of the facet joints. Loss of segmental motion by instrumentation was compensated for by somewhat an increase in ROM in all directions at adjacent and subjacent segments. This increase in ROM is not only at the adjacent levels but also at the other lumbar motion segments.

5. CONCLUSION

This is the first numerical study to compare the effects of adjacent segment and subjacent segment for different positions of spine with and without rod implant. Adjacent and subjacent segments intervertebral, antero-posterior displacement of the lumbar spine, following rigid fixation was significantly greater than that of intact .lumbar spine. In all positions, transverse displacements have higher data except axial neutral position. Moreover, abnormal stress on adjacent and subjacent segments causes spinal instability. Rigid fixation of lumbar spine alters adjacent and subjacent segments level ROM, depending on number of instrumented levels. Loss of segmental motion by instrumentation was compensated for by somewhat an increase in ROM in all directions at adjacent and subjacent segments. In conclusion, the strain at the adjacent and subjacent segment facet joint and disc increases which can develop facet joint degeneration and low back pain. If we understand biomechanical changes at adjacent and subjacent segments, we can prevent the instability for facet joint hyper mobility. This understanding will shed light on the development of new dynamic implant designs.

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