Guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 11: interbody techniques for lumbar fusion

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Recommendations

Standards. There is insufficient evidence to recommend a treatment standard.

Guidelines. In the context of a single-level stand-alone ALIF or ALIF with posterior instrumentation, the addition of a PLF is not recommended as it increases operating room time and blood loss without influencing the likelihood of fusion or the functional outcome.

Options. 1) It is recommended that both PLF and interbody fusion (PLIF, TLIF, or ALIF) techniques be considered as treatment options for patients with low-back pain due to DDD at one or two levels. 2) Placement of an interbody graft is recommended as a treatment option to improve fusion rates and functional outcome in patients undergoing surgery for low-back pain due to DDD at one or two levels. The surgeon is cautioned that the marginal improvement in fusion rates and functional outcome with these techniques is associated with increased complication rates, particularly when combined approaches (that is, 360°) are used. 3) The use of multiple approaches (anterior or posterior) to accomplish lumbar fusion is not recommended as a routine option for the treatment of patients with low-back pain without deformity.

Rationale

The surgical treatment of low-back pain has evolved over the last several decades, and interbody techniques have been proposed as surgical alternatives to posterolateral lumbar fusion. Placement of the graft within the load-bearing column of the spine has biomechanical advantages and has been reported to result in higher fusion rates with improved patient outcomes compared with PLF techniques. A variety of techniques are available for the application of interbody grafts, and each technique has its particular advantages, disadvantages, and champions. The purpose of this review is to examine the literature reporting experience with interbody fusion techniques and their relative safety and efficacy compared with posterolateral fusion techniques for the treatment of patients with low-back pain.

Literature Search

A computerized search of the National Library of Medicine database of the literature published from 1966 to June 2003 was performed. A search using the subject heading “spinal fusion, lumbar, treatment outcome, low-back pain” yielded 1030 citations. Clinical series reported in English-language journals dealing with adult patients...
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who had undergone fusion with instrumentation for degenerative lumbar disease were selected (333 references). Relevant articles pertaining to the comparison of interbody fusion techniques with other surgical techniques or nonsurgically treated controls were selected and are summarized in the evidentiary table. A number of case series provide supporting data and are referenced in the bibliography.

Scientific Foundation

Recent trends in spinal surgery include the use of interbody fusion techniques including ALIF, PLIF, or TLIF as a means to enhance the rate of successful arthrodesis. Authors of several studies have compared the results of these techniques with respect to each other as well as with respect to PLF.

Christensen, et al., studied a series of 148 patients with severe low-back pain who were prospectively randomized to treatment with PLF with pedicle screws or ALIF with Brantigan cages in addition to posterior instrumentation and PLF. Outcomes were measured using the DPQ and the Low Back Pain Rating Scale. There was a trend toward better overall functional outcome for patients treated with the circumferential procedure but this was not statistically significant (p < 0.08). This patient group did have statistically significantly less leg pain at the 1-year follow-up evaluation (p < 0.03), and less peak back pain at 2 years (p < 0.04). The patients who underwent circumferential fusion were found to have a higher PLF rate (92%) than the patients treated with PLF with pedicle screws (80%) (p < 0.04) when fusion status was evaluated based on static plain x-ray films. The circumferential fusion group had an 82% interbody fusion rate. The plain x-ray film findings for the remaining 18% of the circumferential group were described as “ambiguous.” The repeated operation rate was significantly lower in the circumferential group (7%) than in the PLF group (22%) (p < 0.009). This paper provides Class III medical evidence supporting the role of interbody grafts in improving arthrodesis rates because of the lack of flexion-extension views or CT scans to supplement the static radiographs. The medical evidence supporting the role of interbody grafts in improving outcome with respect to back and leg pain is considered Class II despite the randomized design of the study because the difference in the improvement between the surgical groups in the primary outcome measure did not reach statistical significance. This information must be considered in light of the fact that similar measures of back and leg pain were not significantly different between treatment groups at other time points.

Fritzell and colleagues performed a randomized, prospective, multicenter trial involving 294 patients with chronic low-back pain due to DDD at one or two levels. Patients were assigned to one of four treatment groups. Patients in Group 1 (73 patients) underwent a noninstrumented PLF. Those in Group 2 (74 patients) were treated with PLF with pedicle screw fixation; patients in Group 3 were treated with interbody arthrodesis supplemented with pedicle screw fixation (56 of these patients underwent ALIF with pedicle screws). Nineteen of these patients underwent PLIF with PLF and pedicle screws). Group 4 was treated nonsurgically. Ninety-one percent of patients were available for follow up by an independent observer. Although all surgical groups did substantially better than the nonsurgical group, there were no statistically significant differences in ODI, Low Back Pain Questionnaire, Million VAS, and General Function Score between the surgical groups. The early complication rate was 6% in Group 1, 16% in Group 2, and 31% in Group 3. The fusion rate was evaluated by plain radiographs (without flexion-extension views) and was 72% in Group 1, 87% in Group 2, and 91% in Group 3. They concluded that all surgical groups had similar functional outcomes, but they noted that their study did lack power to detect a difference in functional outcome between the surgical groups. There was an increase in the fusion rate in the instrumented group and in the interbody group compared with the noninstrumented group (p = 0.004). This paper provides Class III medical evidence supporting the beneficial effects of instrumentation and interbody grafts on fusion rates because of its reliance on static radiographs. Because of the sample size, the medical evidence against a beneficial effect on functional outcome is also considered Class III.

The same authors analyzed their data with respect to complication rates and found that overall complication rates were higher in the instrumented PLF and interbody groups compared with the noninstrumented PLF group. The early complication rate was 6% in the PLF group, 18% in the PLF with screw group, and 31% in the 360° fusion group (p = 0.001). There was no significant difference in the reoperation rate between the interbody group and the PLF with pedicle screw group. Twenty of the 27 reoperations were performed because of “hardware discomfort” or the patient’s desire for device removal. These reoperations would appear to be unrelated to the use of an interbody implant. Seventeen of the 29 complications reported in the 360° fusion group did not necessarily result from the interbody procedure itself. These complications included donor site pain, pressure sores, and screw malposition. Four complications were specifically related to the anterior approach: two iliac vein lacerations and two sympathetic nerve injuries. There were seven instances of new nerve root pain, two of which required reoperation within 2 years. The 2-year follow-up complication rate was 12% in the PLF group, 22% in the PLF with screws group, and 40% in the 360° group (p = 0.0003). This complication rate includes reoperations for instrumentation removal, whether or not the removal was performed because of any problems associated with the instrumentation. The only delayed complication reported in the interbody group was continued donor site pain in the patients who underwent ALIF. The lack of beneficial effect on functional outcome, along with the higher complication rate associated with the circumferential procedures may be interpreted as evidence against the use of circumferential procedures as a means to improve patient outcomes.

Greenough, et al., performed a nonrandomized study in which a cohort of 135 patients treated with PLFs with pedicle screws were compared with a historical control cohort of 151 patients treated with ALIF by the same surgeon. Fusion assessment was performed based on plain radiographs, occasionally supplemented with flexion-extension films. Outcome was measured using a patient satisfaction score as well as the LBO score. The authors dichotomized the LBO data by considering a score of
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<th>Authors &amp; Year</th>
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<td>Linson &amp; Williams, 1991</td>
<td>III</td>
<td>Retrospective study of 51 patients: Group I (17) stand-alone ALIF. Group II (18) stand-alone ALIF redo. Group III (16) ALIF w/ Harrington or Knodt rod &amp; PLF. Mean FU was 25, 21, and 26 mos, respectively. Assessment was performed w/ ODI questionnaire. Fusion assessed w/ dynamic x-rays. Pseudoarthrosis rate was Group I 24%, Group II 17%, Group III 13% (p value not given).</td>
<td>Suggestion of increased fusion rate w/ posterior instrumentation + ALIF</td>
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<td>Yashiro, et al., 1991</td>
<td>III</td>
<td>Nonrandomized retrospective cohort study. Group I had PLF + PS (28 patients) &amp; Group II underwent PLIF + PS (30 patients). Mean FU 25 mos. Radiographic FU w/ plain films until fusion was established (mean 11 mos PLF, 6 mos PLIF). The op time was &gt; in the PLIF group (p &lt; 0.05). Fusion occurred in 67% of Group I &amp; 92% of Group II (p &lt; 0.01) for I level &amp; 56% and 100% for 2 level cases (p &lt; 0.05). Difference in complication rates was not statistically significant. PLIF graft material not specified.</td>
<td>PLIF w/ PS provides increased fusion rates w/ similar complication rates to PLF + PS.</td>
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<td>Rompe, et al., 1995</td>
<td>III</td>
<td>85 patients w/ degenerative lumbar spine disease &amp; radiological evidence of instability. 55 had PLF w/ pedicle screws; 30 had PLIF &amp; PLF w/ screws. There were no differences in outcome (nonvalidated outcome measure) b/wn the groups. There were fewer cases of hardware failure in PLIF group.</td>
<td>Outcome of PLF + PS was the same as PLIF + PLF + PS.</td>
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<td>Hacker, 1997</td>
<td>III</td>
<td>Retrospective 75 patients. 54 PLIF stand-alone BAK, 21 ALIF w/ allograft + PLF w/ autograft (no screws). Min 2 yr FU. Op time (p &lt; 0.0001), EBL (p &lt; 0.0001), &amp; stay (p &lt; 0.0003) were significantly decreased in PLIF group. Outcome measures were incompletely reported. Many patients lost to FU.</td>
<td>Stand-alone PLIF more cost effective than 360° fusion. Outcomes &amp; fusion rate are similar.</td>
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<td>Greenough, et al., 1998</td>
<td>III</td>
<td>Prospective nonrandomized cohort of 135 patients PLF + PS. Fusion assessment w/ x-rays w/ dynamic films on some patients. Outcome measure is LBO score, &amp; modified somatic perception questionnaire &amp; Zung depression scale (2 yrs min FU). Results inferior to those obtained in historical cohort of patients treated w/ ALIF.</td>
<td>ALIF associated w/ higher fusion rates &amp; patient satisfaction than PLF + PS.</td>
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<td>Vanvanji, et al., 1998</td>
<td>Instrumentation II</td>
<td>56 consecutive patients, op w/ 1 of 4 lumbar fusion procedures. Outcomes determined by postop questionnaires, independent clinical assessment, &amp; radiographic evaluation. Simultaneous ALIF w/ BAK cage &amp; posterior facet fusion provided the highest rate of fusion (88%) &amp; clinical satisfaction (63%). Pain scores significantly lower than facet screw–augmented PLF &amp; ALIF w/ BAK &amp; allograft, but not significantly different from PS instrumented posterolateral fusion. Patients w/ lumbar fusion had better clinical outcomes &amp; a better chance of work resumption.</td>
<td>ALIF requires postfixation to equal results of PLF + PS.</td>
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<td>Barnes, et al., 2001</td>
<td>Interbody III</td>
<td>Retrospectively reviewed a series of 35 patients w/ mechanical low-back or 1- to 2-level discogenic pain; 23 treated w/ PLIF &amp; PSs, 12 w/ noninstrumented ALIF. All had interbody fusion w/ TCBDs. FU was 87% for the PLIF group &amp; 67% for ALIF w/ a mean of 1 yr. 70% satisfactory outcome was noted in PLIF patients &amp; 56% in ALIF patients. Osteosetfusion was present in 95% of patients in the ALIF group &amp; in 13% of the ALIF group. Small sample size, differing patient selection criteria, &amp; large “lost to FU” group limit value of study.</td>
<td>PLIF w/ PS do better than stand-alone ALIF w/ respect to fusion &amp; outcome when TCBDs are used.</td>
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<td>Chitnavis, et al., 2001</td>
<td>III</td>
<td>50 PLIF patients w/ carbon fiber cages for DDD. In 40 patients (80%) w/ stand-alone PLIF, 10 w/ PSs. Prolo results. Fusion assessed based on established classification w/ dynamic x-rays. 2/5 of patients experienced good or excellent outcomes (Prolo score &gt;9) at early &amp; late FU. No difference in clinical outcome b/wn those in whom PSs were and were not implanted (p = 0.83, Mann–Whitney U-test). Unable to draw significant conclusion regarding use of PS due to small sample size.</td>
<td>PS augmentation of carbon fiber cage PLIF may/may not improve outcome or fusion rate.</td>
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<td>Hee, et al., 2001</td>
<td>III</td>
<td>Retrospective 164 patients. 53 had same-day anterior–posterior fusion (Group I), and 111 had TLIF (Group 2). Mean op time (p &lt; 0.0001) and LOS (p &lt; 0.0001) were significantly longer for anterior–posterior patients. Average blood loss was greater for anterior–posterior patients (p &lt; 0.01). Higher complication rates in anterior–posterior (p &lt; 0.004). FU was 2 yrs. PS + PLF was performed for all ALIFs. The TLIFs (100) were performed w/ cage, autograft, PS, &amp; PLF. Radiographs were assessed by Gertzbein method. Pseudoarthrosis rate was 15% for ALIF &amp; 6% for TLIF group (p = 0.07). TLIF was better than 360° fusion w/ regard to fusion rate &amp; cost, but the 360° fusion rate was lower than expected by the authors.</td>
<td>TLIF was better than 360° fusion w/ regard to fusion rate &amp; cost, but the 360° fusion rate was lower than expected by the authors.</td>
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<td>Humphrey, et al., 2001</td>
<td>II</td>
<td>Nonrandomized retrospective comparison of 40 TLIFs w/ l cage, autograft, PS, &amp; PLF &amp; 34 PLIFs w/ l cage &amp; PS/PLF. No outcome measure or fusion assessment performed.</td>
<td>PLIF &amp; TLIF complication rates equivalent for 1-level procedures. TLIF resulted in fewer complications &amp; a lower EBL for 2-level cases compared w/ PLIF.</td>
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<td>Schofferman, et al., 2001</td>
<td>I</td>
<td>Prospective randomized comparison of ALIF + PS + PLF (26) vs ALIF + PS (22). FU averaged 35 mos. Outcome measures include NRS &amp; ODI. Fusion was evaluated w/ static plain radiographs. 68% pseudarthrosis rate noted in PLF. No significant difference in fusion rate of the interbody graft bone groups, but ALIF + PS group tended toward higher fusion rate. ALIF + PS had shorter op time, EBL, LOS, &amp; cost. All differences were statistically significant.</td>
<td>PLF is unnecessary in the context of ALIF + PS &amp; is associated w/ higher blood loss, OR time, &amp; cost.</td>
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<td>Christensen, et al., 2002</td>
<td>interbody II for outcome III for fusion</td>
<td>Prospectively randomized study of 148 patients w/ LBP. Compared PLF w/ screws vs ALIF (Brantigan cage) + PS + PLF. Outcomes: EQQ, the LBPFR. Tendency toward better overall functional outcome for patients w/ circumferential procedure (p &lt; 0.08), &amp; patient group had significantly less leg pain at the 1 yr FU (p = 0.03) &amp; less peak back pain at 2 yrs (p &lt; 0.04). The circumferential fusion patients showed a higher PLF rate (92%) than the posterior group (89%) (p &lt; 0.04). The interbody fusion rate was 82% solid w/ 18% ambiguous on plain x-ray (nondynamic). Repeated op rate was significantly lower in circumferential group (7%) (&lt; 0.009) than in posterolateral group (22%).</td>
<td>360° fusion had a significantly higher fusion rate, better sagittal lordosis, lower reop rate, &amp; a tendency for better clinical outcome than PLF + PS at 2-yr FU.</td>
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<td>DeBerard, et al., 2002</td>
<td>III</td>
<td>Retrospective cohort study of 185 patients w/ PLF &amp; 185 patients w/ BAK (65% ALIF &amp; 35% PLIF). FU by chart review at 2 yrs.</td>
<td>Interbody group did better than PLF group w/ respect to fusion rate (94 vs 74%) &amp; functional outcome (Roland &amp; Morris 8.8 vs 11.4).</td>
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<td>Pradhani, et al., 2002</td>
<td>II</td>
<td>Retrospective study w/ 122 patients examining ALIF vs PLF. FU at 22 &amp; 26 mos. Fusion assessed w/ dynamic x-ray &amp; CT was used for ambiguous cases. No standard clinical outcome. ALIF less blood loss (p &lt; 0.01) &amp; stay. No difference in complication rate, fusion rate, or clinical outcome.</td>
<td>ALIF is associated w/ less morbidity than PLF.</td>
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<td>Fritzell, et al., 2002</td>
<td>outcome Class I fusion Class III</td>
<td>Prospect randomized multicenter study of 294 patients. Group 1 (PLF, 73), Group 2 (PLF w/ screws, 74), and Group 3 (PLF w/ screws &amp; interbody fusion, 75; ALIF [56] or PLIF [19]). Group 4 nonop (72) FU 201 (91%) of 222 patients after 2 yrs. All surgical techniques reduced pain &amp; decreased disability substantially but no significant differences were found among the surgical groups. Groups 2 &amp; 3 consumed significantly more resources. Fairly complication rate was 6% in Group 1, 16% in Group 2, &amp; 3% in Group 3. The fusion rate (plain radiography), was 72% in Group 1, 87% in Group 2, &amp; 91% in Group 3. The high complication rate of instrumentation is related to 9 patients w/ screw removal for new onset radiculopathy. At the time of revision only 3 were found to have a cortical wall breach.</td>
<td>Comparison of noninstrumented fusion vs PLF + PS vs 360°. No differences in outcome. 360° fusion led to the highest fusion rates &amp; complication rates followed by PLF + PS.</td>
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<td>Fritzell, et al., 2003</td>
<td>outcome (complication rate) 1</td>
<td>Multicenter prospective randomized study of 211 patients. PLF (71), PLF + VSP (68), structural autograft interbody + PLF + PS (72). No significant difference in ODI, VAS, General Function Score, or Zung depression scale at 2 yrs (p &gt; 0.05). Power to detect such a difference was low. Early complication rates were 6, 18, and 31%, respectively (p = 0.001). Total complication rate after 2 yrs in the PLF group was 12% vs 22% in the PS group, &amp; 49% in the 360° group (p = 0.0003). Reop rates were 6, 22, &amp; 17%, respectively (p = 0.02). No fusion technique produced a superior clinical outcome.</td>
<td>360° fusion was associated w/ highest complication rate.</td>
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<td>Zhao, et al., 2002</td>
<td>III</td>
<td>Prospective randomized of 1 (13) vs 2 (12) stand-alone PLF-BAK cages in 1.4–5 degenerative spondylolisthesis. FU 2 yrs. Blood loss &amp; op time significantly less in 1 cage. LOS not different. Costs less in 1 cage. Fusion based on dynamic x-ray, Modified Zdeblick outcome score. No difference brown groups. Very small sample size precludes definitive conclusion.</td>
<td>1 cage may or may not be as effective as 2 in stand-alone PLF w/ respect to fusion rates &amp; outcome.</td>
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* EBL = estimated blood loss; FU = follow up; NRS = Numerical Rating Scale; PS = pedicle screw.
greater than 50 as good or excellent and a score of 49 or less as fair or poor. Using this dichotomy, the authors reported that 40% of the ALIF group had good-to-excellent outcomes compared with 19% of the PLF group (p < 0.001, chi square). When comparing the subgroup of patients who were not involved in Workers’ Compensation claims, the good-to-excellent outcome in the ALIF group was 68% compared with 27% in the PLF group (p < 0.01, chi square). This paper provides Class III medical evidence supporting the beneficial effect of an interbody graft on patient outcome.

Yashiro, et al.,31 performed a nonrandomized retrospective cohort study of 58 patients treated with lumbar spinal fusion at one or two levels for the treatment of low-back pain due to DDD, spondylolisthesis, or fracture (eight patients). Patients in Group I underwent PLF with pedicle screws (28 patients), and those in Group II underwent PLIF and pedicle screws (30 patients). There was no mention of whether PLF was added to the PLIF group. The mean follow-up period was 25 months. Radiographic follow up was performed using static radiographs; no flexion-extension views were used to measure fusion. The operating time was longer in the PLIF group (p < 0.05). Fusion occurred in 67% of Group I and 92% of Group II patients for single-level cases (p < 0.01). Fusion occurred in 56% of Group I and 100% of Group II patients for two-level cases (p < 0.05). The difference in complication rates between the groups was not statistically significant. This paper provides Class III medical evidence supporting the use of interbody grafts to increase lumbar fusion rates.

Pradhan and colleagues27 performed a retrospective review of 122 patients who were divided into two treatment groups. Group I consisted of 58 patients who were treated with lumbar ALIF with BAK cages, and Group II consisted of 64 patients who were treated with PLF with pedicle screw fixation. The follow-up period was 22 months for Group I and 26 months for Group II. Fusion was assessed based on flexion-extension x-ray films, and CT scanning was used for cases without clear-cut radiographic fusion. There was evidence of radiographic fusion in 95% of the Group I patients and in 92% of the Group II patients; however, this difference was not found to be significant. The ALIF cohort had a lower operative blood loss, shorter operative time, and shorter duration LOS (p < 0.01). There were no significant differences in complication rates or clinical outcomes between the groups. Although this paper provides Class III medical evidence indicating that placement of an interbody graft through a stand-alone ALIF technique does not improve fusion rates compared with PLF, the small size of the treatment groups in this study makes any statement regarding functional outcomes suspect. The ALIF group was reported to have a shorter LOS, less blood loss, and less exposure to anesthetic agents.

DeBerard, et al.,11 performed a retrospective cohort study in which 185 patients receiving Workers’ Compensation were treated with PLF were compared with 185 patients treated with LIF for intractable low-back pain. An outcome survey was conducted a mean of 5 years after surgery. The authors were able to contact approximately 70% of the surgical cohort, which encompassed approximately 55% of Workers’ Compensation patients. Arthrodesis rates, patient satisfaction, patient function, and overall health were better for the LIF cohort. The results suggest improved arthrodesis rates and outcomes for patients who received Workers’ Compensation and underwent interbody fusion compared with similar patients undergoing PLF. Because of the retrospective chart review nature of the study, the fact that patients in each group were from different states (Minnesota compared with Utah), the large number of patients lost in the follow-up process, and the variable means used to determine fusion, this medical evidence supporting the role of interbody grafts for improving outcomes and fusion rates is considered Class III.

Rome and colleagues35 retrospectively reviewed 85 patients with degenerative lumbar spine disease and radiographic evidence of instability. Fifty-five of the patients were treated with PLF with pedicle screws; the remaining 30 patients were treated with PLIF and PLF with pedicle screws. Patients were followed up for an average of 32 months. Of these patients, 86% reported improvements in their pain symptoms but only 46% reported good-to-excellent overall results. Patients with fair and poor outcomes had undergone significantly more operations on the lumbar spine (p < 0.001) and had a greater extent of preoperative lumbar kyphosis (p < 0.05) than patients with good-to-excellent outcomes. In these patients with radiographic instability, no improvement in functional outcome was realized through the addition of an interbody graft. Because of significant differences between the treatment groups, the small size of the interbody group, and a nonvalidated outcome measure, this paper provides Class III medical evidence that fails to support the placement of an interbody graft in addition to PLF.

Additional Class III medical evidence supporting the use of interbody fusion techniques is provided by numerous case series in which excellent results are described with ALIF and PLIF procedures performed using a variety of techniques.23,26,28,30,32

Comparison of Interbody Techniques

Several authors have compared different LIF techniques with regard to fusion rates and patient outcomes. The most common comparison has been between anterior and posterior interbody techniques. Schofferman and colleagues29 performed a prospective, randomized comparison of 26 patients treated with ALIF with pedicle screws with PLF (360° group) to 22 patients treated with ALIF and pedicle screws without PLF (270° group). All ALIFs were performed with a femoral ring allograft filled with cancellous allograft chips. The follow-up period averaged 35 months. Outcomes were measured by the Numerical Rating Scale and the ODI. Functional outcomes as measured by both scales improved significantly in both groups without significant differences between the two groups when using either outcome measure. Fusion was evaluated based on flexion-extension plain radiographs. In the 360° group, the PLF part of the procedure failed to heal 68% of the time. There was no significant difference (p = 0.6, chi square) in the fusion rate of the interbody graft between the groups, although there was a trend favoring the 270° group (77% fusion rate in the 360° group compared with 89% fusion rate in the 270° group). The 270° group had shorter operating time, less intraoperative blood
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loss, and shorter LOS (all p < 0.05). This study provides Class I medical evidence that the addition of PLF to an ALIF with pedicle screw construct increases blood loss, LOS, and operating time without any resultant benefit. Although the increased interbody fusion rate noted in the 270° group was not statistically significant, the magnitude of the difference is notable and may have reached significance in an adequately powered study.

Barnes, et al., retrospectively reviewed a series of 35 patients with mechanical low-back pain due to DDD at one or two levels. Twenty-three patients were treated with PLIF with TCBBs, PLF, and pedicle screw fixation. Twelve patients were treated with stand-alone ALIF with TCBBs. The follow-up rates were 87% for the PLIF group and 67% for the ALIF group (mean follow up 1 year). Fusion was assessed based on flexion-extension radiographs, and CT scanning was performed to assess fusion in questionable cases. Outcomes were assessed with the modified Prolo scale. Satisfactory outcomes were noted in 70% of the PLIF patients and in 38% of the ALIF patients. Osseous fusion was present in 95% of the patients in the PLIF group and in 15% of those in the ALIF group (probability values not provided). Although this paper provides Class III medical evidence supporting the use of PLIF compared with stand-alone ALIF with TCBBs for better patient outcomes and fusion rates, differences in patient selection criteria, small sample size, and the use of a non-validated outcome measure limit the conclusions that can be drawn.

Similarly, Hacker and colleagues performed a retrospective review of 75 patients. Fifty-four of these patients were treated with stand-alone PLIF with BAK cages, and 21 patients were treated with ALIF with allograft spacers and PLF without screws. A minimum 2-year follow up was performed. The North American Spine Society outcome study form was used but full data on the outcome were not provided. Operative time (p < 0.0001), blood loss (p < 0.0001), and LOS (p < 0.0003) were significantly decreased for the PLIF group. Fusion assessment was performed based on flexion-extension x-ray films. Only 24 of the 54 PLIF patients underwent radiographic follow up. The authors reported a 4% pseudarthrosis rate in the PLIF group. The pseudarthrosis rate in the ALIF group was “approximately 20%” (five patients). There was a quicker return to work and closure of Workers’ Compensation claims in the PLIF group. This study provides Class III medical evidence suggesting that outcomes and fusion rates were improved using a PLIF as opposed to an ALIF plus PLF without screws; however, the large “lost to follow-up” rate and the incomplete reporting of the functional outcome measure decrease the value of this evidence substantially.

Hee, et al., performed a retrospective review of 164 patients. Fifty-three of these patients were treated with same-day ALIF with PLF and screws (Group 1), and the remaining 111 patients were treated with TLIF (Group 2). In Group 1 patients, ALIF was performed with autograft inside either a carbon fiber or titanium cage (21 patients), structural autograft iliac crest (19 patients), or allograft strut graft (13 patients). The TLIFs were performed with titanium cages filled with autograft and supplemented with pedicle screws and PLF. The mean operating time (p < 0.0001) and LOS (p < 0.0001) were statistically signifi-

ificantly longer for Group 1 patients. The average blood loss was greater in Group 1 patients (p < 0.01). Higher complication rates were found in Group 1 patients (p < 0.004). The follow-up period in both groups was at least 2 years. Fusion assessment was performed based on plain radiographs. The pseudarthrosis rate was 15% for Group 1 patients and 6% for Group 2 patients (p = 0.07). This paper provides Class III medical evidence supporting an advantage for the use of a single posterior approach as opposed to a combined anterior–posterior approach for a 360° fusion.

Class III medical evidence in favor of interbody techniques is also provided by Varma, et al., These authors reviewed the data in 56 patients who were treated with one of four different lumbar fusion procedures. Group 1 patients underwent ALIF with BAK cage supplemented with facet screws without PLF. Group II patients underwent facet screw fixation with PLF. Group III patients underwent pedicle screw fixation with PLF. Group IV patients underwent stand-alone ALIF with fibula strut grafts. Simultaneous anterior interbody fusion by using BAK cage and posterior facet fixation provided the highest rate of fusion (88%) and clinical satisfaction (63%). Patients in whom successful lumbar fusion was achieved had better clinical outcomes and a better chance of work resumption.

Other authors have reported comparisons of different techniques of achieving interbody fusion with posterior approaches. For example, Zhao, et al., performed a prospective randomized study in which they compared the use of one stand-alone PLIF BAK cage (13 patients) with two stand-alone PLIF BAK cages (12 patients) to treat L4–5 degenerative Grade I spondylolisthesis. There was a minimum follow up of 2 years. Intraoperative blood loss and operative time were significantly less in the one-cage group (p < 0.01); LOS was not different between the groups (p < 0.01). Fusion was assessed based on flexion-extension x-ray films, and fusion rates were 92% in both groups (no significant difference; p > 0.9, χ² = 0.0035). Outcomes were assessed with a scale adopted from Zdeblick. No significant difference in clinical outcomes was found between the groups. Given the small sample size, no meaningful conclusions can be drawn from this study regarding clinical or radiographic outcome. Humphreys and colleagues performed a nonrandomized retrospective comparison of 40 patients treated with TLIF with a single cage filled with autograft and supplemented with pedicle fixation and PLF compared with 34 patients undergoing PLIF with a single cage filled with autograft and supplemented with pedicle screws with PLF. For single-level fusion, blood loss, operative time, and LOS were no different between the groups. For two-level fusion, however, the TLIF patients had less blood loss (p < 0.01) than the PLIF patients. No outcome measures or fusion assessment were provided.

The requirement for supplemental instrumentation in addition to interbody grafting has been addressed in a few studies that provide Class III medical evidence. Barnes, et al., recommend pedicle screw fixation as an adjunct to ALIF or PLIF with TCBBs. Similarly, in an older study, Linson and Williams found that posterior instrumentation improved fusion rates following interbody grafting. These authors performed a retrospective study in 51 patients who were divided into three groups. Patients in
Group I (17) were treated with stand-alone ALIF; patients in Group II (18) were treated with stand-alone ALIF following previous lumbar surgery, and Group III patients (16) underwent ALIF with Harrington or Knodt rod fixation and PLF. The mean follow up was 25, 21, and 26 months, respectively. The ODI questionnaire was used to assess outcome. Fusion was assessed based on flexion-extension radiographs. The pseudarthrosis rate was 2 and 1\% in Group I, 17\% in Group II, and 13\% in Group III. Conversely, other authors of retrospective series did not detect improved fusion rates with the addition of posterior instrumentation. Chitnavis and colleagues retrospectively studied a cohort of 50 patients with multiple recurrent disc herniations (49 one level, one two level). These patients were treated with PLIF by using carbon fiber cages. Ten of these patients underwent pedicle screw fixation because of suspected instability or because they were treated early in the series. Overall results in both groups were excellent; however, as the authors have stated, a meaningful comparison between the pedicle screw and nonpedicle screw groups is not possible.

Authors of several large case series of stand-alone ALIF with threaded titanium cages report excellent results with regard to patient outcomes and fusion rates.\textsuperscript{5-8,9,10} For example, Burkus et al. published a large multicenter series on patients who underwent stand-alone ALIF with a threaded titanium cage with autograft or recombinant human bone morphogenetic protein-2. The results in both groups with respect to fusion rates (89\%–95\%) and clinical outcome (ODI, back pain, leg pain, and patient satisfaction) were excellent.

**Summary**

The majority of reviewed medical evidence suggests that interbody techniques are associated with higher fusion rates compared with PLF when applied to patients with low-back pain due to DDD limited to one or two levels. The evidence is generally of poor quality and retrospective in nature. Conflicting evidence exists supporting the role of interbody graft placement for improvement of functional outcomes; however, there is no Class I or II evidence to suggest that the use of an interbody graft is associated with worse outcomes, and Class II evidence exists to suggest that outcomes are improved. Complication rates of interbody graft placement, particularly of circumferential procedures, are higher in most series. Many complications, however, are associated with pedicle screw fixation and not with interbody graft placement per se. In the context of a single-level stand-alone ALIF or ALIF with posterior instrumentation, there does not appear to be a substantial benefit to the addition of a PLF. The addition of a PLF to a construct that already includes an interbody graft is, however, associated with increased costs and complications. Therefore, although the addition of supplemental fixation (a 270° fusion) may be necessary for biomechanical reasons, it may not be appropriate to subject the patient to the morbidity of a full posterior exposure for placement of graft material. Significant differences in clinical outcomes between the various interbody techniques have not been convincingly demonstrated. No general recommendation can therefore be made regarding the technique that should be used to achieve interbody fusion.

**Key Directions for Future Research**

Future studies focusing on patient outcomes are required to establish whether the increased fusion rates seen with interbody techniques are truly associated with improved functional outcomes. Application of reliable, valid, and responsive outcome measures in a multicenter randomized trial would serve to answer this question. In terms of the techniques used to achieve an interbody arthrodesis, it is likely that certain techniques will be more applicable to different patient populations. Future studies should be focused on evaluating the individual techniques within specific patient populations. Well-designed cohort studies would provide needed Class II medical evidence. Randomized studies would need to include adequate numbers of patients to ensure sufficient power to be able to assess whether the incremental improvement achieved with interbody techniques is clinically significant.

**References**

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