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THE IMPORTANCE OF THE SAGITTAL BALANCE OF THE SPINE AND SPINOPELVIC PARAMETERS

OMURGADA SAGİTTAL DENGENİN ÖNEMİ VE SPİNOPELVİK PARAMETRELER

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SUMMARY

This article explains the significance of the sagittal balance of the spine and the associated spinopelvic parameters. Here, the parameters related to spinal sagittal balance are the C7 plumb line, gravity line, pelvic incidence, sacral slope, and pelvic tilt angle. Degenerative spondylolisthesis, isthmic spondylolisthesis, lumbar disc herniation, pedicle subtraction osteotomy and posterior lumbar interbody fusion (PLIF) were evaluated as clinical manifestations, with spinopelvic parameters.

Key Words: Sagittal balance, spinopelvic parameters, pelvic tilt, sacral slope, pelvic inclination.

Level of Evidence: Review article, Level V.

ÖZET

Bu makalede omurgada sagittal dengenin önemi ve sagittal denge ile bağlantılı olan spinopelvik parametrelerden bahsedilmektedir. Omurgadaki sagittal denge ile ilişkili anlatılan parametreler; C7 şakül hattı, ağırlık çizgisi hattı, pelvik insidans, sakral eğim, pelvik eğim açılarıdır. Dejeneratif spondilolistezis, istmik spondilolistezis, lomber disk hernisi, pedikül substraksiyon osteotomi ve posterior lomber interbody füzyon (PLIF) klinik tabloları spinopelvik parametreler eşliğinde değerlendirilmiştir.

Anahtar Kelimeler: Sagittal denge, spinopelvik parametreler, pelvik insidans, sakral eğim, pelvik eğim.

Kanıt Düzeyi: Derleme, Düzey V.

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INTRODUCTION

The sagittal balance of the spine is the mutual harmony of cervical lordosis, thoracic kyphosis, and lumbar lordosis. In a balanced spine, a vertical line drawn downwards from the C7 vertebra is called the sagittal vertical axis (SVA), or plumb line, and passes from the upper edge of the posterior of the sacrum in a standing position. The center of the body mass is in front of the thoracic vertebrae, close to the lumbar region in a standing position. A vertical line, drawn from here downwards (gravity line), merges with the ground through the heel, passing through the sacral second vertebral alignment and the center of the femoral head. Therefore, a person can stand straight by taking support from the ground (Figure-1).

Figure-1. Vertical gravity line drawn from body mass center downwards tracks the legs by passing through the sacral second vertebral alignment and femoral bone head, and reaches the ground with the feet as support points. The plumb line is the vertical line that is tangent to the front of C7 in a balanced vertebra, and passes through the posterior of the sacral plate[1].

In a spine with sagittal balance, these two lines are always in harmony. Normally, the gravity line is found in front of the plumb line. If we look down upon a person with normal sagittal balance with these two lines in harmony, the projection of the head remains inside the pelvis. In pathological cases where the sagittal balance is disrupted, sagittal balance is attempted to be regained by adjusting the plumb line and gravity line, and if this harmony cannot be provided then sagittal imbalance occurs (Figure-2)[14].

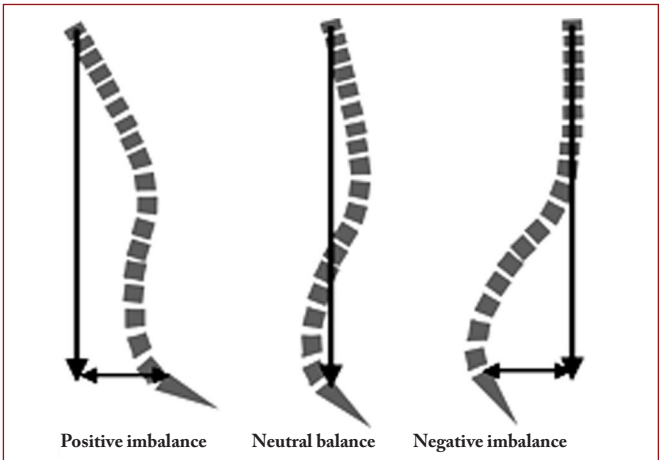

Figure-2. If the plumb line passes in front of the postero-superior edge of S1, this is positive sagittal imbalance. If it passes from the postero-superior edge of S1, this is neutral sagittal balance. If the line passes from the back of the postero-superior edge of S1, this is negative sagittal balance[10].

With disruption of a systemic or functional unit, compensation mechanisms develop to regain sagittal balance after changes in the spine. When the spine starts to change its form on the pelvis, compensatory changes occur in the pelvis in an attempt to regain sagittal balance. These changes in the spine are evaluated according to spinopelvic parameters[11,14].

In 1984, Dubousset focused on the relationship between the spine and the pelvis and spinopelvic balance using his definition of pelvic vertebrae[2]. In 1985, During et al. defined thepelvisacral angle[4]. While Legaye et al. defined the pelvic incidence angle (PI) with the Duval-Beaupère method[10], Jackson et al. developed the measurement of lumbar lordosis for morphological evaluation of the pelvis with the pelvic radius technique in 1998 [7]. In 2006,

Roussouly stated that different variations of the spine are present in a significant part of the population, and emphasized that it is important to have a posture with harmony of the pelvis and the spine[14].

SAGITTAL BALANCE AND SPINOPELVIC PARAMETERS:

In sagittal balance, thoracic kyphosis and lumbar lordosis are in mutual harmony. In this harmony, the relationship between the pelvis and the spine is called spinopelvic balance. Although the importance of the contribution of spinopelvic balance to global sagittal balance was not initially noticed, spinopelvic parameters have begun to be used more frequently by considering the effect of pelvic morphology and the pelvis on global sagittal balance in recent years[13,18]. The line that passes through C7 and the postero-superior edge of S1 and is vertical to the horizontal plane is called the sagittal vertical axis (SVA). If the SVA is between 2 cm anterior or posterior of the postero-superior edge of the sacrum, this means that the spine is sagittally balanced[3]. If the plumb line passes in front of the postero-superior edge of S1, a positive sagittal imbalance is present. If it passes through the postero-superior edge of S1, this is neutral sagittal balance, and if it passes behind the postero-superior edge of S1, a negative sagittal balance is present[6]. The most important spine angles in sagittal balance are the cervical and lumbar lordosis and thoracic kyphosis angles (Figure-3).

Lumbar Lordosis:

This is the angle between a line vertically drawn to the line passing through the L1 upper end plate and a line vertically drawn to the line passing through the sacral end plate. When normal lumbar lordosis at the L3–4 level is accepted as the peak point, it is between 40–70° (Figure-4).

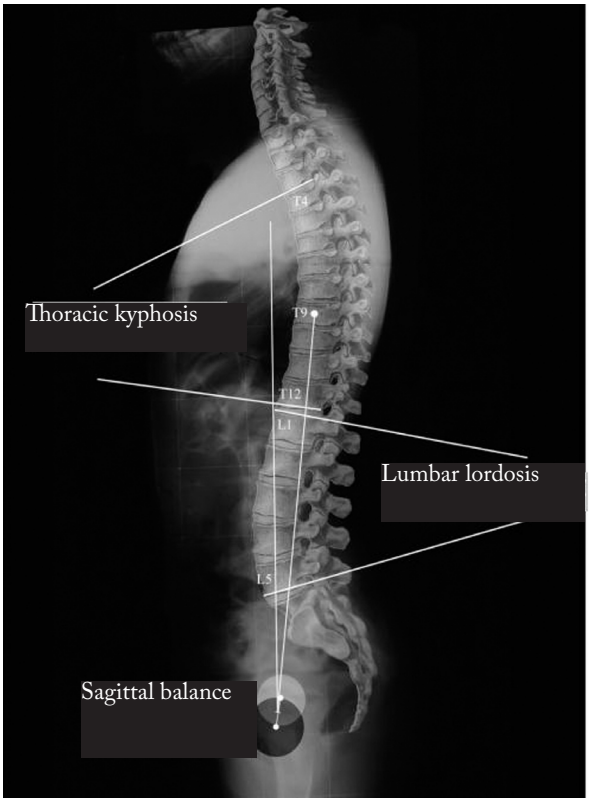

Figure-3. Sagittal balance showing harmony between thoracic kyphosis and lumbar lordosis[7].

Thoracic Kyphosis:

This is the angle between a line vertically drawn to the line passing through the T4 upper end plate and a line vertically drawn to the line passing through the T12 lower end plate. When T7 is accepted as the peak point, the thoracic kyphosis angle was detected as between 20–50°, on average (Figure-4).

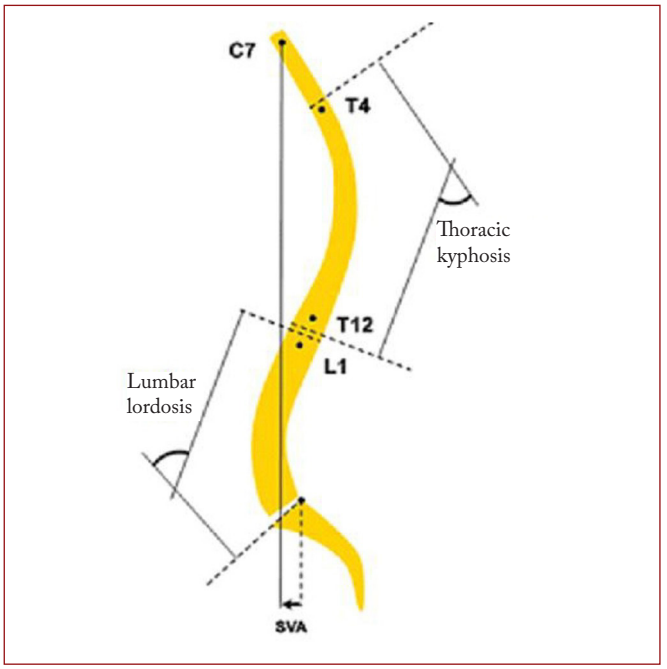

Figure-4. Thoracic kyphosis and lumbar lordosis angles, sagittal vertical axis (SVA)[11].

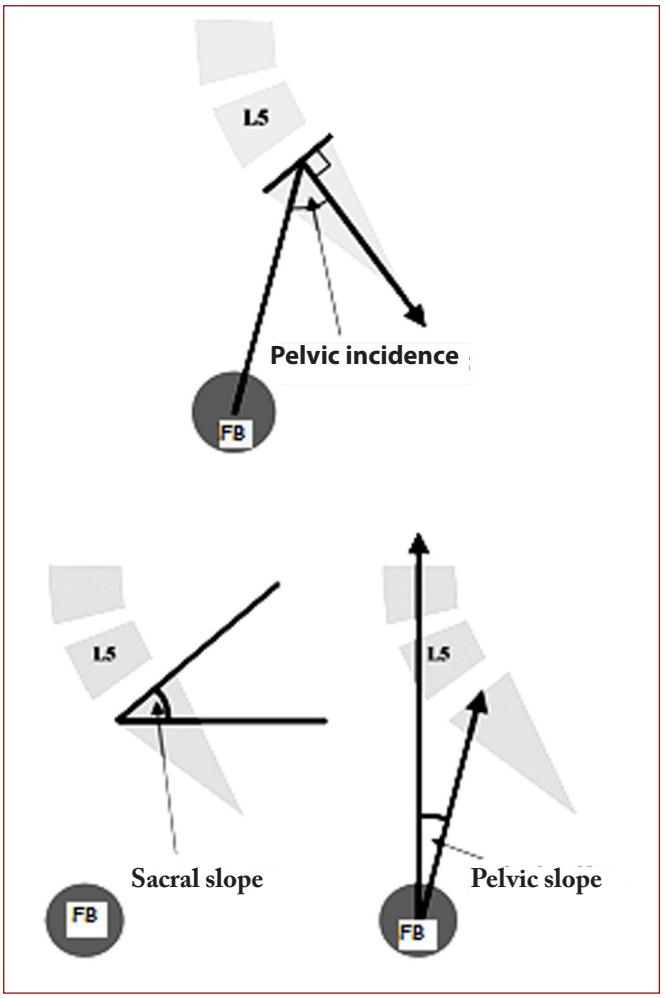

Figure-5. Pelvic incidence, sacral slope and pelvic slope angles, FB: femoral head[10].

Cervical Lordosis:

In evaluations in which C4 is accepted as the peak point, the cervical lordosis angle has been detected between 25–50° [3]. In the Duval-Beaupère method, the most important parameters providing sagittal plane balance in the pelvis are the pelvic incidence, the sacral slope angle (sacral slope), and the pelvic slope angle (pelvic tilt).

Pelvic Incidence:

This is the angle between a vertical line passing the midpoint of the upper sacral end plate and a line connecting the femoral head to this midpoint (Figure-5).

Sacral Slope:

This is the angle between a line drawn from the upper sacral end plate and a horizontal line drawn from the midpoint of the upper sacral end plate (Figure-6).

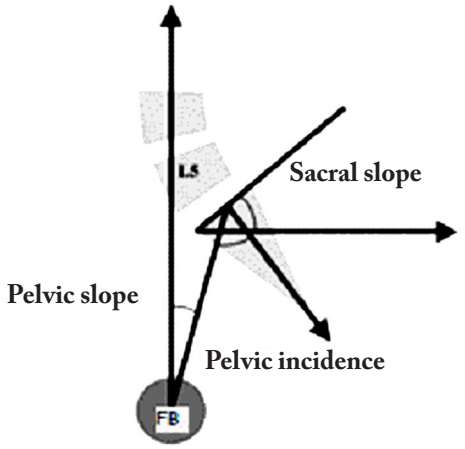

Figure-6. Spinopelvic parameters[10].

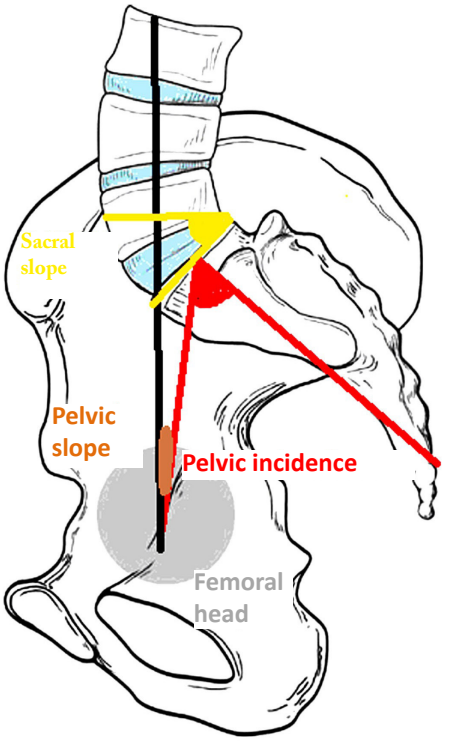

Figure-7. Pelvic incidence = sacral slope + pelvic slope[9].

Pelvic Slope (Pelvic Tilt):

This is the angle between a vertical line passing though the femoral head axis and a line connecting the femoral head axis to the midpoint of the sacral end plate[6]. The pelvic incidence (PI) is the most important measurement among the pelvic parameters, and is also called the pelvisacral angle. The pelvic incidence is a permanent morphological parameter of the pelvis that does not change after adolescence. As PI increases from childhood, lumbar lordosis develops and the sacrum becomes more horizontal.

Sacral slope and pelvic tilt are the positional parameters that vary according to the pelvic position. The pelvic incidence angle is the sum of the pelvic tilt and sacral slope angles(Figure-7)[13].

Compensatory changes in the sacral slope and pelvic slope angles according to the pelvic position ensure the pelvic incidence angle remains stable[13].

In many studies, a correlation has been detected between the pelvic incidence, lumbar lordosis and sacral slope in the normal population[8,17]. When the pelvic incidence angle is low, lumbar lordosis decreases. If the pelvic incidence angle is high, there is an increase in lumbar lordosis and a decrease in thoracic kyphosis (Figure-8)[5,9].

As the pelvic incidence increases, the spine and pelvis show compensatory effects to provide sagittal balance. This is provided by an increase in the pelvic tilt and lumbar lordosis and a decrease in the sacral slope, known as pelvic retroversion[5].

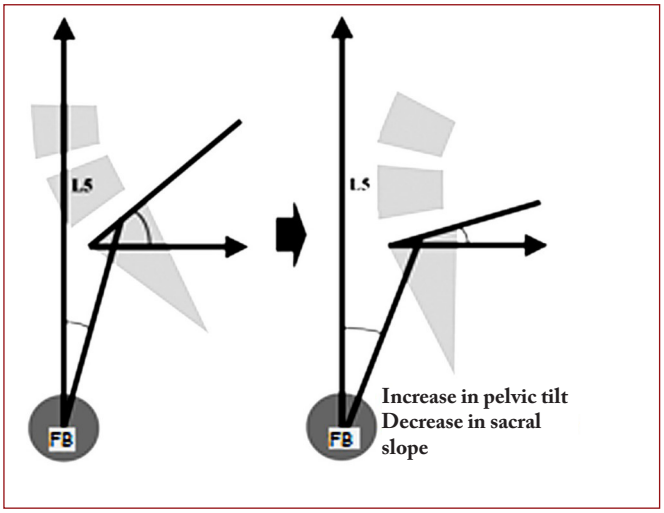

Figure-8. Pelvic retroversion: an increase in pelvic incidence is compensated by pelvic tilt increase and sacral slope decrease.

In a study conducted by Mehta et al., while the average pelvic incidence angle was 48–55°, the sacral slope was 36–42° and the pelvic tilt was 12–18° in asymptomatic adults. The average lumbar lordosis was measured as 43–61° and thoracic kyphosis as 41–48° (Table-1)[13].

Table-1. Average spinopelvic angles[8]

Parameter	Degree
Pelvic incidence	48–55°
Sacral slope	36–42°
Pelvic tilt	12–18°
Lumbar lordosis	43–61°
Thoracic kyphosis	41–48°

In a study containing 709 asymptomatic volunteers, Roussouly evaluated the spinal form and angles[16]. Roussouly mainly defined four different types in the sagittal evaluation of the human spine. Lumbar lordosis in these types occurs in a manner dependant on the sacral slope. In his study, he reported the incidence rate of a type 1 spine as 5%, type 2 as 23%, type 3 as 47% and type 4 as 25%. Based on this study, it can be predicted which types of diseases can be observed in what types of spine. Roussouly named a spine without harmony the type 1 spine. In this type of spine, high pressure is applied to the posterior elements in lumbar region, and contact between the spinous processes can be observed. These changes increase the risk of formation of spondylolisthesis depending on hyperextension. Also, the risk of thoracolumbar discopathy formation is high in this type of spine. A type 2 spine has harmonic alignment but the person has a flat back condition. High pressure is applied to the discs in this spine, and the risk of early degeneration and disc herniation is high. A type 3 spine has the most harmonic alignment. However, the disc tissue collapses due to aging, and changes occur in this spine type. Type 3 can transform to type 1 or type 2 over time. A type 4 spine also has harmonic alignment and extreme lordotic alignment. In this type, load passage mainly occurs through the facet joints. Therefore, early facet arthropathies can be observed. The risk of formation of lumbar stenosis and spondylolisthesis is higher in this type than in the other spinal types(Figure-9)[14,16].

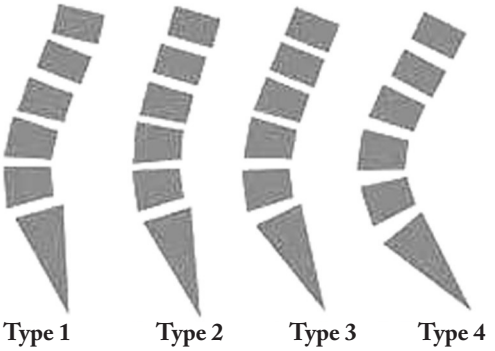

Figure-9. Roussouly classification.

CLINICAL IMPORTANCE OF SPINOPELVIC PARAMETERS:

The presence of abnormal spinopelvic parameters affects the formation and progression of pathologies such as lower back pain, lumbar disc hernia, degenerative disc disease, degenerative and isthmic spondylolisthesis, and hip osteoarthritis. In patients with deformities, the pelvic and spinal parameters are out of the normal ranges.

Degenerative Spondylolisthesis:

In patients with degenerative spondylolisthesis (DSPL), it was observed that the pelvic incidence angle was higher than in the normal population, lumbar lordosis increased, and the sacral slope angle was also high before shift and degeneration occur. Excessive load occurs on the posterior facet joints with the increased lumbar lordosis. This mechanical stress on the facet joints results in facet arthrosis. After facet arthrosis, the sacral slope is affected and a condition predisposing to shift occurs. Intervertebral disc degeneration and collapse follow the shift, and lumbar lordosis reduces. The decrease in lordosis causes a shift of the C7 plumb line towards the anterior of the gravity line. The sagittal vertical axis moves forwards. In cases with degenerative spondylolisthesis, pelvic retroversion with a decrease in the sacral slope angle and an increase in the pelvic tilt angle is observed as a result of compensatory mechanisms. A positive sagittal imbalance occurs due to the limitation of the pelvic retroversion mechanism(Figure-10)[12].

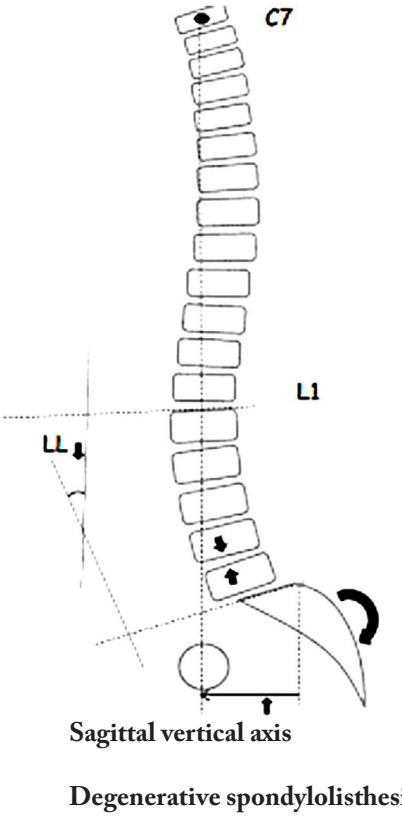

Figure-10. Degenerative spondylolisthesis[16].

Isthmic Spondylolisthesis:

In cases with isthmic spondylolisthesis (ISPL), there is increase in the pelvic incidence, pelvic tilt and lumbar lordosis angles compared with the normal population. The increase in the lumbar lordosis angle increases the load on the pars interarticularis, and spondylolysis and isthmic defects occur as a result of the mechanical stress on the posterior column. Pelvic tilt increases in a compensatory mechanism by pelvic retroversion. The sacral slope angle and sagittal vertical axis are observed in the normal range. Thus, the global sagittal balance is preserved (Figure-11)[12].

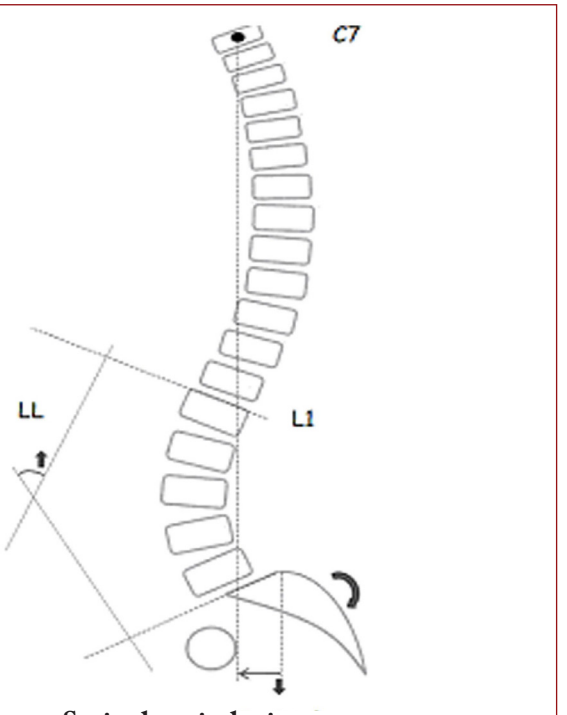

Figure-11. Isthmic spondylolisthesis[16].

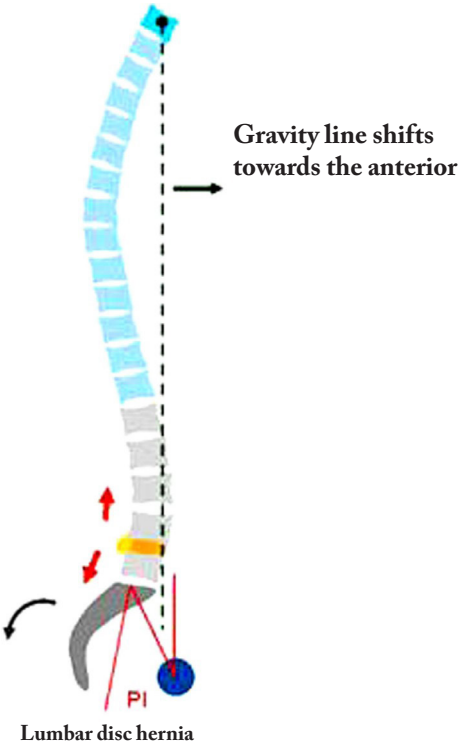

Figure-12. The gravity line shifts towards the anterior in cases with lumbar disc hernia[18].

Lumbar Disc Hernia:

When spinopelvic parameters are evaluated in cases with lumbar disc hernia, it is observed that the sacral slope angle is small, the sacrum is more vertical than in a normal population and there is a decrease in the lumbar lordosis. This results in greater compressive forces being applied to the discs, and progressive degeneration. Displacement of the gravity line towards the anterior causes spinopelvic instability, contraction in the posterior paravertebral muscles, and back pain[15]. In cases with lumbar disc hernia, planning should consider the spinopelvic parameters in the preoperative period to avoid a sagittal imbalance after surgery. It has been reported that interbody implants used to prevent intervertebral stenosis after discectomy could prevent the loss of lumbar lordosis (Figure-12)[1].

Pedicle Subtraction Osteotomy:

Pedicle subtraction osteotomy (PSO) is a method commonly used to regain sagittal balance in adult deformities. In adult spinal deformities, the spinopelvic parameters are closely related to provide global sagittal balance. In a study by Lafage et al., a correlation was found between the PSO degree and degree of correction of the spinopelvic parameters. In postoperative measurements, a notable increase in the lumbar lordosis and thoracic kyphosis is observed after the application of PSO. While the pelvic incidence value remains the same, the pelvic retroversion decreases due to a decrease in the pelvic tilt, and the sagittal vertical axis also decreases as a result of this change (Figure-13)[8].

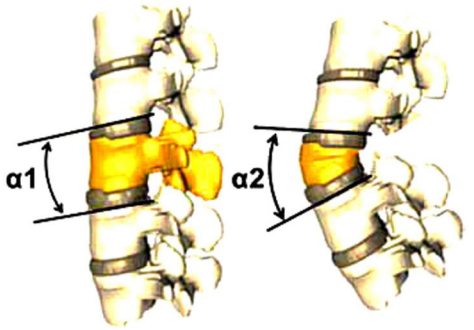

Figure-13. Lumbar lordosis increases after pedicle subtraction osteotomy, α2 > α1[19].

Posterior Lumbar Interbody Fusion (PLIF):

In a study carried out by Feng et al., it was reported that the pelvic incidence, pelvic tilt, sacral slope and lumbar lordosis angles were higher in isthmic spondylolisthesis cases than in a control group from an asymptomatic normal population. Changes in the shift degree and intervertebral spaces with isthmic spondylolisthesis show a correlation with an increase in lumbar lordosis. After the application of PLIF, a significant decrease in the pelvic tilt angle was observed in the patients (Figure-14).

The change in the pelvic slope is effective in the formation of sagittal balance and obtaining positive results in surgical treatment. The cage sizes and forms to be used should be carefully chosen by evaluating the spinopelvic parameters, in order to regain the proper lumbar lordosis and normal intervertebral disc space after surgery[4].

CONCLUSION:

To know the form and position of the pelvis and the morphology of lumbar lordosis are the main points in the treatment of lower back pain. In pathologies such as lumbar disc hernia, degenerative disc disease, and degenerative and isthmic spondylolisthesis, changes in the spine and pelvis due to compensatory mechanisms cause resistant pain development and a deterioration in the quality of life.

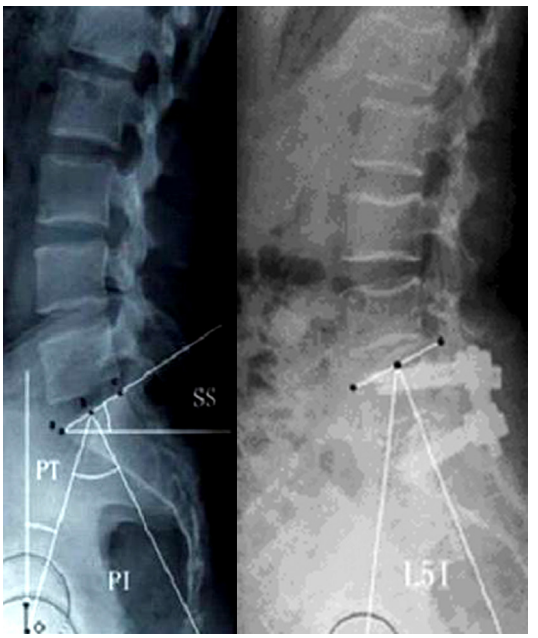

Figure-14. Spinopelvic parameters before and after posterior lumbar interbody fusion surgery[19].

After surgery, if the necessary lumbar lordosis and spinopelvic consistency are not provided to regain the sagittal balance, screw fracture, pseudoarthrosis, or flat lower back condition will occur in patients due to sagittal imbalance, and the expected positive results of surgical treatment will not be obtained.

In spine pathologies, spine surgeons should keep in mind that the spinopelvic parameters should be carefully evaluated before surgery, and the surgical processes should be performed to provide sagittal balance in the postoperative period.

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