**A DYNAMIC MUSCLE ACTIVE SIMULATOR FOR CADAVERIC EXPERIMENTS**

INTRODUCTION:

In biomechanical experiments using cadavers, joint motions are directly measured in detail. In a whole lumbar spine, the aims of cadaveric experiments are to understand the comprehensive motion characteristics and to estimate the lumbar motions in vivo. Hence, it is needed to apply physiological load, especially loads by the muscle forces during motions to the cadavers. The muscle simulator, recently, have been developed to reproduce muscle forces around the lumbar spine [1]. However, the muscle forces were used as resistant forces against pure moments as active loads. To reproduce the natural movements in the lumbar specimens, a cadaver apparatus needs to generate active muscle forces and the loading patterns in time series.

In this study, a dynamic muscle active simulator was developed. The simulator is possible to control continuously the wire tensions as the muscle forces, and to synchronize each tension in time series to reproduce the lumbar motion close to the in vivo condition. The simulator was verified by the cadaver experiment measuring the actual motion such as the coupled motion in the lumbar spine.

**MATERIAL AND METHODS:**

A dynamic muscle active simulator consisted of the base frame, a total of eight muscle tension generators and the safety arm to restrict specimen motions (Fig.1 (a)). The muscle tensions were transmitted to the lumbar specimens with the stainless steel wires. Each tension generator consisted of a stepper motor, a load cell and a tension spring (Fig.1 (b)). Because the wire and tension spring were connected in a series, the wire transmitted the tension proportional to the extended length of the spring when the stepper motor wound the wire.

In this study, seven muscles around the lumbar spine were modeled; rectus abdominis, obliquus internus abdominis, obliquus externus abdominis and erector muscles of spine. The seven muscle lines were decided from the literature [2]. To realize the muscle lines, the thorax and sacrum frame were used (Fig.1 (c)). These frames have the holes to attach the wires, and guides where the wire passes through. The thorax frame is fixed to the T12 vertebra and the sacrum frame is fixed to S1. The sacrum frame is set on the top of the base frame of the dynamic muscle active simulator.

To determine the muscle forces during motions, the three-dimensional musculoskeletal model was used [3]. The muscle forces were searched by the optimization method to move the lumbar model correspondent to the objective postures. In this study, the objective postures were flexion of 30 degrees, extension 20 degrees, lateral bending of 20 degrees and axial rotation of 10 degrees.

The muscle forces were applied to two fresh cadaveric lumbar spines. The motions of the lumbar specimens were measured with opt-electronic measurement system ProReflex (Qualysis, Sweden). Each vertebra had a mean of 0.00 0.05 0.00 0.05 -0.05 0.00 0.05 -0.05 Dors. Vent. R. L. Dors. Vent. R. L.

**RESULTS:**

Figure 2 shows the changes in lumbar postures at one second interval of flexion, right lateral bending and left axial rotation. The origin of the global coordinate axis was at the center of sacrum base. In the flexion, lumbar specimen moved in the medial sagittal plane. In the lateral bending and axial rotation, specimens kept flexion. These two motions almost show the same angles at left and right. The average angles of the two specimens were approximately 90% of the range in the four objective motions. In the all motions, the two specimens showed similar motion characteristics. In this study, statistical analysis was not performed because of the limitation in the numbers of the specimens.

**DISCUSSION:**

During the simulated flexion, the whole lumbar spine did not show the other motions except for flexion, however each vertebra showed small lateral bending. The muscle forces for flexion compress the specimens axially. Thus each vertebra bent laterally as the small lateral curves were larger, because the specimens had a slight asymmetry. In the right lateral bending, L5 vertebra bent to opposite direction. The axial compression should cause L5 reverse motion as a buckling. This means that the whole lumbar vertebral in vivo may not bend to the same lateral direction. In the left axial rotation, the specimens continued to keep flexion and showed right lateral bending. Because oblquus internus abdominis and oblquus externus abdominis had different muscle lines of actions, the difference between the moments by the muscles made the cadaver flexed and bent laterally. Moreover, L1 vertebra had the largest rotation, and L2-L3 moved as one unit, but L5 did not have the motion during the simulated axial rotation. Each vertebra also showed lateral bending, especially L3 vertebrae had the largest bending angle. The observed vertebral motions included the coupled motions, which were seen in lumbar spine in vivo. These results demonstrated that the dynamic muscle active simulator successfully made the active cadaveric lumbar motion. Therefore the dynamic active muscle simulator was an useful tool for cadaver experiments to reproduce the physiological loading condition as in vivo.

**REFERENCES:**


**Paper No:** 1309

**Fig.1** Dynamic muscle active simulator

**Fig.2** Lumbar postures during motions

**Table 1**

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