



Improvement of coronal alignment in fractional low lumbar curves with the use of anterior interbody devices

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Abstract

Study design Retrospective chart review.

Objectives To determine if the addition of an anterior lumbar interbody fusion (ALIF) improves the fractional curve in adult spinal deformity correction when compared to posterior surgery alone.

Summary of background data ALIF is commonly advocated to improve lordosis and fusion in adult deformity surgery. Improved fractional curve correction may help level the pelvis and minimize proximal malalignment.

Methods Patients undergoing thoracolumbar fusion to the pelvis with S2AI screws for deformity were identified and stratified into patients who had an ALIF as part of their deformity correction procedure (ALIF + PSF), and those who had a posterior approach alone. The posterior approach (PSF) includes patients who had a posterolateral fusion with or without a transforaminal lumbar interbody fusion (TLIF). Radiographic parameters measured included pre-op and post-op fractional coronal curve Cobb angle, lumbar lordosis, pelvic tilt, pelvic incidence and sacral slope, major Cobb angle, coronal and sagittal SVA.

Results There were 31 cases in the ALIF + PSF group and 28 in the PSF group. Baseline demographic characteristics of the two groups were similar. Mean pre-op fractional coronal Cobb (18.3° vs 13.4° , $p = 0.027$) was larger in the ALIF + PSF group, whereas lumbar lordosis (31.0° vs 33.6° , $p = 0.487$) and pelvic parameters were similar between the two groups. Post-op lumbar lordosis was similar (48.2° vs 43.0° , $p = 0.092$). Greater fractional coronal curve correction was achieved in the ALIF + PSF group (67%) compared to the PSF group (36%) with a smaller post-op fractional coronal curve in the ALIF + PSF group (6.1°) compared to the PSF group (8.6° , $p = 0.053$).

Conclusion There is a greater correction of the fractional curve in the ALIF + PSF group compared with the PSF group. While this may not be the primary indication for ALIF, it is a benefit which may facilitate overall deformity correction and leveling of the pelvis.

Keywords Adult spine deformity · Anterior lumbar interbody fusion · Fractional curve

Introduction

In Adult Degenerative Scoliosis (ADS), there are many factors to consider when planning a corrective surgery. Sagittal realignment has received the most attention, and some authors have suggested that coronal alignment has been underemphasized [1, 2]. The purpose of this study is to look at the ability to correct the fractional curve (FC), which is

defined as the curve from L4 to S1. Correction of this curve is important in leveling the pelvis and in improving any radiculopathy or neurogenic claudication symptoms. Since the fractional curve is at the base of the construct, even subtle improvements can lead to large global alignment changes in a flagpole type phenomenon. In particular, we sought to determine if anterior surgery has a greater ability to influence the fractional curve when compared to posterior only procedures.

Although fusion to the pelvis is sometimes necessary to achieve the overall treatment goals of ADS surgery, it does increase the risk of pseudarthrosis in the lower lumbar spine. There have been many techniques described to deal with this problem that include use of biologics, combined anterior/posterior approaches, as well as posterior only procedures [3–6].

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Anterior lumbar interbody fusion (ALIF) is a well-established technique, with clearly identified benefits. It is often used to increase fusion rates, particularly at the L5/S1 level which is a common area for pseudarthrosis. The rate of fusion at this level with an ALIF is around 97.2% [7]. An ALIF procedure is also frequently used to restore disc height and segmental lordosis [8–10]. Even when compared to other interbody techniques, such as a transforaminal lumbar interbody fusion (TLIF), it shows statistically significant improvement in restoration of both disc height and segmental lordosis [8]. In addition to radiographic parameters, the ALIF procedure has been shown to improve patient-based outcomes including the SF-36 and ODI [11]. In addition to these established advantages of anterior surgery, this study examines an additional potential advantage as compared to posterior only surgery, better correction of the fractional lumbar curve.

Methods

Patient population

After receiving Institutional Board Review Approval, medical records of patients who underwent surgery for thoracolumbar deformity by three surgeons at a single institution between 2013 and 2019 were reviewed. Inclusion criteria were posterior lumbar fusion to the pelvis with the use of S2AI screws, age ≥ 18 years old and presence of a fractional curve. Patients who had posterior three-column osteotomies or who did not have adequate pre-op or post-op imaging to measure all desired parameters were excluded. Patients were then stratified into patients who had an ALIF in addition to PSF (ALIF + PSF) and those who had a posterior approach only (PSF). All patients had bilateral Smith-Petersen/Ponte osteotomies. Curve correction was achieved using a combination of cantilever and derotation maneuvers during instrumentation.

Standard demographic and surgical data were collected. Full-length 36-inch pre- and 6-month post-operative weight-bearing X-rays that included the femoral heads were reviewed and the following parameters were measured: the pelvic incidence (PI), the sacral slope (SS) pelvic tilt (PT), lumbar lordosis (LL, from L1–L5), sagittal vertical axis (SVA), coronal Cobb angle of the major and lumbosacral fractional curve and coronal vertical axis (CVA, distance from C7 plumb line to the center of the sacrum).

Statistical analysis

All statistical analysis was performed using SPSS V26.0 (IBM, Armonk, New York). The ALIF + PSF group and PSF group were compared using unpaired independent t

tests for continuous variables and Fisher's exact test for categorical variables. A p value threshold of 0.02 was used for statistical significance. To control for confounding and selection bias, a multivariable regression analysis was performed to evaluate associations between performing an ALIF + PSF versus PSF alone, age, smoking status, BMI, ASA grade, pelvic parameters, lumbar lordosis, pre-operative fractional curve Cobb magnitude and surgeon.

Results

A total of 59 patients met the inclusion criteria, 31 in the ALIF + PSF group and 28 in the PSF group (Table 1). Patients in the ALIF + PSF group were younger (63.2 years old) compared to the PSF group (69.3 years old, $p = 0.009$). The sex distribution was similar between the groups with twice as many females being included as males ($p = 0.992$).

Pre-operative pelvic parameters, lumbar lordosis and SVA were similar between the two groups (Table 2). Post-operative lumbar lordosis was similar between the two groups. Although the change from pre-op to post-op lumbar lordosis was greater in the ALIF + PSF group (17.2°) compared to the PSF group this did not reach statistical significance (9.4° , $p = 0.049$). Post-op SVA was smaller in the ALIF + PSF group (49.9 mm) compared to the PSF group (77.6 mm, $p = 0.020$), although the change in SVA was similar between the two groups.

Patients in the ALIF + PSF group had greater main thoracolumbar curve pre-operatively than patients in the PSF group (Table 3). The ALIF + PSF groups had a greater correction of the curve leading to similar curves post-operatively. The primary focus of this study was to compare radiographic correction of the fractional curve. Patients in the ALIF + PSF group had a larger fractional curve pre-operatively compared to the PSF group (18.3° vs 13.4° , $p = 0.027$). The ALIF + PSF group also had a greater reduction in fractional curve (12.1° vs 4.8° , $p < 0.00$) and a smaller final fractional curve (6.1° vs 8.6° , $p = 0.023$).

A sub-analysis of patients in the PSF group showed that the nine patients who had a unilateral transforaminal lumbar interbody fusions had similar radiographic outcomes as the 19 patients who did not (Table 4). Multivariable regression analysis shows that the addition of ALIF to the PSF and magnitude of pre-operative lumbar lordosis were independently statistically significantly associated with fractional curve correction (Table 5).

Table 1 Summary of baseline demographic and surgical parameters

	PSF	ALIF+PSF	<i>p</i> value
	28	31	
Age, years, mean (SD)	69.3 (8.5)	63.2 (8.8)	0.009
Males, <i>n</i> (%)	9 (32%)	10 (32%)	0.992
Smoker, <i>n</i> (%)	12 (43%)	14 (45%)	0.859
BMI, kg/m ² , mean (SD)	30.2 (4.9)	28.9 (5.5)	0.311
ASA grade, <i>n</i> (%)			0.738
2	5 (18%)	7 (23%)	
3	21 (75%)	23 (74%)	
4	2 (7%)	1 (3%)	
Diagnosis			0.043
Adult scoliosis	3	11	
Degenerative scoliosis	19	12	
Fixed sagittal imbalance	6	8	
Operative time, min, mean (SD)	329.8 (88.0)	423.2 (121.7)	0.001
Estimated blood loss, mL, mean (SD)	852.9 (468.0)	861.9 (483.1)	0.942
Number of levels fused	9.8 (3.4)	10.8 (3.0)	0.202

Table 2 Summary of pelvic and sagittal parameters

	PSF Mean (SD)	ALIF+PSF Mean (SD)	<i>p</i> value
Pelvic incidence, °	54.4 (7.6)	58.7 (11.3)	0.090
Sacral slope, °	28.3 (5.3)	31.3 (8.5)	0.102
Pelvic tilt, °	26.2 (5.5)	28.2 (9.5)	0.319
Lumbar lordosis, °			
Pre-operative	33.6 (14.6)	31.0 (14.4)	0.489
Post-operative	43.0 (6.7)	48.2 (15.2)	0.092
Change	9.4 (14.4)	17.2 (15.5)	0.049
Sagittal vertical axis, mm			
Pre-operative	116.8 (84.1)	91.1 (51.1)	0.236
Post-operative	77.6 (47.9)	49.9 (34.4)	0.020
Change	44.2 (58.5)	39.7 (47.6)	0.781

Table 3 Summary of coronal radiographic parameters

	PSF Mean (SD)	ALIF+PSF Mean (SD)	<i>p</i> value
Major thoracolumbar curve, °			
Pre-operative	30.5 (12.5)	40.6 (20.8)	0.027
Post-operative	15.6 (10.3)	17.1 (12.4)	0.625
Change	14.9 (7.6)	23.5 (14.7)	0.006
Curve correction, %	51 (20)	58 (18)	0.219
Lumbar fractional curve Cobb, °			
Pre-operative	13.4 (7.1)	18.3 (9.3)	0.027
Post-operative	8.6 (4.4)	6.1 (5.3)	0.023
Change	4.8 (4.5)	12.1 (6.0)	0.000
Curve correction, %	27 (34)	68 (20)	<0.000
Coronal vertical axis, mm			
Pre-operative	36.2 (41.3)	33.4 (21.6)	0.787
Post-operative	22.4 (20.6)	22.7 (15.7)	0.949
Change	10.9 (35.8)	10.4 (23.5)	0.959

Discussion

There has been much debate over the years regarding the ideal way to treat adult deformity. Initially much of the focus was on the correction of the major coronal curve. More recently, the importance of overall sagittal alignment of the deformity has been established. However, it has also become obvious that the fractional curve at the lumbosacral junction is a significant, although less recognized, part of the symptomatology and disability associated with adult scoliosis. Unfortunately, this element of the deformity often gets overlooked because of the predominance of the major sagittal and coronal curves.

The fractional curve is at the lumbosacral junction and usually effects the L4, L5, and S1 vertebra. This plays

Table 4 Sub-group analysis of PSF group, TLIF vs no TLIF

	No TLIF Mean (SD)	TLIF Mean (SD)	<i>p</i> value
<i>n</i>	19	9	
Lumbar fractional curve Cobb, °			
Pre-operative	14.9 (7.0)	10.3 (6.8)	0.114
Post-operative	9.4 (4.4)	7.1 (4.2)	0.213
Change	5.5 (4.8)	3.2 (3.4)	0.144
Curve correction, %	33 (21)	16 (52)	0.355

Table 5 Results of multivariable regression analysis for factors associated with fractional curve correction

Variable	Standardized Beta coefficient	<i>p</i> value
Cohort (ALIF + PSF vs PSF)	0.674	<0.000
Lumbar lordosis	0.328	0.011
Pre-operative fractional coronal Cobb	0.191	0.110
Body mass index	0.175	0.171
Number of surgical levels (posterior)	−0.120	0.317
Surgeon	0.077	0.510
Pre-operative pelvic tilt	0.193	0.521
Pelvic incidence	−0.139	0.708
Age	0.044	0.711
Smoking status	0.042	0.723
Pre-operative sacral slope	−0.102	0.743
ASA grade	−0.012	0.922

a role in the levelness of the pelvis and can also play a role in radicular leg symptoms [12]. Pugely et al. found that all patients with symptomatic leg pain, either in the femoral or sciatic distributions, had foraminal stenosis (< 40 mm²) on the concavity of the fractional curve [13]. Although back pain is more common in ADS, many times an operation is performed for leg pain which is the result of the fractional curve. Some surgeons have advocated for short selective fusions to only treat the fractional curve in patients with radiculopathy. Although treatment limited to the fractional curve has been shown to have equivalent pain and functional scores as compared to longer fusions, the rate of revision extension surgery is quite high. Revision rate was 26% in one study, compared to 13% in lower thoracic to pelvis fusions and 4% in upper thoracic to pelvis fusions [14]. Although selective fusions may only be appropriate in a small subset of the population, these studies do highlight that addressing the fractional curve is critical for achieving symptomatic improvement in patients with ADS.

The debate over anterior/posterior surgery compared to posterior only surgery has been ongoing. Much of the literature supports similar outcomes if done well, but there are nuances to each technique. There is certainly some increased morbidity with the addition of an anterior approach, although it is usually very well tolerated. The literature has shown an excellent fusion rate with an ALIF as well as increased disc height and segmental lordosis. These characteristics have been well vetted in both the deformity and the degenerative literature.

Similarly, it may also be inferred that the large cage achievable with an ALIF could also help correct the coronal alignment of the fractional curve when performed between L4 and S1. The purpose of this study was to compare the

radiographic correction of fractional Cobb angle between a posterior only group and anterior/posterior group. Based on the results found in this study, the use of ALIF + PSF does appear to have greater ability to correct the coronal fractional curve than the PSF group ($p=0.023$). This is also shown in the multivariable regression which showed that the procedure performed was the strongest variable associated with the degree of fractional coronal Cobb correction. Within the PSF group, the addition of TLIF did not improve the coronal fractional curve correction. However, given the small sample size, this finding should be interpreted with caution.

This study does have several limitations. Although the groups were well matched in terms of curves, pelvic parameters, and gender the ALIF + PSF group was younger than the PSF group. Additionally, the group sizes were small, 31 in the ALIF + PSF and 28 in the PSF group. If the sample sizes were larger, it would have been interesting to do a more robust sub-group analysis to compare ALIF patient to TLIF patients. Also, this study only looked at the radiographic appearance of the fractional curve. This study did not look at patient-reported outcomes or functional scores. It is difficult to know if the radiographic difference reliably translates to a clinical improvement. Despite these weaknesses, this study certainly contributes to the notion that ALIF's in the low lumbar spine may have secondary benefit to already well-known benefits of fusion rate and disc height.

Conclusion

Based on this study, in adults with degenerative scoliosis, there is a greater correction of the fractional curve when an anterior interbody is used compared to a posterior only type surgery. While this may not be the primary indication for ALIF, it is a benefit which may facilitate overall deformity correction and leveling of the pelvis. Further studies should focus on the clinical significance of this radiographic finding in terms of patient-reported outcomes and functional scores.

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