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Complication Profiles Associated with Sacral Alar Iliac Screw Fixation in Patients with Adult Spinal Deformity: A Comparative Analysis to the Conventional Iliac Screw Fixation

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Objective: This study aimed to compare the radiographic and clinical outcomes between sacral alar iliac (SAI) screw fixation and conventional iliac (CI) screw fixation with a particular focus on the rate of reoperation, surgical site infection (SSI), sacroiliac joint pain, instrument failure, and screw prominence.
Methods: Patients who underwent sacropelvic fixation in the authors' institution from June 2011 to May 2017 were retrospectively investigated. Forty-three patients with SAI screw fixation and 25 with CI screw fixation were included. Preoperative patient and surgical characteristics and postoperative outcomes and complications were analyzed between the SAI and CI groups. Radiographic parameters were analyzed before and after surgery.
Results: Lumbosacral fusion rates showed no statistically significant difference between the SAI group and CI groups (90.7% vs. 92.0%, p=0.878). The SAI group showed a significantly good result with regard to SSI compared to the CI group (0% vs. 16%, p=0.016), but had a significantly higher rate of distal screw fracture than the CI group (16.3% vs. 0%, p=0.042).
Conclusion: The SAI screw fixation technique could achieve good outcomes of pain relief, deformity correction, and lumbosacral fusion rate with relatively lower complications such as the rates of reoperation, SSI, and screw prominence as compared to the CI screw fixation technique. However, distal instrument failure was observed more frequently in the SAI group, requiring further biomechanical studies.

Key Words: Lumbosacral region; Sacroiliac joint; Sacrum; Spinal fusion

INTRODUCTION

Despite all the recent advancements and development in spinal instrumentation and surgical techniques and a better understanding of the biology of spinal fusion, pseudoarthrosis, or construct failure of the lumbosacral junction continues to be a major obstacle in spinal surgery[18,26,28]. The sacropelvic junction has some issues such as complex local anatomy, substantial biomechanical force, and poor bone quality that contribute to the high rates of instrumen tation-related complications[13,20,25,29]. Fixation of the sacropelvic spine requires additional instrumentation to overcome the complications associated with fusion ending at the S1 level.

Many sacropelvic fixation techniques have been developed: the Galveston technique and Dunn-McCarthy (S-Rod) technique, as well as the transiliac screw, intrasacral rod, iliosacral fixation, and iliac screw-based techniques[6,7,24]. The conventional iliac (CI) screw fixation technique has been most commonly used to augment the sacropelvic fusion rate and reduce the mechanical failure rate. The sacral alar iliac (SAI) screw fixation technique has been introduced and is low-profile with higher biomechanical property for alternatives to CI screw fixation.

Although there are many biomechanical and cadaveric studies on SAI and CI screw fixation techniques, there are few direct comparative analyses of the difference in clinical outcomes between the two techniques. Therefore, the objective of this study was to compare the clinical and radiographic outcomes between SAI and CI screw fixation techniques in a single institution, with a particular focus on the rate of reoperation, surgical site infection (SSI), sacroiliac (SI) joint pain, rod fracture, screw failure, and screw prominence.

MATERIALS AND METHODS

1. Patient Population and Inclusion Criteria

Institutional Review Board (IRB) approval was obtained (IRB No. 3-2017-0340). The researchers conducted a retrospective consecutive review of all patients who underwent sacropelvic fixation in their institution from June 2011 to May 2017. Sacropelvic fixation was performed for fusion augmentation in the cases of deformity correction operations requiring spinal fusion down to the sacrum. SAI screw fixation was performed in 79 patients and CI screw fixation in 50 patients. The inclusion criteria for this study were at least one year of a follow-up period and patients having the appropriate imaging studies such as whole spine X-ray, computed tomography (CT), and magnetic resonance imaging preoperatively and postoperatively. Based on these criteria, 43 of 79 patients with SAI screw fixation and 25 of 50 patients with CI screw fixation were included.

2. Preoperative Patient Demographics and Surgical Characteristics

Patient demographics were investigated including age at operation, sex, surgical diagnosis, comorbidity such as diabetes mellitus and osteoporosis, smoking history, body mass index (BMI), bone mineral density, duration of follow-up, and preoperative and postoperative visual analog scale (VAS) for pain. Surgical characteristics were also investigated, including the history of previous lumbosacral operation, spinal level of screw fixation, postoperative complications, and reoperation. Postoperative complications included proximal junctional failure or kyphosis, distal instrument failure, rod fracture, wound dehiscence, SSI, and screw prominence. Reoperation was defined as any unplanned procedure required for the treatment of pseudoarthrosis or other complications.

3. Radiographic Measurements

Radiographic parameters were measured on the anteroposterior and lateral radiograph of the standing whole spine X-ray. Preoperative, immediately postoperative, 6 and 12 months after the surgery, and final follow-up standing whole spine X-ray were studied. The measured parameters were sagittal vertical axis (SVA), pelvic inci dence (PI), pelvic tilt (PT), sacral slope, lumbar lordosis (LL), thoracic kyphosis, and cervical lordosis. Proximal junctional failure was defined as "proximal junctional sagittal Cobb angle between the lower endplate of the uppermost instrumented vertebra and the upper endplate of the two supra-adjacent vertebrae ≥10° and at least 10° greater than the preoperative measurement"[4]. Unlike proximal junctional problems, there was no consensus on the definition of distal instrumentation or lumbo-sacro-pelvic fixation failure. With reference to previous studies[3,5,11], distal instrumentation failure was defined as breakage of the SAI or CI screws, halo formation around the screw, or screw pullout. If patients had focal wound dehiscence or tenderness on the buttock areas directly over the SAI or CI screw head immediately after the surgery, they were considered symptomatic screw prominence. Fusion status was assessed by CT scan one year after the surgery and the outcome was expressed as the grading system that was previously used in other studies (Table 1).

4. Surgical Techniques

The step-by-step procedures for the CI and SAI screw fixation techniques are described in detail in previous studies[2,17,25] and will be discussed briefly herein. For the CI screw fixation technique, a simple posterior midline incision is used, followed by an additional dissection of the posterior superior iliac spine that will be the entry point of the screw. A separate skin incision was not used for the insertion of the iliac screws. Before inserting the screw, a portion of bone at the entry point was removed by performing osteotomy to create space to minimize the prominence of the screw head. The screw must be placed between the inner table and the outer table of the iliac bone and the trajectory of the screw directed with an angulation between 20° to 45° caudally and 30° to 45° laterally. For SAI screw insertion, a simple posterior midline incision was made, and the muscle layer was dissected subperiosteally to expose the sacral bone. To preserve muscle coverage over the instrumentation, subperiosteal dissection of the sacrum was limited to the entry point located 2 to 3 mm caudal and 2 to 3 mm lateral to the neural foramen of S1. The SAI screw was directed toward the greater trochanter, rostral to the sciatic notch, and angulation was usually 40° lateral in the axial plane and 40° caudal in the sagittal plane; the exact trajectory was determined based on the preoperative CT and the screw was generally placed under intraoperative fluoroscopic guidance. This trajectory crosses the SI joint and the screw penetrates three cortical surfaces. The tip of the screw is engaged in the dense bone above the sciatic notch.

5. Statistical Analysis

Intergroup comparison of categorical variables was achieved using Fisher's exact test. The unpaired *t*-test was used to analyze continuous variables. Data were presented as the mean±standard deviation unless specified. Moreover, the Mann-Whitney U test was used to analyze nonparametric continuous variables. The Statistical

Table 1. Fusion grading system

Grade	Classification	Anterior fusion criteria	Posterolateral fusion criteria
I	Definite fusion	Fused with remodeling and trabeculae	Solid trabeculated transverse process and facet fusions bilaterally
II	Probable fusion	Graft intact, not fully remodeled and incorporated through; no lucency	Thick fusion mass on one side; difficult to visualize on the other
III	Probable nonunion	Graft intact, but definite lucency at top or bottom	Possible lucency or defect in the fusion mass
IV	Definite nonunion	Resorption of bone graft and collapse	Definite resorption of graft with fatigue of instrumentation

Package for the Social Sciences software (version 20.0; SPSS Inc., Chicago, IL, USA) was used for all statistical analyses. A p-value of less than 0.05 was considered statistically significant.

RESULTS

1. Baseline Characteristics and Surgical Outcomes

The mean duration of follow-up was 640±244 days vs. 627±282 days (SAI group vs. CI group); the mean age of patient was 65.3±9.0 years vs. 60.6±13.5 years (range, 28-79 years); and the mean number of screw fixation levels was 7.3±2.1 segments vs. 7.6±3.1 segments (range, 3-14 segments) (Table 2). The predominant diagnoses were adult spinal degenerative deformity, iatrogenic flat back syndrome, and secondary acquired kyphosis. Secondary acquired kyphosis included post-traumatic and post-infectious kyphosis.

Regarding baseline patient demographics, there were no statistically significant differences in age, sex, BMI, duration of follow-up, smoking, diabetes mellitus, osteoporosis, and previous spinal surgery between the two groups. In both groups, the SVA, LL, PT, and PI-LL improved after surgery compared to before surgery, but no statistically significant difference was observed between the two groups (Table 3). Lumbosacral fusion rates showed no statistically significant difference between the SAI group and the CI group (90.7% vs. 92.0%, p=0.878) (Table 1, 4). There were improvements in the VAS for pain compared to preoperative values, but no statistically significant differences in the SAI and CI groups (6.7±1.6 vs. 1.6±1.4, p<0.01; 7.2±1.3 vs. 2.2±1.3, p<0.01, respectively) (Table 4).

Table 2. Patient demographics and surgical characteristics in SAI group and CI group

	SAI group (n=43)	CI group (n=25)	p-value
Age (year)	65.3±9.0	60.6±13.5	0.131
Male/Female	8/35	4/21	>0.999
BMI (kg/m)	24.0±3.6	23.4±2.7	0.491
Duration of follow-up (month)	35.6±12.5	35.2±14.2	0.986
No. of screw fixation levels (segment)	7.3±2.1	7.6±3.1	0.647
Smoking	4 (9.3%)	1 (4.0%)	0.643
Diabetes mellitus	8 (18.6%)	3 (12.0%)	0.518
Osteoporosis*	14 (32.6%)	8 (32.0%)	0.799
Previous spinal surgery	25 (58.1%)	15 (60.0%)	0.761
Surgical diagnosis			0.227
Iatrogenic flat back	17 (39.5%)	10 (40.0%)	
Deformity	23 (53.5%)	10 (40.0%)	
Secondary acquired kyphosis	3 (7.0%)	5 (20.0%)	

The data is presented as number (%) or mean±standard deviation.
SAI: sacral alar iliac; CI: conventional iliac; BMI: body mass index.
*Bone mineral density < -2.5.

Table 3. Radiographic parameters of sagittal alignment before and after surgery

	Preoperative			Postoperative			Final follow-up		
	SAI group	CI group	p-value	SAI group	CI group	p-value	SAI group	CI group	p-value
SVA	101.0±58.4	111.1±84.1	0.657	35.2±45.7	31.3±42.3	0.775	66.0±44.5	65.0±46.3	0.941
PI-LL	44.7±18.7	46.5±28.0	0.772	10.4±12.8	15.1±11.4	0.217	20.7±15.3	20.9±12.6	0.957
LL	7.6±21.4	11.7±27.3	0.543	40.8±13.4	40.6±15.1	0.964	31.7±14.5	35.4±15.3	0.391
SS	20.6±11.5	23.2±13.1	0.464	30.6±11.5	30.6±10.6	0.993	26.5±9.8	29.2±9.5	0.333
PT	32.0±10.1	34.9±14.6	0.383	20.6±11.0	24.8±8.4	0.193	26.0±10.2	27.1±9.9	0.694
PI	52.3±14.0	58.2±13.6	0.145	51.2±13.5	55.7±13.9	0.279	52.4±13.3	56.3±14.1	0.321
TK	13.2±11.6	21.8±16.6	0.062	23.3±12.2	22.3±20.7	0.821	26.6±14.4	30.1±16.2	0.412
CL	17.0±11.4	19.9±16.5	0.513	13.4±10.4	12.85±16.4	0.868	18.8±12.2	15.2±15.5	0.344

The data is presented as mean±standard deviation.
SVA: sagittal vertical axis; PI: pelvic incidence; LL: lumbar lordosis; SS: sacral slope; PT: pelvic tilt; TK: thoracic kyphosis; CL: cervical lordosis; SAI: sacral alar iliac; CI: conventional iliac.

2. Postoperative Complications

There were no statistically significant differences between the SAI group and CI group with respect to rod fracture, wound dehiscence, and screw prominence. The rate of reoperation, one of the major complications, did not show any statistically significant difference between the two groups (16.3% vs. 28.0%, p=0.270). Additionally, the rate of proximal junctional failure and proximal junctional kyphosis was not different between the two groups statistically. The SAI group had a significantly higher rate of distal screw fracture than the CI group (16.3% vs. 0%, p=0.042) (Fig. 1). The SAI group demonstrated a good result regarding SSI compared to the CI group (0% vs. 16%, p=0.016) (Table 5).

3. Patterns of Distal Instrument Failure and Wound Complications

All of the distal instrument failures occurred in the SAI group except one case of peri-screw halo formation in the CI group. Among eight patients with complications in the SAI group, seven patients experienced distal screw fractures. The screw fracture occurred in the junction between the head of the screw and the neck of the screw shaft in all patients. The duration of screw fracture was 300±30 days (range, 5-29 months). Among these seven patients, pseudoarthrosis in the lumbosacral area was Grade I in two cases, Grade II in two cases, and Grade III in three cases. Inter-group analyses

Fig. 1. A 67-year-old female patient with lumbar degenerative kyphosis showed screw fracture of right S2 alar iliac screw at 14 months after operation. The screw fracture occurred in the junction between the head and the neck of the screw.

Table 4. Preoperative and postoperative VAS score and lumbosacral fusion status in SAI group and CI group

	SAI group (n=43)	CI group (n=25)	p-value
Preoperative VAS	6.7±1.6	7.2±1.3	0.207†
Postoperative VAS	1.6±1.4	2.2±1.3	0.167†
Change in VAS	5±1.8*	5±1.5*	0.740†
L5-S1 fusion status			0.878†
Grade I	19 (44.2%)	9 (36.0%)	
Grade II	20 (46.5%)	14 (56.0%)	
Grade III	4 (9.3%)	2 (8.0%)	
Grade IV	0 (0.0%)	0 (0.0%)	

The data is presented as number (%) or mean±standard deviation.
VAS: visual analog scale; SAI: sacral alar iliac; CI: conventional iliac.
*p<0.01 according to paired *t*-test between preoperative and postoperative values. †p-value according to compared between groups.

Table 5. Complication profiles of SAI group and CI group

	SAI group (n=43)	CI group (n=25)	p-value
Reopeartion	7 (16.3%)	7 (28.0%)	0.270
Proximal junctional failure	3 (7.0%)	1 (4.0%)	>0.999
Proximal junctional kyphosis	17 (39.5%)	10 (40.0%)	0.969
Distal instrument failure			0.242
Screw fracture	7 (16.3%)	0 (0%)	0.042*
Halo formation	1 (2.3%)	1 (4.0%)	>0.999
Pullout	0 (0%)	0 (0%)	>0.999
Rod fracture	8 (18.6%)	1 (4.0%)	0.139
Surgical site infection	0 (0%)	4 (16.0%)	0.016*
Wound dehiscence	0 (0%)	2 (8.0%)	0.132
Screw prominence	1 (2.3%)	2 (8.0%)	0.550

SAI: sacral alar iliac; CI: conventional iliac.
*Statistical significance, p<0.05.

between the distal screw fracture group and the non-distal screw fracture group were also performed. The rate of lumbosacral pseudoarthrosis (Grades III, IV) was higher in the distal screw fracture group compared to the non-distal screw fracture group, but there was no statistical significance (28.6% vs 6.6%, $p=0.112$). The improvements of SVA, LL, PT, and PI-LL after surgery did not show statistically significant differences between the two groups. All screws used in spinopelvic screw fixation were poly-axial and had diameters ranging from 7.5 to 8.5 mm, and their lengths ranged from 80 to 90 mm. There was no statistically significant difference between the two groups.

Regarding the two patients with wound dehiscence and the four patients with SSI in CI groups, the lumbosacral area was the main area for complications. One patient with wound dehiscence had a flap graft surgery performed by a plastic surgeon in the institute. Patients with SSI were initially treated with antibiotics including vancomycin and third-generation cephalosporin for several days. If antibiotic treatment was not working based on laboratory results, the wound was opened and irrigated with normal saline and betadine-mixed saline. Gentamycin-mixed saline was added in one patient.

DISCUSSION

Sacropelvic fixation remains a challenging concept in spinal operation in spite of ongoing developments to improve distal fixation and maintain the stability of constructs in thoracolumbar operation. Sacropelvic fixation is used in spinal operations for the following two purposes: (1) to improve the correction of deformity especially in cases when the apex is located in the lumbar spine; and (2) to stabilize the lumbosacral junction to facilitate arthrodesis[21]. While various surgical instruments and methods have been developed, iliac screw fixation and SAI screw fixation have recently attracted attention. Sponseller et al.[27] and Ishida et al.[17] reported that a better pelvic obliquity correction could be achieved by using the SAI screw fixation technique without postoperative complications such as deep infections, vascular or neurologic complications, anchor migration, implant prominence, skin breakdown, medial pelvic wall violation, or screw pullout. The stability and safety of SAI screw fixation are supported by previous research studies that assessed biomechanical and clinical outcomes[12,17,25,27]. Similar results were observed in the current study's results. The rate of SSI was significantly lower in the SAI group than in the CI group. Additionally, both groups showed appropriate lumbosacral fusion rates, and pseudoarthrosis and proximal junctional kyphosis and failure were not statistically signi- ficantly different between the two groups.

The rate of SSI was previously reported to be lower in the SAI screw fixation than the CI screw fixation according to several meta-analyses[12,16,19]. It is explained because an additional dissection of the posterior superior iliac spine is required to insert a CI screw. Likewise, the rate of SSI was significantly lower in the SAI group in this study, and the rates of wound dehiscence, screw prominence, and reoperation were lower in the SAI group although they were not statistically significant. Screw prominence, as well as additional soft tissue dissections for CI screw entry point, is believed to be one of the causes of SSI[8]. It is presumed that screw prominence puts abnormal pressure on the dissected tissue between the skin and the screw head and inhibits wound healing which can lead to infection.

Some results in this study were different than the findings of previous studies. For instance, the rate of distal screw fracture was higher in the SAI group with a statistically significant difference compared to the CI group. These results are difficult to explain based on the results of previous biomechanical studies in which SAI screw fixation provided superior pullout strengths[23] and reduced the lumbar (L1-L5) and lumbosacral (L5-S1) ranges of motion compared to CI screw fixation[1]. O'Brien et al.[25] reported that biomechanical strength between SAI screws with two lengths (65 and 80 mm) and 90-mm iliac screws was equivalent in seven human cadavers. Only one study[27] reported an asymptomatic fracture of the neck with a 7-mm SAI screw at the two-year follow-up. The authors explained that the SI joints are amphiarthrodial, and that fractures of SAI screws can-occur in the long term. Zhu et al.[30] recommended that an abun dant bone graft should be applied to the SI joint area to avoid this phenomenon. Based on those findings, the authors assumed that distal screw fracture could occur more frequently in the SAI group than in the CI group. Therefore, when using the SAI screw, they recently performed intensive bone grafting on the lumbosacroiliac area. All distal screw fractures occurred in six months (ranges, 6-16 months) after surgery, and some degree of spinal fusion had already progressed, which did not directly affect the VAS score and lumbosacral fusion rates. However, this fatiguetype implant fracture, due to the motion of the SI joint, needs future study to more precisely understand the phenomenon.

All screw fractures occurred at the specific site between the head of the screw and the neck of the screw shaft in the SAI group. In the case of SAI screw fixation, the acute angle develops between the screw head and the shaft of the screw. The head-shaft angulation of the screw increases the stress on the screw head and leads to screw fracture between the head and the shaft neck[9]. Also, according to the finite element model analysis[14], the stress increased around the screw head when the rod and the SAI screw were angled 30 degrees compared to perpendicular. To prevent this problem, the use of mono-axial screws or larger diameter screws can be considered[9,14].

Rod fractures were more common in the SAI group, but there was no statistically significant difference between the two groups. Rod fractures occurred in three cases at L3/4, three cases at L4/5, and two cases at L5/S1 in the SAI group and one case at L4/5 in the CI group. A previous study using the biomechanical finite element model reported that fusion of the SI joint increased the motion of the lumbosacral (L5-S1) segment, and explained that rigid fixation of a motion segment resulted in increased stress on the adjacent segments[22]. Likewise, in the SAI group of this study, it is assumed that the fusion of SI joint creates motion stresses on the lumbosacral segment and consequently leads to rod fractures. On the other hand, two-rod constructs are known to have less stiffness than multiple-rod constructs, which is related to rod fractures[10,15]. In this study, two-rod constructs were 12 and multiple-rod constructs were 13 in the CI group and 34 and nine in the SAI group, respectively. The authors suggest that the risk of rod fracture would be increased because of the rigid fixation of the SI joint and the high rate of two-rod constructs in the SAI group.

The causes of reoperation involved three cases of proximal junctional failure, three cases of rod fracture, and one case of screw prominence in the SAI group and one case of proximal junctional failure, one case of rod fracture, two cases of pseudoarthrosis, one case of screw reposition, and two cases of wound problems in the CI group. In the CI group, postoperative antibiotics were used for a long time due to wound problems, and the patients had to stay in the hospital and eventually went through reoperation. In this study, there was no statistically significant difference in reoperation rate between the two groups. However, as in other studies, the SAI group showed a lower rate of reoperation and proper fusion rate compared to the CI group.

This study had several limitations. The main limitation was that the authors selected the patient's operative method according to the propensity of the surgeon. Other limitations apply to this study as well, such as its single-center, retrospective nature and the relatively small sample size. As such, the results of this study warrant the need for larger prospective, multicenter studies to further extrapolate findings to future patient care involving complex sacropelvic fixation.

CONCLUSION

The SAI group and the CI group achieved pain relief and functional recovery. The SAI screw fixation technique was relatively uncomplicated and resulted in good outcomes compared to the CI screw fixation in the rates of reoperation, SSI, wound dehiscence, and symptomatic screw prominence, whereas the rates of lumbosacral pseudoarthrosis and proximal junctional kyphosis and failure were similar in both groups. However, distal screw fracture was more likely to be observed with the SAI screw fixation technique, so prospective and biomechanical studies of the SAI and CI screw fixation techniques are needed.

CONFLICTS OF INTEREST

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

Kyung-Hyun Kim and Un-Yong Choi contributed equally to this work and should be considered co-corresponding authors.

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