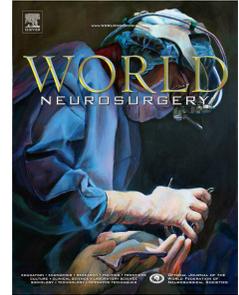


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Restoring L4-S1 Lordosis Shape in Severe Sagittal Deformity: Impact of Correction Techniques on Alignment and Complication Profile

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1 **Restoring L4-S1 Lordosis Shape in Severe Sagittal Deformity: Impact of Correction**  
2 **Techniques on Alignment and Complication Profile**

3

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7

8 **Key Words:** Adult Spinal Deformity; Correction; Caudal Lordosis; Sagittal Alignment;

9 Spinopelvic Parameters; Patient Reported Outcomes; Surgical Outcomes; Anterior Lumbar

10 Interbody Fusion; Pedicle Subtraction Osteotomy; Transforaminal Lumbar Interbody Fusion

11

1 **ABSTRACT:**

2 **Background Context:** Severe sagittal plane deformity with loss of L4-S1 lordosis is disabling and  
3 can be improved through various surgical techniques. However, data is limited on the differing  
4 ability of anterior lumbar interbody fusion (ALIF), pedicle subtraction osteotomy (PSO), and  
5 transforaminal lumbar interbody fusion (TLIF) to achieve alignment goals in severely malaligned  
6 patients.

7 **Purpose:** To examine surgical techniques aimed at restoring L4-S1 lordosis in severe adult spinal  
8 deformity (ASD).

9 **Design:** Retrospective review of prospectively collected data.

10 **Patient Sample:** A total of 96 patients who underwent ALIF, PSO, and TLIF were included in  
11 this study.

12 **Outcome Measures:** The following data were observed for all cases: patient demographics,  
13 spinopelvic parameters, complications, and PROMs.

14 **Methods:** Severe ASD patients with preoperative PI-LL  $>20^\circ$ , L4-S1 lordosis  $<30^\circ$ , and full body  
15 radiographs and patient-reported outcome measures (PROMs) at baseline and six-week  
16 postoperative visit were included. Patients were grouped into ALIF (1-2 level ALIF at L4-S1),  
17 PSO (L4/L5 PSO), and TLIF (1-2 level TLIF at L4-S1). Comparative analyses were performed on  
18 demographics, radiographic spinopelvic parameters, complications, and PROMs.

19 **Results:** Among the 96 included patients, 40 underwent ALIF, 27 underwent PSO, and 29  
20 underwent TLIF. At baseline, cohorts had comparable age, sex, race, Edmonton frailty scores and  
21 radiographic spinopelvic parameters ( $p>0.05$ ). However, PSO was performed more often in  
22 revision cases ( $p<0.001$ ). Following surgery, L4-S1 lordosis correction ( $p=0.001$ ) was comparable  
23 among ALIF and PSO patients and caudal lordotic apex migration ( $p=0.044$ ) was highest among

24 ALIF patients. PSO patients had higher intraoperative estimated blood loss ( $p < 0.001$ ) and motor  
25 deficits ( $p = 0.049$ ), and in-hospital ICU admission ( $p = 0.022$ ) and blood products given ( $p = 0.004$ )  
26 but were otherwise comparable in terms of length of stay, blood transfusion given, and  
27 postoperative admission to rehab. Likewise, 90-day postoperative complication profiles and six-  
28 week PROMs were comparable as well.

29 **Conclusions:** ALIF can restore L4-S1 sagittal alignment as powerfully as PSO, with fewer intra-  
30 operative and in-hospital complications. When feasible, ALIF is a suitable alternative to PSO and  
31 likely superior to TLIF for correcting L4-S1 lordosis among patients with severe sagittal  
32 malalignment.

33  
34 **Keywords:** Adult Spinal Deformity; Correction; Caudal Lordosis; Sagittal Alignment;  
35 Spinopelvic Parameters; Patient Reported Outcomes; Surgical Outcomes; Anterior Lumbar  
36 Interbody Fusion; Pedicle Subtraction Osteotomy; Transforaminal Lumbar Interbody Fusion

37

## 38 INTRODUCTION

39 Adult spinal deformity (ASD) is a disabling condition associated with severe impairments in  
40 quality of life. Many are impacted, with its prevalence increasing with age to nearly 68% among  
41 the elderly.<sup>1-4</sup> Given the aging population in the United States, these numbers are only expected to  
42 rise.

43  
44 Anterior lumbar interbody fusion (ALIF) and pedicle subtraction osteotomy (PSO) are two  
45 common surgical modalities used to correct sagittal malalignment in ASD. Despite its  
46 effectiveness in addressing ASD, PSO utilization, however, has recently been on the decline.<sup>5</sup> PSO  
47 is a technically demanding procedure that requires longer operative times and results in greater  
48 blood loss.<sup>6</sup> It is also associated with higher complication rates, including instrumentation failure,  
49 neurological deficit, and proximal junctional kyphosis (PJK).<sup>7,8</sup> Conversely, ALIF use has been on  
50 the rise, since it offers significantly greater improvements in sagittal alignment and disc height  
51 than other interbody fusion approaches.<sup>9-11</sup>

52  
53 Data comparing ALIF and PSO in the treatment of severe sagittal plane deformity is sparse, with  
54 some hypothesizing that multi-level ALIF may be superior to PSO because it may offer a better  
55 alignment correction and risk profile.<sup>12</sup> Therefore, the current study aims to evaluate ALIF and  
56 PSO in their ability to adequately restore L4-S1 lordosis and lower the apex of lumbar lordosis in  
57 patients with severe sagittal spinal deformity.

58

## 59 METHODS

60 **Study Design:**

61 This was a retrospective cohort study examining a prospectively collected, multicenter dataset of  
62 ASD patients across thirteen spinal deformity centers in the United States. Institutional review  
63 board approval was obtained from all centers before data collection and informed consent was  
64 obtained from each patient included in the study.

65

#### 66 **Participant Selection:**

67 Participants were included in this database if they were adults ages  $\geq 18$  years, had radiographic  
68 evidence of complex ASD (defined as pelvic incidence-lumbar lordosis mismatch [PI-LL]  $\geq 25^\circ$ ,  
69 T1 pelvic angle [TPA]  $\geq 30^\circ$ , sagittal vertical axis [SVA]  $> 15\text{cm}$ , thoracic scoliosis  $\geq 70^\circ$ , lumbar  
70 scoliosis  $\geq 50^\circ$ , or global coronal malalignment  $> 7\text{cm}$ ), and were undergoing spinal deformity  
71 surgery in the next six months. Participants were subsequently included in the current study if they  
72 had (i) severe sagittal malalignment defined as a preoperative PI-LL of  $>20^\circ$  and L4-S1 lordosis  
73 of  $<30^\circ$  and (ii) full body radiographs and patient-reported outcome measures (PROMs) at  
74 preoperative baseline and at postoperative six-week follow up visits.

75

#### 76 **Data Collection:**

77 Participant demographic data included age, sex, body mass index (BMI), race, Charlson  
78 Comorbidity Index (CCI), Edmonton Frailty Score (EFS), and surgical procedure type (i.e., index  
79 or revision). Radiographic measurements based on coronal and sagittal full-length standing films  
80 included sacral slope (SS), pelvic tilt (PT), pelvic incidence (PI), PI-LL, SVA, thoracic kyphosis  
81 (TK), lumbar lordosis (global LL and L4-S1 LL), lordotic apex, T1 spinopelvic inclination  
82 (T1SPi), and global sagittal alignment (GSA). Intraoperative and in-hospital complications  
83 included operating room (OR) time, estimated blood loss (EBL), blood transfusion and units given,

84 motor and sensory deficits, surgical intensive care unit (SICU) admission, occurrence of adverse  
85 events before discharge, length of stay (LOS), and admission to skilled nursing facility (SNF) or  
86 rehab. Postoperative complications included cardiopulmonary, infectious, musculoskeletal,  
87 neurologic, implant-related, and total complications. Finally, PROMs included numerical rating  
88 scale (NRS) for back pain, Oswestry Disability Index (ODI), Scoliosis Research Society 22-item  
89 (SRS-22) for pain, activity, and total scores, and Veterans RAND 12-item (VR-12) for Physical  
90 (PCS) and Mental Component Scores (MCS).

91

## 92 **Statistical Analyses:**

93 Eligible participants were categorized according to surgery type, including ALIF (1- or 2-level  
94 ALIF at L4-S1), PSO (L4 or L5 PSO), and TLIF (1 or 2 level TLIF at L4-S1). Demographics and  
95 baseline, six-week, and change from baseline to six-week radiographic spinopelvic parameters  
96 were summarized for all groups and compared using  $\chi^2$  test for categorical variables and student's  
97 t-tests for quantitative variables. Post-hoc Bonferroni and  $\chi^2$  analyses were subsequently  
98 performed for individual comparisons. Intra-/post-operative complications and postoperative  
99 PROMs were similarly analyzed. All statistical analyses were conducted using SPSS Statistics for  
100 Windows, Version 29.0 (Armonk, NY: IBM Corp), with statistical significance defined as  $p <$   
101 0.05.

102

## 103 **RESULTS**

### 104 **Patient Demographics:**

105 In total, 40 ALIF, 27 PSO, and 29 TLIF patients were included. ALIF patients had higher BMI  
106 (ALIF = 30 kg/m<sup>2</sup> vs PSO = 29 kg/m<sup>2</sup> vs TLIF = 27 kg/m<sup>2</sup>,  $p=0.049$ ) than TLIF but not PSO

107 patients. All groups were otherwise comparable in terms of age, sex, race, rate of osteoporosis,  
108 CCI, and EFS ( $p>0.05$ ) (**Table 1, Figure 1**). PSO was more likely to be performed in revision  
109 cases (50% vs 89% vs 35%,  $p<0.001$ ) than ALIF and TLIF.

110

### 111 **Spinopelvic Parameters:**

112 Baseline radiographic spinopelvic parameters were similar across groups, except for a lower L4-  
113 S1 lordosis ( $15^\circ$  vs  $10^\circ$  vs  $17^\circ$ ,  $p=0.048$ ) and a higher GSA ( $12^\circ$  vs  $14^\circ$  vs  $9^\circ$ ,  $p=0.037$ ) among  
114 PSO patients than TLIF but not ALIF patients (**Table 2**). At six-weeks postoperatively, L4-S1  
115 lordosis correction was higher for ALIF and PSO patients ( $22^\circ$  vs  $26^\circ$  vs  $11^\circ$ ,  $p=0.001$ ) than TLIF  
116 patients. In addition, the caudal lordotic apex migration was higher among ALIF patients (0.5 vs -  
117 0.2 vs 0.3,  $p=0.044$ ) than PSO but not TLIF patients (**Table 3**).

118

### 119 **Intra-/Post-Operative Complications:**

120 Intraoperatively, PSO had higher EBL (0.9L vs 2.3L vs 1.6L,  $p<0.001$ ) and motor deficits (5% vs  
121 26% vs 14%,  $p=0.049$ ) than both ALIF and TLIF but was otherwise comparable in terms of OR  
122 time, and sensory deficits ( $p>0.05$ ). In hospital, PSO was significantly more likely to have a SICU  
123 admission (58% vs 89% vs 66%,  $p=0.022$ ) and receive blood products (53% vs 89% vs 76%,  
124  $p=0.004$ ) but was otherwise comparable in terms of SICU stay, blood transfusion (units given,  
125 crystalloids given, colloids given), occurrence of adverse events, LOS, and postoperative  
126 admission to SNF or rehab (**Table 4**).

127

128 Complication rates were comparable intraoperatively, in hospital, within 30 days postoperatively,  
129 30 to 90 days postoperatively, and over 90 days postoperatively ( $p>0.05$ ) (**Table 5**). The most

130 common intraoperative complications were dural tear (8% vs 15% vs 14%,  $p=0.585$ ), vascular  
131 injury (8% vs 0% vs 0%,  $p=0.114$ ). The most common medical complications were  
132 hypotension/hypertension (10% vs 7% vs 7%,  $p=0.881$ ), ileus (10% vs 4% vs 3%,  $p=0.439$ ), and  
133 deep wound infection (5% vs 15% vs 0%,  $p=0.067$ ). Finally, the most common  
134 surgical/radiographic complications were adjacent segment disease (3% vs 4% vs 3%,  $p=0.955$ )  
135 and motor (15% vs 30% vs 14%,  $p=0.231$ ) or sensory deficit (10% vs 19% vs 0%,  $p=0.059$ ), often  
136 of the lower extremity (15% vs 33% vs 14%,  $p=0.113$ ). Subsequent revision rates were also  
137 comparable (8% vs 11% vs 3%,  $p=0.544$ ).

138

#### 139 **Patient Reported Outcome Measures:**

140 Postoperative PROMs were comparable in terms of NRS back pain, ODI, SRS-22 pain, activity,  
141 and total, and VR-12 PCS and MCS ( $p>0.05$ ) (**Table 6**).

142

#### 143 **DISCUSSION**

144 This investigation of patients with severe sagittal plane deformity revealed that ALIF can restore  
145 L4-S1 lordosis as effectively as L4 or L5 PSO and more effectively than 1- to 2-level L4-S1 TLIF.

146 At the same time, ALIF can produce a more natural caudal apex of lumbar lordosis with fewer  
147 intra-operative, in-hospital and early postoperative complications, and similar postoperative  
148 PROMs. Therefore, ALIF may be more effective in correcting severe ASD than other surgical  
149 techniques. However, when vessel anatomy, body habitus, or fused discs exclude ALIF as an  
150 option, other techniques such as PSO or TLIF with posterior column osteotomy could be  
151 considered.

152

153 Associations between sagittal alignment restoration, clinical outcomes, and postoperative  
154 mechanical complications has been thoroughly studied.<sup>13-15</sup> Primary goal of spinal correction  
155 surgery is to restore patients to an optimal lumbar lordosis with proper segmental distribution.<sup>16</sup>  
156 Globally, correcting total lumbar lordosis to a goal of PI-LL  $<10^\circ$  improves clinical outcomes,  
157 although this measure is not precise enough to inform optimal location of correction.<sup>17</sup> Focally,  
158 ensuring that  $>50\%$  of this total lordosis is generated distally at L4-S1, with increasing contribution  
159 from the proximal lumbar spine in patients with increased PI, has been shown to reduce revision  
160 rates.<sup>16,18-20</sup> Although many prior studies have examined the effectiveness of ALIF in achieving  
161 this level and the distribution of lordotic correction, a direct comparison between ALIF and PSO  
162 has not been previously made.

163  
164 ALIF use in the current study was associated with a  $22^\circ$  increase in L4-S1 lordosis and 0.5 levels  
165 of caudal migration of the lordotic apex (apex around L3-L4), which was statistically similar to  
166 PSO ( $26^\circ$  increase in L4-S1 lordosis and -0.2 levels of caudal migration of the lordotic apex) and  
167 significantly better than TLIF ( $11^\circ$  increase in L4-S1 lordosis and 0.3 levels of caudal migration  
168 of the lordotic apex). This increase in L4-S1 lordosis has previously been reported in the literature,  
169 with Ahlquist et al. demonstrating that ALIF results in a significant PI-LL mismatch and lumbar  
170 lordosis correction especially when compared against other lumbar fusion techniques.<sup>21</sup> Such  
171 lordotic correction is thought to result from release of the anterior longitudinal ligament and  
172 utilization of newer hyper-lordotic cages.<sup>22</sup> The associated improvement in the distribution of  
173 lumbar lordosis to a more natural caudal lordotic apex has also been similarly reported, with Chan  
174 et al. suggesting that ALIF may be more effective in recreating the apex of lordosis than PSO.<sup>23</sup>  
175 Because optimal restoration of the apex of lordosis is essential for the proper shape of the spine

176 and for adequate sagittal alignment in the patient, this may make PSO unfavorable in comparison  
177 to ALIF.<sup>24</sup>

178

179 Unlike PSO, which can be performed at almost all levels of the spinal column, ALIF is most  
180 commonly reserved for the L4-S1 region.<sup>12</sup> This, however, may be beneficial because of the  
181 uneven distribution of lumbar lordosis, with two-thirds of the curve being generated at the L4-S1  
182 levels.<sup>25,26</sup> In fact, prior studies have shown that it is crucial to obtain a strong correction at these  
183 lower segments in order to improve sagittal alignment and postoperative outcomes.<sup>14,16,27</sup> Focal  
184 correction at the proximal segments (i.e., L1-L3), on the other hand, may lead to mechanical  
185 complications such as PJK.<sup>28</sup> ALIF, in comparison to other studied procedures, offers the required  
186 correction at the distal segments without additional mechanical complications and worsened  
187 postoperative complications. Furthermore, although not examined in the present study, ALIF  
188 achieves the said correction at high fusion (95.8-100%) and low subsidence (12.5%) rates, likely  
189 due to the large footprint of the implanted interbody device.<sup>29-36</sup> These findings may make ALIF  
190 more appealing than other more cranial procedures such as lateral interbody fusion.

191

192 Finally, ALIF has previously been shown to be a relatively safe procedure that, when performed  
193 by a qualified team, results in acceptably low complication rates (13%), operative times, and length  
194 of hospital stays.<sup>37-39</sup> On the other hand, PSO is known to be a more technically demanding  
195 procedure associated with higher intraoperative blood loss and postoperatively complications,  
196 especially neurological motor deficits and major cardiopulmonary events.<sup>7,23,30,40-50</sup> Although the  
197 current study showed comparable revision rates, the higher intraoperative EBL and motor deficits,  
198 and in-hospital SICU admission and need for blood products do support the notion of PSO being

199 more technically demanding and requiring more anticipatory planning. In particular, extensive  
200 surgeon experience, as well as proper care to avoid iatrogenic nerve injury at the time of the time  
201 of the surgery, may be required to prevent the high rate of complications seen in this cohort.  
202 However, ALIF is not without its flaws. Though relatively rare and not statistically significant in  
203 our present study, ALIF is infrequently associated with major vascular injuries, lymphatic leak,  
204 prolonged ileus, and retrograde ejaculation.<sup>51-54</sup>

205  
206 The present study has several potential limitations. Firstly, access surgeons were not always  
207 available for all spine surgeries, which may have resulted in a variable technique. Nevertheless, it  
208 has been shown that the presence or absence of an access surgeon did not have an impact on the  
209 intra-operative and approach-related complications.<sup>55</sup> Secondly, subsidence, which was not  
210 assessed in the present study, can occur in hyperlordotic ALIF cages and may influence spinal  
211 biomechanics and alignment used in this study. Thirdly, only short-term radiographic alignment  
212 and PROM data were available, with the primary focus on short-term perioperative complications  
213 and alignment restoration of these techniques. Finally, mastery of each technique can vary across  
214 surgeons and may have influenced the achieved correction in this patient population.

215

## 216 **CONCLUSION**

217 This investigation revealed that ALIF is as powerful in restoring L4-S1 lordosis as L4 or L5 PSO.  
218 Furthermore, ALIF can achieve these improvements at lower intraoperative and in-hospital  
219 complications and comparable PROMs than other procedures. When feasible, ALIF may be  
220 preferred for restoring L4-S1 lordosis among patients with severe sagittal malalignment.

221

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418

419 **FIGURE LEGENDS**

420 **Figure 1.** Preoperative (Left) and postoperative (Right) lateral radiographs of (A) L5-S1 anterior  
421 lumbar interbody fusion (ALIF), (B) L4 pedicle subtraction osteotomy (PSO), and (C) L4-S1  
422 transforaminal lumbar interbody fusion (TLIF). Postoperative spinopelvic parameters, including  
423 pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL), lumbar lordosis apex, and L4-S1  
424 lumbar lordosis, are also provided (Bottom).

1 **Table 1.** Baseline Patient Characteristics

Variable	ALIF (N = 40)	PSO (N = 27)	TLIF (N = 29)	P-value
Age (years)	66 (10)	65 (10)	69 (9)	0.247
Female Sex	29 (73)	14 (52)	18 (62)	0.223
BMI (kg/m <sup>2</sup> )	30 (6)	29 (6)	27 (5)	<b>0.049</b>
Race				0.557
Asian	0 (0)	1 (4)	1 (3)	
Black/African	1 (3)	2 (7)	1 (3)	
White/Caucasian	39 (98)	24 (89)	26 (90)	
Other	0 (0)	0 (0)	1 (3)	
Osteoporosis	8 (20)	2 (7)	7 (24)	0.231
Charlson Comorbidity Index	0.7 (1.0)	0.9 (1.3)	1.5 (1.7)	0.082
Edmonton Frailty Score	3.8 (2.4)	3.7 (2.3)	4.4 (2.5)	0.501
Surgery Type				<b>&lt;0.001</b>
Index	20 (50)	3 (11)	19 (66)	
Revision	20 (50)	24 (89)	10 (35)	

2 Categorical variables are presented as count (frequency) and continuous variables are presented as  
3 mean (standard deviation). Abbreviations: ALIF = Anterior Lumbar Interbody Fusion, PSO =  
4 Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar Interbody Fusion, BMI = Body  
5 Mass Index.

1 **Table 2:** Baseline Radiographic Spinopelvic Parameters

Parameter	ALIF (N = 40)	PSO (N = 27)	TLIF (N = 29)	P-value
SS (°)	22 (12)	23 (13)	21 (13)	0.786
PT (°)	32 (10)	31 (12)	33 (8)	0.772
PI (°)	53 (13)	54 (14)	54 (14)	0.954
LL (°)				
L1-S1	15 (14)	13 (14)	14 (19)	0.829
L4-S1	15 (10)	10 (17)	17 (8)	<b>0.048</b>
TK (°)	-24 (17)	-27 (21)	-24 (16)	0.775
PI-LL (°)	38 (12)	41 (13)	39 (15)	0.576
SVA (mm)	127 (56)	155 (87)	118 (67)	0.111
T1SPi (°)	4 (6)	8 (10)	3 (7)	0.071
L1-S1 Apex <sup>a</sup>	22 (1)	22 (1)	22 (1)	0.834
GSA (°)	12 (4)	14 (8)	9 (5)	<b>0.037</b>

2 Variables are presented as mean (standard deviation). Abbreviations: ALIF = Anterior Lumbar  
3 Interbody Fusion, PSO = Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar  
4 Interbody Fusion, SS = Sacral Slope, PT = Pelvic Tilt, PI = Pelvic Incidence, LL = Lumbar  
5 Lordosis, TK = Thoracic Kyphosis, PI-LL = Pelvic Incidence minus Lumbar Lordosis, SVA =  
6 Sagittal Vertical Axis, T1SPi = T1 SpinoPelvic Inclination, GSA = Global Sagittal Alignment.  
7 <sup>a</sup>Lumbar apex was defined as L1 = 20 and S1 = 25, with increasing value with increasing vertebral  
8 levels.

1 **Table 3:** Six Week Postoperative Change in Radiographic Spinopelvic Parameters

Parameter	ALIF (N = 40)	PSO (N = 27)	TLIF (N = 29)	P-value
SS (°)	10 (7)	9 (7)	8 (6)	0.278
PT (°)	-10 (8)	-9 (6)	-7 (6)	0.282
PI (°)	0.6 (2.9)	0.1 (1.9)	0.8 (3.0)	0.717
LL (°)				
L1-S1	32 (12)	33 (10)	24 (16)	0.059
L4-S1	22 (12)	26 (19)	11 (9)	<b>0.001</b>
TK (°)	-16 (15)	-17 (9)	-13 (11)	0.493
PI-LL (°)	-31 (13)	-33 (9)	-24 (17)	0.057
SVA (mm)	-97 (57)	-99 (63)	-71 (68)	0.253
T1SPi (°)	-8 (6)	-9 (7)	-6 (7)	0.417
L1-S1 Apex <sup>a</sup>	0.5 (0.8)	-0.2 (0.9)	0.3 (0.9)	<b>0.044</b>
GSA (°)	-9 (4)	-7 (5)	-6 (5)	0.157

2 Variables are presented as mean (standard deviation). Abbreviations: ALIF = Anterior Lumbar  
3 Interbody Fusion, PSO = Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar  
4 Interbody Fusion, SS = Sacral Slope, PT = Pelvic Tilt, PI = Pelvic Incidence, LL = Lumbar  
5 Lordosis, TK = Thoracic Kyphosis, PI-LL = Pelvic Incidence minus Lumbar Lordosis, SVA =  
6 Sagittal Vertical Axis, T1SPi = T1 SpinoPelvic Inclination.

7 <sup>a</sup>Lumbar apex was defined as L1 = 20 and S1 = 25, with increasing value with increasing vertebral  
8 levels.

1 **Table 4:** Intraoperative and Immediately Postoperative Complications

Variable	ALIF (N = 40)	PSO (N = 27)	TLIF (N = 29)	P-value
OR Time (mins)	410 (200)	440 (130)	410 (150)	0.754
EBL (mL)	900 (1000)	2300 (1300)	1600 (1200)	<b>&lt;0.001</b>
Motor Deficit	2 (5)	7 (25)	4 (14)	<b>0.049</b>
Sensory Deficit	2 (5)	2 (7)	1 (3)	0.799
SICU Admission	23 (57)	24 (89)	19 (66)	<b>0.022</b>
Stay (Days)	2 (2)	1 (1)	3 (7)	0.209
Blood Transfusion	21 (53)	24 (89)	22 (76)	<b>0.004</b>
Given (Units)	2 (1)	2 (1)	2 (1)	0.891
Crystalloid (CC)	2700 (1900)	2900 (1200)	3400 (2200)	0.261
Colloid (CC)	800 (1000)	1200 (500)	900 (800)	0.100
Adverse Events Before Discharge	9 (23)	12 (44)	9 (31)	0.164
LOS (Days)	7 (3)	8 (6)	8 (5)	0.865
Admission to SNF or Rehab (Days)	13 (7)	14 (9)	15 (7)	0.840

2 Categorical variables are presented as count (frequency) and continuous variables are presented as  
3 mean (standard deviation). Abbreviations: ALIF = Anterior Lumbar Interbody Fusion, PSO =  
4 Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar Interbody Fusion, OR =  
5 Operating Room, EBL = Estimated Blood Loss, SICU = Surgical Intensive Care Unit, LOS =  
6 Length of Stay, SNF = Skilled Nursing Facility.

1 **Table 5:** Complication Rates Stratified By Time

<b>Variable</b>	<b>ALIF (N = 40)</b>	<b>PSO (N = 27)</b>	<b>TLIF (N = 29)</b>	<b>P-value</b>
During Surgery	6 (15)	4 (14)	6 (20)	0.785
Before Discharge	12 (30)	10 (37)	8 (27)	0.729
Within 30 Days	6 (15)	2 (7)	4 (13)	0.633
Within 30 to 90 Days	2 (5)	5 (18)	2 (6)	0.152
After 90 Days	2 (5)	4 (14)	0 (0)	0.067

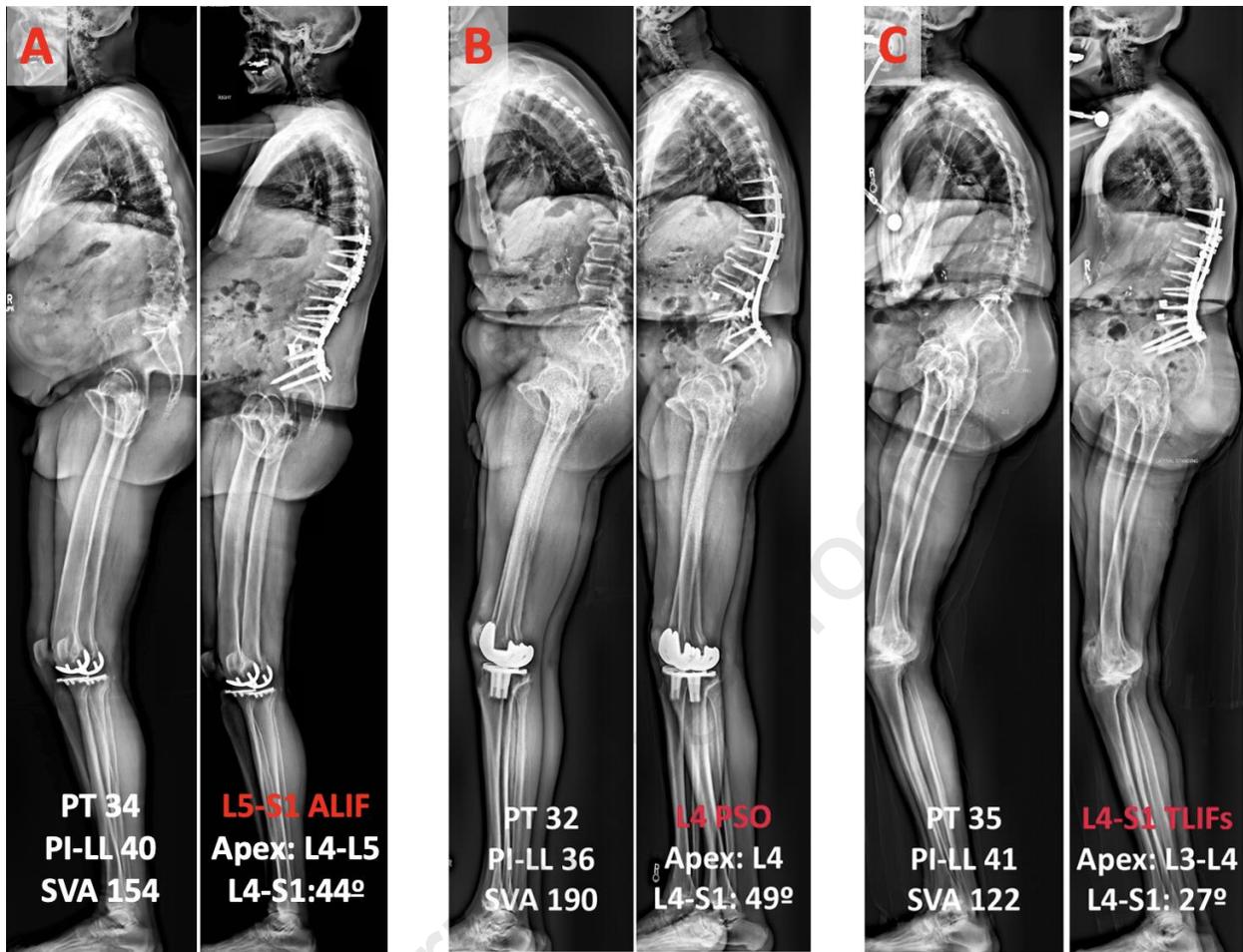
2 Categorical variables are presented as count (frequency). ALIF = Anterior Lumbar Interbody

3 Fusion, PSO = Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar Interbody Fusion.

1 **Table 6:** Patient Reported Outcome Measures

Variable	ALIF (N = 40)	PSO (N = 27)	TLIF (N = 29)	P-value
NRS				
Back Pain	4.5 (3.2)	3.8 (2.7)	4.3 (3.0)	0.745
ODI	43 (22)	40 (23)	45 (20)	0.686
SRS-22				
Pain	2.6 (1.0)	2.4 (0.7)	3.0 (0.9)	0.072
Activity	2.8 (0.8)	2.8 (0.8)	2.5 (0.7)	0.292
Total	3.2 (0.7)	3.1 (0.6)	3.3 (0.6)	0.762
VR-12				
PCS	26 (10)	25 (11)	28 (9)	0.579
MCS	50 (15)	52 (11)	46 (15)	0.328

2 Variables are presented as mean (standard deviation). Abbreviations: ALIF = Anterior Lumbar  
3 Interbody Fusion, PSO = Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar  
4 Interbody Fusion, NRS = Numerical Rating Scale, ODI = Oswestry Disability Index, SRS-22 =  
5 Scoliosis Research Society 22-Item, VR-12 = Veterans RAND 12-Item, PCS = Physical  
6 Component Score, MCS = Mental Component Score.



1  
2 **Figure 1.** Preoperative (Left) and postoperative (Right) lateral radiographs of (A) L5-S1 anterior  
3 lumbar interbody fusion (ALIF), (B) L4 pedicle subtraction osteotomy (PSO), and (C) L4-S1  
4 transforaminal lumbar interbody fusion (TLIF). Postoperative spinopelvic parameters, including  
5 pelvic tilt (PT), pelvic incidence minus lumbar lordosis (PI-LL), lumbar lordosis apex, and L4-S1  
6 lumbar lordosis, are also provided (Bottom).

1 **Supplemental Tables**2 **Supp Table 1: Six Week Radiographic Spinopelvic Parameters**

	<b>ALIF (N = 40)</b>	<b>PSO (N = 27)</b>	<b>TLIF (N = 29)</b>	<b>P-value</b>
SS (°)	32 (13)	31 (14)	28 (11)	0.417
PT (°)	21 (9)	23 (12)	26 (9)	0.189
PI (°)	54 (14)	54 (15)	54 (17)	0.998
LL (°)				
L1-S1	47 (17)	45 (17)	38 (16)	0.106
L4-S1	38 (10)	33 (15)	29 (10)	<b>0.031</b>
TK (°)	-41 (14)	-42 (17)	-36 (13)	0.262
PI-LL (°)	6 (10)	9 (9)	16 (15)	<b>0.011</b>
SVA (mm)	30 (35)	52 (54)	40 (65)	0.327
T1SPi (°)	-3.7 (4.6)	-2.2 (7.2)	-3.5 (6.5)	0.651
L1-S1 Apex <sup>a</sup>	23 (1)	22 (0)	23 (1)	0.063
GSA (°)	2.7 (3)	4.6 (3.5)	3.1 (6.5)	0.455

3 Variables are presented as mean (standard deviation). Abbreviations: ALIF = Anterior Lumbar

4 Interbody Fusion, PSO = Pedicle Subtraction Osteotomy, TLIF = Transforaminal Lumbar

5 Interbody Fusion, SS = Sacral Slope, PT = Pelvic Tilt, PI = Pelvic Incidence, LL = Lumbar

6 Lordosis, TK = Thoracic Kyphosis, PI-LL = Pelvic Incidence minus Lumbar Lordosis, SVA =

7 Sagittal Vertical Axis, T1SPi = T1 SpinoPelvic Inclination, GSA = Global Sagittal Alignment.

8 <sup>a</sup>Lumbar apex was defined as L1 = 20 and S1 = 25, with increasing value with increasing vertebral

9 levels.

## Abbreviations List

Anterior lumbar interbody fusion (ALIF)  
Pedicle subtraction osteotomy (PSO)  
Transforaminal lumbar interbody fusion (TLIF)  
Adult spinal deformity (ASD)  
Intensive Care Unit (ICU)  
Proximal junctional kyphosis (PJK)  
Pelvic incidence-lumbar lordosis mismatch (PI-LL)  
T1 pelvic angle [TPA]  
sagittal vertical axis [SVA]  
patient-reported outcome measures (PROM)  
body mass index (BMI)  
Charlson Comorbidity Index (CCI)  
Edmonton Frailty Score (EFS)  
sacral slope (SS)  
pelvic tilt (PT)  
pelvic incidence (PI)  
thoracic kyphosis (TK)  
T1 spinopelvic inclination (T1SPi)  
global sagittal alignment (GSA)  
operating room (OR)  
estimated blood loss (EBL)  
surgical intensive care unit (SICU)  
length of stay (LOS)  
skilled nursing facility (SNF)  
numerical rating scale (NRS)  
Oswestry Disability Index (ODI)  
Scoliosis Research Society 22-item (SRS-22)  
Veterans RAND 12-item (VR-12) Physical Component Score (PCS)  
Veterans RAND 12-item (VR-12) Mental Component Scores (MCS)

## Restoring L4-S1 Lordosis Shape in Severe Sagittal Deformity: Impact of Correction Techniques on Alignment and Complication Profile

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