Sagittal Alignment After Lumbar Interbody Fusion
Comparing Anterior, Lateral, and Transforaminal Approaches

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Study Design: Retrospective radiographic analysis.

Objective: To determine which lumbar interbody technique is most effective for restoring lordosis, increasing disk height, and reducing spondylolisthesis.

Summary of Background Data: Lumbar interbody fusions are performed in hopes of increasing fusion potential, correcting deformity, and indirectly decompressing nerve roots. No published study has directly compared anterior, lateral, and transforaminal lumber interbody fusions in terms of ability to restore lordosis, increase disk height, and reduce spondylolisthesis.

Materials and Methods: Lumbar interbody fusion techniques were retrospectively compared in terms of improvement of lordosis, disk height, and spondylolisthesis between preoperative and follow-up lateral radiographs.

Results: A total of 220 consecutive patients with 309 operative levels were compared by surgery type: anterior (184 levels), lateral (86 levels), and transforaminal (39 levels). Average follow-up was 19.2 months (range, 1–56 mo), with no statistical difference between the groups. Intragroup analysis showed that the anterior (4.5 degrees) and lateral (2.2 degrees) groups significantly improved lordosis from preoperative to follow-up, whereas the transforaminal (0.8 degrees) group did not. Intergroup analysis showed that the anterior group significantly improved lordosis more than both the lateral and transforaminal groups. The anterior (2.2 mm) and lateral (2.0 mm) groups both significantly improved disk height more than the transforaminal (0.5 mm) group. All 3 groups significantly reduced spondylolisthesis, with no difference between the groups.

Conclusions: After lumbar interbody fusion, improvement of lordosis was significant for both the anterior and lateral groups, but not the transforaminal group. Intergroup analysis showed the anterior group had significantly improved lordosis compared to both the other groups. The anterior and lateral groups had significantly increased disk height compared to the transforaminal group. All the 3 groups significantly reduced spondylolisthesis, with no difference between the groups.

Key Words: interbody fusion, lordosis, spondylolisthesis, sagittal correction, ALIF, XLIF, TLIF

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Surgical fusion of intervertebral segments of the lumbar spine most likely alters the biomechanical forces at adjacent levels, which may increase the rate of degeneration of those segments. The alignment of the fused segment probably influences the biomechanical stresses on the adjacent segments and affects the rate of degeneration.[1,2] The ideal position of fused lumbar segments is in lordosis. The ideal amount of lordosis in each individual patient's entire lumbar spine may be approximated by the pelvic incidence.[3] The ideal amount of lordosis at each specific level within an individual patient is undetermined; therefore, most surgeons strive to obtain as much lordosis as technically and safely possible during a routine lumbar fusion without doing an osteotomy.

Previous studies have shown varying success in the ability to restore lordosis with fusion techniques. The performance of an interbody fusion may increase fusion rate and degree of lordosis at the fused segment. Anterior lumbar interbody fusion (ALIF) has the ability to restore lordosis because of resection of the anterior longitudinal ligament (ALL), thorough discectomy and annular release, and insertion of large lordotic grafts. Lateral lumbar interbody fusion [(LLIF)/extreme lateral interbody fusion/direct lateral interbody fusion] allows for wide discectomy and lateral annular release, insertion of large lordotic grafts that contact the apophyseal ring, and less retraction of the abdominal contents and vessels anterior to the spine compared to ALIF. Transforaminal interbody fusion (TLIF) can be performed with a posterior approach to the spine in conjunction with pedicle screw insertion and direct decompression of spinal nerves. However, the amount of discectomy, endplate preparation, annular release, and graft size typically is limited with TLIF compared to ALIF and LLIF.

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The purpose of our study was to measure the change in the sagittal alignment of disks that underwent lumbar interbody fusion. The results of ALIF, LLIF, and TLIF were compared in terms of segmental lordosis, disk height, and spondylolisthesis.

MATERIALS AND METHODS

A retrospective review of 312 consecutive patients who underwent lumbar interbody fusion with pedicle screw fixation between May 9, 2007 and October 26, 2010 was performed. Patients included in the study were those with preoperative and postoperative lateral radiographs. In total, 220 patients with 309 disks qualified for the study. Average follow-up was 585 days (range, 14–1716 d).

Radiographic measurements were performed on digital images by a medical student (R.H.). Segmental lordosis (eg, L3–L4) was measured by drawing a line parallel to the superior endplate of the cephalad vertebral body (L3) and a line parallel to the inferior endplate of the caudad vertebral body (L4). At L5–S1, the superior endplate of L5 and superior endplate of S1 were used. In cases where a postoperative endplate was obscured because of fusion and/or graft, the best visualized endplate of that specific vertebral body was used. For example, the superior endplate of L4 may have been used if the inferior endplate of L4 was obscured. In every case, the same endplate was used for the preoperative measurement as the postoperative measurement.

Disk height was measured as the vertical distance between the posterior aspect of the inferior and superior endplates at that disk level. Spondylolisthesis was measured as the horizontal distance between the posterior aspect of the inferior and superior endplates at that disk level. Patients with a positive value for preoperative spondylolisthesis were considered for analysis.

The anterior approach was performed with a left-sided retroperitoneal, rectus muscle-sparing technique. Typical graft placement was a femoral ring allograft: 30 mm wide (medial to lateral), 30 mm length (anterior to posterior), 12 mm height (cephalad to caudad), and 6-degree lordotic. The lateral approach was performed with a right-sided or left-sided approach, retroperitoneal, psoas muscle-splitting technique through a tubular retractor. Typical graft placement was a polyetheretherketone graft: 55 mm wide, 18 mm length, 11 mm height, and 6-degree lordotic. Transforaminal approach was an open midline incision with complete removal of 1 facet joint and distraction on the lamina. Typical graft placement was a polyetheretherketone graft: 14 mm wide, 30 mm length, 10 mm height, and nonlordotic.

All the study group patients underwent posterior fusion with pedicle screw instrumentation in addition to the interbody fusion.

Statistical analysis was conducted using STATA Data Analysis and Statistical Software v.10.0 (StataCorp, College Station, TX). All intragroup and intergroup comparisons were made using a Student t test for normally distributed data. Statistical significance was accepted with a $P < 0.05$.

RESULTS

A total of 184 disks in 131 patients underwent ALIF with pedicle screws (A/PSF), 86 disks in 60 patients underwent LLIF with pedicle screws (L/PSF), and 39 disks in 37 patients underwent TLIF with pedicle screws. Results are listed in Tables 1 to 5. Tables 1 to 3 show intragroup analysis comparing preoperative to postoperative values within each group. The population in Table 3 is less than that of Tables 1 and 2 because it only includes levels with a preoperative spondylolisthesis. Table 4 is a summary of the changes seen from preoperative to postoperative for every variable and surgical cohort. These include follow-up time, and the days between a patient's surgery and postoperative measurements. Table 5 shows the P-values from the intergroup comparison of the 3 surgeries against each other.

Our study shows that when comparing preoperative to postoperative measurements, both ALIF and LLIF significantly improve lordosis, whereas TLIF does not show a significant difference (Table 1). Intergroup comparisons showed that ALIF is superior to LLIF and TLIF in ability to restore lordosis (Table 5). Although intragroup analysis shows that LLIF improves lordosis, whereas TLIF does not, intergroup analysis does not show that LLIF significantly increases lordosis more than TLIF. There was no significant difference in follow-up time between any of the groups (Table 5).

In both intragroup (Table 2) and intergroup (Table 5) analysis of our study, the lateral and anterior approaches show a greater improvement in disk height than the transforaminal approach.

Our study shows that all 3 approaches significantly reduce spondylolisthesis (Table 3). Our study does not reveal a significant difference in the reduction of spondylolisthesis between the 3 interbody fusion approaches (Table 5).

DISCUSSION

When performing a lumbar fusion procedure, the addition of an interbody fusion can, among other factors, improve sagittal alignment, indirectly decompress nerve roots, and reduce spondylolisthesis. The choice of which approach to utilize when performing an interbody fusion depends on a multitude of factors including: surgeon experience, patient size, aortic calcifications, previous surgical scar tissue, specific levels of surgery, and goals of the surgery. Our study compares anterior, lateral, and transforaminal lumbar interbody fusions in terms of

TABLE 1. Intragroup Comparison of Segmental Lordosis Change

Procedures	Observations	Premean (SD)	Postmean (SD)	Significance (P)
ALIF	184	15.7 (8.8)	20.2 (8.0)	< 0.001
LLIF	86	8.2 (10.1)	10.4 (8.6)	< 0.001
TLIF	39	14.4 (7.7)	15.2 (8.0)	0.11

ALIF indicates anterior lumbar interbody fusion; TLIF, transforaminal interbody fusion.

TABLE 2. Intragroup Comparison of Disk Height Change

Procedures	Observations	Premean (SD)	Postmean (SD)	Significance (*P*)
ALIF	184	3.8 (2.2)	6.0 (2.5)	< 0.001
LLIF	86	3.3 (2.2)	5.3 (2.5)	< 0.001
TLIF	39	3.8 (1.8)	4.3 (1.8)	0.05

ALIF indicates anterior lumbar interbody fusion; TLIF, transforaminal interbody fusion.

ability to restore segmental lordosis, increase disk height, and reduce spondylolisthesis. Intragroup analyses compare each individual technique in terms of preoperative and postoperative values. Intergroup analyses compare the techniques against each other.

Hsieh et al[4] showed greater improvement of lordosis after ALIF (8 degrees) versus TLIF (0 degrees). Resection of the ALL, large discectomy, and insertion of wedge-shaped lordotic grafts account for the ability of the anterior approach to improve lordosis. Improved lordosis of the fused segment may decrease stress on adjacent levels and decrease incidence of adjacent segment degeneration (ASD).[1,2]

Kumar et al[5] showed that both sagittal alignment and sacral inclination affect the rate of ASD after lumbar fusion. Patients with antepulsion of the C7 plumb line had increased ASD compared to those who were sagittally balanced. Improved lordosis through the fused area may decrease the antepulsion of the C7 plumb line.

In a review of the literature, Park et al[6] concluded that sagittal balance is a potentially modifiable risk factor for the development of ASD after fusion. A study by Wai et al[7] showed a similar incidence of ASD after ALIF as compared to the general population. Perhaps, the restoration of lordosis after ALIF accounted for this finding. Min et al[8] supported the beneficial effects of ALIF in preventing ASD as compared to posterior lumbar interbody fusion.

The downside of the anterior approach is the need for an experienced surgeon to mobilize the peritoneum, bowel, and vessels. The risks include: incisional hernia, peritoneal laceration, deinnervation of the psoas muscle, bowel injury, ileus, vessel injury, retroperitoneal hematoma, retrograde ejaculation, lymphatic injury, and sympathetic trunk injury. Especially in obese patients, elderly patients with a calicified aorta, and patients with previous retroperitoneal dissections, we prefer to perform a lateral or transforaminal approach to the disk space.

TABLE 3. Intragroup Comparison of Spondylolisthesis Change

Procedures	Observations	Premean (SD)	Postmean (SD)	Significance (*P*)
ALIF	73	7.4 (4.1)	4.1 (3.5)	< 0.001
LLIF	33	5.5 (3.1)	2.0 (2.6)	< 0.001
TLIF	24	6.6 (3.4)	4.0 (2.9)	< 0.001

ALIF indicates anterior lumbar interbody fusion; TLIF, transforaminal interbody fusion.

TABLE 4. Difference Between Preoperative and Postoperative Measurements for Each Procedure

Procedures	Lordosis (deg.)	Height (mm)	Spondylolisthesis (mm)	Follow-up Time (d)
ALIF	4.5	2.2	−3.3	573
LLIF	2.2	2.0	−3.5	614
TLIF	0.8	0.5	−2.6	583

ALIF indicates anterior lumbar interbody fusion; TLIF, transforaminal interbody fusion.

Our study does not find a statistically significant difference in the ability of LLIF (2.2 degrees) versus TLIF (0.8 degrees) to restore lordosis at the surgical level ($P = 0.15$). Because both of these procedures fail to resect the ALL, they are not as effective as ALIF in restoring lordosis. However, comparison of the preoperative versus postoperative numbers for each individual procedure shows that both ALIF ($P < 0.001$) and LLIF ($P < 0.001$) significantly improve lordosis, whereas TLIF ($P = 0.11$) does not (Table 1). The lateral approach allows for large discectomy and insertion of large interbody grafts, which may account for the significantly improved lordosis from preoperative to postoperative films.

After LLIF, Sharma et al[9] and Acosta et al[10] reported a significant improvement of lordosis (2.8 and 2.9 degrees, respectively). In comparison, Kim et al[11] did not find a significant improvement of lordosis (1.6 degrees) at final follow-up compared to preoperative with TLIF. A more recent study by Jagannathan et al[12] demonstrated correction of segmental lordosis after a TLIF of up to 20 degrees. However, this technique involves bilateral facetectomies, which is basically a Smith-Peterson osteotomy.

In our study, the lateral (2.2 mm, $P < 0.001$) and anterior (2.0 mm, $P = 0.001$) approaches show a greater improvement in disk height than the transforaminal (0.5 mm) approach. This difference is most likely because of greater discectomy, better release of annular fibers, and insertion of larger interbody grafts. The primary benefit of increasing disk height is the potential indirect decompression of spinal nerve roots. In our anecdotal experience, increasing disk height decompresses the exiting nerve in the foramen more reliably than the traversing nerve in the lateral recess.

TABLE 5. Intergroup Comparison of Difference Between Preoperative and Postoperative Measurements for Each Procedure

Comparison	Lordosis (*P*)	Height (*P*)	Spondylolisthesis (*P*)	Follow-up (*P*)
ALIF vs. LLIF	0.002	0.64	0.78	0.42
ALIF vs. TLIF	< 0.001	< 0.001	0.24	0.88
LLIF vs. TLIF	0.15	0.001	0.22	0.69

ALIF indicates anterior lumbar interbody fusion; TLIF, transforaminal interbody fusion.

Oliveira and colleagues demonstrated the ability of LLIF to increase disk height (42%), foraminal height (14%), foraminal area (25%), and central canal diameter (33%).[13] Kim and colleagues found that both A/PSF (8 mm) and TLIF (2.5 mm) significantly increased disk height.[14] Unfortunately, the study did not test statistical significance comparing the 2 groups against each other.

Kim et al[15] reported similar relief of leg pain after ALIF with indirect decompression as compared to ALIF with posterior decompression. The average gain of 8 mm in disk height and 50% reduction in spondylolisthesis probably indirectly decompressed the spinal nerves accounting for the reduction of leg pain.

Reduction of spondylolisthesis is the final factor of our analysis. Reducing the spondylolisthesis may improve sagittal alignment by moving the C7 plumb line more posterior in relation to the anterior sacrum. Reduction of the spondylolisthesis may also indirectly decompress the spinal nerves by creating more cross-sectional area in the foramen and lateral recess. Our study shows that all 3 approaches significantly reduce spondylolisthesis, with no significant difference.

Limitations

Our study was a retrospective review with inherent limitations. The radiographic measurements were performed by a medical student whose lack of experience may have hurt, or helped, the accuracy of the results. We do not believe the student has a bias towards 1 surgical technique.

The indications for surgery varied between the 3 approaches. For example, a patient with severe kyphosis was more likely to undergo an ALIF as compared to a TLIF. Also, L5–S1 is typically inaccessible from a lateral approach, therefore was biased towards receiving an ALIF or TLIF procedure. Our follow-up time was relatively short in some patients, which may have shown loss of sagittal correction with longer follow-up. However, we did not find a statistically significant difference in the follow-up times between the 3 techniques, so this may not be a confounding factor. Finally, newer TLIF techniques involving osteotomies or expandable lordotic cages may show to improve sagittal correction more than our described technique.

CONCLUSIONS

ALIF and LLIF significantly improve lordosis. ALIF is superior to LLIF and TLIF in restoration of lordosis. ALIF and LLIF are superior to TLIF in disk height restoration. There is no significant difference in the reduction of spondylolisthesis between the 3 surgeries.

REFERENCES

1. Umehara S, Zindrick MR, Patwardhan AG, et al. The biomechnical effect of postoperative hypolordosis in instrumented lumbar fusion on instrumented and adjacent spinal segments. *Spine*. 2000;25:1617–1624.
2. Oda I, Cunningham BW, Buckley RA, et al. Does spinal kyphotic deformity influence the biomechanical characteristics of the adjacent motion segments? *Spine*. 1999;24:2139–2146.
3. Labelle H, Roussouly P, Berthonnaud E, et al. The importance of spino-pelvic balance in L5-S1 developmental spondylolisthesis: a review of pertinent radiologic measurements. *Spine*. 2005;30:S27–S34.
4. Hsieh P, Koski T, O'Shaughnessy B, et al. Anterior lumbar interbody fusion in comparison with transforaminal lumber interbody fusion: implications for the restoration of foraminal height, local disc angle, lumbar lordosis, and sagittal balance. *J Neurosurg Spine*. 2007;7:379–386.
5. Kumar M, Baklanov A, Chopin D. Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. *Eur Spine J*. 2001;10:314–319.
6. Park P, Garton H, Gale V, et al. Adjacent segment disease after lumbar or lumbosacral fusion: review of the literature. *Spine*. 2004;29:1938–1944.
7. Wai E, Santos E, Morcom R, et al. Magnetic resonance imaging 20 years after anterior lumbar interbody fusion. *Spine*. 2006;31:1952–1956.
8. Min J, Jang J, Lee S. Comparison of anterior and posterior approach instrumented lumbar interbody fusion for spondylolisthesis. *J Neurosurg Spine*. 2007;7:21–26.
9. Sharma AK, Kepler CK, Girardi FP, et al. Lateral lumbar interbody fusion: clinical and radiographic outcomes at 1 year a preliminary report. *J Spinal Disord Tech*. 2011;24:242–250.
10. Acosta F, Liu J, Slimack N, et al. Changes in coronal and sagittal plane alignment following minimally invasive direct lateral interbody fusion for the treatment of degenerative lumbar disease in adults: a radiographic study. *J Neurosurg Spine*. 2011;15:92–96.
11. Kim S, Jeon T, Heo Y, et al. Radiographic results of single level transforaminal lumbar interbody fusion in degenerative lumbar spine disease: focusing on changes of segmental lordosis in fusion segment. *Clin Orthop Surg*. 2009;1:207–213.
12. Jagannathan J, Sansur C, Oskouian R, et al. Radiographic restoration of lumbar alignment after transforaminal lumbar interbody fusion. *Neurosurgery*. 2009;64:955–964.
13. Oliveira L, Marchi L, Coutinho E. A radiographic assessment of the ability of the extreme lateral interbody fusion procedure to indirectly decompress the neural elements. *Spine*. 2010;35:5331–5337.
14. Kim J, Kim D, Lee S. Comparison between instrumented mini-TLIF and instrumented circumferential fusion in adult low-grade lytic spondylolisthesis: can mini-TLIF with PPF replace circumferential fusion? *J Korean Neurosurg*. 2009;45:74–80.
15. Kim J, Kim D, Park C. Comparison study of the instrumented circumferential fusion with instrumented anterior lumbar interbody fusion as a surgical procedure for adult low-grade isthmic spondylolisthesis. *World Neurosurg*. 2010;73:565–571.