Research Article

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Clinical and Radiologic Fate of the Lumbosacral Junction After Anterior Lumbar Interbody Fusion Versus Axial Lumbar Interbody Fusion at the Bottom of a Long Construct in CMIS Treatment of Adult Spinal Deformity

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Abstract

Introduction: Surgeons use numerous arthrodesis strategies for fusion of the lumbosacral junction including anterior lumbar interbody fusion (ALIF) and axial lumbar interbody fusion (AxiaLIF). The optimal L5-S1 fusion strategy remains inconclusive. The purpose of this study is to compare the fate of the lumbosacral junction in ALIF versus AxiaLIF patients in terms of clinical and radiographic outcomes.

Methods: Adult spinal deformity patients, treated with CMIS techniques, with at least 2-year follow-up who underwent AxiaLIF or ALIF at the lumbosacral junction were included. Patients were separated into two groups: AxiaLIF (56 patients) and ALIF (38 patients). Outcome measures included segmental lordosis, sagittal vertical alignment, lumbar lordosis (LL), pelvic incidence–LL mismatch, and pseudarthrosis, major complication, and revision surgery rates.

Results: The ALIF group achieved greater postoperative and delta segmental lordosis, higher delta sagittal vertical alignment, higher delta LL, and lower postoperative pelvic incidence–LL mismatch. The pseudarthrosis, major complication, and revision surgery rates were higher in the AxiaLIF group. Five cases of pseudarthrosis at L5-S1 were seen, all in the AxiaLIF group.

Discussion and Conclusion: ALIF patients showed more favorable radiographic correction parameters and lower rates of pseudarthrosis, major complications, and revision surgeries. ALIF is the preferred strategy for L5-S1 arthrodesis at a bottom of a long construct.

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When performing long-construct adult spinal deformity (ASD) corrective surgery, the decision to fuse the lumbosacral junction as opposed to stopping at L5 is often debated. Bridwell[1] suggested several scenarios where inclusion of L5-S1 was preferred. They included L5-S1 spondylolisthesis, previous L5-S1 laminectomy, L5-S1 stenosis, notable L5-S1 degeneration, and oblique take-off of L5-S1. One of the complications associated with fusion to the sacrum is the failure of the S1 screw that can lead to pseudarthrosis and kyphosis.[2] Several ways have been proposed to address the issue of protecting the S1 screw such as S2 screws, four-rod technique, iliac screws, S2 alar iliac screws, and Galveston technique.[2-5] Axial lumbar interbody fusion (AxiaLIF) is another way to provide protection to the S1 screw and achieve fusion at the bottom of a long construct.[2]

Indications for anterior fusion at the bottom of a long construct include lumbosacral fractional curve, big body habitus, and severe spinal stenosis needing decompression.[2] AxiaLIF was demonstrated by several cadaver and clinical studies to be a safe and biomechanically sound construct.[2,6-10] As a percutaneous approach, AxiaLIF is comparable to other minimally invasive techniques with regard to decreased surgical time and reduced blood loss.[2] It leaves the annulus intact and achieves indirect decompression.[6] It reduces S1 screw strain similar to iliac screw fixation and better than pedicle screw or anterior interbody augmentation.[9] In clinical studies, both retrospective and prospective, fusion rates with AxiaLIF have been consistently successful, reported as high as 96% and similar clinical outcomes without rh-BMP2.[2,11-15]

Despite such encouraging results, AxiaLIF is a relatively new technique, and long-term results are lacking. In comparison, the arthrodesis of a lumbosacral junction via anterior lumbar interbody fusion (ALIF) has been commonly performed since the 1990s. With advancement in the mini-open anterior approach and the availability of well-trained vascular access surgeons, the risks of the injury to the iliac vessels and the superior hypogastric plexus associated with ALIF are minimized. The fusion results for ALIF have been quite successful as well, reported as high as 97.2% (range, 91.0% to 99.2%).[16] Hence, the optimal L5-S1 fusion strategy still remains inconclusive. The purpose of this study was to provide more information about this uncertainty by directly comparing ALIF and AxiaLIF in terms of its radiographic and clinical outcomes as arthrodesis strategies for the lumbosacral junction at the bottom of a long-segment construct. Our hypothesis was that the traditional ALIF would be superior to the AxiaLIF.

Methods

This is a single-center study from a prospective database of patients who underwent CMIS correction for ASD (Cobb angle >20° or sagittal vertical alignment (SVA) >50 mm or pelvic incidence (PI)/lumbar lordosis (LL) mismatch >10) by the senior author from April 2007 to August 2015. Internal review board approval was obtained.

Only patients with 2-year follow-up were included. Only patients with at least three levels fused that spanned the L5-S1 junction were included. Indications for surgery included symptomatic back and/or leg pain attributed to ASD that was unresponsive to conservative measures. All patients were treated with MIS strategies using MIS AxiaLIF or ALIF for the L5-S1 segment. All other segments were fused using lateral lumbar interbody fusion with percutaneous pedicle screw and rod instrumentation. Details of our techniques have been published before.[17-28]

Patients were divided into two groups depending on the surgical intervention chosen for the L5-S1 junction: AxiaLIF (56 patients) and ALIF (38 patients). The choice between AxiaLIF and ALIF was really based on the period the surgeries were performed because most AxiaLIF procedures were performed before 2011 (Figures 1 and 2).

Demographics, surgical parameters, radiographic markers, and complication rates were collected. The groups (AxiaLIF and ALIF) were retrospectively compared in terms of segmental lordosis (SL) at L5-S1, SVA, LL, PI-LL mismatch, and pseudarthrosis, major complication, and revision surgery rates. Radiographic measures were assessed using full-length 36-inch radiographs at the time of enrollment and 2-year follow-up. CT scanning and full-length radiographs were used to assess fusion rates. Few patients had inadequate or unavailable 2-year follow-up, so later follow-up imaging was used.

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Radiographic parameters for AxiaLIF and ALIF patients were compared preoperatively and postoperatively. Moreover, the delta change between preoperative and minimum 2-year postoperative parameters was compared between AxiaLIF and ALIF patients. Only patients with complete preoperative and postoperative figures for a given radiographic parameter were included in the delta analysis.

Complications were classified as major based on the consensus from previous studies.[29,30] Moreover, complications requiring revision surgeries were categorized as major. Fusion was graded at a central site using 1- or 2-year follow-up radiographs.

Patient groups were compared using *t*-testing and chi-squared analysis for continuous and categoric variables, respectively. Statistical analyses were two sided, and $P < 0.05$ was considered statistically significant. All statistical analysis was conducted using SPSS (version 22).

Figure 1

AP and lateral preoperative standing radiographs of a patient with adult idiopathic scoliosis (**A**). AP and lateral postoperative standing radiographs demonstrating thoracolumbar spinal fusion with axial lumbar interbody fusion at L5-S1 (**B**).

Results

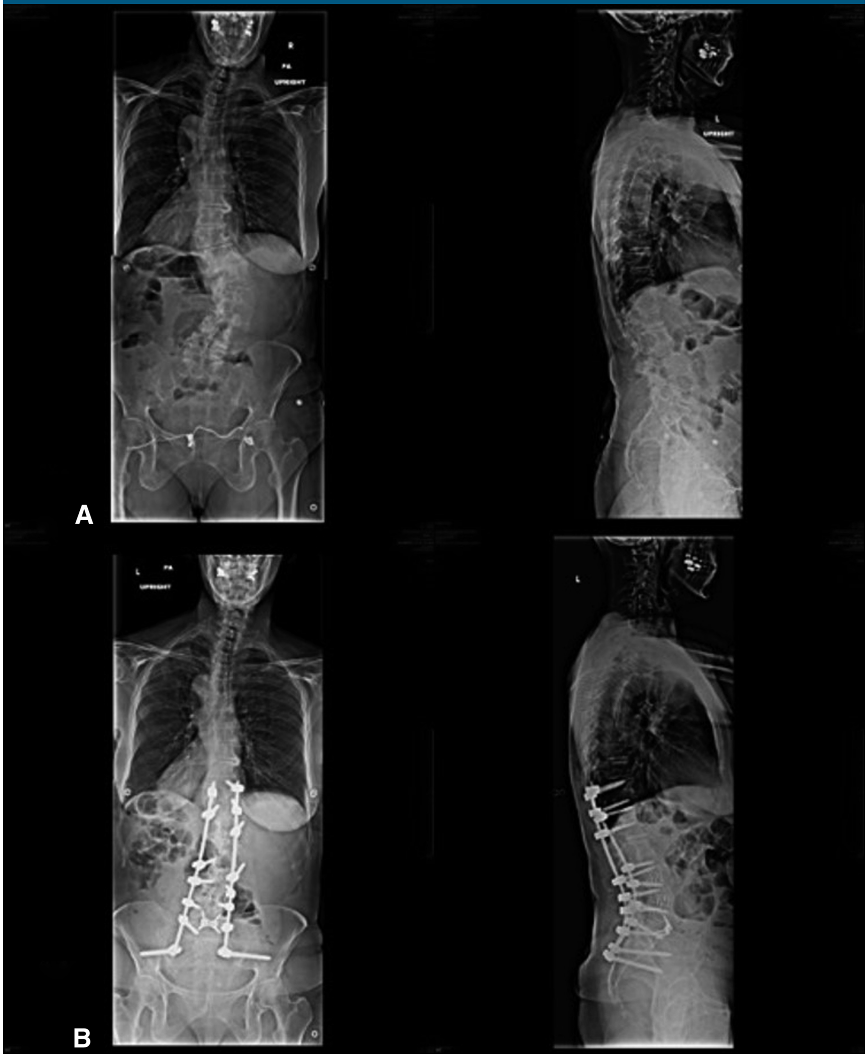
A total of 94 patients met the inclusion criteria: 58 were women and 36 were men. Mean age and body mass index for the entire cohort was 66.9 years (22 to 85 years; 9.72; SD, 9.5) and 27.05 kg/m^2 (17.16 to 44 kg/m^2; 5.39), respectively. An average of 6.45 levels (3 to 16; 3.09) was fused. Fifty-six patients were included in the AxiaLIF group, and 38 patients were included in the ALIF group. Baseline demographic information for each group is included in Table 1.

At baseline, the AxiaLIF group had an average L5-S1 SL of 7.66° compared with 10.12° for the ALIF group ($P < 0.05$). All other radiographic parameters including LL, SVA, and PI-LL mismatch were statistically insignificant between the two groups. SVA trended higher in the ALIF group; however, the sample size was not adequate to reach statistical significance. LL trended higher in the AxiaLIF group but did not reach statistical significance. Baseline radiographic parameters are presented in Table 2.

Compared with the AxiaLIF group, the ALIF group had higher postoperative SL and LL and lower postoperative PI-LL mismatch ($P < 0.05$). Postoperatively, SVA trended lower in the ALIF group. Delta SL, delta LL, and delta SVA from preoperatively to postoperatively in the ALIF group were 8.98°, 14.2°, and 30.36 mm, respectively. These values were statistically significant compared with corresponding delta values in the AxiaLIF group ($P < 0.05$). Postoperative and delta radiographic comparisons are presented in Table 3.

The incidence of pseudarthrosis, major complications, and revision surgery rates was higher in the AxiaLIF group. All three parameters were statistically significant. There were overall six cases of pseudarthrosis in the entire

Figure 2



AP and lateral preoperative standing radiographs of a patient with adult idiopathic scoliosis (**A**). AP and lateral postoperative standing radiographs demonstrating thoracolumbar spinal fusion with anterior lumbar interbody fusion at L5-S1 (**B**).

cohort, five of which occurred as a consequence of AxiaLIF (L5-S1) and none in the ALIF group. These outcome measures are presented in Table 4. Specific complications for each group and subsequent treatment of the complication are presented in Supplemental Table 1 (http://links.lww.com/JG9/A26).

Discussion

In recent years, minimally invasive spinal surgery (MISS) for the treatment of ASD has been an attractive alternative to the traditional techniques that are associated with high-volume blood loss and other medical complications.[22] When extending the thoracolumbar fusion to the sacrum, interbody fusion and pelvic fixation should be considered.[1,22] MISS interbody fusion techniques include, among others, ALIF and AxiaLIF.[22] AxiaLIF has been used as a possible alternative approach to a traditional ALIF for interbody fusion at the bottom of a long-segment construct. Despite successful results reported for both techniques, the optimal method of fixation remains unknown. In this study, we attempted to uncover the uncertainty by directly comparing AxiaLIF with ALIF at the L5-S1 junction at a bottom of a long-segment construct.

Table 1

Baseline Demographic Information

Factor	AxiaLIF	ALIF	*P* Value
No. of patients	56	38	
% Females	55.36	71	>0.05
Mean age	67.13 (22-85, 10.43)	66.66 (48-84, 8.13)	>0.05
Mean BMI	27.44 (17.16-44.00, 5.97)	26.83 (18.21-34.77, 4.58)	>0.05
Mean number of levels fused	5.64 (3-15, 2.07)	7.7 (3-16, 3.9)	<0.05[a]
Mean length of stay	8.64 (3-26, 4.77)	9 (3-20, 3.6)	>0.05
% Current or former smokers	26.79	31.5	>0.05

ALIF = anterior lumbar interbody fusion, AxiaLIF = axial lumbar interbody fusion, BMI = body mass index

The advantage of AxiaLIF is that it may reduce the risk of approach-related complications because it does not require mobilization of vasculature or intra-abdominal contents.[23] The disadvantage of AxiaLIF is that it cannot be performed in cases with prerectal scarring and aberrant vasculature, history of pelvic surgery, infection, radiation, or inflammatory bowel disease.[22,31] ALIF has been associated with vascular injury rates ranging from 0.5% to 15.6%, a bowel injury rate of 1.6%, and a prolonged ileus rate of 0.6%.[23] The advantage of ALIF includes the large grafting surface and indirect neuroforaminal decompression and avoidance of the spinal canal.[22]

Fusion rates have been successful for both techniques. A recent systematic review reported overall fusion rates at L5-S1 of 97.2% (range, 91.0% to 99.2%) for an ALIF and 90.5% (range, 79.0% to 97.0%) for an AxiaLIF.[16] Most of the research for AxiaLIF has focused on one- or two-level interbody fusion at L4-S1, and there are limited clinical data of AxiaLIF at the bottom of a long-segment construct.[2,32] For short-segment constructs, fusion rates for AxiaLIF have been reported at 91% to 96%.[23,31,33] For AxiaLIF at the bottom of a long-segment construct, fusion rates have been reported at s89%.[23] A systematic review of AxiaLIF at L5-S1 found 74 articles on this topic and reviewed 15 studies that met the inclusion criteria. Most studies were classified as level IV evidence.[34] The compiled pseudarthrosis rate at L5-S1 was 6.9%, and the rate of all other complications was 12.9%.[34] Of note, they found that the deformity studies had a much higher complication rate of 46.3%.[34] The pseudarthrosis rate in the deformity groups was also higher at 7.08%.[34] Although the overall pseudarthrosis rate is low, these findings should be approached with caution based on the poor-quality literature. Most of the studies were level IV, underreporting of complications was found in articles with conflicts of interest, and the four prospective studies included in the systematic review did show a statistically significant increase in complications and revisions and a nonsignificant increase in the rate of pseudarthrosis for AxiaLIF.[34]

The general consensus is that patients who develop pseudarthrosis after lumbar fusion have inferior long-term clinical results.[34,35] In the present cohort, we found lower pseudarthrosis rates in the ALIF group (zero) when directly compared with the AxiaLIF group (8.9%), which was statistically significant.

Table 2

Baseline Radiographic Comparisons

Factor	AxiaLIF	ALIF	*P* Value
SL	7.66°	10.12°	<**0.05**[a]
LL	39.58°	31.95°	>0.05
SVA	53.86 mm	66.60 mm	>0.05
PI-LL mismatch	27.34 mm	19.85 mm	>0.05

[a] Bold *p* values indicate statistical significance.
ALIF = anterior lumbar interbody fusion, AxiaLIF = axial lumbar interbody fusion, LL = lumbar lordosis, PI = pelvic incidence, SL = segmental lordosis, SVA = sagittal vertical alignment

Table 3

Postoperative and Delta Radiographic Comparisons

Factor	AxiaLIF	ALIF	*P* Value
Postoperative			
SL	9.53°	18.23°	<**0.05**[a]
LL	42.74°	43.66°	>0.05
SVA	44.18 mm	42.05 mm	>0.05
PI-LL mismatch	16.07°	12.23°	<**0.05**[a]
Delta			
SL	1.90°	8.98°	<**0.05**[a]
LL	8.58°	14.2°	<**0.05**[a]
SVA	25.9 mm	30.36 mm	<**0.05**[a]
PI-LL mismatch	8.04°	9.76°	>0.05

[a] Bold *p* values indicate statistical significance.
ALIF = anterior lumbar interbody fusion, AxiaLIF = axial lumbar interbody fusion, LL = lumbar lordosis, PI = pelvic incidence, SL = segmental lordosis, SVA = sagittal vertical alignment

Table 4

Outcome Measures

Factor	AxiaLIF (n = 56)	ALIF (n = 38)	*P* Value
Incidence of pseudarthrosis (L5-S1)	8.9%	0%	<**0.05**[a]
Incidence of major complications	41.07%	13.1%	<**0.05**[a]
Revision surgery rate	37.5%	13.1%	<**0.05**[a]

[a] Bold *p* values indicate statistical significance.
ALIF = anterior lumbar interbody fusion, AxiaLIF = axial lumbar interbody fusion

The higher fusion rates in ALIF compared with AxiaLIF are similarly demonstrated in a systematic review by Schroder et al, who investigated the fusion rates at L5-S1 in ALIF (97.2%), AxiaLIF (90.5%), and transforaminal lumbar interbody fusion (99.2%).[16] The lower pseudarthrosis rate in our study occurred in the ALIF group despite a larger proportion of smokers in that group. This difference in the pseudarthrosis rate in the ALIF group could be much more significant in a larger sample size and is one of the points that needs to be further studied and should be considered for choosing ALIF over AxiaLIF.

Limited data exist in the literature regarding MISS deformity correction in regards to specific radiographic parameters such as PI, LL, PI and LL mismatch, and SVA, particularly at the bottom of a long-segment construct.[22] The sagittal balance and correction seems to be the most important predictor of functional outcomes.[22] Issack and Boachie-Adjei[32] studied nine patients who underwent AxiaLIF at a bottom of a long-segment construct. Similar to the present study, they reported several radiographic parameters and fusion rates. Their investigated parameters included lumbosacral lordosis, sagittal angulation at L4-5 and L5-S1, SVA, and coronal vertical axis.[32] Their preoperative average SVA was 47.8 compared with our preoperative SVA of 53.86, and their postoperative SVA was 49.1 compared with our postoperative SVA of 44.18.[32] None of their measured parameters showed any statistically significant radiographic changes in alignment after implantation of the AxiaLIF.[32]

Our current study addresses the paucity in the literature by investigating specific radiographic parameters and directly comparing ALIF with AxiaLIF. As reported in our results, the ALIF groups had higher postoperative and delta SL and lower PI-LL mismatch, which were statistically significant and suggest higher magnitude deformity correction. The postoperative SVA in the ALIF group, although not statistically significant from the postoperative AxiaLIF SVA, trended lower despite starting with a higher SVA value preoperatively. In fact, the delta SL, LL, and SVA from pre-op to post-op in the ALIF group compared with the AxiaLIF group were statistically significantly different, indicating a more robust correction of spinal deformity in the ALIF cohort. The SL findings, both postoperative and delta values in the ALIF group, were greater than those in the AxiaLIF group, consistent with previously reported results of less robust correction and loss of SL observed in AxiaLIF surgery.[36,37] Marchi et al[37] prospectively investigated AxiaLIF in 27 patients at the L4-5 and L5-S1 levels. They found that barely notable lordosis was achieved at 1 week but was noted to be lost at 24 months of follow-up and actually had less lordosis than preoperatively.[37] They also reported radiolucent signs (a sign of non-union) in 78.6% of the cases.[37] Similarly, Hofstetter et al[36] reported loss of SL at L4-5 and L5-S1 at an average follow-up period of 26.2 months after AxiaLIF surgery.

Some of the limitations of this study include its retrospective nature, which can certainly introduce selection bias. Another limitation is that the ALIF versus AxiaLIF surgeries were not randomized; rather, they were determined by a single surgeon, which again raises the question of selection bias. Our small sample size may have missed some important correlations that can be evident with a larger population. The strengths of this study include the systematic collection of data on each patient on many of the important radiographic and clinical parameters that are lacking in the literature for MISS.

Conclusion

MISS for ASD has been increasingly used in recent years. Despite numerous publications on the success rates of ALIF and AxiaLIF, the optimal technique for fusion at L5-S1 distal to a long-segment construct is debated. The present study retrospectively compared radiographic parameters and fusion rates for these two techniques and found that ALIF surgery had more favorable outcomes with regard to radiographic correction parameters, pseudarthrosis rate, and complication profile and revision surgery rates. On the basis of these findings and the current literature, we favor the choice of ALIF over AxiaLIF for fusion at L5-S1 distal to a long-segment construct. Future long-term follow-up studies with larger sample population are needed to further elucidate the differences found between these two surgical techniques.

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