Assessment of Proximal Junctional Kyphosis and Shoulder Balance with Proximal Screws vs. Hooks in Posterior Spinal Fusion for Adolescent Idiopathic Scoliosis

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Abstract

Study design: A retrospective review of a prospectively collected multicenter database

Objective: To assess the effect of proximal hooks vs. screws on proximal junctional kyphosis (PJK) as well as shoulder balance in otherwise all pedicle screw (>80%) posterior spinal fusion (PSF) constructs in adolescent idiopathic scoliosis (AIS).

Summary of Background Data: Less rigid forms of fixation at the top of constructs in degenerative lumbar PSF have been postulated to decrease the risk of PJK.

Methods: A multicenter AIS surgical database was reviewed to identify all patients who underwent PSF with all pedicle screw (>80%) constructs and minimum 2-year follow-up. Patients in the “hook” group had two hooks used at the top of the construct, whereas the “screw” group used only pedicle screws at all levels.

Results: A total of 354 patients were identified, 274 (77%) in the screw group, and 80 (23%) in the hook group. There were no significant preoperative differences with regards to curve type, coronal/sagittal Cobb angle, or curve flexibility for either group. At 2 years post-op, the coronal Cobb correction was similar for both groups (60%). There was no difference in correction of shoulder asymmetry and T1 rib angle, including when the groups were matched for preoperative shoulder balance. PJK, defined as the sagittal Cobb angle between the uppermost instrumented and uninstrumented vertebrae, was similar for the screw vs. hook group as well (7.1° vs. 6.2°, p=0.2).

Conclusion: The use of different anchors (pedicle screws vs. hooks) at the top of an otherwise all pedicle screw PSF construct for AIS did not have any significant bearing on the correction of shoulder asymmetry and coronal Cobb angle at two years postoperative. There was also no significant difference in the magnitude of PJK or incidence of marked PJK (>15°) between either group at two years.

Key Words: Adolescent idiopathic scoliosis; posterior spinal fusion; proximal junctional kyphosis; shoulder balance

Level of Evidence: 3
INTRODUCTION

Over the last two decades, segmental pedicle screw instrumentation has been found to be a safe and effective means of spinal deformity correction. The three column fixation afforded by pedicle screws provides an increased ability to correct coronal and axial deformity compared to hooks, which only anchor the posterior column. However, the increased rigidity of all pedicle screw constructs may result in decreased thoracic kyphosis when compared to hook fixation. Additionally, screws have been found to have a higher incidence of proximal junctional kyphosis (PJK) when compared to hook constructs. Several factors may contribute to this including decreasing the structural rigidity of the proximal aspect of the construct, reducing the soft tissue disruption proximal to the construct, and providing a transition to the uninstrumented spine.

Shoulder balance is known to be an important factor in postoperative outcomes and patient satisfaction. The effect of the type of anchor used in PSF for AIS has shown variable results in the literature thus far. O’Brien et al reported no effect on shoulder imbalance with screw vs. hook constructs. Clements et al meanwhile reported improved shoulder height asymmetry in all pedicle screw constructs for Lenke 1 curves.

The purpose of this study is to evaluate the effect of different upper instrumented vertebra (UIV) anchor types (pedicle screws vs. transverse process hooks) on the proximal coronal and sagittal alignment in PSF for AIS. Shoulder balance, sagittal alignment of the overall construct, and PJK were compared between groups utilizing pedicle screws versus hooks at the proximal aspect (UIV) of an otherwise all pedicle screw construct for AIS.
MATERIALS AND METHODS

A prospectively collected multicenter database of AIS patients treated with posterior segmental instrumentation from 2004-2012 was reviewed. Patients were included in the study if their instrumentation constructs contained predominantly (>80%) pedicle screws, and if preoperative as well as 2-year postoperative radiographic data were available. Patients who had additional procedures (i.e. an anterior approach), in whom the UIV was below T5, or those patients with only one hook at the UIV were excluded from the study. Patients meeting the above criteria were then divided into two groups based on the type of instrumentation used at the UIV. The patients in the “hook” group had two hooks used at the top of the construct (Fig. 1AB), compared to patients in the “screw” group in which only pedicle screws were used (Fig. 2AB).

Shoulder balance was assessed by evaluating the difference between the height of the right and left acromioclavicular joint as well as the T1 rib angle (T1RA) on an upright full-length posteroanterior (PA) spine radiograph just prior to surgery and at 2 years postoperatively. While there are several different assessments reported for shoulder balance,13,16,17 T1RA and acromioclavicular joint height were the two most consistently reliable measurements available for all patients in the study. Proximal junctional kyphosis (PJK) was evaluated on a lateral full-length upright radiograph both preoperatively and at 2 years postoperatively. The proximal junctional angle was measured from the caudal endplate of the UIV to the cephalad endplate of the vertebra adjacent to the UIV. Only 1 cephalad vertebra was chosen to measure PJK in order to increase the likelihood that the area of interest was isolated and to reduce the possible dampening effect of including additional segments.9
Data collection and evaluation were conducted by an independent reviewer who was not involved in the surgical treatment. Statistical analysis was performed using analysis of variance (ANOVA) for continuous variables and Chi-square for categorical variables. A $P$-value of 0.05 defined significance.

IRB approval for the study was obtained locally from each contributing institution’s review board, and consent was obtained from each patient prior to data collection.

RESULTS

There were 278 females (79%) and 76 males (21%) with AIS identified (354 patients total) who had segmental PSF with constructs consisting of $>80\%$ pedicle screws and a minimum 2 year follow-up. The mean age was 14.5 years, range 10.4-19.8 years. All 6 Lenke curve types were represented, with Lenke type 1 and 2 curves representing over 75% of the patients at 55.5% and 20.6%, respectively. The Lenke type curves were as follows: 197 Lenke 1 curves, 72 Lenke 2 curves, 20 Lenke 3 curves, 10 Lenke 4 curves, 18 Lenke 5 curves, and 27 Lenke 6 curves. The UIV was T2 in 95 patients (27%), T3 in 81 patients (23%), T4 in 125 patients (35%), and T5 in 53 patients (15%).

The patients were divided into two groups based on the type of implant (pedicle screws versus hooks) used at the proximal aspect (UIV) of the construct. There were 274 patients in the “pedicle screw” group, and 80 patients in the “hook” group. There were no differences between the pedicle screw and hook group with regards to age, sex, preoperative coronal and sagittal Cobb angles, and curve type (Lenke 1, 2, etc.).
The coronal Cobb correction was similar for each group at 2 years postoperatively. The mean thoracic curve correction was 66% and 63% in the hook versus screw groups, respectively (p=0.11) and the mean lumbar correction was 63% and 61% for the hook and screw groups, respectively (p=0.4) (Table 1). Sagittal measurements demonstrated some variability between the two groups at two years follow-up. The T5-T12 Cobb angle was significantly lower in the screw group (hook: 21.1° vs. screw: 16.4°, p<0.001). The screw group also demonstrated a greater loss of kyphosis from T5-T12 (hook: -0.2° vs. screw: -5.7°, p<0.001) at two years postoperative. Of note, there was no difference between either group with regard to the rod diameter or rod type (titanium or stainless steel) utilized.

Given this data, the T2-T5 Cobb angle was specifically assessed. The magnitude of the T2-T5 angle was similar for both groups 2 years postoperatively (hook: 9.8° vs. screw: 11.1°, p=0.12), and the difference from preoperative to postoperative was negligible for both groups (hook: +1.4° vs. screw: +1.9°, p=0.53) (Table 1). Finally, the magnitude of PJK at 2 years postoperatively for the screw and hook group, (7.1° vs. 6.2°, respectively) was not significantly different (p=0.16) (Table 2). Overall, only 1 patient in the hook group (1.3%) and 5 patients in the screw group (1.8%) demonstrated a PJK of >15° at 2 years postoperative, p=0.8.

Preoperative shoulder asymmetry was significantly higher in the screw group versus the hook group (1.8 cm vs. 1.0 cm, p<0.001). Therefore, a separate matched cohort was created from the existing patient groups to match patients with pedicle screws or hooks based on preoperative shoulder asymmetry. In this separate cohort, 75 patients with pedicle screws were identically matched to 75 patients with hooks for preoperative shoulder asymmetry (1.0 cm vs. 1.0 cm, respectively, p=0.987). Also within this separate cohort, there were no differences between the two groups with regards to age, sex, preoperative coronal and sagittal Cobb angles, and curve
type. Two-year postoperative shoulder asymmetry was similar for both groups (hook: 0.8 cm vs. screw: 0.7 cm, p=0.33), as was the change in shoulder asymmetry from preoperative to 2 years postoperative (hook: -0.2 cm vs. screw: -0.3 cm, p=0.6) (Table 3). Assessment of 2-year postoperative T1 tilt angle also did not demonstrate any difference between the two groups (p=0.7) (Table 3).

There were no differences with regards to preoperative SRS-22 scores between the hook and screw groups. Similarly, the SRS-22 clinical outcome scores were nearly identical for both groups at two years postoperative (Table 4). There were no reoperations in either group.

DISCUSSION

Pedicle screw fixation enables 3-column vertebral fixation from a posterior-only approach. The added purchase of screws within the pedicle and vertebral body has significantly increased the corrective power when compared to hooks and/or sublaminar wires. In AIS, the use of pedicle screws for PSF has demonstrated a significant improvement in coronal curve correction when compared to hooks.\(^5,6,11,18\) Pedicle screws have also been shown to be superior to hooks for correcting vertebral rotation associated with scoliosis.\(^19\)

However, pedicle screw PSF constructs may negatively affect postoperative sagittal alignment. Clements \textit{et al}\(^15\) reported that increasing pedicle screw implant density significantly decreased postoperative thoracic kyphosis, whereas increasing hook implant density correlated with increasing postoperative thoracic kyphosis. A decrease in thoracic kyphosis postoperatively has been postulated to potentially contribute to the development of PJK as well as to a decrease in lumbar lordosis.\(^20\)
Kim et al. demonstrated a “weak,” but statistically significant, positive correlation between the decrease of thoracic kyphosis and PJK at 2 years postoperatively. A statistically significant increase in PJK, defined in this study as >10°, was identified between the pedicle screw versus hook groups and between the hybrid (proximal hooks, distal screws) versus hook groups. No difference in PJK was demonstrated when comparing the all screw versus hybrid groups. The authors theorized that the development of PJK after PSF was related to the increased overall rigidity of pedicle screw constructs compared to hooks.

Lastly, Helgeson et al. demonstrated an increase in PJK at 2 years postoperatively in the all pedicle screw PSF constructs (8.2°) for AIS when compared to hybrid (5.7°, p=0.02) and all hook (5.0°, p=0.014) constructs. Postoperative T5-T12 kyphosis was significantly (p=0.016) less in the screw group compared to the all hook group. A trend towards a decrease in PJK was identified in constructs in which hooks were used at the UIV in an otherwise all pedicle screw construct compared to true all pedicle screw constructs. Similar to the report by Rhee et al., the authors attributed the development of PJK in all pedicle screw PSF to increased posterior soft tissue disruption (capsular, ligamentous, and muscular), increased curve correction, decreased kyphosis, and increased construct rigidity.

The clinical significance of PJK in AIS has been debated amongst surgeons. While potentially concerning from a radiographic standpoint, multiple studies have reported that PJK has no significant effect on patient reported outcome scores. Kim et al. reported that patients who developed PJK actually reported higher total scores, including a higher self-image score, on the Scoliosis Research Society-24 questionnaire.
While postoperative PJK may not typically be clinically significant with regard to patient reported outcomes, shoulder balance has been shown to be an important factor in postoperative outcomes and patient satisfaction. Though there is no consensus method by which to assess shoulder balance, authors agree that proper shoulder alignment is positively correlated with patient self-assessment. O’Brien et al. reported that the type of instrumentation had no effect on the development of postoperative left shoulder elevation in Lenke 1 AIS curves. However, Clements et al. found that all pedicle screw compared to hybrid constructs demonstrated a higher percentage improvement in shoulder height asymmetry and trunk shift in Lenke 1 AIS curves.

In this study, the coronal thoracic and lumbar Cobb correction were similar for each group at two years postoperative. The screw group did demonstrate a decrease in the T5-T12 kyphosis at two years when compared to the hook group (16.4° vs. 21.1°, p<0.001). However, given that only 15% of the patients had a UIV of T5, it is less likely that the UIV anchor (screw vs. hook) itself was the significant contributor to overall thoracic kyphosis, and more likely due to surgeon technique. Further, specific evaluation of the proximal thoracic sagittal profile (T2-T5 sagittal Cobb), did not demonstrate any significant difference between the two groups at two years postoperative (Table 1).

This study also demonstrated that the UIV anchor (screws vs. hooks) did not play a significant role in proximal junctional kyphosis at 2 years postoperative. Both the PJK magnitude and change from preoperative to 2 years postoperative were within one degree of one another for the screw vs. hook groups. (Table 2) Further, there was a similar incidence of postoperative PJK >15° in the screw (1.8%) and hook (1.3%, p=0.8) groups, and no patients required reoperation. Clinical patient outcomes assessed by the SRS-22, were identical for both groups at two years.
Similar to PJK, the results of this study exhibited that utilizing screws vs. hooks at the UIV did not have a significant impact on postoperative shoulder balance. Given that the screw group had a significantly higher preoperative shoulder asymmetry compared to the hook group (1.8cm vs. 1cm, p<0.001), a separate matched cohort was created from 75 hook patients being closely matched to 75 screw patients. There were no differences between these two subgroups with regards to all of the aforementioned parameters, including shoulder asymmetry (hook: 1.0 cm vs. screw: 1.0 cm, p=0.99). Two year postoperative shoulder asymmetry and T1 rib angle were similar for both groups in the matched cohort.

Recent studies have shown that a 3D image reconstruction may provide more information of the true spinal deformity, which may be underestimated with standard 2D images.\textsuperscript{24,25} This is a limitation of the study’s radiographic assessment as only a relatively limited number of 3D reconstructions are in our database at this time. The authors have continued to compile 3D reconstructions of radiographs in subsequent patients in hopes of reevaluating this study and many others when a sufficient number are available to critically review. This may also allow for better measurement of proximal thoracic sagittal parameters, which at times can be challenging due to overlapping structures. The authors are also continuing to follow these patients to evaluate shoulder balance and PJK at 5 to 10 years postoperative and beyond to better understand the long-term implications of the current treatment methods. Another limitation of the study is that there was a larger number of screw patients compared to hook patients. This was largely due to surgeon preference and not to specific deformity characteristics, as both groups demonstrated similar preoperative radiographic parameters.
The use of transverse process hooks compared to pedicle screws at the top of an otherwise all pedicle screw construct in posterior spinal fusion for adolescent idiopathic scoliosis did not significantly impact proximal junctional kyphosis or shoulder balance at two years postoperative in this study. Thus, the authors feel that either UIV implant is safe and effective. Surgeon comfort and capability, coupled with meticulous surgical technique and soft tissue preservation, are the primary components to achieving proper coronal and sagittal balance as well as successful patient outcomes.
REFERENCES


FIGURE LEGEND

Figure 1. Posteroanterior (a) and lateral (b) erect radiograph of a PSF with hooks utilized at the proximal end of the construct (UIV).
Figure 2. Posteroanterior (a) and lateral (b) erect radiograph of a PSF with screws utilized at the proximal end of the construct (UIV).
Table 1: Coronal and sagittal parameters at 2 years postoperative

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Hook Group (n = 80)</th>
<th>Screw Group (n = 274)</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coronal thoracic curve</td>
<td>66%</td>
<td>63%</td>
<td>0.11</td>
</tr>
<tr>
<td>Coronal lumbar curve</td>
<td>63%</td>
<td>61%</td>
<td>0.4</td>
</tr>
<tr>
<td>Sagittal Cobb T2-T5</td>
<td>9.8°</td>
<td>11.1°</td>
<td>0.12</td>
</tr>
<tr>
<td>Pre-op to 2y PO Δ T2-T5</td>
<td>1.4°</td>
<td>1.9°</td>
<td>0.5</td>
</tr>
<tr>
<td>Sagittal Cobb T5-T12</td>
<td>21.1°</td>
<td>16.4°</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Pre-op to 2y PO Δ T5-T12</td>
<td>-0.2°</td>
<td>-5.7°</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

y = year
PO = postoperative
Δ = change

**Bold = statistically significant**
Table 2: Proximal junctional kyphosis at 2 years postoperative

<table>
<thead>
<tr>
<th></th>
<th>Hook Group (n = 80)</th>
<th>Screw Group (n = 274)</th>
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<tr>
<td>Proximal junctional</td>
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<tr>
<td>kyphosis</td>
<td>6.2°</td>
<td>7.1°</td>
<td>0.16</td>
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<tr>
<td>Proximal junctional</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>kyphosis: Pre-op to</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2y PO Δ</td>
<td>+2.1°</td>
<td>+3.1°</td>
<td>0.27</td>
</tr>
</tbody>
</table>

y = year  
PO = postoperative  
Δ = change
Table 3: Shoulder Balance Parameters at 2 years postoperative: Assessment of subset of patients for hook and screw group matched for preoperative shoulder balance

<table>
<thead>
<tr>
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<th>Hook Group (n = 75)</th>
<th>Screw Group (n = 75)</th>
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<tr>
<td>Shoulder asymmetry</td>
<td>0.8 cm</td>
<td>0.7 cm</td>
<td>0.33</td>
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<td>Shoulder asymmetry:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-op to 2y PO Δ</td>
<td>-0.2 cm</td>
<td>-0.3 cm</td>
<td>0.6</td>
</tr>
<tr>
<td>T1 rib angle</td>
<td>4.3°</td>
<td>4.5°</td>
<td>0.7</td>
</tr>
<tr>
<td>T1 rib angle: Pre-op to 2y PO Δ</td>
<td>-0.6</td>
<td>0.8</td>
<td>0.06</td>
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y = year
PO = postoperative
Δ = change
Table 4: SRS-22 patient outcome scores at 2 years post-op

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<th>Hook Group (n=80)</th>
<th>Screw Group (n=274)</th>
<th>P value</th>
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<tbody>
<tr>
<td>Pain</td>
<td>4.45</td>
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<tr>
<td>Self-Image</td>
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<td>Mental Health</td>
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<td>4.23</td>
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<tr>
<td>Satisfaction</td>
<td>4.4</td>
<td>4.57</td>
<td>0.23</td>
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