SPONDYLOLİSTHESİS

Classification, balance and development, stability and instability of the spondylolisthesis

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Spondylolisthesis is defined as slow anterior displacement (luxation) of a vertebra at the lower lumbar spine, generally accepted as involving the lowermost vertebra slipping forward on the first sacral segment (9).

Intervertebral loading is due to muscle strength and ligament tension besides the body weight and the external loads (1).

The lumbar region is well endowed with active muscles. The erector spine, abdominal, and psoas muscles are all actively involved in maintaining the functional upright and sitting stability of the lumbar spine. They also contribute to the very high loads to which the lumbar spine is subjected. In this region, these well developed muscles and their characteristic loading patterns may render the lumbar spine less vulnerable to clinical instability. However, it must also be considered that the large and variable loads due to muscle and gravitational forces increase the likelihood that disruptions of the lumbar vertebral column will be associated with severe pain (14).

In addition to the vertebral defect present in spondylolisthesis, degeneration of the adjacent discs ligaments and soft tissues, when present, is of significant clinical importance (1).

Degenerative changes which are caused by continous minor trauma, firstly immurse disc degeneration, which damaged the PLS. Along with disc degeneration, intervertebral distance firstly narrows at the posterior portion (1).

Slipping of the L_5-S_1 region starts different to L_4-L_5 region without this phase. If Slipping is greater than 3^0, pelvic tilt and pain cause spasm of hamstrings muscles and decreasing of increased lumbosacral angle and vertical sacrum. After this, the slipping cannot be prevented by the organism. (Figure 1)

At the position of anterior bending, the proximal part of the body is forced to fall anteriorly by the gravitational forces. This movement is prevented by the contraction of the extensor muscles. Also, these muscles, balance the effect of the gravity and continues the movement of anterior bending. By this movement, the balanced position of the body is provided. If anterior bending goes on, the extensor muscles must provide the effective balance movement against the increasing gravitational force of the proximal part of the body, at every point of movement. This position is well- adjusted till about 60° anterior bending of the posterior ligamentous system (1).

At the position of 60° anterior bending, a tension at the ligamentous system, that can partly support the gravity action, begins to appear. When the sufficient tension is gained, the ligamentous tension reaches to the point at which it supports the whole anterior movement. At this point, the extensor muscles relax (1).

The body weiht loads a compression force to every lumbar intervertebral joint. This weight also brings an anterior and positive shearing force to the L_5 - S_1 joint. The shearing force at, L_1 and L_2 is negative because of the posterior slope of the joint at the upright position. When the lumbar spine is flexed, this force becomes positive (1).

Most of the muscles that effect the lumbar spine are oriented by an angle to the intervertebral joint. So, these muscles give a compression shearing force to the joint, enough to make a turning movement (1).

In flexion, each vertebra turns on itself according to an axis on the intervertebral disc. The ligaments at the joints tighten and form a tension that resists to the flexion force. Annulus posterior, posterior longitudinal ligament, facet joint capsule and ligamentum flavum are oriented at a right angle to the disc plane; so, when they form a tension, they tend to share the forces on the joint (1).

The posterior ligamentous system, formed by the supraspinous and interspinous ligaments and lumbosa-

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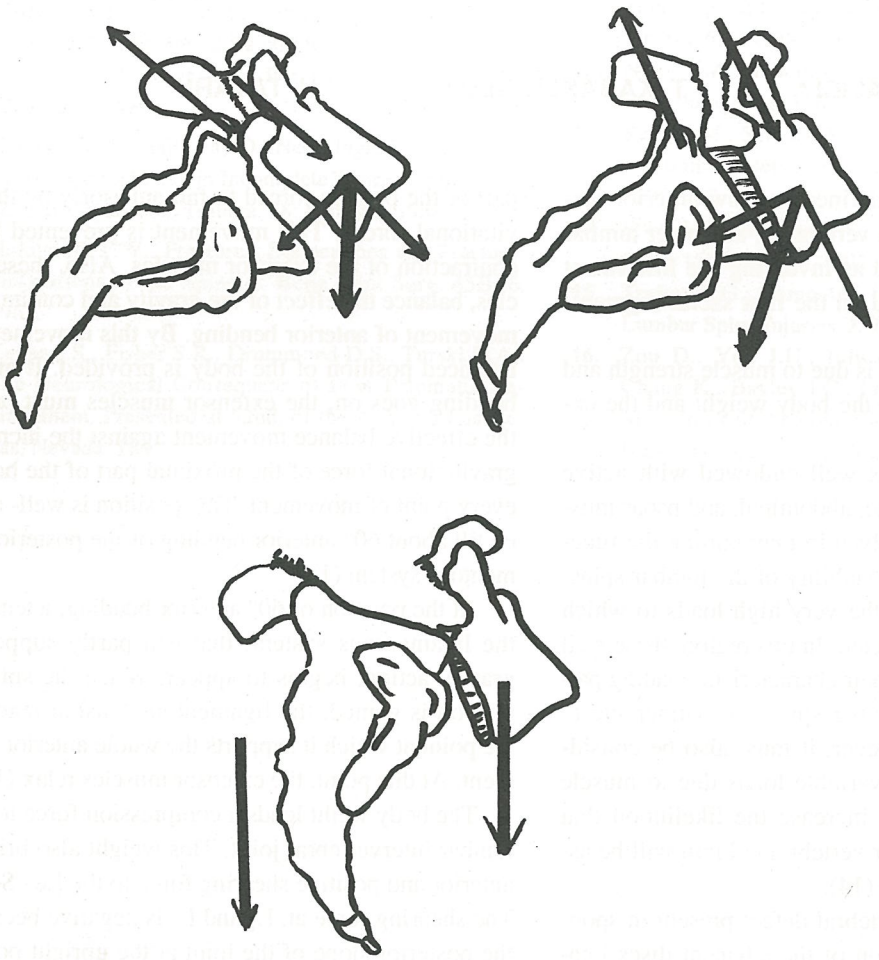

Figure 1. Biomechanics of slipped spondylolisthesis and positions of sacrum

cral fascia, pulls the vertebrae posterior, when contracted. This tension force is shared at all levels of the spine. This sharing increases when the posterior ligamentous system contracts (1).

In extreme flexion, in addition to the body weight, the muscular contraction and the tension of the posterior ligamentous system are effective. At the upright position, the pressure, in the intervertebral increases. In the first phase of the movement, the posterior ligamentous system is inactive. In the second phase, the tension of the system forms the negative shearing (1).

At the distal joints, the sheared forces, due to muscle activity and body weight, are supported by the facets joints and intervertebral discs. At the position of anterior bending, the posterior ligamentous system is responsible of the sheared forces. Some muscles; for example, lattissimus dorsi, provides this shearing. But, this muscles have a little effect on the shearing forces those happen at the joint. At the upright position, the anterior shearing force at the proximal lumbar region is prevented by the posterior shearing at this region. In the lordotic region, this shearing force is due to the disc, the joint capsule and the activity of the transverse muscles (1).

It's convenient to divide the spectrum of clinical manifestation of degenerative changes seen in the lumbar spine into three stages (6) :

1. Temporary dysfunction
2. Unstable phase, and
3. Stabilization. (6)

Instability can be defined as the clinical status of the patient with back problems who with the least provocation steps from the mild symptomatic to severe episode (6).

Two factors influence the state of the affected joint:

1. Increased abnormal motion, and
2. Physical changes that occur at an injured joint.

Each trauma imprints a bone deformation or scar

on the injured structure which in turn, degrades the mechanical function of the joint. Subsequently, the patient with repeated trauma may gradually creep in to the unstable phase. It means that, the important one is mechanical loading (6).

Studies by Detrich and Kurowski employed mechanical models of muscle and bone and photoelastic materials to determine the sites of stress concentration in the lower lumber spine. The analyses show that the highest stress concentration is in the region of the pars interarticularis (14).

Some clinical support of the mechanical failure is offered by a study comparing 43 nonambulatory patients with a group of normals. The prevalence of spondylolysis was 5.8 % in the normals and zero in the nonambulotory patients (14).

There are a number of geometric measurements that constitute a detailed quantitative description of the condition. These have been reviewed by Wiltse and Winter. On a theoretical basis, the opinion is that for following patients, the percentage of anterior translation (anterior deplacement) and tha saggital rotation are the most important parameters (14).

Measurements that may progression of deformity are;

1. Percent rouding of the top of the sacrum,
2. Wedging of the displaced L_5 vertebra,
3. Lumbar lordosis, and
4. A large sacrohorizontal angle.

These parameters tend to indicate geometric relationships that, in the standing position, would maximize gravitational loading vectors and increase the deformity (14).

Degenerative spondylolisthesis is a unique form of spondylolisthesis that is characterized in most patients as a hypertrophyc arthritis of the facet joint resulting in segmental instability predominantly in the sagittal plane. Disk degeneration is associated with degenerative spondylolisthesis to a varying degree. Joint involvement may not be uniform in all patients, and a rotatory component, although small, is often present (2).

Among theories that assume degeneration of the intervertebral disc to be primarily responsible for the disease, Taillard suggested that age-associated degeneration of the intervertebral disc at L_4 - L_5 level reduces the disc function of suppressing anterior shift of the vertebral body, thus allowing the vertebra to slip (13).

In a study on the adolescent patients with L_5 isthmic listhesis, Schlenka and co., analyzed the distal lumbar discs with radiography, discography, and MRI. In 27 cases with a average age of 14.4, they showed that when the slipping of the vertebra increases, intervertebral disc height decrease (12).

Postacchini analyze the clinical features and results of various imaging studies in 77 patients with degenerative lumbar spondylolisthesis. Various pathological conditions were identified : slight narrowing of the central spinal canal without compression of neural structures; isolated stenosis of the nerve root canal; stenosis of both the nerve root canal and the central spinal canal. The extent of the neural structure compression, and thus the clinical picture, depends on three changes factors: the primitive size of the spinal canal, the extent of degenerative changes in the zygapophyseal joints, and the extent of olisthesis (11).

Concerning the cause of vertebral disk slippage in this disease, morphologic abnormalities such as tilting of the intervertebral articulation, high Jacoby line, and degenerative of the intervertebral disk and facet joint with aging have been emphasized. Junghanns considered that an increase in the lamina angel, which is the angel between the axis of the pedicles of the laminae of the affected vertebra and the axis of the inferior articular process, is an important factor in the development of this condition.

Fitzgerald and Newman observed abnormal elevation of the Jacoby line (The line between the upper margings of the bilateral iliac crest) to the intervertebral disk at the L_{4-5} level or to the level of the upper margin of the vertebral body of L_5 and frequent lumbosacral transition. They considered that weakness of the soft tissues between the iliac crest and stability of L_4 due to strea between L_4 and L_5 was responsible for the anterior shift of L_4 (3).

Tsunoda et al was interested also in the morphology of the lamina and inferior articular process and classified it into "X" , "M" , and "W" types. They suggested that, in this disease, "W" type was the most frequently observed and that the angel between the intervertebral articular surfaces approaches a right angel (3).

In addition to the above local factors, general joint laxity serves as an underlying factor in the pathogenesis of this disease. Bird and Jackson (5), reported a

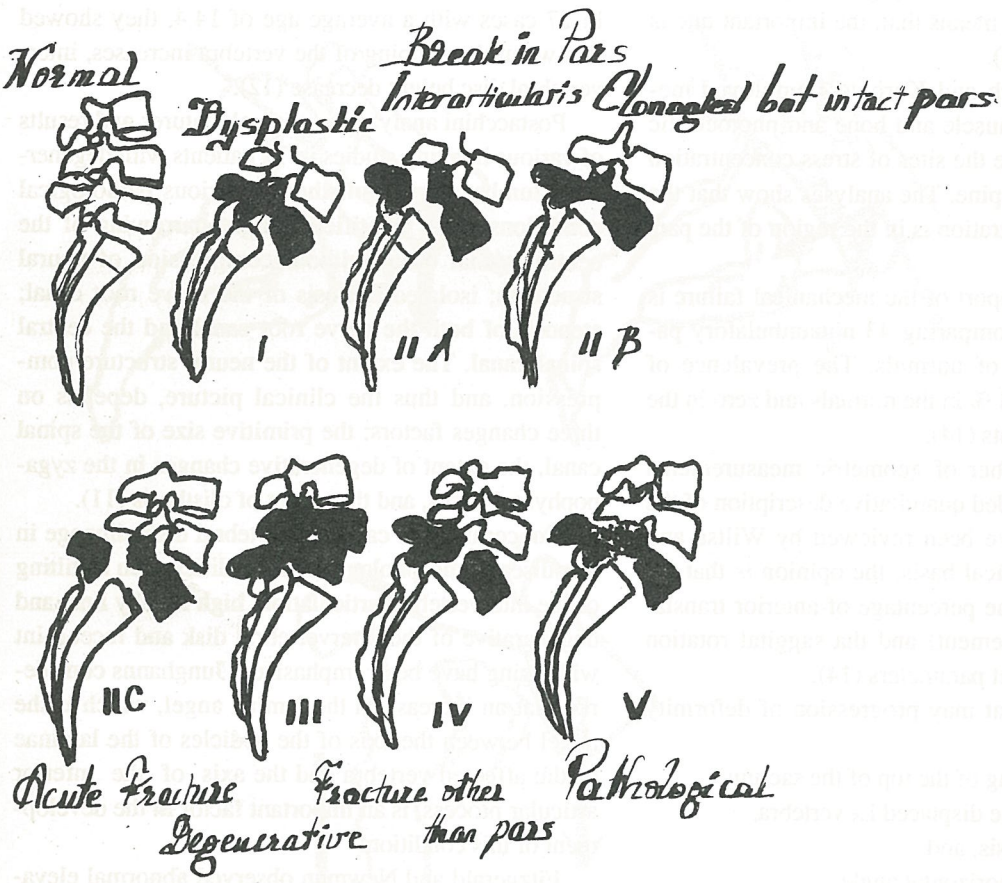

Figure 2.

high incidence of slippage of the lumbar vertebrae in gymnasts who have an abnormally wide motion range of the lumbar spine.

Most of the cases of Matsunaga and co., Showed a high anterior flexibility of the lumbar spine with a significant difference from normal controls of comparable ages. This tendency was particularly notable in woman (7).

The experimental studies of Inouve and co., on cadaveric specimen and according to the same study, disc degeneration predisposes to intersegmental instability and rotational strain, which result in secondary osteoarthiritic change of the articular processes and segmental canal stenosis. Therefore, the original inferior articular process shifts anteriorly, and the old fascet is replaced by newly formed bone. During the process of transformation, remodeling of the bony tissue in the newly formed fascet and the vertebral body results in asymmetry of bony tissues. These finding associated with the difference of facetal angle, indicate that in addition to the instability caused by disc degeneration, the rotational stress on the fascet is significant in the development of degenerative spondylolisthesis(4).

In the study of Matsunaga and co., on 40 cases, the main cause of the disease is the degeneration of the intervertebral disc with aging. Increase in the mechanical stress at the lumbar region a reduction in the abdominal muscle strength, and general laxity may precipitate slippage of the vertebra. Morhologic abnormalities of the intervertebral articulation and the vertebral arch may also contribute to the developmental of the condition (7).

The various classification of spondylolisthesis have attempted to define specific lesion with respect to etiology and pathogenesis. None of these classifications includes retrolisthesis, which refers to a posterior translatory displacement of one vertebra on another, often accompanied by asymmetric posterior disc space collapse and facet subluxation (9).

Wiltse, (10), Macnab, and Newman individually attempted to create classifications, but later combined their concepts in what remains the most widely accepted classification (Figure II).

Type I : Dysplastic spondylolisthesis
Type II : Isthmic spondylolisthesis
Type III : Degenerative spondylolisthesis
Type IV : Traumatic spondylolisthesis
Type V : Pathologic spondylolisthesis

Wiltse and Rothman suggested a common comgenital component in the etiology of dyspastic and isthmic types of spondylolisthesis, and added to the original classification the post-surgical group.

Type I : Congenital or Dysplastic Spondylolisthesis

This subtype is characterized by dysplasia of the upper sacrum and, more specifically, the facet joints. Wiltse and Rothman conceptualized that this abnormality can lead to inability to resist shear stresses, and forward slippage follows. In some cases, increasing anterior shear abnormally stress the pars interarticularis and leads to a thinned-out pars and eventually a pars stress fracture. The pars defect in these cases is a result of the slippage rather than the cause of it. However, in many cases the ring remains intact and, because it is intact, compresses the cauda equina rather soon. Eventually, the spinous process may come to rest on an S1 midline defect. This etiologic group most commonly starts in childhood and often presents with a listhetic crisis characterized by sever back pain, hamstring spasm, and possible neurological compromise.

Two subtype are defferentiated based on the predisposing congenital abnormality.

SUBTYPE A : In this type, dysplastic articular processes are axially oriented, and there is often an accompanying spina bifida.

SUBTYPE B : This type characterized by articular processes that are sagitally oriented.

TYPE II : Isthmic Spondylolisthesis

Wiltse and Rothman differentiate two subtypes.

SUBTYPE A : Lytic type is due to a stress fracture of the pars interarticularis. It is uncertain if some patients have a congenitally weakened pars interarticularis. Clearly, some do not, and the lesion arises do novo. O Neil and Michell demostrated healing of the pars defect in 90 % of cases following a posterior intertransverse stabilization procedure only. Their findings support the theory that the lesion, being a stress fracture, if given enough time and adequate immobilization, will heal. (Figure III)

SUBTYPE B : Here, the pars becomes elongated secondery to repeated craking and healing of the stress fracture in the pars. (Figure IV)

TYPE III : Degenerative Spondylolisthesis

This type is due to long-standing intersegmental instability.

TYPE IV : Traumatic Spondylolisthesis

Wiltse and Rothman emphasize that this lesion is due to acute fractures in areas of the bony hook other than the pars interarticularis and is always due to major trauma.

TYPE V : Pathologic Spondylolisthesis

This lesion is due to localized or generalized bone disease and may present twith an isthmic defect or elangated bur intact pars.

TYPE VI : Post-Surgical Spondylolisthesis

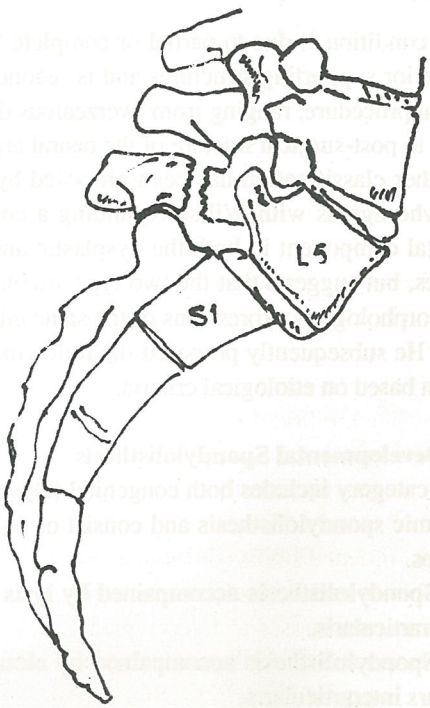

Figure 3. Typical lytic isthmic Spondylolisthesis Subtype A

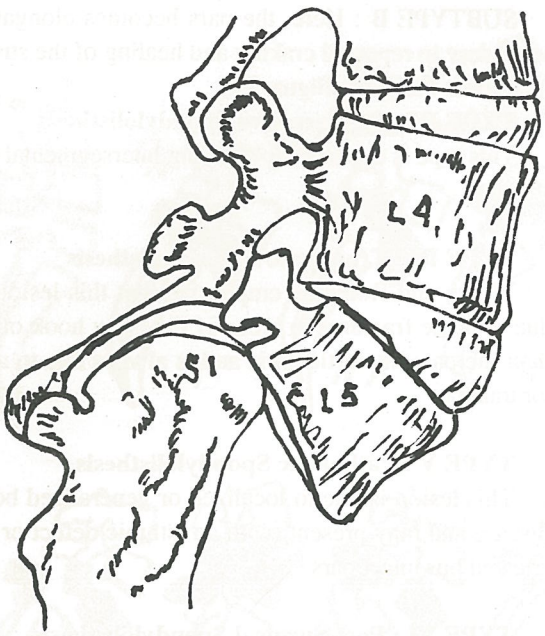

Figure 4. Intact but Elongated pars with Grade III slip

This condition is due to partial or complete loss of the posterior supporting structures and is secondary to a surgical procedure, ranging from overzealous decompression to post-surgical fracture of the neural arch.

Another classification has been proposed by Marchetti, who agreas with Wiltse reganding a common congenital component in both the dysplastic and isthmic types, but suggests that the two type are only different morphological expressions of the same etiologic process. He subsequently proposed the following classification based on etiological criteria.

I. Developmental Spondylolisthesis

This category includes both congenital (Dysplastic) and isthmic spondylolisthesis and consist of only two subgroups.

A : Spondylolisthesis accompained by lysis of the pars interarticularis.

B : Spondylolisthesis accompained by elongation of the pars interarticularis.

II. Acquired Spondyolisthesis

A : Traumatic

1. Acute fracture of the pars interarticularis : This type has a normal bony neural arch and follows sufficient and severe trauma such as a parachute injuries, fall from height, or ejection from car. These injuries may affect other components of the neural arch, and the authors have never seen an isolated pars fracture, either unilateral or bilateral, without other pars of the vertebra being broken.

2. Fatique fracture of the pars interarticularis : Marchetti agrees with Wiltse that repetitive stress at the isthmus can result in a stress fracture of the pars interarticularis in a patient with normal neural arch anatomy. Marchetti summarized his concept of traumatic spondylolisthesis as follows : "Either we are dealing with efficient trauma in a substantially normal bony structure and, therefore, to be included among acquired spondylolisthesis, or fractures in a congenitally dysplastic region, due to inefficient trauma under normal conditions, thereby classifiable under developmental types".

B : Iatrogenic

C : Pathological

D : Degenerative

Despite the evoling and controversial etiologic issues, we will use the Wiltse and Rothman classification. Our focus will be on the types of spondylolisthesis that commonly present in the adult. Because the clinical history and shysical examination may not differentiate the various subtypes, radiologic criteria are most important. Before considering the clinical presentation and treatment, it is important to discuss the essential features of the radiographic evaluation, which from the basis for more our current understanding of etiology, pathogenesis, prognosis, and an appropriate treatment regime.

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