Overview of Clinical Assessment Principles of Treatment of Lumbar Spondylolithesis

Mohamed Mahmoud Fahmy, Magdy El Sayed Hassan, Adel Saad Ismaeil, Atef Kelany Abd El Wanis

Neurosurgery Department, Faculty of Medicine, Zagazig University, Egypt.

Corresponding author Mohamed Mahmoud Fahmy, Email: Medofahmy225@gmail.com

ABSTRACT

Lumbar spinal fusion is a common and effective surgical procedure for the treatment of degenerative lumbar diseases (DLD), such as spondylolisthesis, lumbar spinal canal stenosis associated with deformities, or discogenic pain identified by provocative discography. Careful history and physical examination are the first steps in the diagnosis of lumbar spondylolisthesis. The description of the pain is helpful and important in the diagnosis. The management of degenerative spondylolisthesis as spinal decompression with or without instrumented or noninstrumented spinal fusion. Evidence on the operative treatment of degenerative spondylolisthesis is still divisive. The goal of lumbar fusion surgery is to regain a solid arthrodesis of spinal segments while restoring disk height, immobilizing the unstable segment, and restoring load bearing to anterior structures. Traditionally, bilateral PSF is considered as a widely accepted method for the treatment of a variety of spinal diseases to provide both biomechanical and clinical advantages. However, due to the excessive rigidity of bilateral PSF, this instrumentation is suspected to cause the reduction of bone mineral content and degeneration of adjacent segments. Decrease the rigidity of internal fixation and the unilateral construct seems to be more attractive because it avoids soft tissue disruption of the contralateral side, may take less time, and can be associated with lower implant costs. The effectiveness of unilateral fixation as compared to bilateral fixation in lumbar fusion has been frequently investigated in previous studies. The aim of the present study was to review the clinical assessment principles of treatment of lumbar spondylolithesis.

Keywords: Clinical Assessment; Lumbar Spondylolithesis ; Bilateral Fixation

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Introduction

Degenerative spondylolisthesis is defined as "an acquired anterior displacement of one vertebra over the subjacent vertebra in the sagittal plane, associated with degenerative changes, without an associated disruption or defect in the vertebral ring" (referring to the NASS (North American Spine Society Guidelines) **(1)**. While displacement in other directions, i.e., retrolisthesis, can also occur in degenerative segments, it is usually not included in the term degenerative spondylolistheses **(2)**.

Spondylolisthesis can occur with other disorders and seems to have a link with some of them: Spina Bifida Occulta Cerebral Palsy .A number of studies proved the association between cerebral palsy and spondylolysthesis, certainly in athetoid cerebral palsy (60%)**,** Low back pain, Osteoarthritis, Neuroforaminal stenosis & Spinal Stenosis **(2,3).**

Degenerative spondylolisthesis at L4-L5 level has also been demonstrated to occur more frequently in individuals with more coronal orientation of the L5-S1 facets and further occur more often in individuals with a sacralization of this segment. What is usually defined as a degenerative spondylolisthesis – an anterior slip (anterolisthesis) is more common than a posterior slip (retrolisthesis). A posterior slip may be seen in as many as 30% of patients with any form of vertebral slip caused by degenerative changes. As mentioned, forward subluxation occurs most commonly at L4-L5, however retrolistheses are more common at L3-L4 **(4).**

Patients typically have intermittent and localized low back pain for lumbar spondylolisthesis. Pain is exacerbated by flexing and extending at the affected segment, as this can cause mechanic pain from motion, leading to diminished ROM (spine). There may be sensory loss or leg weakness. Hamstring tightness is always a common finding. Patients with spondylolisthesis may exhibit a type of waddling gait**.**Pain may be exacerbated by direct palpation of the affected segment. Disturbances in coordination and balance. Rarely loss of bowel or bladder control **(5,6)**.

- **Symptoms:**

Patient complaints include low back pain and this is usually attributed to isthmic or facet pseudoarthritis or disc disintegration. Symptoms are "mechanical" in nature, meaning that the pain is aggravated by standing and walking and relieved by lying down, patients will also have radicular symptoms. Neurological findings are unusual, however, and generally limited to L5 dermatomal sensory changes in both isthmic and degenerative spondylolisthesis **(7)**.

In addition, symptoms of spinal stenosis (narrowed spinal canal and intervertebral foramina) are also uncommon. Complaints such as tired legs, numbness and tingling after walking a certain distance are encountered and is termed neurogenic claudication. Symptoms are partially or completely relieved by leaning forward or sitting down for a couple of minutes. In some instances, When stenotic symptoms are severe, a fixed forward-flexed posture, sometimes accompanied by hip-flexion contractures, can be observed **(5).**

- **Evaluating Symptoms**

The neurosurgeon asks several questions about the patient in general and their symptoms. The list below is not all-inclusive. Depending on the patient and their symptoms, additional questions may be posed **(8).**Have you noticed weakness in your legs? Does the weakness come and go or is it consistent? Do you experience muscle twitching? Do you have problems walking? What kind of problems? When do you have problems walking? Climbing stairs? Walking downhill? Do you experience cramps in your legs? Do you have any numbness, tingling, or pain in your back or extremities? Does changing position relieve your symptoms? What makes your symptoms worse? Do you have bowel or bladder problems? **(9).**

There is a close relationship between lumbar lordosis and pelvic incidence. Berthonnaud proposed a model that divides the lumbar lordosis into two tangential arches . The lower arch is constructed by the horizontal line passing through the apex of the lordosis and by a line tangent to the sacral endplate. The upper arch corresponds to the angle measured between the horizontal line passing through the apex of the lordosis and another passing through the point of infection. The superior arch has a constant value between 15° and 19°. The inferior arch varies depending on the orientation of the sacral endplate and corresponds to the value of the sacral slope. There is a strong correlation between sacral slope and lumbar lordosis . The relation between the sacral slope and the pelvic incidence explains the link between pelvic incidence and lumbar lordosis. Several studies sought to find a mathematical relationship between lumbar lordosis and pelvic incidence **(2)**.

- **Diagnostic Procedures**

Step off sign-a noticable step off sign is palpated at the lumbo sacral area due to slippage of the vertebrae.

1-**Straight Leg Raise Test:**

The leg with patient lying on the back causes pain and triggers the entire trunk. The neurologic examination may be useful when the patient has an isolated unilateral radiculopathy. The knee jerk reflex may be reduced or absent when the L4 nerve root is involved. Unilateral dorsiflexion or quadriceps weakness and the pattern of sensory loss are important findings. However, a positive nerve root tension sign is uncommon, particularly in the older population. More commonly, the neurologic findings are nonspecific and may include bilaterally absent reflexes, spotty sensory losses, as well as muscle atrophy or weakness **(5).**

2-Muscle Strength and Tone exam:

Measuring muscle strength and tone is another way to determine if nerve deficit exists. To evaluate muscle strength the patient may be asked to stand on their heels then the toes, hop in place, perform knee bends, and grip an item in each hand. Muscle strength is graded and recorded in the patient’s chart. The following grads includes (Zero: No movement; grad 1: Trace of muscle contraction; grad 2: Active movement without gravity; grad 3: Active movement against gravity; grad 4: Active movement against gravity/resistance; and grad 5: normal) **(10).**The physician tests muscle tone by passively flexing and extending the legs. Normal muscle tone elicits slight resistance to passive motion. Other movements test for proximal (trunk) and distal (distant) weakness. Muscle symmetry is also observed **(11).**

3-Sensory exam:

Numbness, tingling, burning, and pain are abnormal feelings that may be felt in the back and/or extremities. Sometimes these symptoms radiate from one area into another. Sciatica is a good example of pain that can radiate into an extremity (leg) **(12)**. Nerves originate from the spinal cord and divide into sensory and motor nerves. The sensory nerve gives sensation to the skin (dermatomes). The dermatomal patterns appear similar to a map on the body. For example, dermatomes on the trunk of the body correspond to the thoracic spinal nerve roots, those on the arms to the cervical spine nerve roots, and legs to the lumbar spinal nerve roots **(13).**

The physician may use a piece of cotton, a swab, pin or paperclip to test symmetrical feeling in the arms and legs. Abnormal responses may be indicative of a nerve root problem **(12)**.

4-Deep Tendon Reflexes:

Most people have experienced their physician tapping their knees with a rubber hammer. The normal response is a ‘knee jerk’. This is an example of a reflex, which is an involuntary muscular response elicited by the rubber hammer tapping the associated tendon **(14)**.

When reflex responses are absent this could be a clue that the spinal cord, nerve root, peripheral nerve, or muscle has been damaged. When reflex response is abnormal, it may be due to the disruption of the sensory (feeling) or motor (movement) nerves or both. To determine where the neural problem may be, the physician tests reflexes in different parts of the body. See the following examples in the chart below **(15)**.

5-Gait and Balance:

Walking or gait, simply means the way a person walks: rhythmical pattern and speed. Walking is a complex process involving different reflexes stimulated by the nervous system and the person’s awareness of where they are in space (termed ‘proprioception’), which is important for balance. The physician may ask the patient to walk across the room, turn and come back, walk heel to toe, on their toes and heels, hop in place on each foot, and/or rise from a sitting position. The physician observes any listing, erratic movement, or loss of rhythm. These movements may also indicate weakness and difficulty with balance. Patients with spondylolisthesis may exhibit a type of waddling gait **(16)**.

- **Radiological and Neurological tools for the Diagnosis of Lumbar Spondylolithesis:**

1-Plain Radiographs

In degenerative spondylolisthesis X-rays demonstrate the forward displacement of L4 on L5, the most common level at which this disorder occurs, or L5 on S1 or L3 on L4 in the presence of an intact neural arch. Isthmic spondylolisthesis also may occur at this level, and plain X-ray should help to rule out this entity. Concomitant degenerative changes include disc space narrowing, end plate irregularities, sclerosis, osteophytes, and traction spurs. Facet sclerosis and hypertrophy should all be noted on the plain X-ray film **(Fig. 1)**. Patients with isthmic spondylolisthesis are quite likely to be young and have neurological symptoms. The AP radiograph often, but not always, demonstrates the accompanying hemisacralization of L5 **(5,17).**

Further roentgenographic evaluation is not warranted for patients with predominantly mechanical back pain that responds to the usual conservative modalities. However, additional imaging studies may be warranted if significant back pain persists that is unresponsive to nonoperative means or if significant radicular pain intervenes, with progressive neurological claudication or radiculopathy and clinical suspicion that another condition (e.g., metastatic disease) may be causative. The presence of bladder or bowel complaints is an absolute indication **(6).**

X-rays are not "routinely" necessary for most episodes of acute low back pain and have generally been overused. The main purpose of plain x-ray is to detect serious underlying structural, pathologic conditions. However; its usefulness in spondylolithesis has been proved markedly. Neurosurgeons routinely ask for L.S.S X-ray in anterolateral view, lateral view, flexion, extension and both obliques are very helpful in confirming the diagnosis, grading and classification of spondylolithesis. It is a useful and cheap way to follow up patients after surgical intervention as regarding the fusion rates the hardware failure e.g system breakage, screw pull out. It is also valuable in detecting the progression of slippage **(18)**.

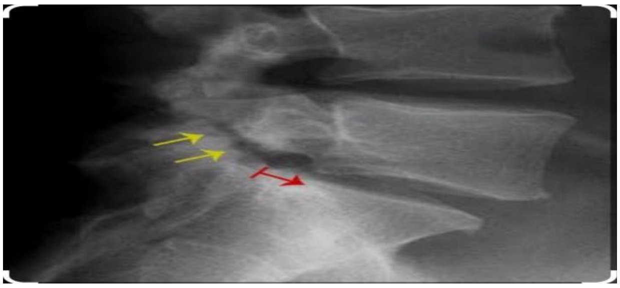

Figure (1): Lateral radiograph of a patient with L5 s1 isthmic spondylolisthesis . Note the defect in the pars (the arrows) (17).

Serial x-rays (radiographs) of the lumbar spine may be helpful to establish the diagnosis. Serial radiographs are x-rays taken over a period of several years. Simple standing x-rays with stress views of the lumbar spine may suffice in patients with a sole complaint of back pain. However, in cases with accompanying sciatica (leg pain), these may not suffice. Further, computed tomography (CT) and magnetic resonance imaging (MRI) are important diagnostic tools used to assess spondylolisthesis **(Fig. 2).** In addition, electromyography (nerve testing) may further help to evaluate symptoms but, it is not a mandatory diagnostic procedure in every case. In general, no correlation was noted between slip progression and clinical deterioration. The lack of correlation between slip progression and progression of symptoms has also been reported by other authors **(19).**

2-Magnetic Resonance Imaging (MRI) and Degenerative Spondylolithesis:

MRI is the most appropriate modality to image spinal canal stenosis or foraminal stenosis accompanying DS **(20).**

Other MRI findings frequently accompanying DS are facet joint hypertrophy and effusion, synovial cysts, high grade osteoarthritis and thickened ligamentum flavum **(21)**.

Spinal MRI should at minimum include conventional sagittal and axial T1 and T2-weighted sequences **(22).**

There are no universally accepted quantitative criteria for which MRI parameters that are best for evaluation of spinal stenosis. Examples of various measurements used are cross-sectional dural sac area, AP diameter of the osseous spinal canal, foraminal diameter, and lateral recess height and angle and ligamentous interfacet distance **(23).**

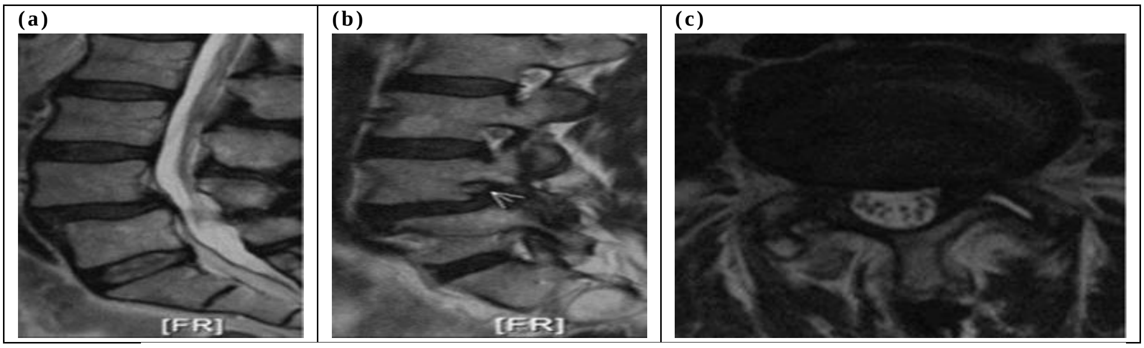

Figure (1): T2-weighted sagittal MRI images of DS at L4-L5 in midsagittal view (A), parasagittal view (B) and axial view at the slip level (C). Foraminal stenosis with diminished fat surrounding the nerve root can be seen (B) (19).

T1-weighted imaging provides detailed information regarding anatomical structures of foremost soft tissues, and pathology within these, while T2-weighted images are best to visualize the spinal canal and foraminal recesses **(20)**.

The cross-sectional dural sac area and AP diameter of the dura are best evaluated at axial T2-weighted images while parasagittal images can display nerve root entrapment by osteophytes, or protruding disc, at the level of the foramina **(Fig. 2)**. Diminished fat surrounding the root in the foramina is a qualitative parameter indicating foraminal stenosis affecting the nerve root **(24).**

The positive sedimentation sign in which the nerve roots are “floating” within the dural sac as opposed to, due to gravity, being packed together within the posterior aspect of the dura on supine axial MRI images **(Fig. 38)**. This sign, the absence of nerve root sedimentation, has been reported to be associated with symptoms of lumbar spinal stenosis **(25).**

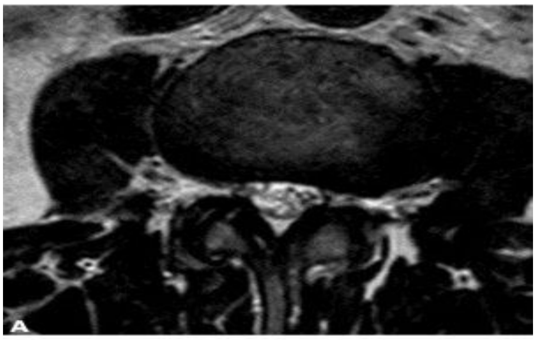

Figure (2): T2-weighted axial MRI images illustrating the positive sedimentation sign at the DS slip level (A) as compared with a superior spinal level with nerve root sedimentation (24).

The development of open MRI systems provides new opportunities to image the spine in various positions (standing, sitting, flexion/extension). Both axial loading during MRI (alMRI) and upright MRI have, similar to functional radiographs, been reported to reveal/increase DS slip as compared to in the supine position **(26)**.

The cross-sectional dural area compared with recumbent MRI without load and MRI performed in a sitting position can reveal anterolisthesis to a greater extent and in more patients as compared to supine MRI **(27).**

The change of MRI position, from supine to upright, influenced spinal changes like disc herniations, spinal stenosis, sagittal translation and lumbar lordosis angle in 4305 low back pain patients. 1178 of these patients had a sagittal translation (> 3 mm) on either supine or upright MRI. Upright MRI revealed significant alterations, defined as the appearance of, or an increase of changes between the positions, in 715 of these 1178 patients **(28)**.

These MRI techniques provide an excellent opportunity to investigate the effect of kinematics on spinal structures, thus having the potential to add clinical useful information for individual DS patients. However, as with functional radiographs, the evidence is insufficient to recommend for or against routine functional MRI **(25).**

It is crucial to recall that it is not a question of whether increased slip can be proven with either method, but rather if this information adds to the clinical decision-making regarding treatment. Prospective, appropriately powered studies are warranted to better assess the utility of functional MRI in the detection and evaluation of stenosis in the setting of DS **(27).**

3-Computed Tomography (CT) and degenerative spondylolithesis:

With development of the MRI technique, providing more detailed anatomic information without radiation, the value of computed tomography (CT) with regard to DS has diminished **(Fig. 3)**. CT may however still be of value, primarily to assess details regarding bony structures such as degenerative changes of the facet joints and bony spurs protruding into the spinal canal causing central and forminal narrowing **(28).**

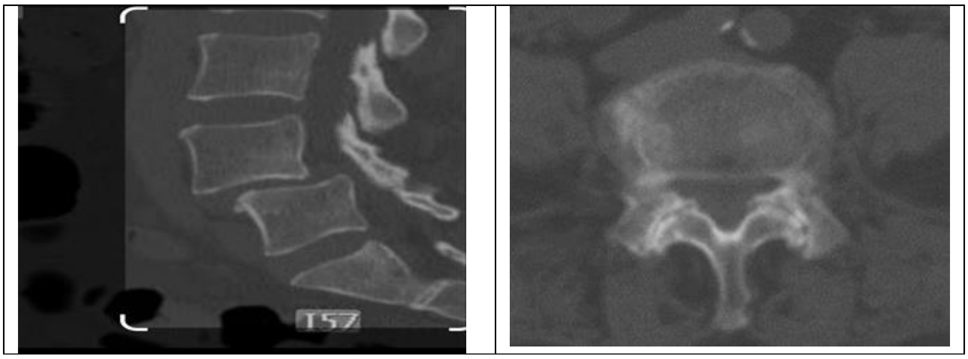

Figure (3): Axial & sagittal CT image at the level of DS slip, illustrating facet joint osteoarthritis with osteophytes (28).

In patients with contraindications for MRI, in whom clinicians suspect DS with accompanying spinal and/or foraminal stenosis, CT myelography is recommended. CT myelography may also be valuable postoperatively, when artifacts from surgical hardware often restrict the MRI assessment. High radiation exposure, the former drawback of CT, has decreased since both hardware and software CT equipment are continuously developing. Therefore "low dose CT protocols," which decrease the radiation dose without sacrificing image quality, might become potential tools to evaluate spinal biomechanics, since they provide the possibility to obtain spinal images in three-dimensions with high resolution **(29).**

4- Electrodiagnosis:

Electrodiagnostic studies including, nerve conduction studies (NCS), needle electromyography (EMG), and somatosensory evoked potential studies (SSEPs) should be considered an extension of the history and physical examination and not merely a substitute for a detailed neurologic and musculoskeletal examination. These studies are helpful in the evaluation of patients with limb pain where the diagnosis remains unclear (e.g. peroneal neuropathy versus radiculopathy). They are also helpful in excluding other causes of sensory and motor disturbances, such as peripheral neuropathy and motor neuron disease. They can also provide useful prognostic information by quantifying the extent and acuity of axonal involvement in radiculopathies **(30).**

5- SSEPs:

Somatosensory evoked potential (SSEP) studies are of limited value in the assessment of acute low back pain and radiculopathy. They are not indicated unless there are neurologic signs and symptoms suggestive of pathology, which would indicate involvement of the somatosensory pathways. Some have found dermatomal and motor evoked potentials helpful in the diagnosis of spinal stenosis, but these are not routinely employed in clinical practice **(31).**

Management of degenerated lumbar spondylolisthesis

The surgical approach that should be used for degenerative spondylolisthesis (DS) is a controversial issue. Decompression and posterolateral fusion (PLF) with or without lumbar interbody fusion is widely used. Many studies have compared the outcomes of these 2 approaches, but the appropriate indications for these approaches are still unclear. The authors retrospectively studied the effects of posterior lumbar interbody fusion (PLIF) after PLF for the treatment of DS **(32)**.

Interbody fusion strategies continue to evolve, improving surgical success rates and reducing morbidity. Open approaches such as anterior lumbar interbody fusion (ALIF), posterior lumbar interbody fusion (PLIF), and transforaminal lumbar interbody fusion (TLIF) have been reported to have high rates of success, although intraoperative concerns and iatrogenic complications are known **(33)**.

- **Unilateral pedicle screw fixation system:**

Lumbar spinal fusion is a common and effective surgical procedure for the treatment of degenerative lumbar diseases (DLD), such as spondylolisthesis, lumbar spinal canal stenosis associated with deformities, or discogenic pain identified by provocative discography **(34)**.

The goal of lumbar fusion surgery is to regain a solid arthrodesis of spinal segments while restoring disk height, immobilizing the unstable segment, and restoring load bearing to anterior structures **(35)**.

Generally, pedicle screw fixation (PSF) can effectively improve bone fusion rate and correct lumbar alignment **(36).**

Although spinal fusion with pedicle screws is widely performed, there is controversial about the need for instrumentation with spinal fusion procedures. Traditionally, bilateral PSF is considered as a widely accepted method for the treatment of a variety of spinal diseases **(37)**.

This standard procedure provides both biomechanical and clinical advantages . However, due to the excessive rigidity of bilateral PSF, this instrumentation is suspected to cause the reduction of bone mineral content and degeneration of adjacent segments **(38)**.

Aiming to decrease the rigidity of internal fixation, the unilateral construct seems to be more attractive because it avoids soft tissue disruption of the contralateral side, may take less time, and can be associated with lower implant costs (**37**).

The effectiveness of unilateral fixation as compared to bilateral fixation in lumbar fusion has been frequently investigated in previous studies (**35-38**).

Biomechanical studies have shown that unilateral fixation provided less rotational stability and stiffness than bilateral pedicle screw fixation **(39,40**). However, previous studies involving clinical outcomes have showed good and similar functional results and fusion rates between the 2 methods after spinal fusion (**41,42).**

Transforaminal lumbar interbody fusion (TLIF) was originally described by Harms and Rolinger (**43**). It has turn out to be one of the ordinary standard techniques for the decompression of the ipsilateral foramen and an appropriate interbody fusion. This procedure is frequently accompanied by the placement of bilateral transpedicular screws in the corresponding segment; this results in immediate rigid segment stabilization that will last while fusion takes places **(44**).

Some authors have proven that excessive stiffness of such a construct can jeopardize the fusion process due to graft resorption that is in hand due to the lack of stress against end plates (**45**).

Scientific evidence in the literature has established that unilateral transpedicular screw fixation, right after fusion, produces radiological results comparable with bilateral fixation: this is done at a lower cost because less amount of implants is used **(46)**.

Minimally invasive transforaminal lumbar interbody fusion was originally described **(47)**. Which is why the absolute requirement for contralateral pedicle fixation to minimally invasive transforaminal lumbar interbody fusion is, therefore, controversial **(44**).

Unilateral pedicle screw fixation as a complement to a minimally invasive transforaminal lumbar interbody fusion has been described **(48)**.

Theoretical advantages of this unilateral paramedian posterior approach include a decrease of blood loss, faster surgery procedure, reduced radiation dose, and of course the preservation of the contralateral posterior articular process. It also has similar radiographic fusion rates than open TLIF and a predisposition to yield better clinical results in the immediate postoperative period **(49)**.

Lumbar fusion combined with unilateral pedicle screw fixation has received favorable clinical reports. However, there are very few reports about the biomechanical properties of this system. In the study of Kasai et al.**(50)** revealed that the results of a bending test demonstrated the excellent fixation achieved by the bilateral PS system in all bending directions.

Conversely, in the unilateral PS (pedicle screw) system, the ROM decreased in the direction of PS insertion (oblique front left and oblique back right directions. But barely decreased in the diagonal direction to that of PS insertion (oblique front right and oblique back left directions). These results suggest that the unilateral PS system caused dispersion in rigidity depending on the direction of bending, and that rigidity is particularly weak in the diagonal direction to that of PS insertion. Use of an intervertebral spacer slightly decreased the ROM of flexion, but the ROM of extension and right-side and left-side bending increased slightly, indicating that the intervertebral spacer is hardly involved in the rigidity of movements other than flexion **(50)**.

Rotation testing indicated a considerable decrease in ROM (range of motion in both right and left directions, thus the bilateral PS system has excellent rigidity in rotation. Conversely, ROM in the counterclockwise direction slightly exceeded that in the clockwise direction, indicating that rigidity differs slightly between clockwise and counterclockwise directions for a unilateral PS system. When an intervertebral spacer was used, the ROM in both directions increased slightly, indicating that the intervertebral spacer is hardly involved in rigidity to clockwise and counterclockwise directions **(51).**

ROM of a unilateral PS system in flexion–extension and right-sided and left-sided bending was 1.5 to 2 times higher than that of the bilateral PS system, and slight differences in ROM were observed between counterclockwise and clockwise directions in the rotation test. Results thus indicate that fixation is less rigid in a unilateral PS system compared to a bilateral PS system. Thus, the unilateral pedicle screw system offers only uneven fixation. This results in dispersion of rigidity depending on the direction of bending and rotation. The bilateral pedicle screw system, however, allows excellent fixation in all directions **(52).**

The ROM (range of motion) after loading on FSU (functional spinal unit) fixed with a unilateral PS (pedicle screw) system. The ROM was approximately double in flexion–extension, approximately double in right-and left-side bending and about 1.4-fold larger in clockwise counterclockwise rotation compared to the values obtained using a bilateral PS system. Thus, the unilateral PS system was a less-rigid fixation method **(53).**

A bending and rotation test of flexion–extension and right-sided and left-sided bending, and reported that fixation by the unilateral PS system was slightly weaker than that of the bilateral PS system in all directions (flexion–extension, right-sided and left-sided bending and clockwise counterclockwise rotation), with fixation being weaker particularly in the rotary direction **(54).**

CONCLUSION:

Degenerative spondylolisthesis is the second most common form of spondylolisthesis in adults and affects the L4-L5 level most frequently. It may affect multiple levels and is at least five times more common in women. It is also more common when the last formed level is fixed to the pelvis.

Lumbar interbody fusion is a recognized surgical technique in treatment of degenerative lumbar instability. Interbody fusion supplemented with pedicle screw fixation has several advantages over posterolateral fusion and has been advocated to improve fusion rates and clinical outcomes.

No conflict of interest.

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