Stand-Alone
Lumbar Lateral Interbody Fusion (LLIF)
vs.
Supplemental Fixation

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Disclosures
- Consultant - Zimmer / Biomet, DePuy Synthes Spine, Amendia, Stryker
- Stock - Innovative Surgical Solutions, Safe Wire, Vivex
- Royalties - Biomet

LLIF Approach
- Good indirect decompression
- Good coronal correction
- Solid stabilization construct
- 41.9% in disc height
- 13.5% in foraminal height
- 24.7% in foraminal area
- 33.1% in central canal diameter
- 2 patients (9.5%) required a second procedure for additional posterior decompression and/or instrumentation.

### Indirect Decompression

#### Pre-op

#### Post-op

### Coronal Correction

- 75°
- 40°
Stability & Fusion Rates

- Strong construct with high rates of fusion (up to 98%)
  - Rodgers et al, SAS journal 2010
  - Anand et al, Neurosurg focus 2010
  - Dakwar et al, Neurosurg focus 2010
  - Zavatsky et al, Ochsner J 2014

- Does it provide adequate rigidity for fusion?
- Does it stand the test of time (maintain indirect decompression & deformity correction)?
- Subsidence
- Do certain conditions affect success?
  - Osteoporosis
  - Spondylolisthesis
  - Scoliosis
  - # of levels
- Can we mitigate complications?
- How much rigidity is necessary to achieve fusion?
- What form of supplemental fixation provides adequate rigidity?
  - Lateral plate
  - Pedicle screws
  - Spinal process fusion device
  - Unilateral pedicle screws
  - Bilateral pedicle screws

Standalone

- Utilized commonly for adjacent level disease

Minimally invasive lateral transforaminal pedicle screw fusion using a stand-alone construct for the treatment of adjacent segment disease of the lumbar spine: Review of the literature and report of three cases

Prospective nonrandomized observational single-center study.

Stand-alone LLIF on 52 consecutive patients (67.6 ± 10 y/o; 73.1% female; 27.4 ± 3.4 BMI) with single-level grade I/II single-level degenerative spondylolisthesis without significant spine instability with 2-year follow-up were included.

Average OR time 73.2 minutes and with less than 50cc blood loss.

VAS and Oswestry scores showed lasting improvements in clinical outcomes (60% and 54.5% change, resp.).

The vertebral slippage was reduced in 90.4% of cases from mean values of 15.1% preoperatively to 7.4% at 6-week follow-up (P < 0.001) and was maintained through 24 months (7.1%, P < 0.001).

Grade II or III cage subsidence occurred in 9/52 cases (17%).

7/52 cases (13%) spine levels needed revision surgery.

At the 24-month evaluation, solid fusion was observed in 86.5% of the levels treated.
- Subsidence risks?
- When does it occur?
- Does it progress?
When Does Subsidence Occur?

Disc Height

Canal & Foraminal Decompression
But....Clinical Improvements Persist

Supplemental pedicle screw fixation was used in 75.7% of patients, 5.6% had lateral fixation, and 18.7% had stand-alone XLIF.

Mean operative time and blood loss were 178 minutes (range, 58 minutes/level) and 50 to 100 mL. Mean hospital stay was 2.9 days (unstaged), 8.1 day (staged, 16.5%), 3.8 days overall.

Five patients (4.7%) received a transfusion, 3 (2.8%) required intensive care unit admission, and 1 (0.9%) required rehabilitation services. Major complications occurred in 13 patients (12.1%): 2 (1.9%) medical, 12 (11.2%) surgical.

Less invasive techniques (XLIF stand-alone or with percutaneous instrumentation), 9.0% had one or more major complications vs open posterior instrumentation, 20.7% had one or more major complications. Early reoperations (3 cell for deep wound infections) were associated with open posterior instrumentation procedures.

The morbidity in adult scoliosis surgery is minimized with less invasive techniques. The rate of major complications in this study (12.1%) compares favorably to most reports from other studies of surgery for degenerative deformity.
62 patients were treated with LLIF for degenerative disk disease, spondylolisthesis, scoliosis, and stenosis with a minimum 2-year follow-up between 2003 and December 2006 were included.

- 26 patients (42%) were single-level, 15 (25%) 2-level, 19 (31%) 3- or more levels.

- 15 (25%) were stand-alone

- 45 (73%) included supplemental posterior pedicle fixation; 4 (6%) lateral fixation

- 57 (92%) included the use of bone morphogenic protein (BMP), the remainder a mixture of allograft and autograft.

- VAS decreased significantly from pre-op to 2-year follow-up by 37% (p<0.0001).

- ODI decreased significantly by 39% from pre-op to 2-year follow-up (p<0.0001).

- Clinical success by ODI-change definition was achieved in 71% of patients.

- Radiographic success was achieved in 91% of patients

- 1 patient with pseudarthrosis requiring posterior revision (Did not specify stand-alone, BMP?)

62 patients were treated surgically for adult degenerative scoliosis between 2004 and 2008.

- 46 (74%) were treated with stand-alone lateral lumbar interbody fusion

- 35 patients (nine men, 26 women; mean ± SD age, 68 ± 10 years) were available for this retrospective review

- 107 levels were treated (mean, three; range, one to seven)

- Mean VAS back pain scores improved from 85 mm pre-op to 27 mm at latest follow-up (p<0.001)

- VAS leg pain scores improved from 91 mm to 24 mm (p<0.001)

- ODI scores improved from 51 to 29 (p<0.001)

- Coronal Cobb improved from 21° to 12° (p<0.001); Lumbar lordosis improved from 33° to 41° (p<0.001); Sacral slope improved from 28° to 35° (p<0.001)

- Fusion rate was 84% at final evaluation

- High-grade subsidence was seen in 10 patients (29%)

- 3 patients (9%) needed further surgical intervention

- Stand-alone

- More revision cases had stand-alone performed

- Insignificant Cobb and lordosis correction

- Significant improvement in ODI (43 → 29)
A multicenter chart review of stand-alone MIS-LIF patients with 3, 6, and 12 month follow-up between 2008 and 2012. 59 patients met the inclusion criteria. Average age was 60 years (range 31–86 years). Spinal pathologies treated were DDD in 37 (63%), spondylolisthesis in 4 (7%) and adult degenerative scoliosis (ADS) in 18 (30%) patients. Mean hospital stay and follow-up were 3.3 days (range 1–10) and 14.6 months, respectively. The mean preoperative VAS and ODI were 69.1 and 51.8, respectively. VAS improved to 37.8 (p < 0.0005). ODI improved to 31.8 (p < 0.0005).

30% (18/59 patients) had Grade I & II subsidence
- 2 patients required re-operation (3.4%)
- 70% (41/59) had grade 0 subsidence
Fusion rate was 93% of patients (95% of levels) at 12 months.

Stand-alone MIS-LIF is a viable option in a carefully selected patient population for both single and multilevel disease and shows significant improvement in health-related quality of life.

Radiographic and clinical evaluation of cage subsidence after stand-alone lateral interbody fusion

Clinical article

Liu, C. C., de Juan, E., Cervera, J. R., et al. (2016). Stand-alone (1- or 2-level) LLIF; 12 months of postoperative follow-up.

46 patients underwent treatment at 61 lumbar levels with standard interbody cages (18 mm anterior/posterior dimension).
- 28 patients underwent treatment at 37 lumbar levels with wide cages (22 mm).

Segmental lumbar lordosis and disc height were observed overall, the 18-mm group experienced less improvement due to the higher rate of interbody graft subsidence.
- 18 vs 22 mm cages - difference in the rate of subsidence at 6 weeks (p = 0.027), 3 months (p = 0.042), and 12 months (p = 0.047).
- At 12 months, 70% in the standard group and 89% in the wide group had Grade 0 or I subsidence, and 10% in the standard group and 1% in wide group had Grade II subsidence.

Subsidence was detected early (6 weeks), at which point it was correlated with transient clinical worsening, although progression of subsidence was not observed after the 6-week time point.
- Subsidence occurred predominantly (80%) in the inferior endplate.
- Fusion rate was not affected by cage dimension (p = 0.008) or by incidence of subsidence (p = 0.280).
- 10 of 74 (13.5%) patients required revision on average 4.2 weeks after surgery (range 2–10 weeks).
- Most patients requiring secondary procedure had experienced Grade II or III subsidence (5 of 10 patients).

Wider cages avoid subsidence and better restore segmental lordosis in stand-alone lateral interbody fusion. Cage subsidence is identifiable early in follow-up and can be assessed using the proposed classification score.
140 consecutive patients with L1-L5 LLIF with 2-year follow-up.

- **Radiographic subsidence occurred in 14.3% (20 of 140 patients; 8.8% (21 of 238 levels)**
- **Clinical subsidence occurred in 3.1%**
- Direct length had a significant positive correlation with increasing subsidence rates.
- **18mm cage - 14.1% (19 of 135)**
- **22mm cage - 1.9% (2 of 103)**
- No significant trends were observed with cage lengths.

- **Bilateral pedicle screw supplementation had lower rates of subsidence vs. lateral plating**

Subsidence occurred at the superior end plate 70% of the time.

Wide cages are protective against subsidence, and should be used when feasible to protect the indirect decompression and indirect arthrodesis.

**TABLE 3: Subsidence Rates as They Relate to Implant Characteristics and Level**

<table>
<thead>
<tr>
<th>Implant Characteristics</th>
<th>Levels</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>18mm</td>
<td>135</td>
<td>14.1%</td>
</tr>
<tr>
<td>22mm</td>
<td>103</td>
<td>1.9%</td>
</tr>
</tbody>
</table>

**TABLE 4: Subsidence Rates as They Relate to Specific Levels Included**

<table>
<thead>
<tr>
<th>Specific Levels Included</th>
<th>Levels</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>10.1%</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>10.1%</td>
</tr>
</tbody>
</table>

**TABLE 5: Subsidence Rates as They Relate to Supplemental Fixation**

<table>
<thead>
<tr>
<th>Supplemental Fixation</th>
<th>Patients</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lateral plate</td>
<td>51/28</td>
<td>24.5%</td>
</tr>
<tr>
<td>Pedicle screws</td>
<td>19/8</td>
<td>8.6%</td>
</tr>
<tr>
<td>Anterior</td>
<td>9/3</td>
<td>30%</td>
</tr>
<tr>
<td>Spinous process plate</td>
<td>3/1</td>
<td>8.8%</td>
</tr>
<tr>
<td>Bilateral pedicle screws</td>
<td>19/12</td>
<td>17%</td>
</tr>
<tr>
<td>Lateral plate screws</td>
<td>2/2</td>
<td>100%</td>
</tr>
</tbody>
</table>

**TABLE 6: Subsidence Rates as They Relate to Specific Levels Included**

<table>
<thead>
<tr>
<th>Specific Levels Included</th>
<th>Levels</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19</td>
<td>10.1%</td>
</tr>
<tr>
<td>2</td>
<td>19</td>
<td>10.1%</td>
</tr>
<tr>
<td>3</td>
<td>19</td>
<td>10.1%</td>
</tr>
</tbody>
</table>

**Non-Union Rate With Stand-Alone Lateral Lumbar Interbody Fusion**

Non-union incidence was 7 levels in 6 patients.

Non-union rates were 7/37 (19%) per level and 6/22 (27%) per patient.

While our study population was relatively low, a non-union rate of 19% to 27% is concerning for modern spine surgery.

Currently, in our practice, we occasionally still perform stand-alone LLIF utilizing 22mm wide grafts in low-demand levels in non-smoking and non-osteoporotic patients.

In the majority of patients, authors utilize supplemental fixation

- Bilateral pedicle screws in most patients
- Lateral plate screws in some patients
117 patients stood-alone LLIF for symptomatic spinal stenosis with an indication for fusion were included in the analysis.

10.3% of patients ultimately required revision surgery
- Persistent radiculopathy
- Symptomatic implant subsidence
- Average time to revision was 10.8 months.
- No difference in radiographic correction between patients who did and did not require revision surgery.
- Authors concluded that LLIF provides a minimally invasive means to treat lumbar spinal stenosis with an acceptable revision rate for formal posterior decompression at early follow-up.

Assuming Subsidence is a Problem... Can it be Prevented?

Subsidence

↑Area = ↓Pressure
Wider Cages (22, 26, 30 mm)

Greater surface area coverage of apophyseal ring = subsidence prevention and improved fusion

Spanning the Apophyseal Ring & Endplate Preservation

- Regional strength and stiffness variations were identified in the lumbar and sacral endplates.
- The center of the endplate, where most implants are placed, is weakest.

Bone Quality & Endplate Preparation

- Subsidence can occur even with pedicle screw supplementation.
- Osteoporosis
- Respect the endplates
712 levels in 335 patients. Patients with subsidence following LLIF were recorded. T-score of patients with subsidence was compared to those without subsidence.

20 of 57 (35%) patients without subsidence had a DEXA T-score between -1.0 and -2.4, consistent with osteopenia. One patient (1.8%) exhibited a T-score < -2.5, consistent with osteoporosis.

13 patients of 23 (57%) with subsidence exhibited a T-score between -1.0 and -2.4, consistent with osteopenia. Five (22%) exhibited a T-score < -2.5, consistent with osteoporosis.

The mean DEXA T-score in patients with subsidence was -1.65 (SD 1.04) vs. to -0.45 (SD 0.97) in patients without subsidence (p < 0.01).

Patients with DEXA T-scores less than -1.0 who undergo stand-alone LLIF are at a much higher risk of developing graft subsidence and requiring additional surgery. In patients with poor bone quality, consideration should be made to augment the LLIF cage with supplemental fixation.

Effects of Endplate Removal on the Structural Properties of the Lower Lumbar Vertebral Bodies


Would Resting a Lateral Interbody Cage Across the Ring Apophysis in the Lumbar Spine Mitigate Endplate Violation?

Zavatsky J, Serhan H, Kumar M, Kodigudda MK, Agarwal A, Vivek, P, Goel. VK
Cage Migration

- Cage migration
- Cage size?
- Contralateral annulus release?
- Inadequate discectomy?
- Supplemental augmentation?
How Much Rigidity is Required?

- Standard cage alone
- Cage + lateral plate
- Cage + spinous process fixation
- Plate + spinous process fixation
- Cage + ipsilateral pedicle screws
- Cage + Bilateral pedicle screws

Biomechanics of lateral lumbar interbody fusion constructs with lateral and posterior plate fixation

Laboratory investigation

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Lateral Bending

Flexion / Extension

Axial Rotation
Take Home

- Subsidence can limit success
  - It begins pre-op
  - Obtain Dexa scan
  - T-score < -1.0 consider supplemental fixation
- Intra-op
  - Respect the endplates
  - Cage size
    - Wider is better (22 & 26 mm)
    - Span the ring apophysis
  - # levels
    - More levels increase risk of subsidence
    - Deformity correction
    - Cobb angle
    - Lordosis
- Destabilizing pathology may necessitate supplemental fixation
  - Scoliosis
  - Spondylolisthesis
- Greatest rigidity is obtained with bilateral pedicle screws
- Lateral plating and spinous process fixation
  - Facet / washer screw system using transfacet-pedicular trajectory

Take home

- Need for supplemental fixation should be considered on a case by case basis...
  - Standalone
    - Younger, non-osteoporotic, 1-2 levels, no instability
    - Meticulous surgical technique with endplates preservation
    - Wide cage (> 22 mm)
  - Supplemental fixation
    - Older, T-score < -1.0, multi-level scoliosis or spondylolisthesis, endplate violation
    - Cage + percutaneous pedicle screws
    - Cage + lateral plate + spinous process fixation
    - Cage + facet / washer screws (transfacet-pedicular trajectory)
Thank you