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Modified Lumbopelvic Technique Using S1 Pedicle Screws for Spinopelvic Dissociation U-Type and H-Type Sacral Fractures With Kyphotic Deformity

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Summary: Spinopelvic dissociation injuries are complex injuries defined as discontinuity between the appendicular and axial skeleton. Fracture patterns are variable, but U-type and H-type fractures are common and often present with kyphotic deformity along with translational displacement and impaction. The ideal method of fixation has not been established for these injuries. The goals of treatment include restoration of alignment, stability, and neural decompression as needed. Traditional methods of lumbopelvic fixation have spanned the upper sacral fracture site. Our novel modified method of lumbopelvic fixation directly instruments the S1 body. This allows for direct manipulation of the fracture which we theorize improves reduction and increases stability across the fracture. This article characterizes the injury patterns, outlines the modified technique, and reports the clinical and radiographic outcomes of our modified lumbopelvic fixation technique and construct.

Key Words: spinopelvic dissociation, sacral fracture, triangular osteosynthesis, lumbopelvic, H-type, U-type

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INTRODUCTION

Spinopelvic dissociation (SPD) represents a spectrum of complex injuries that ultimately encompasses discontinuity between the appendicular and axial skeleton. The injury patterns are variable but are commonly characterized by bilateral vertical sacral fractures that often possess a horizontal or transverse fracture line. This will result in U-type/H-type fracture patterns often characterized by a sacral kyphotic deformity. In addition, there can be disruption of the L5-S1 facet joints and/or L5-S1 disc complex.[1] There is often multiplanar instability that manifests with initial or progressive lumbosacral kyphotic deformity with the potential of sacral nerve root injury and accompanying bladder and/or bowel dysfunction.

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Schildhauer et al first developed the concept of triangular osteosynthesis for the treatment of vertically unstable sacral fractures and demonstrated the biomechanical superiority of this construct along with excellent clinical results.[2–4] Other modalities for treatment of SPD include posterior tension band plating, adjustable plates, iliosacral screws alone, or transsacral bar fixation.[18] However, the use of lumbopelvic fixation has become the standard technique.[5] The traditional fixation construct consists of pedicle screw fixation into 1 or 2 lumbar spine levels in conjunction with iliac bolts and pelvic fixation with iliosacral or transsacral screws depending on available first (S1) or second (S2) sacral segment osseous fixation pathways. This approach has undergone little modification or improvement although lumbopelvic fixation continues to have reported complications related to reduction and instability.[6–8] In addition, a specific focus on bilateral fracture patterns, such as U-type and H-type fracture patterns with sacral kyphosis, is absent from the literature.

Historically, fixation constructs have varied.[4] In previous descriptions of lumbopelvic fixation, there is no mention of routine S1 screws in the construct except in rare instances but often at the expense of iliosacral/transsacral screws.[32] Our strategy for treating most of these injuries includes S1 pedicle screws for direct control of the sacrum. This can be especially beneficial when dealing with fracture variants requiring correction of the kyphotic deformity. There has been concern historically that S1 pedicle screw fixation would block safe and effective iliosacral/transsacral screw placement.[6] With these thoughts in mind, we have developed a modified lumbopelvic construct that includes S1 pedicle instrumentation. The inclusion of the S1 sacral body with instrumentation decreases the working length of the construct, theoretically increases stability, and allows for direct manipulation of the S1 body and sacrum to achieve improved reduction. The purpose of this study was to describe our L5-S1 ilium lumbopelvic fixation technique and report the accompanying radiographic and clinical outcomes in a cohort of patients with high-energy, displaced SPD U-type/H-type injuries with associated kyphotic deformity.

METHODS

A retrospective chart review was performed at a single Level 1 trauma center from 2014 to 2019 after institutional review board approval. The inclusion criteria were patients with the diagnosis of SPD who underwent lumbopelvic fixation with or without sacral decompression, older than 18 years, and had an appropriate medical chart with complete preoperative and postoperative radiographs and CT scans for review. SPD was defined as injuries involving bilateral vertical sacral fractures with a transverse component (ie, U-type/H-type fractures). Additional inclusion criteria included those with at least 5 mm of displacement in the coronal, sagittal, and axial planes, and presence of kyphotic deformity. The exclusion criteria included pelvic ring injuries without SPD, nondisplaced or minimally displaced U-type/H-type sacral fractures treated without lumbopelvic fixation, vertical sacral fractures without a transverse component, unilateral sacral fractures, absence of kyphotic deformity, younger than 18 years, or inadequate imaging or follow-up.

All procedures were performed by trauma and spine fellowship-trained orthopaedic surgeons. Patient demographics, mechanism of injury, injury severity score, associated injuries, and operating room (OR) data were collected. Fractures were classified using the letter morphology and Roy-Camille classifications.[9–11] We additionally documented concomitant anterior pelvic ring injury, L5/S1 facet disruption, and construct configuration. Preoperative neurologic status was obtained from clinical documentation and scored using the Gibbons'[12] Neurologic Scoring System. A score of 1 equates with no neurologic deficit, a score of 2 equates with paresthesia/sensory changes only, a score of 3 equates with motor weakness or loss but bowel/bladder control remains intact, and a score of 4 equates with motor and/or sensory deficits associated with loss of bowel/bladder control.

Radiographic outcomes included adequacy of reduction measured on initial postoperative images: change in sagittal displacement, change in sacrococcygeal angle, and change in focal kyphosis (see Figure 1A and B, **Supplemental Digital Content 1**, http://links.lww.com/JOT/B553). Assessment of fracture displacement and reduction was measured as a percentage of anterior to posterior sacral width on the sagittal CT scan of the sacrum.[7] In addition, we performed volumetric analysis to determine absolute initial displacement and postoperative reduction using multiplanar sequencing of the sacrum on preoperative and postoperative CT imaging (see **Figure 1C**, **Supplemental Digital Content 1**, http://links.lww.com/JOT/B553). Fracture displacement was measured in the coronal, sagittal, and axial planes. The sacrococcygeal angle was calculated by measuring the angle formed between a line bisecting the S1 body and a line bisecting the caudal segment of the coccyx (see **Figure 2**, **Supplemental Digital Content 2**, http://links.lww.com/JOT/B554).[7,8,13] Sacral kyphosis was measured on preoperative and postoperative CT scans by comparing tangent lines to the anterior sacral bodies above and below the affected level. Fracture union, defined as bony bridging across the fracture site in conjunction with maintained instrumentation, was determined based on postoperative radiographs which were obtained at 6 weeks, 3 and 6 months, and 1 year on average. Measurements were performed by 3 independent reviewers (1 orthopaedic surgery fellow, 1 senior orthopaedic surgery resident, and 1 musculoskeletal radiology fellow) and averaged with interclass correlation coefficients (ICCs) calculated.

Postoperative complications, neurologic status, return to work/school, and ambulatory status were recorded. Differences between preoperative and postoperative measurements were determined using paired Student *t*-tests using nonparametric parameters, Wilcoxon matched-pairs signed-rank tests, and χ^2 tests with statistical significance set at $P < 0.05$.

Technical Principles and Surgical Technique

Patient Positioning with Indirect Fracture Reduction

The sequencing of posterior versus anterior pelvic ring fixation was determined by the 2 treating surgeons based on each individual fracture pattern. Typically, for patients with anterior pelvic ring injury, patients were first treated in the supine position for anterior ring fixation followed by staged prone lumbopelvic fixation on a radiolucent open spine table. Pillows were placed on the thigh pads to elevate the thighs and extend the pelvis relative to the spine.

Surgical Reduction and Fixation

The L5 and S1 pedicles were typically first instrumented using 7-mm pedicle screws (DePuy Synthes Spine, Raynum, MA) and then 8-mm iliac bolts were placed (Figs. 1 and 2). S1 pedicle screws are placed in such a method to avoid blocking subsequent iliosacral/transsacral screws (see

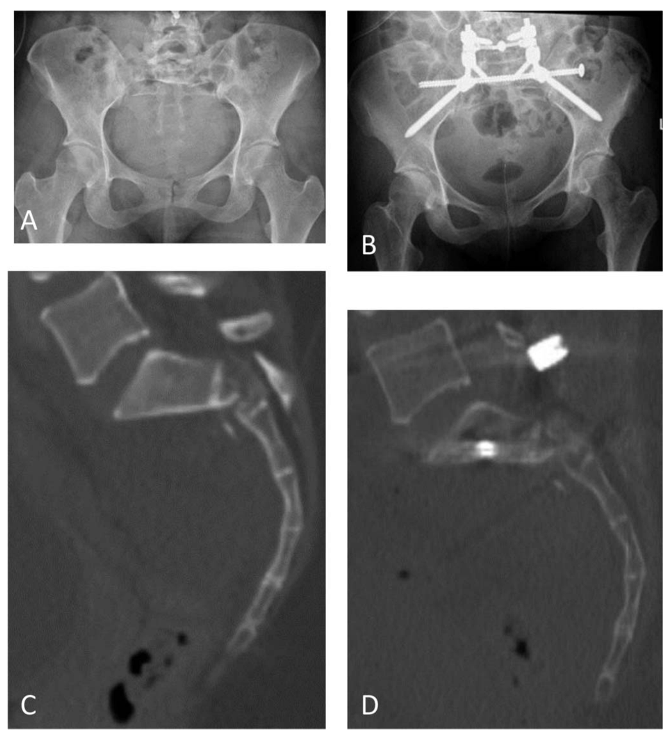

FIGURE 1. Preoperative (A) and postoperative (B) anteroposterior pelvic radiograph and preoperative (C) and postoperative (D) sagittal CT reconstruction demonstrating a patient with symphysis pubis disruption and bilateral sacral fractures with a S1-S2 transverse component with anterior translation and kyphosis of S1 in relation to S2. Postoperative imaging demonstrates overall improved alignment with less anterior translation and increased lordosis and safe juxtacortical transsacral screw placement.

Figure 3, **Supplemental Digital Content 3**, http://links.lww.com/JOT/B555). The entry point of the pedicle screw is defined by the inferior border of the superior facet of S1. The superficial cortex of the entry point is opened with a burr. A pedicle gearshift is used to establish the trajectory of the planned screw down the pedicle into the vertebral. The trajectory is 30 degrees medial with the cranial caudal direction defined by aiming toward the promontory. Fluoroscopy confirms position using a pedicle sounding probe in tunnel at S1 promontory. This should position the pedicle screw in the upper region of the pedicle and therefore minimizes the intrusion into the osseous fixation pathway of any S1 iliosacral or transsacral screw. Regarding the iliac bolt placement, by remaining low in the posterior ilium to anterior inferior iliac spine, osseous fixation pathway, the S1 pathway for IS, or transsacral (TS) screws remain unobstructed.

The titanium rods, typically 6.35 mm in diameter, are hand contoured to facilitate fracture reduction and restoration of lower lumbosacral lordosis. By overcontouring the rods into hyperlordosis, the reduction is facilitated by translating the pelvis (relative to the spine and sacrum), thus restoring pelvic anteversion and lumbar lordosis (see **Figure 4**, **Supplemental Digital Content 4**, http://links.lww.com/JOT/B556). Bilateral S1 pedicle screws serve as the critical hinge. The contoured rods are first attached to the distal iliac bolts and then reduced to the L5 and S1 pedicle screws bilaterally using reduction tower instrumentation and rod holders. The S1 pedicle screws allow the upper lumbosacral segment to be directly manipulated in multiple planes through compression-distraction and rod recontouring to disimpact and/or reduce the fracture, as opposed to indirect reduction when bypassing the S1 level using the traditional L5-ilium technique.[5] This hinge effect corrects both the upper sacral fragment translation and kyphosis while distraction along the rods can reestablish length or disengage the fracture surfaces so that the kyphosis can be reduced (see **Figure 4**, **Supplemental Digital Content 4**, http://links.lww.com/JOT/B5576).

FIGURE 2. A, Inlet fluoroscopic image. B, Outlet fluoroscopic image. C, Lateral fluoroscopic image. D, Postoperative CT.

Reduction of the kyphotic deformity restores the central portion of the S1 osseous fixation pathway, thus allowing for iliosacral/transsacral screw placement. Therefore, all iliosacral/transsacral screws were placed after the reduction was obtained and rods tightened.[14–17] The advantages of implanting these sacral screws are that the perpendicular vector to the fracture lines prevents displacement from shear forces and these screws provide rotational stability.[18,19] The decision to perform sacral decompression was performed on a case-by-case basis based on patient's neurologic status, intraoperative findings of nerve root compression, and CT findings of nerve root compression. Decompression is performed last as the best decompression is an anatomic reduction and restoration of the normal anatomic neural foramen.

In general, there are 2 different fracture displacement scenarios, each that require a different reduction technique. The first scenario is impaction of the S1 fracture with posterior translation and kyphosis of the proximal fragment (see **Figure 5**, **Supplemental Digital Content 5**, http://links.lww.com/JOT/B557). Reduction of this requires distraction, kyphosis correction, anterior translation, and then release of the distraction to allow reimpaction. Hyperlordotic bending of the rod helps with the anterior translation and kyphotic deformity by using tower reducers to bring the rod to the pedicle screws, hence aligning the fracture. Contouring the rod is based on the patient's estimated preinjury lordotic curve and then about 20 degrees added. If the reduction desired is not obtained, then the rod is recontoured differently and reduction reattempted. Occasionally, the use of an osteotome can help with disengagement for distraction and flip up the S1 proximal fragment to correct kyphosis. As the fracture properly reduces, we have not had issue with the rod not lining up with the pedicle screws or bolts because the native anatomy is restored.

In the second scenario, there is anterior translation with spondyloptosis of the S1 proximal fracture fragment (see **Figure 6**, **Supplemental Digital Content 1**, http://links.lww.com/JOT/B558). This fracture reduction requires distraction, posterior translation, and then release of distraction. Distraction and reimpaction/compression are same as previous technique. For posterior translation, using the towers to bring the screws and accompanying bone to the under contoured rod helps correct the displacement. In addition, a bone hook can be helpful to pull the displacement anterior fragment and a ball spike to keep the distal fragment steady. The S1 pedicle screws here again facilitate a better reduction by giving a point of contact for direct pull.

RESULTS

Demographics and Associated Injuries

Forty-three SPD injuries were identified and 20 patients with U-type/H-type SPD met inclusion criteria (Table 1).

Sixty percent of patients were female, and the average age was 37.6 (range 20–71) years. The average patient BMI was 32.1 (range 17.6–120). Fifty-five percent of patients had at least 1 medical comorbidity, including 35% of all patients being smokers and 10% of all patients having diabetes. The most common mechanism of injury was due to motor vehicle collision at 35% and suicide attempt at 15%. The average Injury Severity Score was 33.5 (range 14–57) with 65% of patients having an associated visceral injury and 60% having an associated orthopaedic injury.

Pelvis Morphology, Fracture Characteristics, and Implants

All fractures consisted of U-type and H-type fractures (Table 1). Using the Roy–Camille classification scheme, most were type III (14/20), with the remainder split between type II (5/20) and type I (1/20). Six of the 20 patients treated had sacral dysmorphism.[20]

Anterior pelvic ring injuries occurred in 12 patients, and all underwent fixation with either a plate or intramedullary screw. L5/S1 facet disruption was seen in 60% of patients, with 8 cases involving the bilateral facets. All patients had pedicle screws placed at both the L5 and S1 levels bilaterally. Postoperative CTs demonstrated all iliac bolts and pedicle screws were intraosseous.

The 6 patients with sacral dysmorphism had S1 iliosacral screws placed bilaterally, and 3 of those patients were supplemented with a TS screw at S2 when the transverse component was in the caudal aspect of the S2 body. The other 14 patients all had S1 TS screws placed. There were 14 TS screws at S1, 10 iliosacral screws at S1, and 3 TS screws at S2. No screws were extraosseous, 2 screws were juxtacortical, and the rest were intraosseous.[15,16]

Fracture Reduction, Surgical, and Clinical Outcomes

For reduction, translational displacement improved from a mean of 55.9%–19.3% ($P < 0.01$, ICC 0.801) (Tables 2 and 3). Preoperative axial, sagittal, and vertical fracture displacement improved postoperatively from 17.2 to 4.7 mm ($P < 0.01$, ICC 0.762), 12.4 to 3.2 mm ($P < 0.01$, ICC 0.778), and 10.3 to 2.5 mm ($P < 0.01$, ICC 0.767), respectively. Kyphotic angulation improved from 24.7 degrees to 14.3 degrees ($P < 0.01$, 0.709). Sacrococcygeal angle improved on average by 6.8 degrees ($P < 0.01$, ICC 0.677).

Average time to the OR was 3.5 days (range 1–18 days). Neural decompression was performed in 50% of cases. Fifteen patients presented with neurologic deficits secondary to their injury. The average preoperative Gibbons score was 2.7 which improved to 1.7 postoperatively ($P < 0.01$). There was no

TABLE 1. Patient Demographics, Injury Characteristics, and Fixation Construct for All 20 Patients in Study

Patient	Age/Sex	ISS	Sacral Dysmorphism	Fracture Type	L5/S1 Facet Involvement	Anterior Ring Involvement	Anterior Ring Fixation	S1 Pedicle Fixation	L5 Pedicle Fixation	L4 Pedicle Fixation	S1 Sacral Fixation	S2 Sacral Fixation
1	24M	34	No	U	Yes	Yes	Plate	Yes	Yes	No	TI-TS	No
2	32F	25	No	U	Yes	No	—	Yes	Yes	No	TI-TS	No
3	71F	9	No	U	No	Yes	Screws	Yes	Yes	No	TI-TS	No
4	29F	57	Yes	U	No	Yes	Screws	Yes	Yes	No	IS bilateral	No
5	40F	57	Yes	H	Yes	Yes	Plate	Yes	Yes	Yes	IS R	Yes TI-TS
6	27F	16	No	U	Yes	No	—	Yes	Yes	No	TI-TS	No
7	31F	41	No	U	Yes	No	—	Yes	Yes	No	TI-TS	No
8	26M	36	No	U	Yes	Yes	Plate	Yes	Yes	No	TI-TS	No
9	67M	34	No	U	No	No	—	Yes	Yes	No	TI-TS	No
10	26M	41	No	U	Yes	No	—	Yes	Yes	Yes	TI-TS	No
11	43F	41	No	H	No	Yes	Plate	Yes	Yes	Yes	TI-TS	No
12	37M	18	No	U	Yes	No	—	Yes	Yes	No	TI-TS	No
13	22M	17	No	U	No	No	—	Yes	Yes	No	TI-TS	No
14	23F	48	Yes	H	Yes	Yes	Plate	Yes	Yes	No	IS bilateral	Yes TI-TS
15	20F	41	Yes	U	Yes	Yes	Screws	Yes	Yes	Yes	IS bilateral	No
16	24M	24	No	U	Yes	No	—	Yes	Yes	No	TI-TS	No
17	43F	36	Yes	H	No	Yes	Screws	Yes	Yes	No	IS L	Yes TI-TS
18	68F	10	No	U	No	Yes	Screws	Yes	Yes	No	TI-TS	No
19	66M	48	Yes	U	No	Yes	Plate	Yes	Yes	No	IS bilateral	No
20	32F	36	No	U	Yes	Yes	Screws	Yes	Yes	No	TI-TS	No

TI-TS, transiliac-transsacral; ISS, Injury Severity Score; IS, iliosacral.

statistically significant difference in postoperative Gibbons scores between patients who did have a decompression and those who did not. Two patients improved from 4 to 1 after the procedure. The operative estimated blood loss averaged 785 mL (range 119–2,000) and total OR time averaged 300 minutes (range 133–467) with fluoroscopy time averaging 208 seconds (range 101–312). The mean length of stay in the hospital was 32 days (range 3–118 days). The mean clinical follow-up was 12 months. All patients went on to union with radiographic union diagnosed at an average of 55.5 days (range 29–113 days). The presence of decompression/laminectomy did not affect union or stability. Seventy percentage of patients were ambulating at their last follow-up and 40% ambulating without assistive device. Forty percentage of patients had returned to work and/or school.

Complications and Sequalae

There were 2 (10%) complications. One was a surgical site infection above the level of the fascia that resolved without sequela after I&D and antibiotic treatment. The other complication was a deep surgical site infection (subfascial) in a patient with a large Morel-Lavallée lesion over the surgical site with resulting osteomyelitis that required multiple irrigation and debridement procedures, antibiotic treatment, and ultimately instrumentation removal. Infections were not statistically related to having spinal decompression or not. One additional patient had their instrumentation removed electively. There were no rod or screw fractures, nonunions, iatrogenic nerve injuries, or mortality noted in this patient series.

DISCUSSION

Lumbopelvic fixation was developed in response to the difficulty of obtaining a sufficiently rigid construct in the setting of SPD injuries.[2,4,5,21–23] Theoretically, lumbopelvic fixation unloads the damaged sacrum, bypassing it with fixation into the lumbar spine and ilium, thus reconnecting the hemipelvis to the axial skeleton.[5] The standard lumbopelvic fixation construct involves L5, with or without L4, pedicle screw fixation while bypassing the S1 level. This spanning of the lumbosacral joint may result in instability, causing complications such as residual fracture gaps, loss of reduction, fixation failure, or nonunion leading to decreased patient functional outcomes, increased risk of neurologic injury, increased patient pain, and increased risk of revision surgery.[24–26] We describe a unique modification of the original lumbopelvic fixation construct by including instrumentation of the S1 pedicles while still enabling percutaneous placement of iliosacral or transsacral screws at the S1 level, resulting in improved alignment, enhanced stability, and radiographic union. Our study demonstrates the fracture reduction benefits of this technique in SPD U-type/H-type bilateral sacral fractures with sacral kyphosis.

Our reduction technique is fundamentally different than the traditional method. The current practice discourages attempting reduction by distraction along the spinopelvic rod because the fracture gap may widen, potentially increasing the risk of nonunion.[5] In addition, as the L5/S1 facet joint is commonly disrupted, distraction was believed to cause tilting of the L5 vertebral body in the coronal plane.[5] However, our technique of placing a point of fixation in the upper sacral segment through the S1 pedicle enables the reduction to be achieved directly. Instrumenting the S1 pedicle facilitates the "hinge effect"; the upper sacral segment, through the spinopelvic rod, can be translated in relation to the lower sacral segment, eliminating the incorrect vector and distraction concerns (see **Figures 4 and 7**, **Supplemental Digital Contents 1 and 7**, http://links.lww.com/JOT/B556 and http://links.lww.com/JOT/B559, respectively). Furthermore, the fracture fragments can be disimpacted through distraction along the rod using lamina spreader.

TABLE 2. Average Neurologic Preoperative Score and Fracture Characteristics of 20 Patients

Preoperative Injury Characteristics	Average	SD	Range
Gibbons score	2.7	±1.2	1–4
L5-S1 facet involvement	60%	—	—
Bilateral L5-S1 facet involvement	40%	—	—
Denis classification			
	I	15%	—
	II	20%	—
	III	65%	—
Fracture displacement (%)	55.9%	±38.2%	10.3–193
Fracture displacement (mm)			
AP	17.2	—	—
Sagittal	12.4	—	—
Vertical	10.3	—	—
SCA	86.2	±23.4	39–119
Kyphosis	24.7	±19.5	0–64
Anterior ring involvement	60%	—	—
Sacral dysmorphism	20%	—	—

TABLE 3. Average Postoperative Neurologic Score and Fracture Characteristics After Definitive Fixation Using Described Technique.

Postoperative Injury Characteristics	Average	SD	Range	P*
Gibbons score	1.7	±1.2	1–4	<0.01
Fracture displacement (%)	19.3%	±19.5%	0–97	<0.01
SCA	79.4	±20.4	33–117	<0.01
Kyphosis	14.3	±13.8	0–43	<0.01
Anterior ring fixation	12	—	—	—
	Screws	6	—	—
	Plate	6	—	—
Fracture displacement (mm)				
AP	4.7	±3.6	0–14.6	<0.01
Sagittal	3.2	±1.9	0–7	<0.01
Vertical	2.5	±4.1	0–18	<0.01

*P-value from comparison of same variables from Table 2 preoperative to postoperative in Table 3.

SCA, sacrococcygeal angle.

The use of the spinopelvic rods for reduction enables a greater anatomic reduction because it generates more force and hence mobility compared with using Schanz pin joysticks, bone hooks, AO universal distractor, or other reduction tools.[27] The dissociated pelvis is typically retroverted and dorsal, and by using the rods with a hinge at S1, the pelvis can be anteverted and translated ventrally, restoring normal lumbar lordosis and pelvic alignment directly.

Essential differences in implant placement exist with our modified technique. Previous literature has dissuaded surgeons from S1 pedicle instrumentation over concerns of screw safety, dubious mechanical value, and decreasing space for iliosacral and transsacral screws.[6] In our series, the S1 pedicles were able to be safely instrumented in all patients (Fig. 2). The lumbopelvic fixation occurring first in the sequence facilitates reduction and establishes the iliosacral/transsacral osseous fixation pathway. To avoid blocking the S1 iliosacral/transsacral osseous fixation pathway, the S1 pedicle screw must be appropriately cranial in the S1 pedicle and sacral body. In addition, the iliac bolts are placed as caudal as possible because it courses from the posterior ilium toward the anterior inferior iliac spine. Although technically demanding, the iliosacral/transsacral screws were all still able to be placed safely. The iliosacral/transsacral screws help provide additional rotational stability, but compression of the bilateral sacral fractures is typically achieved with side-to-side compression between the spinal rods using a crosslink. This can happen in conjunction with final tightening of the S1 TS screw as well.

Reduction results of our modified technique compare favorably with those reported in previous literature.[4,6,7] Specifically, kyphotic angulation was improved by 10 degrees, whereas previous reports range from 1 to 22 degrees.[4,6,28–30] We were further able to directly measure the quality of our reductions using contemporary imaging multiplanar reconstructions. Eighty-five percentage of our reductions in the axial, sagittal, and coronal planes were within 5 mm of anatomic, whereas the limited literature on these measurements report 58% of reductions within 5 mm but only in a single plane.[26]

Considerable neurologic improvement postoperatively was noted in our patient cohort. Of the patients who had preoperative neurologic deficits, over 90% had some neurologic improvement after treatment. Previous literature has shown rates of 78%–97%.[26,28,29] Our average improvement in Gibbons score was 1 point, similar to the 1.2 previously reported.[4,29] Postoperatively, our patients were all allowed to be weight-bearing as tolerated. At 1 year, 70% were fully ambulatory and 40% had returned to work/school. No iatrogenic neurological injuries were observed in this patient cohort.

Fracture stability and bony healing were achieved with this modified technique. All fractures went onto union, no fracture collapse occurred, and no progression of kyphosis was observed in our case series compared with the 3%–9% rate noted in the literature.[26,30] This could be multifactorial, but we believe the shorter working length of our fixation construct achieved by inclusion of the S1 pedicle screws is a major contributor. This construct has proven to be clinically safe for early mobilization and weight-bearing to promote rehabilitation. By avoiding the rod spanning of the upper sacral segment, an inherent weak point in the traditional construct, and by placing iliosacral or transsacral screws, we did not see any instrumentation failure, nonunion, or loss of reduction.

The role of open surgical stabilization versus percutaneous stabilization remains controversial. Recently, percutaneous lumbopelvic fixation has been developed to decrease the physiological burden. Although the historical incidence of wound healing issues with open lumbopelvic fixation has been reported as high as 26%, the incidence was 10% in this patient cohort.[24] A meticulous open approach facilitates ease of decompression of the sacrum and allows for direct reduction without increasing risk of infection.

There are limitations to our study; the first being those inherent to any retrospective case series, including selection bias and lack of case-matched control patients. However, SPD injuries are rare, and the literature regarding the subject is largely based on case series.[7,31] Second, we examined only bilateral, high-energy, displaced SPD U-type/H-type fractures with sacral kyphosis. We excluded vertically displaced sacral fractures because the reduction techniques for these injuries are fundamentally different. In addition, this study only demonstrates circumstantial evidence of a proposed mechanical advantage with clinical benefits of this construct. We do have a biomechanical study ongoing to objectively evaluate the mechanics of our modified S1-technique construct compared with the current standard construct. Finally, although we had adequate follow-up of these patients, prospective patient-reported outcomes are not routinely collected, and we used surrogates such as ambulation and return to work to assess patient functionality.

In conclusion, our modified open bilateral lumbopelvic fixation technique using S1 pedicle screw fixation and S1 iliosacral or transsacral screw placement results in improved fracture reduction, improved postoperative neurologic status, and improved patient return of function. Despite the open exposure, soft tissue complications were rare. When treating SPD, consideration should be given to instrumenting the S1 pedicle to enable the hinge reduction maneuver. Further biomechanical studies and larger, collaborative multicenter studies may prove helpful in determining the optimal construct for different injuries on the spectrum of instability in SPD.

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