Positioning Effect of Artificial Disc on Postoperative Motion Pattern in Sagittal Plane

ABSTRACT INTRODUCTION:
Artificial intervertebral discs have been widely applied in total disc replacement surgery in treatment of low back pain resulted from degenerative disc disease nowadays. In preservation of motion ability, pattern of vertebral motion may reflect postoperative stability of replaced segment. Several research literatures have revealed that pattern of motion in human lumbar spine is similar to the “∞” symbol in sagittal view. Since lateral bending and axial rotation were partially restricted by facet joints due to their anatomical structures in lumbar spine, maintaining stable and smooth motion pattern in sagittal plane became an important issue. Previous studies mainly focused on stress distributions of polyethylene components of artificial discs with various insertion positions, while others discussed about the instant axes of rotation with radiographic measurements. However, insertion position effects on postoperative motion pattern and range of motion were still unclear. Purpose of current study was to observe the positioning effect of artificial discs on sagittal motion pattern referring to vertebral center at vertebral body superior to the inserted level and postoperative angular range of motion of inserted segment with dynamic simulation technique.

METHODS:
The human spinal model of L4-L5 was reconstructed through computerized tomography (CT) images. The Charité III artificial disc was consulted in current study. Adequate size of artificial disc was selected according to the geometry of current spinal model (with 7.5mm in dome height and 25mm in core diameter, lordotic angle was 0°), and was virtually inserted into intervertebral space of L4-L5. Three different insertion positions of discs were concerned including anterior insertion (4.5mm anterior to the center of superior endplate of L5), central insertion (center of superior endplate of L5), and posterior insertion (4.5mm posterior to the center of superior endplate of L5). All models were imported into MSC.ADAMS 2005 (MSC.Software, Inc., Santa Ana, CA) as shown in Fig.1, and required force components assigned with coefficients of stiffness were attached referring to anatomic of surrounding ligaments and facet capsules. The anterior longitudinal ligaments were simulated as repaired referring to the suggestion from surgeons. Metallic endplates were fully tied with corresponding vertebral bodies. Static and dynamic frictional coefficients for interfaces of metallic and polyethylene components were respectively 0.05 and 0.04 while facet joints were respectively 0.002 and 0.001. With 400 N applied upon L4 vertebral body as weight of upper trunk and fully fixation at bottom of L5, reciprocation of flexion/extension was assigned with maximal moment of 10 N-m controlled by given step function. Each simulation was set to be accomplished in 10 seconds with 300 steps in calculation. Coordinate information for vertebral centers of L4 was recorded to calculate its motion pattern in sagittal plane, and effect of disc positioning on postoperative angular ranges of motion in sagittal plane was evaluated.

DISCUSSION:
Previous finite element researches for the disc positioning effect on stress distributions showed that central insertion was recommended in order to reduce the stresses on polyethylene component. Under the same loading and boundary conditions in current study, no significant difference due to position of disc was observed. However, differences in sagittal motion patterns were observed among three positions of insertion. Smooth motion pattern was considered as better and more stable postoperative performance, but none of the groups could perfectly restore the sagittal trajectory as “∞” symbol. The unequal performances between flexion and extension were due to more restrictions to flexion were resulted from structures of ligaments and facet capsules on posterior elements of L4-L5, while those restrictions were weaker during extension. Anterior insertion of disc was unfavorable for flexion while posterior insertion was unfavorable for extension because both of them would lift the vertebral center of L4, which could lead to spinal instability. Central insertion of disc showed its motion pattern more closed to the horizontal plane than the other groups, but comparatively, sharper motion pattern were found under flexion than posterior insertion group and under extension than anterior insertion group. According to current results, no single inserting position of the artificial disc was perfect in all respects. Finer increment for offsets of anterior/posterior insertion would be necessary in further study to be more beneficial for design concept of artificial discs. Decrease of angular range of motion was found when insertion of artificial disc shifted from anterior to posterior positions, but differences were minor.

In conclusion, current study revealed the existence of artificial disc positioning effect on sagittal motion pattern, while angular range of motion of insertion level was not significantly influenced. However, current design of artificial discs may not be able to perfectly restore the adequate vertebral pattern of motion of lumbar spine. Further modification or renew of artificial disc designs will be necessary for restoring the postoperative performance to the ideal motion pattern.