Original Article
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Comparison of Clinical Outcomes and Complications of Primary and Revision Surgery Using a Combined Anterior and Posterior Approach in Patients with Adult Spinal Deformity and Sagittal Imbalance

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Background: The purpose of this study was to compare clinical outcomes and complications of primary and revision surgery in patients with adult spinal deformity (ASD) accompanied by sagittal imbalance. Revision surgery has been associated with poor clinical outcomes and increased risk of complications. Previous studies comparing primary versus revision surgery included data for a wide variety of diseases and ages, but few investigated patients with ASD with sagittal imbalance undergoing anterior and posterior combined surgery.

Methods: Retrospective cohort analysis of prospectively collected data. We identified 60 consecutive patients with ASD combined with sagittal imbalance who underwent primary or revision surgery; of these, 6 patients were excluded for lack of a minimal 2-year follow-up. Patients' surgical and radiological data, clinical outcomes, and complications were reviewed.

Results: There were 30 patients in the primary group and 24 patients in the revision group. Patient characteristics, including the prevalence of sarcopenia, were similar between the two groups. Pedicle subtraction osteotomy was performed more frequently in the revision group although there was no statistically significant difference between groups. The primary group had more proximal junctional problems, whereas the revision group had more rod breakage ($p < 0.05$). There were significant improvements in clinical outcomes in both groups when the preoperative and 2-year postoperative values were compared. The Oswestry disability index and visual analog scale score were similar in both groups 2 years postoperatively.

Conclusions: Considering the greater pain and disability at the time of the revision procedure, revision patients benefited more from surgery at the 2-year follow-up than the primary surgery patients. Complication rates were similar between the groups except for proximal junctional problems and rod breakage. Therefore, revision surgery should not be avoided in the treatment of ASD patients with sagittal imbalance.

Keywords: *Adult spinal deformity, Sagittal imbalance, Primary surgery, Revision surgery, Clinical outcome and complication, Pedicle subtraction osteotomy, Oblique lumbar interbody fusion, Combined procedure*

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With the aging of the general population, the incidence of adult spinal deformity (ASD) is also increasing, with a prevalence of up to 32% reported.[1] Many studies on ASD are ongoing, and there is an increasing interest in age-related conditions, such as sarcopenia and back muscle atrophy, which have been thought to be related to ASD.[1-4] As the life expectancy and importance of quality of life increase, there is a growing tendency in spine surgery to actively treat ASD. Surgical interventions, such as anterior column realignment, modern posterior segmental instrumentation, and complex osteotomies, can restore functionality with improvement in pain and disability.[5] Sciubba et al.[6] also reported that reconstructive surgery for spinal deformity provided significant improvements even for patients who were over 75 years of age.

Revision surgery for deformity correction is more complicated and technically challenging than primary surgery because of difficulty in surgical exposure and anatomic alterations.[7,8] Comparative studies on primary and revision surgery for ASD patients show various results. Lapp et al.[9] reported that at a minimum 2-year follow-up, late complications (> 6 months after surgery) were not higher in the revision group than in the primary group. By contrast, Diebo et al.[5] showed that revision correction of ASD has a higher risk of perioperative complications and longer hospitalization than primary surgery. However, these studies were conducted on groups with a variety of ASD diseases, such as flat back syndrome; adult idiopathic, degenerative, and neuromuscular scoliosis; and acquired and congenital kyphosis. ASD has wide and heterogeneous etiologies in terms of deformity types, clinical manifestations, age, and sex.[10] In addition, young patients (below 30 years of age) were included in these studies, and these patient groups are distinguished from patients with degenerative type of ASD. In particular, recent studies have described the importance of sagittal plane analysis and spino-pelvic alignment because of strong correlation with health-related quality of life, pain, and disability.[11] Thus, ASD with sagittal imbalance is clinically important, and a specific study is needed for older patients (over 60 years of age) with degenerative ASD with sagittal imbalance. To date, there is a paucity of studies related to the clinical outcomes and complications of primary and revision surgery using a combined anterior and posterior approach in patients with ASD with sagittal imbalance. This study aimed to test the hypothesis that patients with ASD with sagittal imbalance who underwent revision surgery would not show poor clinical outcomes.

METHODS

The Institutional Review Board of Eulji University Hospital approved this study (IRB No. 2016-05-012), and all participants provided written informed consent.

Patients

Surgical database of patients with ASD accompanied by sagittal imbalance visiting the outpatient department (OPD) at a single center were retrospectively reviewed from January 2013 to December 2017, which included patients with lumbar degenerative kyphosis, degenerative lumbar scoliosis, or postoperative flat back deformity with sagittal imbalance that was defined as sagittal vertical axis (SVA) > 5 cm and pelvic tilt (PT) > 25°. Among these patients, surgery was indicated if: (1) the patient had lordotic change of thoracic curve (existence of a thoracic compensatory mechanism); (2) Oswestry disability index (ODI) was > 40%; and (3) visual analog scale (VAS) score for back pain was > 7. We excluded patients if revision surgery was performed only for reasons such as pseudoarthrosis or junctional failure other than sagittal imbalance. Medical records were reviewed by a single orthopedic surgeon (WJK) who was not involved in the patient treatment. Of the 60 patients who met the inclusion criteria, 6 patients were lost to follow-up before the 2-year follow-up period. Records of 54 patients (42 female and 12 male patients; average age, 66.9 ± 7.5 years) with a minimal 2-year follow-up were reviewed. Patients were classified into a primary group (P group, n = 30) or revision group (R group, n = 24), based on whether they underwent a previous spine fusion surgery for any reason (Figs. 1 and 2). Clinical and radiological data were collected prospectively from each patient during the OPD visit.

Operative Procedure

The operations were performed by the same surgeon (WJK) in two stages with an interval of 1 week. In the first-stage surgery, all patients underwent oblique lumbar interbody fusion (OLIF) or anterior lumbar interbody fusion (ALIF) according to the affected level. After OLIF or ALIF, all patients had bed rest to prevent vertebral endplate damage and cage subsidence. The posterior procedure was performed 1 week after the first-stage procedure and correction methods (Ponte osteotomy or pedicle subtraction osteotomy [PSO]) were determined according to the amount of lumbar lordosis (LL) correction required compared with pelvic incidence (PI) minus LL by referring to the whole spine lateral radiograph before the second-stage surgery.

Fig. 1. Example of primary case. (A) Preoperative whole-spine standing lateral radiographs of a 65-year-old woman with primary adult spinal deformity with sagittal imbalance. (B) She underwent oblique lumbar interbody fusion (L2–3, L3–4, and L4–5). After 1 week, she underwent L3 pedicle subtraction osteotomy and T10–S1 posterior fusion with iliac screw. The sagittal vertical axis was reduced from 24.6 to 5.7 cm, the LL increased from –19.3° to 53°, and the PI–LL decreased from 83° to 10°. LL: lumbar lordosis, PI, pelvic incidence.

Fig. 2. Example of revision case. (A) Preoperative whole-spine standing lateral radiographs of a 75-year-old man with revision adult spinal deformity with sagittal imbalance. At baseline, the patient had PT 36°, PI–LL 58°, and sagittal vertical axis (SVA) 22.3 cm. (B) He underwent surgery by anterior lumbar interbody fusion (L5–S1) and after 1 week, L2 pedicle subtraction osteotomy and T10–S1 posterior fusion with iliac screw. Postoperatively, spinopelvic parameters were improved: PT 15°, PI–LL 8°, and SVA –1.2 cm. PT: pelvic tilt, PI: pelvic incidence, LL: lumbar lordosis.

Patient Demographics and Surgical Data

Patient characteristics included age, sex, body mass index (BMI), bone mineral density (BMD), prevalence of sarcopenia, and duration of follow-up. Prevalence of sarcopenia was calculated using the appendicular skeletal muscle index (ASMI) and handgrip strength. Men with ASMI < 7.0 kg/m^2 and handgrip strength < 26 kg and women with ASMI < 5.7 kg/m^2 and handgrip strength < 18 kg were classified into a sarcopenia group according to the recommendation for Asian Working Group for Sarcopenia.[4] Surgical characteristics included the number of levels arthrodesed, correction methods (facetectomy, Ponte osteotomy, or PSO), use of iliac screws, operative time, and estimated blood loss (EBL).

Radiological Measurement and Analysis

Radiological parameters were measured on whole-spine standing anteroposterior and lateral radiographs, based on the Spinal Deformity Study Group method.[12] Radiologic measurement was conducted using the m-view (Infinitt Healthcare Co., Seoul, Korea) on the picture archiving and communication system. Anteroposterior and lateral radiographs were taken preoperatively, postoperatively, and at the time of every follow-up. SVA, PT, sacral slope (SS), PI, LL, and thoracic kyphosis (TK) were measured. Proximal junctional kyphosis (PJK) was defined as the final proximal junctional Cobb angle between the lower endplate of the instrumented vertebra measured at the top and upper endplate of two supra-adjacent vertebrae, which was at least 10° greater than the postoperative measurement.[13] Proximal junctional fracture was defined as a fracture of the screw fixation site or of adjacent vertebra level, and proximal junctional failure cases included patients who underwent revision surgery due to PJK or fracture.

Clinical Outcomes and Complications Assessment

Clinical outcomes were assessed using the ODI and VAS score. Each patient was evaluated before surgery and at 6 months, 1 year, and 2 years after surgery. The ODI is a recommended condition-specific patient-reported outcome measure, which is used to evaluate the functional status in patients with back pain. Perioperative and postoperative complications were also recorded during the follow-up period by well-trained researchers (HMS, DGS, JWL).

Statistical Analysis

Statistical analysis was conducted using the IBM SPSS ver. 22.0 software (IBM Corp., Armonk, NY, USA). The distribution of variables was presented as mean and standard deviation. Continuous variables were compared using the Student *t*-test, and the chi-square test or Fisher exact test was used to compare the categorical parameters. Clinical and radiological measurements were compared between the two groups preoperatively and at 2-year follow-up using the paired *t*-test. Statistical significance was assigned at $p < 0.05$.

RESULTS

Patient Characteristics

Fifty-four patients with ASD with sagittal imbalance were included in the analysis, with 30 patients (55.6%) in the P group and 24 (44.4%) in the R group. Age, sex, BMI, BMD, and duration of follow-up were similar between the two groups. There was no statistically significant difference in the prevalence of sarcopenia (Table 1).

Surgical Data

Both groups had similar OLIF levels and posterior spinal fusion (PSF) levels. Osteotomy (either Ponte osteotomy or PSO) was performed in 76.7% and 83.3% patients of the P group and R group, respectively. Ponte osteotomy was performed more often in the P group and PSO in the R group, with no significant difference. Use of iliac screw, OLIF/PSF operation time, and EBL were similar between the groups (Table 2).

Radiological Parameters

Radiological parameters for PT, PI, TK, and SVA were comparable between the two groups. Preoperative LL was significantly worse in the R group (P group, –9.8° ± 9.1°; R group, –14.5° ± 8.1°; $p = 0.023$). The correction angle difference between preoperative and last follow-up period was larger in the R group (change in LL: P group, 41.7° ± 13.3°; R group, 51.5° ± 10.1°; $p = 0.015$). Additionally, we

Table 1. Comparison of Patient Characteristics between Primary Group and Revision Group

Variable	Primary group (n = 30)	Revision group (n = 24)	*p*-value
Age (yr)	68.1 ± 6.5	65.4 ± 7.0	0.277
Sex (female : male)	23 : 7	19 : 5	0.645
BMI (kg/m^2)	26.36 ± 2.9	26.12 ± 2.8	0.342
BMD (T-score)	–2.44 ± 1.1	–2.46 ± 1.3	0.920
Prevalence of sarcopenia	10 (33.3)	7 (29.2)	0.191
Duration of follow-up (mo)	29.5 ± 6.1	30.2 ± 6.8	0.415

Values are presented as mean ± standard deviation or number (%). $p < 0.05$, statistically significant.
BMI: body mass index, BMD: bone mineral density.

Table 2. Comparison of Surgical Data between Primary Group and Revision Group

Variable	Primary group (n = 30)	Revision group (n = 24)	*p*-value
OLIF level	2.36 ± 1.7	2.04 ± 1.7	0.086
PSF level	7.7 ± 0.8	7.4 ± 0.6	0.258
Osteotomy	23 (76.7)	20 (83.3)	0.736
Ponte	10 (33.3)	6 (25)	0.561
PSO	13 (43.3)	14 (58.3)	0.412
Iliac screw use	21 (70)	15 (62.5)	0.780
OLIF operative time (min)	163 ± 63.7	124 ± 25.5	0.432
PSF operative time (min)	304 ± 75.9	321 ± 66.3	0.351
Estimated blood loss (mL)	1,547 ± 712	1,752 ± 672	0.230

Values are presented as mean ± standard deviation or number (%). $p < 0.05$, statistically significant.
OLIF: oblique lumbar interbody fusion, PSF: posterior spinal fusion, PSO: pedicle subtraction osteotomy.

measured PI minus LL, which is suggestive of spinopelvic mismatch.[11] The P group tended to have more PI-LL mismatch. PI minus LL was significantly higher in the P group at postoperative and last follow-up period (preoperative PI-LL: P group, 57.3° ± 17.6°; R group, 62.7° ± 15.3°; p = 0.298; postoperative PI-LL: P group, 11.9° ± 8.5°; R group,

Table 3. Comparison of Radiological Parameters between Primary Group and Revision Group

Variable	Primary group (n = 30)	Revision group (n = 24)	*p*-value
PT (°)			
Preoperative	35.8 ± 8.1	35.1 ± 8.9	0.768
Postoperative	20.8 ± 6.1	21.5 ± 8.2	0.683
Last follow-up	26.1 ± 9.2	24.7 ± 8.1	0.664
Change	9.7 ± 8.5	10.1 ± 9.8	0.881
PI (°)			
Preoperative	47.7 ± 12.2	48.4 ± 12.8	0.854
Postoperative	47.9 ± 11.8	48.7 ± 13.1	0.948
Last follow-up	47.7 ± 9.2	48.9 ± 8.8	0.959
Change	0.1 ± 10.9	0.4 ± 13.2	0.878
TK (°)			
Preoperative	2.9 ± 2.8	2.6 ± 2.9	0.512
Postoperative	8.7 ± 3.3	9.5 ± 3.5	0.655
Last follow-up	6.7 ± 4.5	7.2 ± 4.2	0.378
Change	3.6 ± 3.2	3.8 ± 3.4	0.635
LL (°)			
Preoperative	–9.8 ± 9.1	–14.5 ± 8.1	0.023*
Postoperative	36.0 ± 9.9	40.4 ± 6.2	0.189
Last follow-up	32.5 ± 8.7	37.2 ± 8.6	0.129
Change	41.7 ± 13.3	51.5 ± 10.1	0.015*
PI–LL (°)			
Preoperative	57.3 ± 17.6	62.7 ± 15.3	0.298
Postoperative	11.9 ± 8.5	8.5 ± 7.2	0.032*
Last follow-up	15.1 ± 14.2	11.5 ± 10.6	0.029*
Change	44.3 ± 18.4	54.1 ± 15.1	0.003*
SVA (cm)			
Preoperative	15.4 ± 3.4	15.2 ± 4.2	0.886
Postoperative	3.8 ± 1.8	4.1 ± 3.0	0.214
Last follow-up	4.1 ± 2.1	3.9 ± 1.5	0.810
Change	11.4 ± 4.2	11.3 ± 4.3	0.972

Values are presented as mean ± standard deviation.
PT: pelvic tilt, PI: pelvic incidence, TK: thoracic kyphosis, LL: lumbar lordosis, SVA: sagittal vertical axis.
*$p < 0.05$, statistically significant.

8.5° ± 7.2°; p = 0.032; last follow-up PI-LL: P group, 15.1° ± 14.2°; R group, 11.5° ± 10.6°; p = 0.029) (Table 3).

Clinical Outcomes

The R group had significantly higher preoperative ODI scores (P group, 58.7 ± 7.4; R group, 63.3 ± 5.8; p = 0.027) and VAS scores than the P group (P group, 7.9 ± 0.8; R group, 8.3 ± 0.6; p = 0.021). The improvement of both ODI and VAS scores were statistically significantly greater in the R group (change in ODI: P group, 38.1 ± 8.1; R group, 44.7 ± 6.8; p = 0.006; change in VAS score: P group, 4.8 ± 2.0; R group, 5.6 ± 2.1; p = 0.040). Both the primary and revision groups showed significant improvement in clinical outcomes scores (ODI and VAS score) at the 2-year follow-up (p < 0.001) when compared to preoperative values (Table 4, Fig. 3).

Complications

Pseudohernia, a complication of OLIF, showed no significant difference in prevalence between the P and R groups and resolved spontaneously within 1 year. Two patients in the P group and 1 in the R group developed wound infection, which resolved after surgical irrigation with use of intravenous antibiotics. Three patients in the P group and 4 in the R group experienced temporary motor deficit, which resolved spontaneously within 6 months. However, 1 patient in the R group had motor deficit sequelae. Although there were no findings of nerve compression on

Table 4. Comparison of Clinical Outcomes between Primary Group and Revision Group

Variable	Primary group (n = 30)	Revision group (n = 24)	p-value
ODI (%)			
Preoperative	58.7 ± 7.4	63.3 ± 5.8	0.027*
Postoperative 2 years	19.3 ± 4.7	19.5 ± 5.2	0.234
Change	38.1 ± 8.1	44.7 ± 6.8	0.006*
VAS			
Preoperative	7.9 ± 0.8	8.3 ± 0.6	0.021*
Postoperative 2 years	2.1 ± 1.9	2.3 ± 2.1	0.355
Change	4.8 ± 2.0	5.6 ± 2.1	0.040*

Values are presented as mean ± standard deviation.
ODI: Oswestry disability index, VAS: visual analog scale, Change: postoperative 2-year follow-up – preoperative.
*p < 0.05, statistically significant.

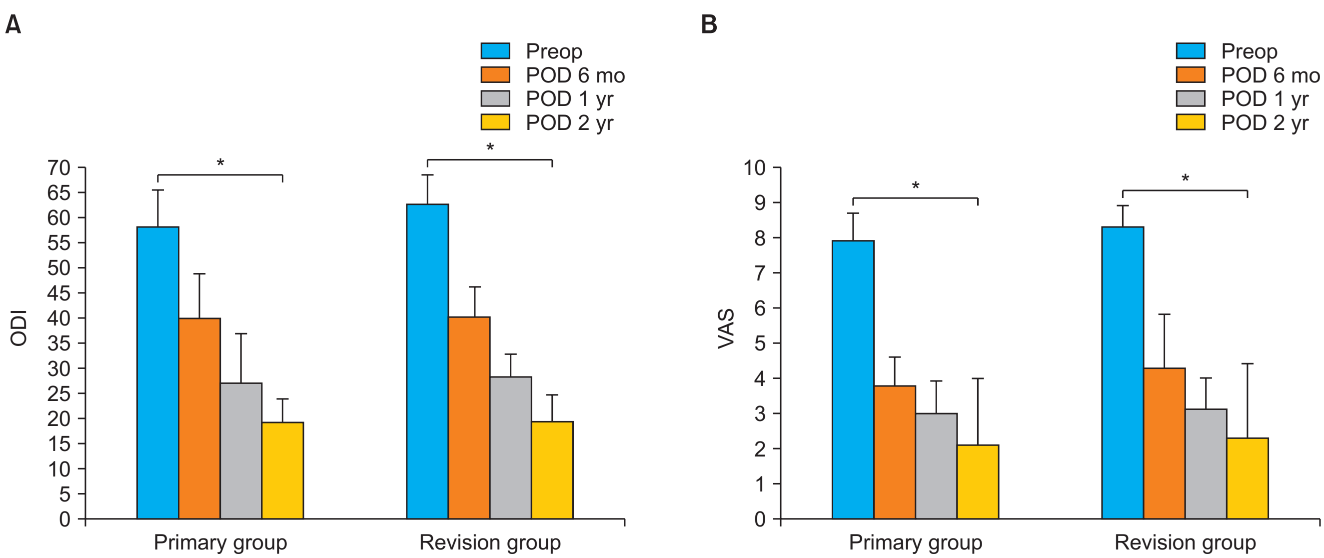

Fig. 3. Both groups achieved significant improvement in Oswestry disability index (ODI; A) and visual analog scale (VAS; B) score between preoperative and postoperative 2-year follow-up. Preop: preoperative, POD: postoperative day. *Statistically significant, p < 0.05.

computed tomography and magnetic resonance imaging scans taken immediately after surgery, the patient showed motor weakness in the left ankle and big toe (grade 3). But at 1 year after the surgery, only ankle dorsi flexor power was grade 4 and the other motor deficit was recovered.

Rod breakage, which is related to pseudoarthrosis, was more common in the R group (P group, 2 [6.7%]; R group, 8 [33.3%]; $p = 0.016$) (Fig. 4), and proximal junctional problems occurred more frequently at a statistically significant level in the P group (P group, 15 [50%]; R group, 5 [20.8%]; $p = 0.026$). Proximal junctional fracture cases included 4 screw fixation site fractures and 2 adjacent level fractures in the P group and 1 screw fixation site fracture in the R group. Among patients with rod breakage, 2 in the P group and 6 of the 8 in the R group underwent revision surgery. Bone graft was performed in all patients who underwent revision surgery due to rod breakage, and teriparatide was additionally used to enhance the fusion of the bone graft.

Six out of 15 patients in the P group and 1 out of 5 patients in the R group had revision surgery due to proximal junctional problems during the study period. Within the first 2 years after the deformity correction surgery, 4 patients in the P group had revision surgery; 1 patient in the R group had revision surgery because of proximal junctional problems (Table 5).

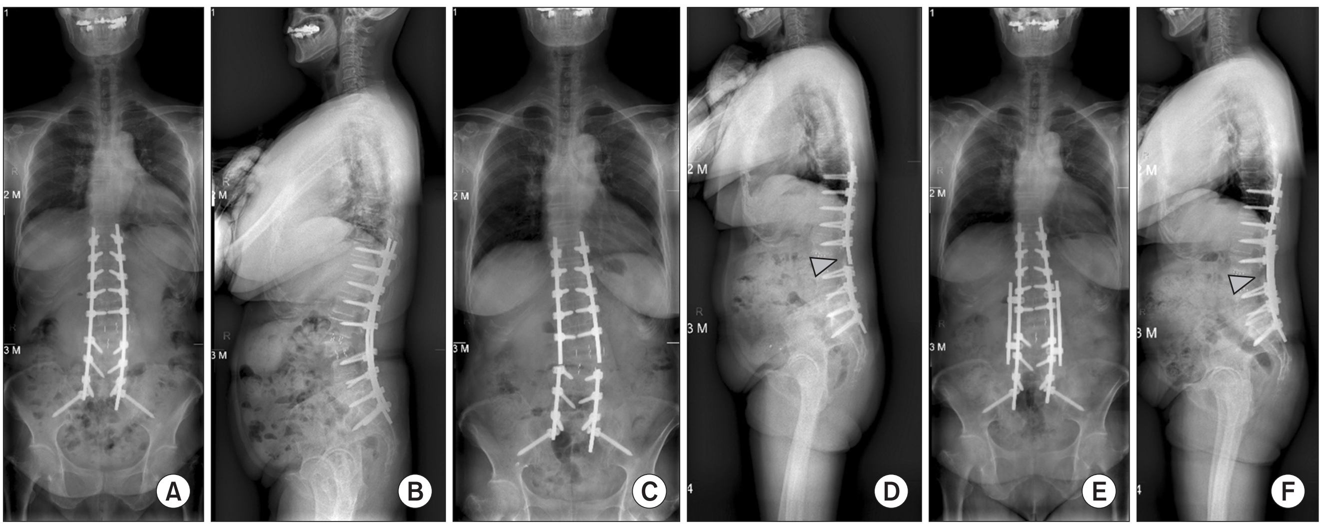

Fig. 4. Example of rod breakage case. (A, B) A revision patient with adult spinal deformity and sagittal imbalance. She underwent oblique lumbar interbody fusion (L2–3, L3–4) and after 1 week, underwent L3 pedicle subtraction osteotomy (PSO) and T10–S1 posterior fusion with iliac screw. (C, D) Bilateral rod breakage at L3–4 around PSO site was diagnosed at postoperative 14 months associated with L3 pseudo-arthrosis. (E, F) She underwent revision surgery by four-rod augmentation technique. The arrowheads show L3 PSO site.

Table 5. Comparison of Complications between Primary Group and Revision Group

Variable	Primary group (n = 30)	Revision group (n = 24)	*p*-value
Pseudohernia	3 (10)	3 (12.5)	0.771
Infection	2 (6.7)	1 (4.2)	0.585
Neurologic complication	3 (10)	4 (16.6)	0.687
Rod breakage	2 (6.7)	8 (33.3)	0.016*
Proximal junctional problem	15 (50)	5 (20.8)	0.026*
Proximal junctional kyphosis	3 (10)	3 (12.5)	0.772
Proximal junctional fracture	6 (20)	1 (4.2)	0.033*
Proximal junctional failure	6 (20)	1 (4.2)	0.033*

Values are presented as number (%).
*$p < 0.05$, statistically significant.

DISCUSSION

In general, revision surgery for deformity correction is difficult to perform, with an increased risk for complications. Therefore, it is essential to compare the clinical outcomes and complications of revision versus primary surgery in ASD patients with sagittal imbalance. Most studies comparing primary and revision surgery in ASD patients investigated a wide range of diseases and ages,[5,7,14,15)] and few studies have mentioned the staged anterior and posterior procedure to correct ASD. By contrast, our study focused mostly on degenerative ASD patients with sagittal imbalance.

In our study, no significant difference was seen in the patient demographics between the P and R groups. The prevalence of sarcopenia varies from 5% to 13% in the general population aged > 60 years.[16)] Eguchi et al.[2)] reported a prevalence of 46.6% for sarcopenia in patients with degenerative lumbar scoliosis, and Kim et al.[4)] reported back muscle degeneration was more strongly associated with sagittal imbalance and back pain than with sarcopenia. In our study, the prevalence of sarcopenia was 33.3% and 29.2% in the P group and R group, respectively. This shows that the prevalence of sarcopenia is higher in ASD patients than in the general population, even considering their age. The older age of the study subjects may have contributed to this high prevalence of sarcopenia in ASD patients, or impaired physical activity caused by spinal deformity may have influenced loss of muscle mass and strength. However, the relationship between sarcopenia and clinical outcome in patients with ASD is not clear. The association between sarcopenia and ASD, especially in patients with sagittal imbalance, would be worth investigating in future studies.

Recently, the use of OLIF has been increasing because of the interest in minimally invasive surgery (MIS).[17-19)] MIS OLIF has advantages, such as minimally invasive access to the lumbar spine and less blood loss. However, the effect of anterior column realignment by MIS has not been verified. Safe development of a corridor anterior to the anterior longitudinal ligament (ALL) through the MIS technique might be challenging because of the presence of critical anatomic structures during the lateral retroperitoneal approach, and deformity correction will be limited even though hyperlordotic interbody cages are inserted without ALL release.[17-19)] Hence, we performed a staged posterior procedure with consideration of the degree of correction of LL after anterior surgery. Based on the whole spine radiographs taken after anterior surgery, the necessary corrective angle was identified before posterior surgery, and then the surgical method and fusion level were determined accordingly. There was no significant difference in cage sedimentation during 7 days after the first-stage procedure. The target correction angle was determined for the PI minus LL to be within approximately 10 degrees. In most cases, we fused from T10 where true rib exists to S1 and used iliac screws to prevent loss of fixation.

Surgical data, including OLIF level, PSF level, operative time, and EBL, were comparable between the two groups. Osteotomy (Ponte or PSO) was needed in 76% and 83% of patients in the P group and R group, respectively. More osteotomies were performed in the current study than in previous studies. Fu et al.[7)] mentioned that 43.4% and 45.2% of primary patients and revision patients, respectively, needed osteotomies, either Ponte osteotomy or PSO. Similarly, Cho et al.[14)] performed osteotomies in 14.3% and 55.6% of patients in primary surgery and revision surgery, respectively. However, these studies involved ASD patients with coronal imbalance. We thought that a larger correction angle was necessary in our patients because they were ASD patients with sagittal imbalance. PSO is useful in correcting sagittal plane deformity, especially in revision spine fusion.[15)] It explains why the rate of PSO was high in the current study (P group, 43.3%; R group, 58.3%).

At baseline, both P and R groups had inadequate lordosis for the amount of PI (PI-LL more than 57°) and PT (more than 35°). We found that preoperative, postoperative, and last follow-up radiographic data were similar in terms of the sagittal plane measurements of SVA in both groups, which implies that the surgeon utilized similar thresholds of SVA for the operative indication in the primary and revision settings. Patients in the R group had poorer LL than those in the P group. Patients who had a previous spinal fusion had more inadequate LL or postoperative flat back posture.[15)] These findings suggest that revision patients need more correction angle and explain why PSO was performed more often in the R group in our study (P group, 43.3% vs. R group, 58.3%).

The higher incidence of rod breakage in the R group than in the P group might be attributed to more frequent use of PSO in the R group in this study. Smith et al.[20)] reported 6.8% of symptomatic rod breakage in ASD patients who underwent corrective surgery; in contrast, the rate of rod breakage increased up to 15.8% among those who underwent the PSO procedure. According to Cho et al.,[8)] instrumentation failure was the most common complication in patients who underwent revision surgery (13.3%) with a 34% rate in the PSO population. Likewise, in our study, PSO was more frequently performed in revision surgery and rod breakage was more commonly observed. Pseudoarthrosis at the osteotomy site and increased instability at the PSO level may create a stress concentration and lead to rod breakage.[21] Some studies have reported that the four-rod augmentation technique and use of bone morphogenetic protein might be helpful in preventing rod breakage.[22,23]

Meanwhile, proximal junctional problems occurred more commonly in the P group than in the R group in this study. In particular, we found that many fractures at the screw fixation site or adjacent level occurred as often as kyphosis. The reported incidence of proximal junctional problems ranges between 10% and 40%.[13,24] Various factors, such as age, fusion to sacrum, TK > 40°, and low BMD, are associated with proximal junctional problems.[25,26] According to Lee et al.,[27] lack of LL than PI was significantly related to the progression of PJK. Kim et al.[28] also found patients with pre-revision PI-LL mismatch < 11° had a smaller proximal junctional angle. We found a significant difference in postoperative PI-LL between the P group (11.9° ± 8.5°) and R group (8.5° ± 7.2°). We took lumbar flexion-extension radiographs before the first surgery in all surgical patients. Although surgery was performed only with OLIF for patients with lumbar flexibility, most patients in the P group had less lumbar flexibility with a correction angle within 50%, requiring additional posterior surgery. And more PI-LL mismatch in the P group occurred after surgery because the ratio of PSO was smaller in the group than in the R group. Also, it is judged that sufficient correction angle was not obtained because ALL was not sufficiently released during the anterior surgery of the patients in the P group. In addition, in obese patients, osteoporotic patients, or multilevel OLIF cases, it was suggested that a posterior fusion technique be combined rather than OLIF alone, and that posterior fixation prevented sedimentation of the cage.[29,30] Therefore, we tried to obtain an appropriate correction angle through the combined anterior and posterior surgery. PI-LL mismatch > 11° was noted in the P group and we believe that the tendency of more PI-LL mismatch in the primary patients may lead to more proximal junctional problems. The mean BMD (T-score) was −2.44 ± 1.1 in the P group and −2.46 ± 1.3 in the R group, and osteoporotic features might have affected the overall high frequency of proximal junctional problems.[25] We suggest that appropriate matching of PI and LL, as well as prophylactic teriparatide treatment, which could improve the volumetric BMD and fine bone structure,[31] is helpful for minimizing the risk of proximal junctional problems. Studies have shown that the minimum clinically important difference (MCID) values of the VAS and ODI were similar for patients with lumbar arthrodesis who underwent revision and primary surgery (2 points for VAS and 13% for ODI.)[32] In this study, the P group obtained MCID at 72.2% for ODI and 85.2% for VAS, whereas the R group gained MCID at 76.5% for ODI and 87.3% for VAS although there was no significant difference between the groups. Although the R group had more pain and disability in the preoperative period, ODI and VAS score were significantly better in the group than in the P group after surgery until 2 years postoperatively. It suggests that the R group benefited more from the surgery than the P group during the minimal 2-year follow-up period.

This study has several limitations that should be considered. First, the sample size was relatively small. Second, we did not include idiopathic or neuromuscular disease, so it seems that there were relatively few neurological complications in R group. Third, in the R group, previous surgery was not limited to surgery due to ASD only.

In conclusion, the R group and P group were not different in terms of patient characteristics and surgical data, and notably, the prevalence of sarcopenia of each group did not differ. The clinical outcomes were comparable at the final follow-up; however, the R group obtained relatively greater improvement considering the poorer preoperative pain and disability associated with previous spinal surgical procedures. Overall complication rates were similar; however, the P group had more proximal junctional problems and the R group had more rod breakage related to pseudoarthrosis. Therefore, revision surgery should not be avoided in treating patients with ASD with sagittal imbalance. We believe that satisfactory outcomes can be achieved through careful patient selection and an understanding of anticipated complications.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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