Is there a difference in range of motion, neck pain, and outcomes in patients with ossification of posterior longitudinal ligament versus those with cervical spondylosis, treated with plated laminoplasty?

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Object. There are little data on the effects of plated, or plate-only, open-door laminoplasty on cervical range of motion (ROM), neck pain, and clinical outcomes. The purpose of this study was to compare ROM after a plated laminoplasty in patients with ossification of posterior longitudinal ligament (OPLL) versus those with cervical spondylootic myelopathy (CSM) and to correlate ROM with postoperative neck pain and neurological outcomes.

Methods. The authors retrospectively compared patients with a diagnosis of cervical stenosis due to either OPLL or CSM who had been treated with plated laminoplasty in the period from 2007 to 2012 at the University of California, San Francisco. Clinical outcomes were measured using the modified Japanese Orthopaedic Association (mJOA) scale and neck visual analog scale (VAS). Radiographic outcomes included assessment of changes in the C2–7 Cobb angle at flexion and extension, ROM at C2–7, and ROM of proximal and distal segments adjacent to the plated lamina.

Results. Sixty patients (40 men and 20 women) with an average age of 63.1 ± 10.9 years were included in the study. Forty-one patients had degenerative CSM and 19 patients had OPLL. The mean follow-up period was 20.9 ± 13.1 months.

The mean mJOA score significantly improved in both the CSM and the OPLL groups (12.8 to 14.5, p < 0.01; and 13.2 to 14.2, respectively; p = 0.04). In the CSM group, the mean VAS neck score significantly improved from 4.2 to 2.6 after surgery (p = 0.01), but this improvement did not reach the minimum clinically important difference (MCID). Neither were there significant improvements in the VAS neck score in the OPLL group (3.6 to 3.1, p = 0.17).

In the CSM group, ROM at C2–7 significantly decreased from 32.7° before surgery to 24.4° after surgery (p < 0.01). In the OPLL group, ROM at C2–7 significantly decreased from 34.4° to 20.8° (p < 0.01). In the CSM group, the change in the VAS neck score significantly correlated with the change in the flexion angle (r = -0.37); however, it did not correlate with the change in ROM at C2–7 (r = -0.1). In the OPLL group, the change in the VAS neck score did not correlate with the change in the flexion angle (r = 0.03), the extension angle (r = -0.17), or the ROM at C2–7 (r = -0.28). The OPLL group had a significantly greater loss of ROM after surgery than did the CSM group (p = 0.04). There was no significant correlation between the change in ROM and the mJOA score in either group.

Conclusions. Plated laminoplasty in patients with either OPLL or CSM decreases cervical ROM, especially in the extension angle. Among patients who have undergone laminoplasty, those with OPLL lose more ROM than do those with CSM. No correlation was observed between neck pain and ROM in either group. Neither group had a change in neck pain that reached the MCID following laminoplasty. Both groups improved in neurological function and outcomes.

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Key Words • cervical spondylotic myelopathy • range of motion • neck pain • correlation • laminoplasty

Cervical stenosis due to either OPLL or spondylosis is a common problem affecting the elderly population. Laminoplasty is an acceptable surgical option for cervical stenosis in patients without cervical kyphosis; however, C-5 palsy, neck pain, kyphosis, and a decrease in ROM have been reported as postoperative problems. There are variations in the surgical technique of laminoplasty, including open door or double door with or without plates or bone grafts. When a lamina hinge fracture occurs, bone grafts or hydroxyapatite spacers are difficult to secure. Possible dislocation of laminoplasty bone grafts or hydroxyapatite spacers with subsequent premature lamina closure and cord compression have been reported.

Plated, or plate-only, laminoplasty is a relatively new tech-
nique for fixation of the opened lamina. The plating systems enable immediate rigid fixation of the opened lamina and may prevent complications related to lamina fracture. Despite the increasing popularity of plate systems, there are little data on the effects of plated open-door laminoplasty on cervical ROM, neck pain, and clinical outcomes. The purpose of this study was first to examine the clinical and radiographic outcomes of plated laminoplasty and then to assess ROM and the relationship between ROM and neck pain. Furthermore, we wanted to compare the results of plated laminoplasty in patients with OPLL versus those with degenerative CSM.

Methods

Patient Demographics

We retrospectively compared patients with a diagnosis of cervical stenosis due to either OPLL or CSM who had been treated with plated laminoplasty in the period from 2007 to 2012 at the University of California, San Francisco. We included in our study only those patients who had preoperative and postoperative cervical spine radiographs. All of the patients had 3 or more levels of stenosis, and none had cervical kyphosis. Patients who had required extension of decompression to C-2 or T-1 were treated using posterior laminectomies with fusion and were not included in our study.

Patient Assessment

Perioperative Data. Perioperative data were collected in all patients and included EBL, duration of hospital stay, complications, and reoperations.

Clinical Outcome. Patients were evaluated using pre- and postoperative Nurick grades, VAS neck pain and arm pain scores, mJOA score, and time until returning to work.

Radiographic Outcomes. We compared pre- and postoperative dynamic radiographs at the final follow-up examination. Range of motion of the cervical spine was assessed by measuring the C2-7 Cobb angle on flexion and extension; a positive value meant lordosis. The C2-7 angle was measured from the inferior C-2 endplate and the superior C-7 endplate. Segmental ROM of the proximal and distal segments adjacent to the plated lamina was also measured.

Surgical Techniques

All patients underwent open-door laminoplasty with titanium miniplates without bone graft. A drill with a matchstick burr was used to open the hemilamina on the side associated with more symptoms. A shallow trough was scored on the contralateral hemilamina with the same drill bit, and this side was used as a hinge to open the laminoplasty. The open-door laminoplasty was secured using a preshaped titanium miniplate, and small screws were placed through the plate apertures into the lateral mass on one side and into the opened hemilamina on the other side. An additional unilateral posterior foraminotomy on the plated side was performed if cervical radiculopathy was present clinically.

Statistical Analysis

The Mann-Whitney U-test and chi-square test were used to compare clinical outcomes, and a paired t-test was used to compare ROM before and after surgery. Correlations between ROM and VAS score were analyzed by using the Pearson correlation coefficient. A p value < 0.05 was considered statistically significant. The SPSS software (version 20, IBM) was used for statistical analysis.

Results

This study included 60 patients, 40 males and 20 females, with a diagnosis of cervical stenosis treated with plated laminoplasty in the period from 2007 to 2012. Forty-one patients had degenerative CSM (CSM group) and 19 had segmental OPLL (OPLL group). The mean age of patients was 63.1 ± 10.9 years, and the mean follow-up was 20.9 ± 13.1 months. The mean number of operated spinal segments and plates used for laminoplasty were 3.8 ± 0.6 and 3.5 ± 0.6, respectively. Fifteen (75%) of the 20 patients who had worked before surgery returned to work successfully after surgery, and the mean time until a patient returned to work was 8 weeks. The return to work rate was not significantly different between the CSM and OPLL groups (79% vs 67%, p = 0.57).

Perioperative Data

In the CSM group, mean operation time (skin to skin) and EBL were 126 ± 43 minutes and 178 ± 104 ml, respectively (Fig. 1). In the OPLL group, mean operation time and EBL were 129 ± 37 minutes and 180 ± 122 ml, respectively (Fig. 2). There was no significant difference in the operation time (p = 0.85) or EBL (p = 0.96) between the groups. The mean hospital stay was 3.5 ± 1.7 days in the CSM group and 4.0 ± 2.6 days in the OPLL group (p = 0.39).

In the CSM group (41 patients), there were 2 dural tears, 3 infections, and 1 delayed wound healing. The cases of infection and delayed wound healing required revision surgery; however, implant removal was not necessary. There was also a case with asymptomatic partial screw backout of a C-5 laminoplasty screw from the lateral mass, but it did not require revision surgery.

In the OPLL group (19 patients), there were 2 postoperative C-5 palsies. No revision surgeries were performed in these cases.

Overall, there was no dislocation of any plate in any patient. The symptomatic complication rate was 13.3% and the revision rate was 6.6% in the entire cohort of 60 patients.

Clinical Outcome

In the CSM group, the mean Nurick grade significantly improved from 2 before surgery to 1 after surgery (p = 0.002; Table 1). The mJOA score was available for 87% of the entire cohort; it was available for 90% of the patients in the CSM group. The mean mJOA score significantly improved from 12.8 ± 3.1 before surgery to 14.5 ± 2.7 after surgery (p < 0.001). The mean VAS neck pain score significantly improved from 4.2 ± 3.4 before surgery to 2.6 ± 2.9 after surgery (p = 0.01), but this change did not reach...
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the MCID. The mean VAS arm pain score significantly improved from 3.3 ± 3.4 before surgery to 1.8 ± 2.6 after surgery (p < 0.01).

In the OPLL group, the mean Nurick grade significantly improved from 2.0 ± 1.0 before surgery to 1.2 ± 1.2 after surgery (p = 0.01). The mJOA score was available for 79% of the patients in the OPLL group, and the mean score improved from 13.2 ± 2.2 before surgery to 14.2 ± 2.8 after surgery (p = 0.04). The mean VAS neck pain score improved from 3.6 ± 3.2 before surgery to 3.1 ± 2.3 after surgery (p = 0.17), but again this change did not reach the MCID. The mean VAS arm pain score significantly improved from 2.8 ± 3.0 before surgery to 1.5 ± 2.3 after surgery (p = 0.047).

Radiographic Outcomes

Range of Motion at C2–7. In the CSM group, the mean preoperative C2–7 Cobb angle was −12.1° on flexion and 20.6° on extension (Table 2). At the final follow-up examination, the mean postoperative C2–7 Cobb angle was −12.9° on flexion and 11.5° on extension. Range of motion at C2–7 significantly decreased from 32.7° before surgery to 24.4° after surgery (p < 0.01). The ROM preservation rate was 75%.

In the OPLL group, the mean preoperative C2–7 Cobb angle was −12.8° on flexion and 21.6° on extension. At the final follow-up examination, the mean postoperative C2–7 Cobb angle was −9.3° on flexion and 11.5° on extension. Range of motion at C2–7 significantly decreased from 34.4° before surgery to 20.8° after surgery (p = 0.01). The ROM preservation rate was 61%.

In a comparison between the CSM and the OPLL groups, there was a significant difference in the decrease in ROM at C2–7 (8.3° vs 13.6°, p = 0.04; Table 3).

Range of Motion at Segments Adjacent to Plated Lamina. In the CSM group, the mean preoperative ROM at the proximal adjacent segment decreased from 6.6° before surgery to 5.8° after surgery (p = 0.1). The mean ROM at the distal adjacent segment decreased from 4.4° before surgery to 3.5° after surgery (p = 0.054).

In the OPLL group, the mean preoperative ROM at the proximal adjacent segment decreased from 5.1° before surgery to 4.5° after surgery (p = 0.3). The mean ROM at the distal adjacent segment significantly decreased from 5.3° before surgery to 3.8° after surgery (p = 0.015).

There was no significant difference between the CSM and the OPLL groups in the decrease in ROM at either the proximal adjacent segment (0.8° vs 0.5°, p = 0.7) or the distal segment (0.9° vs 1.3°, p = 0.7; Table 3).
Relationship Between Neck Pain, Clinical Outcome, Dynamic Alignment, and ROM. A correlation coefficient was calculated in the change in the VAS neck pain score, flexion angle, extension angle, ROM at C2–7, and at the segments adjacent to the plated lamina.

In the CSM group, the change in VAS neck pain significantly correlated with the change in the flexion angle \( (r = -0.31, p = 0.049; \text{Fig. 3}) \) and the extension angle \( (r = -0.37, p = 0.02; \text{Fig. 4}) \); however, it did not correlate with the change in ROM at C2–7 \( (r = 0.1, p = 0.6) \). These results meant that patients in the CSM group with more neck pain had an increased flexion angle and a decreased extension angle after surgery.

In the OPLL group, the change in VAS neck pain did not correlate with the change in the flexion angle \( (r = 0.03, p = 0.9) \), the extension angle \( (r = -0.17, p = 0.5) \), or the ROM at C2–7 \( (r = -0.28, p = 0.3) \). Neither was there a significant correlation between the change in ROM and Nurick grade or mJOA score in either the CSM or OPLL group.

The change in segmental ROM at the segments adjacent to the plated lamina correlated with the change in ROM at C2–7; however, it did not correlate with the

**TABLE 1: Preoperative and postoperative clinical findings**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preop</th>
<th>Postop</th>
<th>p Value</th>
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</thead>
<tbody>
<tr>
<td><strong>CSM group (n = 41)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurick grade</td>
<td>2.0 ± 1.2</td>
<td>1.3 ± 1.3</td>
<td>0.002*</td>
</tr>
<tr>
<td>mJOA score†</td>
<td>12.8 ± 3.1</td>
<td>14.5 ± 2.7</td>
<td>0.001*</td>
</tr>
<tr>
<td>VAS neck score</td>
<td>4.2 ± 3.4</td>
<td>2.6 ± 2.9</td>
<td>0.01*</td>
</tr>
<tr>
<td>VAS arm score</td>
<td>3.3 ± 3.4</td>
<td>1.8 ± 2.6</td>
<td>0.01*</td>
</tr>
<tr>
<td><strong>OPLL group (n = 19)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nurick grade</td>
<td>2.0 ± 1.0</td>
<td>1.2 ± 1.2</td>
<td>0.01*</td>
</tr>
<tr>
<td>mJOA score‡</td>
<td>13.2 ± 2.2</td>
<td>14.2 ± 2.8</td>
<td>0.04*</td>
</tr>
<tr>
<td>VAS neck score</td>
<td>3.6 ± 3.2</td>
<td>3.1 ± 2.3</td>
<td>0.17</td>
</tr>
<tr>
<td>VAS arm score</td>
<td>2.8 ± 3.0</td>
<td>1.5 ± 2.3</td>
<td>0.047*</td>
</tr>
</tbody>
</table>

* Significant, \( p < 0.05 \).
† Available for 37 patients.
‡ Available for 15 patients.
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**TABLE 2: Dynamic alignment and ROM before and after surgery***

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Preop</th>
<th>Postop</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>CSM group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2–7 Cobb angle on flexion</td>
<td>−12.1 ± 10.6</td>
<td>−12.9 ± 12.3</td>
<td>0.5</td>
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<tr>
<td>C2–7 Cobb angle on extension</td>
<td>20.6 ± 9.9</td>
<td>11.5 ± 12.0</td>
<td>&lt;0.001†</td>
</tr>
<tr>
<td>ROM at C2–7</td>
<td>32.7 ± 11.4</td>
<td>24.4 ± 10.5</td>
<td>0.01†</td>
</tr>
<tr>
<td>ROM at proximal adjacent segment</td>
<td>6.8 ± 4.2</td>
<td>5.8 ± 3.4</td>
<td>0.1</td>
</tr>
<tr>
<td>ROM at distal adjacent segment</td>
<td>4.4 ± 3.4</td>
<td>3.5 ± 3.5</td>
<td>0.054</td>
</tr>
<tr>
<td>OPLL group</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C2–7 Cobb angle on flexion</td>
<td>−12.8 ± 10.9</td>
<td>−9.3 ± 17.5</td>
<td>0.28</td>
</tr>
<tr>
<td>C2–7 Cobb angle on extension</td>
<td>21.6 ± 8.9</td>
<td>11.5 ± 17.1</td>
<td>0.007†</td>
</tr>
<tr>
<td>ROM at C2–7</td>
<td>34.4 ± 12.2</td>
<td>20.8 ± 12.2</td>
<td>0.01†</td>
</tr>
<tr>
<td>ROM at proximal adjacent segment</td>
<td>5.1 ± 3.6</td>
<td>4.5 ± 3.1</td>
<td>0.3</td>
</tr>
<tr>
<td>ROM at distal adjacent segment</td>
<td>5.3 ± 3.4</td>
<td>3.8 ± 2.3</td>
<td>0.015†</td>
</tr>
</tbody>
</table>

* All values expressed as degrees.
† Significant, p < 0.05.

There are several documented reasons for the loss of ROM after laminoplasty. Seichi et al. reported that only 22% of preoperative ROM was maintained after laminoplasty. These authors also mentioned that the loss of ROM after laminoplasty was caused by unexpected fusion of the facet joints. The high fusion rate in their series may have occurred because they used iliac crest as struts for the laminoplasty.

Machino et al. reported that 88% of preoperative ROM was maintained after a laminoplasty preserving the C-2 muscle and active rehabilitation. In their study, the ROM preservation rate was 89% in flexion and 87% in extension. Meyer et al. noted that plated laminoplasty leads to a loss of ROM in extension. Kang et al. and Maeda et al. documented a strong correlation between ROM and cervical lordosis. In our current study, the loss of ROM was caused mainly by a decrease in the extension angle in both groups. We speculate that this restriction of extension may have occurred partly as a result of impingement of the opened lamina because the spinous processes were preserved in all our cases. Another reason would be scarring of the cervical extension muscles. The posterior extensor muscles of the cervical spine help to stabilize the head and increase in ROM still occur. There are several documented reasons for the loss of ROM after laminoplasty. Seichi et al. reported that only 22% of preoperative ROM was maintained after laminoplasty. These authors also mentioned that the loss of ROM after laminoplasty was caused by unexpected fusion of the facet joints. The high fusion rate in their series may have occurred because they used iliac crest as struts for the laminoplasty.

**Range of Motion and Alignment After Laminoplasty**

Laminoplasty preserves more posterior elements than laminectomy; however, postoperative kyphosis and a decrease in ROM still occur. There are several documented reasons for the loss of ROM after laminoplasty. Seichi et al. reported that only 22% of preoperative ROM was maintained after laminoplasty. These authors also mentioned that the loss of ROM after laminoplasty was caused by unexpected fusion of the facet joints. The high fusion rate in their series may have occurred because they used iliac crest as struts for the laminoplasty.

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to maintain alignment of the cervical spine and neck function.35 The OPLL group tended to have a greater loss of extension angle and flexion angle than the CSM group. In total, the ROM at C2–7 was significantly more restricted in the OPLL group than in the CSM group. This may have occurred because the cervical spine with OPLL was likely to partially spontaneously fuse after laminoplasty due to OPLL progression.6,25 Hyun et al. studied ROM at the 5-year follow-up in 23 patients who had undergone laminoplasty.14 Preservation of ROM in the OPLL group was significantly less than in the CSM group (47% vs 73%). Chiba et al. similarly reported that ROM decreased from 44° to 14° in a CSM group and 32° to 11° in an OPLL group after laminoplasty.4

Neck Pain After Laminoplasty

Neck pain has been one of the concerns following laminoplasty. Hosono et al. reported that the prevalence of preoperative axial neck pain in patients with CSM was 27%.12 They noted that postoperative neck pain was apparent in 60% of the patients who had undergone laminoplasty. However, the cause of the neck pain is a matter of debate. Posterior muscle damage or contracture of the cervical spine has been posited as a possible cause of postoperative neck pain. In our study, the correlation coefficient analysis showed that neck pain was more strongly associated with loss of the extension angle and that no correlation was observed between neck pain and ROM at C2–7. Hyun et al. and Albert and Vacarro reported that no correlation was observed between neck pain and ROM before and after surgery.2,13 These reports correspond to ours in that ROM did not correlate with neck pain. Another question is, does the loss of extension angle cause neck pain? Takeuchi et al. and Sakaura et al. revealed that preservation of the semispinalis cervicis muscle insertion into C-2 prevented the loss of extension in ROM at C2–7 and axial neck pain after laminoplasty.30,33,34 Preservation of the semispinalis cervicis muscle attachment to the C-2 spinous process was also thought to be important for maintaining cervical lordosis and ROM.34 Vasavada et al. noted that most of the extension moment-generating capacity is derived from the semispinalis cervicis muscle.35 Therefore, it may be more reasonable to conclude that damage to the semispinalis cervicis muscle caused both loss of the extension angle and neck pain.

Few authors have examined the adjacent-segment ROM of laminoplasty. Ratliff and Cooper were concerned that there was adjacent-segment disease because of the compensatory increase in adjacent-segment stress due to a restricted ROM after laminoplasty.24 Before this study, we speculated that some increase in ROM might occur at these adjacent segments; however, we found a decrease in ROM at the adjacent segments, which correlated with a decrease in ROM at C2–7. This result suggests that plated

<table>
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<tr>
<th>Change*</th>
<th>CSM Group</th>
<th>OPLL Group</th>
</tr>
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<tbody>
<tr>
<td>VAS neck pain vs flexion angle</td>
<td>-0.31†</td>
<td>0.03</td>
</tr>
<tr>
<td>vs extension angle</td>
<td>-0.37†</td>
<td>-0.17</td>
</tr>
<tr>
<td>vs ROM at C2–7</td>
<td>-0.1</td>
<td>-0.28</td>
</tr>
<tr>
<td>vs ROM at proximal adjacent segment</td>
<td>0.05</td>
<td>0.19</td>
</tr>
<tr>
<td>vs ROM at distal adjacent segment</td>
<td>-0.02</td>
<td>-0.1</td>
</tr>
<tr>
<td>ROM at C2–7 vs mJOA</td>
<td>-0.17</td>
<td>-0.19</td>
</tr>
<tr>
<td>vs ROM at proximal adjacent segment</td>
<td>0.13</td>
<td>0.48†</td>
</tr>
<tr>
<td>vs ROM at distal adjacent segment</td>
<td>0.43†</td>
<td>0.56†</td>
</tr>
</tbody>
</table>

* Change from preoperatively to postoperatively.
† p value of correlation coefficient < 0.05.

44° to 14° in a CSM group and 32° to 11° in an OPLL group after laminoplasty.3
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Laminoplasty is unlikely to cause adjacent-segment degeneration.

Recent reports on sophisticated laminoplasty techniques have documented less neck pain than earlier reports. Many studies have focused on postoperative pain after laminoplasty; however, few have compared neck pain before and after laminoplasty. In our study, neck pain significantly improved after laminoplasty in the CSM group. However, this change did not reach an MCID. The MCID for neck pain has been reported to be approximately 2.5. In our study, the decrease in neck pain after surgery was 1.6 ± 3.2 for both cohorts combined, and this was less than the MCID. Therefore, even though there was a significant decrease in neck pain in the CSM group, it is questionable whether this change is clinically meaningful. In the OPLL group, there was no significant change in neck pain postoperatively. Overall, we found that laminoplasty does not lead to worsening neck pain postoperatively.

Authors of prior studies have found that laminoplasty is an effective alternative to fusion procedures performed to treat cervical stenosis. Though fusion procedures are associated with a reduction in neck pain, they are also associated with a greater loss of cervical ROM when compared with plated laminoplasty.

Conclusions

Plated laminoplasty is an effective treatment for cervical stenosis due to degenerative spondylosis or OPLL. Neck pain was mildly improved after laminoplasty in the degenerative CSM group; however, the improvement did not reach the MCID. In the OPLL group, neck pain did not significantly change. Loss of ROM after laminoplasty mainly came from loss of the extension angle in both groups. The patients with OPLL lost more ROM after a plated laminoplasty than did those with CSM. No correlation was observed between postoperative neck pain and the change in ROM in either group. Patients and surgeons considering plated laminoplasty to treat OPLL- or CSM-related stenosis should be aware that the procedure is associated with sustained neurological improvement, although plated laminoplasty is also associated with a reduction in extension ROM and no meaningful change in preoperative neck pain.

Disclosure

Dr. Mummaneni has received honoraria from DePuy Spine, Inc., and Globus Medical, Inc., and royalties from DePuy Spine, Inc., Quality Medical Publishing, Inc., and Thieme publishers. Dr. Chou is a consultant for Orthofix and has received honoraria from Globus, DePuy, and Medtronic.

Author contributions to the study and manuscript preparation include the following: Conception and design: all authors. Acquisition of data: all authors. Analysis and interpretation of data: Mummaneni, Fujimori, Ie. Drafting the article: Fujimori. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Mummaneni. Statistical analysis: Fujimori. Administrative/technical/material support: Mummaneni. Study supervision: Mummaneni.

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