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Research Article

Clinical Outcome of Minimally Invasive Repair of Pars Defect Using Percutaneous Pedicle Screws and Hook-Rod System in Adults with Lumbar Spondylolysis

Yoichiro Takata, Toshinori Sakai, FumitakeTezuka, YuichiroGoda, KosakuHigashino and Koichi Sairyo*

Department of Orthopedics, University of Tokushima, Japan

***Corresponding author**

Koichi Sairyo, Department of Orthopedics,University of Tokushima, Tokushima, 3-18-15 Kuramoto-cho, Tokushima 770-8503, Japan, Tel: 81-88-633-7240; Fax: 81-88-633-0178; Email: sairyokun@hotmail.com

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Abstract

Various techniques to directly repair a pars defect have been described. The aim of these procedures is to restore normal lumbar kinesiology, preserve a spinal motion segment and retain the associated spinal mobility. We have already reported a minimally invasive technique for the direct repair of a pars defect using a percutaneous pedicle screw system. This time, we report the clinical outcome obtained with this procedure. In all patients, both the Japanese Orthopedic Association score and pain assessed using a visual analogue scale improved postoperatively. Bony union was attained in 80% of the patients. Using this procedure, normalization of the lumbar kinesiology in terms of the instantaneous axis of rotation during lumbar extension/flexion was attained. Also, it was possible to preserve the spinal motion segment and to retain lumbar spine mobility.

INTRODUCTION

The incidence of lumbar spondylolysis (pars defect) has been estimated to be approximately 6% in the general population [1]. Regarding surgical treatment, various techniques to directly repair the pars defect have been described [2–10]. These techniques include bone grafting with the placement of wire, screws, or hook-screw constructs to stabilize the fractured pars. The aim of these procedures is to restore normal lumbar kinesiology, preserve a spinal motion segment and retain the associated spinal mobility. Most of them require large skin incisions and they injure par vertebral muscles (PVM) during the exposure. Recently, minimally invasive surgery (MIS) has been proposed as an alternative to these classical procedures. First, in order to resolve these problems, we developed an endoscopic direct repair of the pars using a modification of the classical Buck's procedure [11]. Although the damage of PVM was reduced, the procedure had the following shortcomings: (1) it was not applicable in patients with a thin lamina, (2) screws themselves limited the size of the graft bone mass, (3) it took a long operation time due to the difficulty of the technique. Then, since 2006, we started to employ applied a pedicle screw-hook-rod (PSHR) method using a percutaneous pedicle screw system to reduce the damage of PVM. The preliminary report on this technique has been published [12]. In this paper, we report the clinical outcome we obtained with this MIS-PSHR procedure.

MATERIALS AND METHODS

Patients

Ten patients (8 men, 2 women) with bilateral L5 spondylolysis were treated using our MIS-PSHR method (Table 1). Their mean age was 32.8 (range: 23-53) years. None of the patients had responded to conservative treatment for at least six months. Preoperatively all patients were confirmed the relief of their daily low back pain (LBP) after lido canine infiltration of the pars defects.

Surgical procedure

The details of the surgical procedure have been reported elsewhere [12]. After making a 3-4 cm midline incision, the par vertebral muscles are separated from the lamina. Then, the defect is confirmed, and the fibro cartilage mass is removed from the defect. In the cases with LBP as well as leg pain due to the ragged edge around the pars defect, the ragged edge is respected to decompress the L5 nerve root (Case 3-6,8,9). Next, pedicle screws are inserted through 2-cm longitudinal incisions on both sides, 5 cm laterally from the midline incision. Prior to screwing, chancellor's bone is harvested through the same lateral incision using a bone harvester. As the iliac crest is located close to the point of pedicle screwing, we can use the same lateral incisions. After the 2 screws are inserted, hooks are inserted into the caudal lamina and rods are inserted into the hole of the pedicle screws. Finally, the bone grafts are packed onto the defects.

Clinical assessments

All patients were evaluated using the Japanese Orthopedic Association (JOA) score, visual analogue scale (VAS) for low back pain and leg pain, operation time, intra operative blood loss, and complications.

Radiographic measurements

Bony union was confirmed by multi detector computed tomography (CT). From the lateral dynamic radiographs of the lumbar spine obtained pre- and post-operatively, inter vertebral motion of L5-S1, % slip of L5-S1, and instantaneous axis of rotation (IAR) were measured (Figure 1) [13].

RESULTS

The mean operation time was 278 (range, 205 to 326) minutes and the mean intra operative blood loss was 301 (range, 250 to 350) mL. There were no wound infections or neurologic complications. No hardware breakage or loosening was observed.

The results are summarized in Table 1. The mean postoperative follow-up was 16.1 (range: 12-25) months. Preoperative JOA score ranged from 4 to 20 (mean 15.8 points). Postoperative JOA scores of all patients ranged from 14 to 29 (mean, 26.4 points) were improved. The preoperative assessment of pain using a visual analogue scale (VAS) ranged from 50 to 100 (mean, 75.8 points) and greatly improved postoperatively (0 to 15; mean, 2.5 points). Multi-detector CT in eight patients except for Case 3 and Case 7 confirmed bony fusion.

Radiographic measurements were performed in eight patients except for Case 3 and Case 10 (Table 2). In Case 3, no postoperative lateral dynamic radiographs of the lumbar

Table 1: Clinical results after direct repair of a pars defect using our percutaneous pedicle screw and hook-rod system.

No.	Sex	Age	Follow-up (months)	Op. time (minutes)	Blood loss (mL)	VAS (LBP) Pre-op.	VAS (LBP) Post-op.	VAS (leg pain) Pre-op.	VAS (leg pain) Post-op.	JOA score Pre-op.	JOA score Post-op.
1	male	32	18	281	300	100	0	0	0	15	29
2	male	23	20	284	280	100	0	0	0	20	27
3	male	35	15	326	350	70	0	0	0	18	29
4	male	35	25	301	332	83	0	60	0	4	26
5	male	31	14	309	300	50	0	70	0	16	28
6	male	53	13	294	250	80	0	82	0	19	28
7	female	34	16	267	25	70	15	0	0	11	14
8	male	31	16	241	350	100	10	85	10	17	27
9	male	25	12	269	350	50	0	40	10	19	28
10	female	33	12	205	250	55	0	0	0	19	28

Abbreviations: Op: Operation; VAS: Visual Analog Scale; LBP: Lower Back Pain; JOA: Japanese Orthopedic Association

Table 2: Radiographic results of direct repair of a pars defect using our percutaneous pedicle screw and hook-rod system.

	L5-S1 intervertabral motion (degree)		L5-S1% slip (%)		location of IAR of L5-S1	
No.	Pre-op.	Post-op.	Pre-op.	Post-op.	Pre-op.	Post-op.
1	15.6	6.3	14.2	6.3	AD	PD
2	11.9	11.2	0	0	AR	PR
3	NA	NA	NA	NA	NA	NA
4	4.3	5	12.8	10.5	AR	PC
5	11.8	5.1	6	4.2	AR	PR
6	10.7	2.3	9.4	75	PR	PD
7	9.8	2.1	14.1	16.3	AD	PR
8	9.4	4.9	12.4	11.8	AR	PD
9	13.5	5.9	17.7	16.1	PC	PC
10	NA	NA	NA	NA	NA	NA

Abbreviations: Op: Operation, IAR: Instantaneous Axis of Rotation spine were obtained. Case 10 had lumbar scoliosis as well as spondylolysis, and a correct evaluation was impossible. After the direct repair, L5-S1 inters vertebral motions decreased in all patients except for Case 4. The L5-S1 slip at maximum lumbar flexion decreased in all patients except for Case 7. Location of the instantaneous axis of rotation of L5-S1 moved poster caudally in all patients except for Case 7.

REPRESENTATIVE CASE

A 33-year-old woman with a 2-year history of low back pain. She had no leg pain. Tenderness at the spinous process of L5 was apparent. The radio graphical examination revealed bilateral pars defects at L5, which was in the pseudoarthrosis stage. Additionally, grade 1 spondylolisthesis according to Meyer ding's classification, and scoliosis were found (Figure 2). Her daily LBP was verified to be transiently relieved by local anesthetic injection into the bilateral pars defects. Her preoperative JOA score was 19/29 points, and her VAS of LBP was 55/100 points.

She underwent the direct repair using MIS-PSHR (Figure 3). We found synovial tissue (usually described as fibro cartilage mass in the literature) in the pars defect. The pathological examination showed synovial lining cells and a loose fibrous mass (Figure 4). Immediately after the operation, she experienced relief of LBP. About 2 months later, the postoperative JOA score had improved to 27 points, and VAS assessment of LBP had decreased to 10 points. Twelve months later her JOA score was 28 points, and VAS assessment of LBP indicated complete relief (VAS: 0/100 points).

DISCUSSION

Various techniques for repairing lumbar spondylolysis have been described, including bone grafting with the placement of wire, screws, or hook-screws across the pars [2–10] . Kimura was the first to describe a method for direct repair of the pars defect in Japanese literature; he used bone graft and postoperative plaster immobilization [14]. Thereafter, Buck introduced another method for direct repair that employed internal fixation [2]. His method was based on screwing to secure the floating lamina to the pedicle. Nicol and Scott proposed the use of a tension-band wire around the transverse process and spinous process to secure fixation and healing of the defects [7]. Morscher et al introduced a hook screw for the fixation of pars defects. [15] Taddonio et al first introduced segmental pedicle screw hook fixation. The biomechanical comparison of fixation techniques carried out by Deguchi et al demonstrated the pedicle screw hook device was one of the most rigid systems [16]. However, these procedures required bilateral exposure of the posterior structures down to the base of the transverse processes. They obviously caused more iatrogenic damage to the soft tissues. Thus, large soft tissue damage should be prevented using minimally invasive techniques. Therefore, we adapted minimally invasive surgical (MIS) techniques to these procedures. The principles of our procedure are similar to those reported by Tokuhashi and Kakiuchi [6,17]. However, the development of devices that allows percutaneous pedicle screwing, the setting method of the rod and hook, and bone harvester has enabled us to perform direct repair more easily than previously reported.

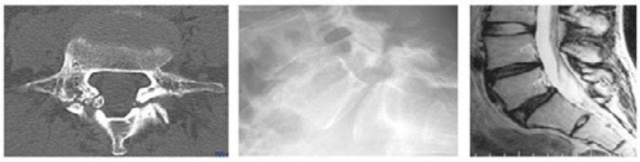

Figure 2 Left panel shows bilateral defects of the pars inter particular is at L5, which was in the pseudoarthrosis stage. Middle and right panels show the grade 1 spondylolisthesis (Meyerding's classification).

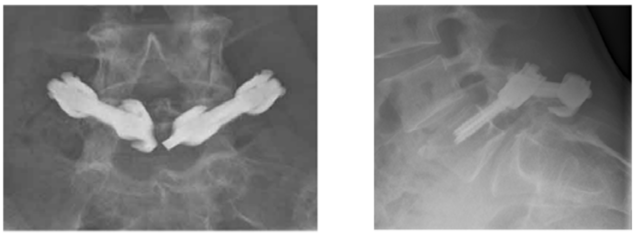

Figure 3 Postoperative plain radiographs of the spine after direct repair using our percutaneous pedicle screw and hook-rod system.

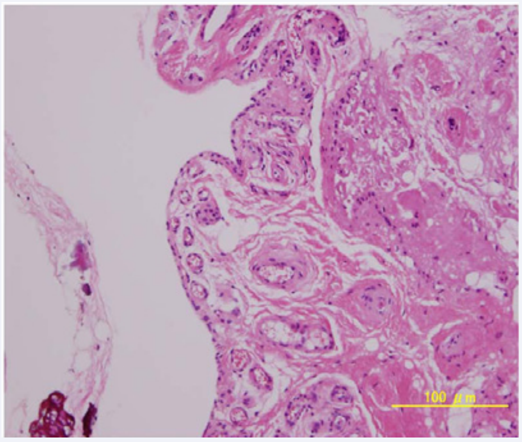

Figure 4 The pathological examination showing synovial lining cells and a loose fibrous mass.

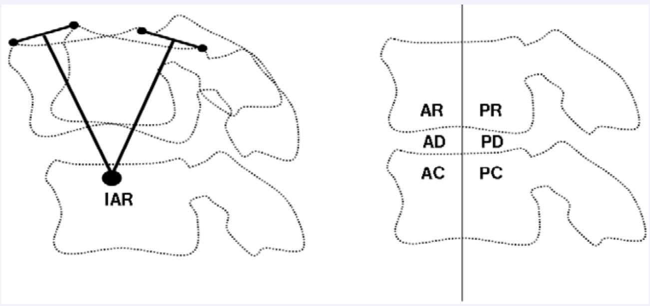

Figure 1 The left panel shows measurement of the instantaneous axis of rotation (IAR): IAR is defined as the point where the two perpendicular bisectors of two points on the moving vertebra intersect. The right panel shows the compartment system explaining the location of the IAR (AR: Anterior Rotating cranial vertebral body, PR: Posterior Rotating cranial vertebral body, AD: Anterior Disc space, PD: Posterior Disc space, AC: Anterior Caudal vertebral body, PC: Posterior Caudal vertebral body).

The aim of our procedures was to restore normal lumbar kinesiology, preserve the spinal motion segment and retain lumbar spine mobility. In the present study, the motion preservation of L5-S1 was achieved and L5-S1 slip was slightly reduced in all evaluated patients. Location of the IAR of L5-S1 moved postero-caudally in all patients except for Case 7. It correlated with the clinical result, because in Case 7 LBP did not alleviate completely (postoperative JOA score: 14/29, postoperative VAS, 15/100 points). The IAR of the lumbar spine has been reported to be located around the disc when the disc is normal Sakamaki et al [18–22] . reported that the IAR of the spondylolytic spine deviated cranially [13]. Actually, in the present study, in all but one patient, the IAR moved posterior-caudally after the operation. These results suggested that the normal kinematics had been restored.

For this procedure to be successful, the pain source must be the pars defect itself. In all our patients we preoperatively verified that their pain disappeared after injection of an anesthetic into the defects. Bradford and Iza recommended anesthetic injection into the defect and disc to localize the pain source [23]. Such reported the value of pars infiltration as a prognostic test of surgical outcome [10] Wu et al. performed direct repair in 93 patients who had experienced pain relief after pars injection and whose bone scan was negative [24]. They achieved excellent or good results in 91% of the patients after 30 months on average. Kakiuchi operated on 16 patients who had temporary pain relief after local infiltration of an anesthetic [6]. The rate of excellent results after 25 months in his series was 88%. Therefore, we do not recommend the direct repair for patients whose pain does not alleviate after local injection of an anesthetic. In such case, other causes of low back pain should be searched.

The bony-healing rate varies among reports and procedures. It is difficult to correctly assess bony healing after direct repair from plain X-ray findings. A fissure-like pseudoarthrosis may remain undiscovered. In addition, metal implants obscure the vision. The findings previously reported in the literature regarding bony healing should be judged taking into consideration that they were obtained based only on plain X-ray films. Pai and Hodgson compared the status of bony union seen on plain X-ray films and on CT scans following Scott procedure and van Dam modification of the Scott procedure, their results showed a very different union rate (90% versus 50%) [25]. Our results assessed by multi-detector 3-dimensional CT showed a bony union rate of 80%. Recently, bone morphogenetic proteins (BMPs), which are a group of secreted growth factors that belong to the transforming growth factor-beta super family, were used to create a solid lumbar spinal fusion [26,27]. Recombinant BMP proteins, rhBMP-2 and rhBMP-7 (OP-1), have been successfully used in preclinical and clinical trials and are commercially available for clinical applications. These BMPs will probably be used in the future to improve the bony union rate of the pars defects.

However, it should be noted that the non-union detected by CT did not affect the clinical results, indicating that bony fusion was not required to achieve good clinical results. Our patients experienced immediate LBP relief after the operation, which showed that there was little association between bony healing and clinical results.

There has been controversy concerning the relationship between pars defect and LBP. Eisenstein et al showed that there were neural elements in the spondylolytic tissue with the potential to act as nociceptors [28], and Hasegawa et al confirmed the presence of nociceptive free nerve endings [17]. Whereas, Miyauchi et al reported that the spondylolytict issue itself was not innervated [29]. We speculate that the pain of spondylolysis is due to synovitis in a pars defect communicated with the adjacent facet joint: the pain in terminal-stage spondylolysis may be caused by synovitis derived from the adjacent facet joint. In fact, all the patients reported in this study had communications with the adjacent facet joints, and synovial tissue was found in the pars defects. In addition, regardless of whether the bony union was obtained or not, all our patients experienced immediate pain relief after the operation. Shipley et al explained the origin of pain in a similar way as us [30]. They concluded that most patients of spondylolysis requiring surgical treatment present a synovial pseudoarthrosis in the pars interarticularis, which communicates with the adjacent superior facet. Additionally, they suggested that synovial fluid might prevent healing and lead to persistent synovial pseudoarthrosis. However, this theory is difficult to prove because it is almost impossile for us to obtain radio graphical and pathological findings from asymptomatic patients. Further research on this aspect will be required in the future.

CONCLUSION

All our adult patients operated on employing the minimally invasive technique for lumbar spondylolysis using a percutaneous pedicle screw and hook-rod system had clinically good results. The bony union rate was 80%. Normalization of the lumbar kinesiology, in terms of the instantaneous axis of rotation during the lumbar extension/flexion motion, was attained. Moreover, the spinal motion segment was preserved and lumbar spine mobility was retained.

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