Technique for Lumbar Pedicle Subtraction Osteotomy for Sagittal Plane Deformity in Revision

Ravi Patel, MD, Safdar N. Khan, MD, M. Craig McMains, MD, and Munish Gupta, MD

Abstract

Pedicle subtraction osteotomies are being used with increasing frequency to treat the problem of sagittal imbalance caused by a variety of diseases. Here we describe a simple technique that assists in osteotomy closure and has proved effective and reliable in maintaining correction.

Pedicle subtraction osteotomies (PSOs) have been used in the treatment of multiple spinal conditions involving a fixed sagittal imbalance, such as degenerative scoliosis, idiopathic scoliosis, posttraumatic deformities, iatrogenic flatback syndrome, and ankylosing spondylitis. The procedure was first described by Thomasen[1] for the treatment of ankylosing spondylitis. More recently, multiple centers have reported the expanded use and good success of PSO in the treatment of fixed sagittal imbalance of other etiologies.[2,3] According to Bridwell and colleagues,[2] lumbar lordosis can be increased 34.1°, and sagittal plumb line can be improved 13.5 cm.

PSO is a complex, extensive surgery most often performed in the revision setting. Multiple authors have described the technique for PSO.[4,5] There are significant technical challenges and many complications, including neurologic deficits, pseudarthrosis of adjacent levels, and wound infections.[6] Short-term challenges include a large loss of blood, 2.4 L on average, according to Bridwell and colleagues.[6] Time of closure of the osteotomy gap is a crucial point in the surgery. Blood loss, often large, slows only after the gap is closed and stabilized.

In this article, we describe a technique in which an additional rod or pedicle screw construct is used at the peri-osteotomy levels to close the osteotomy gap during PSO and simplify subsequent instrumentation. In addition, we report our experience with the procedure.

Materials and Methods

Seventeen consecutive patients (mean age, 58 years; range, 12-81 years) with fixed sagittal imbalance were treated with lumbar PSO. The indication in all cases was flatback syndrome after previous spinal surgery. Mean follow-up was 13 months. Mean number of prior surgeries was 3. Thirteen PSOs were performed at L3, and 4 were performed at L2.

Radiographic data were collected from before surgery, in the immediate postoperative period, and at final follow-up. All the radiographs were standing films. Established radiographic parameters were measured: thoracic kyphosis from T5 to T12, lumbar lordosis from L1 to S1, PSO angle (1 level above to 1 level below osteotomy level), sagittal plumb line (from center of C7 body to posterosuperior aspect of S1 body), and coronal plumb line (from center of C7 body to center of S1 body).[2]

Good clinical outcomes in the treatment of spinal disorders require careful attention to the alignment of the spine in the sagittal plane.[7,8] When evaluating the preoperative radiographs, we measured and documented pelvic parameters. **Figure 1A** shows how pelvic incidence was determined. We measured this as the angle between a line drawn from the center of the S1 endplate to the center of the femoral head and the perpendicular off the S1 endplate. **Figure 1B** shows pelvic tilt as determined by the angle between a line drawn from the center of S1 to the femoral head and a vertical line originating from the center of the femoral head. **Figure 1C** shows the sacral slope, which we measured as the angle between a line drawn parallel to the endplate of S1 and its intersection with a horizontal line.

Surgical Technique

The overall surgical technique for PSO has been well described.[4,5] Here we describe the "outrigger" modification to osteotomy closure (**Figures 2, 3**).

Most of our 17 cases were revisions. In these cases, new fixation points are first established. All fixation points that will be needed for the final fusion are placed. If a pedicle above or below the osteotomy level is not suitable for a screw, it can be skipped.

Wide decompression of the involved level is performed from pedicle to pedicle, ensuring that the nerve roots are completely decompressed. The dissection is then continued around the lateral wall of the vertebral body. While the neural elements are protected with gentle retraction, the pedicle and a portion of the posterior aspect of the vertebral body are removed with a combination of a rongeur and reverse-angle

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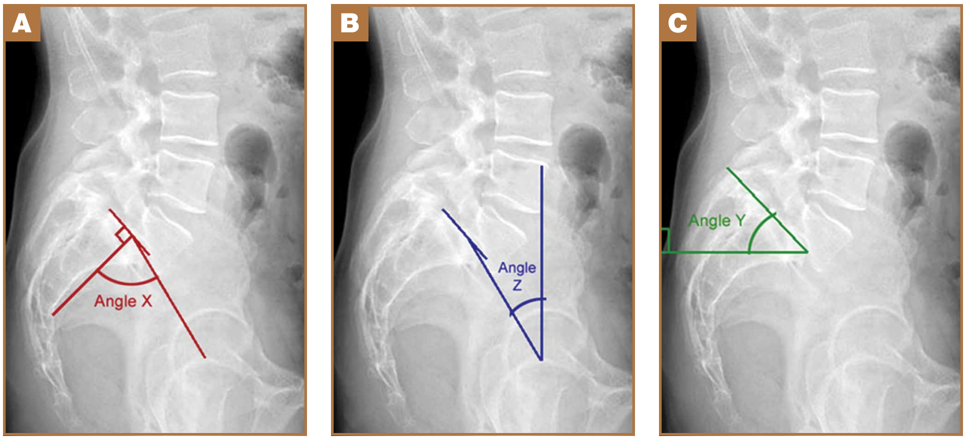

Figure 1. Pelvic parameters. (A) Pelvic incidence is angle between line drawn from center of S1 endplate to center of femoral head and perpendicular off S1 endplate. (B) Pelvic tilt is angle between line drawn from center of S1 to femoral head and vertical line originating from center of femoral head. (C) Sacral slope is angle between line drawn from center of S1 to femoral head and vertical line originating from center of femoral head. Reprinted with permission from Orthobullets. Moore D. Adult isthmic spondylolisthesis. Orthobullets website. http://www.orthobullets.com/spine/2038/adult-isthmic-spondylolisthesis. Updated February 11, 2015. Accessed March 19, 2015.

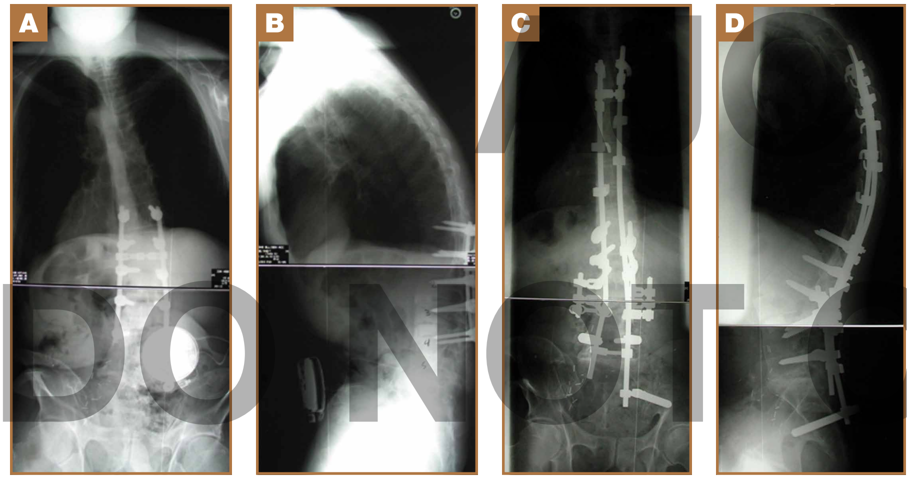

Figure 2. (A) Preoperative anteroposterior radiograph. (B) Preoperative lateral radiograph shows prior lumbar fusion and sagittal decompensation. (C) Postoperative anteroposterior radiograph. Note outrigger rods at level of pedicle subtraction osteotomy. (D) Postoperative lateral radiograph shows improved sagittal alignment.

curettes. Resection of the vertebral body can be facilitated by attaching a short rod to the pedicle screws on either side of the osteotomy level and using it to provide gentle distraction.

Once sufficient bone has been removed to close the osteotomy, short rods are placed in the pedicle screws in the level above and the level below the osteotomy site. These rods are attached with offset connectors that allow the rods to be placed lateral to the screws. Before the surgical procedure is started, the patient is positioned on 2 sets of posts separated by the break in the table. The break in the table allows flexion to accommodate the preoperative kyphosis and allows hyperextension to help close the osteotomy site. Now, with the osteotomy site ready for closure, the table is gradually positioned in extension along with a combination of posterior pressure and compression between the pedicle screws above and below the osteotomy. Once the osteotomy is adequately compressed, the short rods are tightened, holding the osteotomy in good position. With the osteotomy held by the short rods and table positioning, decompression of the neural elements is confirmed and hemostasis obtained.

Final instrumentation is then performed with long rods that can bypass the osteotomized levels, allowing for simpler contouring. If desired, a cross connector can be placed between the long rod of the fusion construct and the short rod holding the osteotomy. The rest of the fusion procedure is completed in standard fashion with at least 1 subfascial drain.

Results

Our 17 patients' results are summarized in the **Table**. Mean sagittal plumb line improved from 17.7 cm (range, 5.9 to 29 cm) before surgery to 4.5 cm (range, –0.2 to 12.9 cm) after surgery, for a mean improvement of 13.2 cm. At final follow-up, mean sagittal plumb line was 5.1 cm (range, –1.4 to 10.2 cm).

Mean lumbar lordosis improved from 10° (range, –14° to 34°) before surgery to 49° (range, 36° to 63°) after surgery, for a mean improvement of 39°. Mean PSO angle improved from 3° (range, –36° to 23°) before surgery to 41° (range, 25° to 65°) after surgery, for a mean improvement of 38°. At final follow-up, mean lumbar lordosis remained at 47° (range, 26° to 64°), and mean PSO angle was 39° (range, 24° to 59°).

Mean thoracic kyphosis improved from 18° (range, –8° to 52°) before surgery to 30° (range, 3° to 58°) after surgery, for a mean improvement of 12°. At final follow-up, mean thoracic kyphosis was 31° (range, 2° to 57°).

Fourteen patients did not have complications during the study period. Of the 3 patients with complications, 1 had an early infection, treated effectively with irrigation and débridement and intravenous antibiotics; 1 had a late deep infection, treated with multiple débridements, hardware removal, and, eventually, suppressive antibiotics; and 1 had cauda equina

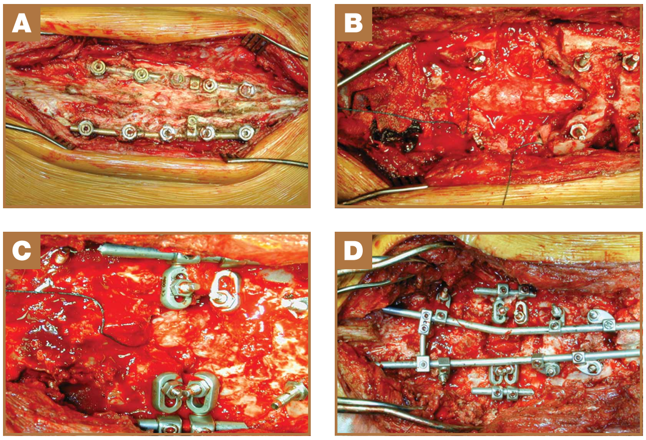

Figure 3. (A) Intraoperative view after exposure of prior hardware and fusion mass. (B) Old hardware removed, new points of fixation placed, and extensive decompression performed at level of pedicle subtraction osteotomy from pedicle to pedicle with wide decompression of nerve roots. (C) Osteotomy closed with combination of extending table and compressing the 2 periosteotomy pedicle screws. Short "outrigger" rod placed to hold correction. (D) Final fixation leaves short rods in place, easily maintaining correction.

syndrome (caused by extensive scar tissue on the dura, which buckled with restoration of lordosis leading to cord compression), treated with duraplasty, which resulted in full neurologic recovery.

Discussion

In the present series of patients, the described technique for facilitating PSO for correction of sagittal imbalance was effective, and complications were similar to those previously reported.

The benefit of the outrigger construct is that it allows controlled compression of the osteotomy site and can be left in place at time of final instrumentation, locking in compression and correction. Other techniques involve removing the temporary rod and replacing it with final instrumentation[4,5]—an extra step that complicates instrumentation of the additional levels of the fusion construct and possibly adds pedicle screw stress and contributes to loosening when the new rod is reduced to the pedicle screw. The final long rod construct can bypass the osteotomy levels and allow for simpler instrumentation.

Mean age was 58 years in this series versus 52.4 years in the series reported by Bridwell and colleagues.[2] Given the higher

Table. **Demographics and Radiographic Parameters**[a]

Patient	Age, y	Sex	Follow-Up, mo	Prior Surgery, n	PSO Level	Fusion Levels	Sagittal Balance, cm			Lumbar Lordosis, °			PSO Angle, °			Thoracic Kyphosis, °		
							Pre	Post	Final	Pre	Post	Final	Pre	Post	Final	Pre	Post	Final
1	38	F	55	3	L3	T12–S1	5.9	−0.2	−0.8	34	55	44	1	25	25	18	26	23
2	63	M	0	2	L3	T2–pelvis; L5–S1 ASF	18.2	8.2	—	24	50	—	10	48	—	32	35	—
3	80	F	0	1	L3	T5–pelvis	23.4	4.2	—	−9	47	—	2	46	—	14	27	—
4	63	M	16	4	L3	L5–S1 ASF; T11–sacrum PSF	29	8.1	10.1	17	54	57	23	54	53	33	46	49
5	77	F	11	2	L3	T5–pelvis	7.1	−0.1	−1.4	2	47	51	6	38	44	10	43	49
6	70	F	56	2	L3	L1–L5	11	3.3	3.1	26	63	61	10	65	59	15	14	22
7	57	M	11	8	L2	T5–pelvis PSF, then HWR	15.6	6.1	10.2	24	58	51	18	40	40	38	47	40
8	65	M	4	1	L3	T11–pelvis	14.8	4.3	4.8	1	36	42	−13	30	30	23	27	47
9	81	M	4	3	L3	T5–pelvis	26.1	4.4	16	−6	38	34	−11	38	33	10	33	27
10	64	F	6	2	L2	T4–pelvis	17.5	2.3	3.2	−14	38	35	−36	29	24	−6	23	22
11	56	F	8	4	L2	T10–pelvis	8.6	4.3	0.8	16	63	64	14	52	41	0	27	24
12	51	F	7	3	L3	T3–pelvis	20.3	4.1	5.7	11	36	35	6	37	33	5	3	2
13	50	M	13	3	L3	T4–pelvis; L5–S1 ASF	21	6	7.6	11	37	26	2	32	32	−8	16	11
14	53	M	19	2	L3	T6–pelvis	18.5	4.5	4.8	0	38	39	−2	42	43	52	58	57
15	44	F	3	1	L3	T10–pelvis PSF; L5–S1 ASF	20.1	4.1	4.3	11	57	59	10	37	47	15	18	26
16	12	F	12	1	L3	T2–pelvis	23.2	0.3	0.4	19	55	54	13	45	46	10	12	15
17	69	M	7	8	L2	T4–pelvis	20.6	12.9	7.6	4	56	54	−11	39	35	36	49	53

Abbreviations: ASF, anterior spinal fusion; HWR, hardware removal; Post, postoperative; Pre, preoperative; PSF, posterior spinal fusion; PSO, pedicle subtraction osteotomy.
[a]The diagnosis was degenerative disc disease for all patients, except patient 16 (diagnosis, isthmic spondylolisthesis). The only early complications were deep infection (patient 3) and cauda equina, which was resolved with duraplasty (patient 17); the only late complication was osteomyelitis, which required hardware removal (patient 7).

mean age of our patients, though no objective measures of bone quality were available, this technique is likely applicable to patients with poor bone quality.

The complications we have reported are in line with those reported in previous series, and maintenance of radiographic parameters at final follow-up indicates that this osteotomy technique allows for solid fusion constructs.

The outrigger technique for controlling PSO closure is an effective method that simplifies instrumentation during a complex revision case.

Dr. Patel is Attending Physician, Department of Orthopaedic Surgery, Mercy Hospital, Sacramento, California. Dr. Khan is Assistant Professor, and Dr. McMains is Resident Physician, Department of Orthopaedics, Ohio State University, Columbus, Ohio. Dr. Gupta is Professor, Co-Director of Spine Center, and Chief of Orthopaedic Spinal Disorders Service, Department of Orthopaedic Surgery, University of California at Davis Medical Center, Sacramento, California.

Address correspondence to: Safdar N. Khan, MD, Department of Orthopaedics, Ohio State University, 725 Prior Hall, Columbus, OH 43210 (tel, 614-293-2165; fax, 614-293-4755; e-mail, safdar.khan@osumc.edu).

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