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Posterior lumbar interbody fusion with cages: an independent review of 71 cases

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Object. The authors conducted a retrospective study to provide an independent evaluation of posterior lumbar interbody fusion (PLIF) in which impacted carbon cages were used. Interbody cages have been developed to replace tricortical interbody grafts in anterior and PLIF procedures. Superior fusion rates and clinical outcomes have been claimed by the developers.

Methods. In a retrospective study, the authors evaluated 71 consecutive patients in whom surgery was performed between 1995 and 1997. The median follow-up period was 28 months. Clinical outcome was assessed using the Prolo scale. Fusion results were interpreted by an independent radiologist.

The fusion rate was 90%. Overall, 67% of the patients were satisfied with their outcome and would undergo the same operation again. Based on the results of the Prolo scale, however, in only 39% of the patients were excellent or good results achieved. Forty-six percent of the work-eligible patients resumed their working activity. Clinical outcome and return-to-work status were significantly associated with socioeconomic factors such as preoperative employment ($p = 0.03$), compensation issues ($p = 0.001$), and length of preoperative sick leave ($p = 0.01$). Radiographically demonstrated fusion was not statistically related to clinical outcome ($p = 0.2$).

Conclusions. This is one of the largest independent series in which PLIF with cages has been evaluated. The results show that the procedure is safe and effective with a 90% fusion rate and a 66% overall satisfaction rate, which compare favorably with those of traditional fixation techniques but fail to match the higher results claimed by the innovators of the cage techniques. The authors' experience confirms the reports of others that many patients continue to experience incapacitating back pain despite successful fusion and neurological recovery.

KEY WORDS • **spinal fusion** • **degenerative disc disease** • **spinal stabilization** • **cages** • **spinal instrumentation**

CHRONIC low-back pain, often with some degree of lower-extremity distribution, is not an uncommon problem encountered in patients with and without a history of back surgery. The origin of this pain remains unclear and controversial.[44] It is often referred to as "lumbar segmental instability"[12,37] and is thought to be caused by degenerative disc disease,[42] or facet joint syndrome[13,28] when no signs of increased motion or spondylolisthesis exist. Despite the absence of a reliable and objective diagnostic test,[44] a fusion procedure is often advocated when a prolonged course of conservative treatment has failed.

Among other techniques, posterior lumbar interbody fusion (PLIF) was popularized by Cloward[9] in the early 1950s, and encouraging results have since been reported.[8,10,15,20,22,24,31,36,40] From a biomechanical, biological, and functional standpoint interbody fusion provides several theoretical advantages over other fusion techniques.[2,15,17] Progressively, the original technique was modified and developed, posterior instrumentation was added to increase the fusion rate, and more recently, cages were designed to contain the interbody graft and separate its biological and mechanical (structural) functions.[4,5,16,36] All of these characteristics were considered important to achieve a higher fusion rate, better biomechanical stability, and more important, a better clinical outcome.

To date, several series in which PLIF has been performed with cages have been reported.[3,21,32,39] All but one[39] were reported by the developers of the different cages. These authors/developers have claimed superior results compared with more traditional techniques, including those that involve posterolateral fusion.

We claim no involvement in the development of, nor any commercial benefit from, the devices evaluated. In this independent single-institution study we review the records of 80 patients who underwent a PLIF procedure in which instrumentation and flat-faced carbon cages were placed (Ostapek, Co-Ligne, Zurich, Switzerland) (Fig. 1), with special attention to the clinical outcome.

Clinical Material and Methods

Patient Population

Between April 1995 and July 1997, at the Geneva Uni-

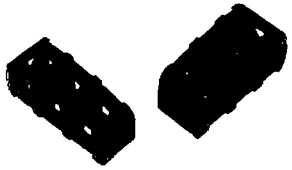

FIG. 1. Photograph of the Ostapek carbon cages used in the present series. Of note is the rounded lateral edge, which is intended to minimize the risk of a nerve root injury. There are different sizes available (9, 11, and 13 mm) with various lordotic angles (2, 5, and 7°).

versity Hospital, 80 consecutive patients underwent a PLIF procedure for chronic mechanical low-back pain. In all of these patients a trial of prolonged multimodal nonoperative management, consisting mainly of stretching and strengthening exercises and a course of analgesic and muscle relaxant agents, had failed. Current follow-up information was obtained in 71 patients (89%); nine could not be located. These nine cases were distributed throughout the study period. Five other patients underwent follow-up assessment only via telephone interview, and the clinical assessment form was mailed to them. These five patients were included in the clinical outcome study (71 patients) but excluded from the fusion assessment calculations (66 patients). Epidemiological data are given in Table 1.

None of the patients were working at their jobs prior to the time of surgery. Details of their socioeconomic situation are provided in Table 1. Data on the exact length of sick leave were available in 44 patients; the mean duration of sick leave was 9.8 months (range 1–36 months).

TABLE 1

Epidemiological and socioeconomic characteristics of 71 patients who underwent PLIF

Characteristic	No. of Patients (%)
epidemiological data*	
sex	
male	42 (59)
female	29 (41)
obese (BMI > 27.5 kg/m^2)	24 (34)
cigarette smoker	28 (39)
socioeconomic data	
work-eligible at time of surgery†	58
compensation issues	34 (48)
self-employed	8
heavy-duty worker	33 (46)
light-duty worker	25 (35)
disabled w/ social pension‡	6 (8)

* The patients' mean age was 47 years (range 19–81 years). Abbreviation: BMI = body mass index.

† One patient retired during convalescence.

‡ Two patients received a pension for unrelated reasons (stroke and cancer).

Clinical and Follow-Up Studies

The medical records and radiographic studies were reviewed individually. Clinical data were recorded according to the type of pathological entity, symptoms, contributing medical history, current and past employment history, operative details, and complications. The follow-up evaluation consisted of a reexamination of the patients by an independent physician (S.A.) who was not involved in the care of these patients, mailed questionnaires, and radiographic workup. The median follow-up period was 28 months (range 12–39 months). Clinical outcome was evaluated using the Prolo economic and functional rating scale (Table 2), in which there is a maximum score of 10 points. Good and excellent results were considered a clinical success (poor, 2–4; fair, 5–6; good, 7–8; and excellent, 9–10 points). Finally the patients were asked to rate their condition as improved, unchanged, or worse; they were also questioned as to whether they would undergo the same procedure again under the same circumstances.

Radiographic Evaluation

At the time of the follow-up visit, a lateral view radiograph was obtained in each patient and an anteroposterior Ferguson view radiograph was obtained at each operated level (Fig. 2). The extent of fusion was assessed using the criteria defined by Brantigan and Steffee[3] (Table 3). Because the carbon cage was radiolucent, its struts were clearly visible against the hyperdense bone graft when a solid union was achieved. Fusion outcome was considered successful if the Brantigan–Steffee criteria D and E were met at all operated levels. If the radiologist expressed a doubt about the fusion, including the concerns outlined in Category C, the level was considered a nonunion. All the x-ray films were interpreted by a single senior spine radiologist who was blinded to the clinical results.

Clinical Presentation and Diagnostic Categories

All patients reported experiencing mechanical low-back pain, increased by flexion, extension and rotation that was completely or partially relieved by bedrest. Of 71 patients, 55 (77%) reported experiencing sciatic pain that radiated to the feet. In 13 (18%) of 71 patients the pain never radiated below the knee (pseudoradicular), and three patients complained of back pain but had no radicular symptoms.

The patients were separated into three groups. Group 1 contained 23 patients who had already undergone disc surgery (one-level discectomy [eight patients]; two-level discectomy [14 patients]; and anterior lumbar interbody fusion [one patient]. Group 2 consisted of 28 patients with no history of surgery but with evidence of spondylolisthesis on preoperative radiographs. Group 3 contained 20 patients with neither a history of surgery nor the presence of spondylolisthesis but with signs of monosegmental degenerative disc disease.

Operative Technique

A standard PLIF technique, similar to the one described by Steffee, et al.,[36] was used. The posterior elements were exposed to the origin of the transverse processes via a posterior midline incision. Using external landmarks,[7,11,35] the pedicle screws (G II system, Co-Ligne, Zurich, Switzerland) were inserted under the guidance of lateral fluoroscopy. Plates were selected and bent to match the lumbar curvature. A wide posterior decompressive procedure was then performed, removing the spinous processes, the laminae, and part of the facets to allow enough space for insertion of the cage. To avoid excessive thecal and root retraction, the facets had to be resected to the medial pedicle line in most instances. After completing a bilateral discotomy, the disc height was restored by distraction and secured by tightening the plate–screw system. Bone that was derived from the posterior elements was used to fill the carbon cages. After complete discectomy and preparation of the vertebral endplates, two cages were inserted in the disc space, one on each side. Finally the plate–screw system was securely tightened in compression.

TABLE 2

Prolo economic and functional rating scale

Score	Description
economic status	
E1	complete invalid
E2	no gainful occupation (including ability to do housework or continue retirement activities)
E3	able to work but not at previous occupation
E4	working at previous occupation on part-time or limited basis
E5	working at previous occupation w/ no restrictions of any kind
functional status	
F1	total incapacity (or worse than preop)
F2	mild to moderate level of low-back pain &/or sciatica (or pain same as preop but able to perform all daily tasks of living)
F3	low level of pain & able to perform all activities except sports
F4	no pain, but has had 1 or more recurrences of low-back pain or sciatica
F5	complete recovery, no recurrent low-back pain, & able to perform all previous sports activities

Postoperatively, the patients wore a brace for 3 months and underwent progressive rehabilitative therapy.

Surgically Treated Disc Levels

A total of 84 levels were surgically treated. Fifty-four (76%) of the 71 patients underwent a one-level fusion: L4–5 (30 patients), L5–S1 (22 patients), and L2–3 (two patients); 16 (23%) patients underwent a two-level fusion: L4–S1 (13 cases) and L3–5 (three cases). One patient underwent a three-level fusion from L-2 to L-5.

Statistical Analysis

Statistical analysis was performed using contingency tables with chi-square test or Fisher's exact test (as required), unpaired t-tests, and analysis of variance.

Results

Outcome was assessed according to the following criteria: 1) radiologically demonstrated fusion, 2) clinical improvement of pain and level of activity, and 3) active employment status at the time of follow-up examination.

Fusion Outcome

Of a total of 84 levels evaluated, 90% (76 of 84) were radiographically shown to have fused. We considered a fusion to be successful when all the operated levels were fused. Eighty nine percent of patients were considered to have undergone successful fusion. The distribution of successful fusion was as follows: at L2–3, two of two patients; at L4–5, 25 of 26; at L5–S1, 20 of 21; at L3–5, three of three; at L4–S1, eight of 13; and at L2–5, one of one patient. The fusion status was not associated with the clinical outcome ($p = 0.2$). A lower fusion rate was significantly associated with having undergone a multiple level fusion ($p = 0.01$), but not with a history of smoking.

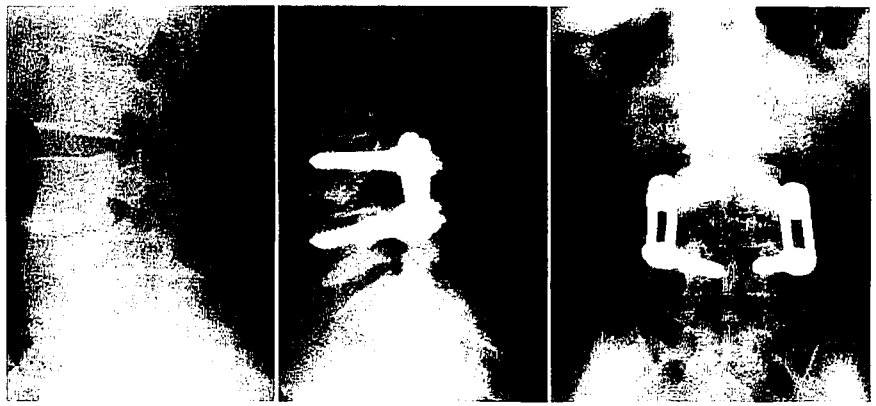

FIG. 2. Pre- and postoperative radiographic studies. *Left:* Preoperative lateral radiograph revealing spondylolisthesis at the L4–5 level. Postoperative anteroposterior *(center)* and lateral *(right)* radiographs demonstrating interbody fusion with restoration of the disc height and the sagital balance. The cages are seen as radiolucent structures against the bone within the vertebral space.

Clinical Outcome

At the time of the follow-up visit, 66% of the patients were satisfied with the results of the surgery. When the outcome was evaluated by more objective means, such as the Prolo economic and functional scale, 18% (13 of 71) of patients experienced excellent results, 21% (15 of 71) had good results, 25% (18 of 71) had fair results, and 34% (24 of 71) had poor results. When asked if, under the same circumstances, they would undergo the procedure again, 66% of the patients answered affirmatively.

No statistically significant difference in outcome was found according to the three diagnostic categories, the type of presenting pain (radicular compared with pseudoradicular), or between single- or multiple-level fusion procedures.

Considering the socioeconomic background of the patients, 21 (84%) of 25 light-duty laborers were improved by the surgery, whereas satisfaction among 33 patients with heavy-duty jobs was only 52% (17 patients). The association between clinical outcome and preoperative employment was statistically significant ($p = 0.03$). Improvement was reported by 16 (47%) of the 34 patients already involved in compensation claims prior to the surgery compared with 31 (84%) of the 37 patients not involved in such issues.

Postoperative Working Status

Forty-six percent (57) of work-eligible patients resumed their work. They represented 30% (10 of 33 patients) of the heavy-duty laborers and 64% (16 of 25 patients) of the light-duty laborers. Of the 33 patients involved in compensation claims at the time of surgery, only two resumed working as opposed to 24 of the 30 not involved in such an issue who did resume employment. In work-eligible patients who resumed employment postoperatively, a shorter mean duration of preoperative sick leave (5.6 months) was demonstrated compared with those who never resumed work (12.6 months). Postoperative working status was significantly associated with preoperative employment ($p = 0.02$), workers' compensation issues ($p = 0.001$), and length of preoperative sick leave ($p = 0.01$).

Of the 47 patients in whom surgery improved pain, 24 (51%) were working, six (13%) were retired, and 17 (36%) were receiving workers' compensation benefits. Postoperative working status was significantly associated with clinical outcome ($p = 0.0005$).

Surgery-Related Complications

We recorded nine surgery-related complications: seven neurological and two minor. We considered a neurological complication to have occurred when a new postoperative radicular pain or deficit was sustained that had not been previously described and that lasted for more than 2 days postsurgery. Of those patients, six developed radicular pain and one developed a radial palsy caused by improper positioning during surgery. The radial palsy resolved over a period of 3 months. The radicular symptoms resolved spontaneously in four patients within 1 month, whereas in two, it resolved only after removal of the screw–plate system. Minor complications consisted of small dural tears that were repaired during the same operation and that caused no postoperative problem.

TABLE 3

Classification of fusion results according to Brantigan and Steffee

Classification	Description
A: obvious pseudarthrosis	collapse of construct, loss of disc height, vertebral slip, broken screws, displacement of the carbon cage, resorption of bone graft
B: probable pseudarthrosis	significant resorption of the bone graft, major lucency or gap visible in fusion area (≥ 2 mm around the entire periphery of graft)
C: uncertain (here nonunion)	bone graft visible in the fusion area at approximately the density originally achieved at surgery; a small lucency or gap may be visible involving just a portion of the fusion area w/ at least half of graft area showing no lucency between graft bone & vertebral bone
D: probable fusion	bone bridges entire fusion area w/ at least the density achieved at surgery; there should be no lucency between the donor bone & vertebral bone
E: fusion	bone in the fusion area is radiographically more dense & mature than originally achieved at surgery; optimally, there is no interface between the donor bone & the vertebral bone, although a sclerotic line between graft & vertebral bone indicates fusion; other signs of solid fusion include mature bony trabeculae bridging the fusion area, resorption of anterior traction spurs, anterior progression of the graft w/in disc space, fusion of facet joints

The instrumentation was removed in six patients: in four because of invalidating persisting low-back pain localized at the operative level and in two because of persisting radicular pain. Back pain improved significantly in two patients who were very thin. In the two others the improvement was only marginal. The radicular pain resolved almost completely.

Discussion

Interbody fusion provides several theoretical advantages over other fusion techniques.[2,9,10,15,17,24,30,32] From a biomechanical point of view, the graft is placed at the weight-bearing center of the spine where 80% of the axial load occurs.[33] The disc height and the sagittal balance can be restored just as well because optimal conditions are created for a higher fusion rate by placing the graft under compression with an extensive blood supply from the adjacent vertebral endplates[2] (Fig. 2). Finally, the amount of bone required for the graft is significantly reduced.

Problems, however, do exist. Collapse, slippage, and graft migration have been reported in 3 to 10% of cases in large series in which PLIF has been performed.[10,20,24,32] As a possible solution, interbody cages have been designed specifically to separate the structural and biological functions of the graft. They can resist forces several times those measured in the disc space and those of a tricortical iliac graft.[3,4,21,29,30,32,34] The flat-faced cages are available with different lordotic angles and allow better correction of the sagittal balance. To avoid migration, they are either threaded or ridged. They can be inserted anteriorly or posteriorly, each approach having specific advantages and indications. Via a posterior approach, the spinal canal can be easily explored, fixation can be achieved during the same operative session, and the use of locally derived bone obviates the need to harvest iliac bone. Dural and nerve root manipulations, however, represent a particular risk of this procedure.

TABLE 4

*Data from series in which cage and classical PLIF were used**

Authors & Year	No. of Patients	Fusion Rate (%)	Successful Clinical Outcome (%)	Return to Work (%)
Hutter, 1983	492	90	82	-
Lin, et al., 1983	465	88	82	39 (compensation patients) 71 (noncompensation patients)
Collis, 1985	50	94	92	-
Prolo, et al., 1985	34	94	85	-
Brantigan & Steffee, 1993	26	100	81	-
Zdeblick, 1993	124	95	95	-
Lee, et al., 1995	54	94	89	-
Tullberg, et al., 1996	51	89	-	-
Ray, 1997	236	96	65	-
Kuslich, 1998	356	90.6† at 24 months	84	78
present series	71	90	43	46

* — = not reported.
† Rate represents that obtained 24 months postoperatively.

Fusion Rates

In the present series the fusion rate of 90% is close to the 89% reported by another independent group from Sweden who used the same technique[38] but does not reproduce the higher rate claimed by the innovators of the procedure (Table 4). It is, however, debatable as to whether flexion–extension angular differences of up to 7° should still be considered to represent a successful union, as is the case in the report by Kuslich, et al.[21]

The need for supplemental pedicle fixation remains an unresolved issue. The results of biomechanical studies are contradictory. Lund, et al.,[25] have reported no stabilization effects in extension and rotation in cases in which cages alone were implanted, whereas Brodke, et al.,[5] have reported high stabilization of the motion segment with the use of cages alone and no significant increase in stiffness when pedicle screws were added. In the series reported by Kuslich, et al.,[21] migration was observed in 3% of the cases. In addition, there have been increasing numbers of cases of migration reported when rounded, stand-alone cages were used. In addition to a possible ball-bearing effect with rounded cages, the extended exposure required to insert the cages and the difficulty often experienced in preserving the facet joints make the case for supplemental instrumentation of the unstable segment to reconstruct the posterior tension band and preserve the best possible stability in extension and rotation.[27,33,41] In doing so, no cage migration was observed in our series. The possible benefits of routine supplemental instrumentation, however, need to be weighed against the additional costs and complications.

Clinical Outcome

A sound fusion is often believed to be a prerequisite for clinical success in patients with mechanical low-back pain. In previous studies in which other fusion techniques were used, the clinical outcome did not always parallel the radiographically observed success.[1,40] Because there is the possibility with cages and PLIF to fuse a segment at the weight-bearing level and to restore and maintain the disc height and the sagittal balance, there is again the hope for improved clinical results.

Of the first 26 patients reported by Brantigan and Steffee,[3] in 18 (69%) excellent and good clinical results were demonstrated at 12 months and in 21 (81%) at 2 years postoperatively. Unfortunately the evaluation scale they used was not described. Ray[32] has reported excellent or good results in 47% at 6 months and in 65% at 2 years postoperatively in

TABLE 5

Indication for fusion in PLIF and posterolateral series in which cages were not used

Authors	Indication
Hutter	lumbar disc degenerative w/ posterior protrusion; previous laminotomy for disc lesion, spondylolisthesis w/ or w/o previous op
Lin, et al.	lat herniated disc; midline disc; degenerative disc; recurrent disc; spinal stenosis; instability
Collis	lumbar pain w/ or w/out sciatica; degenerated disc w/ or w/o protrusion; midline disc protrusion; post–lumbar laminectomy–discectomy syndrome; recurrent soft-disc protrusion; spondylolisthesis Grade I or II; reverse spondylolisthesis
Prolo, et al.	spondylolisthesis; chronic arthritic changes w/ bilat myelographic deformities; chronic arthritic changes w/ positive response to body jacket
Lee, et al.	mechanical lumbar pain w/ positive provocative test during discography, excluded were the following: previous lumbar op, significant abnormal findings on preop radiological workup
Zdeblick	spondylolisthesis (degen & isthmus); degenerative disc disease; degenerative scoliosis; spinal stenosis, failed back op

236 patients, based on the use of the Prolo scale. In the series of Kuslich, et al.,[21] 85% of the 356 patients who underwent PLIF reported less pain at 2 years postsurgery, and 91% were improved functionally. In our series two thirds of the patients (66%) reported significant pain relief and declared they would undergo the same operation again. When the clinical results were evaluated using the function and economic scale described by Prolo, et al., [31] only 39% demonstrated excellent or good results. Although the functional results reported by Kuslich, et al., are better, they are difficult to compare because they did not describe the evaluation scale they used.

Outcome results can vary greatly depending on the measurement criteria. In a report by Howe and Frymoyer,[19] they rated the same series by using 14 different scores, and the proportion of that defined as a "clinical success" varied from 60 to 97%. More recently in a series by Greenough, et al.,[18] 65% of the patients rated their pain as significantly improved by the procedure, but only in 19% of cases was a good or excellent result obtained on their low back outcome score. On one hand, the patient's own satisfaction will largely depend on the perception of pain and expectations from the surgery; on the other hand, pain perception and expression are highly variable and subject to personal, cultural, and emotional factors. Comparisons without unequivocal, objective criteria are therefore almost impossible to make. It is also true that even moderate pain improvement is sometimes sufficient for a better quality of life, independent of the further need for medication or the difficulty to reach the premorbid level of functioning.

Return-to-Work Status

Compensation issues, the type of job held prior to onset of pain, and the level of education all seem to affect outcome. With regard to the return-to-work rate in our study group, twice as many light-duty workers resumed normal working status as compared with the heavy-duty workers, regardless of the radiographically demonstrated fusion rate. This reached statistical significance. The prognostic effect of litigation and compensation status on resuming work was even stronger (6% compared with 80%). This is in agreement with the reports of others[6,14,21,24] but does not necessarily indicate patient dissatisfaction. In a study by Franklin and colleagues[14] in which they analyzed the outcome after lumbar fusion in the Washington state workers' compensation system, 32% of the patients only reported significant pain reduction but 64% were ready to undergo the same surgery again under similar circumstance. These authors suggested, as a possible explanation for this discrepancy, the perception that the condition must be all the more serious because it requires surgery.

Indications for Surgery

Another source of difficulty is the lack of uniformity in the indications for surgery. Brantigan and Steffee[3] mainly treated patients in whom previous lumbar fusion, including PLIFs, had failed and those with radiologically proven high-grade spondylolysthesis. On the contrary, in the series reported by Ray[32] and Kuslich, et al.,[21] these were factors for exclusion. The criteria for surgery that these authors retained were primarily painful degenerative disc disease and Grade 1 or lower spondylolisthesis.[38] Concomitant disc herniation was often present. Several patients had a history of surgery but had not undergone a PLIF. We tried to determine, by grouping our patients into three diagnostic categories, whether any one indication would be of prognostic significance. We found no such difference among the three groups. The patients with a history of disc surgery responded the same as those in whom no previous surgery had been performed. Evidence of spondylolisthesis or the number of levels fused had no influence on the clinical outcome.

Surgery-Related Complications

Complications associated with PLIF can be quite serious. Of special concern are the neurological deficits often related to excessive retraction of the nerve roots or the dural sac. According to the authors of various reports, these complications occur in 4 to 10% of the patients[10,20–24,32] who have undergone the procedures with or without supplemental pedicle screw placement. Our total rate of 8.5% (six of 71 patients) falls within that range. Considering that two nerve root deficits were related to the fixation material, the proper neurological complication rate related to the cages is 5.6%. No patient sustained a motor deficit, and all improved within the 1st month postoperatively. Dural tears are usually not associated with any clinical sequelae.

Comparison With Other PLIF Techniques and Posterolateral Fusion

According to the authors of several reports, PLIF in which autologous bone alone is used, and even posterolateral fusions, achieve very similar results. The fusion rates range from 88 to 94%, and clinical success ranges from 82 to 92% (Table 4).[10,20,22,24,26,31,43] These good results, however, have to be tempered, in some series, by the indications for surgery. A PLIF was sometimes performed for simple disc protrusions; it represented situations in which other, less aggressive procedures would probably have warranted similar, or even better, results (Table 5).

We would like to emphasize again the difficulty of comparing results obtained from different series when there exist no strict and uniform criteria to define standards for the diagnostic categories, surgical procedures, and outcome evaluation, among many others.

Despite these restrictions, the case for the use of cages in PLIF lies in the theoretical and biomechanical advantages of a strong distraction device, which provides anatomical restoration, that could potentially be used without or in place of pedicle screws, and finally with less bone donor–site morbidity. The case against the device is essentially a matter of its associated complications and its cost, with no clear benefit for the use of cages in terms of clinical success as compared with regular PLIF or even posterolateral fusion procedure. Larger studies clearly need to be designed to clarify the indications for the use of interbody cages in lumbar surgery.

Conclusions

This is the largest independent study in which the results of PLIF with impacted flat-faced carbon cages supplemented with pedicular screws and plates have been evaluated. The procedure is safe and effective; however, the fusion rate of 90% and the overall satisfaction rate of 66% do not reproduce the superior results reported by the innovators of the technique. Finally, as with other techniques, socioeconomic factors and compensation issues seem to be significant prognostic indicators of outcome, whereas the diagnostic categories seem much less significant. The most important issues regarding lumbar spine fusion clearly remain the patient selection and indications for surgery. Spine fusion is not always an effective treatment for chronic low-back pain. Our experience confirms the reports of others that many patients continue to experience incapacitating back pain despite successful fusion and neurological recovery.

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