Chapter 17
Spondylolysis and Spondylolisthesis in Athletes

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Etiology

Lumbar spondylolysis is the most common pathology identified in adolescents with chronic back pain. It has been widely accepted that lumbar spondylolysis is a stress fracture of the pars interarticularis that commonly appears in children and adolescents [1–3]. Alternatively, genetic predisposition is another theory in the etiology of lumbar spondylolysis. In 1975, Wiltse et al. stated that a pars fracture (spondylolysis) is a fatigue fracture based on a strong hereditary basis [4]. We have seen evidence of this genetic predisposition in our own practice. Figure 17.1 demonstrates three separate cases of lumbar spondylolysis from three brothers [5].

In 1978, Haukipuro et al. reviewed the pedigrees of spondylolysis families and concluded that inheritance of lumbar spondylolysis is autosomal dominant [6]. Finally, Cai et al. [7] found a possible gene associated with spondylolysis. Future studies are likely to identify specific genetic alleles that predispose patients to pars fractures.

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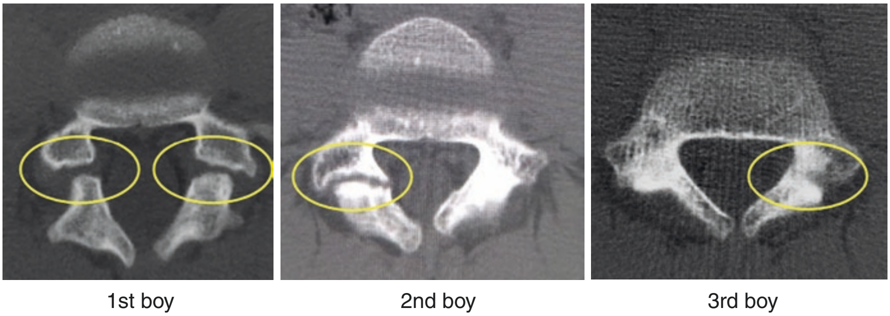


Fig. 17.1 Three cases of spondylolysis from one family

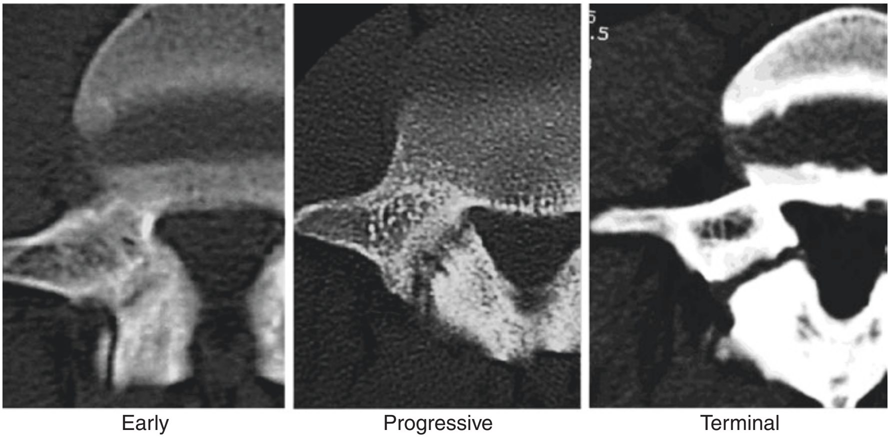


Fig. 17.2 CT stages of the pars fracture

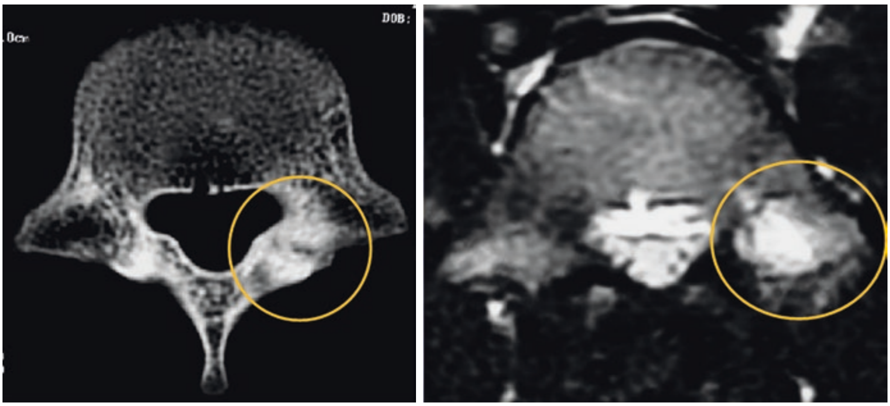
CT Stage Classification

A key component to the diagnosis and treatment of lumbar spondylolysis in our practice relies on CT stage classification. Figure 17.2 demonstrates the CT stages of lumbar spondylolysis [8, 9]. The heart of this classification relies on a baseline understanding of fracture healing. As the pars fracture develops, it will ultimately undergo changes that will lead to union or non-union. These unique stages in healing will lead to varying clinical presentations and treatments in patients with spondylolysis. Bone absorption is seen in the early stage and is demonstrated as an incomplete fracture on sagittal reconstruction CT scan. The progressive stage shows evidence of a complete fracture of the pars without sclerotic fracture margins. The terminal stage is equivalent to a pseudoarthrosis and demonstrates sclerotic fracture margins and blunting of the fracture edges.

In our classification schematic early- and progressive-stage defects are designated as acute pars fractures. These acute fractures still have the opportunity to form a bone union under the correct biomechanical circumstances. The terminal CT stage is classified as a chronic pars fracture, since it is a pseudoarthrosis. Once a fracture is in this stage, it will never progress to a union, and this influences management.

Early Diagnosis of the Pars Fracture

It is very difficult to diagnose the early stage using plain radiographs. For the accurate diagnosis of the early-stage defects, we have proposed two hallmark findings: bone marrow edema of the adjoining pedicle on MRI [3] and bone absorption at the caudal aspect on the sagittal reconstructed CT scan [10]. Figure 17.3 demonstrates a CT scan and T2-weighted MRI for a patient with the early-stage defect. Even though the fracture is not clear on CT (left panel), bone marrow edema in the adjoining pedicle is clear on MRI (right panel). We have found that assessment of these early-stage defects on CT scan is more readily identifiable on the sagittal reconstructed CT scan. In Fig. 17.4, we present three cases of the early-stage defects. As you can see, the pars fracture is most identifiable at the caudal aspect of the pars interarticularis. This area should be scrutinized on an adolescent presenting with back pain and a CT scan. This inferior aspect of the pars is especially vulnerable to stress fracture development due to the high concentration of mechanical stress during lumbar motion, which has been proven using the finite element analysis [10]. Technetium (Tc-99 m) single-photon emission CT often is used to identify acute lesions in athletes for whom the clinician has a high suspicion for spondylolysis in the setting of negative results on plain radiography, but this imaging modality can expose patients to high levels of radiation.



CT Scan T2 wt MRI

Fig. 17.3 Early-stage defects with pedicle marrow edema

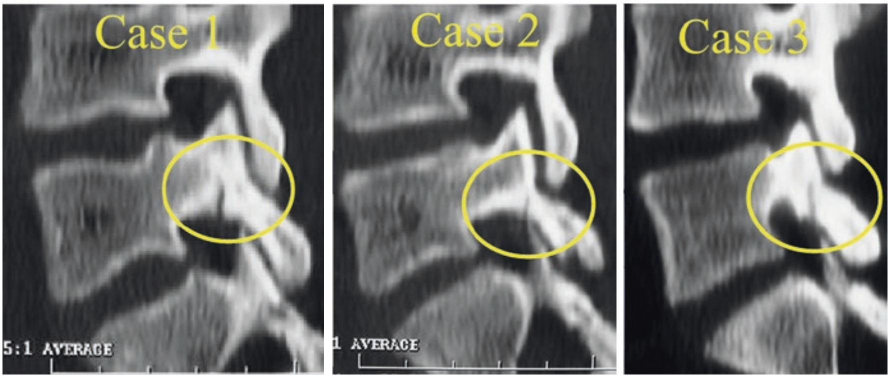


Fig. 17.4 Sagittal reconstructed CT scans in the early-stage defect

Although MRI historically has not been recommended for detecting pars defects, more recent evidence suggests that specific sequences can enable successful detection in up to 98% of patients with pars defects. In totality, this information has led us to recommend MRI as the first-line imaging in a patient suspected of spondylolysis. Diagnosis of progressive and terminal stages of pars fractures is readily identified on advanced imaging, either MRI or CT scan. If the suspicion is still high for a pars fracture after a negative MRI, then a bone scan should be ordered.

Pain Mechanism

For each stage, the pain mechanism is different. Therefore, the goal of conservative treatment is also different. For the early and progressive stages, pain is due to an acute fracture, which is obvious on STIR-MRI as marrow edema and/or extra-osseous bleeding (edema) (see Fig. 17.3).

Figure 17.5 presents two cases that plainly illustrate the difference in the stage of fracture healing and therefore pain mechanism. The left pars in Case 1 and right pars in Case 2 can both be classified as the progressive stage. The CT scan shows a complete fracture without overt blunting of the fracture margins. The associated MRI findings are in the right panels. Once again, the left pars in Case 1 and right pars in Case 2 demonstrate marrow edema and extra-osseous edema consistent with the progressive stage. This is in direct contrast to the right pars in Case 1 and the left pars in Case 2 which demonstrate the radiographic characteristics of the terminal stage. In these pars, the fracture edges are clearly blunted on CT scan, and there is no marrow edema or extra-osseous bleeding. These images clearly show that although each patient has bilateral spondylolysis, the classification of each particular pars fracture can be unique. In the progressive stage, the edema indicates a more acute fracture that stands a chance at union. In the acute fracture, inflammation is

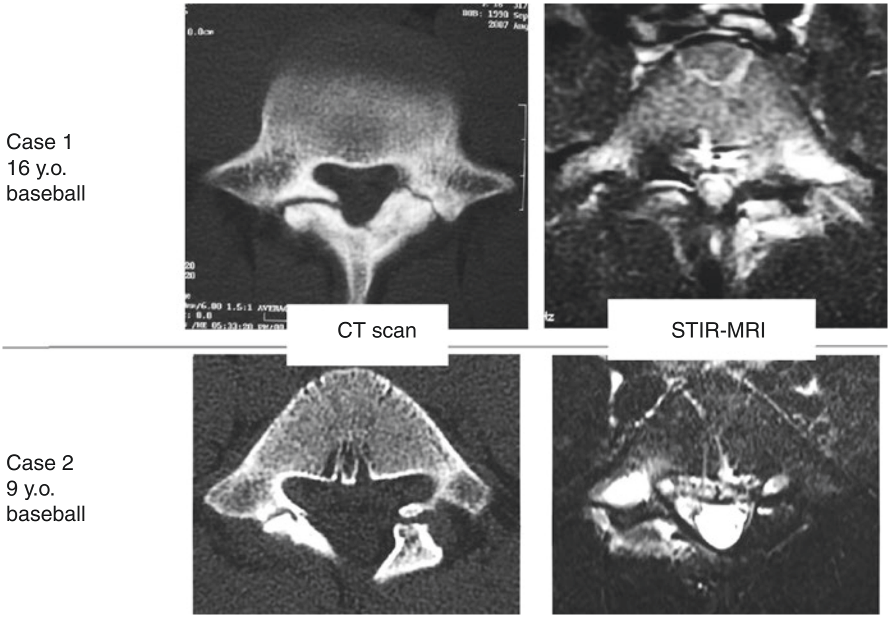


Fig. 17.5 Painful defects on STIR-MRI [11, 12]

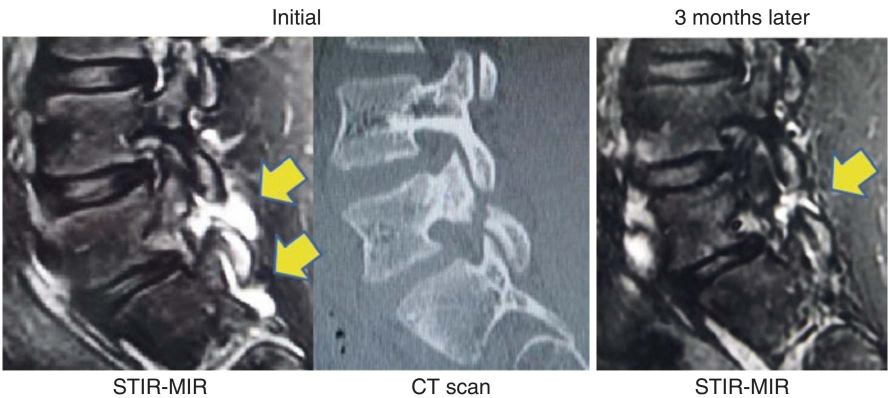


Fig. 17.6 Communicating synovitis of facet joint (14-year-old soccer player, male)

the pain generator. The terminal stage has no edema, and the pain generator is communicating synovitis from pseudoarthrosis [13].

Figure 17.6 demonstrates the typical MRI findings of communicating synovitis in terminal-stage spondylolysis. Effusion is obvious in the defect and adjoining facet joints (yellow arrows). With conservative management, low back pain can be decreased, and the effusion due to synovitis can subside. The decreased effusion is obvious in the STIR-MRI taken 3 months after conservative treatment.

Slippage Mechanism

Regarding slippage in spondylolytic spines (spondylolisthesis), it has been well reported that slippage is very common in children and adolescents and very rare after the skeletal maturation [14–16]. Seitsalo et al. followed 272 children with spondylolysis and found that in age groups of early puberty (girls, 9–12 years; boys, 11–14 years), slippage was likely to progress [15]. Our data is in good agreement with them [16]. We followed 46 pediatric patients aged under 18 years. The mean follow-up period was 6 years. We evaluated correlation between their skeletal age and progression of slip. As shown in Fig. 17.7, skeletal age of the spine can be evaluated by the condition of the secondary ossification center (SOC) of the vertebral body. In the cartilaginous (C) stage of the spine (Fig. 17.7, left panel), SOC is cartilage and cannot be seen on a plain radiograph. The SOC is ossified and is visible at the apophyseal (A) stage (Fig. 17.7, middle panel). Finally, the ossified SOC is fused to the vertebral body; and this defines the epiphyseal stage (Fig. 17.7, right panel). We reviewed the progression of spondylolisthesis to skeletal maturation. The most prevalent stage regarding slippage was found to be the C stage. From stage C to A, 80% of patients showed slip progression. On the contrary, after maturation, there were no slip progressions. Thus, surgeons should be cautious of slip progression in patients in the cartilaginous stage; this corresponds roughly to elementary school age.

The pathomechanism associated with slippage in the immature spine was analyzed by Sairyo and co-workers using calf [17, 18] and rat models [19, 20]. The growth plate in the immature spine is located between the vertebral body and the SOC. This area is a weak point and fails under the biomechanical stress experienced after spondylolysis. Figure 17.8 demonstrates the separation of the growth plate and

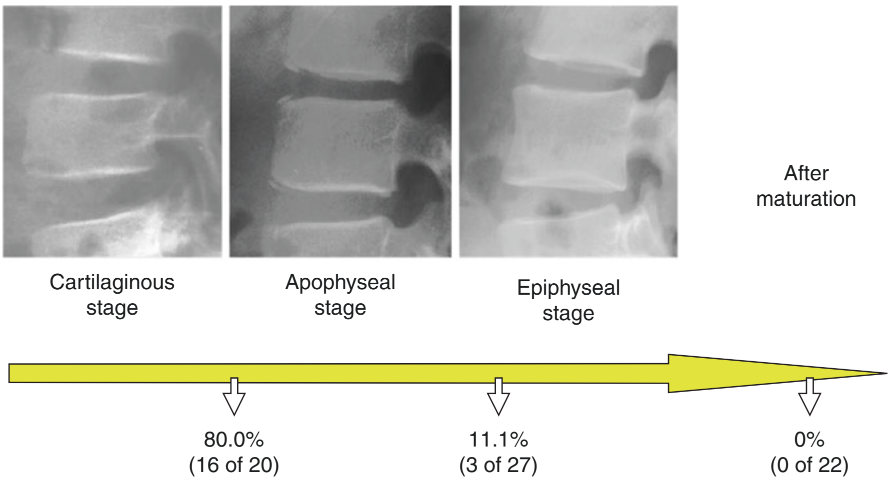


Fig. 17.7 Slippage with the skeletal age

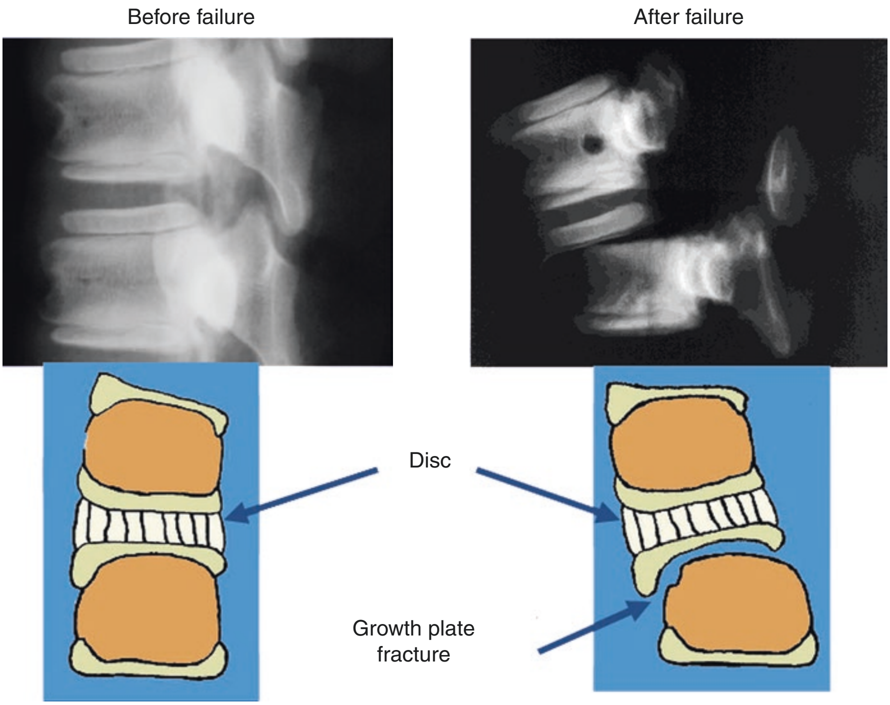


Fig. 17.8 Calf spine slippage model

the location of pediatric spondylolisthesis pathoanatomy. This explains why progression of the slip is common in children and adolescents. After skeletal maturation, the growth plate disappears; and the weak point for slippage also disappears.

Treatment Strategy for Elite Athletes in Children and Adolescents

There are two goals of conservative treatment. For the acute pars fractures (early and progressive stages), bone union is still possible. We therefore attempt to achieve bone healing with the use of a hard brace. Figure 17.9 demonstrates a case where bone union was achieved after 6 months of conservative treatment. We have shown that in general, it takes 3 months for the early stage and 6 months for the progressive stage to achieve bone healing as shown in Fig. 17.10 [9].

For the chronic pars fracture (terminal stage), pain management is the goal because there is no possibility of bone union for pseudoarthrosis. Again, the pain mechanism at this stage is synovitis of the pars defects and adjoining facet joints. Treatment for this pain is focused on anti-inflammation of synovitis. Lumbosacral soft brace is usually used to prevent extension during performance. When pain persists, steroid infil-

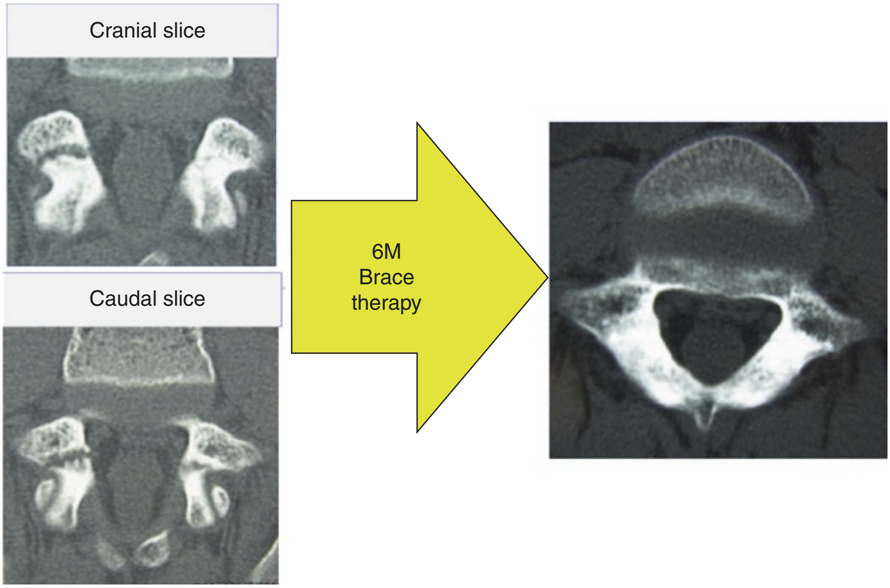


Fig. 17.9 Bone union with the conservative treatment

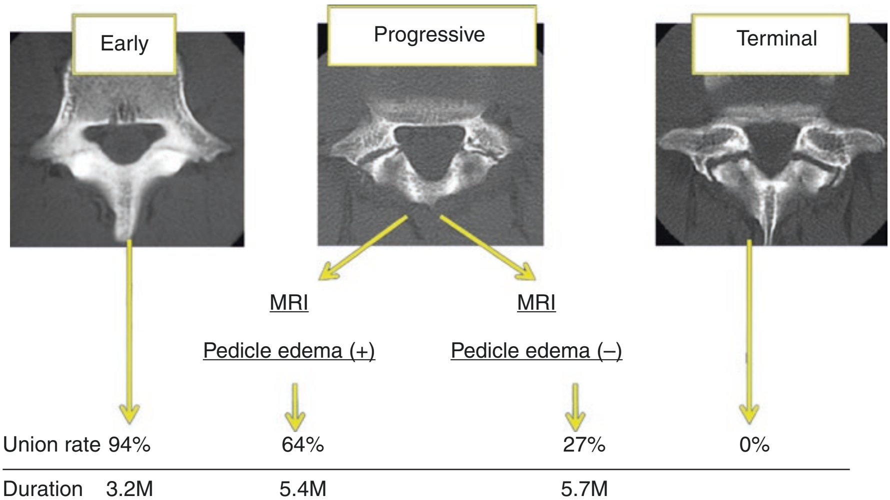


Fig. 17.10 Bone union with the conservative treatment

tration in the defects and intake of NSAIDs are other options. Almost all pediatric patients can return to the baseline activity with such conservative care.

The concern when pediatric patients with pars fracture return to the original activity is slip progression. Progression of the slippage should be carefully checked in the pediatric immature spine [14–16]. We recommend performing and evaluating lateral plain radiographs two to three times a year to check the status of the slippage, deformity, and skeletal age until the spine reaches maturation.

Treatment Strategy for Adult Elite Athletes

Acute pars fractures tend to occur in children and adolescents. An acute adult pars fracture would be considered very rare. Thus, most of cases of spondylolysis in adult athletes are chronic (pseudoarthrosis). The chronic pars fractures in adults are mostly painless. Rarely, the chronic pars fracture can become a pain generator, which would be due to synovitis at pseudoarthrosis. Similar to pediatric patients, steroid infiltration in the defects and intake of NSAIDs are effective for such pathology.

We have experienced 11 cases of acute pars fractures in adults [21], and all of them were very active athletes. Basically, pain management is the treatment strategy regardless of the stage. The biggest difference from pediatric patients is that the adult elite athlete cannot be expected to endure long-term conservative treatment due to short career lengths and reliance on performance for salary.

Figure 17.11 demonstrates a male case of bilateral pars fractures in the adult (20 years old). Although the left pars showed a progressive stage and it had a possibility of bone healing with conservative treatment, we selected just pain management. We decided the time required to achieve a union was not appropriate for this elite athlete. One month later, the pain disappeared, and thereafter he participated in the Olympic Games 2012 in London.

Recurrence (Refracture After Union) and Prevention

Sakai et al. [22] reviewed 63 pediatric cases with lumbar spondylolysis. Results showed that in the very early stage, the bone healing rate was 100%; in the early stage, it was 93.8%; and it was 80.0% in the progressive stage. Surprisingly, the recurrence (re-pars fracture) rate was 26.1%. They stated that physical therapy before return to the sport may prevent and/or decrease recurrence.

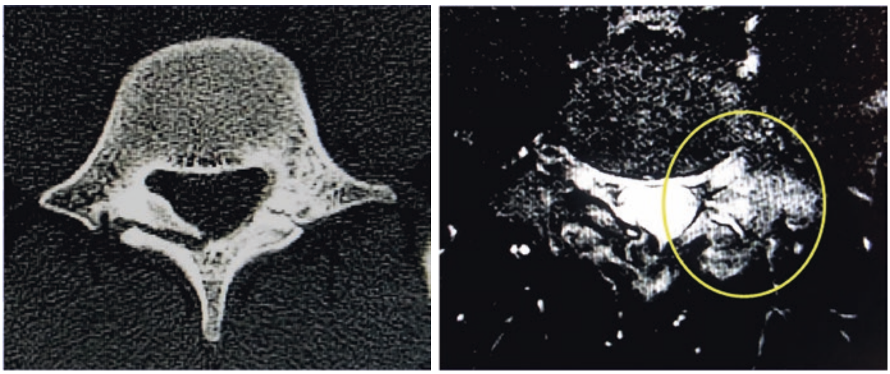


Fig. 17.11 Adult-onset acute pars fracture: 20-year-old male, track and field. RT: chronic (terminal stage). LT: acute (progressive stage)

We believe that the joint-by-joint theory is the most effective physical therapy in reducing the mechanical stress experienced by the lumbar spine during sport [23]. This theory relies on mobilization of the hip joint and thorax to prevent recurrence. Thus, we recommend stretching of the hamstrings, quadriceps, and thoracic spines. For the purpose of efficient stretching, we propose active stretching utilizing reciprocal inhibition [24] and stabilization of the trunk core muscles [25].

Operative Management

Spondylolysis is clinically benign, and more than 90% of the athletes with the disorder can return to the original activity with conservative treatment [26]. However, in certain cases pain management is not effective with conservative treatment, and surgical intervention is required. In general, three surgical methods have been reported: direct repair, segmental fusion, and decompression. For athletes, the direct repair of the pars fracture is favorable. There have been a variety of maneuvers for direct repair such as Scott wiring [27], Buck screwing [28], pedicle screw hook rod [29, 30], V-rod [31], and smiley face rod method [32].

For very active athletes, we have been recommending minimally invasive "smiley face" rod method [32] using percutaneous pedicle screw system [30]. Figure 17.12 demonstrates radiographs of the direct repair surgery using the "smiley face" rod method for a professional tennis player. First a 4–5 cm midline skin incision is made; then, removal and decortication of pseudoarthrosis are performed. Two small skin incisions are made bilaterally as shown in the figure. The percutaneous two pedicle screws are inserted under the guidance of the fluoroscope. Via the midline skin incision, a U-shaped rod is inserted underneath the spinous process,

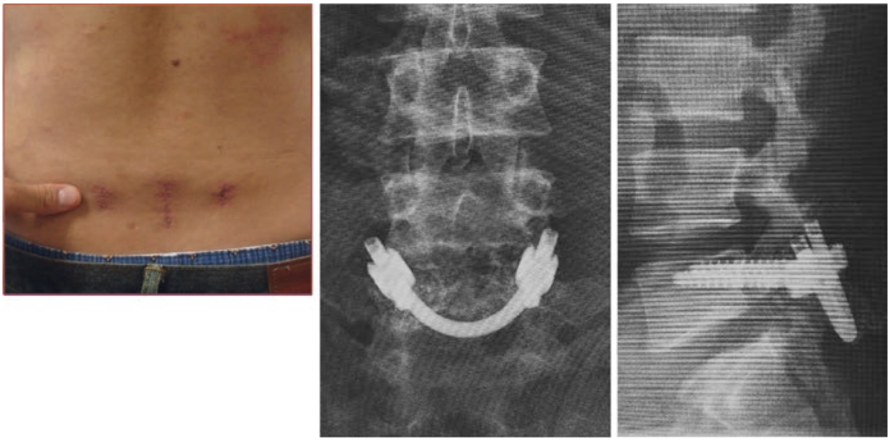


Fig. 17.12 Direct repair of the pars fracture using the smiley face rod method: 30-year-old professional tennis player

and the end of the rod is secured with the screw heads; then, stabilizing the loose lamina, finally on-lay bone graft is made.

Usually, 6 months after the surgery, moderate sports are allowed; however, complete return to the field would be 1 year after the surgery.

Conclusion

Here, we described how to manage spondylolysis and spondylolisthesis in athletes. The skeletal age and CT stage of spondylolysis dictate treatment strategy. Before returning to sports, effective physical therapy is recommended based on the joint-by-joint theory.

Expert Opinion

We believe that classification of the pars fracture based on CT stage yields important information on the etiology of the pain mechanism and thus drives treatment. Early defects are best found on MRI with assessment for edema in the adjacent pars. Slippage is the long-term sequela to be avoided. Evidence has shown that the immature spine is more prone to slippage, and therefore routine surveillance is required. In general, lumbar spondylolysis is a benign disease, and pain management in the athlete is an effective strategy. In the rare case that requires operative intervention, we favor techniques that lead to direct pars union and spare spinal segment fusion in young active individuals.

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