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CLINICAL AND RADIOLOGICAL COMPARISON OF SPINOPELVIC FIXATION METHODS: S2-ALAR-ILIAC SCREW VERSUS CONVENTIONAL ILIAC SCREW IN LONG SEGMENT FUSION

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ABSTRACT

Objective: This study aimed to compare two different screw techniques used in spinopelvic instrumentation: the S2-alar-iliac (S2AI) method and the conventional iliac screw method, in terms of their radiographic parameters, health-related quality of life and associated complications.

Materials and Methods: A total of 56 patients aged over 60 years, who underwent spinopelvic fixation using two different screw techniques, because of degenerative spinal diseases between 2012 and 2017 were retrospectively enrolled. They were divided into two groups based on the type of screw technique used; twenty-nine patients underwent the S2AI screw method (group 1) while 27 patients underwent the iliac screw method (group 2). Preoperative and postoperative radiographic parameters [sagittal vertical axis (SVA), sacral slope (SS), pelvic tilt (PT) and lumbar lordosis (LL)] and the Oswestry Disability index (ODI) were measured and compared.

Results: Generally, all the radiographic parameters (SVA, SS, PT, LL) demonstrated a significant postoperative improvement in the whole study group; however, there were no significant differences between group 1 and group 2 (p=0.696, p=0.218, p=0.245, p=0.117). Regarding the ODI, a significant improvement was observed in all the patients in the postoperative period compared with the preoperative period, although no significant differences were detected between group 1 and group 2 (p=0.522). Overall, complications occurred in 32.1% (18/56) of patients: 24.1% (7/29) of patients in group 1 and 40.7% (11/27) of patients in group 2 (11/270), but no statistically significant difference was found.

Conclusion: This study revealed that the two screw methods being compared have yielded similar results in terms of radiographic parameters and clinical outcomes. Therefore, we recommend that surgical teams should use the screw technique they are most experienced and familiar with.

Keywords: Long-segment fusion, spinopelvic fixation, S2-alar-iliac screw

INTRODUCTION

High-grade spondylolisthesis, long-segment posterior thoracolumbar instrumentation, sacral fractures and instability after sacral tumours are indications that require the ilium to be included in the fusion procedures(1-6). Particularly, after long-segment posterior thoracolumbar instrumentation (generally over five levels), spinopelvic fixation is performed to prevent insufficiency in the lumbosacral junction. Therefore, many publications recommend that the ilium should be included in the fusion procedure from the thoracolumbar area to the sacrum, to prevent pseudarthrosis(7-10).

Fixation of the pelvis to the spine may be performed using different techniques(11,12). Due to their high biomechanical strengths, conventional iliac screw placement and the S2-alar-iliac (S2AI) screw technique are widely accepted in spinal surgery(6,13).

The purpose of this study was to compare two different spinopelvic fixation methods applied to patients with long-segment posterior instrumentation, in terms of radiological parameters and quality of life.

MATERIALS AND METHODS

This was a retrospective study involving patients over 60 years of age, who had undergone iliac fixation with inclusion of the ilium in the long-segment (minimum 5 levels) posterior fusion between 2012 and 2017. Informed consent was obtained from all the participants included in the study. We included patients with multilevels of degenerative lumbar disease, who had not responded to physical therapy and medical treatment in the past 6 months. However, patient who had undergone previous decompression or fusion involving the L5 or S1 vertebrae were excluded from the study. In total, 56 patients were included in this study and they were separated into two groups based

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on the screw technique used: S2AI screw group (group 1) and conventional iliac screw group (group 2). There were 29 patients in group 1 and 27 patients in group 2, and all the patients were followed-up for at least 24 months.

A diagnosis of symptomatic degenerative spinal disease was made by radiological examination (plain radiography, computed tomography and magnetic resonance imaging) and clinical neurological examination. All the patients had undergone a hemilaminectomy or a bilateral hemilaminectomy for decompression after posterior pedicle screwing. Smith-Petersen and pedicle subtraction osteotomies were frequently done, while interbody cage with otograft placement between the vertebral bodies was selectively performed in some patients. All the surgical procedures were performed by two experienced spinal surgeons.

The S2AI screws were placed at 2 mm lateral to the first dorsal sacral foramen and in line with the S1 screw, to place rods without offset connectors. S2AI screws were placed towards the major trochanter, aiming at 45° horizontally and 30° caudally. Conventional screws were applied from the posterior superior iliac spine toward the superior portion of the acetabulum, using a longer incision and more dissection, at 45° horizontally and 30° caudally. Rod placements were done with offset connectors. Screws with 8 mm diameter and 80-100 mm length were applied in all cases.

All the patients were evaluated with a full-body orthoroentgenogram preoperatively and on postoperative day one, during the first month and at all outpatient follow-up visits. Considering the long follow-up duration, the preoperative and final postoperative images were used for the measurements. The following radiographic parameters were measured: Sagittal vertical axis (SVA), lumbar lordosis (LL), sacral slope (SS) and pelvic tilt (PT). The pelvic incidence parameter was not evaluated because it was considered as a constant value.

Quality of life was evaluated preoperatively and postoperatively using the Turkish version of the Oswestry Disability index (ODI), which consists of 10 questions[14]. The first and final calculated values for each group were used to make comparisons.

Since the study group consisted of patients with degenerative spines, the left femoral neck value was used to measure the bone mineral density (BMD) and to prevent inaccurate results due to osteophytic spurs.

Complications such as screw cover loosening, S1 and iliac screw loosening, rod fracture, infection, haematoma, iliac screw malposition and sacroiliac joint pain were also assessed.

Statistical Analysis

SPSS 25.0 (IBM Corparation, Armonk, New York, United States) and PAST 3 (Hammer, Ø., Harper, D.A.T., Ryan, P. D. 2001. Palaeontological statistics) softwares were used to analyse the variables. Conformity of the univariate and multivariate data to a normal distribution were evaluated with the Levene's test and the Mardia (Dornik and Hansen omnibus) test, respectively, while variable homogeneity was evaluated with the Box's M test. An independent samples t-test with bootstrap results was used to compare the two independent groups based on the quantitative data, while the Mann-Whitney U test was used with Monte Carlo results. The Wilcoxon signed-rank test was used with Monte Carlo results to compare duplicate measurements of the dependent quantitative variants, while the general linear model repeated ANOVA was evaluated using bootstrap results to examine repeated quantitative measurements of variables according to groups. To compare categorical variables, Fisher's exact test was evaluated using exact results while testing with the Fisher-Freeman-Halton test with a Monte Carlo simulation. Quantitative variables used mean ± standard deviation and median (minimum/maximum), while categorical variables were shown as n (%). Variables were examined at 95% confidence, and p<0.05 was considered statistically significant.

RESULTS

A total of 56 patients participated in this study: 53 females and three males. The mean age of the study participants was 69.4±5.8 years and there was no significant difference in age between the two groups (p=0.948) (Table 1). The mean follow-up duration was 38.5 months and there was no significant difference between the two groups in terms of follow-up duration (p=0.784) (Table 1). The mean instrumentation level was 10 and the mean BMD was 2.64; no statistically significant difference was observed between the groups in terms of instrumentation level and BMD (p=0.115, p=0.324, respectively) (Table 1) (Figure 1 and 2).

Among the radiographic parameters, SVA decreased from 102 mm (50/235) to 60 (16/180) mm in group 1 and from 96 mm (30/184) to 64 mm (30/122) in group 2 (p=0.796, p=0.863). No significant difference was observed between the two groups when SVA changes were examined (p=0.696) (Table 2).

SS increased from 28° (13-41) to 33° (19-55) in group 1 and from 24° (8-50) to 33° (16-62) in group 2 (p=0.973, p=0.5). No significant difference was observed between the two groups when SS changes were examined (p=0.218).

The PT value decreased from 27.5°±8.0° to 21.0°±6.3° in group 1 and from 30.9°±6.4° to 22.7°±5.8° in group 2 (p=0.089, p=0.317). No significant difference was observed between the two groups when PT changes were compared (p=0.245).

LL values were significantly increased in both groups in the postoperative period (p<0.001, p<0.001). The LL value increased from 23° (4/46) to 40° (26/50) in group 1 and from 21° (4/52) to 33° (17/62) in group 2. There were no significant differences between the two groups with regards to LL (p=0.117) (Table 2).

A total of 113 osteotomy procedures (105 SPO+8 PSO) and 21 interbody cage with otograft placements were done in the participants of this study (Table 3).

In terms of quality of life, both groups demonstrated significant improvements in the postoperative ODI scores (p<0.001, p<0.001 respectively). There were no significant differences between the two groups in terms of changes in the postoperative ODI scores (p=0.522) (Table 2) (Figure 3 and 4).

A total of 18 complications were observed in this study (Table 1). The total complication rate was 32.1% (18/56): 24.1% (7/29) in group 1 and 40.7% (11/27) in group 2. After evaluating the complications in terms of specific causes, screw cover loosening was observed only in group 2 among two patients (7.4%) (2/27). S1 and iliac screw loosening were observed in 8.9% of patients (5/56) (Figure 5); two out of 27 patients (6.9%) in group 1 and 3 out of 27 patients (11.1%) in group 2. Rod fractures were observed in 7.1% of patients (4/56): 6.9% of patients (2/29) in group 1 and 7.4% of patients (2/27) in group 2. Superficial surgical site infection was detected only in one patient (3.7%) in group 2 within the whole study population. Postoperative haematoma was observed in three patients (5.4%) within the whole cohort. Postoperative haematoma was observed in one patient (3.4%) in group 1 and two patients (7.4%) in group 2. Only one patient (3.7%) in group 2 presented with sacroiliac joint pain in the whole study. Iliac screw malposition was observed in two out of 29 patients (6.9%) in group 2 (Figure 6). Four patients with rod fracture, five patients with sacral and iliac screw loosening and two patients with screw cover loosening underwent revision surgery. Patients with postoperative haematoma and superficial infection were re-operated for debridement and irrigation. Revision surgery was proposed to patients with sacroiliac joint pain, although they refused.

No pain related to screw prominency was reported.

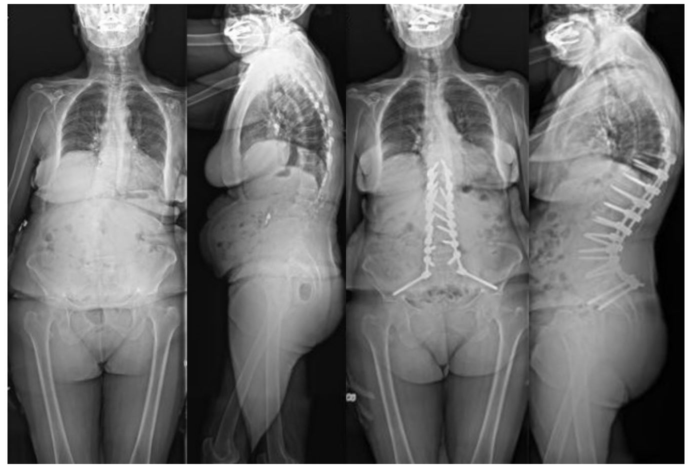

Figure 1, 2. Standing preoperative/postoperative (2 year after surgery) radiographs in the anteroposterior and lateral projections of a 71-year-old woman who underwent a posterior instrumented fusion from T10-ilium (S2AI). In the 2-year period, preoperative LL improved from 21° to 56° and SVA decreased from 45 mm to 16 mm

Table 1. Demographic data and list of complications in the study cohort

	Total (n=56) Mean ± SD (min/max)	Group 1 (S2AI) (n=29) Mean ± SD (min/max)	Group 2 (ILIAC) (n=27) Mean ± SD (min/max)	p
Age (yr)	69.4±5.8 (60/82)	69.4±6.3 (60/82)	69.3±5.3 (61/80)	0.948¹
	n (%)	n (%)	n (%)	
Gender				
Female	53 (94.6)	29 (100.0)	24 (88.9)	0.106²
Male	3 (5.4)	0 (0.0)	3 (11.1)	
Complications				
Screw nut loosening	2 (3.6)	0 (0.0)	2 (7.4)	0.428³
Sacral and iliac screw loosening	5 (8.9)	2 (6.9)	3 (11.1)	
Rod fracture	4 (7.1)	2 (6.9)	2 (7.4)	
Infection	1 (1.8)	0 (0.0)	1 (3.7)	
Haematoma	3 (5.4)	1 (3.4)	2 (7.4)	
Sacroiliac joint pain	1 (1.8)	0 (0.0)	1 (3.7)	
Iliac screw malposition	2 (3.6)	2 (6.9)	0 (0.0)	
Total	18 (32.1)	7 (24.1)	11 (40.7)	
	Median (min/max)	Median (min/max)	Median (min/max)	
Follow-up period (month)	38.5 (24/62)	41 (24/62)	38 (24/59)	0.784⁴
Level of instrumentation	10 (6/16)	10 (7/16)	10 (6/16)	0.115⁴
BMD (femur neck)	−2.25 (−4.1/1.5)	−2.3 (−4.1/1.5)	−2.2 (−3.9/−0.2)	0.324⁴

SD: Standard deviation; min: Minimum, max: Maximum, BMD: Bone mineral density
[1]Independent sample t-test (Bootstrap); [2]Fisher's exact test (exact); [3]Fisher−Freeman−Halton test (Monte Carlo); [4]Mann-Whitney U test (Monte Carlo)

DISCUSSION

Fusion between the sacrum and the lumbar spine has been very challenging, since the time instrumentation was introduced in spinal surgery. The anatomical properties of the lumbosacral intersection and the weak and cancellous structure of the sacrum makes it difficult to achieve rigid fusion. Therefore, many surgical strategies have been developed, one of which is inclusion of the pelvis in the instrumentation and this has been commonly used in spinal surgery[12]. This new strategies are very important because historical pelvic fixation techniques did not ensure adequate fusion and pseudarthrosis was also observed at a rate of 40%[6,12]. Fusion success was achieved in 90% of cases using iliac and S2AI screws[15,16].

Iliac and S2AI screws form a significant fixation force for lumbosacral intersection. Biomechanically, McCord et al.[17] defined the pivot point located in the middle column of the sacrum in the lumbosacral area. Both iliac and S2AI screws

Table 2. Comparison of radiographic parameters and health-related quality index between the groups

	Total (n=56) Median (min/max)	Group 1 (S2AI) (n=29) Median (min/max)	Group 2 (Iliac) (n=27) Median (min/max)	p value for between groups
ODI				
Preoperative	67 (15/98)	66 (15/98)	68 (40/86)	0.850^3
Postoperative	39.5 (5/91)	38 (5/91)	40 (16/86)	0.923^3
Change in ODI (postoperative-preoperative)	−24 (−69/25)	−26 (−60/25)	−18 (−69/10)	0.522^3
p value for intra groups	**<0.001^4**	**<0.001^4**	**<0.001^4**	-
SVA				
Preoperative	99.5 (30/235)	102 (50/235)	96 (30/184)	0.796^3
Postoperative	63 (16/180)	60 (16/180)	64 (30/122)	0.863^3
Change in SVA (postoperative-preoperative)	−41 (−175/95)	−42 (−175/58)	−36 (−126/95)	0.696^3
p value for intra groups	**<0.001^4**	**<0.001^4**	**<0.001^4**	-
Sacral slope				
Preoperative	27.5 (8/50)	28 (13/41)	24 (8/50)	0.973^3
Postoperative	33 (16/62)	33 (19/55)	33 (16/62)	0.500^3
Change in SS (postoperative-preoperative)	8 (−4/19)	6 (−4/19)	8 (0/19)	0.218^3
p value for intra groups	**<0.001^4**	**<0.001^4**	**<0.001^4**	-
Lumbar lordosis				
Preoperative	23 (4/52)	23 (4/46)	21 (4/52)	0.647^3
Postoperative	38 (17/62)	40 (26/50)	33 (17/62)	0.031^3
Change in LL (postoperative-preoperative)	15.5 (−4/29)	17 (−4/29)	8 (−4/24)	0.117^3
P value for intra groups	**<0.001^4**	**<0.001^4**	**<0.001^4**	-
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	
Pelvic tilt				
Preoperative	29.1±7.4	27.5±8.0	30.9±6.4	0.089^1
Postoperative	21.8±6.0	21.0±6.3	22.7±5.8	0.317^1
Change in PT (postoperative-preoperative)	−7.3±5.6	−6.5±6.0	-8.2±5.0	0.245^2
P value for intra groups	**<0.001^2**	**<0.001^2**	**<0.001^2**	-

SD: Standard deviation, min: Minimum, max: Maximum, ODI: Oswestry disability index, SS: Sacral slope, LL: Lumbar lordosis, PT: Pelvic tilt
^{1}Independent samples t-test (Bootstrap), ^{2}General linear model repeated ANOVA (Wilks's Lambda, bootstrap), ^{3}Mann-Whitney U test (Monte Carlo), ^{4}Wilcoxon signed ranks test (Monte Carlo)

create a strong fixation centre in the anterior portion of the pivot point, thereby reducing the load applied on the sacral screw[13,18]. Although they are similar in terms of their fixation

Table 3. Types of osteotomies and levels

Levels	Interbody cage + otograft	SPO osteotomy	PSO osteotomy
L1-2	-	-	-
L2-3	-	9	-
L3	-	-	2
L3-4	1	17	-
L4	-	-	6
L4-5	6	35	-
L5-S1	14	44	-
Total	21	105	8

SPO: Smith-Petersen osteotomy, PSO: Pedicle substraction osteotomy

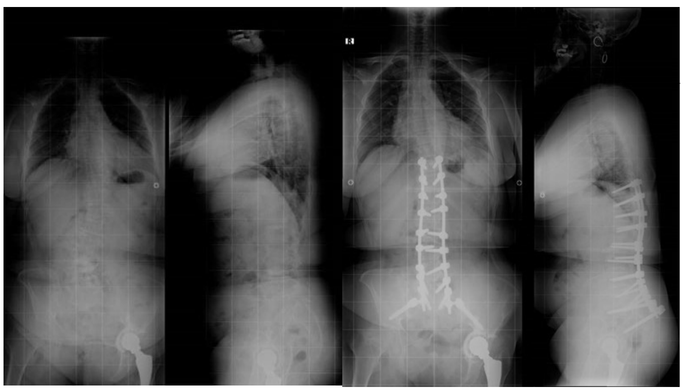

Figure 3, 4. Standing preoperative/postoperative radiographs in the anteroposterior and lateral projections of a 66-year-old woman who underwent posterior instrumentation from T10-ilium (conventional iliac screw). Please note that offset connectors were used to place the rods. LL improved from 40° to 53° and SVA remained same

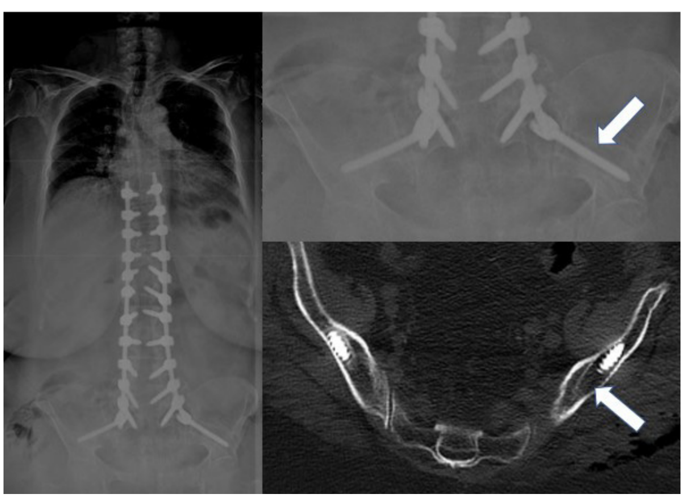

Figure 5. White arrow indicates loosening of the iliac screw

force, iliac and S2AI screws can be distinguished in several ways. One of the greatest disadvantages of conventional iliac screws is that they create a prominence under the skin and cause pain, especially in slim patients[11]. In addition, the entry point of the iliac screw on the posterior/superior iliac bone is far from that of the sacral screw, requiring a longer skin incision and the use of an offset connector. Kebaishi et al.[19] aimed to identify solutions to these problems when defining S2AI screws. The screw which extends to the iliac crest passing through the dorsal foramen of S1 and S2, ends within the iliac crest in parallel with the S1 screw tip, by passing through the sacroiliac joint. This anatomical superiority makes it easy to place rods and tightly fixes the sacroiliac joint[18].

In this study, we examined the results of two different iliac screw applications in patients who had undergone sacropelvic fixation. There were no significant differences between group 1 and group 2 in terms of the radiographic parameters measured (SVA, SS, PT, LL). While recovery was observed in the sagittal alignment in both groups, no significant difference was observed between the groups in terms of SVA, PT, SS and LL. This result supports the assertion that both screws have similar effects in terms of their pelvic adhesion force[13].

In the ODI scale, we used a life-quality index, which demonstrated significant recovery in both groups in the postoperative period with respect to the preoperative assessments ($p<0.001$). No significant difference in the ODI was observed between the two groups ($p=0.522$). Although there are no studies comparing the direct effect of iliac fixation and the S2AI screw method on the quality of life, some previous studies are similar to the present study. Güler et al.[20] examined the complications of patients with adult spinal deformity and sacropelvic fixation and found a moderate recovery according to the ODI measurements in the first 6 months and during the last follow-up assessments. Another study performed three pelvic fixation procedures (Galveston technique, iliac screw and S2AI) on patients with spinopelvic deformities and found significant recovery in the Oswestry scores of the patients who underwent each of the three techniques[21] ($p<0.001$). In light of this information, the recovery observed in the ODI scores in this study is in agreement with existing literature.

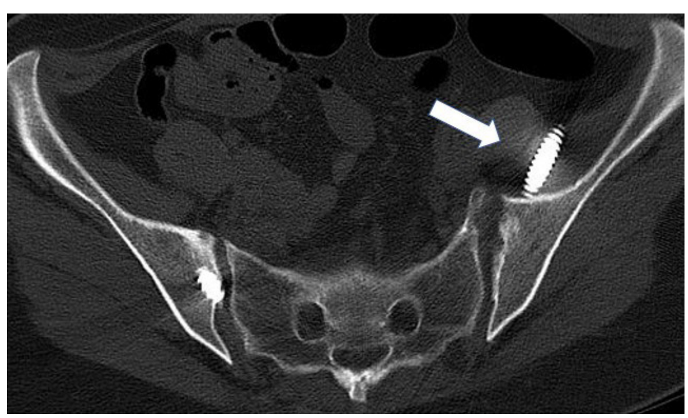

Figure 6. White arrow indicates the malposition of the iliac screw

Numerous publications evaluated the complications in patients who had undergone surgery for spinopelvic fixation. The perioperative process is time-consuming and the patients experience problems postoperatively. Conditions are hemodynamically challenging and problems occur in relation to clinical management in both the early stages and in the long-term. In the present study, we studied patients for an average of 40 months. Complications were observed in 18 (32.1%) (18/56) patients in all the groups. There were seven (7/29) (24%) of S2AI screw patients and 11 (11/27) (40%) of conventional iliac screw patients with complications. Implant-related complications, evaluated as mechanical complications (screw cover loosening and screw loosening), were more common in patients with conventional iliac screw placements. However, no statistically significant difference was found, since the sample size of the study was relatively small. The frequency of implant-related complications could be explained by the fact that may be the entry point of the iliac screw is not in parallel with the screw head placed from the S1 pedicle. We think that a non-proportional increase in the load applied on the iliac screw creates a strong pull-out effect on the implant at the distal-most portion. Nonetheless, further biomechanical studies will help confirm this assertion more accurately. In this study, only one patient belonging to the iliac screw group developed a wound infection and was treated with appropriate antibiotic therapy and debridement.

Persistent hip pain is a commonly encountered problem after sacropelvic fixation and it generally occurs due to degeneration of the sacroiliac joint or irritation of the screw head under the skin[22,23]. The mechanism responsible for the sacroiliac joint degeneration are similar to that of the adjacent segment disorder[24]. In the present study, sensitivity upon palpation of the sacroiliac joint and degeneration of the sacroiliac joint in computed tomography were detected in one patient in group 2, after prolonged persistence of his hip pain. It seems that pain occurred in the joint due to increased stress and capsular tension. In the present study, no parameters were specifically studied to identify sacroiliac pains and only one patient in group 2 experienced severe pain. In group 1, no patient went through a similar clinical process, which is likely because S2AI fixation rigidly fixates the joint[17,22].

Study Limitations

The present study has certain limitations, the most important of which is its retrospective design. The second limitation is that the quality of life measures were limited when evaluating the patient groups. Although the ODI scale was used, incorporating additional quality of life measures would ensure a more objective assessment of the study groups. However, a strength of the present study is that a long follow-up period was used to examine the cases both clinically and radiologically.

CONCLUSION

The use of multilevel fixation in degenerative spinal surgery has increased in recent years. The inclusion of pelvic fixation is one of the most controversial points. In this study, the two pelvic fixation methods provided an improvement in both radiographic and functional parameters. We believe that both techniques positively impact patient comfort in the postoperative period, especially in the geriatric population.

Ethics

Ethics Committee Approval: Retrospective study.

Informed Consent: Informed consent was obtained from all individual participants included in the study.

Authorship Contributions

Concept: A.A., S.K.O., İ.İ., V.A., Y.G., Design: A.A., S.K.O., İ.İ., V.A., Y.G., Data Collection or Processing: A.A., S.K.O., İ.İ., V.A., Y.G., Analysis or Interpretation: A.A., S.K.O., İ.İ., V.A., Y.G., Literature Search: A.A., S.K.O., İ.İ., V.A., Y.G., Writing: A.A., S.K.O., İ.İ., V.A., Y.G.

Conflict of Interest: No conflict of interest was declared by the authors.

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