Title:
Biomechanical Comparison of Different Vertebral Plate Designs for Anterior Cervical Discectomy and Fusion Using Nonlinear C3-T2 Multi-Level Spinal Models

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Introduction:
Anterior cervical discectomy and fusion is a common surgical procedure to treat spinal cord or nerve root compression [1]. However, the clinical complications of anterior cervical plate system still occur. Past researchers have tried to improve the clinical complications by changing the screw thread or the screw orientation. The conclusion on the screw thread is quite consistent [2]. Unfortunately, the studies on the screw orientation reached inconsistent conclusions [3-4]. In addition, the effects of the screw orientation which are determined before the surgery are mainly based on the surgeon's experiences without biomechanical evidences. Therefore, the purpose of this study was to investigate the clinical performances of anterior cervical plate for the anterior cervical discectomy and fusion.

Materials and Methods:
To analyze anterior cervical plate with different insertion angle of screw, six design variables of the anterior cervical plate system were considered including the insertion angle of locking screw inserted in C5 segment in Superior-Inferior direction (C5SI), the insertion angle of locking screw inserted in C5 segment in Medial-Lateral direction (C5ML), the insertion angle of locking screw inserted in C6 segment in Superior-Inferior direction (C6SI), the insertion angle of locking screw inserted in C6 segment in Medial-Lateral direction (C6ML), the insertion angle of locking screw inserted in C7 segment in Superior-Inferior direction (C7SI), and the insertion angle of locking screw inserted in C7 segment in Medial-Lateral direction (C7ML) (Fig. 1). Those design variables were arranged according to an L25 orthogonal array. Analysis of the variance (ANOVA) was calculated to investigate the contribution and significance of each design variable. Three-dimensional finite element model, which consisted of C3-T2 multi-level spine and anterior cervical plate system, was developed to investigate the fixation stability using ANSYS Workbench 14.5. In the loading condition, a flexion moment of 1.5 N-m and a body weight of 73.6 N were applied on the top surfaces of the C3 vertebra. The boundary conditions were constrained on the bottom surfaces of T2 vertebra. The interfaces between the locking screws and the vertebrae were contact. In the post-processing analysis, the total strain energy of the anterior cervical plate system was calculated.

Results and Discussions:
All of the solid models were properly meshed and successfully solved. The total strain energy of the anterior cervical plate system was obtained (Fig. 2). The ANOVA table was calculated according to the total strain energy of the anterior cervical plate system (Table 1). The results showed that the C7SI and C5SI were the main determining factors with contributions of 77.9% and 7.8%, respectively. In addition, the anterior cervical plate with inclined screw insertion angle might provide better biomechanical performances.

Conclusions:

The fixation stability of the C3-T2 multi-level spine with the anterior cervical plate system was analyzed using three-dimensional nonlinear finite element simulations and Taguchi robust design methods. The C7SI and the C5SI were the key control variables, and changing the screw orientation in a superior-inferior direction could significantly improve the fixation stability. The outcomes of the current study could assist orthopedic surgeons in understanding the biomechanical performance of anterior cervical plate systems.

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Variables	Degrees of freedom	Sum of squares	Mean square	Contribution
C5SI	4	0.526	0.131	7.8%
C5ML	4	0.121	0.030	1.8%
C6SI	4	0.302	0.075	4.5%
C6ML	4	0.259	0.065	3.9%
C7SI	4	5.228	1.307	77.9%
C7ML	4	0.275	0.069	4.1%
Total	24	30.081		100%

Tab. 1: ANOVA table for total strain energy.

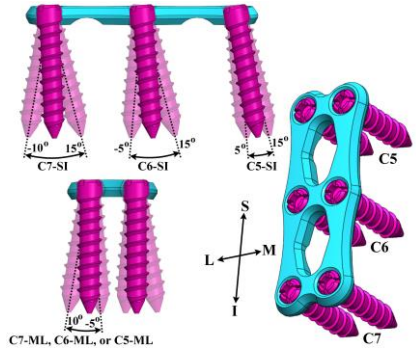

Fig. 1: Design variables of cervical plate system.

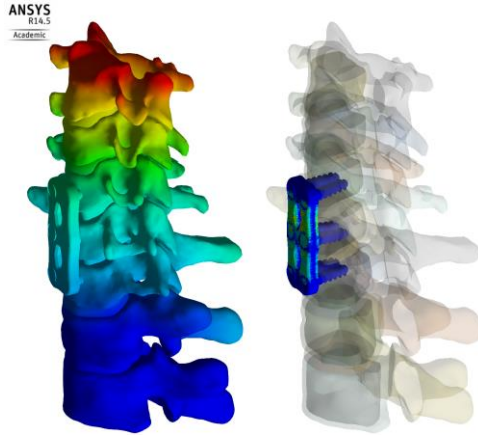

Fig. 2: The results of finite element models.

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