# Kyphosis: Diagnosis, Classification and Treatment Methods

## *Kifoz: Tanı, Gruplama ve Tedavi Yöntemleri*

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**ABSTRACT**

A Cobb angle measurement, the angle between upper end plate of T5 and lower end plate of T12, higher than 40 degrees known as kyphosis. Although various etiologies cause kyphosis, the best-known form, Scheuermann's kyphosis causes disorder in sagittal balance. Surgery should be considered for persistent pain despite conservative treatment, progressive neurological deficits and cosmetic reasons. For this purpose, correction osteotomies have to be performed to provide spinal alignment and to maintain sagittal balance.

**KEYWORDS:** Deformity, Kyphosis, Sagital balance, Osteotomy

**ÖZ**

T5 üst uç plağı ile T12 alt uç plağı arasındaki Cobb açı ölçümünün 40 dereceden daha fazla olmasına kifoz denir. Çeşitli nedenlere bağlı olarak kifoz görülse de en iyi bilinen şekli ile Scheuermann Kifozu sagital dengede bozukluğa neden olmaktadır. Konservatif tedaviye rağmen geçmeyen ağrı, ilerleyici nörolojik defisit yada kozmetik nedenlerle cerrahi düşünülmelidir. Bu amaçla hastaya uygun olan düzeltme osteotomileri ile omurganın dizilimi sağlanarak bozulan sagital denge yeniden kurulmaya çalışılır.

**ANAHTAR SÖZCÜKLER:** Deformite, Kifoz, Sagital denge, Osteotomi

### KYPHOSIS

#### *Diagnosis, Classification and Treatment Methods*

Kyphosis refers to the condition when the thoracic spine curves is outside of the normal range. The angle of the thoracic curve is measured by the Cobb angle. The Scoliosis Re-search Society (SRS) reported values ranging between 10 to 40 degrees in the angle measurements between the upper end plate of T5 and the lower end plate of T12 (27). Boulay found values ranging from 33.2 to 83.5 degrees measured by using actual Cobb angles (angle between the superior end plate of the upper end cranial vertebrae with the biggest curvature and the inferior end plate of the lower end vertebrae with the biggest curvature) (7). Thoracic kyphosis occurs predominantly in males compared to females (9.6%).

The sagittal alignment of the spine is always changing from birth to old ages. The whole spine remains in the kyphotic posture extending from the occiput to the sacrum at birth; whereas when one starts standing in the upright posture, first lordosis occurs in the lum-bar region and then kyphosis occurs in the thoracic region.

The degree of kyphosis is divided into two types: low degree (such as postural round-back) and high degree (angular gibbus deformity, congenital kyphosis, Pott disease and best known form which is Scheuermann).

### ETIOLOGY of KYPHOSIS

Kyphosis may be secondary to a trauma; while congenital and developmental anomalies may also cause kyphosis. The etiologies of kyphosis include degenerative disc disease, inflammatory diseases, infectious diseases, muscular and neuromuscular diseases, muscu-lar dystrophy, spinal muscular atrophy, myelomeningocele, neurofibromatosis, Paget's disease, spinal tumors and post-surgical iatrogenic causes.

#### *1. Scheuermann Kyphosis (Juvenile kyphosis)*

Scheuermann disease also known as 'Osteochondritis deformans juvenilis dorsi' was de-fined for the first time by the Danish radiologist Holger Werfel Scheuermann. It is characterised as a rigid kyphosis predominantly in young adults caused by the osteochondritis of the secondary ossification centres (34). It usually occurs in the lower thoracic and upper lumbar regions. This might affect not only a few spinal segments but also the whole spine. It occurs predominantly in children between 13 and 16 years of age. Patients are usually taller than their peers (16). Its incidence in the USA is 0.4-8%. It occurs more of-ten in boys than in girls by 2/1-7/1.

Scheuermann Disease was reported to be caused by the disturbances in the vertebral epi-physeal growth (34). There is a 'growth deficiency' in some parts of the bone rather than a destruction. Bone structure was reported to have large amounts of proteoglycans and low amounts of collagen.

Anterior part of the vertebrae is less resistant to loads than the posterior part, which increases kyphosis further and causes a vicious cycle.

Sorenson proposed the initial criteria for the diagnosis of the Scheuermann Disease (36):

1. More than 5 degrees of wedging of at least 3 adjacent vertebrae
2. Kyphosis of more than 40 degrees in the sagittal plane.
3. Vertebral endplate irregularities.
4. Although Scheuermann's Disease usually occurs in the thoracic region (classic type); Edgren et al. also reported an atypical form of this disease in the lumbar region (14). Scheuermann's Disease Classification was finalised based on the contribu-tions of Blumenthal (5, 14) (Table I).

The most common symptoms of Scheuermann's Disease are pain and deformity. Pain usually occurs on the apical area after sitting for a long time and due to motion. Pain also decreases when growth stops. People with Type 2 Scheuermann kyphosis feel more pain than those with Type 1. Deformity is usually recognised during school age. Lumbar lor-dosis and cervical lordosis may increase to balance the kyphosis.

Treatment of patients with Scheuermann Kyphosis depends on the degree of kyphosis and the maturity of the patient. Risser Sign and Greulich-Pyle Atlas are the main methods used to assess maturity (Figure 1) (18). Risser Sign shows the ossification of the iliac crest apophysis from lateral to medial. Iliac crest is divided into 4 equal quadrants. Risser 5 shows that iliac apophysis fuses to the iliac crest. Risser 4 indicates the cessation of spinal growth, while Risser 5 indicates the cessation of height increase. Brace wear and physical therapy should be proposed for adolescent patients with 55-degree thoracic ky-phosis or 40-degree thoracolumbar kyphosis until they reach maturity (31). Braces should be used longer than 20 hours a day, while brace wear should be continued for a minimum of 18 months. Brace wear can be reduced to 12-14 hours a day during the period when a correction of kyposis is achieved. Thoracolumbosacral orthosis should be preferred as the brace type to be used.

The absolute and only indication for surgery in Scheuermann disease is the neurological deficit arising due to the thoracic disc or pathology. Other surgical indications are relative. Surgical indications for Scheuermann's Disease are summarized in Table II (Figure 2,3).

***2. Post1aminectomy Kyphosis***

Postoperative spinal deformities might develop on the sagittal plane following the lami-nectomy performed for decompression or as an approach due to various pathologies. Such deformities develop more commonly after the neoplasic lesions including especially intramedullary lesions compared to the laminectomy performed to treat stenosis caused by degenerative spinal diseases. If neoplasia causes bone destruction, intraoperative iat-rogenic damage will increase the likelihood of deformity (Figure 4).

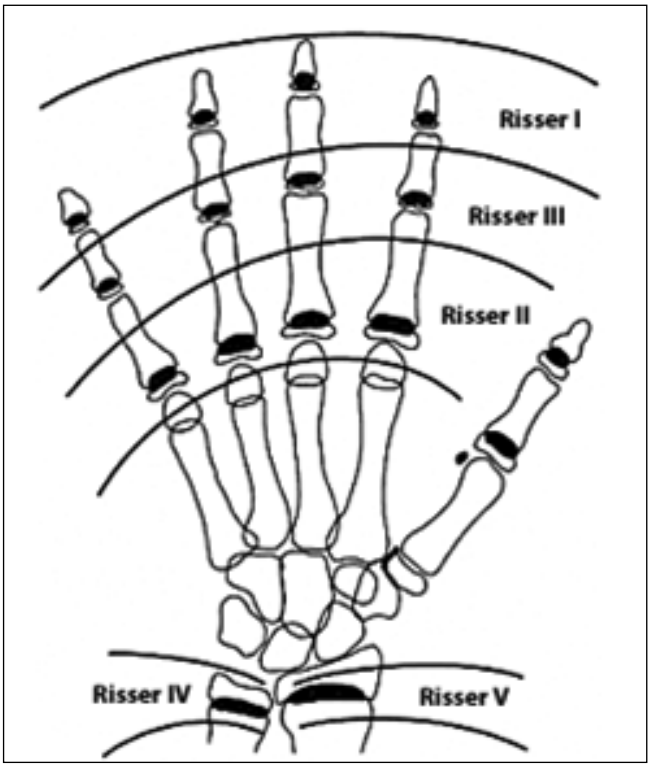


**Figure1:** Risser Sign assessment of wrist and hand maturation.

**Table I:** Scheuermann Classification

| |
|---|
| **Type 1 (Classic)** |
| More than 5 degrees of wedging of at least one or more adjacent vertebrae in the thoracic or thoracolumbar region |
| End plate irregularities |
| Narrowing of the disc space |
| Thoracic or thoracolumbar kyphosis |
| **Type 2 (Lumbar) Atypical** |
| Endplate irregularities in the lumbar or thoracolumbar region |
| Increased sagittal diameters of the vertebral bodies |
| Reduction in the disc space |

**Table II:** Surgical Indications for Scheuermann Kyphosis

| Certain indication | Relative indication |
|---|---|
| Progressive neurological deficit | Progressing curves |
| | Failed non-surgical pain treatments |
| | Thoracic curve greater than 80 degrees |
| | Thoracolumbar curves greater than 65 degrees |

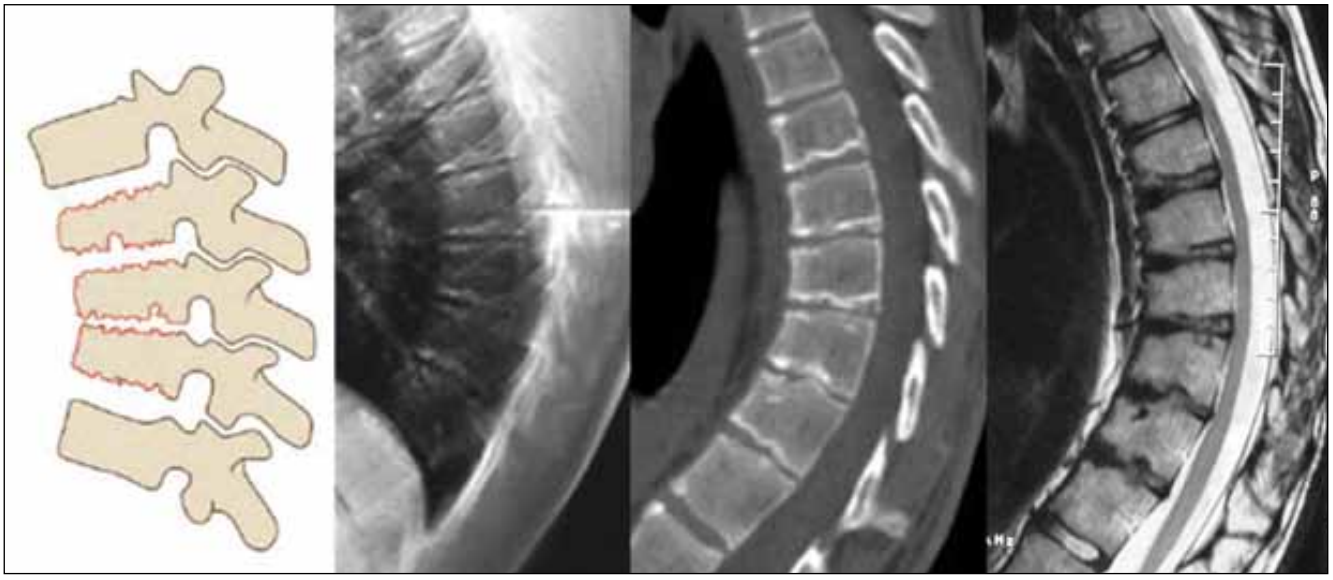

**Figure 2:** Radiological findings of Scheuermann's Disease: Endplate irregularities, vertebral wedging, vertebral body elongation, narrowing disc space. Direct radiography, CT and MRI.

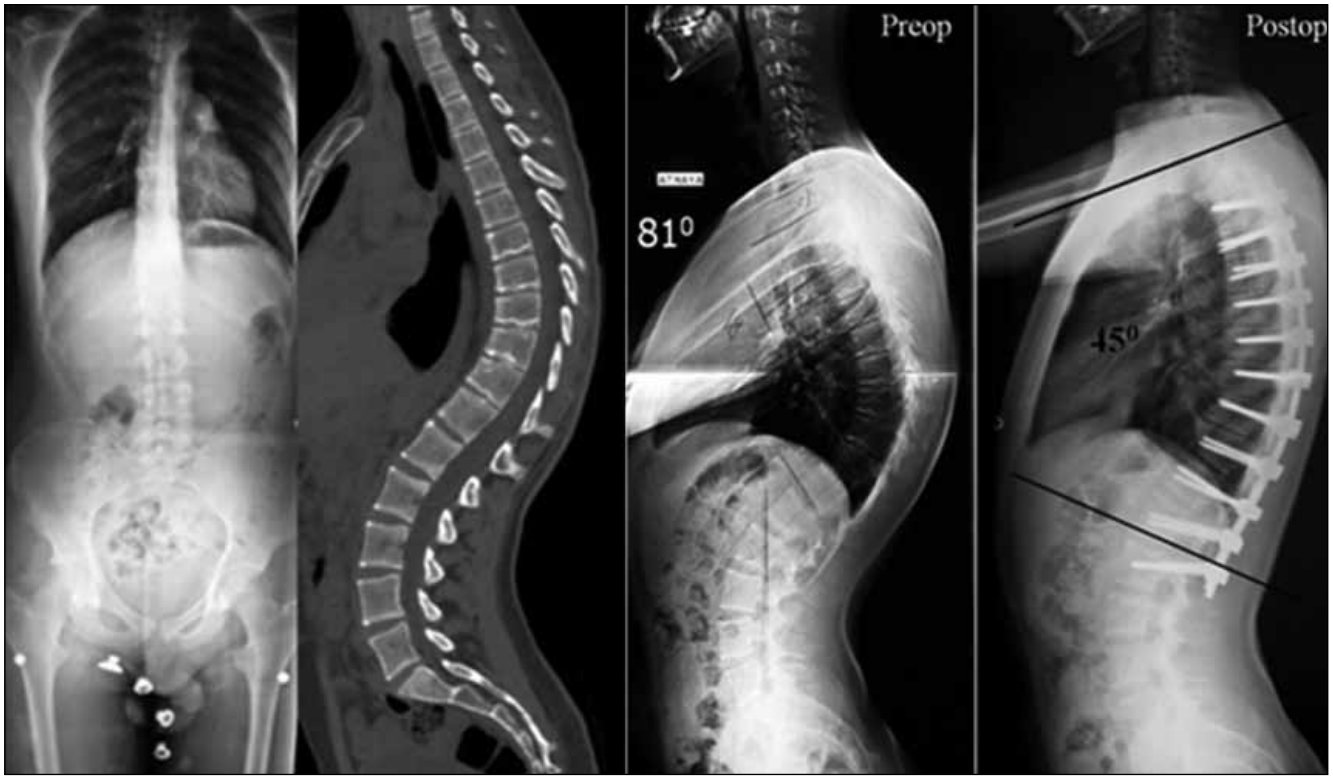


**Figure 3:** 16-year old male patient with Scheuermann kyphosis presenting with progressive thoracic kyphosis and back pain. Preoperative 81-degree kyphotic angle was reduced to 45 degrees postoperatively.

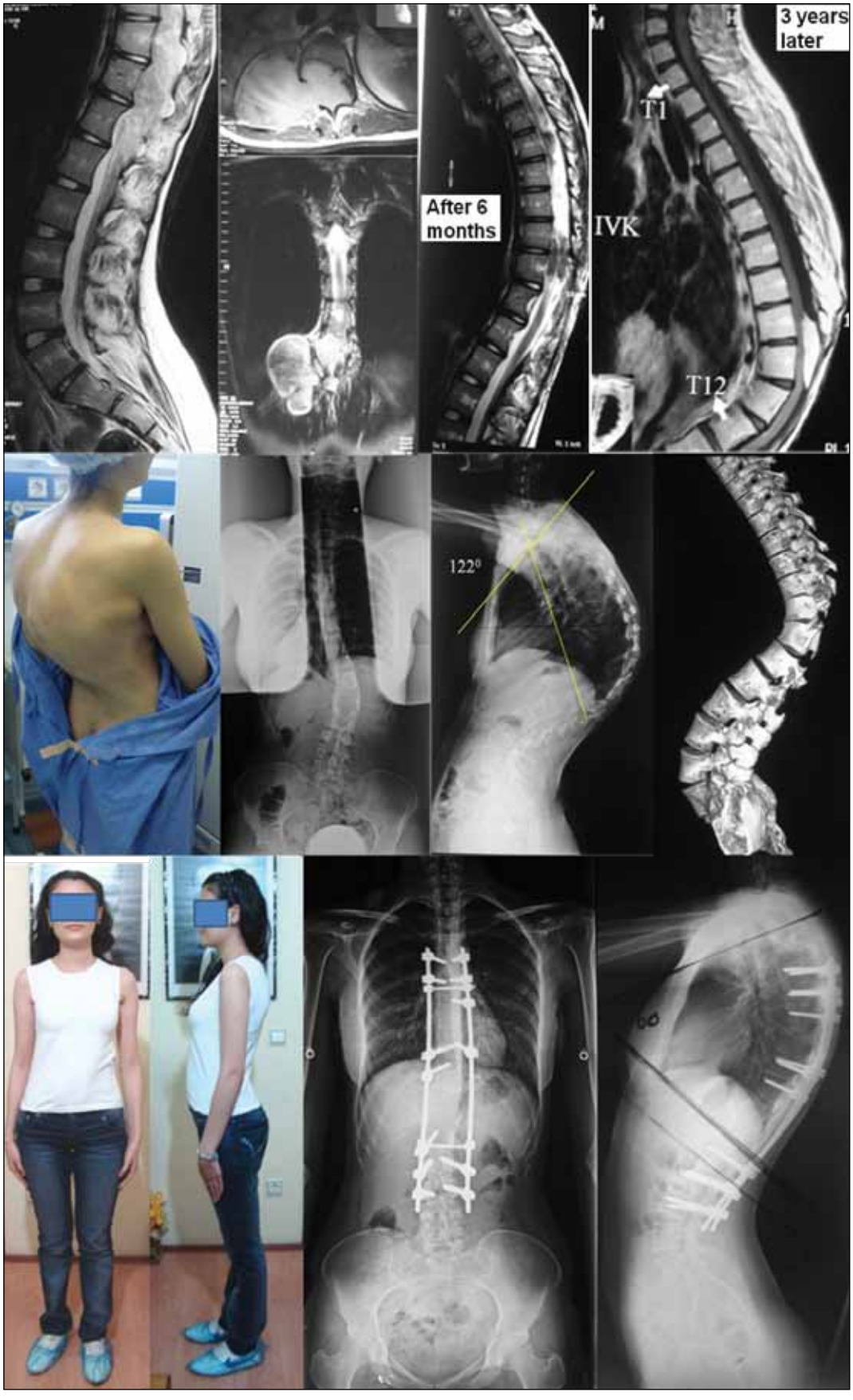


**Figure 4:** 18-year old female patient undergoing laminectomy and facetectomy due to intradural tumor (schwannoma). Progressive deformity, back pain and paraparesis existed (2/5). She had a scoliotic and severe kyphotic deformity up to 122 degrees due to relapsing tumor. Correction was achieved up to 60 degrees by combined PSO and Ponte osteotomies following control IVC MRI. She had neither a relapsing tumor nor a deformity in the postoperative 4th year.

Scope of laminectomy and facetectomy, number of laminas removed, location of lami-nectomy, preoperative loss of anatomical alignment and posoperative radiation treatment of spinal cord have been reported to influence the risk of postlaminectomy spinal deform-ities.

The risk of developing kyphosis increases after extensive laminectomy. 36% of the load is distributed to the forearm while 65% is carried by the facets in the posterior column in the cervical region. It should therefore be remembered that the stability is disrupted when the posterior tension band (of the interspinous ligaments, ligamentum flavum and nuchal ligament) is damaged. Furthermore, removal of more than 1/3 of the cervical facets cause instability (15). Postlaminectomy kyphosis development rate in children was reported to be 100% in some series (13,19) (Figure 5).

Patients should be selected accurately for laminectomy to avoid the development of postlaminectomy kyphosis. The presence of preoperative lordosis (10 degrees and greater), lack of instability findings in the flexion and extension radiograms and preservation of the facets during the surgery will reduce the likelihood to develop postlaminectomy kyphosis. The risk of postlaminectomy kyphosis is doubled in patients without cervical lordosis. Posterior fusion following decompression is recommended in cases when the facets could not be protected (30, 33). McAllister et al. propose fusion for cases where 30%-50% of the facets are removed (25). The most common fusion method today is to use the lateral mass screws. Kumar et al. reported that kyphosis did not develop during the follow-up period in any of the patients they treated with cervical laminectomy and fusion (21).

***3. Post-traumatic Kyphosis***

Majority of post-traumatic kyphosis usually occurs at the thoracolumbar junction (Figure 6). Kyphosis may occur following a spinal trauma and also after a surgery (28, 29, 41). Segmental kyphosis might be caused by a height loss in the anterior column due to the loads applied to the thoracic region during compression flexion mode. Progressive ky-phosis can develop due to pseudoarthrosis that occurs after the surgery performed to treat the spinal fractures of patients and due to lack of fusion. Although Kümmel's disease is a rare spinal disorder characterised as the post-traumatic osteonecrosis of the vertebral body, it may lead to progressive deformity (47). Progressive neurological deficit and pain are the exact surgical indications of the post-traumatic kyphosis (Figure 7).

***4. Ankylosing Spondylitis (AS)***

AS was first described by Vladimir von Bechterew in 1893 (4). Ankylosing spondylitis affects the entire spine the most among the other spondylarthropathies (SPA) (3). Its incidence ranges from 0.2% to 1.1% (3). AS involves the sacroiliac joint, entire spine, major joints (knee, hip, shoulder) and extra-articular elements (enthesitis and uveitis). It involves the thoracic and lumbar regions of the spine the most. AS typically reveals erosion in the bone, sclerosis, syndesmophytes, ankylosis (bamboo spine) and osteoporosis in the radiological images (23).

The most common symptoms of the patients include a pain in the whole spine, stiffness of the joints, limitation of movement and respiratory distress (3). Lumbar lordosis secondary to the increased thoracic kyphosis may decrease

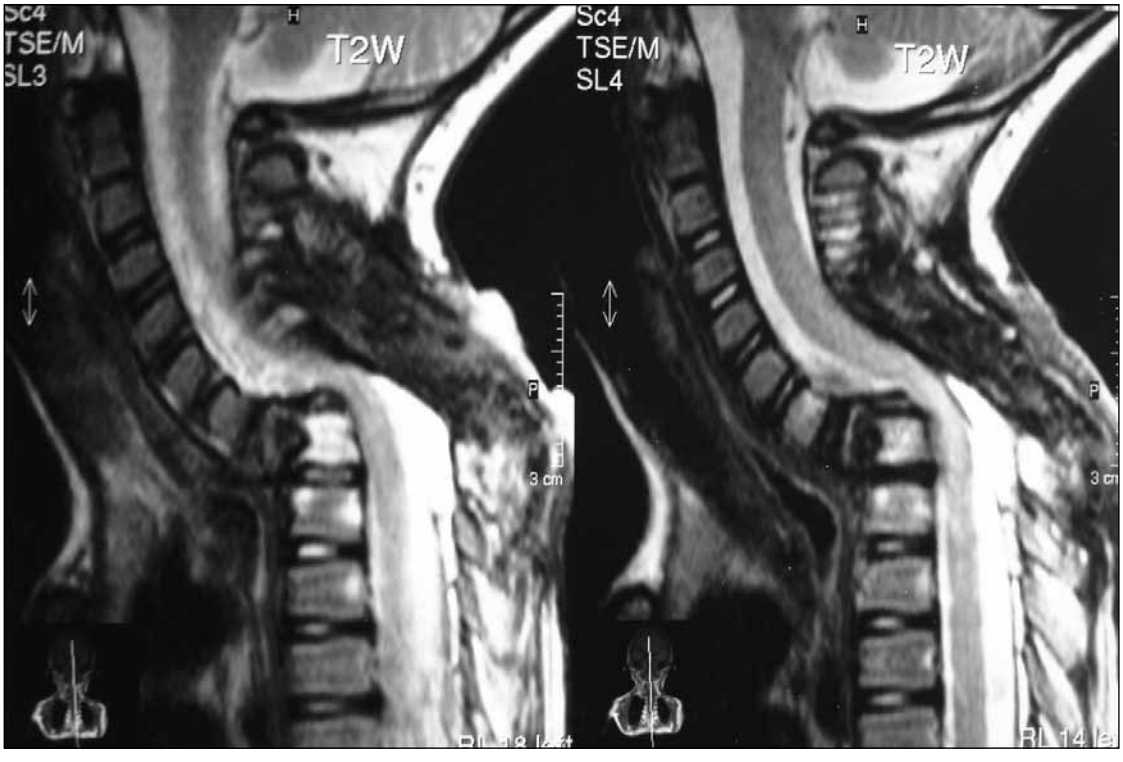


**Figure 5:** 8-year-old patient with Pott's disease. Postlaminectomy severe kyphotic deformity.

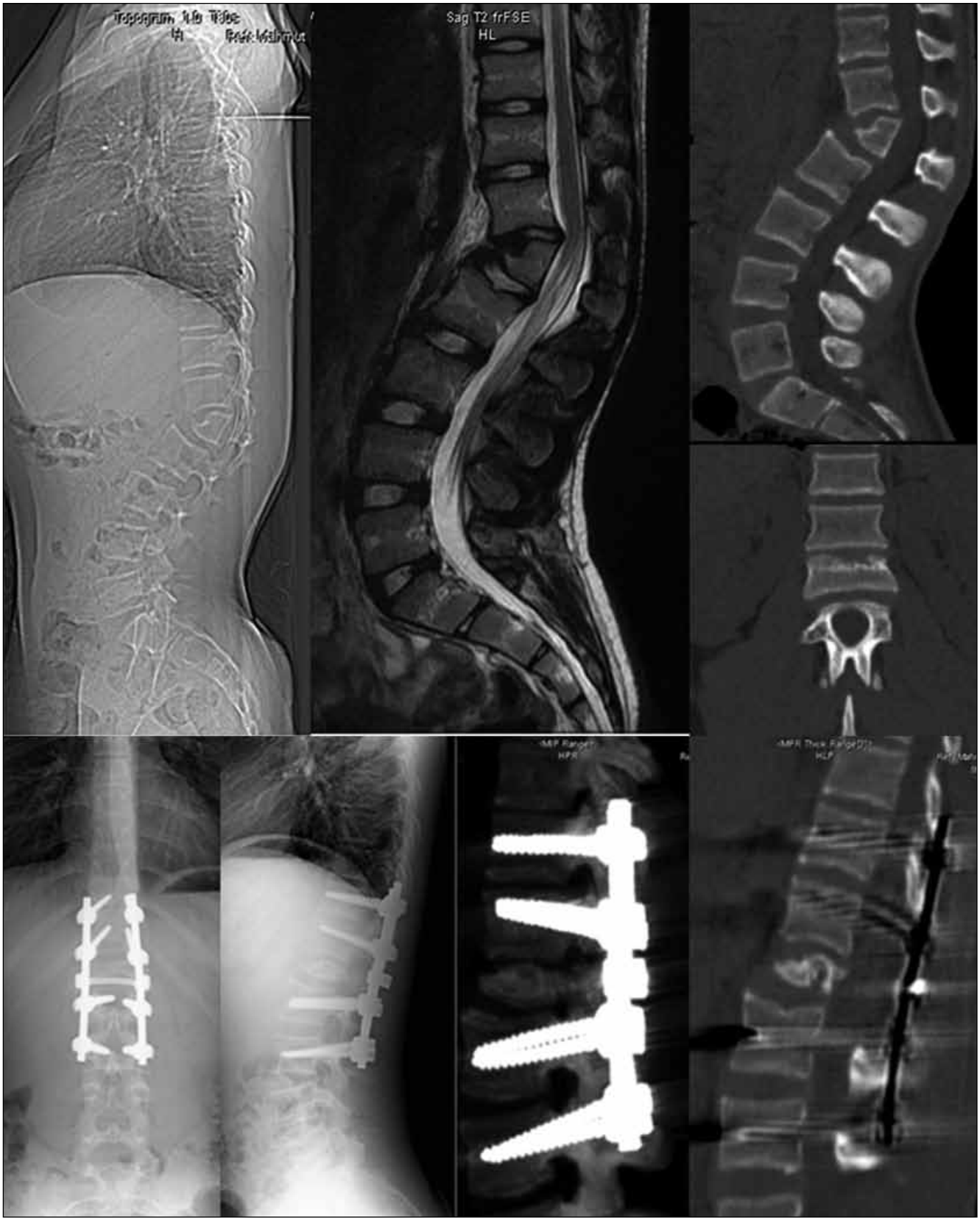


**Figure 6:** A 21-year-old male patient fell from height five years ago. He presented with back pain, progressive deformity, no deficit, kyphotic deformity due to a previous L1 fracture. Correction was achieved by PSO.

and cervical lordosis may be flat-tened (3). Horizontal gaze restriction might occur in patients due to the increased thoracic kyphosis (1,2). The centre of mass in patients with ankylosing spondylitis shifts forward and downward (1,2). The center of mass (COM) shifting forward is balanced by the ex-tension of the hip, flexion of the knee and flexion of the wrinkle (2).

Surgery is required for only a few AS patients. Many patients can be managed with med-ical treatment and exercise. Surgery should be considered in case of failed conservative pain treatment and progressive deformity. Unstable vertebral fractures, myelopathy de-veloping due to progression of kyphosis and progressive spondylodiscitis are the absolute indications for surgery. The painful sagittal imbalance, loss of horizontal gaze, segmental instability are the relative surgical indications (Figure 8).

***5. Congenital Kyphosis***

The term congenital kyphosis was first used in 1844 by Von Rokitansky. It occurs in girls more commonly than in boys (1.3/1). It can occur in any part of the spinal column whereas the apex is often located between T10 and L1 (25). The studies have shown that the degree of kyphosis increases during adolescence period while it is decelerated once one stops growing. Although Cobb angles are usually measured to follow up the progression of congenital kyphosis, they do not explain what happens to the apex of the curve (12, 42, 44, 45).

There 3 types of congenital kyphosis:

Kyphosis caused by formation failure of vertebral bodies (Type 1)

Kyphosis caused by segmentation failure (Type 2)

Kyphosis caused by both formation failure and segmentation failure of vertebral bodies (Mixed Type- Type 3).

This classification is important to predict the prognosis of each type and possible neuro-logical deficits (45, 46). Kyphosis caused by the formation failure of the vertebral body is more distinct, whereas kyphosis caused by the segmentation failure is vaguer. Devel-opmental anomalies of the vertebra occur during the chondrification and ossification stages (40). The longitudinal growth of the spine extends from the superior and inferior endplate epiphysis of the vertebral body (8). The deficiency in the growth plate in front of the transverse axis of vertebral rotation on the sagittal plane leads to congenital kyphosis (40). Hemivertebrae, butterfly vertebrae and wedge vertebrae are formed due to the formation failure of the vertebral body. Longitudinal growth is achieved by the epiphysis in the superior and inferior endplates, which causes progressive kyphosis.

Posterior fusion is adequate for the patients with Type 1 deformity, younger than 5 years of age and with a kyphotic angle lower than 50 degrees; whereas combined anterior and posterior surgery would be more suitable for the patients with a kyphotic angle greater than 55 degrees (46) (Figure 9). Winter and Moe proposed posterior fusion without correction for Type 2 deformities (45). The upper and lower vertebrae should be included in the fusion in case of segmenta-tion failure of a vertebral body. When there is a need for correction in later phases, com-bined anterior-posterior surgery should be preferred. Growth stops as the childhood tu-berculosis spondylitis damages the anterior portion of the vertebral body and kyphosis increasingly progresses until the end of the developmental age in line with the growth of the posterior column.

***6. Neuromuscular Kyphosis***

Scoliosis Research Society divided neuromuscular kyphosis into neuropathic and mye-lopathic kyphosis. NM kyphosis is usually accompanied by lumbar hyperlordosis and pelvic imbalance in addition to kyphoscoliosis. The treatment goal is to restore spinal balance, increase the respiration capacity and relieve pain. Neuropathic deformities are characterized by injury of the upper motor neurons; cerebral palsy, syringomyelia, spinal cord injury as well as diseases of the lower motor neurons (poliomyelitis, spinal muscular atrophy) (5). Duchenne's and Becker's muscular dystrophy is an example of myopathic kyphoscoliosis. It is difficult to treat the NM kyphoscoliotic patients. The deformity that develops due to NM diseases has a large C shape and is accompanied by the pelvic obliquity. Limitations in movements and difficulty in sitting, cardiac and respiratory problems, weak bone structure of pelvis are the factors that make the surgery challenging (17, 48). The spinal column should be connected to the pelvis during the surgery. Combined anterior and posterior surgical approach facilitates the correction of the curve and prevents the risk of developing pseudoarthrosis. Pedicle screws are problematic for an osteoporotic spine. Therefore, every segmental level should be instrumented with thick screws so that the fusion area can be enlarged and the correction is facilitated since three-column fixation is performed in the vertebrae. Sarwahi stated that pneumonia (0.7- 3.5%), respiratory distress (9.2-24.1%), urinary tract infection (0.7-5.3%), surgical site infection (0.3-1.3%) developed postoperatively in patients who underwent surgery due to NM deformities. It was found that the complication rates went up to 44-80% when the other complications caused by implant failure and gastrointestinal problems were added. Postoperative mortality rate was reported to be 7% (32, 39).

## CORRECTION OSTEOTOMIES DURING THE SURGERY OF KYPHOSIS

***Posterior Closing Wedge Osteotomy: Ponte Osteotomy***

This osteotomy was first described by Alberto Ponte to be used in the treatment of Scheuermann Kyphosis (43). In Ponte osteotomy, bone is resected from the inferior artic-ular processes of the upper vertebra and the superior articular processes of the lower ver-tebra. Furthermore, the ligamentum flavum and interspinous limaments should also be resected (43). Resection of the posterior part of the vertebra allows shortening of the pos-terior column. Ponte


**Figure 7:** A 36-year-old male patient fell from a construction 14 years ago. He had left leg pain and was able to walk for a short time, Left AT and EHL 4/5. Lumbar kyphotic deformity due to a former L4 fracture. Correction and stabilisation by L4 PSO.

osteotomy can yield 5 to 15 degrees correction for each level. Com-pared to other osteotomies, Ponte osteotomy is an effective correction osteotomy that is easy to perform and has low rates of complications (Figure 3, 4, 10, 11).

***Posterior Column Osteotomy with Opening of the Anterior Column: Smith-Peterson Osteotomy (SPO): "Chevron"***

SPO was first decribed by Smith-Peterson to correct ankylosing spondylitis kyphosis (20, 26, 35). It can also be performed to treat posttraumatic kyphosis, flat-back syndrome and Scheuermann Kyphosis (22). Asymmetric SPO can also assist in restoring the coronal balance. Both facet joints, lower portion of the superior vertebrae lamina and spinous process as well as flavum are removed in SPO. The osteotomy space is closed with pedicle screws and lordosis is increased (9). The anterior part of the disc space is widened in SPO; that's why it is also referred to extension osteotomy. At the end of the osteotomy, vertebral posterior column is shortened and the anterior column is extended (43). To perform SPO, the anterior disc space should be mobile. SPO cannot be performed in case of a fixed kyphosis with an osteophyte in the anterior part. Every 1 mm- widening achieves 1-degree lordosis through SPO osteotomy. On average 10-degree correction can be achieved in each SPO osteotomy (10, 11).

***Three-Column Closing-Wedge Posterior Osteotomy:***

***Pedicle Subtraction Osteotomy***

Pedicle Subtraction Osteotomy (PSO) was first described by Thomasen in 1985 (38). High morbidity rates were reported in patients operated with PSO (19, 31). Pedicle sub-traction osteotomy is usually performed on L2 or L3 levels. The reason why it is most commonly used for these two levels is that they are located distal to the conus medullaris, they present less risk, and they form the apex of the lumbar lordosis. Approximately 30-40 degree lordosis is gained by pedicle subtraction osteotomy (9, 10). Prior to the pedicle subtraction osteotomy, screws should be inserted to the pedicles of the

**Figure 8:** A 36-year-old male patient had ankylosing spondylitis for 10 years. Progressive forward curvature. Attempt was made to restore sagittal balance with PSO on L3.

superior and infe-rior vertebrae. All posterior elements of the level where PSO will be performed should be removed. After entering the corpus of the vertebra by means of the pedicle, the dorsal cortex of the vertebrae should be fractured. Some part of the vertebrae should remain in the ventral area for support (Figure 4, 6, 7, 8, 10, 11).

### *Vertebral Column Resection*

Vertebral column resection (VCR) was first described in 1922 by MacLennan (24). One or more vertebrae are removed by combined anterior-posterior or posterior alone ap-proach. Suk et al. developed the posterior alone intervention technique for VCR and stat-ed that VCR with this technique lasted shorter and the complication rates were low compared to the combined approach (37) (Figure 9, 10).

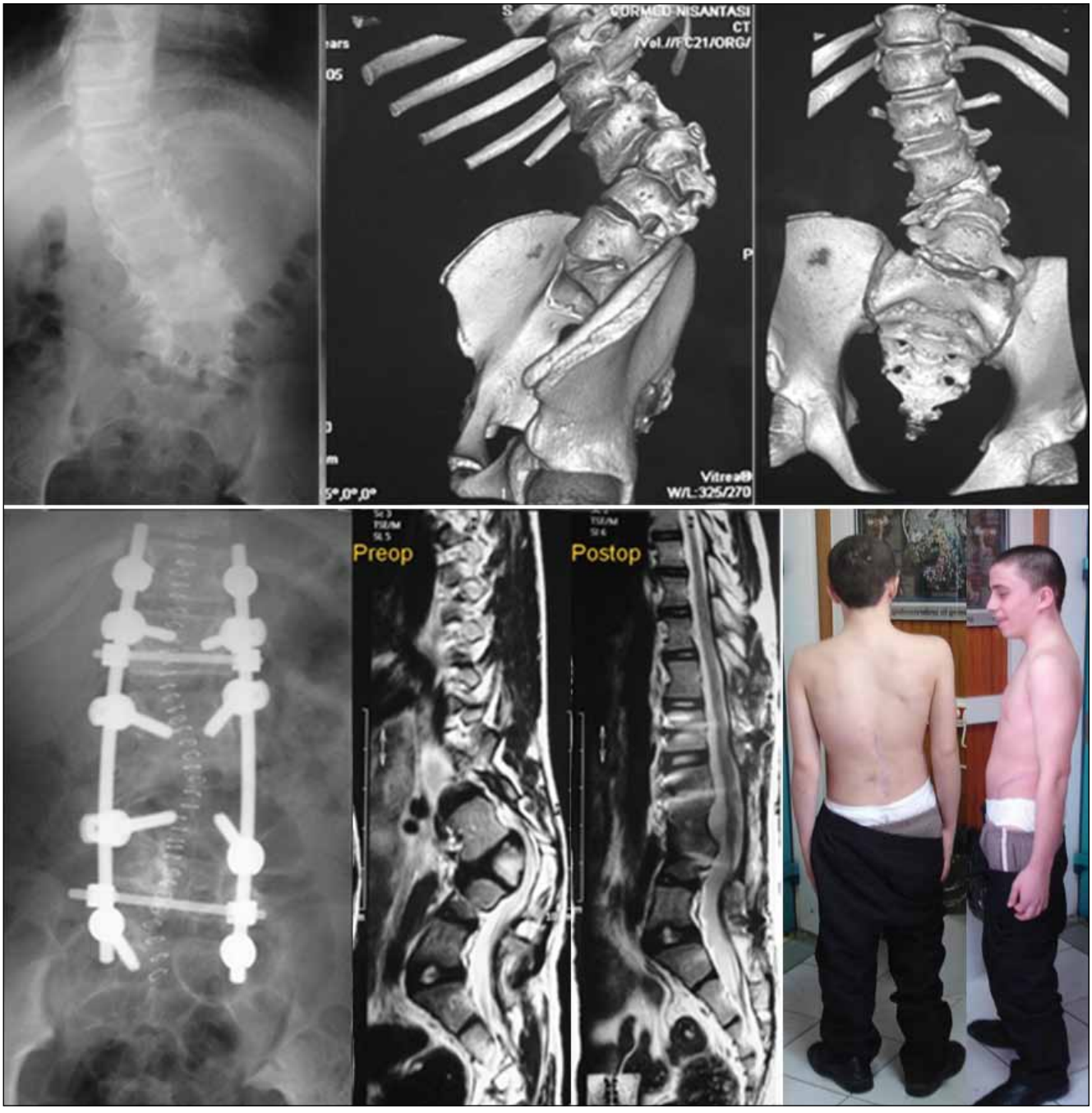


**Figure 9:** A 14-year-old male patient with congenital kyphosis. Severe kyphotic deformity due to the L2 and L3 hemivertebra anomaly. He had back and right leg pain, deformity in the right foot, AT 3/5, lower left limb 4/5, right side hypoesthesia, and urinary incontinence. Correction and stabilisation were achieved by vertebral column resection.

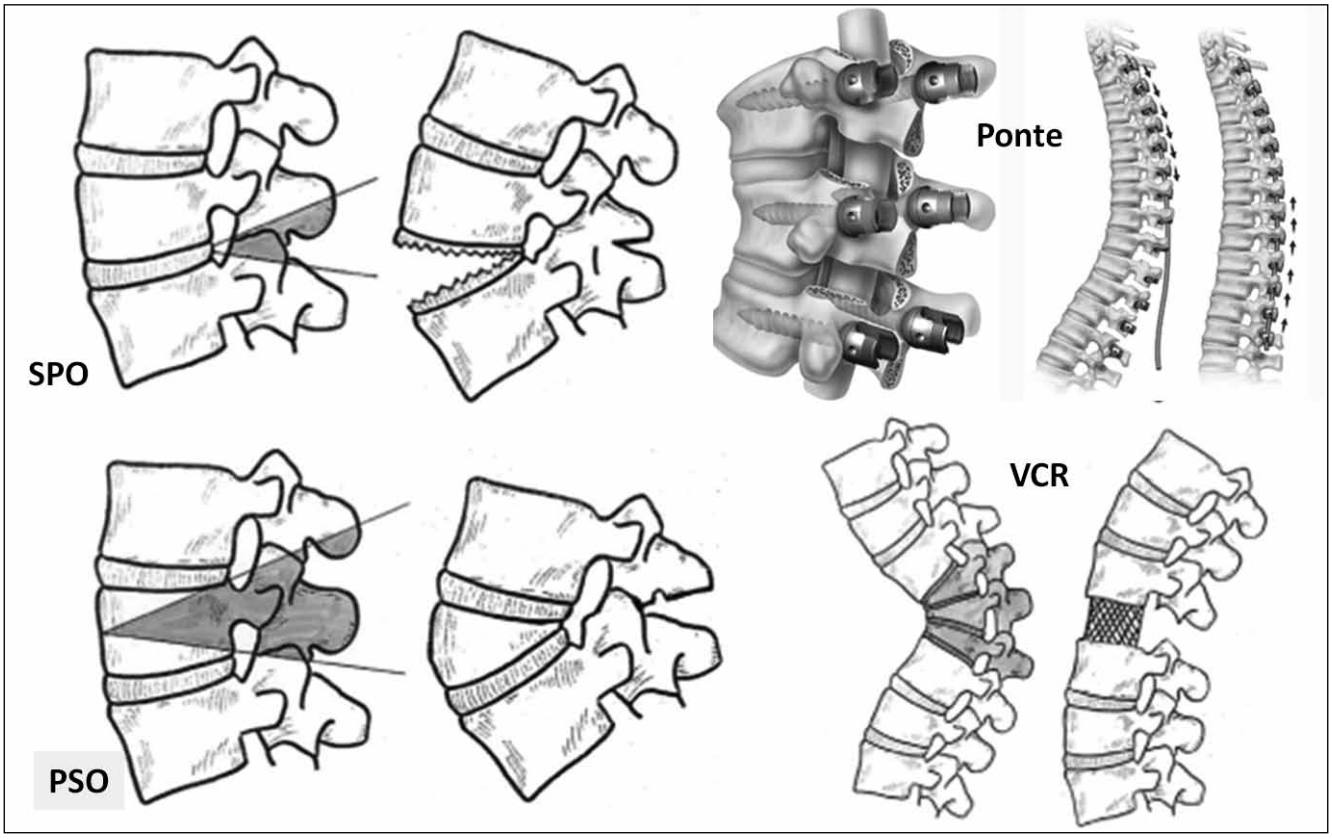


**Figure 10:** Osteotomies performed to treat kyphotic deformities. SPO: Smith-Peterson Osteotomy. PSO: Pedicle subtraction osteotomy. VCR: Vertebral column resection.

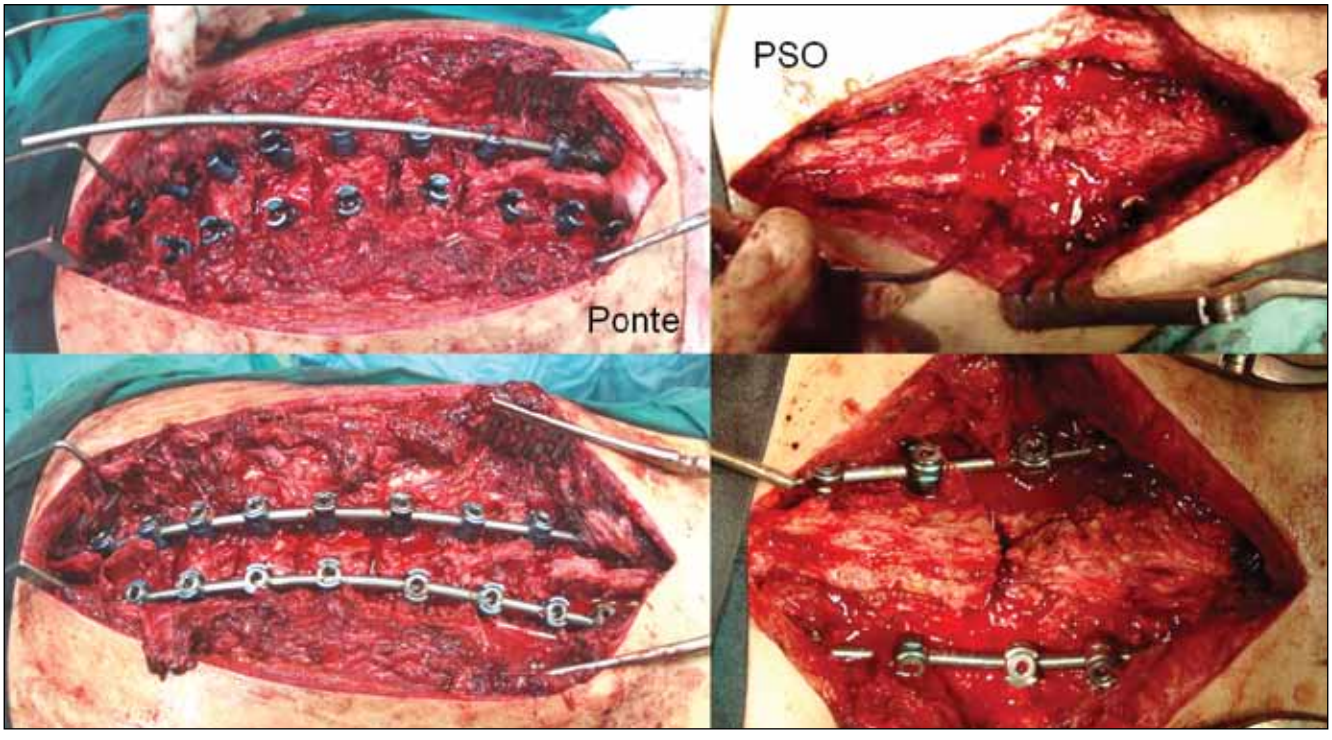


**Figure 11:** Preop images of kyphotic deformity correction with Ponte osteotomy (left) and PSO (right).

## CONCLUSION

Basic rules that will provide spinal balance should be kept in mind in spinal surgical in-terventions. It would be easier to prevent the occurrence of kyphosis rather than treating it. It is important to decide the degree of correction of kyphosis in addition to the surgical intervention planned to treat the kyphotic patients. It should always be remembered that the patients with negative sagittal balance can compensate for it with hip flexion but it is far more difficult to compensate for positive sagittal balance.

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