



A Review of Treatment for Acute and Chronic Pars Fractures in the Lumbar Spine

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Abstract

Purpose of Review Spondylolysis remains one of the most common causes of lower back pain in the pediatric and adolescent populations and is particularly prevalent in young sporting individuals. Despite this, approaches to diagnostic imaging and both conservative and surgical treatment vary widely among surgeons. The current review investigates recent literature on the etiology, clinical presentation, diagnosis, and treatment of spondylolysis. In particular, it interrogates the use of various advanced imaging modalities (CT, MRI, SPECT) in diagnosis as well as common surgical approaches to the condition.

Recent Findings Recent data has provided more information on how pars defect laterality, stage, and presence or absence of bone marrow edema impact healing potential. Other studies have highlighted the advantages of using MRI for spondylolysis diagnosis. Other data has provided more clarity on which adults may benefit from direct pars repair, while other studies have compared the various techniques for direct repair of pars defects.

Summary While the exact cause of spondylolysis remains unclear, there is growing understanding of the behavioral, genetic, and biomechanical risk factors that predispose individuals to the condition. MRI may be emerging as the advanced imaging modality of choice for diagnosis due to its lack of radiation and comparable sensitivity to other advanced imaging techniques. Conservative treatment remains the first step in management due to excellent outcomes in most patients, with surgical intervention rarely necessary. In patients that do require surgery, direct repair using a pedicle screw-based approach is preferred over spinal fusion and other direct repair techniques.

Keywords Spondylolysis · Pars Defect · Spondylolisthesis · Spine surgery · Athletics

Introduction

Spondylolysis is a condition defined as a defect or fracture of the pars interarticularis, the portion of the vertebra between the superior and inferior articular processes. It occurs most commonly at the level of L5 (85–95%) and presents as either a unilateral or bilateral defect, which may lead to

spondylolisthesis with anterior slippage of the vertebral body [1, 2]. Together, spondylolysis and spondylolisthesis are some of the most common causes of lower back pain in the pediatric and adolescent population, particularly in those involved in athletics [3]. The prevalence of spondylolysis in the general population is estimated to be 6%; however, this may vary widely due to a variety of factors that can enhance or reduce the development of pars fractures within the lumbar spine [4]. Specific associated factors that have been studied include age, ethnicity, sex, heredity, and involvement in sports [5–7]. Treatment tends to be conservative; however, there are surgical options available for patients who fail to respond to conservative treatment or develop sequelae including spondylolisthesis. Choices in diagnostic imaging and treatment may also differ depending on the patient population treated, with some imaging and treatment courses being more appropriate for the elite athlete than the general population. The primary aim of this article is to provide a current review of

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this condition's etiology, natural history, clinical presentation, and imaging approach, as well as a comprehensive discussion of both conservative and surgical treatment.

Etiology

While its cause remains mostly unknown, spondylolysis likely occurs due to a combination of chronic mechanical stress and genetic predisposition. Symptoms often arise in adolescent athletes experiencing increased athletic demand and growth spurts [8]. Mechanical stress is a likely explanation, as spondylolysis has never been demonstrated in nonambulatory patients and is not found in newborns [4, 9]. Athletics involving axial stress combined with hyperextension such as gymnastics and weightlifting have been shown to predispose athletes to higher rates of spondylolysis as well, likely due to repetitive microtrauma induced by sports-specific maneuvers [10–12]. Mechanically, the pars is susceptible to chronic axial loading injury due to the high stress load it experiences during extension of the lumbar spine. These tensile stresses have been measured to be the greatest at the ventral-caudal aspect of the pars which is the location most commonly seen [13]. Congenitally narrow pars structure and uneven trabeculation in the lower lumbar vertebrae may also play a role [14]. Neural arch strength continues to increase up to the age of 50, increasing the risk of pars fractures in children and adolescents [15]. In patients with a higher pelvic incidence and sacral slope, there is greater shear force at the lumbosacral junction, generating higher stress in the pars and potentially increasing susceptibility to stress fracture [16–19]. While pars fractures most often occur as the result of chronic stress, these injuries can also occur acutely in a single overload injury [20].

Recently, evidence has emerged supporting a genetic component to this diagnosis. Wynne-Davies et al. demonstrated significantly increased incidence in first-degree relatives of patients with spondylolysis, an observation reported by multiple other investigators [7, 21–23]. Furthermore, in 2015 an autosomal dominant mutation of the diastrophic dysplasia sulfate transporter gene was found in patients with dysplastic spondylolysis [24]. Additional diagnoses such as spina bifida occulta and scoliosis have also been associated with spondylolysis, indicating a congenital predisposition in some patients [25, 26–28].

Natural History

Spondylolytic defects exist on a spectrum, ranging from an early stress reaction to a terminal pseudarthrosis. Stress reactions in the pars precede fractures and likely represent a grey area of a physiologic stress response transitioning to a pathologic lysis. Morita et al. defined pars fractures into 3 stages:

early, progressive, and terminal [29]. Early fractures are hair-line defects with focal bony resorption, while progressive fractures have wider defects and often the presence of small fragments. Terminal stage fractures exhibit sclerotic change and are effectively a pseudarthrosis. Fractures that reach the terminal stage will never progress to union, impacting management [30]. Defects may progress from unilateral to bilateral, with 80% of defects bilateral and 20% unilateral. Adolescent athletes may present with a unilateral defect due to asymmetric axial loading. Once a unilateral defect occurs, stresses increase at the contralateral pars, likely explaining the greater proportion of bilateral cases [31]. L5 is the most common location for spondylolysis (85–95%), and the remaining cases are typically observed at L4 or L3 [32]. Defects can be found at more than one level in 4% of patients [29, 33]. Patients with bilateral pars defects are at risk for spondylolisthesis, while unilateral pars defects generally do not lead to slippage [33, 34]. It is estimated that 75% of patients with bilateral spondylolysis will go on to develop some degree of spondylolisthesis [34–36]. A cross-sectional study by Aoki et al. in 2020 demonstrated that 51% of patients with spondylolysis exhibited spondylolisthesis on CT scan, with no unilateral defects exhibiting spondylolisthesis. The same authors also demonstrated an age-dependent increase in progression to spondylolisthesis, with 90% of bilateral spondylolysis patients greater than 60 years old exhibiting spondylolisthesis and only 8.3% of patients less than 60 years old showing spondylolisthesis [33]. Several studies have demonstrated that progression of spondylolisthesis, previously thought to only occur during adolescence, can occur in older adults as well [37, 38]. Beutler et al. demonstrated that patients with bilateral pars defects typically follow a clinical course comparable to the general population and only a small percentage develop *symptomatic* slip progression [34].

Epidemiology

Age is a key factor in the development of spondylolysis, with an estimated prevalence of 4.4% in children growing to 6% by adulthood [4]. Sex also plays a role, with males 2–3 times more likely to develop spondylolysis than females [4, 39]. The role of ethnicity has been demonstrated in the USA: spondylolysis occurs in 6.4% of white men, 2.8% of black men, 2.3% of white women, and 1.1% of black women [40, 41]. Athletes are also more likely to develop spondylolysis, with an 8–15% prevalence in asymptomatic adolescent athletes and 47% prevalence in adolescent athletes with concomitant LBP [6, 8]. This rate in adolescent athletes with LBP can be contrasted with just a 5% prevalence in adult athletes with LBP [2]. Prevalence in specific sports has also been studied, with up to 15% of college football players and 11% of female gymnasts developing spondylolysis [42, 43]. Even higher

rates have been observed in weightlifters (20–30%) and wrestlers (30–35%) [44]. Sport-specific rates likely vary due to differing levels of trunk rotation and hyperextension movements required in each sport. Iatrogenic spondylolysis is another less-known entity that can occur as a postoperative complication and has been described in up to 20% of patients after spinal fusion or decompression [45–47].

Clinical Presentation

Spondylolysis can present in multiple ways, including as an incidental finding on radiographs in an asymptomatic patient [48]. However, the key patient population to suspect spondylolysis in are adolescents involved in athletics who present with LBP, as almost half of this patient population will be diagnosed with spondylolysis [8, 20]. The mean age of presentation in the juvenile population is 15, aligning with the adolescent growth spurt [49]. While acute spondylolysis most often presents in adolescents or children, it has also been described in adult high-level athletes and should be considered in such patients presenting with acute LBP [50, 51]. It is important to gain a complete history from the patient including acuity, sports involvement, and any other physical activities. A family history of low back pain or spondylolytic defects may be helpful for diagnosis.

On physical exam, low back pain worsened by extension or repetitive movement may be seen, as well as weakness of the L5 myotome [52]. Pain with back extension has been shown to have a sensitivity of 81% in patients with spondylolysis [53]. Considering that some patients may have a congenital component to their spondylolysis, inspection of the spine for skin discoloration, dimples, patches, or tufts should also be performed. The neurologic exam is typically unremarkable; if positive neurologic signs are found then spondylolisthesis or alternate diagnoses should be considered. The one-legged hyperextension test remains the only test that has been specifically evaluated for its ability to diagnose lumbar spondylolysis and was shown by Masci et al. to have a low sensitivity of 50–55% in detecting SPECT-confirmed spondylolysis, translating to very little clinical utility in diagnosing patients [54, 55]. Conversely, spondylolisthesis may present with radiculopathy symptoms including numbness, tingling, and pain, typically in the lower limbs in the case of lumbar spondylolisthesis. Sudden worsening of pain in a patient with known spondylolysis may indicate progression to spondylolisthesis. Lumbar spinous process palpation was shown to have a sensitivity of 60% and specificity of 87% for diagnosis of spondylolisthesis [56]. Ultimately, physical exam findings can be used to increase the degree of suspicion for spondylolysis but when used by themselves have very poor sensitivity and diagnostic reliability and therefore should be used in combination with the correct choice of imaging.

Diagnostic Imaging

Radiographs

The initial assessment of suspected spondylolysis starts with standing AP, lateral, and flexion/extension lumbar radiographs. Historically, oblique plain radiographs have been described for initial assessment but are no longer routinely used as they do not provide any additional increase in sensitivity or specificity for spondylolysis detection compared with AP or lateral radiographs [57]. One scenario in which oblique radiographs may be useful is in identification of upper lumbar spondylolysis [58]. AP and lateral standing radiographs have been shown to have a sensitivity of 75% compared to a 90% sensitivity provided by CT scans [3]. Surgeons must therefore have a high degree of suspicion in adolescent athletes presenting with LBP when evaluating radiographs [59]. Plain radiographs are a reasonable first step in diagnosis due to high availability and cost effectiveness. Advanced imaging studies such as CT, SPECT, or MRI should be pursued in the case of patients with persistent lower back pain and negative radiographs. Need for an expedited diagnosis in elite athletes also typically warrants advanced imaging in tandem with radiographs.

Computed Tomography

Computed tomography (CT) scans provide improved sensitivity and specificity compared to plain radiography in diagnosis of spondylolysis [3]. Advantages of CT include high resolution of bony anatomy and ability to properly stage spondylolysis, as well as assessment of healing in chronic defects [60–62, 63••]. Multiple studies have identified CT as the best modality for tracking healing following initial diagnosis [63••, 64•]. CT scans better visualize cortical integrity compared to MRI, allowing CT to identify chronic fractures with sclerotic margins with very high fidelity [65]. It has also been suggested that CT be used as the primary imaging modality in patients with dysplastic or abnormal pars anatomy due to higher false-negative and false-positives rates on MRI in this patient population [63••]. For detection of early-stage pars defects on CT, sagittal reconstructed CT may be best due to improved visualization of defects isolated to the ventral-caudal aspect of the pars, as well as better differentiation between the pars defect and facet joints [13, 30, 64•].

Although CT is less reliable for distinguishing active fractures from chronic non-unions, it can still provide valuable information for prognostic purposes: wide sclerotic margins indicate a chronic non-union that will not heal with conservative treatment, while a narrow pars defect with non-corticated margins indicates an acute fracture that may heal with activity reduction and other conservative measures [63••, 64•]. Early, pre-lysis lesions without fracture are often occult on CT,

limiting potential for earlier diagnoses [65]. A principal disadvantage of this modality is increased radiation exposure, which is particularly relevant in the choice of imaging for juveniles with suspected spondylolysis. Lifetime cancer mortality risks attributable to the radiation from a pediatric CT examination are estimated to be much higher than for adults [66]. A 2013 study of 680,000 individuals exposed to CT scans in childhood or adolescence found an incidence rate ratio of 1.13 for cancers of all types from spine CT scans [67]. In 2015, Fadell et al. found that z-axis limitation and CT protocol optimization were able to reduce radiation exposure to even less than standard radiographs in some cases while maintaining the enhanced diagnostic utility of CT scans (Fig. 1) [68]. Overall, CT is an excellent option for proper staging and visualization of pars defects but generates significant radiation exposure that must be weighed carefully, particularly when selecting advanced imaging for juveniles.

Magnetic Resonance Imaging

While early investigations of magnetic resonance imaging (MRI) for detection of spondylolysis reported poor sensitivity and positive predictive value, recent reports have provided support for use of MRI as the advanced imaging modality of choice in spondylolysis evaluation [60, 62, 63•, 65, 69–72]. Development of thin-slice MRI protocols specifically designed for evaluation of the pars interarticularis have likely improved performance, with reports of sensitivity as high as 92–98% for detection of spondylolysis [30, 64•, 71]. Specifically, fat-suppressed fast-spin T2-weighted images in the sagittal plane are key for making the diagnosis using MRI [71•, 73]. Higher field strength (3-tesla MRI) generates a higher signal-to-noise ratio and may be preferred by some surgeons [74, 75]. Ancillary findings on MRI have also been

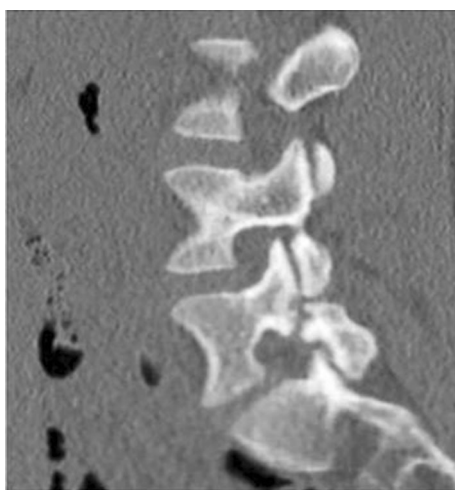


Fig. 1 Sagittal limited z-axis CT scan, optimized to decrease radiation dose, demonstrating a complete fracture of the left-sided L5 pars interarticularis. Courtesy of Fadell et al. ⁶⁸. Published with permission from Springer Nature Inc.

documented that may help increase test sensitivity, including widened sagittal diameter of the spinal canal, wedging of the posterior aspect of the vertebral body at the level of spondylolysis, and marrow changes in the adjacent pedicle [69, 76]. MRI has demonstrated high negative predictive value (97%) for spondylolysis when marrow is seen across the pars region, providing valuable rule-out ability for initial diagnostic evaluation [77].

In 2002, Hollenberg et al. devised a classification scale for pars defects on MRI with high intraobserver and interobserver agreement: grade 0: normal; grade 1: stress reaction; grade 2: incomplete fracture; grade 3: acute complete fracture; grade 4: chronic complete fracture [78]. Campbell et al. performed a prospective analysis comparing MRI vs. CT vs. SPECT, concluding that MRI was highly accurate for grade 0, 3, and 4 defects, with limitation in distinguishing stress reactions from incomplete defects [63•]. Despite this potential limitation, multiple investigators have performed studies comparing MRI, CT, and SPECT using this scale and concluded that MRI should be used as the advanced imaging modality of choice because of its risk-benefit ratio [63•, 64•, 71•]. One key advantage MRI has over other imaging techniques is the ability to pick up on stress reactions and early fractures that may be missed on CT or plain radiography [65]. Cortical edema (high signal change, HSC) in the pedicle adjacent to the pars on MRI is one of the earliest indicators of spondylolysis and is a positive predictor of bony healing: HSC-positive defects have a higher rate of healing than HSC-negative defects [49, 79]. Early recognition of these stress reactions and pre-lysis lesions on MRI may enable earlier initiation of conservative treatment, preventing progression to chronic non-union and avoiding surgical intervention [71•, 80]. Other principal advantages include the absence of ionizing radiation and superior assessment of concomitant pathology including nerve root compression, disc degeneration and tissue within the pars defect [64, 72]. The combination of these advantages with sensitivity comparable to SPECT and CT as well as potential prognostic information not offered by other imaging modalities makes MRI an attractive option as the primary advanced imaging choice in spondylolysis evaluation.

SPECT/Bone Scan

Single-photon emission computed tomography (SPECT) is a nuclear imaging technique which produces a 3-dimensional image showing distribution of a radiotracer taken up by certain tissues [81]. SPECT is extremely sensitive and will pick up on stress reactions and acute lesions that may be missed on CT or plain radiographs [82, 83]. It may also provide information on the ability of a pars lesion to heal, similar to the presence or absence of HSC in adjacent pedicles on MRI [52]. However, SPECT has significant downsides that must be

considered. Radiation exposure is a concern, with an estimated dose of 5 mSv from SPECT alone and 10 mSv with combined CT-SPECT testing [52, 64]. SPECT imaging cannot reliably distinguish between stress reactions and overt pars fractures and detects only 17% of chronic lesions [63, 84]. A positive SPECT result for spondylolysis is increased radio-tracer uptake in the pars region, which may be mimicked by facet joint arthritis or unilateral lesions including infection and osteoid osteoma [64]. This produces a high false-positive rate which is compounded by false-negatives from missed chronic lesions and non-unions. It has thus been suggested that SPECT can essentially be abandoned in the general population, except in cases where MRI may be contraindicated or nondiagnostic [63]. However, SPECT may still have a role in expedited diagnosis of elite athletes with lower back pain for more than 3 weeks. If SPECT is positive, a CT scan can be performed to better delineate the pathology; SPECT and CT can also be merged for definitive diagnosis and prognosis. A positive SPECT without fracture on CT is a stress reaction and has a favorable prognosis, while a negative SPECT with a positive pars fracture on CT is likely a chronic non-union and will likely not heal. It has been estimated that in 8–10% of cases SPECT is positive and MRI is nondiagnostic, indicating slightly higher sensitivity on SPECT than MRI [74]. This should be interpreted with caution however, as positive SPECT imaging has been documented in asymptomatic athletes, and may be picking up on a physiologic stress reaction that would not naturally progress to spondylolysis [83].

Treatment

The vast majority of patients with acute symptomatic spondylolysis can be treated successfully with conservative measures, while asymptomatic and incidentally discovered cases do not require treatment at all. Treatment is always conservative initially, while surgical intervention is reserved for refractory cases in patients with debilitating pain for more than 6–12 months. Positive predictors of pars defects spontaneously healing include unilateral defects, earlier fracture stage, and lumbar level other than L5 [85]. While good clinical outcomes with conservative treatment do not necessarily depend on the bony healing of the lesion, osseous union should still be an objective because this reduces the risk of progression to spondylolisthesis [29, 62, 77, 86]. It is important to differentiate acute from chronic pars defects when selecting management: acute lesions include stress reactions and early/progressive fractures, while chronic defects are non-unions that will not heal spontaneously. Pain mechanism likely differs between acute and chronic defects, with inflammation from the acute fracture causing pain while chronic defects generate pain due to communicating synovitis from the pars pseudarthrosis [30]. The goal in treatment of early and

progressive defects is therefore to achieve bony union through immobilization, while in terminal defects, the goal is to limit pain from synovitis and ultimately achieve bony union through surgical means. Spondylolysis in adult athletes tends to be chronic, so pain relief is key. In the rare case of acute pars fractures in an adult elite athlete, immobilization and conservative treatment is preferred; however, this must be weighed against the ability of the athlete to miss training for prolonged periods of time (3–6 months).

Conservative/Non-operative

Conservative measures are often able to achieve favorable outcomes in both the general population and athletes. A prospective study by Lee et al. compared 145 young patients with spondylolysis treated surgically and conservatively and found that at 12 months there was no significant difference in pain and Oswestry Disability Index between the two groups [87]. Similar results have been reported in athletes, with conservative treatment successful in 85% of athletes versus 87.7% in athletes treated surgically [88]. A 2016 review found that athletes return to play at 3.7 months on average when treated conservatively [89]. Interestingly, non-bony union of the defect may not negatively impact overall short-term outcome or sports resumption: prospective cohort studies by Sys and Iwamoto respectively found that athletes without bony union still had excellent subjective outcomes and rates of return to play [90, 91]. This may be due to fibrous, non-bony union stabilizing the defect and preventing pain [10, 12].

Union rate with conservative measures is highly dependent on fracture stage: a retrospective study by Sakai et al. in 2017 demonstrated 100% bony healing rate in “very early,” 93.8% in “early,” and 80% in “progressive” stage defects with no attempt made for conservative measures in terminal defects [92]. Diagnosis of each stage is based on a combination of plain X-ray, CT, and MRI findings: “very early” stage defects have a stress reaction on MRI with no visible fracture line on CT, “early” stage have a visible hairline fracture, “progressive” stage have an obvious fracture with a gap, while “terminal” stage defects are a pseudarthrosis. A similar prospective study by Sairyo et al. demonstrated the impact that presence or absence of pedicle edema (HSC) on MRI has on healing: 64% of progressive defects with pedicle edema healed by 3 months compared to 27% of lesions without pedicle edema [80].

Conservative treatment typically consists of a combination of bracing, activity restriction, pain control, and physical therapy. Evidence for bracing is mixed, and positive results from bracing are likely a product of the activity restriction that bracing enforces versus the actual bracing itself. The 3 predominant brace types that have been studied are TSLO, LSO, and non-rigid braces [89]. Studies comparing patients treated with or without a brace have found no significant difference in clinical outcomes and demonstrated that pain relief and

functional recovery can be achieved without bracing [77, 93]. Physical therapy is an integral component of treatment: the patient should stop all pain-producing activity for at least 6 weeks, followed by initiation of a back exercise physical therapy program, which may help lower the rate of refracture after union [92•]. Oral nonsteroidal anti-inflammatory drugs (NSAIDs) may reduce pain; local anesthetic/corticosteroid combination (e.g., lidocaine/methylprednisolone) injections infiltrating the pars defect have been reported to produce significant temporary pain relief as well [94, 95]. Teriparatide is occasionally used in professional athletes due to reports of faster recovery of osteoporotic fractures and increased bony union in spine fusion but has not specifically been shown to improve spondylolysis healing [96, 97].

Low-intensity pulsed ultrasound (LIPUS) is a technique that has recently emerged with promising results for increasing bony union rates, particularly in progressive stage pars fractures. In one clinical study, LIPUS increased bony union percentage in progressive fractures with HSC on MRI from 10% in a conventional treatment group to 67% in the LIPUS-treated group [86]. Another prospective study in athletes with spondylolysis demonstrated that LIPUS reduced time required to return to sport by 72%, from a mean of 167 days to 61 days [98]. This therapy may become a key component in conservative treatment of early and progressive spondylolysis defects.

Operative Intervention

While rare, there are patients who do not have symptom improvement with conservative treatment and continue to have severe pain interfering with quality of life or ability to return to sports. A total of 5% of athletes fail conservative treatment and require surgery [99]. A systematic review by Scheepers et al. found that in adult athletes who fail conservative management, surgery is likely to enable return to sport, reduce pain, and improve overall function [100]. Indications for surgery include persistent pain after 6–12 months of conservative treatment, neurologic deficits, and worsening symptomatic spondylolisthesis. Factors that may positively influence clinical outcomes after surgery include unilateral defects and younger patient age [101]. There are 2 principal surgical methods that can be used for spondylolysis: fusion or direct repair. Posterolateral fusion was once the only method of choice until the introduction of direct repair by Buck in 1970 [102]. Spinal fusion for spondylolysis without spondylolisthesis has become less popular with time largely due to loss of range of motion at the fused level and the potential for adjacent segment disease (ASD). Regardless of the surgical intervention, thorough debridement of the pars defect is crucial to remove fibrous or cartilaginous tissue as well as the sclerotic bone margins. Bone grafting and use of alternative sources such as bone morphogenetic protein may

improve bony healing rates and should be strongly considered, particularly in fractures without any metabolic activity evident on SPECT/MRI [95, 103].

Spinal Fusion

While no longer the preferred method for surgical treatment of spondylolysis, there remain scenarios in which spinal fusion is indicated instead of direct pars repair. Spondylolisthesis Meyerding grade I or greater, significant degenerative disc disease and dysplastic pars anatomy preclude direct pars repair, leaving spinal fusion as the primary surgical option in patients with refractory pain [74, 95]. Spinal fusion increases stability and reduces translation in the sagittal plane [104]. In the case of a bilateral L5 spondylolysis causing anterolisthesis of L5, an L5-S1 in situ fusion with autogenous iliac crest bone graft historically has led to excellent clinical outcomes approaching 90% [105]. More recently, lumbar interbody fusion has been utilized during surgical treatment in hopes of increasing bony fusion rates and restoring lordosis, particularly at the L5-S1 level. Transforaminal lumbar interbody fusion (TLIF) possesses advantages compared to posterior lumbar interbody fusion (PLIF) including reduced complication rate, blood loss, and operation duration [106–110]. While spinal fusion provides excellent stability, its intersegmental fixation causes loss of natural range of motion and carries significant risk of ASD: 36% of patients who undergo posterior lumbar fusion will require additional surgery at 10 years postoperatively due to ASD [111]. Additionally, spinal fusion should be avoided in professional athletes if possible due to lower chances of returning to prior athletic level as well as necessity to take a prolonged period of time off from athletics [74]. These downsides are significant and are reduced if not obviated in the alternative method of direct pars repair.

Direct Repair

Since its introduction in 1970 by Buck, direct repair of the pars has become the preferred intervention for pars defects after conservative measures fail [102]. Direct repair does not restrict range of motion in the involved segments, can restore normal anatomy, and has good clinical functional outcomes [112]. Contraindications for direct repair include facet joint arthropathy, significant degenerative disk disease, and associated spondylolisthesis [113]. Pfirrmann grade III disc degeneration may be an acceptable limit to offer pars repair [114]. Spondylolisthesis greater than Meyerding grade 1 is a contraindication, although the actual amount of slippage that requires fusion vs. direct repair is controversial. In patients with lower extremity symptoms such as neurogenic claudication and associated stenosis, direct repair alone is insufficient and a decompressive laminotomy or laminectomy should be considered [95]. Anesthetic infiltration of the pars is useful for

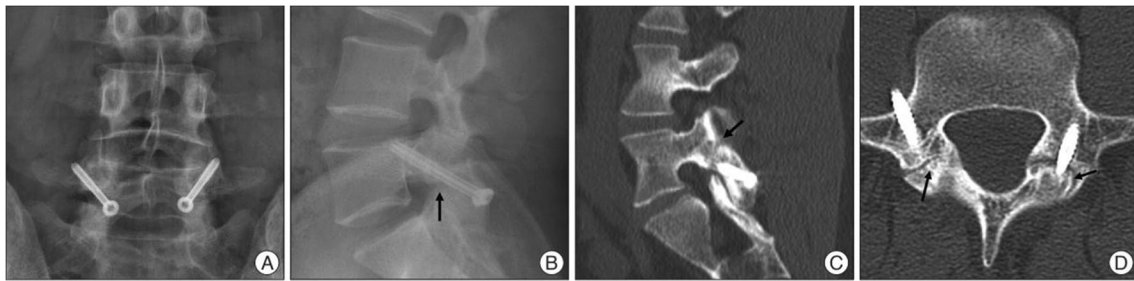


Fig. 2 Buck method of direct repair using a direct pars lag screw. **A,B** Postoperative AP (**A**) and lateral (**B**) plain X-rays showing placement of the pars screw through the pars defect (black arrow). **C,D** Sagittal (**C**) and axial (**D**) CT scans depicting a well fused pars defect 26 months after the operation (black arrows). Figure 2 labeled for reuse according to Creative Commons Attribution Non-Commercial 3.0 Unported License (From

Shin MH, Ryu KS, Rathi NK, Park CK. Direct pars repair surgery using two different surgical methods: a pedicle screw with universal hook system and direct pars screw fixation in symptomatic lumbar spondylolysis patients. *J Korean Neurosurg Soc.* 2013. 51(1): p. 14–9, <https://dx.doi.org/10.3340%2Fjkns.2012.51.1.14>

identification of patients most likely to benefit from surgical treatment, as it can confirm the pars defect as the pain-generating source [115]. It has previously been suggested that direct repair should be reserved for patients younger than 20 due to reduced union rates and potentially worse clinical outcomes in older patients [116, 117]. Despite this, a 2021 systematic review by Kumar et al. demonstrated that in adults aged 18–45 with a positive pars infiltration test and no signs of degenerative disc changes, direct repair is still highly successful [118•]. The evidence-based literature suggests excellent clinical results from direct repairs regardless of level [119, 120, 121•].

There are a variety of methods for performing direct repair, including the Buck repair (direct pars lag screw, Fig. 2), Scott repair (segmental wire fixation, Fig. 3), Morscher repair (screw hook, Fig. 4), and pedicle screw-based techniques (Fig. 5) [95, 102, 122–127]. A 2018 meta-analysis by Mohammed et al. compared these four direct repair methods and assessed overall pooled fusion, complications, and positive outcome rate. Pedicle screw techniques had the highest fusion rate (90.21%) and lowest complication rate (12.8%), with the Buck repair providing the second-best results. Positive outcome rates were high with all methods, with positive outcomes seen in 84.33% of Buck repair-treated patients and 80.1% of pedicle screw-treated patients. These results

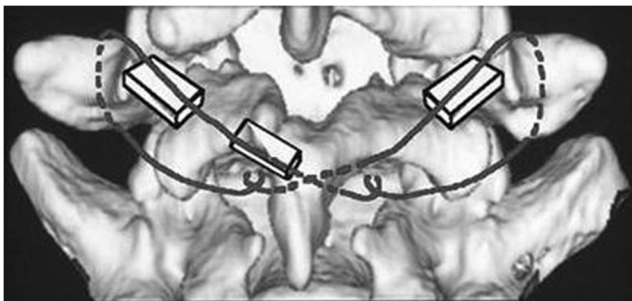


Fig. 3 Scott method of direct repair using segmental wire fixation. Courtesy of Yamamoto et al. ¹²⁵. Published with permission from Springer Nature Inc.

indicate that the Buck repair and pedicle screw-based methods are highly comparable in fusion and complication rates and both provide a high rate of good clinical outcomes [128•]. Biomechanical data support these two methods as well, with cadaveric studies demonstrating that Buck and pedicle screw-hook systems have the least amount of displacement and greatest stability during flexion/extension [113, 129].

Challenges associated with the direct screw technique may include difficult screw placement due to narrow area of the lamina as well as decreased area available for bone graft placement due to the screw [130, 131]. Laminae may also fracture upon screw placement [132]. Conversely, challenges with the pedicle screw-hook method may include difficult hook placement on dysplastic or abnormal lamina, as well as applying enough compression to approximate the defect [124]. Keys to success with the pedicle screw-hook method include use of polyaxial pedicle screws and selection of a sublaminar hook that fits well on the lamina [95]. Overall, the pedicle screw-based direct repair is preferred due to higher fusion rates and lower complication rates, followed by the Buck repair. Postoperatively, the patient should be placed in a rigid lumbosacral brace for 3 months and perform daily isometric core-strengthening exercises. A gradually escalating physiotherapy program can be begun at 1 month postoperatively. Athletes are typically permitted to return to play within 1 year of surgery, but should not return until pain free [133].

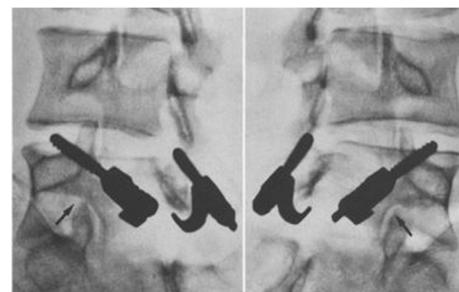


Fig. 4 Morscher method of direct repair using a screw hook. Courtesy of Hefti et al. ¹²⁶. Published with permission from Springer Nature Inc.

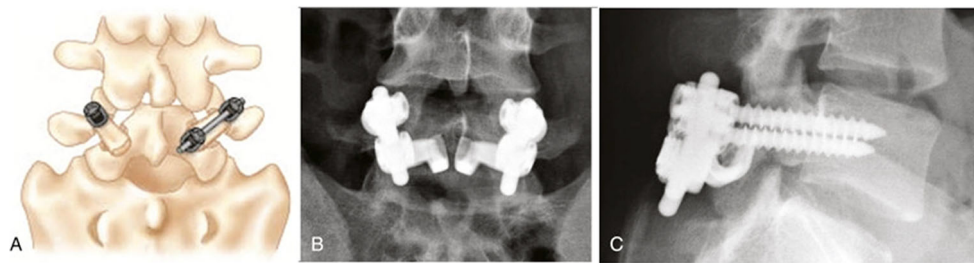


Fig. 5 Pedicle screw-hook-rod method of direct repair depicted in **A** schematic view, **B** AP plain X-ray, and **C** lateral plain X-ray. (Adapted with permission from Elsevier: Spondylolysis repair, in Vaccaro A,

Baron E [eds]: *Spine Surgery*. Third edition. Philadelphia, PA: Elsevier, 2018. pp 322–328.)

Conclusion

Spondylolysis and spondylolisthesis are extremely common causes of lower back pain in the pediatric and adolescent population. It is particularly important for surgeons to have a high degree of suspicion in young athletes presenting with low back pain, especially those involved in gymnastics, wrestling, and weightlifting. While etiology remains unclear, pars defects likely occur due to repetitive microtrauma in a genetically susceptible individual. Multi-sport involvement may help interrupt this cycle of microtrauma and should be encouraged in young athletes. Appropriate diagnostic imaging is crucial due to the poor sensitivity of isolated physical exams: MRI is a highly sensitive tool for diagnosis of spondylolysis that avoids radiation exposure and provides information about the ability of a lesion to heal naturally. Treatment is almost always conservative and consists of a combination of physiotherapy, activity restriction, and bracing, with the key component being cessation of activities causing pain. Surgical intervention is rarely required, but in patients with refractory pain interfering with daily activities or sports, direct repair of the pars offers effective pain relief and excellent clinical outcomes. Various methods may be utilized for direct pars repair, but pedicle screw-based systems and percutaneous placement of a direct pars screw appear to perform best. Continued development of minimally invasive approaches will likely help reduce postoperative pain and hospitalization time after surgery for spondylolysis.

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