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Clinical Article

Unilateral Augmented Pedicle Screw Fixation for Foraminal Stenosis

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Objective : The purpose of this study is to evaluate the effectiveness of unilateral decompression and pedicle screw fixation for the unilateral symptomatic foraminal stenosis.
Methods : The study group comprises consecutive 16 patients who underwent unilateral decompression and bone cement augmented pedicle screw fixation from May 2003 to January 2006. The patients were evaluated by visual analog scale (VAS) for pain and the scoring system of the Japanese Orthopedic Association (JOA) for low back pain. The result of surgery was also evaluated with McNab's classification. Excellent or good outcome was considered as successful. The patients were followed at postoperative 1 month, 3 month, 6 month, and 1 year with standing AP and lateral films.
Results : The average VAS and JOA score of the 16 patients were 7.8 (range, 6-9) and 5.8 (range, 3 - 10) before surgery and 2.2 (range, 0 - 5) and 12.3 (range, 9 - 15) at the time of last follow up. Both VAS and JOA score improved significantly after the surgery ($p < 0.05$, t-test). All patients improved after the operation and no revision surgery was required. No metal failure or pseudoarthrosis was observed during the follow-up. The success rate was 87.5%.
Conclusion : Our data suggest that unilateral decompression and pedicle screw fixation for the unilateral symptomatic foraminal stenosis is an effect method for obtaining satisfactory clinical outcome. Its possible advantage is shorter operation time and reduced surgical extent. We believe that the reduced stiffness of unilateral fixation was compensated by pedicle screw augmentation and interbody fusion.

KEY WORDS : Foraminal stenosis · Pedicle screw · Bone cement.

INTRODUCTION

Stenosis of the intervertebral foramen is usually associated with decreased disc height, thickening of ligamentum flavum, bulging of intervertebral disc, hypertrophy of facet joint, and the growth of spur[5,15]. For enough decompression of the nerve root that passes the intervertebral foramen, the surgical procedure frequently involves removal of part of laminar, superior or inferior articular processes and protruded intervertebral disc. Wide decompression may cause postoperative instability if weight bearing structures are compromised. Instrumented fusion is necessary when preexisting or surgically induced instability is present.

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Pedicle screw instrumentation is a popular method of strong fixation to achieve high fusion rate. For stabilization of one spinal functional unit, four pedicle screws are usually used. The screws are connected with rods bilaterally. Although the ideal stiffness of instrumentation is unknown, pedicle screw fixation proved to be very strong and showed high fusion rate.

The foraminal stenosis is the result of degenerative change of spinal segment. The radicular pain may be unilateral if the progression of stenosis is different in both sides. In that situation, there is no need to expose contralateral side for the decompression of the corresponding nerve root. If the unilateral pedicle screw fixation is strong enough to achieve acceptable fusion rate, the surgeon can get the advantage of reduced surgical extent by exposing only the symptomatic side.

There are some studies testing the effectiveness of unilateral fixation. The idea of unilateral fixation was initially proposed to decrease the stiffness of fixation, thereby to reduce the degree of adjacent segment degeneration and the

decrease in mineral density of fused vertebra. The unilateral fixation may have some advantages such as a smaller surgical exposure, lower cost, and lower rate of screw-related complications. According to the reports by Suk et al.[19] and Fern ández-Fairen et al.[8], the unilateral screw fixation was effective as bilateral screw fixation in lumbar fusion. However, the fusion rates of unilateral fixation were lower than bilateral counterpart. Although the difference was not statistically significant, the advantage of unilateral fixation can hardly overweigh the possible risk of nonunion.

The purpose of this study was to evaluate the effectiveness of unilateral decompression and pedicle screw fixation for the unilateral symptomatic foraminal stenosis. We also applied the technique of pedicle screw augmentation with bone cement and interbody cage to increase the fusion rate.

Table 1. Scoring system for low back pain by JOA (maximum 15 points)

Categories	Degree	Score
Subjective symptoms (maximum 9 points)		
A. Low back pain	None	3
	Occasional mild pain	2
	Frequent mild or occasional severe pain	1
	Frequent or continuous severe pain	0
B. Leg pain and/or tingling	None	3
	Occasional slight symptoms	2
	Frequent mild or occasional severe symptoms	1
	Frequent or continuous severe symptoms	0
C. Gait	Normal	3
	Able to walk farther than 500 m although resulting in pain, tingling, and/or muscle weakness	2
	Unable to walk farther than 500 m owing to leg pain, tingling, and/or muscle weakness	1
	Unable to walk farther than 100 m owing to leg pain, tingling, and/or muscle weakness	0
Clinical signs (maximum 6 points)		
D. Straight leg raising test	Normal	2
	30 - 70 degrees	1
	< 30 degrees	0
E. Sensory disturbance	None	2
	Slight disturbance (not subjective)	1
	Marked disturbance	0
F. Motor disturbance (MMT)	Normal (grade 5)	2
	Slight weakness (grade 4)	1
	Marked weakness (grade 3 - 0)	0

JOA : Japanese Orthopedic Association

MATERIALS AND METHODS

The study group comprises consecutive 16 patients who underwent unilateral decompression and bone cement augmented pedicle screw fixation from May 2003 to January 2006. The indications for the procedures were; 1) Unilateral radicular pain on their leg that was not controllable with nonoperative treatment and lasted more than 3 months, and 2) Ipsilateral intervertebral foraminal stenosis that is responsible for the radicular pain is evident on magnetic resonance imaging.

Nine were men and seven were women, with a mean age of 60.4 years (range, 42 - 77). The mean duration of the symptom was 9.7 months (range, 3 - 22). Three patients had foraminal stenosis combined with degenerative spondylolisthesis. The sagittal slip did not exceed 10% of vertebral in anterio-posterior dimension in any case. No patient had spondylolysis. Four patients had history of previous spinal operation. All were laminectomies to decompress the nerve root.

The presence of foraminal stenosis was diagnosed in sagittal and axial MRI scans. The affected levels were L5-S1 in 9 patients, L4-5 in 4 patients, L3-4 in 2 patients. The patients were evaluated by visual analog scale (VAS) for pain and the scoring system of the Japanese Orthopedic Association (JOA) for low back pain (Table 1). The data were collected at the time of admission before the surgery and during the follow-up visit. The result of surgery was evaluated with McNab's classification. Excellent or good outcome was considered as successful. The patients were followed at postoperative 1 month, 3 month, 6 month, and 1 year with standing AP and lateral flexion / extension films. Less than 2^{O} of motion between the fusion segments of flexion and extension view and/or the presence of the presence of a contiguous trabecular graft were required to be solid or healed. More than 2^{O} of motion or the presence of translation, independent of the appearance of the graft, was considered a failure of fusion.

Operative procedure

The patient was placed on a radiolucent spine frame in prone position. After midline incision at the affected level, careful dissection was performed unilaterally out to the facet joint. The affected nerve root was decompressed by laminectomy and facetectomy. The intervertebral disc was removed with rongeurs and curette. Single cage with packed with laminectomy bone was inserted into the intervertebral space. The insertion site of the pedicle screws were marked

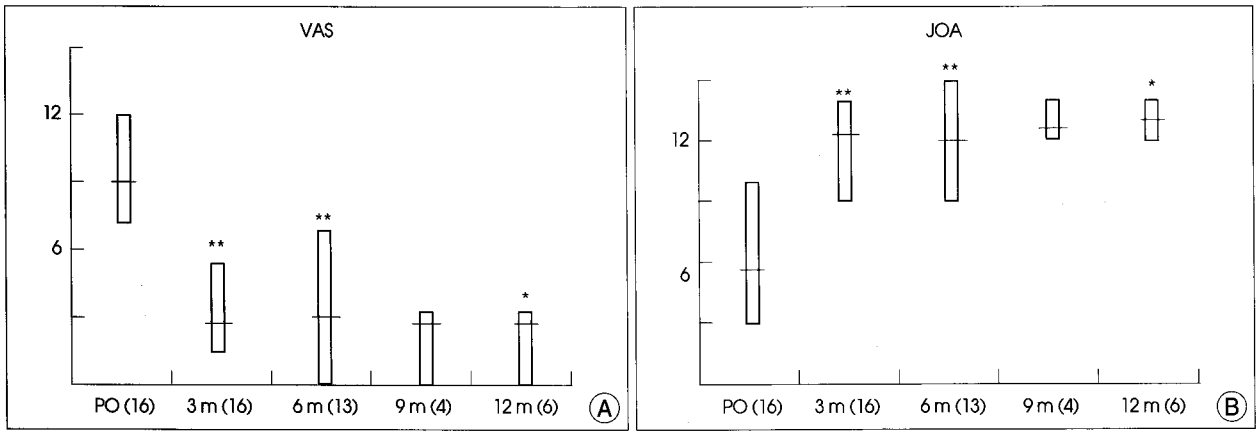

Fig. 1. Graphs showing visual analog scale (VAS) and Japanese Orthopedic Association (JOA) score (A and B respectively) before the surgery and during the follow-up. Both VAS and JOA score improved after the surgery and the improvement maintained thereafter. The improvement at 3, 6, 12 months are statistically significant compared with the preoperative values (Wilcoxon sign rank test, $*p < 0.05$, $**p < 0.01$). PO : preoperative.

Table 2. Surgical outcome by MacNab classification

Classification	Description	Number of cases
Excellent	Complete relief of back/leg pain	3
Good	Occasional pain in back/leg	11
Fair	Some improvement in back/leg pain Occasional use of pain medication	2
Poor	Little of no change in pain or worse than before surgery Regular use of pain medication	0

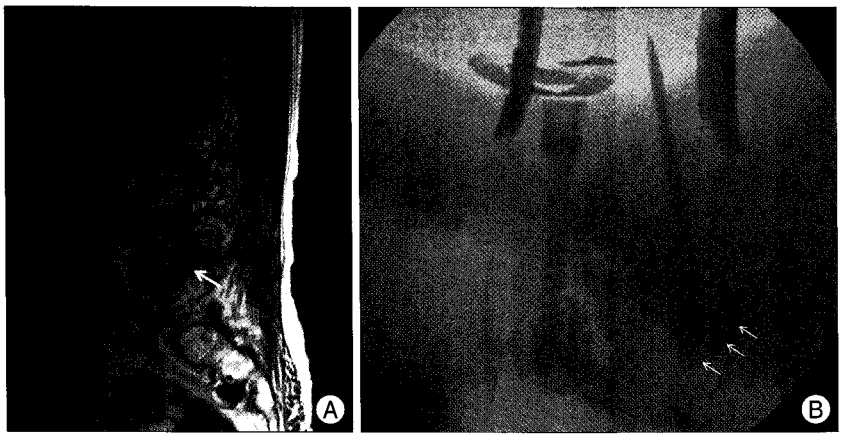

Fig. 2. Preoperative images of the illustrative case. A : Preoperative T2 weighted sagittal magnetic resonance image of the illustrative case. Note the left L5 root impingement in the intervertebral foramen by the protruded disc and collapsed disc space (arrow). B : Photograph which were taken during the operation. The pedicle screw is inserted into the L5 vertebra after injection of PMMA cement. Cement is being inserted into the S1 vertebra with 11 gauge needle for augmentation (small arrows). PMMA : polymethylmethacrylate.

with stainless pins, then holes were made with the serial use of awl and probe. After the 11G bone biopsy needle was inserted into the hole, about 3 cc of polymethylmethacrylate (PMMA) cement was injected through the needle. The procedure was monitored by C-arm fluoroscopy. Mid-third of the vertebra around the tract was considered as ideal distribution of the cement for the effective augmentation of the screws. The needle was pulled out and the pedicle screws were inserted before the cement became solid. The screws were connected with rod applying compressive force for better contact of the cage with the endplate.

RESULTS

There was one case of asymptomatic pulmonary embolization of the cement, which was detected postoperative chest film. Special attention was paid to the patient, but no specific treatment was required because the patient showed no symptom related to the embolism during the admission and follow up period. In other patients, no operation-related complication was noted. The mean duration of hospital stay was 6.7 days. Six patients were followed for 12 months. The average follow up duration was 7.9 months (range, 3 - 12).

As illustrated in Fig. 1, the VAS and JOA score improved in all patients after the surgery with statistical significance and the improvement maintained during the follow-up period (Wilcoxon sign rank test). Development of symptom or sign related to contralateral side of operation was not noted. In overall improvement, the average VAS and JOA score of the 16 patients were 7.8 (range, 6 - 9) and 5.8 (range, 3 - 10) before surgery and 2.2 (range, 0 - 5) and 12.3 (range, 9 - 15) at the time of last follow up. The improvement was statistically significant in both VAS and JOA score ($p < 0.05$, t-test). The average recovery rate in JOA score was 68.1% (range, 25.0 - 100.0).

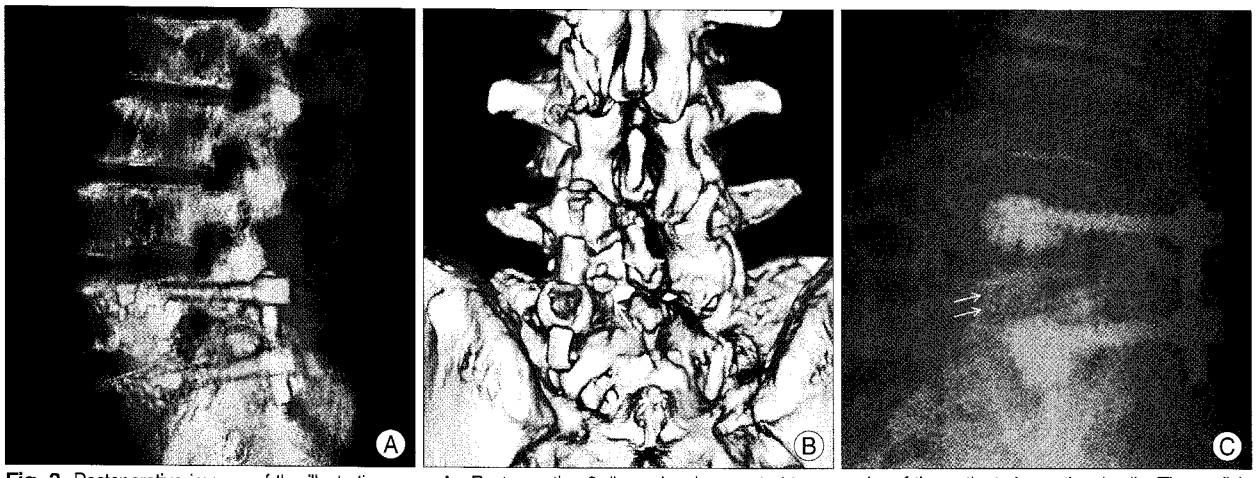

Fig. 3. Postoperative images of the illustrative case. A : Postoperative 3-dimensional computed tomography of the patient shows the details. The pedicle screws are surrounded by PMMA cement. B : Note the extent of laminectomy and facetectomy indicated by arrows. C : There is no metal failure and substantial amount of bone graft incorporating to neighboring vertebra is identifiable in lateral film which was taken 12 months after the surgery. PMMA : polymethylmethacrylate.

Mean duration of radiological follow-up was 7.5 months (range, 3 - 12). Varying amount of bone graft was visible at the fused level without more than 2^{O} motion in every case. There was no case which can be categorized to fusion failure. The final outcome by McNab classification is summarized in Table 2. The success rate, excellent or good, was 87.5%.

Illustrative case

A 63-year-old woman suffered from left-sided sciatica and had been unable to walk more than two hundred meters for 6 months. After making the diagnosis of left L5-S1 stenosis in MRI (Fig. 2A), she underwent unilateral laminectomy and facetectomy with augmented pedicle screw fixation and interbody fusion (Fig. 2B). Her VAS and JOA score improved from 8 to 2 and from 5 to 13, respectively. The improved VAS and JOA score did not change until the last follow up at the 12th month. Postoperative CT images showed enough decompression by laminectomy and facetectomy with good distribution of bone cement around the pedicle screws (Fig. 3).

DISCUSSION

As Jenis and An[10] noted, the foraminal stenosis is a common etiology of lumbar radicular symptoms. The incidence of foraminal stenosis is reported to be 8% to 11%. But, the diagnosis of foraminal stenosis is often difficult and when unrecognized, it is a frequent cause of failed back surgery syndrome[2,18]. The boundaries of the intervertebral foramen are not well defined. The authors used Jenis and An's definition of intervertebral foramen in the diagnosis of the patient in this study. In their definition, the intervertebral foramen is vertical interpedicular zone. So, the foraminal stenosis caused compression of the exiting nerve root in every case of this study. For the diagnosis of foraminal stenosis causing radicular pain, MRI may be the preferred imaging tool. The parasagittal images allow visualization of the contour and size of the intervertebral foramen with exiting nerve root. Direct contact of nerve root with neighboring bony spur, intervertebral disc, or ligaments and loss of intervening fat tissue may be the highly suggestive finding of symptomatic foraminal stenosis. However, as Attias et al.[1] suggested, there is poor intraobserver agreement in the diagnosis foraminal stenosis with MRI. We carefully observed the sagittal and axial scans of MRI to exclude other causes of radicular pain for correct diagnosis.

Because the foraminal stenosis involves the facet joint, pars interarticularis which are essential parts weight transmission between the vertebrae, best surgical method for its relief remains controversial. Macnab[13] proposed performing facetectomy and fusion as a standard method. There are also several methods that are not involving arthrodesis. Kunogi and Hasue[12] used lateral fenestration. Maher and Henderson[15] reported removal of the superior articular process sparing the facet joint. Ozeki and Henderson[17] introduced partial pediculectomy which was used in the treatment of their 36 patients. The decompression without fusion may have the advantage of preserving the segmental motion. But, as seen in the cases of Ozeki et al.[17], it is often difficult to achieve enough decompression preserving the facet joint. That is the reason why the authors chose facetectomy and fusion for the primary surgical method in this study. The fixation with pedicle screws allows enough facetectomy to decompress the nerve root. The placement of cage for interbody fusion distracts the disc space, thereby

enlarges the intervertebral foramen. We think that enough decompression by facetectomy made it possible that all of our patients improved after the surgery.

The effectiveness of unilateral pedicle fixation was investigated by several authors. The clinical results of unilateral pedicle screw fixation were nearly identical with that of bilateral fixation in Kabins et al.[11]'s and Suk et al.[19]'s report. Whereas Kabins et al. restricted unilateral fixation to single level, Suk et al. widened its application to multilevel fixation. The unilateral fixation had several advantages due to its less invasiveness such as shorter operative time, hospital stay and lower medical expenses.

Although we believe unilateral pedicle fixation is useful especially when the patient's symptom is unilateral, therefore only ipsilateral decompression and arthrodesis is required, we also concern about the decreased strength of unilateral fixation, which can result nonunion. Looking into the fusion rate of unilateral fixation in Suk et al.'s series, the fusion rate was lower than that of bilateral fixation, 91.5% vs. 97.5%. The biomechanical study also showed decreased strength of unilateral fixation. In Yücesy et al.[21]'s experiment, the unilateral fixation provided significantly worse stabilization. Goel et al.[9] also concluded that the unilateral screw system was less rigid and was likely to reduce stress shielding of the vertebral body compared with the bilateral model. The lower stiffness may contrioping bute to lowering the possibility of develadjacent segment degeneration. However, it also can cause metal failure or pseudoarthrosis.

To overcome the decreased stiffness caused by reduced number of pedicle screws in unilateral fixation, we adopted two methods that were proved to be useful. First, we applied augmentation method of injecting PMMA cement into the vertebral body[16]. The strengthening effect of PMMA in pedicle screw fixation was proven in many biomecha-oping nical studies especially in osteoporotic spine[4,6,17,20,22]. Although most of our patients did not have osteoporosis, we used bone cement to increase the pull-out strength of the screws because fixation with two screws should be weaker than fixation with four without augmentation. Second, we chose posterior interbody fusion rather than posterolateral fusion. Theoretically, posterior interbody fusion has higher strength than posterolateral fusion because it provides anterior column support. Higher fusion rate of posterior interbody fusion was reported in previous reports[3,7,14]. We think that no fusion failure in our series may be the result of combination of the two methods, at least partially.

The shortcoming of our study is that it consists of relatively limited number of cases and short follow-up duration. Therefore, there is possibility that the clinical or radiological outcome can change in longer follow-up. Larger scale study is required to further validate the effectiveness of the authors' operative method.

CONCLUSION

Our data suggest that unilateral decompression and pedicle screw fixation for the unilateral symptomatic foraminal stenosis is an effect method for obtaining satisfactory clinical outcome. Its possible advantage is shorter operation time and reduced surgical extent. The reduced stiffness of unilateral fixation may be compensated by pedicle screw augmentation with PMMA and interbody fusion.

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