Spondyloysis is the term used for a defect in the pars interarticularis of the vertebra. The term is from the Greek roots spondylos, meaning vertebra, and lysis, meaning break or defect. Spondylolisthesis is from spondylos and lysis, meaning movement or slipping, and refers to the slipping forward of one vertebra on the next caudal vertebra. Spondylolisthesis was first described in 1782 by Herbiniaux, a Belgian obstetrician. Spondylysis is most common at L5, and therefore a slip is most common at this level, with L5 slipping forward on S1. Even though this discussion is about spondylolisthesis, some discussion of spondyloysis is necessary, because this is the cause of the most common type of spondyloysis.

**Classification**

The most well-known classification is that of Newman, which was reiterated by Wiltse et al. Spondylolysis is divided into five types: Type I is dysplastic or congenital. There is a congenital deficiency in the L5–S1 facet joints that allows forward slipping of L5 on S1. There is no defect or elongation of the pars. In Type II, isthmic or spondylolytic, there is a lesion in the pars interarticularis that permits the forward slippage. The articular facets are normal. Type II is divided into three causes: lytic fracture of the pars, elongated but intact pars, and acute pars fracture. Type III is degenerative and involves degenerative arthritis of the facet joints as well as degeneration of the disc. Type IV, traumatic, involves an acute fracture in an area of the vertebra other than the pars. Type V, pathologic, involves a lesion of the pars or pedicle due to generalized bone disease that allows forward slippage.

Only two of these types, I and II, occur in children and adolescents, and they are discussed here.

**Cause and Incidence**

Because the dysplastic and isthmic types are different, they are discussed separately.

**Dysplastic Spondyloysis**

The dysplastic type is true congenital spondylolisthesis due to a congenital anomaly of the lumbosacral articulation with facet joints that do not buttress the forward slip of L5 on the sacrum. The facets may have a transverse orientation, a sagittal orientation, or, more rarely, may involve lumbosacral kyphosis due to an anterior failure of vertebral formation. The pars is intact but may be poorly developed, and as the posterior arch moves forward with the anterior translation of L5, symptoms of spinal stenosis occur early, with a slip of more than 35% being unusual. The exact incidence is unknown, but this type makes up 14–21% of treated cases in large series, with a 2:1 female-to-male ratio.

**Isthmic Spondyloysis**

A defect in the pars has been sought at birth, but never found. The earliest cases have been observed at 6 weeks to 10 months, with only one case of spondylolisthesis found in a newborn, reported by Borkow and Kleiger. More commonly, the incidence is 4.4–5.0% at age 5–7 years, increasing to 6% at age 18. The number of these patients who have slippage is not well known. It has been reported by Wiltse et al in 50% of cases with spondylolyis and in 13 (68%) of 19 cases of spondylolyis at age 6, increasing to 20 (74%) of 27 cases at age 18 in the series of Frederickson et al. Saraste in her 20-year follow-up review of 255 patients with spondylolyis and spondylolisthesis found an 81% prevalence of spondylolisthesis on initial examination, but only 23% were less than 18 years of age at initial examination. The amount of slippage was not stated by Wiltse et al. In the series of Frederickson et al, all slippage was less than 30%, but the radiographs were obtained with patients supine. The incidence of different grades of slippage is reported in two series, both in children and adolescents. Osterman et al found in their 71 cases that 79% were Grade I, 20% Grade II, and 1% Grade III. Blackburne and Velikas in their 126 treated cases found 71% with slippage of less than 20%, 25% between 21% and 50%, 17% between 51% and 80%, and 5% more than 81%

There is a difference between the sexes and races in the United States, as reported by Rowe and Roche, with an incidence of spondylolyis of 6.4% in white men, 2.8% in black men, 2.3% in white women, and 1.1% in black women. It is interesting to note that although pars defects are half as common in girls as in boys, high-grade slippage is four times more common in girls. The highest incidence is in Alaskan Eskimos (26%) with the highest rate in Eskimos from north of the Yukon River.

The exact cause of spondylolyis and spondylolisthesis is unknown. Theories have indicated hereditary factors, a congenital predisposition, trauma, posture, growth, and biomechanical factors.

**Hereditary Factors.** Family studies have shown a high incidence of spondylolyis and spondylolisthesis in first-
degree relatives of children with these conditions, with the incidence varying from 19% to 69%\(^1\),\(^3\),\(^4\),\(^6\),\(^9\),\(^5\),\(^7\).

Wynne-Davies and Scott\(^1\) noted an increased incidence of dysplastic lesions in affected relatives, in addition to a higher incidence of spina bifida of S1.

**Trauma.** Trauma is considered to be a factor in the cause of spondylolysis and spondylolisthesis. Acute trauma is obviously the cause of the acute traumatic type of spondylolysis. In addition, many cases occur after a traumatic episode. Is the trauma the cause of the lesion or does it make an asymptomatic defect symptomatic? Wiltse et al\(^1\) theorized that spondylolysis is a stress fracture in the pars and that repetitive microtrauma or microtresses is a factor in the cause. Repetitive hyperextensions, in which the caudal edge of the inferior articular facet of L4 makes contact with the pars interarticularis of L5, are considered to be causative trauma. This is confirmed by the higher incidence of spondylolysis in people engaged in certain sports: female gymnasts,\(^2\),\(^4\) college football linemen,\(^2\),\(^5\),\(^8\) and weight lifters.\(^1\) It is also thought to be causative in Scheuermann’s disease.\(^6\)

In addition, spondylolysis has not been reported in adults who have never walked,\(^7\) pointing to the mechanical effects of the upright posture.\(^2\),\(^1\),\(^9\),\(^6\)

**Growth.** Growth plays a definite role in the cause of spondylolysis, shown by the fact that defects do not occur in the newborn, reach a prevalence of 4% at age 6, and reach the prevalence found in adults by age 14. This increase in prevalence is more marked during the adolescent growth spurt.\(^2\) In spondylolisthesis, an increase in slippage occurs during the adolescent growth spurt.\(^3\),\(^9\),\(^7\),\(^9\) Growth, with an earlier growth spurt occurring in girls, may also be the factor that explains the difference in the predominance of a pars defect in boys and the predominance of high-grade slippages in girls.

The cause is thus multifactorial, with an inherited predisposition that probably manifests as a weakening of the pars interarticularis, with the defect occurring after repeated microtrauma. The dysplastic variety with an elongated pars has a strong familial pattern with congenital abnormalities in the lumbosacral area: abnormal facet orientation and spina bifida of S1.

**Natural History**

The natural history of spondylolisthesis is poorly described in the literature. There are a few population studies, but they are not large, and because the incidence is low, the number of cases of spondylolisthesis observed has been low. In addition spondylolysis and spondylolisthesis are often reviewed together.\(^2\),\(^6\),\(^6\) Results in studies from the literature indicate that 50–81% of cases of spondylolisthesis are associated with spondylolysis, as discussed previously.\(^2\),\(^6\),\(^7\),\(^5\),\(^1\) These figures are difficult to compare, because only one is a population study\(^2\); the others are studies of two patients.\(^5\),\(^1\)\(^) As a rule spondylolisthesis is painless, its appearance occurring with the onset of pain, neurologic problems, or gait or postural changes. It is generally agreed that in most cases 90% of the slippage has already occurred at the time of initial examination.\(^2\),\(^6\),\(^6\) In addition, as noted, most of the cases in treatment or population reviews have a slippage of less than 30–50%. Slippages above this range are unusual. These figures indicate that most cases of spondylolysis are associated with spondylolisthesis, but no large population studies have been performed to verify these figures, and most of spondylolysis probably is not associated with slippage. Most people with a lytic pars defect are asymptomatic, never seek medical attention, and are therefore not considered in these statistics.

There are two important questions when discussing the natural history of spondylolysis and spondylolisthesis. How frequently does the slippage in spondylolisthesis progress? How often is pain a problem?

**Progression.** Progression occurs in a low percentage of cases: 4% in the series reported by Frennered et al\(^2\) and 5% in Saraste’s cases.\(^7\) In the series of Frederickson et al,\(^2\) it appears that progression was unlikely after adolescence, whereas other investigators reported progression in adolescence, most probably because of disc degeneration.\(^3\),\(^9\),\(^7\),\(^9\) In adolescence, progression usually occurs during the growth spurt and is more common in females and in those with dysplastic spondylolisthesis.\(^2\) In addition, slippage progression is more common in a child or adolescent with initial slippage of more than 50%.\(^9\) Females are at a greater risk for progression to a higher grade slippage.\(^9\),\(^1\),\(^3\),\(^7\),\(^9\) From the literature, it appears that slippage progression is usually minimal after skeletal maturity.\(^2\),\(^6\),\(^6\),\(^1\)

It must be emphasized that the technique of radiographs is critical in the evaluation of spondylolisthesis and in surveillance of cases for progression. A standing lateral view is essential, with the radiographic field encompassing the lumbosacral area, not the lumbar spine. Thus, the radiographs are obtained in a standing lateral lumbosacral view, ideally with the central x-ray beam going through the lumbosacral joint. Small variations can yield a high error rate,\(^1\) and to document definite progression, a change of 10–15% slippage or 4–5 mm is necessary.\(^1\)

Additional radiographic factors have been identified as associated with a greater chance of progression. The degree of slippage at initial examination has been found to be associated with risk of progression by some investigators,\(^2\),\(^8\),\(^8\) but not by others.\(^2\),\(^7\) The amount of lumbosacral kyphosis, or the slippage angle, especially when severe, is associated with progression in the growing child. Other changes are found with high-grade slippages (e.g., dome-shaped sacrum and trapezoidal L5, which are secondary to the slippage and not prognostic for slippage progression).\(^2\)

**Pain.** Pain is the most common initial symptom. Are there prognostic features for pain? Saraste\(^7\) found in her review of adults that there were radiographic features that correlated with low back symptoms. These were a slippage of greater than 25%, L4 spondylolysis or spon-
spondylolisthesis, or early disc degeneration at the level of the slippage.

**Management**

A large number of treatment choices are available for the child with spondylolisthesis, including no treatment, observation, limitation of activities, exercises, bracing, casting, repair of a pars defect, fusion, decompression, and reduction of the slippage. The problem is selecting the appropriate treatment for the individual child. In making this choice the following factors are considered: initial symptoms, age, growth potential, physical findings (especially neurologic signs), and the amount of displacement and slippage (slippage percentage and slippage angle).

The overall management plan for children with spondylolisthesis most often followed is based on recommendations in Wiltse and Wiltse and Jackson:

1. In a slippage of up to 25% in an asymptomatic child, observe with radiographs, initially every 4–6 months if under age 10, semiannually until age 15, then annually until the end of growth. No limitation of activities is recommended, but the child is advised to avoid an occupation with heavy labor.
2. A slippage of 26–50% in an asymptomatic child. Same strategy as in 1 with perhaps a warning regarding participation in contact sports, or sports with lumbar hyperextension (football, gymnastics).
3. A slippage of less than 50% in a symptomatic child. Institute nonoperative therapy (exercises, brace, activity modification), with the same recommendations as in 2. If the pain persists, fusion should be performed.
4. A slippage of more than 50% in a growing child, with or without symptoms, should be treated surgically.

These are the generally accepted guidelines used by most spine surgeons today. It must be remembered that these are guidelines, and there is no prospective study to support these divisions. In fact, the Frederickson et al.26 disagree with this follow-up advice, suggesting annual lateral standing radiographs in the asymptomatic child, because of the very low incidence of progression.

**Nonoperative Treatment.** The results of nonoperative treatment of spondylolisthesis, which involves a combination of bracing and exercises, are well documented. The reported series have usually been small and the follow-up short, but the results are generally good in two thirds or more of the children.

Turner and Bianco99 reported on the results of treatment of isthmic spondylolisthesis with an antilordotic brace worn full time for 6 months, with gradual discontinuation during the next 6 months. Once pain free, the child could participate in all sports while wearing the brace, as long as symptoms did not return. A physical therapy program of hamstring and lumbar dorsal fascia stretching was an integral part of the program. They reported success in two thirds of their patients, with the remaining one third subsequently treated surgically.

Bell et al.3 reviewed 28 symptomatic patients with slippages of less than 50% treated with an antilordotic brace worn for an average of 25 months. With this program they reported that all the patients became pain free with no increase in slippage.

Blanda et al.10 reported on the treatment of athletes with symptomatic spondylolysis and spondylolisthesis with cessation of sports and full-time use of a lumbosacral orthosis for a minimum of 2 months until lumbar extension could be performed. In addition, when the child was pain-free, an active exercise program of hamstring stretching, pelvic tilts, and abdominal strengthening exercises was begun, with nonoperative treatment continued for a minimum of 6 months. This program was successful in 82% of the children with spondylolysis and 40% of the children with spondylolisthesis. They also noted that the longer the symptoms were present before treatment, the more likely they would not resolve without surgical treatment.

Pizzutillo and Hummer67 reviewed the treatment of painful spondylolysis and spondylolisthesis in adolescents, most of whom (77 of 82) had spondylolisthesis. Fifty-three were Grade 1, 12 Grade 2, and 12 Grades 3 and 4. The follow-up ranged from 1 to 14.8 years, averaging 5.5 years. The nonoperative treatment used depended on the severity of the pain. The most effective treatments were limiting activities, a thoracolumbar sacral orthosis, and Williams flexion exercises. The success also depended on the degree of the slippage, with 45 of the 65 patients with Grade 1 or 2 slippages reporting sustained pain relief (69%), whereas only one of the 12 patients with Grade 3 or 4 spondylolisthesis had significant pain relief.

Operative Treatment. Surgical stabilization of the spondylolisthesis should be considered for the symptomatic child whose condition does not respond to nonoperative management and when pain prevents full participation in normal activities. In addition, the growing child with a slippage of more than 50% or the mature adolescent with a slippage of more than 75% should be treated surgically, even if there are no symptoms. Less frequent indications are neurologic symptoms and signs caused by the compression of the L5 nerve root and the postural and gait changes due to the slippage and the associated muscle spasm.

In the discussion of surgical treatment, two important factors are analyzed. The first is the amount of the slippage or translation, expressed according to Myerding’s four grades or as a percentage.106 The second is the main deformity in spondylolisthesis, the lumbosacral kyphosis, which is measured as the slippage angle of L5 on the sacrum.106 It is generally agreed that the more important deformity is the kyphosis, not the amount of anterior translation or slippage.24,102

The decision-making process has become more diffi-
cult and controversial with recent articles in the literature. Many of these studies involved children and adults with higher degrees of slippage, which make up a small percentage of the total number of cases of spondylolisthesis treated. Questions that should be resolved include the number of levels to be fused, the role of decompression, the role of reduction, the need for anterior fusion, the use of instrumentation, and decisions regarding immobilization and bed rest. To examine these issues in children and adolescents, large, long-term follow-up studies are necessary so that the different treatment methods and their results, benefits, and complications can be compared. There are very few such studies, and existing studies have few patients with a short follow-up.

The basic procedure is a bilateral posterolateral fusion (transverse process to sacral alae) using autologous iliac bone graft. In slippages of less than 50%, this involves a single-level L5–S1 fusion, with the fusion extending to L4 with more severe slippages, because the L5 transverse process is anterior and inferior to the sacral alae.37,68 This causes the bone graft placed from L5 to the ala to be horizontal and subjected to shear forces, whereas graft from the ala to the L4 transverse process lies more vertically. The best approach is that pioneered by Wiltse et al34 who used a posterolateral muscle-splitting technique, usually through a midline skin incision. This approach preserves the midline stabilizing ligaments, avoids contusion of the floating L5 lamina, and produces excellent results, as will be noted later.

These posterolateral fusions can be either in situ or with reduction. In situ posterolateral fusion provides excellent results with all degrees of slippage. Wiltse fuses in situ without decompression, no matter how high the degree of slippage. He reports good results with negligible complications, even in slippages of more than 50% with sciatica and neurologic change, in which cases he reports good or excellent results in 30 patients and a 100% fusion rate.104

Other reports confirm these results.37,41,44,48,84 The results are maintained on long-term follow-up. Harris and Weinstein34 compared 11 patients treated nonoperatively with 21 who were treated with in situ posterior fusion; all had more than 50% slippage. The nonoperative group were 10–24 years of age at first examination (mean, 17.8 years) and had an average 18-year follow-up, whereas the operative group was 11–25 years of age at operation (mean, 17.1 years) and had an average 23.6-year follow-up. At follow-up in the nonoperative group, 4 were asymptomatic, 6 had mild symptoms, and 1 had severe pain. Five had neurologic signs of atrophy and weakness, 4 were symptomatic, and 7 of the 11 noted that their conditions did not affect their work. In the operative, group 12 were asymptomatic, 8 had mild symptoms, and 1 had severe pain. Fourteen of the 21 noted that their backs had not affected their work. Radiographically, 5 patients had instability at the level above the fusion, but none had pain. In summary, the authors noted that the operative group were less symptomatic and more active than the nonoperative group. No woman had obstetric problems, and no patients were dissatisfied with their cosmetic appearances.

Johnson and Kirwan44 reported on an average 14-year follow-up in 17 patients who underwent in situ posterolateral fusion for spondylolisthesis of more than 50%. Only 1 patient had occasional backache at follow-up, and all but one rated their results as excellent. All had solid fusions, and only two patients were unhappy with their cosmetic appearances.

Seitsalo et al79 reviewed the follow-up results of fusion in situ in 87 children and adolescents with more than 50% spondylolisthesis an average of 13.8 years after treatment. Fifty-four had had posterior fusion, 30 posterolateral fusion, and 3 anterior fusion. There were 16 reoperations for nonunion or nerve root symptoms. At follow-up, there were 3 nonunions. There was an increased slippage of 10% or more in 19 and increased kyphosis of 10° or more in 45%. At follow-up, the conditions of 89% of the patients were improved, with no correlation between the results and fusion technique, degree of slippage, or slippage angle.

Frennered et al29 reviewed the midterm follow-up of 105 patients less than 25 years of age (mean, 15.5 years at the time of surgery) reviewed a mean of 8.2 years after surgery, with a 98% follow-up. All had had posterolateral in situ fusions, with the 39 patients with a Grade 3 slippage or more having an anterior fusion in addition. The pseudarthrosis rate was 6%. There was minimal change in the slippage angle or slippage percentage on follow-up.

Decompression. Decompression of the canal and nerve roots without concurrent fusion is contraindicated in children, because it increases the instability and is associated with a high incidence of slippage progression. When a fusion is to be performed, many surgeons recommend decompression in the presence of any neurologic deficit, including tight hamstrings and gait disturbance, especially with a severe slippage.6,20,47,65,95,96,98 Others think that decompression is rarely indicated, because neurologic improvement occurs once solid fusion has been obtained.8,9,56,102 Wiltse and Rothman104 do not decompress even with motor or sensory signs or congenital spondylolisthesis, stating that the neurologic loss improves once the fusion is solid, and if it does not, decompression can be performed late.

It is generally agreed that tight hamstrings or gait disturbance are not neurologic signs and do not necessitate nerve root decompression. The only absolute indications for decompression are motor deficit, radicular pain, and bowel or bladder dysfunction. These occur more commonly with congenital spondylolisthesis, when the posterior arch is dragged forward by the anterior translation of the vertebral body. With decompression by posterior approach, the posterior tether is removed with a chance of increased slippage and also nonunion.8,9,68,71,84 In these cases additional immobilization is necessary.
Postoperative Immobilization. Immobilization after fusion varies from no immobilization, \(^9,10,102\) to a brace, to a single or bilateral spica cast, \(^37,95\) with the patient ambulatory or restricted to a period of bed rest after surgery. In addition, surgeons use a cast after surgery to reduce the chance of increased slippage in the postoperative period. \(^15,22,66,68,69,79,90\)

Anterior Fusion. To help ensure solid fusion in severe slippages, anterior \textit{in situ} fusion has been advocated. The procedure can be part of a two-stage approach with the anterior fusion achieved through a trans- or retroperitoneal approach \(^13,27,83,97\) or through a posterior approach. \(^6,16\) Bohlman and Cook \(^6\) reported a procedure involving a posterior approach with a fibula placed from S1 to the displaced body of L5, allowing interbody fusion in high-grade spondylolisthesis. \(^88\) These studies included adults and children without reporting of results according to age, and thus the role of an anterior fusion in the operative treatment of spondylolisthesis in adolescents is unclear.

Reduction. When treating spondylolisthesis, the question of reduction is always brought up. A large number of articles have been written describing different techniques for reduction without in fact demonstrating that the outcome is improved after reduction. The investigators, in studies of adolescents and adults, state a need for reduction of spondylolisthesis of more than 50% slippage, citing the following reasons:

1. Pseudarthrosis: The pseudarthrosis rate in the literature varies from 0% to 25%, \(^8,9,15,36,37,47,71,72,81,84,96\) with the rate in most studies less than 15% and the higher rate occurring with severe spondylolisthesis. \(^9\) Most of the studies in the literature are small, and some include adults as well as adolescents. No correlation has been found between the degree of slippage and the pseudarthrosis rate. \(^9\) Molinari et al \(^55\) compared results in three groups of patients: 11 treated with \textit{in situ} posterior fusion without decompression (Group 1), 7 treated with posterior fusion and instrumentation (5 with reduction; Group 2), and 19 treated with posterior decompression and reduction with posterior instrumentation and anterior and posterior fusion (Group 3). The slippage angles were 13°, 27°, and 40° in the three groups, respectively. Pseudarthroses occurred in 5 in Group 1, 2 in Group 2, and none in Group 3. In the patients who had posterior fusion in Groups 1 and 2, pseudarthrosis correlated with a small transverse process of L5, with no pseudarthroses in cases treated with combined fusion. \(^55\)

2. Postoperative slippage progression: Studies show progression of the slippage after \textit{in situ} posterolateral fusions, despite solid arthrodesis, because of bending and shear forces on the fusion mass. The reported rate of progression is 11–72%, with an average incidence of 33%. \(^4,8,9,15,17,37,38,44,47,60,65,81,102\) The slippage angle increases more than the amount of slippage. \(^8,9,96\) This slippage progression is more common after a Gill laminectomy, in which no postoperative immobilization is provided or in which there is a high initial slippage angle. \(^17,71\) There is no evidence in any of the long-term studies that increased slippage poses a problem. \(^34,44,79\)

3. Loss of motion segments: Fusion to L4 theoretically reduces the number of motion segments, but in long-term studies these patients function well with no reduction in their functional abilities. \(^34,44,79\)

4. Residual deformity: In patients with high degrees of slippage (more than 50%) there is some residual deformity, consisting of a shortened waistline, which does not bother the patients. \(^34,44,79\) There is a definite change in the cosmetic appearance noted during initial examination, but with solid \textit{in situ} fusion, muscle spasms and tight hamstrings improve, with marked improvement in cosmetic appearance. \(^44,49,70\)

5. Neurologic deficit: Cases of cauda equina syndrome after posterolateral \textit{in situ} fusion for spondylolisthesis have been described by Maurice and Morley \(^52\) and Schoenecker et al. \(^78\) Schoenecker et al reported a collected series of 189 cases in which 12 (6%) having both midline and muscle-splitting incisions had Cauda equina syndrome. Cauda equina syndrome was more common, with a slippage angle of more than 45°.

The potential advantages that surgeons state for reduction are thus to reduce the pseudarthrosis rate, stabilize the deformity, minimize the extent of fusion, improve the cosmetic deformity, and prevent acute postoperative cauda equina syndrome. First, there is no evidence in the literature that these problems occur with \textit{in situ} fusions in the child and adolescent, and second, there is no study with results that show that these factors are significantly altered by reduction.

Many different techniques have been described for reduction of spondylolisthesis after Jenkins’s initial description in 1936. \(^43\) The techniques include halo–femoral traction, \(^12,35,93,94\) cast reduction, \(^76\) instrumentation, \(^23,32\) and the combined anterior and posterior approach. \(^13,20,22,31,50,64,87\) An important complication of instrumented reductions is nerve root lesions due to the traction on the L5 root during reduction, many of which are permanent. \(^13,14,20,35,51,53,54,86\) This high rate of neurologic complication occurs after all techniques of instrumented reduction and should be kept in mind when considering reduction, the need for which is unknown in the child and adolescent.

The topic of reduction remains controversial and confusing. Distraction instrumentation across the lumbar spine has shown poor results, because it reduces lumbar lordosis and has a major effect on sagittal balance. Of the two deformities in spondylolisthesis, kyphosis and translation, kyphosis is the more
important problem and should be the focus of treatment. The degree of instability shown on flexion-extension radiographs is important, as is the magnitude of the symptoms.

In larger degrees of slippage translation and kyphosis, cast reduction can be used. The cast is a single- or double-leg spica that is applied 5–7 days after posterolateral fusion. The cast is applied on a Risser frame with the child in traction, a support under the sacrum, and the thigh (and pelvis) in extension. In these greater degrees of slippage, even with slippages more than 75% the relation of L4 to the sacrum is important, because the fusion extends to L4. This improves the sagittal relation, and the slippage angle of L4 to the sacrum. For lesser degrees of slippage, a single-leg spica cast is applied, and the patient is ambulated, whereas with greater degrees of slippage, a double-leg spica is applied, and the patient is kept nonambulatory for 3–4 months.

Burkus et al showed that their results in 24 patients treated with posterolateral fusion and cast reduction were better than the results in 18 without casting, with improvement in both sagittal translation and the lumbosacral kyphosis. These improved results were also shown by other surgeons.

Shufflebarger reported on his results with reduction of severe spondylolisthesis in 18 adolescents. In this prospective series a L5 nerve decompression, temporary distraction for reduction, posterior lumbar interbody structural graft placement with excision of the sacral dome, and a compression pedicle screw construct fusing only the lumbosacral joint were used. The average slippage of 77% (70–90%) improved to 13% (5% to 25%), and the average slippage angle improved from 35° to 4°. Forty percent had neurologic deficits before surgery. All deficits resolved, and there were no root lesions, infections, or instrumentation complications. These results are in contrast to those in the other series of description above.

**Instrumentation**

Instrumentation for reduction of severe spondylolisthesis (slippage more than 50%) has been discussed in this review, including the use of pedicle fixation. Transpedicular fixation is commonly used in the lumbar spine in adults for various conditions, including spondylolisthesis to stabilize the spine and improve the fusion rate. Is there a similar role for instrumentation in spondylolisthesis in adolescents to stabilize the spine during incorporation of the fusion and to supply the necessary immobilization, thus obviating the need for a postoperative cast? Most articles in the literature involving instrumented reduction report the use of pedicle fixation, but there have been no studies to date on the use of pedicle screws in adolescents with spondylolisthesis, with instrumentation used to stabilize the spine and replace the postoperative cast. With positioning of the patient on a four-poster frame on the operating table, some reduction of the spondylolisthesis occurs, with the lumbosacral relation maintained internally with the instrumentation or after a reduction maneuver, the reduction can be maintained with pedicle instrumentation. Worldwide, there is more use of pedicle instrumentation in adolescents for these purposes but no large series has been published.

In summary, the literature on the natural history of spondylolisthesis is very incomplete. No studies on the long-term outcome of a large series are available, and most studies involve a symptomatic study group seen at a spine center and then maintained under observation. Most patients who need treatment have a slippage of less than 50%, but few series are available on the treatment of this group; most of the literature is reports of treatment of slippages of more than 50% in few patients with a short follow-up.

**Posterolateral in situ fusion** for all grades of spondylolisthesis has been shown in large series to be effective in obtaining solid fusion with excellent long-term results, whereas results of some series challenge the high fusion rates reported. The use of casts after surgery in spondylolisthesis of more than 50% is effective in stabilizing the fusion area, especially with the addition of postoperative Risser frame reduction. Additional studies are needed to support the stated benefits of instrumented reduction and to determine the role of anterior fusion and pedicle fixation, which have shown good results in the short-term in some series. These results must be compared with the excellent results of in situ fusions.

**References**

Spondylolisthesis is an infrequent sequelae of spondylolysis. It can be progressive and cause pain. In adolescents, the common subtypes are dysplastic and isthmic. The etiology of spondylolisthesis is unknown, although there is a genetic predisposition, and repetitive trauma is strongly implicated. The literature does not provide good data to allow prediction of which patients with spondylolysis will have progressive slip. Standing spot lateral radiographs taken in a standardized manner are essential for analysis of the natural history. Semin Spine Surg 1989;1:78–94.

In situ posterolateral fusion is the recommended treatment for slips of up to 50%. Moderate-to-severe slips cannot be predictably stabilized by posterolateral in situ fusion, and are at higher risk for pseudoarthrosis and progressive deformity. Combined anterior and posterior fusion with cast immobilization, or deformity reduction and instrumented fusion, may be needed in these cases. Techniques for instrumented reduction are evolving, but treatment symptomatic, mild-to-moderate spondylolisthesis with activity modification, physical therapy, stretching, and exercises, although no scientific data are available regarding the outcome of this treatment. Bracing is thought to be helpful to control pain in patients with severe symptoms.

In certain cases, the symptoms are persistent despite nonoperative treatment, or the slip is found to be progressive, and surgical fusion is indicated. Slips of greater than 50% are thought to be at high risk for progression to spondyloptosis accompanied by neurologic deficit and/or neurogenic intermittent claudication. Spine 1979;4:68–77.

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Consensus Summary

Spondylolysis is an infrequent sequelae of spondylolysis. It can be progressive and cause pain. In adolescents, the common subtypes are dysplastic and isthmic. The etiology of spondylolisthesis is unknown, although there is a genetic predisposition, and repetitive trauma is strongly implicated. The literature does not provide good data to allow prediction of which patients with spondylolysis will have progressive slip. Standing spot lateral radiographs taken in a standardized manner are essential for analysis of the deformity and documentation of progression. Patients with dysplastic posterior elements have a higher risk of slip progression. Most slips are not severe and once growth is complete are unlikely to progress. There is no proven increased rate of disability in patients with mild spondylolisthesis.

The role of the treating physician is to identify the nature of the slip, treat the symptoms, and monitor the patient for progression. The goal of nonoperative treatment is pain relief and return to full function. In the absence of conclusive studies, the current consensus is to treat symptomatic, mild-to-moderate spondylolisthesis with activity modification, physical therapy, stretching, and exercises, although no scientific data are available regarding the outcome of this treatment. Bracing is thought to be helpful to control pain in patients with severe symptoms.

In certain cases, the symptoms are persistent despite nonoperative treatment, or the slip is found to be progressive, and surgical fusion is indicated. Slips of greater than 50% are thought to be at high risk for progression to spondyloptosis accompanied by neurologic deficit and/or neurogenic intermittent claudication. Spine 1979;4:68–77.


currently are associated with higher rates of temporary or permanent nerve root injury. Instrumentation for \textit{in situ} stabilization of severe slips is widely used in an attempt to improve fusion rates, but long term studies are not yet available to document the efficacy of this approach.

Further studies are needed to identify the patient with a high risk for slip progression, so that they can be followed more closely. In patients with severe spondylolisthesis, studies comparing the results of combined anterior and posterior fusion to fusion with instrumented reduction are needed.