"Temporary" Short Segment Fixation in Treating Adolescent Lumbar Spondylolysis

Yunfei Huang, Jijun Liu, Lei Guo, Yibin Meng, Dingjun Hao, Jinpeng Du

■ BACKGROUND: **We have introduced a new operation for isthmic spondylolysis in adolescents and evaluated its clinical efficacy.**

■ METHODS: **A total of 30 adolescent patients with isthmic spondylolysis and chronic low back pain underwent "temporary" short-segmental pedicle screw combined with transverse device fixation and isthmic bone graft repair treatment. Radiograph and computed tomography images were evaluated during regular follow-up examinations to confirm successful bone graft fusion, after which the fixation was removed. Lumbar magnetic resonance imaging was performed before and 1 year after fixation surgery and 1 year after fixation removal. Modic and Pfirrmann grading standards were used to observe the effect of "temporary" fixation on the corresponding vertebral endplate and intervertebral disc.**

■ RESULTS: **All 30 patients had complete follow-up data available at 2 years postoperatively. The low back pain symptoms had disappeared completely, and radiographs and computed tomography showed that the isthmus in all patients had achieved bony fusion. With removal of the internal fixation, motion of the fixed segment recovered. "Temporary" rigid internal fixation did not increase the corresponding vertebral endplate or intervertebral disc degeneration.**

■ CONCLUSIONS: **"Temporary" short-segmental pedicle screw combined with transverse device fixation is a simple and effective method for adolescent isthmic spondylolysis with rigid internal fixation and accelerated bone graft fusion.**

INTRODUCTION

Lumbar spondylolysis is one of the most common causes of lumbago in the clinic. The cause of pain is abnormal activity at the end of the isthmus and stimulation of the surrounding scar nerve tissue. Most patients will experience relief through conservative treatment. However, 10%–20% of patients will still require surgical treatment after formal nonoperative treatment.[1] In the past, more conservative treatments for lumbar spondylolysis (e.g., pelvic traction, functional exercise, excessive exercise avoidance, and wearable support) were pursued. However, the spondylolysis can rupture. The spinal lamina is located under the articular process as a unit, and the spine and back extensor will pull the ligament to create the isthmus. Abnormal events can occur at the head end, causing back extensor muscle contraction, before bending strains the ligaments. The crowded embedded spine, when straightened, frees the end of the vertebral arch. The existence of this abnormal activity results in healing of the spondylolysis fracture.[2] Thus, it has been difficult to solve the problem and avoid worsening of symptoms or causing slippage using conservative treatment. Therefore, many investigators have maintained that for patients with persistent low back pain, a long disease duration, and a disintegrating isthmus, nonoperative treatment will not be effective,[3] although surgical treatment will be feasible. At present, pedicle screw fixation and intervertebral fusion are performed simultaneously. Although this approach is stable and reliable, it is at the expense of the spinal motor function unit. It is possible to have a fracture present in the long term. From 2013 to 2016, our hospital adopted "temporary" short segment fixation to strengthen the treatment of 30 patients with juvenile isthmus, with satisfactory curative effects.

METHODS

The inclusion criteria were as follows: 1) radiographs and computed tomography scans showed 5 unilateral or bilateral

Key words
- Isthmic bone graft
- Lumbar isthmic spondylolysis
- Short segment fixation
- Temporary

Abbreviations and Acronyms
MRI: Magnetic resonance imaging

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Citation: World Neurosurg. (2019) 123:e77-e84.
https://doi.org/10.1016/j.wneu.2018.11.046

Journal homepage: www.journals.elsevier.com/world-neurosurgery

Available online: www.sciencedirect.com

isthmic disintegrators; 2) patient age 18–40 years; 3) lumbar magnetic resonance imaging (MRI) showed the Pfirrmann classification of the intervertebral disc; 3) lumbar I decollement present; and 4) unsuccessful conservative treatment for 6 consecutive months. The exclusion criteria were as follows: 1) intervertebral disc Pfirrmann grade >2; 2) second degree slippage or greater; 3) previous lumbar surgery or the presence of tuberculosis or infection; and 4) lumbar spinal stenosis with lumbar disc herniation.

From August 2013 to October 2016, 30 patients with lumbar spondylolysis split disease were included and underwent surgery. Of these 30 patients, 18 were men and 12 were women, with a collar size ranging from 18 to 27 (Table 1) and a disease duration lasting 1–2 years. The clinical manifestations included different degrees of lumbosacral pain and/or progressive lower back pain with prolonged standing, long-distance walking and bending and remission after bed rest.

Surgical Methods

Exposure and Nailing. After administration of general anesthesia, the conventional spine approach was used to expose the posterior median approach, showing the surgical section of the isthmus, the fractured vertebral body, and the vertebral body. The laminae on both sides of the small joints were exposed, because the bilateral vertebral arch pedicle screw was embedded into L5-S1. Pedicle screws were fixed into the nail points using a Weinstein slightly lateral positioning method to reduce the influence of the small joints on both sides (Figure 1A, B).

Treatment of Scarring and Bone Grafting in the Isthmus. The scar and hyperplastic tissue of the isthmus fracture were completely eliminated, and the bone was grafted using a ball mill (Figure 1C).

Table 1. Baseline Characteristics

Parameter	Value
Patients (*n*)	30
Female gender (*n*; %)	12 (40)
Age (years)	24.4 ± 3.7
BMI (kg/m^2)	23.8 ± 3.5
Operative time (minutes)	107 ± 23
Blood loss (mL)	126 ± 30
Fusion time (months)	13 ± 6
Fusion rate (%)	100
Fixed stage activity retention (%)	88.5
Vertebral endplate Modic change (*n*; %)	16 (53)
Intervertebral disc changes (*n*)	0

Fixed retention rate calculation methods included segmental mobility of postoperative segmental mobility × 100% preoperative segmental mobility, fixed segment endplate Modic changes, Modic changes aggravating to "negative," reduced to "is"; the change in the intervertebral disc was classified using the Pfirrmann grade, and the aggravator was "negative" and alleviated to "positive."

Iliac Bone Graft. Iliac blocks were administered to patients after the iliac spine under the same skin incision. After lumbar dorsal fascia lateral resection showed the iliac spine, the ilium of the iliac crest was sized appropriately, and the implant was placed on the spondylolysis end after pruning and tapping the mutual compression (Figure 1D–F).

Creating the Rod Connection. A connecting rod of appropriate length was selected. Next, a high-speed grinding drill was used to drill holes in the spinous process, and transverse joint rods of the appropriate length were used to connect the rods through the spinous process. Finally, the spinous process and vertebral plate were firmly fixed in the vertebral body (Figure 2).

Postoperative Treatment

At 2 days postoperatively, the patients were allowed to lower the back support to increase their activity. They continued to wear the support at the small of the back for 3 weeks with a regular postoperative examinations. After the isthmus had undergone osseous healing, the internal fixation was removed, and the patients returned to fixed phase activity.

RESULTS

The average operative time was 107 ± 23 minutes, the average intraoperative hemorrhage was 126 ± 30 mL, and the average fusion time was 13 months. All 30 patients were followed up for 2 years. Clinical efficacy was evaluated using the Henderson standard, and all patients showed excellent performance. The fusion standard for bone grafting was continuous bone morphosis or bone trabecula present in the fusion area of the radiographic plane, with disappearance of the fracture line of the isthmus. Lumbar computed tomography scans showed that the bone grafts had fused into 1 body and the bone trabecula of the original fracture line was continuous (Figure 3). Next, the internal fixation device was removed, and the radiographic overextension test was performed to show the activity level of the fixed stage (Figure 4).

In addition, after fixation and internal fixation of all patients, MRI examination of the lumbar spine was performed. The MRI scan of the lumbar spine was compared with the preoperative lumbar MRI scan, specifically to evaluate the intervertebral disc and vertebral endplate. The reference evaluation criterion was the Pfirrmann classification method for the intervertebral disc.[4] Changes to the vertebral endplate were determined using the Modic classification.[5] The fixed stage activity retention rate was 88.5%, and 16 patients (53%) experienced vertebral endplate Modic changes, with no patient experiencing intervertebral disc changes during the follow-up period.

DISCUSSION

Lumbar spondylolysis is one of the major causes of symptomatic lower back pain and affects 15%–47% of young people.[6] However, some findings will be specific to adolescent patients. First, the morphology and signal of the intervertebral disc in the disintegrating stage will be good, with no obvious degeneration. Second, no slip or displacement will be present in the calving vertebral body, and the stage stability will be good. Finally,

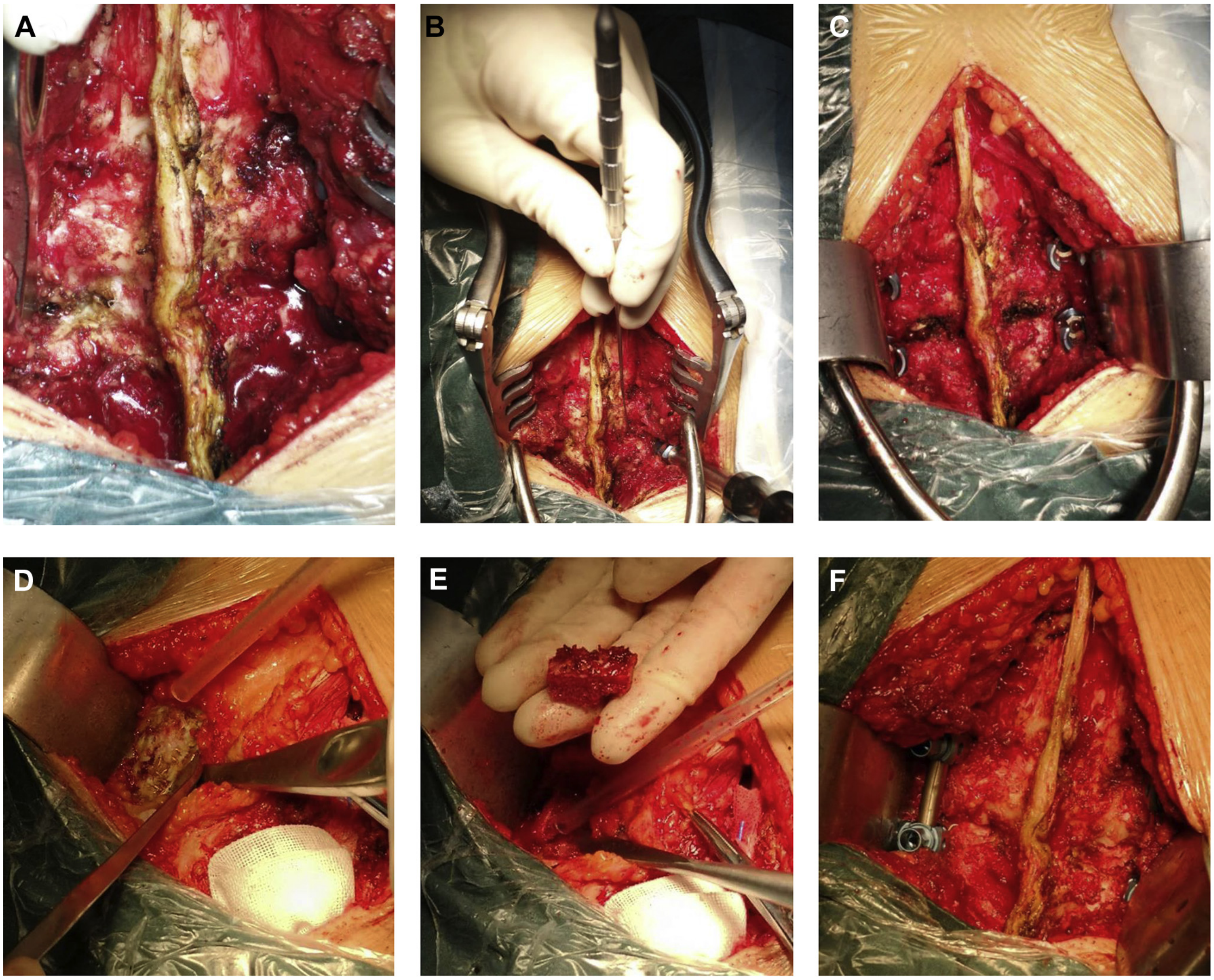

Figure 1. Details of the surgical procedures. (**A**, **B**) The gap fracture was checked using a nerve probe. (**C**) A bilateral isthmus fault was exposed. (**D**–**F**) The ilium of the iliac crest was size for isthmus defects appropriately, the bone was trimmed into grafts, and the graft was repaired.

healing the gap will be difficult, in particular because of the large amount of social activities and because future life and career expectations that require waist activity are high. Therefore, the treatment of these patients should differ from the traditional slide out of intervertebral fusion to retain the activity degree of the lumbar spine and reduce the likelihood of adjacent segment degeneration. For the first time since 1968, Kimura[7] described direct repair of spondylolysis. The direct repair of cleft logical operations has become common in young patients. A variety of internal fixation mechanisms has been developed to increase the repair success rate. At present, many methods are available, including the Buck screw, Nicol and Scott transverse steel wire, Morscher hook screw, and other methods, to directly provide internal fixation.

Buck Screw Method

In the most classic fixed method, the Buck screw is placed directly using the fixed spondylolysis end screw method. However, the operation screw would directly occupy part of the graft surface, reducing the effective contact area inside the graft. In addition, correct nailing has greater technical difficulty.

Nicol and Scott Steel Wire

The Nicol and Scott steel wire method involves an 8-word steel wire method that provides a wide range of dissection. The Nicol and Scott steel wire method results in more bleeding, a less operation, and the risk of nerve root injury.

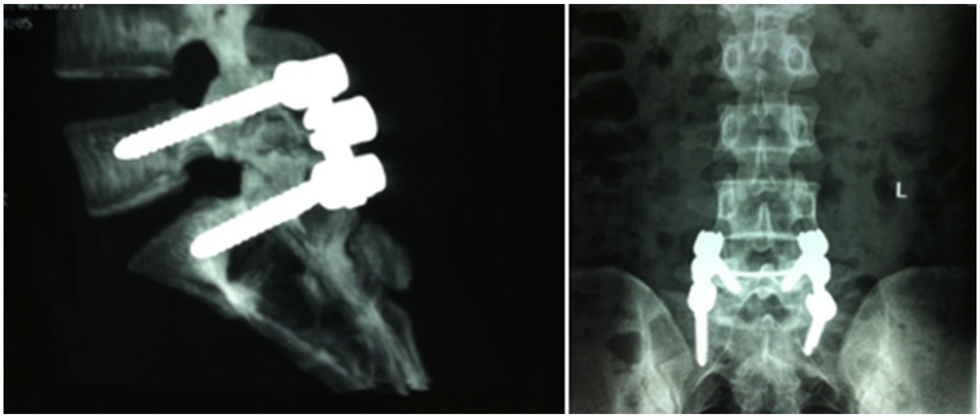

Figure 2. Imaging studies of the fracture graft of the L5 bilateral isthmus, transverse connecting device, and pedicle screw rod system. The spinous process and vertebral plate were firmly fixed in the vertebral body.

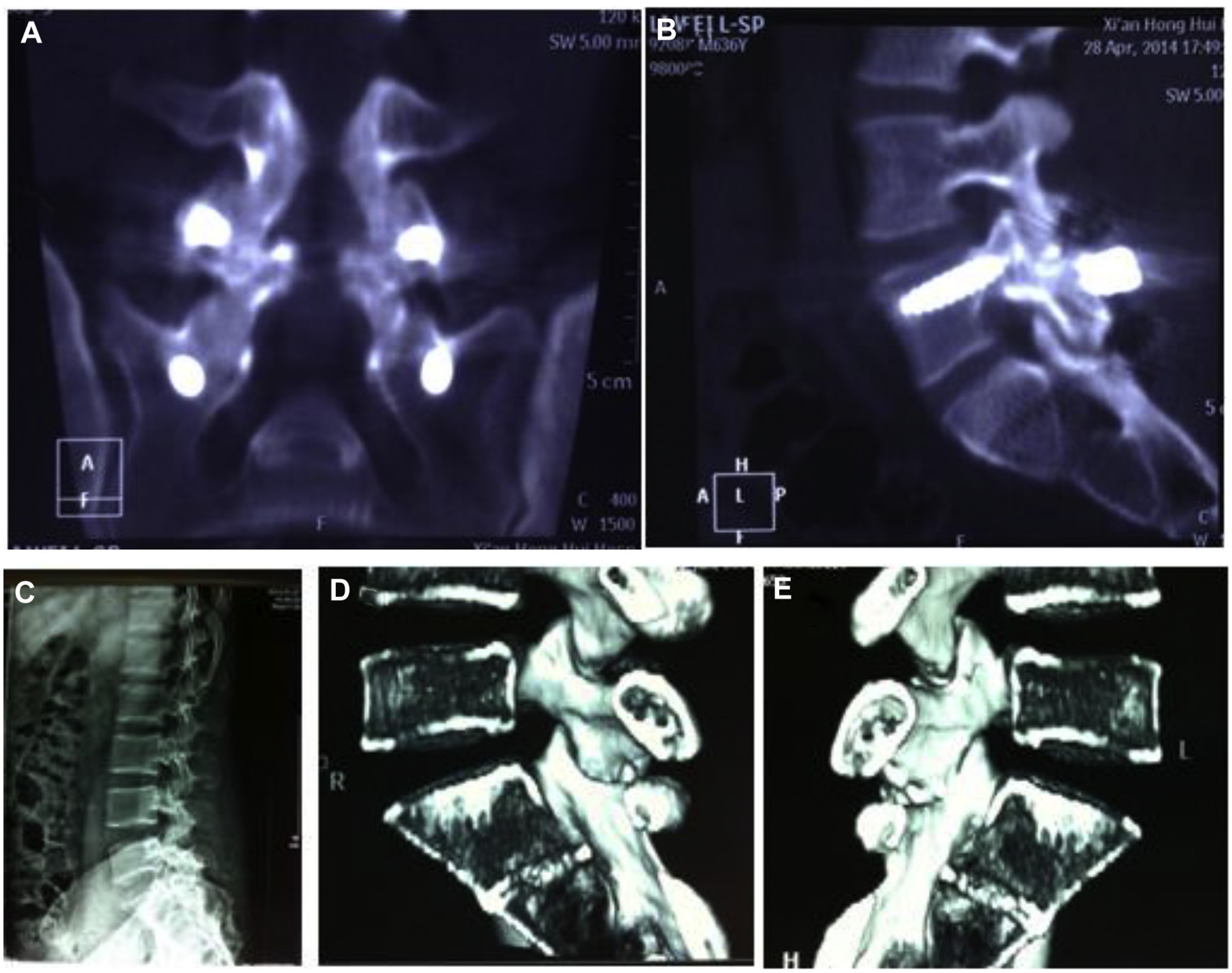

Figure 3. (**A**) The bone graft in the isthmus had healed in June. (**B**) After the internal fixation device had been removed, radiography and computed tomography were performed again, showing that the bone graft had healed well in the bilateral isthmus, **C**–**E** is the Isthmus fusion after internal fixation removal.

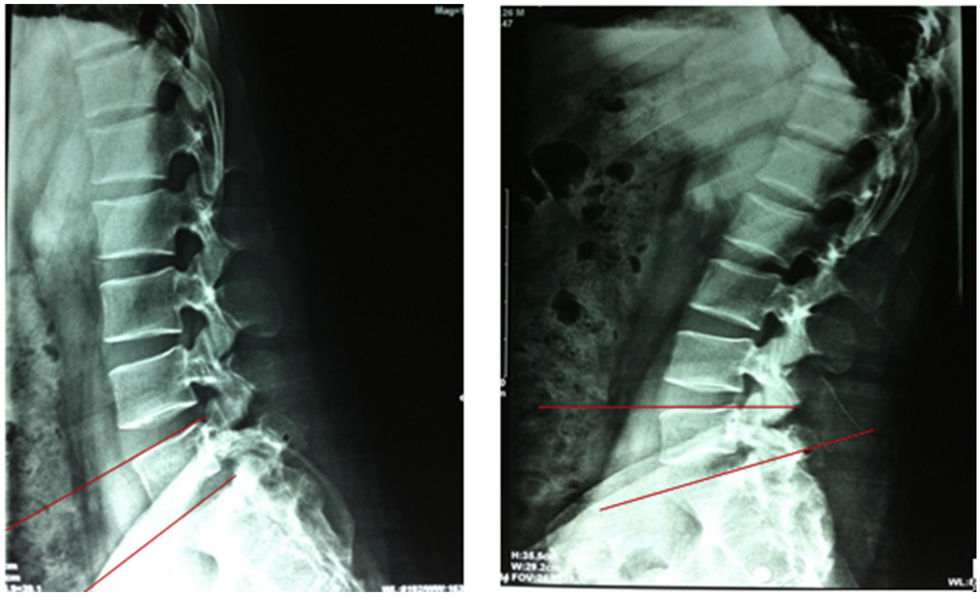

Figure 4. Radiographs after removal of the internal fixation device to check the lumbar spondylolisthesis, which showed that the activity of L5-S1 was good, with an L5-S1 to overbend with 15° of activity.

Morscher Hook Screw Method

The Morscher hook screw method and screw hook are placed at the laminae. However, a screw hook placed into the spinal canal carries the risk of iatrogenic spinal canal stenosis and lamina fracture.

Advantages and Disadvantages

These fixation methods each have their advantages and disadvantages. The Buck screw method runs directly through the broken end of the fixed isthmus.[8] It has become the most classic fixation method, with a reported success rate for this approach of 83%–100%.[9] However, placement of the screw through the fracture end of the isthmus fracture directly occupies a part of the graft surface, reducing the effective contact area of the bone grafts. In addition, correct placement of the nail has high technical difficulty. Nicol and Scott[10] proposed an 8-word steel wire method. However, the intraoperative dissection was extensive, with significant bleeding, and the operation was not easy. In addition, the method carries the risk of nerve root injury. Salib and Pettine[11] improved this using pedicle screws as the fulcrum and the posterior structure of the wound wire. This simplified the operation and improved the fixation strength; it is known as the improved Scott method. Subsequently, a variation of the hook screw (rod) method was successively developed under the influence of the 3 columns of the Scott method.[12,13] However, even after modified single-vertebral body nail fixation, the screw hook was placed on the vertebral plate and still had access to the spinal canal, resulting in the risk of iatrogenic spinal stenosis and lamina fracture. The Isobar TTL system is a semirigid pedicle fixation system composed of pedicle screws and dynamic rods.[14] The flexible device on the dynamic rods can reduce the stiffness of internal fixation and allow micromotion of the fixed segments. Collapse of the vertebral isthmus can have difficulty healing because of the instability of the isthmus, which makes bone graft fusion difficult. Isthmic bone graft repair requires a relatively stable fixed environment. Therefore, the Isobar TTL system was not suitable for our study.

Fixation Method Used in the Present Study

As much as possible in the present study, the most important point was protection of the fixed section and adjacent segmental joints. Therefore, we used the method of the articular process to affect the smallest Weinstein area.[15] The pedicle screws were placed in an improved nail position compared with the Weinstein method. Also, the nail end was screwed in as far as possible away from the joint. Our standard was to not contact the joints, keeping the joint pin on the tail apart from the joint by a distance of 3 mm. The bone graft was only placed at the isthmus and was not used for the joint and intervertebral bone graft; thus, the activity of the joint was preserved. In addition, we found 16 patients had a fixed segment of the final plate with a Modic change that was less than that before surgery. Evidence of strong fixation was the absence of imaging showing the disc in the fixed segment. After fixation, the stress was transmitted

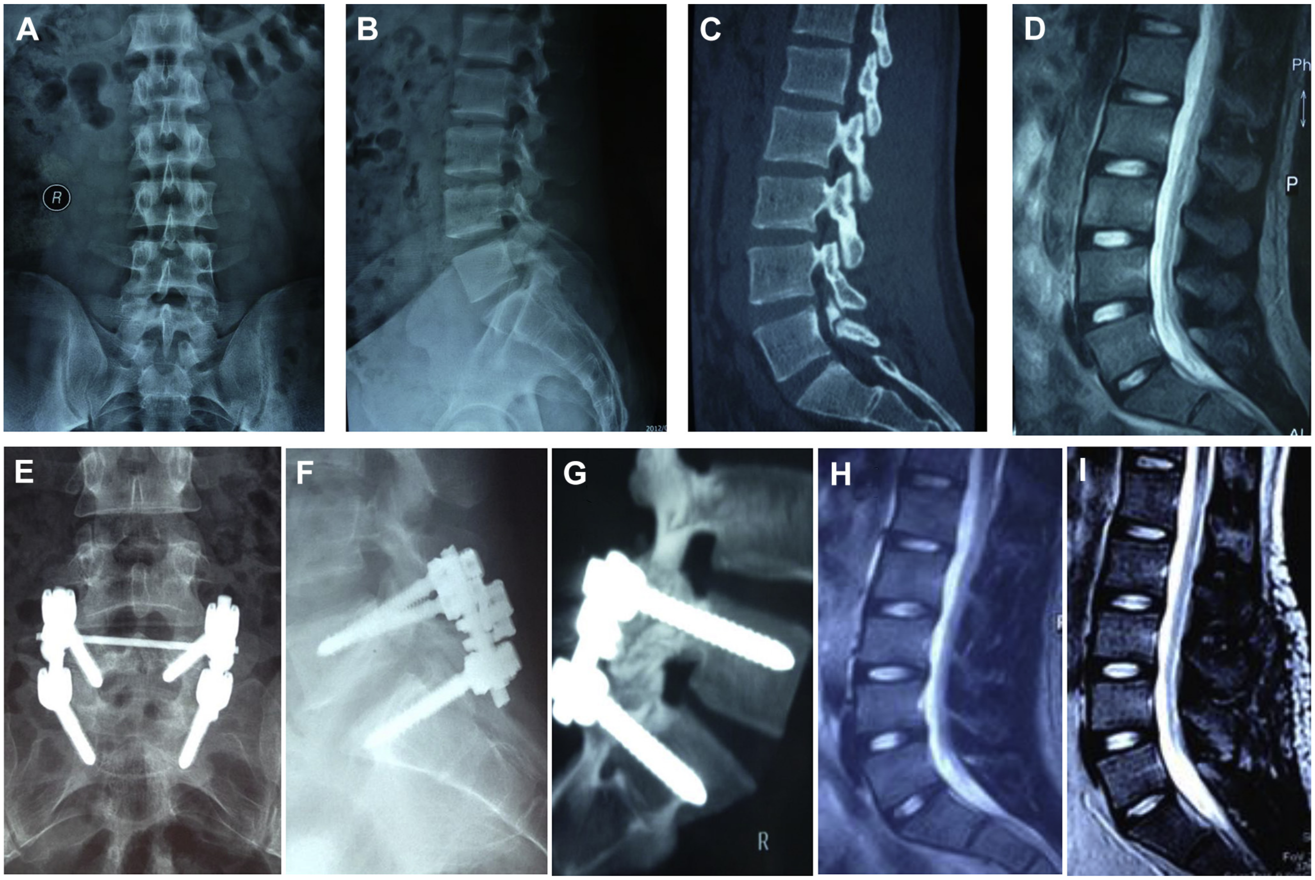

Figure 5. Imaging studies of patient 1, a 24-year-old man. (**A**–**D**) Preoperative radiographs showing L5 spondylolysis. (**E**–**G**) Postoperative radiographs. (**H**) Magnetic resonance image of the lumbar spine, L5-S1 segment, with slight Modic 3 changes of the final plate in the S1 and Pfirrmann grade 2 in the L5-S1 disc. (**I**) In the 2 years after repair and fixation of the isthmic region, magnetic resonance imaging of the lumbar vertebra showed that the response after fixation removal was acceptable at 1 year after internal fixation placement. In the L5-S1 stage, the final plate of the S1 was modified with mild Modic 3 changes, and the intervertebral disc was Pfirrmann grade 2.

through the screw, reducing the pressure on the disc and the stress of the intervertebral disc to the endplate.

The operation plan was as follows. First, we performed pedicle screw implantation using the classic Weinstein positioning method (modified by our method of nailing into the point to reduce the effect on the joints), combined with the development of spine surgery. With >10 years of experience with spinal pedicle screw implants, the operation is very mature and, thus, relatively simple. Second, we used a fixation method for strong 3-column fixation. Also, the use of a cross-connect device can make the direct pressure on the spine isthmus end with a close chimeric between bone blocks, improving the stability and reducing the microgap between extremities, which is conducive to integration. Third, compared with the single-vertebral nail hook system, our method does not result in spinal canal-occupying effect. Because the internal fixation does not pass through the fracture area, the increased bone contact area in the isthmus provides good conditions for bone healing of the isthmus. Finally, this bone graft fusion surgery is a simple spondylolysis bone graft fusion and does not involve the lamina and intervertebral joints. After waiting for 1–2 years for spondylolysis union, the internal fixation device was removed, and the patients returned to fixed phase of activity. The scar and muscle and soft tissue injury caused by the patient's secondary operation for fixation removal were not obviously uncomfortable at the final follow-up examination. Perhaps this was because our study group was younger and gave more attention to strengthening the muscles of the lower back. In addition, with continuous MRI guidance, rigid fixation of the pedicle in the short segment did not accelerate the degeneration of the vertebral endplate or the fixed stage of the intervertebral disc (**Figures 5** and **6**).

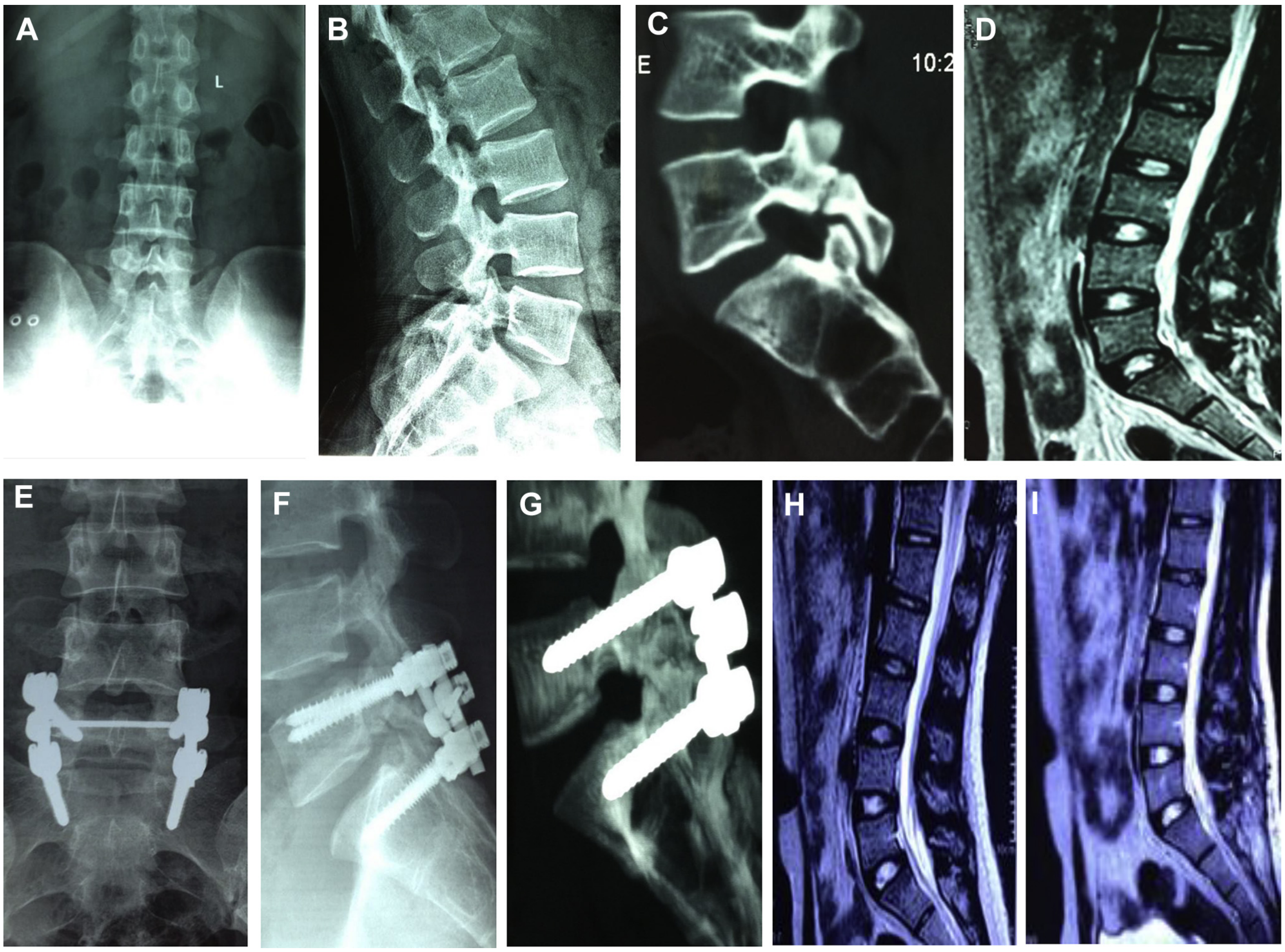

Figure 6. Imaging studies of patient 2. (**A**–**D**) Preoperative imaging studies of L5 spondylolysis. (**E**–**G**) Postoperative imaging studies. (**D**, **H**) Preoperative magnetic resonance imaging studies of patients with isthmus were performed that included the anterior L5-S1 stage; the final plate of the sacral 1 was modified by Modic 3 changes, and the Pfirrmann grade of the L5 sacral vertebra was 1. (**I**) Postoperative magnetic resonance image of patient without fixed lumbar spine after 1 year. The S1 on the endplate remained Modic type 3. However, the endplate on the sacral 1 T1-weighted and T2-weighted images showed lower signals on the preoperative narrowed down area (phase analysis for fixed lower back L5-S1) caused by stress reduction; waist L5-S1 intervertebral disc Pfirrmann grade 1.

CONCLUSION

The analysis of our procedure's technical feasibility and advantages and disadvantages showed that this operation is simple fixation with a bone graft and has a high healing rate, without affecting the motion characteristics of the lumbar spine. Thus, the presented procedure is worthy of clinical promotion.

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Received 28 August 2018; accepted 7 November 2018

Citation: World Neurosurg. (2019) 123:e77-e84.
https://doi.org/10.1016/j.wneu.2018.11.046

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