Advantages of Unilateral Transpedicular Screw Fixation in Transforaminal Lumbar Interbody Fusion - Biomechanical Study with Finite Element Method

1Chen, W C; 2Chen, H H; 3Lai, Y S; 4Lin, K I; 5Chang, T W; 6Lai, H J; +1,3Cheng, C K
+1Institute of Biomedical Engineering, National Yang-Ming University, Taipei, Taiwan
2Department of Physiology, Taipei Medical University, Taipei, Taiwan
3Orthopaedic Device Research Center, National Yang-Ming University, Taipei, Taiwan
Senior author: ckcheng@ym.edu.tw

ABSTRACT INTRODUCTION:
Transforaminal lumbar interbody fusion (TLIF) with transpedicle screw (TPS) fixation was accepted as a minimally invasive surgery to treat degenerative disc disease for decompression and maintaining stability. According to previous researches, spinal fusion using bilateral TPS (BTPS) fixation with single or paired cages could sufficiently maintain vertebral stabilities, but the unilateral TPS (UTPS) fixation was considered that it could not afford sufficient stabilization. However, in our clinical observations, good postoperative performances were found in the further follow-ups (Fig.1). It was believed that application of unilateral approach could reduce the incision and the period for recovery, but still the biomechanical evidences for its capability to maintain stability were required. Purpose of this study was to evaluate the biomechanical performances of single cage insertion with BTPS and UTPS fixations using finite element method. Furthermore, analyses of different vertebral levels for UTPS surgery were also compared.

METHODS:
Finite element model of human spine (L2-S1) was reconstructed and validated for simulation with ANSYS Workbench 11.0. Comparisons of fusion with oblique single cage insertion (Fig. 2a) and BTPS/UTPS (Fig. 2b and 2c) fixation on L45 and biomechanical behaviors of unilateral pedicle screw fixation on different fusion level (L45 and L5S1, Fig. 3) were performed and evaluated. With fixation of the bottom of S1 vertebral body, a 150N compressive load was applied as weight of upper trunk, and additional 10N-m moment for simulating flexion, extension, both sides of lateral bending and axial rotation. Maximum compressive stresses (minimal 3rd principal stress) on vertebral bodies (inferior side), and von Mises stresses on cage and TPS were evaluated.

RESULTS SECTION:
Both groups with UTPS fixation showed higher von Mises stresses on TPS than on either side in BTPS group (Table 1). Severe increases (over 100%) of stress were found in flexion and right lateral bending. Differences between UTPS on L4S and L5S1 were not toward identical tendency. All values of von Mises stresses on TPS were not exceeded the yielding stress (criteria for implant failure) of titanium alloy. High compressive stresses on inferior vertebral bodies after implantation were found in all groups (Fig. 4a), and generally UTPS group is higher than BTPS. But significant high compressive stress was found in BTPS group under flexion (27.307 MPa). Comparing with stresses on the cage (Fig. 4b), highest von Mises stress was also found in BTPS group under flexion (150.23 MPa). Stresses on cages were almost vanished under extension in all groups. Distributions of stress on vertebral bodies and cages were shown in Fig.5.

DISCUSSION:
There’s an interesting observation for asymmetrical fixation with UTPS: significant high stress on cage and inferior vertebral body from BTPS under flexion could be reduced. Symmetrical fixation method (BTPS) tended to restrict the forward flexion of the motion unit to be symmetrical on coronal and transverse planes, but the supporting component (i.e. cage) was inserted obliquely. So BTPS would force the contact to occur at the front tip of cage under flexion, which led to high-stress concentration that was not observed in traditional surgical approach with insertion of paired cages. Since the oblique cage insertion was an asymmetrical approach, UTPS either on L4S or L5S1 could just give an adequate assistance for supporting the structure under flexion according to current study. In the opinion of mechanical balance, asymmetrical fixation may be applicable for TLIF, the current trend of minimally invasive spinal fusion surgery. However, vanish of stresses on the cages remained a problem that cage dislodgements would occur during extension due to the lack in normal contact force. Positioning of cage to increase the stress on cage under extension is necessary to be concerned in further studies.