Biomechanical Evaluation of Anterior Cervical Spine Fixation Devices

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Introduction

The anterior cervical plate fixation systems have been widely used in treatment of complex spinal disorders such as traumatic lesion, disc herniation, tumor, spondylitis, arthropathies, and others. Combined with bone graft or other fusion techniques the satisfactory outcomes were higher than 88% (Clements 1990, Naito 1993,Bose 1998, Schneeberger 1999). Among the screw plate fixation systems, Caspar plating and AO titanium locking plate system are markedly popular by many surgeons. The Caspar anterior plate system has been proven to yield solid construct, and to obviate the need for simultaneous posterior stabilization( Tippets, 1988; Garvey, 1992; 1993;Naito, 1993;Bose, 1998). AO anterior cervical locking plate is recommended for situation where traditional technique might be unsatisfactory; such as multilevel anterior spine defects, post-traumatic cervical kyphosis, and cervical fractures with posterior disruption require anterior fusion. It is considered to be safer and effective, due to the system does not gait purchase on the posterior cortex (Suh, 1990; Kostuik, 1993, Tominaga, 1994).

But what is the efficacy in restoring the cervical stability between AO cervical locking plate and Caspar plate system, and the effects of graft after corpectomy? The purpose of this study is to evaluate the stable effect of discectomy, corpectomy, and different types of fusion techniques: bone grafting, AO cervical locking plate or Caspar plate implantation.

Methods

Eighteen fresh swine cervical spines from C3 to C7 were undergone axial compression rotation, and sagittal flexion-extension tests by using the Bionix 858 MTS material testing machine. The biomechanical experiment was sequentially repeated for the intact, C5-6 discectomy, C5 corpectomy, and fused by either type of plate fixation device with or without PMMA bone cement grafting.

The strains in axial compression and bending tests were measured by a blade type extensometer of 25mm gage length. The extensometer was attached to the cut slots placed over the anterior surface of vertebral bodies across the operated disc. In compression test, the axial load was cycled from 0 to 800 N after a 50 N of preload to simulate the weight of head. The sagittal bending was cycled from neutral to a 25° flexion. The axial torsion was performed in clockwise and counterclockwise of 25° from neutral with a 50 N of preload. Each test consisted of five sinusoidal load cycles at 0.25 Hz. The first four were considered as the conditioning cycles to reduce viscoelastic characteristics of spinal connective tissues, and the fifth cycle was used for analysis.
Results & Discussion

In compression test, the results indicated that after discectomy the strain increased 2.06 times than the intact one. Corpectomy with AO cervical locking plate or Caspar plate implantation only, increased the strain from 0.579% of intact spine to 2.538% and to 2.574%, respectively. With PMMA grafted, the strains were reduced to 0.228% for the AO plating and 0.252% for the Caspar plating. In 25° flexion, the mean strain of intact spine was measured as 2.745%. After plates implanted with graft, the mean measured strains were 0.012 % and 0.035 % for AO and Caspar plate, respectively (Fig. 1). The resistive torques were about symmetric in both rotation directions in all simulations (Fig 2) the torsion rigidity was highest in intact specimens. Either type of anterior fixation plate system provided less rigid than the intact spine but an adequate restored stability once combined with PMMA grafting (Table 1).

Statistically, there was no significant difference in biomechanical evaluation for the stability effect between AO plate system and Caspar plate system (P<0.005). Both systems showed similar statistical results, except in flexion motion, the AO cervical locking plate system provided better rigidity than the other one. This result matched the experiment from Grubb(1993). Conversely, Clausen(1996) reported that Caspar plating withstood cyclic loading conditions better than AO unicortical fixation system after complete ligamentous disruption.

We concluded that the swine cervical spine is an excellent model for the study of anterior cervical spine implant and fusion procedures. In this study, both devices are equally effective in restoring the stability of the injured cervical spine except the rigidity of flexion. The size of swine geometry is the most important factor to affect the result, since a scatter data will be induced.

<table>
<thead>
<tr>
<th>Plate</th>
<th>AO / Intact w/o PMMA</th>
<th>PMMA</th>
<th>Caspar / Intact w/o PMMA</th>
<th>PMMA</th>
<th>AO to Caspar ratio w/o PMMA</th>
<th>PMMA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressive strain</td>
<td>0.393</td>
<td>4.383</td>
<td>0.435</td>
<td>4.445</td>
<td>.904 (0.986)</td>
<td></td>
</tr>
<tr>
<td>Flexion strain</td>
<td>0.004</td>
<td>0.941</td>
<td>0.012</td>
<td>0.990</td>
<td>.330 (0.951)</td>
<td></td>
</tr>
<tr>
<td>Torsional rigidity</td>
<td>0.994(1.000)</td>
<td>0.731</td>
<td>0.960(0.948)</td>
<td>0.775</td>
<td>1.045(0.944)</td>
<td></td>
</tr>
</tbody>
</table>

*(   ) clockwise rotation,  # (  ) with PMMA

**Table1:** The ratio of AO and Caspar implanted spine to intact spine without or with PMMA grafted.
Figure 1: The mean strain under 25° flexion
Int: intact, Dis: Discectomy, CAG: Corpectomy +AO plate +PMMA graft, CCG: Corpectomy +Caspar plate +PMMA
CA: Corpectomy +AO, CC Corpectomy+ Caspar

Figure 2: Resistive torque ± 25° rotation

References
Garvey T.A. et al. SPINE 17:S431-5, 1992;
Grubb MR, Currier BL, Bonin V, Grabowski JJ, Transection of the 39th Meeting of the ORS, 714. 1993

Acknowledgements
This study was supported by National Science Council of Republic of China, through a grant
NSC 84-2213-E010-014