

Clinical Article

A Mid-Term Follow-Up Result of Spinopelvic Fixation Using Iliac Screws for Lumbosacral Fusion

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Objective : Iliac screw fixation has been used to prevent premature loosening of sacral fixation and to provide more rigid fixation of the sacropelvic unit. We describe our technique for iliac screw placement and review our experience with this technique.

Methods : Thirteen consecutive patients who underwent spinopelvic fixation using iliac screws were enrolled. The indications for spinopelvic fixation included long segment fusions for spinal deformity and post-operative flat-back syndrome, symptomatic pseudoarthrosis of previous lumbosacral fusions, high-grade lumbosacral spondylolisthesis, lumbosacral tumors, and sacral fractures. Radiographic outcomes were assessed using plain radiographs, and computed tomographic scans. Clinical outcomes were assessed using the Oswestry Disability Index (ODI) and questionnaire about buttock pain.

Results : The median follow-up period was 33 months (range, 13-54 months). Radiographic fusion across the lumbosacral junction was obtained in all 13 patients. The average pre- and post-operative ODI scores were 40.0 and 17.5, respectively. The questionnaire for buttock pain revealed the following: 9 patients (69%) perceived improvement; 3 patients (23%) reported no change; and 1 patient (7.6%) had aggravation of pain. Two patients complained of prominence of the iliac hardware. The complications included one violation of the greater sciatic notch and one deep wound infection.

Conclusion : Iliac screw fixation is a safe and valuable technique that provides added structural support to S1 screws in long-segment spinal fusions. Iliac screw fixation is an extensive surgical procedure with potential complications, but high success rates can be achieved when it is performed systematically and in appropriately selected patients.

KEY WORDS : Spinopelvic fixation · Iliac screws · Lumbosacral fusion · Outcome · Complication.

INTRODUCTION

Fusions of the lumbosacral spine continue to be a challenging area in spine surgery^{4,8)}. The complex local anatomy, unique biomechanical forces, and poor bone quality of the sacrum are just a few of the many reasons why fusions of the lumbosacral spine have been difficult to perform^{13,15,17)}. To offset these limitations, many spine surgeons have attempted to place S1 screws that traverse the posterior and anterior

cortices of the sacrum (i.e., a bicortical purchase) or have aimed these S1 screws at the promontory of the sacrum to capture the anterior and superior cortices of the sacrum as well as the posterior cortex to achieve a tricortical screw purchase¹⁰⁾.

In cases in which S1 screw fixation is potentially inadequate or impossible, the addition of pelvic fixation should be considered. The primary indications for pelvic fixation include high-grade lumbosacral spondylolisthesis (grade III or higher), as well as long segment fusions for spinal deformity, osteoporotic fractures, or traumatic fractures¹⁵⁾. In addition, revision of symptomatic lumbosacral pseudoarthrosis with loosened S1 screws is another indication for extension of fixation to the pelvis²⁾. In these cases, the purpose of pelvic screw fixation is to provide added caudal structural support that unloads the biomechanically weak S1 screws until lum-

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bosacral fusion has taken place. Ultimately, these pelvic screws may loosen over time because a fusion is not performed across the sacroiliac joint. However, the added structural support in the short term helps to prevent complications, such as S1 screw loosening, or catastrophic failures, such as sacral fractures from heavily overloaded S1 screws.

Other indications for pelvic fixation include destructive lesions of the sacrum (neoplasms, infections, or fractures) that preclude instrumentation of the sacrum altogether because of involvement of the sacral pedicles^{6,8}. In these cases, care is exercised to perform a L5-S1 anterior lumbar interbody fusion (ALIF) or placement of a bone graft laterally from the L5 transverse process to the sacral ala onto the medial ilium in an attempt to achieve bone fusion¹⁹.

Methods of sacropelvic fixation include the Galveston (L-rod) technique¹, Dunn-McCarthy (S-rod) technique¹¹, transiliac screws, intrasacral rods, and iliosacral fixation^{16,20,22}. More recently, spine surgeons have used iliac bolts (fixed-angle iliac screws) or polyaxial pelvic screws (polyaxial iliac screws) to achieve pelvic fixation. Herein we report our comprehensive surgical results using iliac bolts and describe our preferred iliac screw fixation technique, with analysis of clinical and radiographic results (1-year minimum) of these constructs.

MATERIALS AND METHODS

Thirteen consecutive patients who underwent spinopelvic fixation using iliac screws by the senior spine surgeon (SCR) between August 2005 and November 2008 were enrolled. The median follow-up period was 33 months (range, 13-54 months). The patients included 12 women and 1 man; the median age was 59 years (range, 18-67 years). The indications for spinopelvic fixation included long segment fusions for spinal deformity (four patients), post-operative flat-back syndrome (four patients), symptomatic pseudoarthrosis of previous lumbosacral fusions (two patients), high-grade lumbosacral spondylolisthesis (one patient), a lumbosacral tumor (one patient), and a sacral fracture (one patient).

Clinical assessment and radiographic analysis

Clinical data were collected by retrospective chart review. Details on prior surgeries, intra-operative blood loss, surgical complications, and post-operative clinical course, including persistent pain, screw prominence, and infection, were of particular interest. Oswestry Disability Index (ODI) scores obtained before and after surgery, in a prospective manner, were analyzed⁷. Patients were also asked to complete a post-operative questionnaire to determine overall satisfaction at the latest follow-up. Questions included the quantification of

buttock pain using a numeric rating scale (NRS; score range 0-10, with 10 indicating the worst pain), screw prominence/awareness, and desire for elective iliac screw removal. Each patient was questioned and his or her responses were recorded by a spinal surgeon not involved in the procedure.

Radiographic outcomes were assessed using post-operative anteroposterior and lateral radiographs, and computed tomographic (CT) scans. Lumbosacral fusions were evaluated by two observers (SJH and YBK) from the Ferguson anteroposterior radiograph or CT scan using the reported criteria⁹. Sagittal balance was analyzed on a long-cassette (14 × 36 inches) standing lateral radiograph. The lumbosacral pivot point was defined as the point at the middle osteoligamentous column between the last lumbar vertebra and the sacrum (Fig. 1)¹². Screw failures, including violation of the acetabulum or sciatic notch, breakage, back-out, peri-screw halo, and postoperative change of the sacroiliac joints were also recorded. The collection and review of clinical data and radiographic assessments did not involve the operating surgeon.

Operative detail and post-operative course

The patient is positioned prone in a lordotic position (to avoid post-operative flat back). For iliac screws, the distal ilium is dissected via midline fascial incision and a rongeur or burr is used to breach the cortex at the posterior superior iliac spine (PSIS). Care is taken to skirt the Bovie cautery (Bovie Medical Corp., St. Petersburg, FL, USA) around the dorsal sacral foramina to avoid neural injury and bleeding, and we do not insert the Bovie cautery into the sacroiliac joint. The

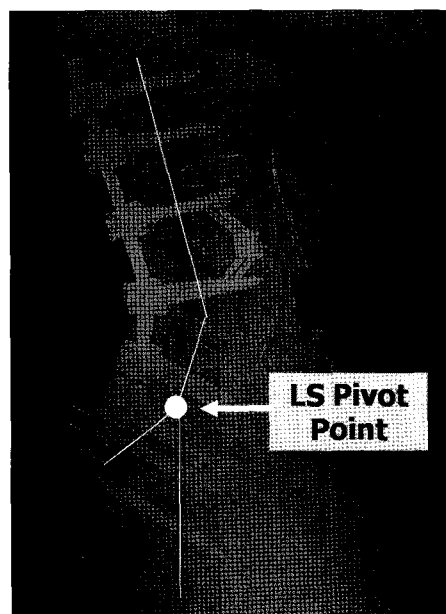


Fig. 1. The lumbosacral pivot point is defined as the point at the middle osteoligamentous column between the last lumbar vertebra and the sacrum. Pivot point position on a plain X-ray of the lumbar spine. LS : lumbosacral.

entry point for the iliac screw is 1 cm rostral to the palpated inferior overhang of the PSIS and 1 cm below the superficial ridge of the PSIS. The pelvic gearshift is then placed into the entry point and aimed toward the thick bone that is just superior to the greater sciatic notch and potentially onward toward the anteroinferior iliac spine. The gearshift is gradually advanced to reach the target bone above the greater sciatic notch. Care is taken not to enter the greater sciatic notch itself to avoid injuring the superior gluteal vessels and sciatic nerve. In the experience of the senior author (SCR), manual digital palpation of the sciatic notch provides adequate guidance to direct the pelvic gearshift to the bone just superior to the greater sciatic notch. Along the way, a sounder is used to keep within the cortices of the ilium. Screw length is measured with the sounder. The screw channel is then tapped, most commonly with a tap that is either 0.5 or 1.0 mm smaller than the ultimate screw diameter. Fluoroscopy can facilitate lining up the iliac screw, but it is not routinely used.

Subsequently, the iliac screw is threaded into the pilot hole until the head of the screw is recessed into the PSIS to prevent the patient from feeling a prominent screw head. The iliac screws were usually 6.5×7.5 mm in diameter and 60-80 mm in length. The final step is to connect the iliac screw to the lumbosacral rod. Routinely, corticocancellous bone is harvested from the outer cortex of the posterior ilium with an osteotome and curettes. Care is taken to stay at least 1 cm from the iliac screw projection while avoiding undercutting. In cases of insufficient autologous bone, allografts with or without demineralized bone matrix were placed to supplement fusion. Although a unilateral iliac screw had been used early in this study, bilateral iliac screws were fixated burying the screw heads into the PSIS.

Patients are routinely referred for rehabilitation therapy and mobilized on post-operative day 1 with standing and/or walking in place at the bedside, if appropriate. The standard protocol included progressive walking, as tolerated, with avoidance of squatting and bending at the waist. A 3- or 6-month course of thoracolumbosacral orthosis or lumbosacral orthosis with a thoracic extension pad is typically prescribed for any patient in whom the construct is supported only by segmental posterior instrumentation. In any patient whose construct was supplemented by an anterior column interbody fusion, either no orthosis was suggested, or a supportive lumbosacral corset was worn for 1-3 months.

RESULTS

Surgical outcomes

Of the 13 patients reported herein, spinopelvic fixations have been secured with bilateral iliac screws in 8; however, 5

Table 1. Anterior load-sharing constructs

Anterior column support	No. (total = 9)
Carbon cage with morselized autograft	3
Carbon cage with morselized autograft and DBM	3
Titanium mesh cage(s) with morselized autograft	2
PEEK cage with morselized autograft	1

DBM : demineralized bone matrix, PEEK : polyetheretherketone

patients were very thin and were fixated with only a unilateral iliac screw because of potential hardware prominence. The numbers of fused vertebrae ranged from 5-10 (mean, 7.46). Corrective pedicle subtraction osteotomy (PSO) was performed in three patients with fixed sagittal imbalance. The mean operative time was 5 hours 30 minutes (range, 3 hours 15 minutes to 9 hours 10 minutes), and the mean operative blood loss was 2,250 mL (range, 600-5,500 mL). Anterior load-sharing/fixation devices were used in 9 of 13 constructs (69%) (Table 1). The nine patients who underwent ALIFs had staged operations (anterior-posterior or posterior release-anterior-posterior approaches). Detailed patient demographics and outcomes are summarized in Table 2.

Radiological outcomes

Radiographic fusion across the lumbosacral junction was obtained in all 13 patients available for radiographic follow-up, even though 6 of these patients had previous lumbar spine surgery. Radiographically, sacroiliac joint problems were not perceived. In all of the patients, there was no fusion of the sacroiliac joints. The median follow-up period was 33 months (range, 13-54 months). Both patients presenting with pre-operative pseudoarthrosis had a solid fusion of L5-S1 at the latest follow-up after our reconstruction. There was loosening of the iliac screws in two (patient No. 8 and 13) of the patients who had a radiographic fusion across the lumbosacral junction (Fig. 2). In 11 of 13 patients, tip of the iliac screws extend anterior to the lumbosacral pivot point; however, radiographic fusion across the lumbosacral junction was obtained in the remaining two patients (patient No. 8 and 11) (Fig. 3).

Three patients (patient No. 4, 7, and 10) underwent PSO with long-segment instrumentation for spinal deformities (Fig. 4). The mean correction angle at the PSO site was $30.4 \pm 6.2^\circ$. Thoracic kyphosis angle was increased from $21.3 \pm 10.9^\circ$ pre-operatively to $25.3 \pm 9.6^\circ$ post-operatively. Lumbar lordosis was increased significantly from $-15.1 \pm 8.2^\circ$ pre-operatively to $-45.1 \pm 7.8^\circ$ post-operatively. The C7 plumb line value was decreased significantly from 109 ± 37 mm to 30 ± 17 mm. All measurements were performed at least three times by two surgeons to ensure accuracy and reliability. The margins of inter- and intra-observer error were plus-or-minus $1.7 \pm 0.8^\circ$ and $1.3 \pm 0.8^\circ$, respectively.

Table 2. Patient demographics and clinical/radiological outcomes

No.	Age/Sex	Diagnosis	Levels fixated	Iliac screw	Corrective osteotomy	F/U (mo)	ODI scores		Complications	Iliac screw location comparing LS pivot point	Radiologic fusion at LS junction
							Preoperative	Last F/U			
1	67/F	Degenerative lumbar kyphoscoliosis, L5-S1 spondylolisthesis	T12-S1-pelvis, ALIF L4-S1	Unilateral	-	18	43	18	None	Ventral	Yes
2	63/M	Lumbar scoliosis	T12-S1-pelvis	Unilateral	-	36	34	19	None	Ventral	Yes
3	59/F	Degenerative lumbar kyphosis	L1-S1-pelvis, ALIF L3-S1	Bilateral	-	14	39	22	Deep wound infection	Ventral	Yes
4	60/F	Degenerative lumbar kyphosis, L3-4 autofused vertebrae	T12-S1-pelvis, ALIF L2-S1	Bilateral	PSO at L4	18	42	16	None	Ventral	Yes
5	57/F	Postoperative flat-back, prior L4-5 fusion	T10-S1-pelvis, ALIF L3-4, L5-S1	Bilateral	-	13	43	18	None	Ventral	Yes
6	63/F	Postoperative flat-back, prior L4-5 fusion	L2-S1-pelvis, ALIF L2-4, L5-S1	Unilateral	-	29	36	12	None	Ventral	Yes
7	53/F	Postoperative flat-back, prior L4-5 fusion	T10-S1-pelvis, ALIF L2-3, L3-4	Bilateral	PSO at L3	49	39	14	None	Ventral	Yes
8	67/F	Postoperative flat-back, prior L4-5 fusion	L2-S1-pelvis, ALIF L3-S1	Unilateral	-	54	41	14	Peri-screw halo	Dorsal	Yes
9	18/F	Pseudarthrosis at L4-S1, prior L4-S1 fusion d/t giant cell tumor at L5	L3-S1-pelvis, ALIF L4-S1	Unilateral	-	40	42	13	None	Ventral	Yes
10	62/F	Pseudarthrosis at S1, prior T12-S1 fusion d/t degenerative lumbar kyphosis	T12-S1-pelvis, ALIF L2-S1, inter-laminar hook L2-5	Bilateral	PSO at L3	41	39	15	None	Ventral	Yes
11	50/F	Isthmic spondylolisthesis Grade 3 L4 on L5	L2-S1-pelvis	Bilateral	-	51	32	14	Violation of sciatic notch, however, asymptomatic	Dorsal	Yes
12	49/F	Metastatic tumor at L5	L3-S1-pelvis	Bilateral	-	50	48	15	None	Ventral	Yes
13	37/F	Burst fracture at L1, sacral fracture	T10-S1-pelvis	Bilateral	-	20	42	37	Peri-screw halo	Ventral	Yes

ALIF: anterior lumbar interbody fusion, F/U: follow-up, LS: lumbosacral, ODI: Oswestry Disability Index, PSO: pedicle subtraction osteotomy, T12: transforaminal interbody fusion

Clinical outcomes

All 13 patients completed ODI questionnaires and questions, including the quantification of buttock pain, screw prominence/awareness, and desire for elective iliac screw removal before and after surgery. The average pre- and post-operative ODI scores were 40.0 and 17.5, respectively (mean improvement, 22.5). The mean pre- and post-operative NRS scores for buttock pain were 7.1 and 3.8, respectively (mean improvement, 3.3). The questionnaire for buttock pain revealed the following: 9 patients (69%) perceived improvement in pain; 3 patients (23%) had no change in pain; and 1 patient (7.6%) had an aggravation in pain. A large percentage of patients believed that they were aware of the iliac screws (46%; 6 patients); however, only one-third of these patients were bothered by iliac screw awareness (15%; 2 patients). The two patients complained a prominence of the iliac hardware declined hardware revision/removal.

Complications

No patient died or had a neurological deficit as a result of surgery. The complications in this series included one violation of the greater sciatic notch and one deep wound infection. The patient (No. 11) who had violation of the greater sciatic notch was asymptomatic after surgery (Fig. 3). One patient had a deep wound infection (patient No. 3). This patient presented to us with degenerative lumbar kyphosis, and we initially performed an ALIF L3-S1, and subsequently a L1-S1 pelvis fixation using bilateral iliac screws. He developed a deep wound infection which was successfully treated using intravenous antibiotics without further wound problems and

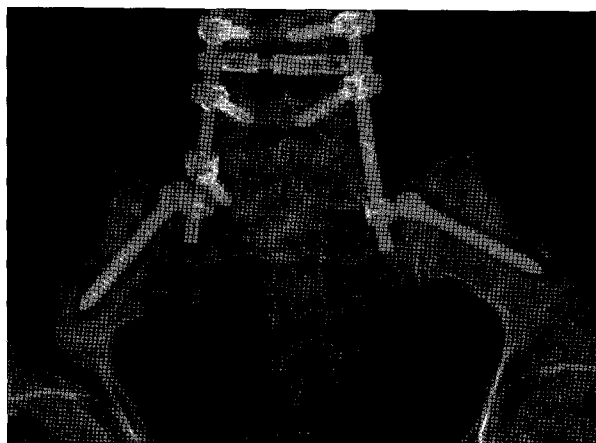


Fig. 2. Representative case of peri-screw halo (Patient No. 13). Post-operative anteroposterior radiograph showing loosening of the iliac screws, but a radiographic fusion across the lumbosacral junction.

explanation of the hardware.

Massive bleeding (> 5,000 mL) occurred in 1 patient (7.6%) without accidental damage to the major blood vessels. The hemorrhage occurred during decancellation of the vertebral body in the PSO procedure (patient No. 10). During the pre-operative laboratory analysis, these patients had normal bleeding times. The operative time for this patient was > 7 hours. In addition, two patients complained of prominence of the iliac hardware, but declined hardware revision/removal. There were some loosening of the iliac screws in 2 of the patients (no. 8 and 13) who had a radiographic fusion across the lumbosacral junction. No instrumentation failures occurred, including violation of the acetabulum, breakage, or back-out of the instruments.

DISCUSSION

Spine surgeons can achieve rigid immobilization and fusion of the lumbosacral spine with lumbosacral pedicle screw fixation. It is important to note, however, that the sacral pedicles typically have a large diameter and are filled with cancellous bone, and this anatomic feature may limit the ability of the surgeon to achieve solid screw purchase at S1¹⁴. Because of the high pseudarthrosis rate which has been reported, spine instrumentation systems and surgical techniques have rapidly developed over the past two decades^{1-4,10-11,16,22}.

Iliac screw fixation is a logical advancement from the development of Galveston iliac fixation. The modularity of this implants and screws and the various options for connectors to the longitudinal rods cannot be overemphasized. Overall, high fusion rates have been reported at the lumbosacral junction. Kuklo et al.⁹ reported a 5% pseudoarthrosis rate in a large series of 81 patients with a long fusion to the sacrum and high-grade spondylolisthesis. Of 38 patients who

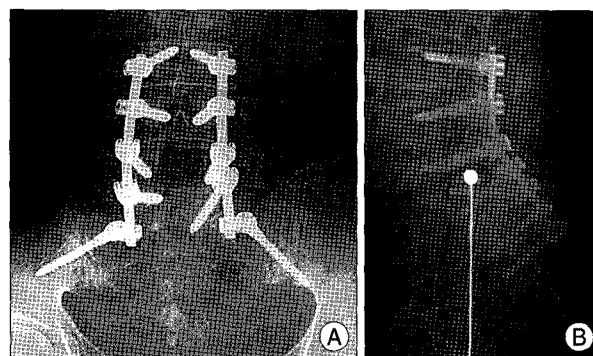


Fig. 3. Post-operative anteroposterior (A) and lateral (B) films demonstrate the iliac screws located dorsal to the lumbosacral pivot point; however, radiographic fusion across the lumbosacral junction is obtained. Post-operative image suggests a violation of left greater sciatic notch by tip of the iliac screw.

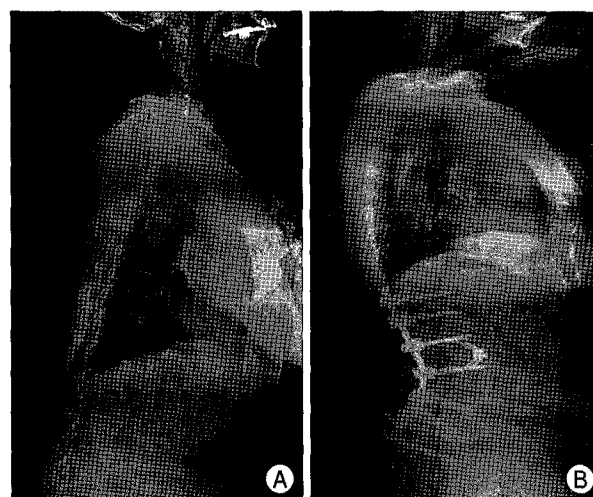


Fig. 4. A representative case of pedicle subtraction osteotomy (PSO) for fixed sagittal imbalance patients. A : Lateral long-cassette standing radiograph reveals global degenerative sagittal imbalance. B : The patient underwent L4 PSO with anterior column support, and the plain film obtained at recent follow-up examination shows dramatic improvement in lumbar kyphosis.

underwent revision, 36 had had a previous harvest of an iliac bone graft, but that did not preclude placement of the iliac screws. In our series, radiographic fusion across the lumbosacral junction was obtained in all 13 patients with a long fusion to the sacrum, even though 6 of these patients had previous lumbar spine surgery. Although the number of patients enrolled in the current study was small, the fusion rate was better than we had expected.

Outcome questionnaire

The overall outcome of function and buttock pain was good based on NRS and Oswestry scores at the final follow-up. There is no perfect way to isolate clinical problems with the sacroiliac joints. Moreover, there can be many potential sources of buttock pain other than the sacroiliac joint. We attempted to assess the sacroiliac joints by questionnaires,

including the quantification of buttock pain, screw prominence/awareness, and desire for elective iliac screw removal. The questionnaire for buttock pain showed that 9 patients (69%) had perceived improvement in pain, 3 patients (23%) had no change in pain, and 1 patient (7.6%) had an aggravation of pain. The mean pre- and post-operative NRS scores for buttock pain were 7.1 and 3.8, respectively, but an average NRS score was relatively low. We also assessed the patients by Oswestry questionnaires, which consider many factors other than the sacroiliac joints. We assumed that if there were substantial problems with the sacroiliac joints, the patients' pain and Oswestry scores would deteriorate. The overall functional outcome was favorable based on Oswestry scores at the final follow-up. The average pre- and post-operative ODI scores were 40.0 and 17.5, respectively. No sacroiliac joint fusion problems were detected radiographically. Therefore, based on our radiographic and clinical evaluation, we had no evidence of the iliac screws predisposing the sacroiliac joints to degeneration at follow-up ranging from 13-54 months.

Complications of iliac screw and rod placement

The placement of iliac screws or rods is a major surgical procedure with potentially substantial morbidity. The technique requires extensive surgical exposure, which is associated with a higher risk of blood loss and infection. In our series, massive bleeding (> 5,000 mL) occurred in 1 patient (7.6%) without any accidental damage to major blood vessels. The case with hemorrhage occurred during decancellation of the vertebral body in the PSO procedure. The infection rate associated with iliac fixation alone is difficult to ascertain from the literature because iliac fixation is performed in conjunction with other procedures^{13,17}. However, in a thorough 2-year follow-up study of patients treated with iliac fixation, Kuklo et al.⁹ reported an infection rate of 4% (3 of 81 patients). Those authors also noted iliac screw back-out in three patients, all of whom had spondylolisthesis; however, no pseudoarthrosis occurred in these patients. In our series, one patient had a deep wound infection which was successfully treated using intravenous antibiotics without pseudoarthrosis and explantation of the hardware.

Other complications associated with iliac screw fixation include the development of halos (or the "windshield wiper sign"), injury to structures in the sciatic notch, acetabular violation, and hardware prominence^{6,18,21}. Halos around the iliac screws have been reported fairly frequently, but they seem to have no effect on the ultimate achievement of a solid lumbosacral fusion^{6,18}. Indeed, halos around the iliac screws are merely a radiographic finding indicating micromotion around the iliac screw. In this series, there were some halos around the iliac screws in 2 of the patients (patient No. 8 and

13) who had radiographic fusions across the lumbosacral junction. In these cases iliac fixation was used as a temporary structural adjunct until lumbosacral fusion could develop.

Injury to the structures in the sciatic notch (primarily the superior gluteal artery and sciatic nerve) during placement of the iliac screw and rods is rare, and no rates have been reported in large series. In this series, one violation of the greater sciatic notch was suggested radiographically; however, the patient was asymptomatic after surgery. The risk of violating the acetabulum or sciatic notch can be minimized by aiming the screws at the anterior inferior iliac spine¹⁹. Hardware prominence continues to be a problem, particularly in thin patients. In one series of 36 patients with iliac screw fixation, 8 required subsequent hardware removal⁵. In our series, two patients complained of prominence of the iliac hardware, but declined hardware removal. Tumialán et al.¹⁹ reported that they could avoid hardware prominence in most cases by burying the screw heads into the PSIS. Additional advances in instrumentation are necessary to resolve this problem.

One of the weaknesses of this study might be the heterogeneous diagnostic categories. However, the surgeries, types of implants, and surgical goal were all relatively uniform. Therefore, the goals and treatments were uniform in that the surgical goal was fusion of the lumbosacral spine as opposed to a purely degenerative or traumatic etiology.

CONCLUSION

Iliac screw placement is a safe and effective adjunct for the management of various complex spine disorders, including long segment fusions, symptomatic pseudoarthrosis of previous lumbosacral fusions, high-grade lumbosacral spondylolisthesis, destructive lumbosacral neoplasms, and sacral fractures. The fusion rate of the lumbosacral junction was satisfactory. The overall outcomes of function and pain were reasonable based on a questionnaire about buttock pain and ODI scores at the final follow-up. Iliac screw placement is an extensive surgical procedure with numerous potential complications, but high success rates can be achieved when it is performed systematically and in appropriately selected patients.

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