The Effect of Iliac Crest Autograft on the Outcome of Fusion in the Setting of Degenerative Spondylolisthesis

A Subgroup Analysis of the Spine Patient Outcomes Research Trial (SPORT)

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Background: There is considerable controversy about the long-term morbidity associated with the use of posterior autologous iliac crest bone graft for lumbar spine fusion procedures compared with the use of bone-graft substitutes. The hypothesis of this study was that there is no long-term difference in outcome for patients who had posterior lumbar fusion with or without iliac crest autograft.

Methods: The study population includes patients enrolled in the degenerative spondylolisthesis cohort of the Spine Patient Outcomes Research Trial who underwent lumbar spinal fusion. Patients were divided according to whether they had or had not received posterior autologous iliac crest bone graft.

Results: There were 108 patients who had fusion with iliac crest autograft and 246 who had fusion without iliac crest autograft. There were no baseline differences between groups in demographic characteristics, comorbidities, or baseline clinical scores. At baseline, the group that received iliac crest bone graft had an increased percentage of patients who had multilevel fusions (32% versus 21%; $p = 0.033$) and L5-S1 surgery (37% versus 26%; $p = 0.031$) compared with the group without iliac crest autograft. Operative time was higher in the iliac crest bone-graft group (233.4 versus 200.9 minutes; $p < 0.001$), and there was a trend toward increased blood loss (686.9 versus 582.3; $p = 0.057$). There were no significant differences in postoperative complications, including infection or reoperation rates, between the groups. On the basis of the numbers available, no significant differences were detected between the groups treated with or without iliac crest bone graft with regard to the scores on Short Form-36, Oswestry Disability Index, Stenosis Bothersomeness Index, and Low Back Pain Bothersomeness Scale or the percent of patient satisfaction with symptoms averaged over the study period.

Conclusions: The outcome scores associated with the use of posterior iliac crest bone graft for lumbar spinal fusion were not significantly lower than those after fusion without iliac crest autograft. Conversely, iliac crest bone-grafting was not associated with an increase in the complication rates or rates of reoperation. On the basis of these results, surgeons may choose to use iliac crest bone graft on a case-by-case basis for lumbar spinal fusion.

Level of Evidence: Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

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Degenerative spondylolisthesis is the most common form of spondylolisthesis. For patients who undergo surgery, achieving a solid lumbar spinal fusion is of paramount clinical importance[1,2]. Iliac crest autograft has been commonly used for achieving a fusion in lumbar spine surgery[3-5]. However, short and long-term morbidity associated with iliac crest bone-graft harvest is a concern to many surgeons and patients[6-9].

The Spine Patient Outcomes Research Trial (SPORT) includes a prospective, randomized study of patients treated for degenerative spondylolisthesis. These data provide an opportunity to compare the outcomes of patients who underwent fusion with or without the use of iliac crest autograft. The purpose of this study was to compare the complications and change in primary outcome measures between patients who underwent fusion with or without autologous iliac crest bone graft. This study may aid in clinical decision making for patients and physicians about the outcomes and complications of iliac crest bone-grafting for surgical treatment of degenerative spondylolisthesis. The specific issues addressed in this study were (1) whether there is a difference in the change in clinical outcome measures between patients who did or did not undergo autogenous iliac crest bone-grafting, (2) whether there is a difference in perioperative complications between patients who did or did not undergo autogenous iliac crest bone-grafting, and (3) whether there is a difference in the revision rate between patients who did or did not undergo autogenous iliac crest bone-grafting.

Materials and Methods

Study Design

This investigation was a subgroup analysis of a prospective study with randomized and observational arms. The SPORT was conducted in eleven states at thirteen multidisciplinary spine practices across the United States. The trial was registered at ClinicalTrials.gov under registry number NCT00000409. Methods and additional background information have been well described in previous publications[10,11].

Patient Population

The population of this study includes patients enrolled in the degenerative spondylolisthesis cohort of SPORT who underwent spinal fusion. The human subject committees at each center approved the standardized protocol. All patients fit the following inclusion criteria: an age of over eighteen years with twelve weeks of persistent radicular pain with associated neurologic deficit and/or neurogenic claudication, confirmatory cross-sectional imaging showing spinal stenosis and lateral radiographs showing degenerative spondylolisthesis, and physician confirmation as a surgical candidate. Patients with adjacent levels of stenosis were eligible, but those with spondylolysis and isthmic spondylolisthesis were not. Exclusion criteria included progressive neurological deficit or cauda equina syndrome, active malignancy, scoliosis measuring >15°, prior back surgery, and other established contraindications to elective surgery. Enrollment began in March 2000 and ended in February 2005. Patients with scoliosis measuring >15° were excluded to avoid the confounding effect of complex, multilevel deformity reconstruction. Patients in the study population were specifically selected for treatment of neurological symptoms due to degenerative spondylolisthesis, and the investigators thought that inclusion of patients with a major deformity may confound decision making for surgical versus nonsurgical treatment and selection of fusion levels.

The study population included all patients who were surgically treated, whether they were originally enrolled in the randomized or observational cohorts. Patients in the original study who met the inclusion criteria were offered the choice of randomization or enrollment into an observational cohort study for treatment of degenerative spondylolisthesis. Patients in the randomized cohort were randomly assigned to either surgical or nonsurgical treatment. Patients in the observational cohort chose surgical or nonsurgical treatment. For the purposes of this subgroup analysis, all of the patients who underwent surgery were combined into an as-treated analysis. The nonsurgically treated patients were excluded, and the surgically treated patients were considered the study population. Patients were then subdivided according to whether they had or had not undergone autologous iliac crest bone-grafting.

Study Interventions

The protocol surgery used in this study population consisted of a standard posterior decompressive laminectomy with an additional bilateral lumbar spinal fusion. The fusion was performed with posterior iliac crest autograft, morselized allograft, local bone graft, or bone-graft substitutes. Fusions were performed with or without the use of instrumentation according to the clinical judgment of the surgeon. There was no standardized iliac crest bone-graft harvest protocol.

Study Measures

Data used in this study were obtained prospectively and reviewed retrospectively from patient questionnaires completed at baseline, six weeks, three months, six months, one year, two years, three years, and four years following surgery. Primary outcome measures were the Short Form-36 (SF-36) outcome instrument[12], including the physical function and bodily pain subscales and the physical component summary score, and the Oswestry Disability Index[13].

Secondary measures included satisfaction with current symptoms, the Stenosis Bothersomeness Index, the Low Back Pain Bothersomeness Scale, and the Leg Pain Bothersomeness Scale[14]. These indices[14] consist of four questions regarding pain, numbness, weakness, and walking difficulty during the previous week scored on a 0 to 6-point scale. The SF-36 scores and the Oswestry Disability Index range from 0 to 100; the Leg Pain Bothersomeness Scale and the Low Back Pain Bothersomeness Scale, from 0 to 6; and the Stenosis Bothersomeness Index, from 0 to 24. Higher scores indicate less severe symptoms on the SF-36, whereas higher scores indicate more severe symptoms on the Oswestry Disability Index, the Stenosis Bothersomeness Index, the Leg Pain Bothersomeness Scale, and the Low Back Pain Bothersomeness Scale[13]. Since there are no specific outcome measures, to our knowledge, for iliac crest donor-site morbidity, we postulated that the Low Back Pain and Leg Pain Bothersomeness indices would be sensitive tools to identify and quantify donor-site morbidity. Donor-site morbidity has been shown in other studies to present as residual back or leg pain[15-18]. The bothersomeness indices specifically inquire about the intensity of symptoms of back or lower-extremity pain, in contrast to general health-related quality-of-life measures (for example, the SF-36) or functional measures (for example, the Oswestry Disability Index) that may not be sensitive to donor-site pain that does not limit function.

Change in outcome was adjusted for age, sex, work status, body mass index, stenosis, hypertension, depression, osteoporosis, joint problems, current symptom duration, lower-extremity reflex deficit, number of moderately or severely stenotic vertebral levels, treatment preference, other comorbidity, baseline score (for SF-36 and Oswestry Disability Index), baseline Stenosis Bothersomeness Index, and center.

Statistical Analysis

Baseline characteristics between the groups managed with or without iliac crest bone-grafting were compared with use of a chi-square test for categorical variables and t tests for continuous variables. Outcome analyses were performed as they were done in the primary SPORT papers[10,11]. Outcomes were analyzed with use of longitudinal mixed-effects models with a random individual effect to account for the correlation among repeated observations within individuals over time. Adjusting covariates that were found to predict missing data, treatment received, and outcome were included in the model (details of the covariate selection process have been described in the SPORT primary

TABLE I Operative Treatments, Complications, and Events

	Group Treated without Iliac Crest Autograft (N = 246)	Group Treated with Iliac Crest Autograft (N = 108)	P Value
Procedure *(no. of patients)*			0.72
Noninstrumented fusion	56 (23%)	22 (20%)	
Instrumented fusion	190 (77%)	86 (80%)	
Multilevel fusion	52 (21%)	35 (32%)	0.033
Decompression level *(no. of patients)*			
L2-L3	31 (13%)	9 (8%)	0.33
L3-L4	123 (50%)	45 (42%)	0.20
L4-L5	234 (95%)	107 (99%)	0.076
L5-S1	63 (26%)	40 (37%)	0.031
No. of levels decompressed *(no. of patients)*			0.94
0	2 (1%)	1 (1%)	
1	103 (42%)	44 (41%)	
2	89 (36%)	37 (34%)	
≥3	52 (21%)	26 (24%)	
Operative time* *(min)*	200.9 (85.7)	233.4 (70.6)	<0.001
Blood loss* *(mL)*	582.3 (451.2)	686.9 (523.7)	0.057
Blood replacement *(no. of patients)*			
Intraoperative replacement	83 (34%)	45 (42%)	0.22
Postoperative transfusion	53 (22%)	24 (22%)	0.96
Length of hospital stay* *(days)*	4.8 (3)†	4.8 (2.1)	0.96
Intraoperative complications† *(no. of patients)*			
Dural tear and/or spinal fluid leak	22 (9%)	11 (10%)	0.86
Vascular injury	1 (0.4%)	0 (0%)	0.67
Other	6 (2%)	1 (1%)	0.60
None	218 (89%)	96 (89%)	0.91
Postoperative complications or events§ *(no. of patients)*			
Nerve root injury	1 (0%)	0 (0%)	0.68
Wound hematoma	0 (0%)	1 (1%)	0.68
Wound infection	5 (2%)	6 (6%)	0.16
Other	25 (10%)	9 (8%)	0.71
None	171 (70%)	69 (64%)	0.28
Postoperative mortality *(no. of patients)*			
Within 3 mo of surgery	1 (0.4%)	0 (0%)	1
Additional surgeries# *(no. of patients)*			
1-year rate	15 (6%)	6 (6%)	0.834
2-year rate	28 (11%)	11 (10%)	0.743
3-year rate	33 (13%)	12 (11%)	0.562
4-year rate	35 (14%)	14 (13%)	0.755
Reason for additional surgery** *(no. of patients)*			
Recurrent stenosis or progressive listhesis	11 (4%)	4 (4%)	
Pseudarthrosis or fusion exploration	3 (1%)	1 (1%)	
Infection	5 (2%)	4 (4%)	
Other	12 (5%)	5 (5%)	
New condition	5 (2%)	3 (3%)	

*The values are given as the mean, with the standard deviation in parentheses. †One of the patients in the group treated without iliac crest autograft had a length of hospital stay of 372 days—not counting that patient, the average length of hospital stay (and standard deviation) for that group would be 4.8 (3).

‡No cases of aspiration into the respiratory tract, nerve-root injury, or operation at wrong level were reported. §Complications or events occurring up to eight weeks after surgery are listed. There were no reported cases of bone-graft complication, cerebrospinal fluid leak, paralysis, cauda equina injury, pseudarthrosis, or wound dehiscence. #One, two, three, and four-year reoperation rates are Kaplan-Meier estimates, and p values are based on the log-rank test. Numbers and percentages are based on the first additional surgery if more than one additional surgery. Surgeries include any additional spine surgery—not just a reoperation at the same level. **Several patients underwent more than one reoperation.

TABLE II Analysis of Results from the Adjusted As-Treated Analyses According to Bone-Graft Source*

	1 Year			2 Year		
	Group Treated without Iliac Crest Autograft (N = 192)†	Group Treated with Iliac Crest Autograft (N = 83)†	P Value	Group Treated without Iliac Crest Autograft (N = 224)†	Group Treated with Iliac Crest Autograft (N = 102)†	P Value
Short Form-36 scores†§						
Bodily pain	32.4 (1.7)	35.5 (2.6)	0.32	31.4 (1.7)	31.9 (2.7)	0.88
Physical function	29.9 (1.6)	32 (2.5)	0.49	26.8 (1.6)	28.9 (2.6)	0.50
Physical component summary	12.5 (0.68)	13.8 (1)	0.31	12 (0.68)	12.4 (1.1)	0.78
Mental component summary	2.6 (0.65)	4.2 (1)	0.18	2.5 (0.65)	3.2 (1.1)	0.57
Oswestry Disability Index score†#	−25.5 (1.3)	−27.7 (2)	0.35	−24.1 (1.3)	−26.7 (2.1)	0.29
Stenosis Bothersomeness Index score†**	−9.6 (0.43)	−10.3 (0.66)	0.43	−9 (0.43)	−9.8 (0.69)	0.40
Low Back Pain Bothersomeness Scale score†††	−2.4 (0.1)	−2.5 (0.2)	0.78	−2.1 (0.1)	−2.2 (0.2)	0.76
Leg Pain Bothersomeness Scale score†††	−3.1 (0.1)	−3 (0.2)	0.80	−2.9 (0.1)	−3.1 (0.2)	0.41
Patients very or somewhat satisfied with symptoms *(%)*	71.4	69.4	0.61	66.2	63.2	0.77

*Adjusted for age, sex, work status, body mass index, any neuroforamen (L or R), hypertension, depression, osteoporosis, joint problems, current symptom duration, reflex deficit, number of moderately or severely stenotic levels, treatment preference, other comorbidity (problems related to stroke, cancer, lung, fibromyalgia, chronic fatigue syndrome, posttraumatic stress disorder, alcohol, drug dependency, liver, kidney, blood vessel, nervous system, migraine, or anxiety), baseline score (for Short Form-36 [SF-36] and Oswestry Disability Index), baseline stenosis bothersomeness, and center. †The sample sizes for the as-treated analyses reflect the number of patients contributing to the estimate in a given time period with use of the longitudinal modeling strategy explained in the Materials and Methods section. ‡The values are given as the mean score, with the standard error of the mean in parentheses. §The SF-36 scores range from 0 to 100, with higher scores indicating less severe symptoms. #The Oswestry Disability Index ranges from 0 to 100, with lower scores indicating less severe symptoms. **The Stenosis Bothersomeness Index ranges from 0 to 24, with lower scores indicating less severe symptoms. ††The Low Back Pain Bothersomeness Scale ranges from 0 to 6, with lower scores indicating less severe symptoms. ‡‡The Leg Pain Bothersomeness Scale ranges from 0 to 6, with lower scores indicating less severe symptoms.

papers[10,11]). In addition, baseline outcome, center, age, and sex were included in all longitudinal outcome models. All analyses were as-treated, and treatment was considered a time-varying covariate. Therefore, patients were categorized at each time point as to whether they received surgical treatment, follow-up times were measured from the beginning of treatment, and baseline covariates were updated at the time of surgery. Secondary and binary outcomes were analyzed with use of generalized estimating equations assuming a compound symmetry working correlation structure. Analyses were performed with the use of the PROC MIXED procedure for continuous data and the PROC GENMOD procedure for binary and non-normal secondary outcomes from the SAS software package (version 9.2; SAS Institute, Cary, North Carolina). Statistical significance was defined as $p < 0.05$ on the basis of a two-sided hypothesis with no adjustment made for multiple comparisons.

One, two, three, and four-year postsurgical reoperation rates are Kaplan-Meier estimates, and p values are based on the log-rank test. Numbers and percentages are based on the first additional surgery if there was more than one additional surgery. Surgeries include any additional spine surgery (not just re-operation at the same level).

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Results

A total of 354 patients, including 246 who had not had iliac crest bone-grafting and 108 who had iliac crest bone-grafting, were identified. Baseline characteristics are reported in the Appendix. There were no significant baseline differences in primary or secondary outcome measures (SF-36, Oswestry Disability Index, Stenosis Bothersomeness Index, and Low Back Pain Bothersomeness Scale) between the groups managed with or without iliac crest bone-grafting. There were significant differences in clinical presentation between the groups. Compared with the group without iliac crest bone graft, the group that had iliac crest bone-grafting had an increased percentage of patients with a neurological deficit (65% versus 50%; $p = 0.011$), asymmetric depressed lower-extremity reflexes (35% versus 22%; $p = 0.017$), and neuroforaminal stenosis (51% versus 39%; $p = 0.041$). There was a significant increase ($p = 0.043$) in the percentage of patients with three or more stenotic vertebral levels in the group that had not had iliac crest bone-grafting than in the group that had iliac crest bone-grafting (8% versus 1%).

Operative details are reported in Table I. Compared with the group that had not had iliac crest bone-grafting, the patients

TABLE II (*continued*)

3 Year			4 Year		
Group Treated without Iliac Crest Autograft (N = 209)†	Group Treated with Iliac Crest Autograft (N = 94)†	P Value	Group Treated without Iliac Crest Autograft (N = 174)†	Group Treated with Iliac Crest Autograft (N = 74)†	P Value
32.2 (1.7)	32.5 (2.7)	0.91	30.8 (1.8)	30.3 (2.9)	0.88
25.8 (1.7)	27.7 (2.6)	0.55	27.5 (1.7)	27.5 (2.8)	0.99
11.7 (0.71)	11.7 (1.1)	1	11.2 (0.75)	11.9 (1.2)	0.65
1.9 (0.68)	3.2 (1.1)	0.31	2 (0.73)	3 (1.2)	0.48
−22.7 (1.3)	−22.6 (2.1)	0.96	−23 (1.4)	−25.4 (2.2)	0.38
−9 (0.45)	−9.9 (0.7)	0.32	−9.4 (0.46)	−9.2 (0.75)	0.82
−2.1 (0.1)	−2.1 (0.2)	0.98	−2.2 (0.1)	−2.3 (0.2)	0.57
−2.9 (0.1)	−3.3 (0.2)	0.07	−3.1 (0.1)	−3.1 (0.2)	0.82
63	58.4	0.39	59.4	62.4	0.91

who received iliac crest autograft were more likely to have a multilevel fusion (32% versus 21%; p = 0.033) and decompression of L5-S1 (37% versus 26%; p = 0.031). Procedures performed with iliac crest autograft were also significantly longer (mean, 233.4 minutes versus 200.9 minutes; p < 0.001). Intraoperative blood loss in the iliac crest autograft group trended higher (mean, 686.9 versus 582.3 mL), but the difference did not reach significance (p = 0.057). The rate of intraoperative blood replacement was not significantly different between the groups (42% of 108 patients treated with iliac crest autograft and 34% of 246 treated without iliac crest autograft; p = 0.22). The rate of postoperative blood transfusions was not significantly different between the groups (22% in both; p = 0.96). There was no significant difference in the use of spinal instrumentation between groups (80% and 77%, respectively; p = 072). There was no significant difference in length of hospital stay between groups (4.8 days in both; p = 0.96). There were no significant differences between groups with regard to postoperative complications, including wound hematoma (1% and 0%, respectively; p = 0.68), wound infection (6% and 2%; p = 0.16), postoperative mortality within three months of surgery (0% and 0.4%; p = 1), or other complications (8% and 10%; p = 0.71). There were no significant differences in the rate of additional

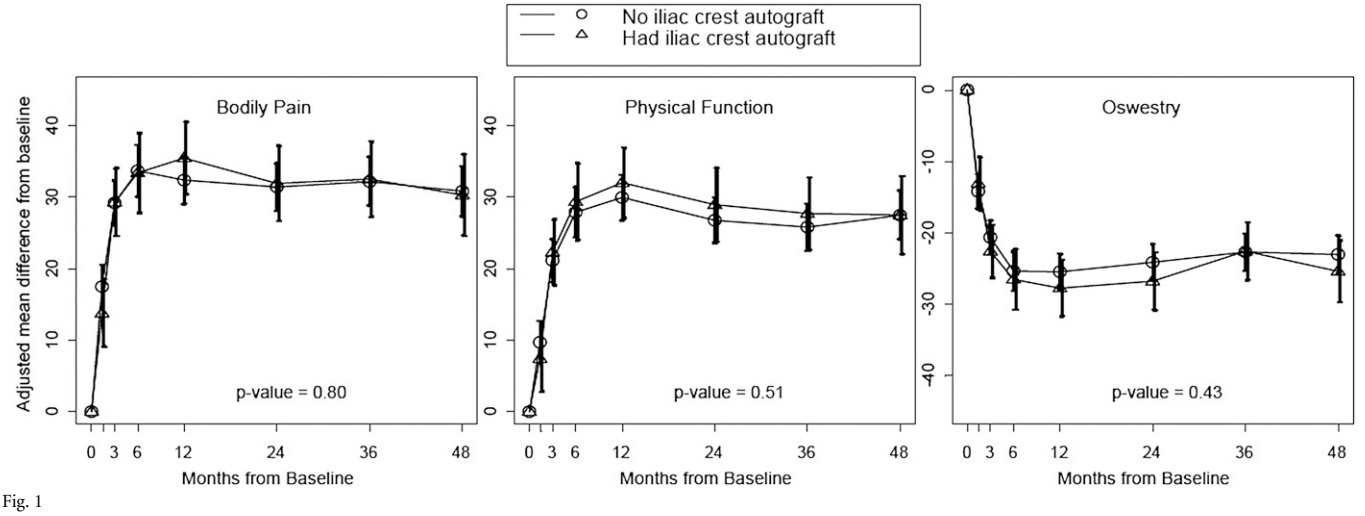

Fig. 1

Graphs showing the primary outcomes over time by bone-graft source and the p values for the comparison of the groups with or without iliac crest autograft with respect to the time-weighted average four-year area under the curve. The I bars indicate the standard deviation.

TABLE III Average Four-Year Area Under the Curve Estimates

	Group Treated without Iliac Crest Autograft*	Group Treated with Iliac Crest Autograft*	P Value
Short Form-36			
Bodily pain	30.8 (1.2)	31.4 (1.9)	0.80
Physical function	26 (1.2)	27.6 (1.9)	0.51
Physical component summary	11.4 (0.5)	11.6 (0.8)	0.77
Mental component summary	2.4 (0.4)	3.5 (0.7)	0.20
Oswestry Disability Index	−23.1 (1)	−24.6 (1.5)	0.43
Stenosis Bothersomeness Index	−8.9 (0.3)	−9.5 (0.5)	0.40

*The values are given as the average, with the standard deviation in parentheses.

surgical procedures between the groups at one year (6% of 108 patients treated with iliac crest autograft and 6% of 246 patients treated without iliac crest autograft; p = 0.834) or at two (10% and 11%, respectively; p = 0.743), three (11% and 13%; p = 0.562), or four years (13% and 14%; p = 0.755).

Changes in the primary outcome measures at all time points are illustrated in Table II and Figure 1. On the basis of the numbers available, there were no significant differences between the groups with respect to primary or secondary outcome measures at any time point. The area under the curve estimates for change in primary and secondary outcome measures were not significantly different between the groups (Table III).

A post hoc power analysis was conducted with use of t tests for two samples to determine the minimum effect that the study was powered to detect, given the observation of no significant difference between groups[19]. On the basis of the sample sizes and standard deviations observed in the four-year area under the curve data, there was 80% power to detect a difference in the score of 0.6 for SF-36 bodily pain, 0.6 for SF-36 physical function, 0.3 for SF-36 physical component summary, 0.2 for SF-36 mental component summary, 0.5 for the Oswestry Disability Index, and 0.2 for the Stenosis Bothersomeness Index.

Discussion

These findings suggest that the use of autogenous iliac crest bone graft in fusion for degenerative spondylolisthesis does not result in a worse outcome or increased complications than that after fusion without iliac crest autograft. In the current study, on the basis of the numbers available, there was no difference in general or disease-specific health outcome measures between the groups treated with or without iliac crest bone-grafting. There was no difference between groups with respect to the presence of symptomatic pseudarthrosis requiring reoperation. On the basis of the length of hospital stay, intraoperative complications, postoperative complications, and reoperation rate, the postoperative courses of the groups were nearly identical.

There is considerable controversy with regard to the reported incidence and severity of complications related to iliac crest bone-graft harvesting. Some studies have demonstrated that the use of iliac crest bone graft has substantial donor-site morbidity[6,7,16,17,20-23]. However, other authors have reported that assessment of iliac crest donor-site pain is overestimated[15,24] and confounded by the concomitant pain from lumbar radiculopathy[17,18,25,26]. Our results are consistent with previous studies that have found no long-term morbidity or worsening in outcome after iliac crest bone-graft harvest.

The strengths of this study include the large study population and the long-term follow-up (four years). To our knowledge, the current study is the largest study in the literature and includes a broad array of general, back, and leg pain-specific outcome measures, in contrast to previous studies. On the basis of the post hoc power analysis, the magnitude of the difference observed in SF-36 bodily pain, physical function, and physical component summary scores and the Oswestry Disability Index was equal to or less than that of the minimum detectable effect size, given the sample sizes between groups[19]. Furthermore, the magnitude of difference between the groups was less than the minimum clinically important difference between the groups with regard to the SF-36 and Oswestry Disability Index[27].

The limitations of this study include the fact that it was a retrospective subgroup analysis that was not specified a priori. There is a possibility of unknown confounders biasing the results, such as sagittal balance or surgeon experience with bone-grafting techniques. Also, a heterogeneous group of bone-grafting techniques was used, even for autologous iliac crest bone-graft harvest. There was no standardization of iliac crest bone-graft harvest techniques. While scar and paresthesias may be associated with incision and approach, donor-site pain is arguably mostly osseous in nature and dependent more on the presence or absence of iliac crest harvesting. To the extent that these donor-site issues are disabling, we would expect that their effects would be incorporated into the outcome measures. More multilevel spinal fusions occurred in patients who had iliac crest bone-grafting than in those who had not (32% versus 21%; p = 0.033). It may be that surgeons chose iliac crest bone-grafting for patients undergoing multilevel fusion to offset the higher risk of pseudarthrosis in the multilevel fusion group. The difference

between the groups with respect to fusion levels and stenosis levels may account for the increased operative time and trend toward increased blood loss in the group that had iliac crest bone-grafting. Surgery at L5-S1 was more likely to have iliac crest bone graft, possibly because of the known increased risk of pseudarthrosis at that level. Another limitation of this study is the exact nature of the graft used in the group treated without iliac crest bone-grafting. Because this was not specified within SPORT, it therefore could not be separately analyzed in this study to directly compare iliac crest bone-graft substitutes, including local autograft, allograft, synthetic agents, or bone morphogenic protein. However, such heterogeneity is reflective of actual clinical practice, with decisions to augment local bone with allograft as needed on the basis of the surgeon's judgment. Since the primary research question was the difference in outcome after fusion with or without the use of iliac crest autograft, we do not believe this limitation hinders the ability to draw conclusions regarding the use of iliac crest bone graft compared with substitutes for iliac crest bone graft. It should be noted that among patients undergoing fusion in situ, the use of iliac crest bone graft might have held greater importance in preventing the development of a symptomatic nonunion. Another limitation is the lack of radiographic assessment of spinal fusion between the groups. The SPORT database does not include postoperative radiographs or the surgeons' assessment of fusion. As an indirect marker of success of lumbosacral fusion, we report that there was no significant difference in reoperation rates between the groups managed with or without iliac crest bone graft. To the extent that pseudarthrosis is a clinically important event, we would expect pseudarthrosis to be reflected in either clinical outcome scores or reoperation rates. The degenerative spondylolisthesis cohort in the present study had a reoperation rate of 1% for symptomatic nonunions. This is far lower than reported nonunion rates for both instrumented[8,22,28,29] and noninstrumented[23,29] fusions of the lumbar spine. We recognize this disparity and consider that this rate represents the rate of reoperation for symptomatic pseudarthrosis, whereas previous studies have described reoperation for asymptomatic radiographic pseudarthrosis.

In conclusion, the results of this study demonstrate similar outcomes of lumbar spinal fusion with or without the use of iliac crest bone graft in patients with degenerative spondylolisthesis. These results imply that surgeons may consider either iliac crest bone graft or graft that is not from the iliac crest for lumbar fusion, depending on their preference and the pathological findings in the patient, without an increase in complications.

Appendix

(eA) A table showing the baseline patient demographic characteristics, comorbidities, and health status measures according to the bone-graft source is available with the online version of this article as a data supplement at jbjs.org. ■

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