Pedicle Subtraction Osteotomy for Kyphosis Following Lumbar Fusion Surgery

Kazuyuki Otani[1)], Shigeo Shindo[1)], Koichi Mizuno[1)], Kazuo Kusano[1)], Norihiko Miyake[1)], Takashi Taniyama[1)], Osamu Nakai[1)] and Atsushi Okawa[2)]

1) Department of Orthopaedic Surgery, Kudanzaka Hospital, Tokyo, Japan
2) Department of Orthopaedic Surgery, Tokyo Medical and Dental University, Tokyo, Japan

Abstract:

Introduction: Pedicle subtraction osteotomy (PSO) is performed to correct sagittal plane deformity. This procedure is useful with revision cases in which the number of intact discs for correction is limited.

Methods: Forty-four patients (10 male and 34 female) with minimum follow-up of 2 years were reviewed; all had undergone PSO revision surgery for kyphosis following previous lumbar fusion surgery. The average age at operation was 72.8 years (range 42-85 years), and the average follow-up period was 4.1 years (2-9 years). The average fusion level was 7.5 (4-13 level), and the average previously fused level was 2.4 (1-7 level).

Results: The average operation time was 424 min, and average blood loss was 2880 g. The average JOA score of 14.0 before operation changed to 21.8 at 1-year follow-up and to 20.7 at final follow-up. The average recovery rate at final follow-up was 45.7%. Four patients underwent re-operations for proximal junctional kyphosis and 3 patients for rod fracture. The fusion rate was 88.6%, and 13 patients (29.5%) developed subsequent vertebral fracture. The average PI-LL (Pelvic incidence minus Lumbar lordosis) at pre-op of 52.9 degrees changed to 3.8 degrees at post-op, to 13.4 degrees at 1-year follow-up, and to 14.8 degrees at final follow-up. The average correction at the PSO site was 36.0 degrees at post-op, 36.7 degrees at 1-year follow-up, and 37.0 degrees at final follow-up. The average sagittal vertical axis at pre-op of 145.0 mm decreased to 51.2 mm at 1-year follow-up; however, it increased to 75.3 mm at final follow-up.

Conclusion: PSO for correction of kyphosis following previous lumbar fusion surgery was an effective procedure without correction loss at the local osteotomy site; however, its surgical invasiveness and complication rate were high. Subsequent vertebral fracture, adjacent segment degeneration, and rod fracture contribute to deterioration of outcome that is evident at long-term follow-up.

Keywords:

pedicle subtraction osteotomy, kyphosis, revision surgery, proximal junctional kyphosis

Spine Surg Relat Res 2018; 2(3): 221-225
dx.doi.org/10.22603/ssrr.2017-0059

Introduction

Proximal junctional kyphosis (PJK), proximal junctional fracture, and iatrogenic kyphosis following previous malalignment fusion surgery often lead to sagittal plane imbalance, which requires correction surgery, and to primary adult spinal deformity. Correction of kyphosis at disc level - such as through multilevel posterior interbody fusion (PLIF)[1)], dorsal ventral dorsal correction[2)], and lateral lumbar interbody fusion[3)] - is indicated for cases in which several intact discs remain. However, for revision cases, the number of intact discs that can be used for kyphosis correction is limited, and pedicle subtraction osteotomy (PSO) that can correct kyphosis at the vertebral body is indicated in most cases.

The purpose of this study was to investigate clinical and radiological results of PSO for correction of kyphosis following lumbar fusion surgery and to determine the efficacy and the limitations of this procedure.

Materials and Methods

A retrospective review of 44 patients (10 male and 34 fe-

Corresponding author: Kazuyuki Otani, ootani_k@kudanzaka.com
Received: August 5, 2017, Accepted: November 8, 2017, Advance Publication: March 15, 2018

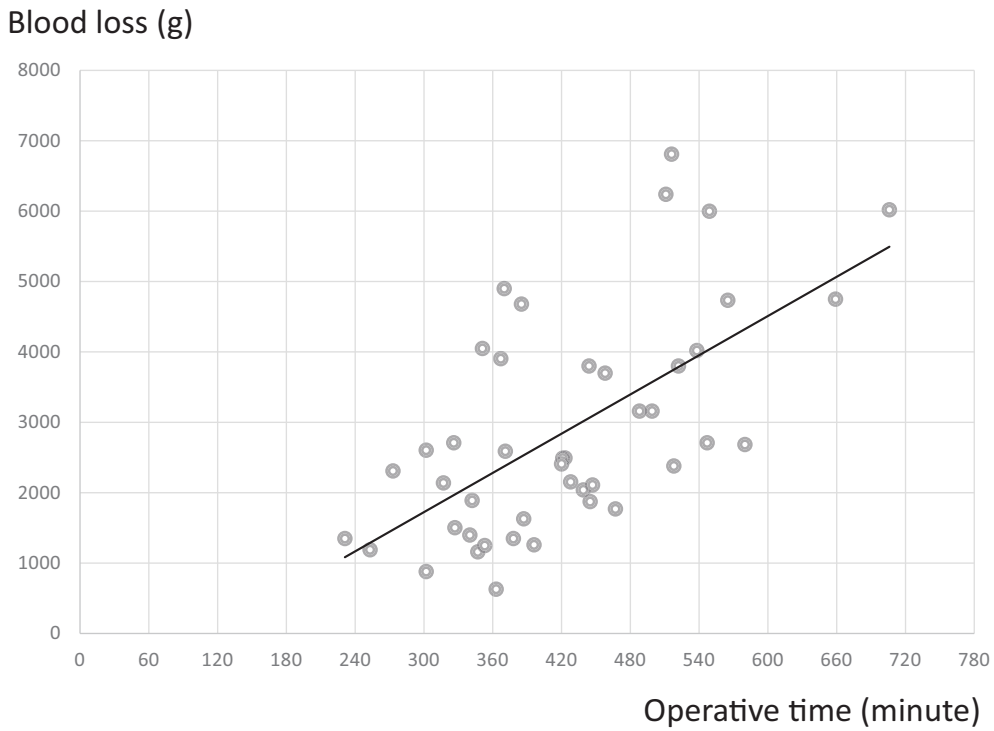

Figure 1. Operation time and estimated blood loss were highly correlated (R=0.623, p<0.001).

male) who underwent PSO for kyphosis following lumbar fusion surgery, with minimum follow-up of 2 years, was performed. The average age at operation was 72.8 years (range 42-85 years), and the average follow-up period was 4.1 years (2-9 years). The average fused level was 7.5 (4-13 level) including the fused level of previous surgery of 2.4 (1-7 level). Our method of PSO was grade 4 osteotomy (Schwab classification)[4], and the partial vertebral body and superior disc were removed as described by Lehmer[5]. The average interval of PSO and previous lumbar fusion surgery was 4.8 years (1-12 years). PSO was performed at the proximal vertebra of the previously fused area in 22 patients, at the upper fused vertebra in 16 patients, at the middle vertebra in the fused area in 1 patient, at the lower fused vertebra in 2 patients, and at the distal vertebra of the fused area in 3 patients. The exact osteotomy level was L1; 1 patient, L2; 11 patients, L3; 26 patients, L4; 4 patients, and L 5; 2 patients. As co-morbidities, 5 patients had Parkinson's disease, 3 patients had depression, 1 patient had rheumatoid arthritis, and 1 patient had Cushing disease.

Surgical invasiveness was evaluated using operation time and estimated intra-operative blood loss. Clinical results was evaluated using the Japanese Orthopaedic Association's 29-points system (JOA score) and visual analog scale (VAS). Intra-operative and post-operative complications were investigated. Radiologically, the fusion rate of the PSO site and fusion area, lordosis in the fused area, lumbar lordosis (LL; L1-S1), thoracic kyphosis (TK; T4-12), sagittal vertical axis (SVA), pelvic tilt (PT), sacral slope (SS), and pelvic incidence (PI) were evaluated[6]. Fusion at the PSO site was defined as no bony gap at the PSO site and no motion observed between standing and supine lateral films, and fusion at the fusion area was defined as having a range of motion of 3 degrees or less on standing flexion-extension lateral film or standing and supine films. The Cobb angle between the PSO vertebra and the superior vertebra was measured to evaluate local correction by PSO.

Statistical analysis was performed using a paired t-test, with a significant p-value of 0.05.

Results

Surgical invasiveness

Average operative time was 424 ± 105 min (231~706 min) and average estimated blood loss was 2880 ± 1557 g (630~6810 g). Forty-three patients (98%) required blood transfusion (27 patients; autologous blood only, 11 patients; autologous and allogeneic blood, and 5 patients; allogeneic blood). Operation time and estimated blood loss were highly correlated (R = 0.623), as shown in Fig. 1.

Clinical results

The average JOA score at pre-op of 14.0 ± 3.8 points changed with a significant difference to 21.8 ± 4.3 at 1-year post-op and to 20.7 ± 4.8 at final follow-up. The average low back pain VAS score of 37 patients at pre-op of 67.9 ± 24.2 mm decreased with a significant difference to 36.9 ± 28.7 mm at 1-year post-op and to 39.9 ± 32.5 mm at final follow-up. Leg pain and leg numbness VAS scores had no significant improvement (Table 1).

The reasons for poor outcomes for 10 patients were re-operation for PJK for 4 patients, re-operation for rod fracture for 3 patients, and deterioration of co-morbidity for 3

Table 1. Change of JOA Score and VAS.

	Pre-op	1 year post-op	Final follow-up	*P* value*
JOA score	14.0±3.8	21.8±4.3	20.7±4.8	<0.001
Low back pain VAS (mm)**	67.9±24.2	36.9±28.7	39.9±32.5	<0.001
Leg pain VAS (mm)**	49.3±31.0	41.3±30.7	45.5±32.2	N.S.
Leg numbness VAS (mm)**	47.1±32.3	43.7±30.3	44.2±32.7	N.S.

*: Pre-op - Final follow-up, paired t-test

**: 37 patients since 2007

Table 2. Obtained Correction and Change of Radiological Parameters.

	Pre-op	Post-op	1 year post-op	Final follow-up	*P* value*
Lordosis in fused area (°)	-14.5±22.5	36.2±15.7	25.0±19.5	22.8±19.4	<0.001
Obtained lordosis in fused area (°)		50.7±17.7	39.5±17.9	37.3±17.7	
Correction at PSO site (°)		36.0±9.7	36.7±9.1	37.0±9.2	
TK (°)	23.9±17.2		40.7±15.5	45.1±15.0	<0.001
LL (°)	-2.5±18.0	46.6±10.4	38.7±11.8	37.0±11.4	<0.001
PT (°)	36.3±9.8		27.9±10.2	28.8±10.7	<0.001
SS (°)	14.3±10.8		24.1±11.3	23.9±11.1	<0.001
PI (°)	50.5±12.2		52.1±12.9	51.8±15.0	N.S.
PI-LL (°)	52.9±19.8	3.8±13.5	13.4±14.2	14.8±15.9	<0.001
SVA (mm)	145.0±69.9		51.2±46.7	75.3±56.0	<0.001

*: Pre-op - Final follow-up, paired t-test

patients (depression for 2 patients and Parkinson's disease for 1 patient).

Complications

Six patients developed neurological complications. One patient required re-operation due to L4 root motor deficit at the level of L4 osteotomy, 1 patient developed transient L3 root motor deficit at the level of L3 osteotomy, 3 patients developed transient nerve root irritation and sensory deficit at the osteotomy level (2 patients at L3 and 1 patient at L5), and 1 patient developed transient iatrogenic foraminal stenosis at the lower level of osteotomy. One patient who had osteotomy at the middle vertebra of the fused area developed a dural tear; however, it was repaired without cerebrospinal fluid leakage. Other peri-operative complications included deep vein thrombosis for 3 patients, post-operative delirium for 2 patients, re-intubation due to respiratory dysfunction for 1 patient, and inappropriate blood transfusion without any adverse event for 1 patient.

Re-operations

Eight re-operations were performed in 6 patients. One patient required L4 nerve root decompression following L4 osteotomy immediately at post-op and another re-operation for PJK at 4 years post-op. One patient required re-operation for PJK at 1 month post-op and another re-operation for rod fracture at 2 years post-op. Re-operations for PJK including proximal junctional fracture were performed in 4 patients, and the average interval from PSO was 32 months (1-62 months). Re-operations for rod fracture were performed in 3 patients, and the average interval from PSO was 33 months (20-51 months).

Radiological results

Bone fusion at the PSO site was obtained in 93.2% of patients, and the fusion rate of the fused area was 88.6%. Subsequent vertebral fracture (including sacrum) during the follow-up period was observed for 13 female patients (29.5%). The average PI-LL at pre-op of 52.9 ± 19.8 degrees changed with a significant difference to 3.8 ± 13.5 degrees at post-op, to 13.4 ± 14.2 degrees at 1-year follow-up, and to 14.8 ± 15.9 degrees at final follow-up. The average obtained lordosis in the fusion area was 50.7 degrees at post-op, 39.5 degrees at 1-year follow-up, and 37.3 degrees at final follow-up. The average correction at the PSO site was 36.0 degrees at post-op, 36.7 degrees at 1-year follow-up, and 37.0 degrees at final follow-up. The average SVA at pre-op of 145.0 ± 69.9 mm decreased with a significant difference to 51.2 ± 46.7 mm at 1-year follow-up; however, it increased to 75.3 ± 56.0 mm at final follow-up (Table 2).

Discussion

PSO was described originally for the correction of sagittal plane deformity in ankylosing spondylitis patients[7]; however, recently, this procedure became widely used to correct adult spinal deformity of the thoraco-lumbar spine[8]. PSO performed in patients who had previous spinal fusion can be difficult compared with that of primary cases. The dissection of neural tissue from the scar at the level in which decompression was previously performed is challenging. Gupta et al. reported the finding from a multi-center study comparing

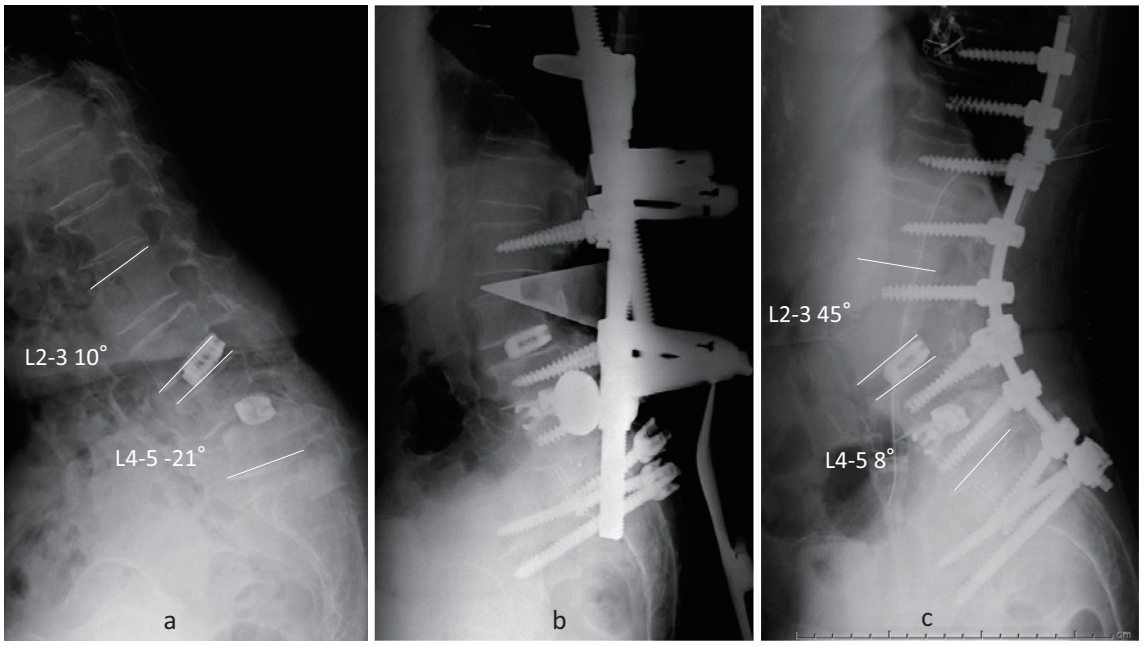

Figure 2.
a. Eighty-year-old female with previous fusion at L3/4/5 by using TLIF 4 years prior to salvage PSO. The pedicle screw system was removed because of implant prominence 1 year before PSO was performed. L4/5 TLIF failed to obtain bone union.
b. PSO at L2/3, L4/5 TLIF revision, and L5/S TLIF was performed.
c. Lordosis was obtained of 35 degrees at L2/3 and of 29 degrees at L4/5.

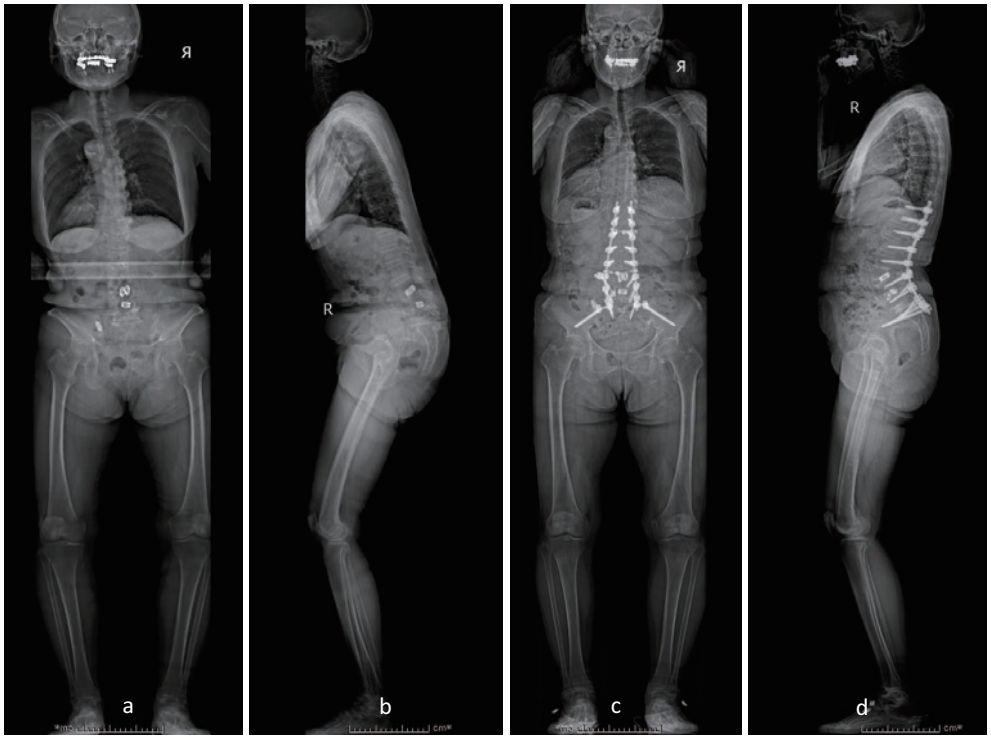

Figure 3.
a, b. Preoperative whole-body X-ray of the patient in Figure 2. TK 12° LL -5° PT 55° SS 15° PI 70° SVA 186 mm TPA 66°.
c, d. Whole-body X-ray at 6 months post-op. TK 30° LL 55° PT 36° SS 36° PI 72° SVA 7mm TPA 28°.

primary and revision groups that PSO was performed in both groups with similar sagittal deformity correction and similar complication rates[9]. In this study, we could also obtain good correction of kyphosis and a high fusion rate; however, we experienced dural tear and neurological complications. PSO can be a strong tool to achieve adequate lumbar lordosis in patients who had previous fusion surgery that led to kyphosis or inadequate lordosis (Fig. 2, 3).

High surgical invasiveness is also a weak point of PSO. Estimated blood loss increased with operation time. Intraoperative bleeding was mainly from cancellous bone at the site of osteotomy and the exposed epidural venous plexus, so surgical planning to perform osteotomy in as short a time as possible will be key to reducing blood loss during operation. Iatrogenic nerve injury, deep vein thrombosis, and delirium were the most-often-observed peri-operative complications. Intra-operative neuromonitoring and intensive postoperative care with team support are necessary to discover complications at an early phase.

Rod fractures following PSO were reported recently as a long-term complication. Smith et al. reported the finding from a multi-center prospective study that 22% of patients with PSO developed rod fractures[10]. The rod fracture rate of this study was 6.8%. We performed interbody fusion at the proximal level using Lehmer's PSO and also performed interbody fusion at the distal level using TLIF. We believe that our procedure (in which the mobile intervertebral disc did not remain on either side of the PSO vertebra) was effective in preventing rod fractures.

PJK following correction surgery for adult spinal deformity is one of the main reasons for poor outcome. Lau et al. reported in a systemic review that the re-operation rate due to PJK was 13%~15%[11]. In this study, we performed re-operation for PJK in 4 patients (9.1%). PJK and subsequent vertebral fracture (29.5%) were major reasons resulting in poor outcomes for patients. Only female patients required re-operation and developed subsequent vertebral fracture in this study; hence, we believe that more careful follow-up and intensive treatment for osteoporosis is necessary for female patients.

In conclusion, PSO as a salvage operation for kyphosis following previous lumbar fusion surgery was an effective procedure without correction loss at the local osteotomy site; however, its surgical invasiveness and complication rate were high. Subsequent vertebral fracture, adjacent segment degeneration, and rod fracture contribute to deterioration of outcome that is evident at long-term follow-up.

Conflicts of Interest: The authors declare that there are no conflicts of interest.

Author Contributions: Kazuyuki Otani wrote and prepared the manuscript, and all of the authors participated in the study design. All authors have read, reviewed, and approved the article.

References

1. Hasegawa K, Homma T. One-stage three-dimensional correction and fusion: a multilevel posterior lumbar interbody fusion procedure for degenerative lumbar kyphoscoliosis. Technical note. J Neurosurg. 2003;99(1 Suppl):125-31.
2. Nakai O. Dorsal-ventral-dorsal three way correction & fusion for lumbar degenerative kyphosis. Sekitui-Sekizui. 2007;20(11):1187-94. Japanese.
3. Strom RG, Bae J, Mizutani J, et al. Lateral interbody fusion combined with open posterior surgery for adult spinal deformity. J Neurosurg Spine. 2016;25(6):697-705.
4. Schwab F, Blondel B, Chay E, et al. The Comprehensive anatomical spinal osteotomy classification. Neurosurgery. 2014;74(1):112-20.
5. Lehmer SM, Keppler L, Biscup RS, et al. Posterior transvertebral osteotomy for adult thoracolumbar kyphosis. Spine (Phila Pa 1976). 1994;19(18):2060-7.
6. Schwab F, Patel A, Ungar B, et al. Adult spinal deformity—postoperative standing imbalance; how much can you tolerate?; An overview of key parameters in assessing alignment and planning corrective surgery. Spine (Phila Pa 1976). 2010;35(25):2224-31.
7. Thomasen E. Vertebral osteotomy for correction of kyphosis in ankylosing spondylitis. Clin Orthop Relat Res. 1985;Apr(194):142-52.
8. Bridwell KH. Decision making regarding Smith-Petersen vs. pedicle subtraction osteotomy vs. vertebral column resection for spinal deformity. Spine (Phila Pa 1976). 2006;31(19 Suppl):S171-8.
9. Gupta MC, Ferrero E, Mundis G, et al. Pedicle subtraction osteotomy in the revision versus primary adult spinal deformity patient: is there a difference in correction and complications? Spine (Phila Pa 1976). 2015;40(22):E1169-75.
10. Smith JS, Shaffrey E, Kineberg E, et al. Prospective multicenter assessment of risk factors for rod fracture following surgery for adult spinal deformity. J Neurosurg Spine. 2014;21(6):994-1003.
11. Lau D, Clark AJ, Scheer JK, et al. Proximal junctional kyphosis and failure after spinal deformity surgery: a systematic review of the literature as a background to classification development. Spine (Phila Pa 1976). 2014;39(25):2093-102.