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Study Design: This is a retrospective study.

Objectives: To evaluated the clinical and radiological effectiveness of sacral alar screws for augmentation of S1 pedicle screws in long-level fusion including L5-S1 segment.

Summary of Literature Review: The fusion rates of lumbosacral junction in long-level fusion are various when S1 pedicle screws are used without augmentation. But, reports of sacral alar screw augmentation are rare.

Material and Methods: From 1996 to 2005, 63 patients performed more than two-level fusion including lumbosacral junction were reviewed. 47 patients underwent lumbosacral fusion with S1 pedicle screws only (S1 group), and 16 patients with sacral alar screws augmentation in addition to S1 pedicle screws (S1-2 group). Radiologically, bony union, halo sign, and breakage of implants were evaluated. Clinically, complications associated with screw placement and general complications were evaluated.

Results: Bony union was obtained in 56 cases(89%) at postoperative 4.3 months. Nonunion was observed in 7 cases(11%, S1 group:5, S1-2 group:2). Loosening of S1 pedicle screw was observed in 32 cases(89%) of S1 group and in 4 cases(25%) of S1-2 group. It showed statistical significance between two groups. Sacral alar screw loosening occurred in 8 cases(50%) of S1-2 group. Metal breakage was developed in 2 cases of S1 group without nonunion or loosening. Postoperative infection occurred in 7 cases(11%, S1 group:5, S1-2 group:2).

Conclusions: Sacral alar screw augmentation was effective on protecting the loosening of S1 pedicle screw. Additional sacral alar screw can improve the rate of fusion for lumbosacral junction despite no statistical significance.

Key Words: Lumbosacral fusion, Long level fusion, Sacral alar screw augmentation

INTRODUCTION

The spinal fusion is one of the surgical methods that are frequently performed for the spinal disorder. As the advancement of various types of internal fixator, higher rate of fusion has been reported. The internal fixator withstands the loadings which is generated after spinal fusion. Also it provides the initial stability and enhances achieving the solid fusion. Particularly, instrumentation of pedicle screw produces a strong fixation force and it thereby raises the the rate of fusion for the long-segmental fixation extending to the sacral vertebrae as well as the short-segmental fixation.[1-5]

Despite of the advancement in the fixation methods, the nonunion followed by pseudoarthrosis is one of the most concerned problems that might occur after spinal fusion. The incidence of pseudoarthrosis after lumbosacral spinal fusion

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varies depending on the authors. It is generally known, however, that there is a close relationship between the rate of fusion and the number of fixation segments. In particular, in cases in which the long-segmental fusion is performed including the lumbosacral segment, the rate of fusion between the L5 and S1 has been reported to vary. Besides, it has also been reported that the incidence of pseudoarthrosis is increased as the number of fused segments increased.[1-3,6,7] As part of an effort to reduce failure of fusion, such methods as iliosacral screw or iliac screw, S2 screw or sacral alar screw and the insertion of hook in various locations have been introduced, each of which has been reported to have merits and demerits.[1,3,8-12)]

The purpose of this study is to evaluated the clinical and radiological effectiveness of sacral alar screws for augmentation of S1 pedicle screws in long-level fusion including L5-S1 segment.

RESEARCH SUBJECTS AND METHODS

We retrospectively analyzed the cases of which more than three segments were fused following the use of fusion of more than three segments including the L5-S1 or following the fusion of lumbosacral segment after the primary fusion of more than two segments in the lower lumbar region. All procedures were performed by one senior surgeon(J.Y.C) at a single institution from 1996 to 2005. We reviewed the medical records and radiological data of those patients. A total of 63 cases were enrolled in the this study. Including the degenerative lesions of the adjacent segments, there were 59 cases of degenerative diseases such as multi-level spinal stenosis, degenerative scoliosis, degenerative kyphosis or spondylolisthesis. There was one case of multi-level ossification of the ligamentum flavum, the metastatic tumor of the L5 vertebra, the tuberculosis of the L4-5 vertebrae and the hemivertebra of L5 level. In addition, there were 48 cases of the primary surgery and 15 cases of revision surgery. Of these, patients in whom the S1 pedicle screw was used to fix the lumbosacral region and those in whom the sacral alar screw was additionally used were classified as the S1 group and the S1-2 group, respectively. One patient had a sacral alar screw inserted during the surgery. For this patient, however, the sacral alar screw was removed due to the fixation failure. The patient was therefore classified as the S1 group. The additional insertion of the sacral alar screw for the long-segmental fixation was initiated since 2000.

Table 1. Fusion Grades (by Lenke Classification)

Grade	
A	Definitely solid with bilateral stout fusion masses present
B	Probably solid with a unilateral stout fusion mass & contralateral thin fusion mass
C	Probably not solid with a thin unilateral fusion mass & probable pseudarthrosis on the contralateral side
D	Definitely not solid with thin fusion masses bilaterally with obvious pseudarthrosis or bone graft dissolution bilaterally

The S1 pedicle screw was chosen by diameter which was as large as possible. The S1 pedicle screw should penetrate the anterior cortex of the sacral promontory. The sacral alar screw was inserted in the superolateral region of sacral ala based on the reference point of the S2 pedicle. Otherwise, it was laterally inserted in the sacral ala which corresponded to the S1 segment. The anterior support for the L5-S1 vertebrae was not performed for cases in which only the posterolateral fusion was performed by the methods of fusion. Except of the one case in which the autologous iliac bone was grafted because of the tuberculous spondylitis, the trapezoidal metal mesh cage was used in all the cases in which the posterior interbody fusion or the anterior fusion were performed.

In the group S1, there were 47 patients who were composed of 8 male and 39 female. In these patients, mean age was 60 years (range, 44~74 years) and the mean follow-up period was 5 years and 8 months (range, 26~108 months). In the group S1-2, there were 16 patients who were composed of 3 male and 13 female. In these patients, mean age was 58 years (range, 26~72 years) and the mean follow-up period was 4 years and 1 month (range, 20~73 months). Radiological assessments were performed both preoperatively and postoperatively, which was also based on a principle that a follow-up study should be performed 1, 36 and 12 months after surgery postoperatively. The rate of bony union was evaluated based on the Lenke classification system[13)] only in the lumbosacral segment (Table 1). Then, the grade B and more were evaluated as cases in which the complete bony union were achieved. It was determined that the bony union was achieved in cases in which there was a radiolucent line was observed but there was a sclerosis despite a lack of the further progression of the increased density on a

follow-up radiography or those in which there was a fusion of the grafted bone (sentinel sign) in the anterior aspect to metal cage without the erosion around the metal cage.

Including the difference in the rate of bony union between the two groups, radiological findings were compared. To do this, the loosening and breakage of the internal fixators were compared. Besides, in addition to the presence of discomfort associated with the implanted device, it was examined whether there were such complications as cauda equina syndrome due to the postoperative infection and hematoma. In addition, a comparative analysis was also performed to identify the correlations between the range and methods of fusion, the anterior support to the lumbosacral segment, the diameter of the S1 pedicle screw and the bone mineral density (BMD).

Statistical analysis was performed using SPSS 12.0 statistical program (Chicago, Ilinois, USA), where a t-test and a regression analysis were performed. A value of $p<0.05$ was considered statistically significant.

Table 2. Demographic data of S1 and S1-2 group.

	S1 group	S1-2 group	P value
Age	60.3 ± 6.6	57.8 ± 11.7	0.283
mean±SD(range)	(44~74)	(26~72)	
Sex			
M : F	8 : 39	3 : 13	1.000
Op			
primary : revision	37 : 10	11 : 5	0.501
Fusion level			
mean(range)	3.4 (3~6)	3.4 (3~6)	1.000
Screw diameter			
6mm / 7mm (%)	29 / 18 (62 / 38)	4 / 12 (25 / 75)	0.019
Fusion method, No.(%)			
PLIF or Anterior fusion	26 (56)	5 (31)	0.006
P-L	19 (40)	5 (31)	
PLIF+P-L	2 (4)	6 (38)	
BMD (g/cm^2)	0.920±0.154	0.800±0.143	
mean±SD	(0.637~1.195)	(0.623~1.125)	0.041

RESULTS

Between the two groups, there were no significant differences in the age, sex, whether patients underwent the primary surgery or revision one, the level of fusion and the anterior support to the lumbosacral segment. But there were significant differences in the methods of fusion, the diameter of the S1 pedicle screw and the bone mineral density between the two groups (Table 2).

In 89% (56/63) of total cases, the bony union was achieved postoperatively, average of 4.3 months(range, 2.5~12 months) (Fig. 1). Non-union occurred in 7 cases (11%) including 3 cases suffered from the postoperative infection. Except for one case of

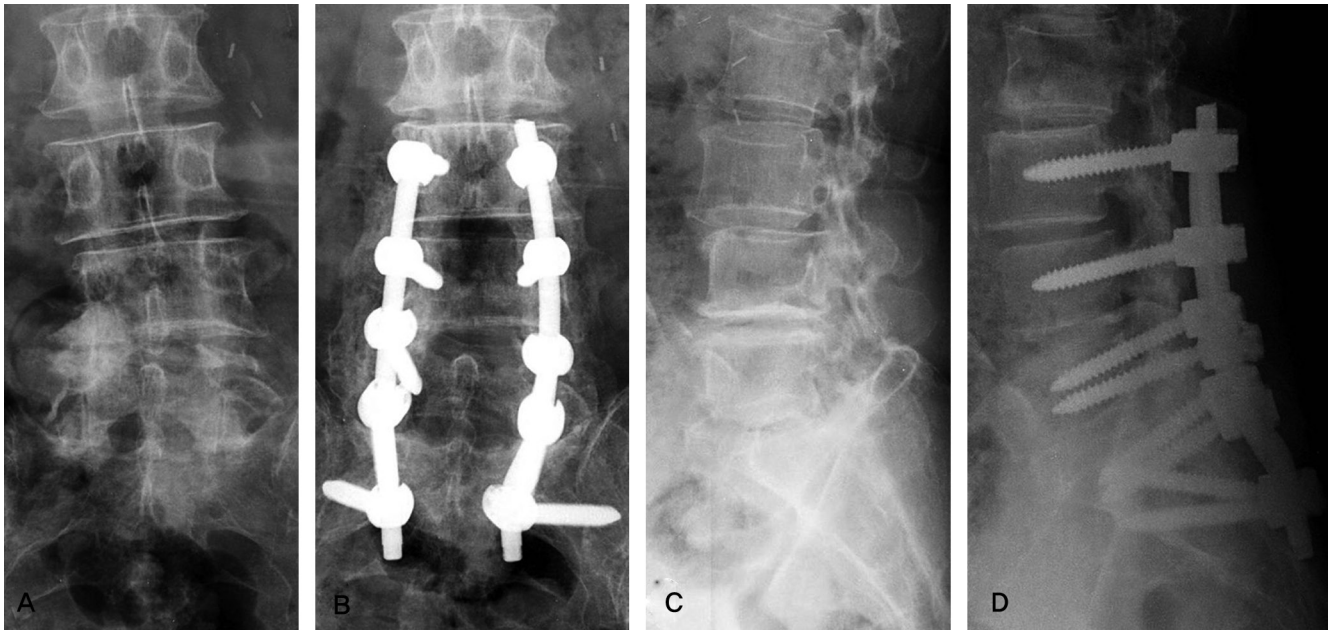

Fig 1. (A, B) Preoperative anteroposterio(AP) and lateral views of a 59 year-old female show degenerative spondylolisthesis, L3-4 and narrowing of L4-5-S1 disc spaces. **(C, D)** 2 years follow-up AP and lateral views fixed with S1 pedicle sacral screw and augmentation with sacral alar screw show solid union and no evidence of metal failure.

Table 3. Comparison of radiological results.

	S1 group	S1-2 group	P value
Nonunion No. (%)	5 (11)	2 (13)	1.000
S1 screw loosening No. (%)	32 (68)	4 (25)	0.004
Metal breakage No.	2	0	0.347

the LTFU (lost-to-follow-up), the bony union was achieved following the additional surgery. Of these, there were 5 cases (71%) of the group S1 and 2 cases of the group S1-2. Besides, there were 4 cases of nonunion without postoperative infections, all of which occurred only in the group S1. But there was no statistically significant difference between the two groups (Table 3).

The loosening of the S1 pedicle screw was seen in 57% (36/63), and it was seen in 32 cases (89%) of the group S1 and 4 patients (25%) of the group S1-2. This difference reached a statistical significance. Of these, the loosening occurred due to the postoperative infection in 5 patients of the group S1 and two patients of the group S1-2. In 24 cases of the group S1 who presented with no non-union, the loosening of the S1 pedicle screw occurred on approximately postoperative 6 weeks, being the earliest, and it transiently progressed but underwent sclerosis without further presence of the radiolucent lines. In the group S1-2, the loosening of sacral alar screw was observed in eight patients (50%).

There were 2 cases of the breakage of the internal fixator in the lumbosacral segment only in the group S1. In one case, there was a unilateral presence of the breakage of a pedicle screw and a contralateral presence of rod (Fig. 2). In the other case, there was a presence of the breakage of a pedicle screw but there was no loosening of a screw or nonunion. In 7 cases (11%), the postoperative infections were occurred. Of these, 5 cases occurred in the group S1. The skin protrusion associated with screws occurred in 13 cases of the S1-2 group, ten of whom complained of a discomfort.

DISCUSSION

In the surgical treatment of the degenerative spinal disease, the spinal fusion is the treatment of choice together with the spinal decompression surgery. The successful fusion is the most crucial element that can obtain the excellent postoperative outcomes.[14] With the recent development of internal fixation instrument and the technical advancement of surgery, however, the pseudoarthrosis due to nonunion is one of the most serious problems that might occur following the operation of spinal fusion.

It has been reported that the breakage of internal fixator and the nonunion frequently occur in the lumbosacral region as compared with other vertebral segments because of the anatomical characteristics of the lumbosacral region when the instrumentation was performed.[15,16] Kornblatt et al.[5] reported that the incidence of the breakage of internal fixator and nonunion was 3.5-10% in a single segment of L5-S1, 15-20% in two segments of L4-S1 and 25-33% in three segments. According to Ogilvie and Schendel et al.[17] the rate of nonunion was 72% and this corresponded to a higher value in patients with scoliosis for whom the fusion was performed up to the sacral level. Other studies have also reported that the rate of the failure of the fusion was relatively higher in patients who underwent the fusion up to the sacral level with the use of a pedicle screw.[7,17-19] These results might be due to an excessive flexion force exerted

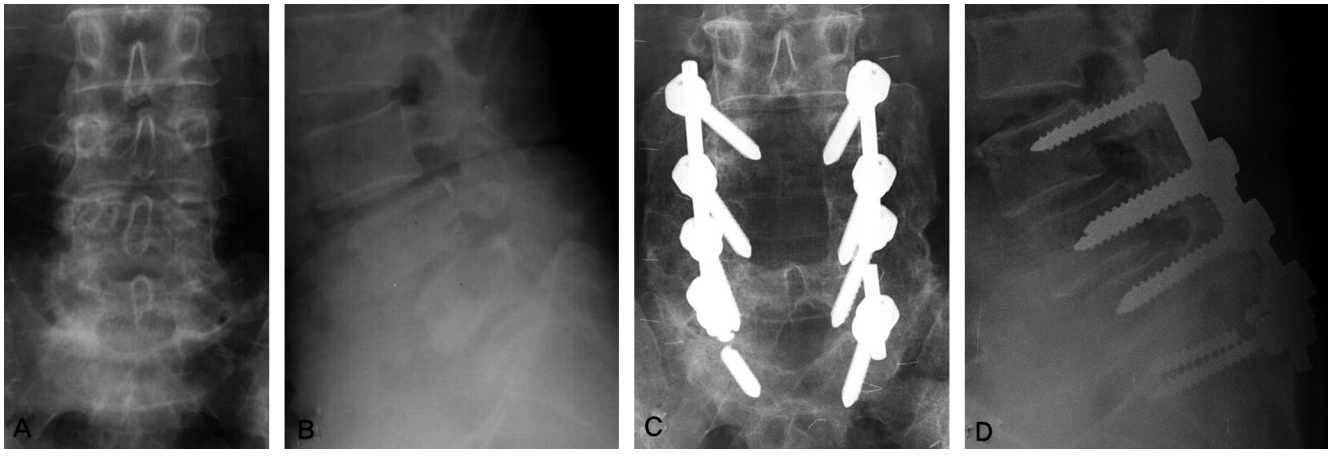

Fig 2. (A, B) Preoperative AP and lateral views of a 53 year-old female show isthmic spondylolisthesis L3-S1. **(C, D)** 5 years 10months follow-up anteroposterior and lateral views fixed with single sacral screw show union of posterolateral fusion but breakages of one sacral screw and one opposite rod.

to a screw which was inserted in the sacrum during the multi-level fixation, osteoporotic features of the sacrum, an insufficient degree of fixation force between a screw and the sacrum and the inappropriate direction to and depth at which a screw was inserted.[20]

Other authors maintained that the fixation force could be increased if a multiple number of segmental screw should be inserted in the sacrum.[18,19] Ogon et al.[21] reported that the fixation force was increased by 73% when dual screws were inserted anteriorly in a trigonal shape. Leong et al.[22] conducted a cadaveric study, according to which two radiating trigonal screws rather than a single sacral screw raised the traction force by 126% and the twisting force by 120% and thereby produced more rigid fixation force. In addition, recommending the anterior trabecular bone graft for scattering the load, these authors also maintained that the additional fixation using a rod between the sacral vertebrae or that between the bilateral iliac bones should be considered.[23]

Besides, in an actual clinical setting, the rate of the breakage of a screw was relatively higher in cases in which the sacral region was fixed as compared with otherwise cases because an excessive degree of the flexion force and the shear force were exerted to a screw inserted in the sacral vertebra.[24-26] Shin et al.[24,25] reported that a general type of the breakage of a pedicle screw occurred at an incidence of 7.7% and the mechanical failure of a sacral screw occurred at a higher incidence of 13.5% following the use of a single pedicle screw as compared with dual pedicel screws. In addition, Kim et al.[26] reported that the loosening of a screw occurred at an incidence of 41.9% in cases of the lumbosacral fusion. Also in our clinical series of patients, the breakage of the S1 pedicle screw occurred only in two patients (3%) of the group S1. Besides, the loosening of the S1 pedicle screw occurred in 57% (36/63) of total cases, 32 of which (89%) occurred in the group S1 where only the S1 pedicle screw was used. But the S1-2 group also showed that the loosening of sacral alar screw occurred at higher incidence (four cases, 50%). This might cause the stress concentration in the most inferior part of the fixation. At the same time, the loosening of the S1 pedicle screw occurred in 4 patients (25%) of the group S1-2. It was statistically significantly decreased because the stress loading was dispersed due to a sacral alar screw($p= 0.004$).

Kuklo et al.[27] reported that the rate of fusion was 95.1% following the fusion of S1 and the lumbosacral fusion with an iliac screw. Smith et al.[28] and Halvorson et al.[29] reported that the strength of dual pedicle screws was not greatly increased as compared with a single pedicle screw despite the additional insertion of the screw because the central region of the S1 had a lower degree of the bone mineral density as compared with the sacral ala. According to Smith et al.[28] following a comparison of the strength between cases in which a screw was inserted in up to the anteromedial cortical bone in the older sacrum and those in which a screw was inserted in the adjacent area to the cortical bone without being inserted in up to it, the strength was just increased by 4.8% in the former cases. The above authors noted that the strength was not greatly increased because the anterior cortical bone was fragile in the sacrum of elderly patients. In this study, on the other hand, the rate of fusion was found to be 89% in total. Except for 3 cases of postoperative infection, the rate of bony union was found to be 91% in the group where only the S1 pedicle screw was used. In the group where a sacral alar screw was concomitantly used, the bone fusion was achieved in all the cases.

Besides, the incidence of complications such as the infection (7 cases, 11%) occurring in our clinical series of patients might be relatively higher as compared with the reports made by Kim et al.[30] This might be due to the following reasons: As the preoperative risk factor, a majority of patients had the degenerative spinal disease (59 cases, 94%) and these patients were the elderly. As the intraoperative risk factor, the depth and size of tissue dissection were relatively greater during surgery. To such an extent that the decompression was needed, the operation time was prolonged. Besides, from an anatomical perspective, the depth from the epidermal layer and the volume of posterior muscle were not relatively greater in the sacral region as compared with the lumbar region. The symptoms due to skin irritation might also affect the results of the current study. In association with this, the discomfort that the internal fixator was postoperatively palpated was of higher degree. To avoid this, therefore, surgical methods should be improved in such a manner that the curvature of a rod should be adjusted so as to close it to the bone as maximally as possible in inserting a sacral screw. In addition, further studies are also warranted to examine the correlations with risk factors in a larger clinical series.

CONCLUSIONS

In the long-segmental fixation including the lumbosacral region, by using a sacral alar screw concomitantly with the S1 pedicle screw for the sacral fixation, the loosening of the S1 pedicle screw can be prevented and the rate of fusion for the lumbosacral segment can be raised. Not only because there is a higher risk of developing the postoperative infection but also because the subcutaneous protrusion of a sacral alar screw might cause a discomfort. However, more meticulous surgical methods with caution might be necessary.

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요천추분절을 포함한 장분절 유합술시 사용한 천추익 나사못의 효과

정재윤 • 서형연 • 임지현 • 강경도 • 김성규 • 이건우
전남대학교 의과대학 정형외과학교실

연구 계획: 후향적 연구
목적: 요천추분절을 포함한 세 분절 이상의 장분절 유합술시 사용한 천추익 나사못의 효과를 알아보고자 하였다.
선행문헌의 요약: 요천추분절을 포함한 장분절 유합술시의 유합율에 관한 문헌들의 결과는 다양하다. 하지만 천추익 나사못을 함께 사용한 문헌들의 보고는 드물다.
대상 및 방법: 1996년부터 2005년까지 제 5 요추-천추 사이를 포함한 3분절 이상 유합을 시행하였던 63예를 대상으로 하였다. 천추 고정을 위해 제 1 천추경 나사못만을 사용했던 경우(S1 군)가 47예, 천추익 나사못을 추가로 사용했던 경우(S1-2 군)가 16예로, 두 군 간의 골 유합의 차이를 포함하여 내고정물의 이완 및 파단 등 방사선학적인 결과를 비교하였으며, 임상적 술 후 합병증 등을 조사하였다.
결과: 총 63예 중 56예(89%)에서 술 후 평균 4.3 개월(범위, 2.5~12개월)에 골 유합을 얻었으며, 불유합은 7예(11%, S1 군: 5, S1-2 군: 2)에서 발생하였다. 제 1 천추경 나사못의 이완은S1 군에서는 32예(89%)가, S1-2 군에서는 4예(25%)가 발생하여 통계학적인 유의성을 보였다. S1-2 군에 있어서 천추익 나사못의 이완은 8예(50%)에서 관찰되었다. 요천추분절에서의 내고정물 파단은 S1 군에서만 2예 발생하였다. 7예(11%, S1 군: 5, S1-2 군: 2)에서 술 후 감염이 발생하였다.
결론: 요천추부를 포함한 장분절 고정술시 천추 고정을 위해 제 1 천추경 나사못과 함께 천추익 나사못을 사용함으로써 제 1 천추경 나사못의 이완을 막을 수 있고 요천추분절의 유합율을 높일 수 있었다.

색인 단어: 요천추분절, 장분절 고정, 천추익 나사못
약칭 제목: 요천추분절유합과 천추익 나사못