Recent Trends in Management of Spondylolysis

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Contents

1] Introduction and classification

2] Embryology and anatomy

3] Pathomechanics of spondylolysis

4] Clinical and radiological diagnosis

5] Different techniques in management of spondylolysis

6] Summary and conclusions

7] References

8] Arabic summary
Index

Chapter One:
Embryology, Anatomy and Biomechanics
Osteology and Arthrology

Chapter Two:
Pathogenesis of Lumbar Spondylolysis

Chapter Three:
Clinical evaluation of lumbar spondylolysis

Chapter Four:
Treatment of Lumbar Spondylolysis

Chapter five:
References

Summary

Summary in Arabic
List of Figures

Chapter one:

(fig.1) typical lumbar vertebra……………………………..5
(fig.2) structure of a lumbar vertebra………………………..7
(fig.3) lumbar isthmus……………………………………………..10
(fig.4) measurements of the fifth lumbar vertebra………………..11

Chapter two:

(fig.5) Stork test………………………………………………………………………………………………….26
(fig.6 A) Oblique radiograph of lumbar spine showing the Scotty dog…………..30
(fig.6 B) Bone scan showing increased uptake --……………………32
(fig.7) CT scan showing pars defect…………………………..
The aim of this study is to review recent trends in management of spondylolysis and reviewing the aetiology, types, surgical techniques and complications.
Introduction

Lumbar spondylolysis is a bony defect in the pars interarticularis of the spine. It occurs in ~6% of the population and has been reported more commonly in men. It occurs frequently in L5 pars interarticularis and can be unilateral or bilateral. Only a few cases of multilevel spondylolysis and its treatment have been reported in the literature. The origin of the pain could be in the tissues rich in nociceptive nerve endings in the looser posterior arch. Extra load exerted on the adjacent levels may cause disc degeneration, which is therefore an accompanying disorder of spondylolysis. Most patients respond well to conservative treatment, although some need surgical intervention (Bonnici, 1991)

The cause of spondylolysis in these patients is repetitive stress of the pars interarticularis with subsequent microfracture, which in turn may lead to a bony defect and cause progressive spondylolisthesis in up to 25% of cases. In some patients progressive back and radicular pain ensue. Surgery is indicated when there is no evidence of fracture healing and symptoms are persistent despite at least 3 months of treatment. Surgical options include decompression in those rare cases where radiculopathy is the chief complaint, lumbar fusion, and direct repair of the pars defect. Decompression has been the main approach for years, but it has a great disadvantage of overload on adjacent levels. Direct repair of pars defects has been used to treat young patients with healthy-appearing disks on MRI and no evidence of instability. The Buck's screw
technique is a widely accepted method of direct pars repair. Other methods of stabilization have been reported including: stabilization of the diseased vertebra by wiring between the spinous process and the transverse process, stabilization by the combined use of pedicle screw and wiring or cable, stabilization by the combined use of pedicle screw and a hook screw, or stabilization with pedicle screw-V rod. These methods have achieved variable success. Buck’s technique resisted forces and moments in any direction. This technique was indicated for patients less than 30 years of age, pars defects less than three or four millimeters, with or without grade 1 spondylolisthesis, with a normal disc and facet joint confirmed by MRI. (Hensinger, 1989)

There was no significant difference in outcome between the spondylolytic/spondylolisthetic patients with non-degenerative disc, who were treated with direct repair of defect only, and those with degenerative disc, who additionally underwent a fusion procedure. Preoperative assessment of the disc degeneration with MRI is of great assistance in making the protocol choice of which option for fusion (Albassir et al, 1990)

Recently, minimally invasive surgery (MIS) has been proposed as an alternative to these classical procedures. First, in order to resolve these problems, They developed an endoscopic direct repair of the pars using a modification of the classical Buck’s procedure. Although the damage of PVM(par vertebral muscles) was reduced, the procedure had the following drawbacks:
(1) it was not applicable in patients with a thin lamina.

(2) screws themselves limited the size of the graft bone mass.

(3) it took a long operation time due to the difficulty of the technique. Then, since 2006, They started to employ applied a pedicle screw-hook-rod (PSHR) method using a percutaneous pedicle screw system to reduce the damage of PVM. (N. Amoretti et al, 2012)
**Embryology, Anatomy and Biomechanics**

A typical vertebra chondrifies via six chondrification centers. Two centers appear in the vertebral centrum; two additional centers form and fuse dorsally to become the neural arch; the remaining two centers appear lateral to the junction of the neural arch and centrum to provide the chondrification center for each transverse process (Fig.1) (Gordon, 1996).

(Fig.1) Formation of a typical lumbar vertebra. The vertebral body is formed by the centrum and a portion of the neural arch (Gordon, 1996).

The pars begins to ossify at 12 to 13 weeks' gestation by endochondral ossification. The ossification center originates in the region of the pars in the lower lumbar vertebrae, resulting in uneven distribution of trabeculation and cortication in this region. The ossification center arises at the end of the pedicle in the upper lumbar segments giving rise to uniform trabeculation through the pars. (Gordon, 1996).

By 17 weeks all of the pars are ossifying with trabecular bone, nineteen and 20 weeks old spines show increased growth in the diameter of the pedicles, pars, and facets through endochondral ossification. There is denser cortication of the pedicle and inferior articulating facet. Upper lumbar segments show a uniform distribution of trabeculation and cortication from the pedicle through the pars up to the inferior facet. The
diameter of the pedicle is smaller in the lower segments than in the upper segments. And so, uneven distribution of isthmic ossification results in formation of a potential stress riser in the region of the pars in the lower lumbar vertebrae, which could be susceptible to fatigue fracture. (Sagi et al, 1998).

Initially it was thought that the origin of an isthmic defect was the failure of fusion of two separate ossification centers in each hemi neural arch but it was confirmed that there is indeed one ossification center in each half of the neural arch. (Sagi et al, 1998).

In addition to this, the ossification of the superior articulating facet lags behind the inferior articulating facet, and is in fact still cartilaginous at 20 weeks of gestation. These demarcations appear in the region of the pars. If this differential in tissue type and density were to persist into childhood, a potential area of weakness or a stress riser could be present.

When the infant becomes ambulatory and begins to place loads through this weak region a fatigue fracture could conceivably occur. (Sagi et al, 1998)
Osteology and Arthrology:

The vertebral column is composed of 33 vertebrae - 7 cervical, 12 thoracic, 5 lumber, 5 sacral (fused to form sacrum), 4 coccygeal (the lower 3 are commonly fused).

Because it is segmented and composed of vertebrae, joints, and pads of fibrocartilage called intervertebral discs, it is a flexible structure. The intervertebral discs form about one-fourth the length of the vertebral column. (Richard, 2000)

Typical vertebra is composed of an anterior cancellous vertebral body and a posterior vertebral arch, which is connected to the body by two pedicles. The transverse processes from the upper four lumbar vertebrae are more posteriorly located than those of the L5 vertebra, sitting well back on the pedicle (Fig.2).

(Fig.2) Structure of a lumbar vertebra. (Bellenir, 1997)
**Pedicles:**

They are short, thick, rounded dorsal projection from the body at the junction of its lateral and dorsal surfaces and nearer the superior, so the concavity formed by its curved superior border is shallower than the inferior one. Adjacent vertebrae contribute to an intervertebral foramen when vertebrae are articulated by the intervertebral discs and zygapophyssial joints.(Roger,2000)

**Lamina:**

Directly continuous with pedicles, are vertically flattened and curve dorsomedially to complete, with the base of spinous process, a vertebral foramen.(Roger,2000)

**The spinous process:**

It projects dorsally and often caudally from the laminal junction. Spines vary much in size, shape and direction. They are levers for muscles, which control posture and active movement (flexion /extension, lateral flexion and rotation) of the vertebral column.(Roger,2000)

**Transverse processes:**

Project laterally from pediculolaminar junctions as levers for muscles and ligaments particularly concerned in rotation and lateral flexion. The thoracic transverse process articulates with ribs. At other levels the mature transverse process is a composite of ‘true’ transverse process and an incorporated costal element.(Roger,2000)
The mamillary process:

Is a small elevation that projects posteriorly from the superior articular process behind the articular facet. (Roger, 2000)

The Facet Joints

The facet joints bear a portion of axial loads. They do so more actively when the spine is in an extended posture. They are apophyseal joints; each has a loose capsule and a synovial lining.

In the lumbar region, the facet joints are oriented sagittally. Their ability to resist flexion or subluxation in this region is minimal, whereas their ability to resist rotation is substantial. (Roger, 2000)

Pars interarticularis

The lumbar isthmus which is also called pars interarticularis is the part of the lamina between the articular facets, it is related to the body, pedicles, transverse processes, and posteriorly to the spinous process, laminae and inferior articular facet. It represents a narrowing between two large parts and it is located at the point of maximum shearing force. (Krenz et al, 1990)

The narrowest region of the pars contains a curved anterolateral surface but posteromedially it tends to be biconcave, divided by a ridge of bone extending from the superior to the inferior articular process. (Krenz et al, 1990)

The pars interarticularis bears smooth facets for articulations between neural arches of vertebrae below and above, thus there are paired superior and paired inferior articular facets (Fig. 3).
The anatomic data and the quantitative structural features about the lumbar isthmus can be demonstrated in the following study where linear and angular parameters are determined. The length of the superior edge of the isthmus is measured between the midline of the spinous process and the medial border of the superior facet. The thickness of the isthmus is measured at the junction of the superior border of the isthmus and the medial border of the superior facet. The inferior length of the isthmus is measured between the inferolateral edge of the superior facet and the superior edge of the inferior facet. (Ebraheim, 1997)

The superoinferior diameter of the isthmus is measured linearly at the narrowest place. The transverse diameter of the pedicle is measured at its midlevel. The superoinferior diameter of the pedicle is measured between its superior and inferior edges. The orientation of the superior and inferior facets is measured between the sagittal plane and the surface of each facet. Caudal and medial inclinations of the axis of the isthmus relative to the axis of the pedicle are also determined (Fig.4A-D)
(Fig. 4) Schematic illustrations of measurements on the fifth lumbar isthmus. (Ebraheim, 1997)

A) Oblique view of the lumbar isthmus.  
\(a\) = superior length of the isthmus;  
\(b\) = superior thickness of the isthmus;  
\(c\) = superoinferior diameter of the isthmus;  
\(d\) = inferior length of the isthmus.  

B) Inferior view of the isthmus:  
inferior thickness of the isthmus \((e)\).

C) Inferior view of the lumbar vertebra:  
medial angle of the isthmus \((f)\).

D) Lateral view of the lumbar vertebra:  
caudal angle of the isthmus \((g)\).
The length of the superior edge of the isthmus gradually increases from L2 to L5, and that of its inferior edge progressively decreases from L2 to L5. The superoinferior diameter of the isthmus decreases from L3 to L5. The superior edge of the isthmus is the thinnest at L4, and its thickness inferiorly increases from L1 to L5. The medial and caudal inclinations of the isthmus with respect to the pedicle gradually increase from L1 to L5. (Krenz et al, 1973)

There are two dense layers of cortical bone in the isthmus, anterolateral and posteromedial layers, the former being the thicker. Both layers are thickest in the narrowest region of the pars. The two layers are joined together by a thick trabecular structure arranged at about 90 degrees to the layers being directed infero-latero-anteriorly. These trabeculae between the two layers appear to be of greater strength than those elsewhere in the neural arch. This suggests that the pars is capable of withstanding considerable stress. However, it is notable that where the cortical bone is thickest it is not only the narrowest part, but also the site of the defect in spondylolysis. (Krenz et al, 1973)

The stresses to which this part is subject are complex. They arise primarily from shearing forces between the articular processes. But the effects of these forces vary with posture, and the angles between articular facets change with movement where the angulation is most marked on lateral flexion, and greater in extension than flexion. When the trunk is horizontal in stooping, gravity tends to displace each vertebra anteriorly on the one below. Thus, the superior articular facets resist a downward vertical force and the inferior facets an upward force. Mainly this induces
a shearing stress between the articular processes. When erect, the lumbar spine is extended but on the sloping surface of the first sacral body so there is still a force causing a shearing strain on the neural arch. These stresses are applied to the inferior margin of the superior facet by the tip of the inferior facet, the two facets now being at an angle. This implies that the pars must withstand a compressive force concentrated at the inferior margin of the superior facet, and a bending force producing mainly tensile stresses in the anterolateral zone. These forces will be magnified on the side to which there is lateral flexion in the extended posture. (Bogduk, 1991)

The superoinferior diameter of the isthmus is relatively smaller in the lower lumbar vertebrae, especially at L5. The length of superior and inferior edges of the isthmus and the superoinferior diameter also correlated with the vertebral levels, suggesting that the L5 isthmus is anatomically weaker than at other levels. (Bogduk, 1991)

The superior and inferior lengths of the isthmus change remarkably in the lower lumbar vertebrae. The difference is greatest at L5. The medial and caudal inclinations of the isthmus are also maximum at L5. These unique anatomic features may result in more shear forces from axial loading acting on the L5 isthmus. (Cyron et al, 1980)

Correlation analysis indicated that the orientation and dimensions of the isthmus are associated with the orientation of the facet joints and the morphologic changes of the pedicle. The facets of the fifth lumbar vertebra in the normal spine are oriented more coronally than at other vertebral levels. (Van et al, 1985)
The oblique orientation of the facet joints results in marked limitation of axial rotation within the lumbar spine and increased torsional strength. A more coronal orientation of the facet joints at L5 may lead to greater axial load transmission to the isthmus at that level, because the usual stresses are not dissipated through the facet joints, as they are at the higher levels. Therefore, the additional stress is taken up by the isthmus at L5, resulting in a higher incidence of spondylolysis at this level. (Farfan et al, 1981)

<table>
<thead>
<tr>
<th>Stresses affecting the pars interarticularis</th>
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</thead>
<tbody>
<tr>
<td>1-shearing forces between the articular processes</td>
</tr>
<tr>
<td>2-angles between articular processes change with movement</td>
</tr>
<tr>
<td>3-gravity when the trunk is horizontal in stooping</td>
</tr>
<tr>
<td>4-sloping surface of the first sacral vertebra</td>
</tr>
<tr>
<td>5-small superoinferior diameter of the isthmus in lower lumbar vertebrae</td>
</tr>
<tr>
<td>6-marked difference in superior and inferior lengths in the lower lumbar vertebrae</td>
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</tbody>
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(Table.1) types of stresses affecting the pars.
**Biomechanical aetiology:**

Several mechanical factors contribute to the development of spondylolysis:

**Upright position:**

It is pointed out that the requisite obliqueness of the pars interarticularis is only possible in conjunction with lordosis, so that the latter is an essential condition for the pathogenesis of spondylolysis.

It is also pointed out that excessive load due to upright position of the subject is the triggering factor for spondylolysis, because it is only from this position that the articular processes of the small vertebrae can exercise an action on the pars interarticularis. In four-footed animal articular processes cannot act on the pars interarticularis to trigger spondylolysis. Hence, it is only in humans that the precondition and triggering factors for spondylolysis exist at all. (*Kohlbach, 1988*)

**Shape of the vertebral column:**

The double S-shaped of the vertebral column usually is explained to be an adaptation to the functional requirement of the axial shock absorption. In the few milliseconds after impact induction, the vertebral column shows a tendency of lumbar straightening. This effect may be one reason for high stresses in the vertebral arches, promoting spondylolysis. (*Recknagel et al, 1996*)

The stresses that the posterior elements are subjected to are highest in the lumbosacral region. This resulted from the combination of lumbar...
lordosis causing stress concentration in the posterior elements, the long
trunk lever arm in the lumbosacral region, and the transition between the
mobile lumbar segment and the immobile sacral segment.\textit{(Diectrich et al, 1999)}

It is the stress concentration at the L5 lamina that largely account for
the predominance of spondylolysis at L5 compared to other levels.\textit{(Hutton et al, 2003)}

Less commonly, L4 may be involved with a spondylolysis defect,
particularly if L5 is a transitional vertebra (sacralized), resulting in stress
concentration in the posterior elements of L4.

In normal erect and gait, the posterior elements bear only about 20% of
the weight transmitted through the spine. However, the force
transmitted through the lumbar spine increases to about 50% when the
spine is in a hyperlordotic (extended) position.\textit{(White et al, 1990)}

Additionally, when the lumbar spine is in a hyperextended position,
the inferior facet of L4 impinges and levers on the posterior elements of
L5 in the region of the pars interarticularis, although this has been
disputed.\textit{(Hutton, 2003)}

This may result in direct force transmission through this vulnerable
region. Thus, activities that are associated with accentuated lumbar
lordosis place the pars interarticularis region of L5 at particularly high risk
for spondylolysis. The correspondingly high incidence of spondylolysis in
gymnasts, weight lifter, and interior line football players has been documented in several studies. *(Jackson et al, 1990)*

In anatomic studies, the pars interarticularis in children is thin and elongated. This region of relative weakness may contribute to the development of stress fracture here. *(Letts et al, 2005)*

Spondylolysis has been rarely documented in those younger than 6 years of age. The incidence increases between the ages of 6 and 14 years, when it approximates the 5% seen in adults. *(Backer et al, 1994)*

It has been hypothesized that the involvement of children in organized athletics activities when they reach this age may account for the increased incidence during these years. *(Wiltse, 1988)*

It is certainly conceivable that repetitive movements, particularly spinal hyperextension, may result in fatigue fracture of the pars interarticularis. *(Wiltse, 1988)*

**Role of pars and ligament:**

With mechanical equations it has been established that, the pars interarticularis and the ligaments resist together the tensile and shear forces and the bending moment if the pars interarticularis is not cracked. If the tensile stress in the pars reaches its strength, crack occurs and the spondylolysis is developed. The cracked pars interarticularis is no longer capable of sustaining tension; the tensile force is transferred to the ligament. *(Klemencsics et al, 2001)*
**Mechanisms of failure:**

There are three mechanisms that may result in failure of the neural arch with or without displacement of the vertebral body:

- Flexion overload.
- Unbalanced shear forces.
- Forced rotation.

It is understood that all types of overload may be applied simultaneously and in various combination. Of all the forces acting on the lumbar spine torsional violence is the most disruptive of the neural arch. It is capable of producing lysis of the pars especially if the dorsal spine has the added restraint of high tensile stresses in the posterior ligamentous system. Under normal conditions, the L5-S1 intervertebral joint is subject to the highest forces and it therefore receives the first damage. However, in the presence of adverse effects, damaging stress occurs in the next higher joint. While the antitorsional large transverse process may protect the L5 joint from torsion, it may not protect the L5 vertebra from excessive flexional strains that may fracture the process. This mechanism remains unconvincing except possibly in instances where there is a pathological condition affecting skeletal tissue. (Farfan, 1992)

The forces applied to the superior and inferior articular facets are concentrated on the pars interarticularis and transmitted to the pedicle. However, almost no stress was generated in the lamina. Highly stressed areas are found in the pars interarticularis and around the lateral process. (Arai et al, 1985)

The analysis of biomechanical movement involved in the sports with greater prevalence of spondylolysis has led to include the element torsion...
against resistance as another possible causative factor for spondylolysis that should be added to the already known causative mechanisms, lumbar hyper extension and rotation. (Soler et al, 2000)

In the other hand Green T.P. (1994) postulates that:

Activities that involve alternating flexion and extension movement cause large stress reversals in the pars and pose the greatest threat of spondylolysis. Compression loading has little effect.

In gymnastics, back walkovers should be avoided, since they place the L5 pars interarticularis at particularly high risk for stress fractures. Lumbar braces and corsets do not have an established role in minimizing the risk of spondylolysis in high risk activities.

The clinical importance of these biomechanical factors is that they provide the basis for identifying individuals at risk for spondylolysis and appropriately minimizing that risk. The avoidance of repetitive, forceful lumbar hyperextension in children may significantly decrease the risk of development of spondylolysis; however, controlled studies are lacking. (Green et al, 1994)
Natural History

The natural history of the defect seems to lie in the continuity, beginning with subtle stress reactions and ending in spondylolisthesis, but the progression along this continuum is very unpredictable. (W.J Beutter, 2003)

>10% displacement was observed in 23% subjects with symptomatic spondylolisthesis. (S.Seitsalo,1991)

Competitive sports did not affect the progression of spondylolytic spondylolisthesis. Muschik et al (1996) observed only 13% of athletes had increased displacement of >10% and suggested that participation in school and competitive sports is possible for children and adolescents with spondylolisthesis when the following conditions are met: a) limited spondylolytic spondylolisthesis, b) lordosis in the displaced segment, c) absence of symptoms, d) regular medical monitoring. (J.vciullo,1985)

Early or late development of pars defects was not associated with early or late segmental laxity. Later slip progression could not be predicted by the age of the subject at time of the initial slip. Unilateral pars defects were not associated with spondylolisthesis or significant disability. (W.JBeutler,2010)

Bilateral pars defects develop symptomatic progression in only a small percentage of subjects in long-term follow-up studies. It has been suggested that while counselling parents of a child or adolescent presenting with bilateral L5 pars lesions it is appropriate to suggest a 5% incidence of progression of slip to adulthood. (S.Seitsalo,1991)
Clinical presentation

Risk groups:

1-Athletes:

Factors predisposing young athletes to back injury include the growth spurt, abrupt increase in training intensity, improper technique, unsuitable sports equipment, and leg length inequality. Athletes who participate in sports involving repeated and forcible hyperextension of the spine may suffer from spondylolysis. (Harvey et al, 1991)

Nyska N. et al. emphasized that spondylolysis is a frequent injury in athletes mainly weight lifters, wrestlers, gymnasts, divers, and ballet dancers. (Nyska et al, 2000)

Diving pole-vaulting, collision/contact sports such as football, soccer, and hockey are common sports with a disproportional frequency of spondylolysis.

This may be due to rotational forces around the long axis of the spine with load bearing hyperextension. (Weir et al, 1989)

Another factor is the large sacro-horizontal angle:

Athletes have larger sacro-horizontal angle than non-athletes, and it is larger in athletes with spondylolysis as compared with those without. It is suggested that an increased sacro-horizontal angle may predispose to spondylolysis especially in combination with the high mechanical loads sustained in certain sports. (Sward et al, 1998)
2-Age:

It was emphasized that the defect is rare in children who are less than 5 years old and is more common in childhood and adolescence. *(Hensinger et al, 1989)*

Spondylolysis occurs in children after learning to walk, but rarely before they are 5 years old. The incidence of spondylolysis increases until the age of twenty years and then remains constant. *(Stinson, 1993)*

3-Increased lumbar lordosis:

**Shown in:**

- **Athletes.**

- **Patient with sheuermann`s disease:**

  An increased incidence of spondylolysis has also been noted in adolescents who have thoraco-lumbar sheuermann`s disease. In this
condition, which is now believed to be caused by excessive and repetitive mechanical loading on the immature spine, thoraco-lumbar kyphosis is often associated with a compensatory increase in lumbar lordosis. (Green et al, 1994)

➢ **History:**
A detailed history obtained from the patient is essential for making a diagnosis, assessing disability, and dictating management. (Jeremy et al, 1996)

- **Age:**
Age can be a good indicator of the nature of likely pathological process. Spondylolysis and spondylolisthesis may manifest themselves at any age but they tend to cause back pain before the age of forty years and neurogenic symptoms in older patient. (Jeremy et al, 1996)

- **Sex:**
Overall prevalence of back pain in the two sexes is similar; however spondylolysis and spondylolisthesis are more common in men. (Jeremy et al, 1996)

- **Occupation:**
Prolonged sitting or standing in one position, particularly, if repetitive lifting involved as well, appear to be a factor in increasing the incidence of back pain in patient with spondylolysis. (Jeremy et al, 1996)
Weight lifting can cause serious musculoskeletal injuries such as spondylolysis. (Risser, 1991)

- **General medical questions:**

  Some systemic conditions may be present; infection including tuberculosis, metastases, lymphoma. Patient should be asked about osteoporosis, osteomalacia, and other metabolic bone disease. All may be factors in the development of back pain due to spondylolysis. (Jeremy et al, 1996)

**Clinical diagnosis:**

**A) Symptoms:**

In the majority of cases spondylolysis is asymptomatic and identified incidentally. Of the symptomatic individuals, the major complaint is the focal low back pain, which frequently radiates into the buttock or proximal lower limb. The onset of pain is acute or gradual, after an intense athletic activity (lumbar spinal rotation or extension). Some patients may also report a recent or old history of local trauma. The pain is intense and restricts everyday activities. Symptoms typically worsen acutely after a particular stressful event. (Standaert, 2002)

**B) Signs:**

Physical examination may be normal in child who has spondylolysis. 80% of symptomatic patients have tight hamstring. (Hensinger, 1989)
Increasing pain with repetitive extension suggests a pain source in the posterior element of the spine.

The length of the spine is palpated for tenderness on the side of the back, muscle spasm, or bony defect (Jeremy et al, 1996)

Based on the pertinent literature, the only possible pathognomonic finding during physical examination, is the reproduction of pain by performing the one legged hyperextension manoeuvre (the patient stands on one leg and leans backwards). Interestingly, unilateral lesions often produce pain when standing on the ipsilateral leg (Figure 5). (Solomon, 2000)

(Figure 5) Stork test (Solomon, 2000)

The one legged hyperextension manoeuvre
Imaging Studies

Multiple imaging modalities are available for use in the diagnosis of a patient with a suspected pars lesion, notably plain radiography, nuclear imaging, computed tomography scan (CT), and magnetic resonance imaging (MRI). There is limited available data comparing these studies directly in the diagnosis of spondylolysis; thus, it is difficult to identify the true relative sensitivity and specificity of these tests. The degree and quality of literature on each of these modalities in the setting of spondylolysis is variable as well, with MRI having the least available data when compared with the other types of imaging studies. Given the frequency with which pars defects are identified radiographically in asymptomatic individuals, the goal of diagnostic imaging is not just to identify a pars lesion but also to find indications that that the lesion is likely to be symptomatic. Generally speaking, multiple imaging modalities are usually required to establish an accurate diagnosis (K. Anderson et al 2000)

1-Plain radiography has been an important diagnostic tool for spondylolysis for some time. The defect in isthmic spondylolysis is visualized as a lucency in the region of the pars interarticularis. The lesion is commonly described as having the appearance of a collar or a broken neck on the “Scotty dog” seen in lateral oblique radiographs. Visualizing a defect in the pars on plain radiographs can be difficult, however, and frequently requires multiple views of the lumbosacral spine. In a study by Amato and coworkers, the single most sensitive view was the lateral spot view of the lumbosacral junction, which revealed the lesion in 84% of
Clinical Evaluation

their cases. When just using anterior/posterior, lateral, and lateral oblique views, roughly 19% of the pars defects identified were seen only on the lateral oblique views. (R.J Bodner 2009)

(Fig. 6 A) An oblique radiograph showing a “collar” (arrow), or “broken neck,” of the “Scotty dog.” The nose of the Scotty dog is the transverse process, the eye is the pedicle, the neck is the pars interarticularis, the ear is the superior articular facet, the front leg is the inferior articular facet, and the body is the lamina (Hu et al, 2008).

2-Nuclear imaging:

Although widely used and studied, plain radiography has been shown to be relatively insensitive compared with newer imaging modalities. In the last 20 years, multiple studies using radionuclide imaging have shown that bone scan and, particularly, single-photon emission computed tomography (SPECT) offer many advantages over isolated plain radiographs in the diagnosis of spondylolysis. Several
studies have shown that SPECT is significantly more sensitive than both plain films and planar bone scan. (S. Elliott et al., 2004)

A study by Anderson and coworkers, for example, found that, when compared with SPECT, plain radiography failed to demonstrate the pars lesion in 53% of their patients and planar bone scan in 19%. In addition to simply being more sensitive in the identification of pars lesions than plain radiography, there is also evidence that bone scan or SPECT may be helpful with the crucial task of identifying symptomatic lesions. (J. Lowe, 2002)

A significant limitation of nuclear imaging is that, although seemingly quite sensitive in the identification of pars lesions, the specificity of this type of imaging is more suspect. Potential abnormalities that may result in an abnormal SPECT that would otherwise be consistent with spondylolysis include facet arthropathy or fracture, infection, and osteoid osteoma. Additional imaging, particularly with a CT scan, is generally required to clarify the bony abnormality in a patient with a positive SPECT study.
Bone scan indicating increased uptake at pars interarticularis at the L3 pars interarticularis (Ulibarri et al, 2006).

**3-CT scan:**

Like radionuclide imaging, CT scan has been shown to be more sensitive than plain radiography in revealing pars lesions. (J.congeni, 2011)

Some authors have used CT as their “gold standard,” although direct comparisons to SPECT are few and there are little to no data on the correlation between the findings on CT scan and symptoms or clinical outcome, as there has been for nuclear imaging. There is also debate as to the optimal means of data acquisition with CT scan, particularly regarding slice thickness and the angle of the gantry. Some recent studies have used CT scan to “stage” pars defects (figure.7) and have noted clear correlations between the radiographic stage of the lesion and the chance of obtaining a bony union with conservative management. (S.Katoh et al 1997)
(Figure.7)  
(A) A CT scan showing an early-stage pars lesion (arrow) associated with sclerosis and an incomplete fracture line but no significant separation, cortication, or cystic change.  
(B) CT scan showing a progressive stage pars lesion (arrow) associated with sclerosis, fracture with minimal separation, and cyst formation. There is no cortication of the fracture margins. (C) CT scan showing a terminal stage pars lesion (arrow) with separation and clearly defined, corticated margins.(S.katoh,1997)
4-Magnetic Resonance Imaging:

The early detection and treatment of spondylolysis are important in preventing progression to established pseudarthrosis. Until now, the diagnosis of spondylolysis has relied on plain radiographs, CT, and bone scan. The first two methods, however, are not reliable in the early stage of the disease and bone scintigraphy, although useful for early diagnosis, has the disadvantage of radiation exposure, so MRI provides a reliable, noninvasive (and less radiation exposure) diagnostic tool for detecting spondylolysis in pediatric patients (Yamane et al, 1993).

Early fracture which is unclear on the traditional radiographs including CT, may be obvious on MRI as the signal changes to high signal (hyperintense) on T2- and low signal (hypointense) on T1-weighted images.

They called the lesion bone bruise (Fig.8) (Mink et al, 1989 and Sairyo et al, 2006). This hypointense area may be due to hemorrhage in the pars interarticularis or edema of adjacent tissues (Stafford et al, 1986 and Lee et al, 1988).
A case of right unilateral spondylolysis at the very early stage. Note the high signal change of the right pedicle on T2-weighted MR image (Sairyo et al, 2006).

As shown in the previous figure, the medial side of fracture line of spondylolysis reaches the dorsal base of the pedicle. It is reported that high signal intensity on T2-weighted image surrounds the stress fracture line.

Since the pedicle is anatomically adjoining the pars interarticularis, the high signal changes of the pedicle may be influenced by the stress fracture line of the pars, not from the changes in the pedicle itself (Craig et al, 2003 and Sairyo et al, 2006). If pseudoarthrosis occurs, MRI shows isointensity at the site of the pars interarticularis . (Yamane et al, 1993)

The pars interarticularis is anatomically difficult to identify on the standard coronal, sagittal, and axial MRI images. On the other hand, the pedicle is clearly seen on the simple slicing methods, and most physicians are more familiar with radiologic anatomy of the pedicle than the pars interarticularis. So,
signal changes at the pedicle are useful to diagnose spondylolysis (Sairyo et al, 2006).

<table>
<thead>
<tr>
<th>Imaging method</th>
<th>Advantages</th>
<th>Disadvantages</th>
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<tbody>
<tr>
<td>1-plain x ray</td>
<td>-important initial diagnostic tool.</td>
<td>-not reliable method in early stage.</td>
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<td></td>
<td>-broken neck on scotty dog.</td>
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<td>2-Nuclear imaging</td>
<td>-more sensitive than plain x ray.</td>
<td>-radiation exposure.</td>
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<td></td>
<td>-reliable in early stage.</td>
<td>-not specific positive in:</td>
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<tr>
<td></td>
<td></td>
<td>1-fracture</td>
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<td></td>
<td></td>
<td>2-infection</td>
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<td></td>
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<td>3-osteoid osteoma</td>
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<td></td>
<td>4-facet arthropathy.</td>
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<td>3-CT</td>
<td>-more sensitive than plain x ray.</td>
<td>-No correlation(findings on CT &amp; clinical outcome.</td>
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<tr>
<td></td>
<td>-help in staging of pars defect.</td>
<td>-radiation exposure.</td>
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<td></td>
<td>-reliable in early stage.</td>
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Clinical Evaluation

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<th>Description</th>
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<td>4-MRI</td>
<td>-reliable in early stage.</td>
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<tr>
<td></td>
<td>-non invasive.</td>
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<td></td>
<td>-less radiation exposure.</td>
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<tr>
<td></td>
<td>-showing haemorrhage &amp; edema in adjacent soft tissue.</td>
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<td></td>
<td>-expensive.</td>
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(Table 2) showing different imaging methods in diagnosis of pars defect.
Algorithm for athletes with low back pain and suspected spondylolysis or spondylolisthesis. (S. Elliott et al, 2004)

Algorithm for athletes with low back pain and suspected spondylolysis or spondylolisthesis; standing AP and lateral radiographs obtained after 3 weeks. If a pars defect is seen, conservative treatment begins. If no pars defect is seen on x-rays, a SPECT scan can be obtained. If the result is positive, conservative treatment begins. If SPECT scan result is negative, MRI or CT scan can be obtained. If CT scan shows a
pars defect, surgery can be considered if nonoperative treatment fails. MRI can be helpful in detecting other sources of pain. (S. Elliott et al., 2004)
**Nonoperative Treatment**

Most young athletes with symptomatic spondylolysis can be successfully managed nonoperatively, even if defects do not heal. (D.F. Bell, 1998)

Miller et al. followed up athletes with established pseudarthrosis (radiographically nonhealed with positive bone scan result) and found a 91% good to excellent outcome with nonoperative treatment with all patients returning to athletics. In these cases, many patients develop a fibrous union that is sufficient for a good outcome.

Most strategies for treatment include a period of restricting competition, with rehabilitation and possible bracing. Although the recommended duration of activity modification is controversial and ranges from 4-12 weeks, there is agreement that a period of rest is necessary and athletes should be pain free before returning to competition. (P. Ad’hemecourt, 2002)

There are several different methods and types of bracing available, with no clear best choice. Compliance with restriction of activity and a period of rest are more important than the type of brace used. A retrospective study of adolescent soccer players with spondylolysis found that compliance with the treatment plan (cessation of activity for 3 months) significantly influenced clinical outcome and return to play. Return to sport with a nonrigid brace is recommended at 8-12 weeks if the patient is pain free at rest, in hyperextension without the brace, and during sporting activities with the brace. (J.N Daniel et al, 2010)
Rehabilitation should be focused on therapeutic strengthening and flexibility training, including treating any hip or hamstring contractures. An individualized treatment plan is necessary as the timing of rehabilitation is controversial. Early interventions develop muscle strength and flexibility, combined with low-impact conditioning and core stabilization with activities such as deep water running or cycling. Rehabilitation can then progress gradually to sport-specific training exercises.(K.A Pettine, 2006)

Bone stimulators have been used successfully to improve fracture healing, and case reports have demonstrated some benefit to healing chronic pars defects in athletes. Fellander-Tsai and Micheli reported 2 athletes with unilateral defects who had bone stimulators placed at 14 months, and by 18 months, the defects were healed. Another case of a 15-year-old competitive gymnast with low back pain and bilateral pars defects at L5 had a bone stimulator and brace placed at 18 months. The patient had previously completed a 4-week course of physical therapy; however, it is unknown if he had a period of rest during this treatment. After 6 weeks of bone stimulator treatment, the patient showed clinical improvement, and a CT scan at 12 weeks showed healing of the defects. They recently treated a 17-year-old high school football player who was experiencing axial low back pain, which was exacerbated with extension following squat weight lifting. He was braced for 3 months without pain relief and underwent physical therapy. He was then placed in an external bone stimulator for 3 months. His pain improved and was able to return to play (Figure.9, Figure.10 and Figure.11). Although these case reports demonstrate a
potential benefit of bone stimulators, further investigations need to be done to prove their efficacy in larger studies.

(Figure.9)

Lateral flexion radiograph of the lumbar spine in a patient with L4 spondylosis before treatment with a bone stimulator. (P.B.O’sullivan, 2006)
Lateral extension radiograph after 1 month of treatment with a bone stimulator. (P.B.O’sullivan, 2006)
Lateral flexion radiograph after 3 months of treatment with a bone stimulator, demonstrating a healed defect. (P.B.O’sullivan, 2006)
**Outcome of conservative Management:**

More than 80% of children treated non-operatively have resolution of symptoms. There is no consensus in the literature on the healing rate of spondylolysis, but it has been estimated that 75% to 100% of acute lesions heal, all unilateral acute lesions heal, 50% of bilateral acute lesions heal, but no chronic defects heal. Cephalad lumbar defects heal more often than L5 lesions do. Even with these numbers, more than 90% of children return to their previous levels of activity. This suggests that the stability of a fibrous union can be acceptable. (Hu et al, 2008)
Operative treatment:

Historically, surgical management of spondylolysis has included posterior and posterolateral fusion, and pars interarticularis repair. Intersegmental fusion results in loss of a motion segment and may be complicated by adjacent segment degenerative disease, requiring additional surgery. Pars interarticularis repair offers the advantage of sparing motion segments. Pars repair is most likely appropriate for adolescents without the same segment degenerative changes, while fusion may be more appropriate in older patients with degenerative changes. (Ghiselli, 2004)

Indications for Direct Surgical Repair of Spondylolysis

Lower back pain that proves refractory to at least 6 months of activity modification and other nonoperative treatment modalities is the main indication for surgical direct repair of a spondylolysis. Symptomatic spondylolysis is most common in young athletes between the ages of 12 and 16 years. Most of these youngsters will become asymptomatic if they give up the sport that is exacerbating their symptoms. Therefore, before recommendation of surgical intervention, a discussion with the patient and family should be done about the benefits and risks of finding alternative activities versus surgery. Obviously, most of these young athletes will not become professional athletes or be candidates for scholarships. They routinely encourage young athletes to alter their activities rather than pursue surgery unless the athlete has professional or scholarship potential. On the other hand, some young athletes will continue to experience lower
back pain despite doing only activities of daily living and can be considered candidates for surgery. (Ghiselli, 2004)

**Contraindication of surgical pars repair includes:**

1. Magnetic resonance imaging show disk degeneration at the level of the lysis.
2. Significant spondylolisthesis (grade 2 or more).
3. Dysplastic lamina or spina bifida occulta making certain fixation techniques unlikely to provide stability.

The results of direct defect repair depend, to a considerable degree, upon the degree of degeneration of the intervertebral disc involved, however there might be other sources of pain in spondylolysis than the spondylolysis defect, and disc degeneration and subsequent segmental instability might be a cause of symptoms persistent after defect healing. (Hu et al, 2008)

In adults with a potentially repairable pars interarticularis defect, it is important to establish that the defect is the source of pain. Pain relief after a lidocaine injection at the pars interarticularis supports the concept that the defect is the cause of pain. When the L5-S1 intervertebral disc appears normal on a magnetic resonance imaging scan and there is minimal dynamic instability, a pars interarticularis repair can be considered. (Hu et al, 2008)
Results with direct repair are usually satisfactory even in older patients, but younger patients have a better clinical outcome than older patients. However, adult patients require a segmental fusion rather than direct repair, which was deemed to be a suitable method only in young patients. (Daily, 2001)

Repair of the pars interarticularis is recommended for adolescents and young adults with L4 or more cephalad spondylolysis as the transverse process, which may serve as an anchor site or a site for fusion, is sufficiently large compared with a relatively small L5 transverse process. (Hu et al, 2008)

**Preoperative Workup**

An imaging study should clearly delineate the lytic defect, and a positive single-photon emission computed tomography bone scan is recommended. This is to ensure that there is metabolic activity in the lysis likely to cause pain as well as increase the likelihood of obtaining a solid osseous union of the lysis with surgery. They prefer computed tomography scans to clearly outline the bony anatomy of the lytic defect. The orientation of the lysis mandates the type of internal fixation best suited to achieve union. A spondylolisthesis of a few millimeters seems to allow for acceptable results, but more significant slips should not be repaired with the following techniques. Other causes of lower back pain should be ruled out. Some authors have recommended preoperative diskography to rule out a “painful disk”; however, this has not been they said because most candidates for direct repair are younger than 20 years of age. (Brigham, 2005)
Surgical modalities:

Direct repair of a pars interarticularis defect can be done in several ways with or without instrumentation including:

a. Direct repair using Buck's screw and grafting  
b. Direct repair using hook screw and grafting  
c. Grafting without instrumentation  
d. Scott wiring technique  
e. V-shaped rod and screw technique  
f. Novel technique  
g. Cable-screw technique  
h. minimally invasive technique(Brigham,2005)

Surgical Technique

A standard midline approach to the lumbar spine is performed. Care is taken to preserve the multifidi attachment to the lateral capsules of the L4-5 and L5-S1 facet joints (unless pedicle screws are being used) and keep the supraspinous and interspinous ligaments intact. The pars defect is exposed, and fibrous tissue is removed. If the lytic defect is in the coronal plane, direct exposure of the defect is not needed. Internal fixation is then applied. A small amount of cancellous bone can be harvested from the iliac crest through a 3-cm window made over the posterior inferior iliac spine. Harvest of cancellous bone from the ala of the sacrum has also been described. This bone graft is placed at the defect as an onlay graft. Care should be taken not to place bone graft ventral to the defect because the exiting nerve root may be compromised. Regardless of the method of internal fixation, resection of the caudal 3 to 5 mm of the inferior facet
joints of the cephalad vertebra is recommended. This will theoretically reduce the chance of impingement of the inferior facets into the pars region when the athlete is standing or loading the spine, particularly in hyperextension. (Brigham, 2005)

(I) Direct repair of pars interarticularis without instrumentation:

Kimura 1968, used bone graft without internal fixation, confining the patients to bed for 2 months and then asking them to wear a plaster cast until union of the lysis. This technique aims at restoring the normal anatomy and motion of the involved vertebra by carrying out direct repair between the loose arch and the anterior part of the vertebra; it involves less surgical dissection and runs less of neurological risk (Wiltse, 1988).

The procedure may be performed through a midline approach or through a paraspinous muscle splitting approach. The former approach has the advantages of familiarity to surgeons and a greater surface area for fusion, whereas the latter approach is associated with less blood loss and preserves the soft tissue stabilizers. This technique has the disadvantages of prolonged bed rest (Wiltse, 1988).

Postoperative protocols vary widely, from no immobilization to the use of a lumbosacral orthotic with unilateral hip immobilization. There is no any data supporting the efficacy of one bracing protocol over another, but it is recommended to use at least a lightweight rigid brace for most patients, with a greater degree of immobilization for younger patients who have a greater slip and a lesser degree of immobilization for older adolescents or young adults with a lesser degree of slip. (Hu et al, 2008)
1. Single Lag Screw Fixation (Buck)

For most simple pars repairs, this method is reliable and relatively straightforward. A classic pars defect in L5 will usually accept a 3.5-mm cortical screw or a 4.0-mm malleolar screw. They do not use a gliding hole technique in the caudal lamina, although it has been described. They recommend manually holding the lamina in compression while a fully threaded screw is placed across the pars defect. Alternatively, over-drilling of the lamina may be done to allow compression across the lysis when the screw is tightened. Using a burr on the inferior edge of the L5 lamina allows for a “countersink” area for the screw head and facilitates starting of the drill hole. The ability to use a standard drill depends on the angle of inclination needed for the trajectory of the screw. At L5, the lamina is typically lordotic enough to easily accept a standard drill bit and gun. If a more cephalad level of the lumbar spine is addressed, consideration of a flexible drill bit driver should be done to decrease the likelihood of needing to extend the caudal aspect of the incision to allow the drill to achieve the correct trajectory in the sagittal plane.(Brigham,2005) (Figure 12).
Pars repair with screw fixation as described by Buck.

(Brigham, 2005)

Postoperatively the patient is placed flat on his back for 5 days. Then a plaster corset which include one thigh is applied and full mobilization is allowed. The cast is removed after 4 months. Sports and strenuous work are not recommended until after 6 months and a follow up examination is performed (Figure 13) (Deguchi et al, 1999)
Treatment

(Fig.13) Anteroposterior and lateral views of lumbar spine 2 weeks after direct pars repair with Buck screws. (Reitman, 2002)

The rates of healing of the isthmic defect have been reported to be 82-100% with Buck’s technique and complication rates related to this surgical technique or hardware failure have been reported to be 5.6-40%. (Deguchi et al, 1999)

**Biomechanics of Buck technique:**

When spondylolysis (bony gap) is present at the lumbar spine, load cannot appropriately be transmitted through the posterior bony elements.

Thus, the load mainly transmits through the anterior element such as nucleus pulposus (NP) and annulus fibrosis (AF), and induces higher stresses there.

Thus, disc stress at L4/5 and L5/S1 would increase which facilitate disc degeneration at L4/5 and L5/S1 levels. (Sairyo et al, 2006)

However, the increase in stresses is higher at the affected caudal level, when compared to the cranial level. Buck’s technique may restore the disc stresses back to normal at both disc levels. Thus, this technique
Treatment

may be beneficial from a biomechanical perspective as well. (Sairyo et al, 2006)

In case of L5 spondylolysis, annulus fibrosis (AF) and nucleus pulposus (NP) stresses at L4/5 increased to 111% and 120%, respectively.

After the Buck’s technique they recovered to 102% and 105%, correspondingly. On the other hand, at L5/S1, (AF) stress increased to 168%, and (NP) to 155%, which was much higher when compared to the stresses at L4/5. After the Buck’s technique the stresses were normalized to 125% and 120%, correspondingly. In terms of lumbar motion, in extension motion, Buck’s technique reduced mean stresses of (AF) and (NP) at L4/5 and L5/S1 from 132% to 118%. Similarly in flexion, it decreased from 139% to 116%. During lateral bending motion, it decreased to 121%. On the other hand, during rotation motion, it normalized the disc stress completely (Fig.14). (Sairyo et al, 2006)
Treatment

(Fig.14) Spondylolysis and Buck’s operation at L5 FE (Finite Element) model. The location of the gap defect is depicted as ‘‘L’’ shaped red line at the left picture. Buck’s direct repair surgery is simulated and depicted at the right picture as dotted line. (Sairyo et al, 2006)

After screwing of pars defects by Buck’s technique, the disc stresses could not be normalized completely as during lateral bending, especially, the stress still showed 121% of the intact spine. The results indicated that screwing alone could not provide complete stability at the pars defects. Even after Buck’s technique, the defect edge may show micromotion. Thus, to completely recover the intact lumbar kinematics, bony fusion of the entire area of the defects may be required. (Sairyo et al, 2006)

**Advantages:**

It resists forces and moments in any direction, it is low profile, and not expensive. The use of Buck's screws across the pars defect is advantageous in that its fixation force direction is consistent with the anatomic direction of the lamina. (Deguchi et al, 1999)

**Disadvantages:**

Buck's technique is technically demanding, and some complications have been reported, such as screw breakage or root irritation requiring screw removal. Unfortunately, this technique decreases the area available for bone grafting, which remains an essential part of the operation. (Gillet, 2006)

Improper placement of the screws appears to be the major cause of the early failures; but reoperation and replacing the screws in the proper
position will lead eventually to complete healing. Buck 1970, stressed the technical difficulties of accurate screw placement. In his original report, he stated also that the method probably is applicable only when the gap in the neural arch is less than 3 or 4 mm wide. (Gillet, 2006)

2. **Repair of the defect with a hook screw:**

**Concept and patient selection:**

In 1984, Morscher introduced a modified method developing a hook screw for the direct repair of a defect in the pars interarticularis, which connects the arch with the anterior articular process. It allows compression of the defect without crossing the defect with the screw.

The composite implant includes a hook, a screw with a spongiosa thread at the tip and short thread at the end and two nuts to achieve firm locking. (Ivanic, 2003)

(Fig.15) The hook screw according to Morscher. (Ivanic, 2003)
(Fig.16) Another implant including the special hook (two sizes), a screw with cancellous thread and a triangular profile at one end, a spring and two nuts.(Hefti et al,1990)

**Postoperative results of patients were presented as follows:**

- Radiographic evaluation showed no evidence of nonunion.
- Screw breakage was not encountered.
- Seven patients were completely relieved of their pain.
- Three patients had continuation of mild symptoms.
- Two patients had no relief of pain.
- The authors attributed the failure in the later two patients to degeneration of the involved disc. Therefore disc degeneration is a contraindication to this procedure.(Morscher et al,1984)

Advantages of hook screw over compression with screw alone are provision of a solid grasp which is maintained, use in cases of dysplastic vertebral arch, with dysplasia it is difficult or impossible to appropriately place the screw across the neural arch and the lack of fixation by screw alone and inadequate bone for fusion lead to breakage of the screw in a high percentage of cases.(M.Deguchi,1999)

**Technique:**
The patient is placed in the prone position. A midline approach is used. The spinous process, lamina, and base of the transverse process of the lytic vertebra are exposed subperiosteally.

The lysis is prepared by removing fibrous tissue in and around the gap. The bony elements on both sides of the lysis are decorticated to assure bony healing of the lysis after pars repair. Internal fixation is now performed. A modified Harrington hook is placed bilaterally under the lamina and fixed to the pedicle of the lytic vertebra with a screw. This screw has been specially designed and has a thread of 20 mm. The entry point of the screw is located at the base of the superior articular facet of the lytic, vertebra, just cranially to the lysis, midway between the medial aspect of the pedicle and the lateral border of the articular process.

The screw crosses the pedicle in a caudo-cranial direction and exits the pedicle cranially, just posteriorly to the junction with the vertebral body. After the hook has been inserted over the screw and placed around the lamina, a spring and a nut are inserted bilaterally and provide continuous compression on the lysis for weeks after the primary compression load has decreased. Cancellous bone graft is placed into and laterally to the lysis, between the base of the transverse process and the lamina. To prevent impingement with the isthmus, the caudal tip of the articular process of the adjacent superior vertebra is chiseled off. The wound is closed in layers with suction drainage. The patient is allowed to get up the second day after surgery with a corset for 3 months.(Jeanneret,1993)
(Fig.17A) Oblique view showing the position of the hook-screw construct (Sales et al., 2000)

After 2 years, Morscher construct and healing of pars defect. (Sales et al., 2000) (Fig.18B)

In comparative analysis of the outcome after two surgical techniques for pars interarticularis repair:
• Buck screw fixation

• And modified Morscher designed spondylolysis distraction hook.

This is to determine whether any technique was associated with higher radiographic, clinical, or implant failure. Twenty patients were included in this study. All patients had spondylolytic defect with either a grade 0 or grade 1 spondyloliesthesis. Nine patients were treated with the Morscher hook implants, and 11 patients were treated with the Buck technique. Radiographic follow up of the Morscher implants demonstrated loosening in three and breakage in one. Radiographic analysis of the Buck technique demonstrated implant failure in one. Failure occurred in four instances with the Morscher implant compared with two instances with Buck technique. So, the Morscher implant had a high failure rate. Furthermore, the clinical outcome in this group of patients was poor using either technique. (Dreyzin, 1999)

Advantages:

The advantages of this treatment include preservation of the motion segment. Function of the segment is retained or, rather, restored into physiologic form and compared with other techniques, it does not need extensive dissection. Patients younger than 20 years of age had better relief of symptoms with 88% satisfactory compared to 71% in patients over 20 years of age. (Ivanic, 2003)

Disadvantages:

The main problem with the Morscher technique was screw placement. An analysis of screw placement showed that there was a 15% technical error with penetration of the inferior articular process of the
vertebra above and transpedicular placement. Other errors included using short screws that were only unicortical and did not penetrate both cortices of the superior articular process. The technique is technically difficult and the hardware is bulky. *(Songer, 1998)*

Another problem with the Morscher technique is the high incidence of screw loosening. Since the hardware is bulky, screw loosening led to swelling and pain in more than half of the patients and required removal of the implant. *(Sales et al, 2000)*

**Modification of Morscher hook screw system:**

Segmental pedicle screw hook fixation (evolution of the Morscher’s concept) is nowadays performed to overcome its drawbacks. This implant type is a titanium pedicle screw hook system, which is made up of a standard or polyaxial pedicle screw (5.5 or 6.2 mm) and a rod laminar hook complex (30 degrees angle inclination for a more anatomic reconstruction and an easy introduction). This complex is connected to the screw through a hemispherical clamp, which allows self positioning, thus avoiding complicated bending and positioning of the rod. The clamps move laterally on the spherical part of the screw, and the hook and the screw are positioned according to the anatomy of the graft defect and the pedicle, respectively. *(Debusscher, 2007)*
(Fig. 19) Pedicle screw hook system. (Debusscher, 2007)

This hook is available in two sizes; small and larger sizes, for an adequate fit. The operative technique is the usual placement of pedicle screws in each pedicle of the spondylolytic vertebra by a midline incision. All pseudarthrosis tissue is removed and the defect is filled with cancellous allograft. The hook-rod complex is inserted and impacted, the clamp is positioned on the rod and it is introduced into the screw head.

The construct is then loaded by means of a secured hook compressor (to avoid subluxation of the posterior facet joint). Adequate positioning of the implants is checked by intraoperative radiography (Fig. 20). Two days after surgery, patients are allowed to stand up, no brace is worn after surgery because the construct is stable enough to keep the graft and the lamina in compression until the fusion is acquired. (Debusscher, 2007)
Treatment

(Fig.20) Postoperative anteroposterior (Left), and lateral radiographs (Right). (Debusscher,2007)

Patients stay for 4-5 days in the hospital, they are encouraged to walk, daily activities are authorized with caution and without excessive load. Physiotherapy, exercise, sport and most of professional activities can be restarted 3 months later. Heavy activities (with heavy loads) are to be totally avoided for 6 months postoperatively. (Debusscher,2007)

This new device seems to offer several advantages; strength of the hardware (rod and screws) avoids the need for postoperative immobilization and decreases the probability of device failure; pedicle screws are placed in a classic manner and any surgeon experienced with pedicle screw systems should be able to learn the technique rapidly.

This system is also very easy to use and allows anatomic pars interarticularis reconstruction of spondylolysis. The blade of the hook can grasp the lamina in a very closefitting way and put the graft in compression. Using a hemispherical clamp for binding the rod hook and the screw allows an easy connection regardless of position of the hook. (Debusscher,2007)
3-Scott wiring technique

In (1970) James Scott described a wiring technique for repairing a defect of the pars interarticularis in patients with spondylolysis. He reported a satisfactory outcome with the procedure in six of seven patients. Since then, Bardford and Iza (1985) and Hambly et al; have published favorable reports using Scott's technique.

Repair of the pars defect alone offers a number of advantages over intersegmental fusion. A motion segment is not lost, only the defect is addressed and normal anatomy is restored and failure of the wire presents no threat to neural elements.(Hambley,1998)

Procedure:

The patient lies prone on a spine frame. Through a posterior longitudinal midline incision, extending between adjacent spinous processes, the paravertebral muscles are stripped to expose the spinous process, lamina and both transverse processes, leaving the facet joints and their capsules undisturbed. The soft tissues attached to the anterior aspect of the transverse processes are carefully elevated, avoiding the nerve roots which lie ventrally. The presence of bilateral pars interarticularis defects is confirmed by demonstrating abnormal movement at these sites when adjacent spinous processes are rotated in the transverse plane.

The defects are then cleared of fibrous and cartilaginous tissue. The underlying nerve can be decompressed at this stage through a limited laminectomy, if indicated. The sclerotic bony margins of the defects are curetted to expose healthy bone and the base of the transverse process.
A 2mm-diameter hole is drilled in the base of each transverse process through which a 15 cm length of 20 gauge braided wire is passed and curled superiorly over the transverse process. A 4 mm diameter hole is then drilled in the base of the spinous process through which both wires are passed so that each makes a figure of eight with the cross over at the defect. Through a subcutaneous extension of the wound, one posterior iliac crest is partially exposed and four corticocancellous bone strips 1cm x 2.5cm are taken from the outer table of the iliac wing. Six oblong grafts of cancellous bone are removed with a gauge and are gently packed into the defects, taking care not to compress the underlying nerve roots. Two bone strips are then placed beneath the wires across each defect so that they lay over the decorticated areas of the transverse process, the superior facet and the lamina. The wires are tightened to hold the underlying bone grafts in place and to stabilize the defect. Absence of movement at the defects on rotation of the spinous processes should now be demonstrated. (Johnson, 1992)

After a satisfactory radiograph at two days, the patient is immobilized with a light removable brace, which is worn for three months. Activities are restricted until the defect is shown to have united radiographically and on a CT scan, usually about six months after the operation. Thereafter patients can return to normal activities. (Johnson, 1992)
The anatomy of the lumbosacral region to show the relationship between the transverse process and the nerve root (A). The defects have been curetted and holes drilled in the transverse and spinous processes. The braided wire is in position (B). On the left the defect has been packed with cancellous graft (black). On the right, corticocancellous onlay grafts extend from the transverse process to the lamina. The wire has been tightened to secure the grafts (C). (Johnson, 1992)

MacNab criteria (Table 4.1) were used to assess pre- and postoperative status. Out of patients continued to have severely restricted activities of daily living after surgery, and their results were classified as poor. Both of these patients had bilateral spondylolytic defects at L5 before surgery. Later, they were shown to have abnormal discs on discography at L4-L5 and underwent two-level instrumented posterolateral fusion. (Askar et al, 2003)
## Treatment

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<th>Grade</th>
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<td>Excellent</td>
<td>No pain; no restriction of activity</td>
</tr>
<tr>
<td>Good</td>
<td>Occasional back or leg pain of sufficient severity to limit the person's ability to do normal work or enjoy leisure hours</td>
</tr>
<tr>
<td>Fair</td>
<td>Functional capacity but intermittent pain of sufficient severity to curtail or modify work or leisure activities</td>
</tr>
<tr>
<td>Poor</td>
<td>No improvement or insufficient improvement to enable increase in activities; further operative intervention required</td>
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(Table.3) Macnab Classification.(Askar et al, 2003)

(Fig.22) CT showing Scott’s procedure.(Pai et al, 2008)

Postoperative check radiographs showed that the spondylolytic defects had healed in all 14 patients. One patient had leg pain after surgery, which resolved in 3 weeks. There were no other postoperative complications. None of the wires needed to be removed. (Johnson, 1992)
Advantages:

Scott wiring is simple. It functions as a tension band, leaving the bony surface of each side of the defect free to participate in the bony healing. (Askar et al, 2003)

Disadvantages:

The Scott technique requires greater surgical exposure, with extensive stripping of the muscle to expose the transverse process completely. Placement of the wires under the transverse processes is difficult and can lead to substantial bleeding and there is a risk of nerve root injuries. Furthermore, several cases of wire breakage have been reported. The wires are not strong enough and thus patients are obliged to wear a postoperative brace for 3 months. (Nicol, 1999)

Olsson et al 1976, demonstrated that there is a slight decrease in the mobility of the motion segment after Scott wiring, presumably because of scar tissue. (Olsson et al, 1976)

4-Direct repair using v-shaped rod construct and grafting

The pedicle screw-V rod system was first reported by Gillet et al. in 1999. The authors used single axis pedicle screw and a V rod that has a sagittal upper curve to fit the vertebral plate. The single segment pedicle screw-V rod is safer than the pedicle screw-vertebral plate hook system, but bending and placement of V rod is technically difficult. To ease the technical difficulty involved in the use of the pedicle screw-V rod system, they designed a multiple axis pedicle screw with an adjustable end that facilitated the assembly of V rod. (Gillet et al, 1999)
**Surgical Procedure**

The supraspinal ligaments were preserved during surgical exposure and a universal pedicle screw was inserted into the pedicle on each side at L5. Approximately 1/5 (2 to 3 mm) of the articular process under L4 was excised with an osteotome, with care taken to remove as little capsular structure as possible, for exposure of lesions in the isthmus of L5. Scar tissues were excised down to bleeding bone (Gillet et al, 1999). Bone graft was harvested from the right iliac crest and was trimmed into 2 wedged bone blocks to be placed in the defect in the isthmus, and the adjacent area was filled with morselized cancellous bone. A titanium rod was bent in a “V” shape and put under the L5 spinous process after removal of the L5–S1 interspinous ligament. The rod was firmly pushed anterosuperiorly to lock onto the pedicle screw so that the V-shaped rod, the spinous process and vertebral plate jointly promoted the compression of the bone graft in the defect and stabilized the posterior arch (Figure.23). In patients with nerve root canal stenosis, a small portion of the distal aspect of the lamina, where stenosis occurred, was excised and the yellow ligament was also excised and the nerve root canal was dilated to achieve decompression. The proper positioning of the implants was checked by intraoperative radiography. (Gillet et al, 1999)

(Figure.23) Vertebral stabilization by the pedicle screw-V rod system.
Force F (arrow indicates direction of F) compresses the isthmic bone graft through the V rod, the spinous process and the vertebral plate. Meanwhile, the pedicle screw-V rod system prevents anterior displacement of the diseased segment and does not affect flexion and axial rotation of the spine.(Gillet et al,1999)

Radiological Evaluation

Preoperative radiological evaluation included anteroposterior, lateral, oblique, and flexion-extension plain radiograph and CT scans. The scan data were evaluated independently by two radiologists with respect to clinical and personal data. The entire lumbar spine was reviewed using bone windows and both axial views and multiplanar reconstruction were analyzed. Antero-posterior, lateral, oblique, and flexion-extension plain radiographs were evaluated for healing of isthmic bone graft, intervertebral space height, and spondylolisthesis at 3 d and 3, 6, 12 and 24 months postoperatively. Fusion rates were assessed by an independent radiologist at 6 months. Definitive fusion was considered to be established on static and dynamic plain X-rays by 1) the formation of trabecular bony bridges between contiguous isthmuses; 2) the interface between the preoperative low density area and bone graft shadow, and the “dog neck sign” became indistinct. Fusion of bone graft was confirmed by cross-section bone windows on CT scan. 3) Intervertebral space height was measured from the mid points of the upper and lower endplate on lateral radiographs of the lumbar spine. 4) The range of motion (ROM) of the angle between intervertebral spaces was the difference in the degree of angle at extension and flexion. Changes of ROM at L5/S1 and L4/5 were evaluated preoperatively and 24 months postoperatively.
Postoperative radiographs show the contact points between the rod and the posterior arch. (A, spinous process; B, laminae) and the custom-made bending of the rod in the frontal (x angle) and sagittal (y angle). C, Healing of the pars defect after removal of the hardware. (Gillet et al, 1999)

Patients can sit and walk 1 or 2 days after surgery. No brace is recommended, because the construct is considered solid enough to secure the posterior arch until fusion of the bone graft is obtained. Patients are encouraged to walk as much as possible, anterior bending is discouraged but not strictly forbidden, and physiotherapy and exercises are avoided for 3 months. (Gillet et al, 1999)

Biomechanics

Sairyo et al. showed that direct repair of the isthmus could improve the biomechanical environment of the diseased and adjacent intervertebral disks. The pedicle screw-V rod system directly repairs the isthmus of the vertebra and the procedure does not impact on adjacent vertebral segments and causes no injury to the diseased intervertebral disc. Our findings indicate that intervertebral space height (L5/S1) markedly improved at 24
months postoperatively. No anterior nor posterior displacement at L5 was observed in all patients upon overflexion or overextension, indicating that the pedicle screw-rod system can effectively prevent anterior displacement of the diseased segment. The screw-V rod could prevent anterior displacement of L5 vertebra, thus lessening the forward shear stress on the intervertebral disk of L5/S upon flexion. The V rod is indirectly placed above the sacral crest, which partially transmits the vertical load on the intervertebral disk of L5/S1 to the sacral crest through the pedicle screw-V rod system. This could partially lessen the vertical load on the intervertebral disk of L5/S1. In addition, there was no marked difference in the ROM of the intervertebral disk of L5/S1 before and following surgery, suggesting that the pedicle screw-V rod system does not impact the motion of the intervertebral disk of L5/S1 while stabilizing the vertebral segment. (Osterman et al, 2011)

In addition, there was no significant change in the height and ROM of the intervertebral disk of L4/5 prior to and after surgery, indicating that there is no increased burden on the cephalic adjacent segment (L4/5). Thus, the modified pedicle screw-V rod system provides elasticity in stabilization, exerting no apparent effect on flexion and extension of the spine while preventing anterior displacement of the diseased vertebral segment. Their three dimensional finite element analysis of the modified pedicle screw-V rod system for stabilizing the bilateral isthmus of L5 showed that the system applied pressure axially and not only provided good stabilization for anterior flexion and back extension, lateral flexion and rotation but also maximally preserved the motion of the adjacent vertebral segments (manuscript in preparation). It was particularly
effective in stabilizing the caudal vertebral segment during rotation. In one patient, roentgenography at 4 years of follow up revealed apparent absorption of bony outgrowth at the anterior edge of L5 vertebra, suggesting effective stabilization of L5-S1 by the modified pedicle screw-V rod system. As a result, these properties of the pedicle screw-V rod system offer a more favorable kinetic environment for the intervertebral disk, which facilitates the improvement of the intervertebral disk.(Spruit et al,2005)

Advantages:

This technique reported here has several advantages. The strength of the hardware (rod and screws) avoids the need for postoperative immobilization, and patients engage in everyday activities during the first weeks after surgery. The postoperative convalescence is comfortable. The pedicle screws are placed in a classic manner, and any surgeon experienced with pedicle screw systems should be able to learn the technique rapidly(Fujwara et al,2013)

This construct could be made with any top loading rod and screw system, and there is no need for special instrumentation. The bone grafting procedure is not hindered by the hardware and compression of the graft to fit into the pars defect is possible. Implant removal is not to be considered as a routine procedure, because all adjacent segments remain free.(Gillet et al,1999)

It is effective in alleviating back pain, achieving bone graft healing, preventing anterior displacement of the diseased segment. It also does not impact on the ROM of the diseased segment and adjacent segments and it improve and maintains intervertebral space height.
Disadvantages:

The only demanding points of the procedure are proper bending of the rod and meticulous avoidance of any impingement between the rod and the posterior arch of the underlying vertebra. Proper placement of the patient to preserve normal lordosis is essential. It makes the preparation of the pars defect more difficult, but it avoids any misplacement of the hardware that could lead to a mechanical conflict and pain. (Gillet et al, 1999)

5- Direct repair using the Novel technique and grafting

The Novel technique for surgical repair of spondylolysis consists of a pair of multiaxial pedicle screws connected with a modular link that passes beneath the spinous process of the same segment. Tightening the link to the screws compresses the bone grafted pars defect. This system provides rigid intrasegmental fixation with minimal intersegmental motion interference. Given these advantages, we hypothesize that this intralaminar link construct is biomechanically superior as a direct pars repair to other constructs.

In 2006, Ulibarri et al reported the results of five adolescent patients, the age range was from 11 to 18 years, and included 2 males and 3 females. Pars defects were at L3 and L5 in 1 patient (Fig.27), and L5 in 4. In Patient no.5, because there was increased uptake on bone scanning at L3 while L5 defects showed no increased uptake (Fig.28), surgical repair was performed at L3 (Fig.29). Furthermore, this patient had significantly greater pain relief with pars injection of Marcaine at the L3 level and no pain relief with injection at the L5 level. (Newton et al, 2011)
(Fig.25) Preoperative CT of patient showing lytic defects at the pars interarticularis at L3 and L5. Although plain radiographs confirmed the L5 spondylolysis, they were negative for any obvious defects at L3; no spondylolisthesis was present at any level. (Ulibarri et al, 2006)

(Fig.26) Preoperative bone scan showing increased uptake at pars interarticularis at the L3 pars interarticularis. No uptake is present at L5. (Ulibarri et al, 2006)
Surgical Procedure.

A midline incision is made, and the paraspinal musculature is elevated laterally to expose the lamina, pars, and transverse process base. Care is taken not to injure the facet joint capsule. The pars interarticularis defect is exposed and the fibrocartilaginous defect curetted. Bone graft is harvested from the iliac crest through the same incision. Anatomic landmarks and fluoroscopy are then used to determine the pedicle screw starting point. A starting hole is burred, and a pedicle finder is used to enter the pedicle. Walls and floor are assessed with a ball-tip probe, and the hole is tapped and prepared for a multiaxial pedicle screw. Bone graft is placed in the defect before screw insertion. After screw insertion, a link is contoured to fit, and placed just caudal to the spinous process, deep to the interspinous ligament of the affected level, and attached to each pedicle screw. The link compresses the defects when tightened to the
pedicle screws. Final fluoroscopic imaging confirms correct screw and link placement. Postoperative management included protected activities for 3 months without bracing and gradual return to full activities at 6 months.

Postoperative follow up was from 3 to 5 years, including plain film radiography of the lumbar spine of anteroposterior, oblique and lateral flexion and extension films. Criteria for a healed lesion were bridging bone on all views, while unhealed spines showed an obvious lucency. If the pars defect was obscured by instrumentation or healing was unclear, it was said to be indeterminate. At the latest follow up, visual analog scores ranged between 0 and 4 for all patients, indicating excellent overall pain control. One patient had recurrent pain in the lumbar spine that started one year after repair of L3 spondylolysis. MRI revealed normal signal intensity of the discs. CT showed solid fusion across the defect (Fig.4.19A) and slight erosion of the superior surface of the L4 spinous process (Fig.4.19B). This finding is caused by the inferior margin of the intralaminar link. In this patient, the recurrent pain resolved after implant removal (Fig.4.20). (Ulibarri et al, 2006)
(Fig.28) (A) Follow up CT of the lumbar spine 2.75 years later shows healing across the pars interarticularis. (B) Follow up CT of the lumbar spine also indicates slight erosion of the superior surface of the L4 spinous process. This erosion was presumed to be causing the patient’s recurrent pain. (Ulibarri et al, 2006)

(Fig.29) Follow up lateral radiograph after implant removal. The patient’s recurrent pain had subsequently resolved. (Ulibarri et al, 2006)
The novel spondylolysis fixation technique described here is biomechanically sound in reducing defect displacement in flexion and extension. Clinically, this technique may result in a higher fusion rate for fixation of spondylolysis defects. In addition, the intralaminar link construct provides similar stiffness in interbody flexion-extension and torsion compared to the normal spine, which may be beneficial in maintaining adjacent level motion and prevention of stress shielding. Clinically, this small group had good-to-excellent functional outcomes as indicated by visual analog scales, the ODI, and SRS questionnaires. This correlated with biomechanical results of similar stiffness to the normal spine in flexion and rotation between the instrumented level and the one below.

6-Cable screw construct for surgical repair of lumbar Spondylolysis

The cable screw construct uses the strongest anchors (the pedicle and the lamina) and uses compression obtained with cables to stabilize the pars interarticularis (Songer, 1998).

Surgical Technique. The affected vertebra is approached posteriorly with the patient in a prone position over towel or silicone rolls. An x-ray table is required to guide placement of the pedicle screw. The pars defect or pars fracture site is first meticulously cleaned of soft tissue. Good, bleeding bone is exposed both on the pedicle side and the laminar side. Care is taken to keep the facet joint intact. A laminotomy is created to decompress the lateral recess and the foramen, if necessary. The nerve root must be exposed to ensure that it is not compressed during insertion of the
bone graft. A 6.25-mm or 5.5-mm pedicle cable screw is inserted into the pedicle. Caution must be taken to not disturbing the facet joint and also to enter the pedicle superiorly enough to keep the screw out of the defect site. The screw is inserted to approximately 75% of its length and its position verified radiographically. A tricortical bone graft is harvested and shaped to fit into the defect. During preparation of the pars defect, a small burr is used to square off the defect. The bone graft is slightly wedge shaped, and posteriorly a small lip is left both superiorly and inferiorly to prevent migration of the bone graft anteriorly toward the nerve root. The screw is then completely inserted and locked on top of the graft (Figure 30. A and B).

(Fig.30) (A) Representation of the insertion of the bone graft between pedicle and lamina on left and right sides of the patient on the patient's right side, the pedicle cablescrew has been inserted into the pedicle just below and lateral to the facet joint. The modified pedicle screw locks the bone graft in place. (B) Photograph demonstrating the insertion of the bone graft and pedicle cable-screw on right side at L5. (Songer, 1998)
A 1-mm double cable (AcroMed Songer cable, Cleveland, Ohio) is passed sublaminarily from the caudal to cranial of the vertebra under repair. The tip is cut off, and the cables are separated and brought to each side: First, the leader is passed through the hole of the pedicle screw on the opposite side (the cables will cross each other). Second, the leader is wrapped around the cranial side of the spinous process. Third, the leader is threaded through the loop at the opposite end of the cable. The same maneuver is made with the other cable. Now the cables are loaded into the tensioners. The leader is threaded through the crimp and then into the self-locking spool. The cables are simultaneously tensioned on each side (Figure 31). Care is taken to check that the bone graft is firmly locked in place and that it is not compressing the nerve root. Finally, the crimp is crimped by squeezing the crimper and the excess cable is cut off and removed.

(Fig.31) Passage of the cables. A double cable is passed underneath the lamina and is split in two. Leader of each cable is threaded through the hole in the pedicle screw and woven around the cranial end of the spinous process and through the loop at the other end of the cable. (Songer, 1998)
The same maneuver is made with the other cable. Now the cables are loaded into the tensioners. The leader is threaded through the crimp and then into the self locking spool. The cables are simultaneously tensioned on each side (Fig.32).

(Fig.32) Cable tensioning process. Leader is passed through the crimp, which is held in the jaws of the crimper, and then through the spool. The cables are tensioned and crimped. (Songer, 1998)

Care is taken to check that the bone graft is firmly locked in place and that it is not compressing the nerve root. Finally, the crimp is crimped by squeezing the crimper and the excess cable is cut off and removed (Fig.33,34).
(Fig.33) End product after cables have been tensioned and crimped, with excess cable removed. (Songer, 1998)

(Fig.34) (A) Anteroposterior radiograph of the pedicle screw and cables in place with successful incorporation of the bone graft. (B) Lateral radiograph of lumbar spine, demonstrating the cable-pedicle screw construct in place with successful incorporation of the bone graft. (Songer, 1998)
After surgery, the patient wears a Boston type lumbosacral orthosis for 3 months. At postoperative week 6, a swimming and exercise bicycle program is instituted. At 3 months, a strengthening and range of motion program is begun for rehabilitation of the back musculature.

**Advantages:**

There are three factors that should be considered when stabilizing the pars interarticularis. First, there is high stress on the pars with extension and torsion forces. Second, there should be adequate surface area for bone grafting. Third, the instrumentation must have strong anchors, be low profile and not irritate the facet joint, and resist the forces applied to the pars interarticularis. The cable screw construct meets these criteria. The lamina and the pedicle are the strongest anchors of the vertebra. The instrumentation does not pass through the defect and allows maximal area of bone graft incorporation. Equal and strong compression can be delivered across the pars repair by simultaneously tensioning the cables. As long as the pedicle screw is inserted laterally to the facet joint, the facet joint is free from impingement or irritation. The cable screw construct, with the flatheaded screw has a low profile. So it is clear that this technique is successful in fusing the pars interarticularis.

**Contraindications:**

Contraindications for using cable screw repair are the presence of a displacement of more than 5 mm, significant degenerative changes seen on radiographic film or MRI scans and failure to reproduce pain with infiltration of the pars defect. (Songer, 1998)
7-Minimally Invasive Direct Repair of spondylolysis:

Recently, minimally invasive surgery (MIS) has been proposed as an alternative to these classical procedures. First, in order to resolve these problems, it has been developed an endoscopic direct repair of the pars using a modification of the classical Buck’s procedure. Although the damage of PVM (para vertebral muscles) was reduced, the procedure had the following drawbacks: (1) it was not applicable in patients with a thin lamina, (2) screws themselves limited the size of the graft bone mass, (3) it took a long operation time due to the difficulty of the technique. But, since 2006, it was started to employ applied a pedicle screw-hook-rod (PSHR) method using a percutaneous pedicle screw system to reduce the damage of PVM.

Operative Technique:

Biplanar fluoroscopy was used in conjunction with the Universal Cannulated Screw Set (UCSS; Medtronic, Memphis, TN, USA) and the METRx tubular table-mounted retractors (Medtronic). Lateral fluoroscopy was used to determine incision location by visualizing the trajectory required to access the pars defect.

Either a single midline incision or paired parasagittal skin incision was made, followed by separate fascial incisions on both sides of the spinous process. Sequential dilators were placed under fluoroscopic guidance directed at the pars, and then an 18 mm diameter tubular retractor was placed in order to visualize the pars defects (Figure 34). The pars defects were identified, and the fibrous tissue debrided and a high-speed burr used to prepare the bony edges until the bleeding bone was encountered (Figure 37). (Brennan et al, 2008)
Fluoroscopy was again used to identify the pars screw trajectory, and a separate single midline incision made in order to accommodate the UCSS cannula. The cannula was then tunneled through soft tissues and docked onto the inferior surface of the lamina, under fluoroscopic guidance. The guide wires were then drilled across the pars defects (Figures 38(a) and (b)). Once they were satisfied with the position of the wires, an intraoperative computed tomography (CT) scan was performed to confirm proper wire placement. They then drilled over the wires and placed 4 mm diameter partially threaded titanium cortical lag screws measuring 36–40 mm in length across the pars defects in order to achieve compression (Figures 39(a) and (b)). Prior to final tightening of the screws, one-half of a bone morphogenetic protein (BMP) sponge (Infuse; Medtronic) and bone shavings from the decortication were placed into each defect, and then final screw tightening was performed. The incisions were then closed in layers in the usual fashion. (N. Amoretti et al, 2012)
(Figure.35): Flexion/extension preoperative rays of patient showing increased separation of the pars defect with flexion.(Brennan et al,2008)

(Figure.36): Intraoperative picture showing the METRx tube directed at the pars defect (left side of picture, which is towards the
Treatment

patient’s head) and the guidewire for the screw (right side of the picture). In this case, a single midline cephalad incision was used to access both pars defects with the METRx tube, and a single midline caudal incision used the pass the guidewires and screws. Alternatively, two paired parasagittal incisions can be used to access each pars defect and a single incision used to pass the guide wires and screws. (Brennan et al, 2008)

(Figure 37): An 18 mm METRx tube was then directed towards the pars defect using fluoroscopy. The pars defect was decorticated with a high-speed drill, and local autograft and BMP were placed in the defect. Note that this step is done prior to placing the wire. This fluoroscopy image shows a currette in the pars defect after it is prepared with the bur. (Brennan et al, 2008)
(Figure.38): ((a) and (b)) The UCSS cannula is advanced towards the undersurface of the lamina and then the guide wire drilled across the pars defect. (Brennan et al, 2008)

(Figure.39): ((a) and (b)) Cortical partially-threaded screws are passed across the pars defect. (Brennan et al, 2008)
Three-month post-operative CT shows appropriate intraosseous screw placement with healing of the pars defect and no signs of nonunion. (K. Higashino et al, 2007)

Postoperative Course:
All patients had minimal post-operative pain and controlled by oral narcotics and were discharged home on post-operative day 1 or 2. Their incisions were well healed at the time of their first followup (10–14 days). CT scans obtained at three months post-operatively demonstrated definite healing of the pars fracture in two patients and evidence of early healing in one patient, satisfactory screw placement, and no signs of nonunion such as lucency around the screws. Flexion-extension imaging at three months as well showed no gap at the site of the pars defect and no spondylolisthesis. All patients have returned or are planning a return to their sport. (M.R. Lim et al, 2013)
Treatment

Cases had short operative time and minimal intra operative blood loss. There were no wound infections or neurologic complications. No hardware breakage or loosening was observed.

All adult patients operated on employing the minimally invasive technique for lumbar spondylolysis using a percutaneous pedicle screw and hook-rod system had clinically good results. The bony union rate was 80%. Normalization of the lumbar kinesiology, in terms of the instantaneous axis of rotation during the lumbar extension/flexion motion, was attained. Moreover, the spinal motion segment was preserved and lumbar spine mobility was retained.
<table>
<thead>
<tr>
<th>Methods of direct pars repair</th>
<th>Advantages</th>
<th>Disadvantages</th>
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| 1-Buck’s repair               | - resist forces & movement in any direction.  
- not expensive  
- fixation force is consistent with anatomic direction of lamina. | - technically demanding.  
- possible complications as screw breakage & nerve root irritation.  
- decrease area available for bone grafting. |
| 2-hook screw                  | - preserve motion segment.  
- does not need extensive dissection.  
- better relief of symptoms in patient younger than 20 years. | - technically demanding  
- common technical errors as:  
- short screws & misplacement of screws in inferior articular process of vertebra above.  
- bulky hardware.  
- high incidence of screw loosening. |
| 3-Scott wiring                | - simple  
- function as tension banding leaving the bony surface of each side of the defect to participate in bony healing. | - great surgical exposure.  
- difficult placement of wires under transverse process.  
- risk of nerve root injury.  
- wire not strong enough so patient obligate to wear brace for 3 months.  
- slight decrease in mobility of motion segment. |
| 4-V-rod construct & grafting  | - strong hardware so no need for bracing.  
- patient engage in every day activities during first weeks after surgery.  
- surgeon able to learn technique rapidly.  
- implant removal not | - misplacement of hardware may lead to impingement()rod & posterior arch of underlying vertebra. |
<table>
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<th>Treatment</th>
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| routine procedure.  
  -does not impact on ROM of diseased segment & adjacent segments.  
  -maintain intervertebral space height. |  
| 5-Novel technique & grafting |  
  -rigid intersegmental fixation  
  -minimal intersegmental motion interference.  
  -higher fusion rates. |  
| 6-Cable screw construct |  
  -instrumentaion does not pass through the defect.  
  -allows maximal area for bone grafting.  
  -facet joint is free from impingement.  
  -low profile screw.  
  -cannot be done if displacement more than 5mm & presence of significant degenerative changes. |  
| 7-minimally invasive tecnique |  
  -no wound infection neurologic complications.  
  -no hardware breakage.  
  -minimal blood loss.  
  -not applicable in patients with lamina.  
  -screws limited the size of the graft bone mass.  
  -long operation time due to difficulty of technique. |  

(Table.4) showing methods of direct pars repair.
Summary

Spondylolysis is a defect in the pars interarticularis. It affects approximately about 5% of all population.

It was postulated that it results from of a fatigue fracture caused by repeated stresses with underlying genetic or constitutional predisposition.

Athletes are the most vulnerable group to be affected by spondylolysis, mainly gymnastics and fast bowlers.

It is usually affects lower lumbar region and rarely occurs in upper lumbar and cervical regions.

Clinically patients usually complains of back pain rarely referred to lower limb (only when facet joint hypertrophy reduces width of intervertebral foramen).

Radiologically, it could be detected using plain X-ray, and a specific radiological signs usually found in oblique views. C.T. tomogram also, is useful in its diagnosis; there is a sure sign; double defects in one cut.

On the other hand, MRI provides little knowledge. As MRI specificity is not so great. Bone scan is an important investigation to detect on going healing.

It is noted that the defect heal in some patients and the symptoms disappear with conservative treatment, while in other pseudoarthrosis
develops, symptoms persist and roentgen graphic finding of spondylolysis become evident.

Some patients who had excellent healing of the defect had persistence of symptoms. On the other hand, there were patients with non union who nevertheless experienced a substantial reduction in the level of their pain. The possible cause is the presence of disc degeneration.

The majority of patients who have reoentgengraphic finding of spondylolysis or grade I spondylolisthesis don’t need surgical treatment, and conservative treatment is usually sufficient.

Conservative treatment ranges between just stopping sharing in sports and following a program to strength the abdominal and back muscles. Wearing a brace is an important option. Conservative treatment monitored usually using bone scan.

However, operative treatment seems to be indicated in those who have

* Persistent pain despite adequate trials of conservative treatment.
* Documentation of progressive slipping over than 25-30%.

Operative options range from direct repair of spondylolytic defect and fusion in situ.
Ideal candidates for repair of pars defect are young patients with lysis but no spondylolisthesis with lytic defect between L1- L4. Pars defect repair is contraindicated in patients more than 30 years old, slippage more than 2 mm across the pars defect and early associated disc degeneration as seen by MRI. When fusion is indicated, posterior rather than anterior fusion is preferred.
References


الانحلال الفقارى هو خلل بالصفيحة الواقعه بين النتوء المفصلي العلوي والسفلى لفقرة من فقرات العمود الفقري وهو ما أن يكون في جهة واحدة أو جهتين من الفقرة ومن الناحية التشريحية هو شق بالبرز.

هذه الحالة عادة ما تؤثر على الفقرات القطنية وخاصة السفلى وقد تحدث في الفقرات العنقية وهو أقل شيوعا.

وقد اشتمل البحث على دراسة أسباب هذا المرض وطرق علاجه المختلفة.

ويشمل البحث على عدة امور:

- استعراض أراء الباحثين والمؤلفين المختلفة المتصلة بهذا المرض وشرحها خاصة ما يتعلق منها:
  1- أسباب المرض
  2- باثولوجيا المرض

وباستقراء اراء الباحثين تبين ان أهم اسبابه ترجع الى:

- عوامل وراثية و عائلية و خلقيه.
- الأمراض التي تسبب الفقرات.
- نوع العمل الذي يقوم به المريض والذي عادة ما يكون شاقا ومرهقا.
- الانشطة الرياضية التي تسبب أجهادا بالفقرات.
- الصور الاكلينيكية للمرض؛ والتي منها:
- عدم وجود آية أعراض، ويكتشف بطريق المصادقة عند إجرء فحص
بالأشعة السينية لسبب آخر.
• وقد يعاني المريض من آلام أسفل الظهر.
• المشي بطريقة غير طبيعية.
• العزز العصبي.

• الطرق والوسائل التشخيصية المختلفة: مثل الفحص بالأشعة السينية، خاصة المناظر الجانبية والمائلة، وكذلك المسح الذي باستخدام النظائر المشعة، الأشعة المقطعية، أو الرنين المغناطيسي حسب الأمكانيات المتاحة.
• استعراض أراء الباحثين والمؤلفين حول الوسائل المختلفة لعلاج المرض سواء

علاج تحفظي أو جراحي.

ويشمل العلاج التحفظي:

1- تجنب الأنشطة والأعمال المرحة للظهر في المرضى الذين يعانون من آلام الظهر واستعمال القابل لثبت الظهر حتى يتسمى التام الخلل.
2- العفافر المسكنة للآلام والمضادة للالتهاب.
3- العلاج الطبيعي. كتمريضات تقوية عضلات الظهر والبطن.

العلاج الجراحي:

يتم من خلاله التدخل في الحالات التي لا تستجيب للعلاج التحفظي.

ويشمل الآتي:

1- الأصلاح المباشر للخل في حالة سلامه: الغضروف الواقع أسفل الخل

بوسطة:

أ- الأصلاح المباشر بواسطة المسامير بعد وضع رقعة عظمية في الخل البرزخ.

ب- الأصلاح المباشر بواسطة طريقة "سكوت" باستعمال الأسلاك أو الخيوط المعدنية.

2- الطرق المختلفة لثبت الفقرات في حالة إنحلال الغضروف الواقع أسفل الخل.
ومعظم جراحى العظام يفضلون إجراء التثبيت العظمى في الجزء الخلفى الوحشي في الفقرات باستخدام رقعة عظمية من عظام الحوض، وآخيرا من أهم مضاعفات طرق علاج الانحلال الفقارى المختلفة هي ما يلي:

1- التحلل الغضروفي.
2- عدم التحام الفقرات وعدم ثباتها.
3- ازدياد معدل الانزلاق رغم طرق العلاج المختلفة.
4- اختلال وظائف الأعصاب بسبب الضغط عليها.
الوسائل الحديثة
لعلاج الانحلال الفقاري
رسالة مقدمة من
الطبيب/ مصطفى محمد سعد محمد
بكالوريوس الطب و الجراحة
توطنة للحصول علي
درجة الماجستير في جراحة العظام
تحت إشراف
أ/د/ هاني بسيوني
استاذ جراحة العظام
كلية الطب - جامعة بنها

أ/د/ ممدوح الكرماني
استاذ م جراحة العظام
كلية الطب - جامعة بنها

د/ محمد عنتر
مدير جراحة العظام
كلية الطب - جامعة بنها

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