A Novel Technique for Pars Defect Direct Repair with a Modified Smiley Face Rod for Spondylolysis and Isthmic Spondylolisthesis

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Abstract:

Introduction: Lumbar spondylolysis is a common fatigue fracture of the pars interarticularis of the lamina of the lumbar spine in adolescent athletes presenting with pars clefts. Some pseudarthrotic lumbar spondylolysis causes low back pain or radiculopathy. This study presents a case of pseudarthrotic lumbar spondylolysis that was successfully treated using a modified smiley face rod technique.

Technical Note: We developed a modified smiley face rod technique, which places pedicle screws in the lateral edge of the pedicle to preserve the erector spinae muscles and inserts a U-shaped rod between the spinous processes to preserve the supraspinous ligament. When a U-shaped rod penetrates the interspinous ligament subcutaneously, the resection of the supraspinous ligaments can be avoided. When the screw head is positioned more anterolaterally, a compression force is applied perpendicular to the surface of the pars cleft by rod clamping. This intrasegmental fusion technique preserves the mobile segment and simultaneously repairs the pars cleft. It is less invasive and more appropriate than interbody fusion for young athletes to avoid the possibility of future adjacent segment disorders.

Conclusions: This is a minimally invasive procedure that can easily achieve bone fusion and should be introduced for patients who are suffering from the symptoms of pseudarthrotic lumbar spondylolysis.

Keywords:

spondylolysis, pars defect, direct repair, smiley face rod, isthmic spondylolisthesis, pseudarthrosis, pars repair, technical note

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Introduction

Lumbar spondylolysis is a common fatigue fracture of the pars interarticularis of the lamina of the lumbar spine in adolescent athletes presenting with pars clefts. The bone fusion rate of overall spondylolysis with conservative treatment has improved to only 76% in recent years[1)]. Therefore, pseudarthrosis of spondylolysis is not uncommon.

Although most pseudarthrotic lumbar spondylolysis cases are asymptomatic, some patients develop low back pain[2)] and/or radiculopathy[3)]. Spine surgery is indicated when the symptoms of lumbar spondylolysis are severe[4)]. Fusion surgery, such as posterior lumbar interbody fusion, is the most common surgical treatment for lumbar spondylolysis[5)]. However, compared with interbody fusion, preserving the mobile segment and repairing the pars cleft simultaneously are less invasive and more appropriate for young athletes to avoid the possibility of future adjacent segment disorders. The original concept of the smiley face rod technique was reported by Gillet et al. in 1999 using a V-shaped rod[6)]. Ulibarri et al. reported a modified U-shaped rod in 2006[7)]. This technique was called the smiley face rod technique by Voisin et al.[8)]. We developed a further modification of the technique that places the pedicle screws in the lateral edge of the pedicle to preserve the erector spinae muscles and inserts a U-shaped rod between the spinous processes to preserve the supraspinous ligament. In this paper, we introduce our technique for repairing pseudarthrosis in lumbar spondy-

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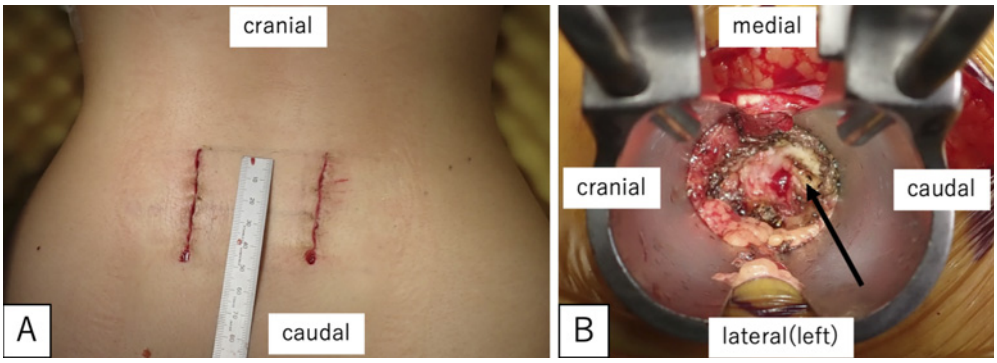

Figure 1. Intraoperative surgical site imaging.
A, The Wiltse approach is used for skin incision. Compared with the midline approach, only two skin incisions of 3–4 cm on both sides are sufficient to complete the surgery.
B, A left-side approach is observed using an expandable tubular retractor. After the synovial membrane is completely dissected to expose the pseudarticular surface (arrow), we should be careful not to damage the facet joints.

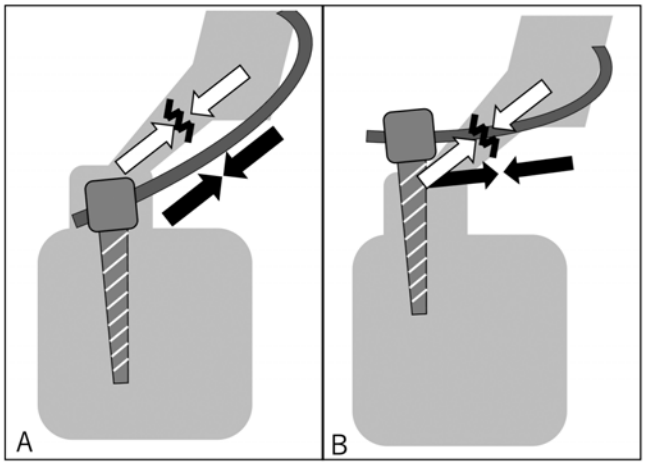

Figure 2. Anatomical schematic showing mechanical stresses.
A, The Weinstein's technique has the advantage that the screw head is positioned more anteriorly, resulting in greater anteroposterior pressure (black arrows) applied perpendicular to the pars interarticularis (white arrows) by rod clamping.
B, By contrast, medial screw insertion is not suitable for clamping the pars interarticularis because the pressure is applied in the cephalocaudal direction (black arrows), which does not match the perpendicular direction (white arrows) to the pars interarticularis.

lolysis patients.

Technical Note

Indications for surgery

The smiley face rod technique using pedicle screws is the best choice for direct interarticular pars repair in low-grade spondylolisthesis[9]. Bilateral lumbar spondylolysis with pseudarthrosis complicating persistent low back or leg pain that is refractory to conservative treatment is an indication for surgery. However, because the rate of progression to vertebral slip is as high as 43%-74% even in patients with minimal pain or other symptoms[10], surgery can be indicated to prevent future slips and disc degeneration in patients with little pain or other symptoms.

We do not believe that there are any limitations based on age because bone fusion can be achieved if appropriate surgery is performed. However, skeletally immature patients are not considered candidates for this procedure because of the pull-out stresses applied to the pedicle screw during the reduction process. In addition, in elderly cases of severe degeneration of the facet joints or intervertebral discs, it is difficult to determine whether the cause of the symptoms is only the pars cleft. Therefore, this procedure should be performed with caution in patients with these conditions.

Patients without vertebral slips are appropriate candidates for the introduction of this technique. Even if the Meyerding classification of first-degree grading coexists, the vertebral slip can be repositioned using this technique[11]. If there is no symptom originate from the intervertebral foramen, even the second-degree Meyerding grading may be an indication for surgery.

Repair of the pars cleft is also indicated in the presence of nerve root symptoms. In particular, when nerve root symptoms are caused by the ragged edge protruding into the spinal canal due to the pseudarticulated pars cleft, the resection of the protruding ragged edge and decompression of the spinal canal improve the clinical results. However, because the resection of the ragged edge results in a massive bony cleft, careful decompression is required to avoid the excessive resection of the ragged edge.

If the pars cleft is small and has bone marrow edema, direct fixation using the cannulated screw insertion method is indicated[12].

Preoperative preparation

Preoperative plain functional X-ray of the lumbar spine is performed to evaluate the instability of the pars clefts and intervertebral segment. MRI should be performed to confirm the presence of intervertebral disc degeneration and cystic

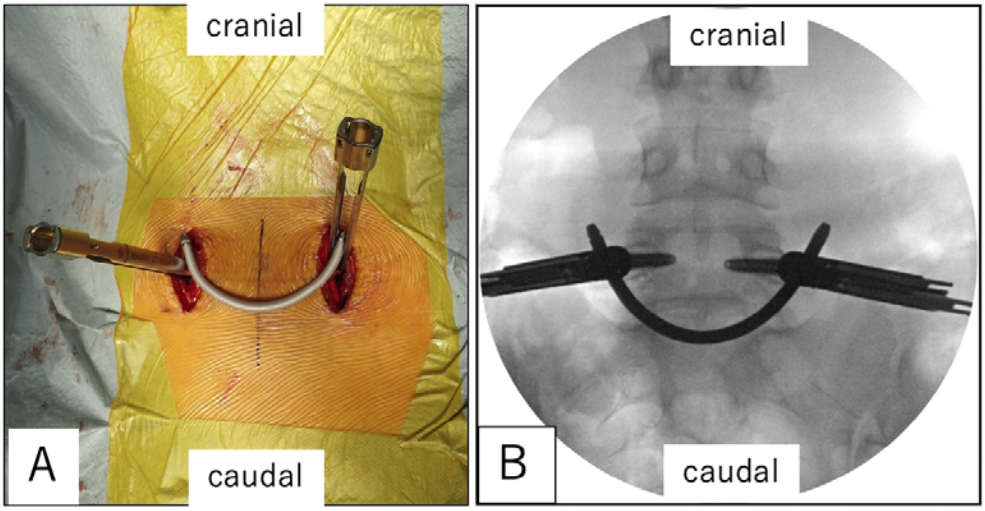

Figure 3. Intraoperative surgical site and fluoroscopic imaging.
A, A bent rod is placed on the skin to check its curve.
B, Fluoroscopic imaging to check whether the rod is properly bent.

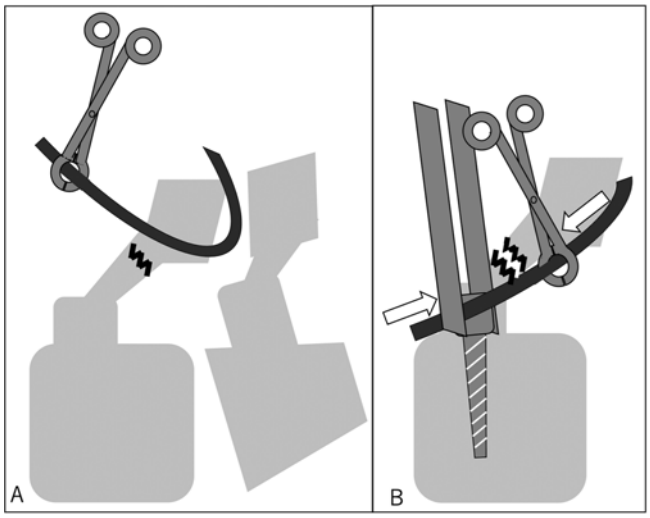

Figure 4. Anatomical schematic showing passing the rod and closing the gap.
A, The rod is passed between the spinous processes using fluoroscopy to preserve the supraspinous ligament.
B, The rod holder carrying the U-shaped rod and the screw head is compressed to close the gap at the pars cleft. The actions of closing the gap are performed on each side.

lesions in the pars cleft. Naturally, infection and tumor lesions must also be ruled out.

Measuring the location of the septum of the erector spinae muscles by preoperative CT is important for an accurate intermuscular approach. In addition, CT should be used to evaluate the shape of the vertebral body and pedicle when planning the length and angle of the pedicle screw insertion.

Surgical technique

Skin incisions are made using the bilateral Wiltse approach, which is made 3-4 cm laterally from the midline (Fig. 1A). Most patients with lumbar spondylolysis are young athletes or workers with well-developed erector spinae muscles. In young patients, the midline approach for screw insertion should be avoided because it is invasive to the muscles, whereas the Wiltse approach is less invasive. Moreover, the Wiltse approach is suitable for optimal screw insertion, pars cleft dissection, and bone implantation.

A tubular retractor with shadowless lighting is useful for preserving the muscle layers. It is also helpful to use a long and small endoscopic device with an antireflective coating. The transverse process is an important landmark for identifying the pars cleft. The transverse process is exposed to locate the lateral edge of the lamina while preserving the articular capsule of the facet joint. The pseudocapsule of the pars cleft is found on the caudal side of the facet joint. In some cases, synovial tissue erupts from the inside of the pseudocapsule because of the internal pressure when an incision is made into the pseudocapsule. The synovial tissue of the pseudarthrosis is removed to expose the pars cleft while taking care not to damage the facet joint (Fig. 1B). Because the surface of the pars cleft has become sclerotic, decortication is performed until the cancellous bone is exposed on both the laminar and pedicle sides. If nerve root symptoms are present in the preoperative diagnosis, decompression is indicated. In such cases, widen the drilling using a high-speed drill in the direction of the spinal canal. A large bone resection around the pars cleft is performed to decompress the nerve root. If a ragged edge remains, bone resection can be performed using a small curved endoscopic chisel. After decortication, the autologous cancellous bone is harvested from the iliac crest through the same skin incision using a trephine.

Next, bilateral pedicle screws are inserted using the Weinstein's insertion technique[13]. The percutaneous pedicle screw system with a long tab is also useful to avoid muscle damage. When the screw head is positioned more anterolaterally using Weinstein's technique, reduced force is applied per-

Figure 5. Preoperative imaging findings.
CT revealed penetrating fracture lines on both sides of the bilateral pars cleft.
A, The right pars cleft on the right paramedian slice of preoperative CT.
B, The left pars cleft on the left paramedian slice of preoperative CT.
C, The bilateral pars cleft on the axial slice at L5 on preoperative CT.
D, The disappearance of bone marrow edema bilaterally on MRI, indicating pseudarthrosis.

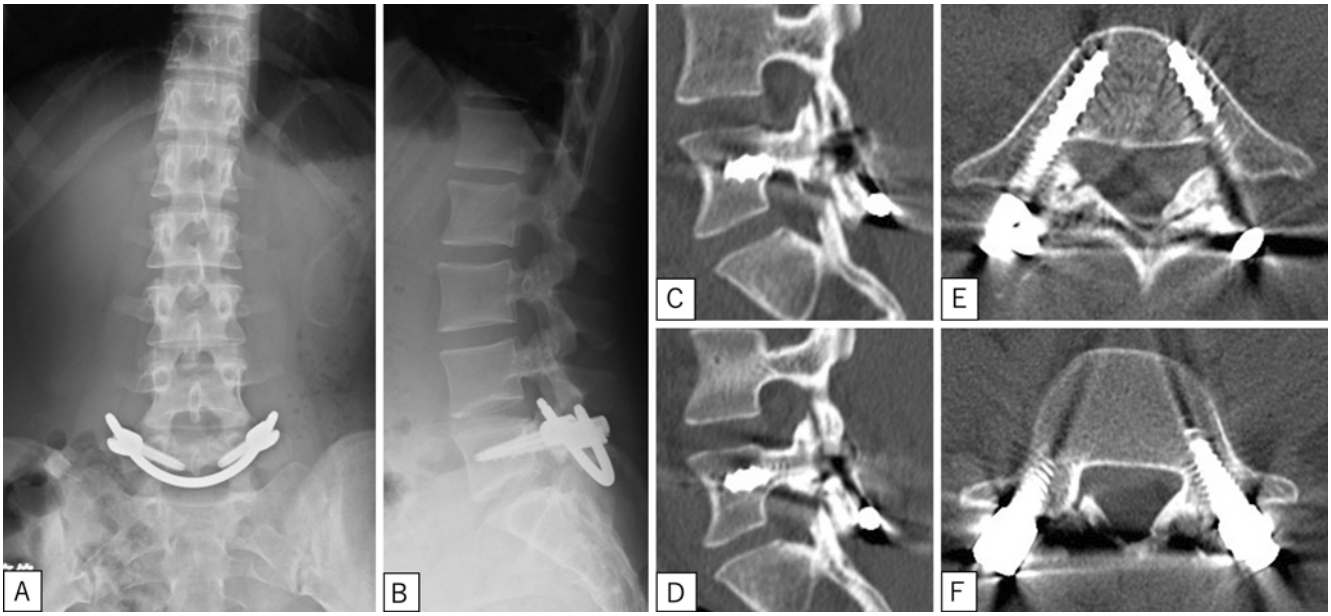

Figure 6. Postoperative imaging findings.
A, Postoperative plain X-ray image of the anteroposterior view.
B, Postoperative plain X-ray image of the lateral view.
C, The gap disappearance due to the compression of the pars interarticularis on the right paramedian slice of postoperative CT.
D, The gap disappearance due to the compression of the pars interarticularis on the left paramedian slice of postoperative CT.
E, The gap disappearance on the axial slice at L5 of postoperative CT.
F, The screw heads were placed properly using the Weinstein's method on the axial slice of postoperative CT.

pendicularly to the surface of the pars cleft by rod clamping, which is the same as the rod reduction technique. As a result, the compression force on the pars defect becomes stronger (Fig. 2A). By contrast, the screw head is placed backward when the screw insertion is medial. This creates shear forces in the cephalocaudal direction, lowering the compression force on the pars defect (Fig. 2B). Although the smiley face rod technique has been reported in the past[14], we believe that our technique, in which the screws are inserted laterally and the screw head is placed anteriorly, is more useful for applying pressure to the pars defect.

After screw insertion, the rod is bent so that it passes through the caudal side of the spinous process and fits into the pedicle screw heads on both sides. The advantage is that the U-shaped rod can be placed perpendicular to the fracture line to apply a compressive force between the pars cleft. The bent rod is placed on the skin (Fig. 3A), and a fluoroscopic imaging is performed to check whether the rod is properly bent (Fig. 3B).

Next, the bent rod is inserted from the left wound, passed between the spinous processes, and tipped out from the right wound (Fig. 4A). It is important to avoid the resection of

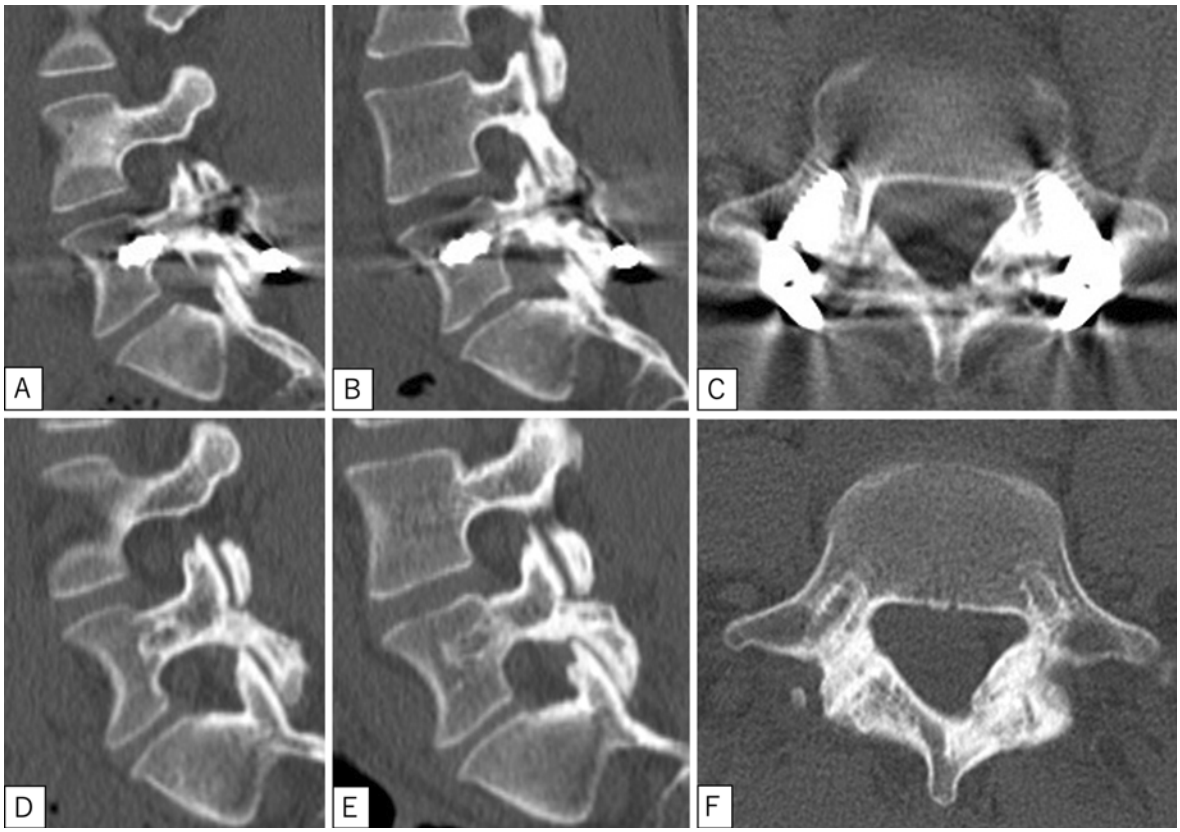

Figure 7. Imaging findings at the pre and post implant removal.
A, Bone fusion on the right paramedian slice of CT one year after surgery.
B, Bone fusion on the left paramedian slice of CT one year after surgery.
C, Bilateral bone fusion on the axial slice at L5 of CT one year after surgery.
D, Bone fusion on the right paramedian slice of CT after implant removal.
E, Bone fusion on the left paramedian slice of CT after implant removal.
F, Bilateral bone fusion on the axial slice at L5 of CT after implant removal.

the supraspinous ligaments on the caudal side of the lamina. The inserted rod should be pressed anteriorly to maximize the contact area with the dorsal surface of the lamina.

Next, the set screws are placed. The long-tab percutaneous pedicle screw system makes it easy to place the set screws. After the set screws are placed and the rod is temporarily fixed, the autologous cancellous bone is transplanted into the space of the decorticated pars cleft. Finally, the rod holder carrying the U-shaped rod and the screw head is compressed to close the gap at the pars cleft (Fig. 4B). The actions of closing the gap are performed on each side. In our experience, bone fusion was achieved approximately 6-12 months after surgery. We are considering using autogenous bone for early bone fusion and return to sports activities.

There is a pitfall to this method. The inappropriately large decompression of the pars cleft during decompression around the nerve root sometimes results in a large bone defect at the pars cleft. It has been reported that the vertebral arch migrates into the intervertebral foramen when compression is applied in the absence of anterior-posterior bony contact[15]. Therefore, the decompression of the pars cleft should be limited to one side only, and large decompressions should be avoided.

Representative case

A 20-year-old female tennis player visited our hospital with a chief complaint of low back pain for over 6 years. On initial examination, she complained of low back pain on spinal extension, but no nerve root symptoms were observed. Imagings revealed bilateral pseudarthrosis at the L5 pars interarticularis without bone marrow edema (Fig. 5A-D). Conservative treatment was implemented, and a lidocaine block was administered to the pars clefts. Because her pain relief was temporary, we determined that the source of the pain was the pars clefts. Because the low back pain persisted and her low back pain visual analogue scale (VAS) score was 60 mm even with conservative treatment, the patient underwent repair of the pseudarthrotic lumbar spondylolysis using the smiley face rod repair technique (Fig. 6A, B). Postoperative CT showed that the gap had disappeared because of the compression of the pars cleft (Fig. 6C-E) and that the screw had been properly placed using the Weinstein's method (Fig. 6F). CT one year postoperatively revealed fusion of the pars cleft (Fig. 7A-C). The patient's back pain improved, and the VAS score was 0 mm. No re-

currence was observed after implant removal (Fig. 7D-F).

Conclusion

This paper describes the further modified smiley face rod technique for pseudarthrosis. This is a minimally invasive procedure that can easily achieve bone fusion and that should be introduced for patients who are suffering from the symptoms of pseudarthrotic lumbar spondylolysis.

Conflicts of Interest: The authors declare that there are no relevant conflicts of interest.

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Author Contributions: M.T. designed this technique and drafted the manuscript. S.O., H.G., and R.A. developed this technique. F.E., K.N., Y.T., and T.F. cotreated the patients. M.Y. revised the draft manuscript. All authors approved the final version submitted for publication.

Ethical Approval: The study's protocol was reviewed and approved by the Institutional Review Board of Tsukuba University Hospital Mito Clinical Education and Training Center/Mito Kyodo General Hospital (IRB No. 22-11).

Informed Consent: Oral informed consent for publication was obtained from all patients in this study.

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