Overview about Management and Role of operative Treatment of Thoracolumbar kyphosis

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Abstract

Background: Thoracolumbar kyphosis types show many variations. According to the rigidity of the deformity, it may be postural or structural. Postural kyphosis which is mainly caused by poor posture can be corrected with exercises to strengthen the back muscles to improve posture. Structural kyphosis refers to deformities that does not correct with the change of posture due to abnormalities within the structure of the spine. Those abnormalities may be congenital as fused vertebra, idiopathic like Scheuermann's disease or acquired as malunited fractured vertebra and degenerative changes of spine segments. Those structural types require different strategy for management according to the cause and degree of the deformity. In cases where the conservative treatment is not indicated, spinal osteotomies are the way to correct the deformities. Putting in consideration that the thoracolumbar kyphosis can be classified according to the shape of the deformity into global rounded as in Scheurmann's disease, degenerative lumbar spine and Ankylosing Spondylitis or sharp angular as in congenital and posttraumatic kyphosis, there are many types of osteotomies to deal with each pattern of deformity as: Smith-Peterson osteotomy, transpedicular decancellation, pedicle subtraction osteotomy and vertebral column resection.

Keywords: Thoracolumbar kyphosis

Introduction

The spine and the body function within a cone of equilibrium with the target of maintaining sagittal alignment with minimum energy expenditure. The purpose is mostly to maintain a mechanical balance in the sagittal plane with the head over the pelvis. The center of gravity in a standing posture is typically about 10 cm lower than the navel, near the top of the hip bones. It lies approximately anterior to the second sacral vertebra. It moves up with upward lifting of the arms and moves anterior with leaning forward. **(1)**

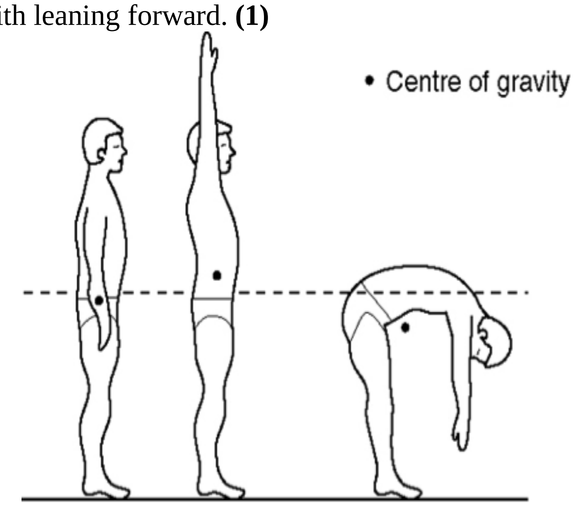

Figure (1): Centre of gravity of human body. **(1)**

The prevalence of patients with thoracolumbar kyphosis has been reported as at higher rates nowadays. The kyphotic deformity ends eventually in sagittal imbalance by pushing the body's center of gravity forward. Several different etiologies exist, such as: congenital fixed kyphotic segments due to maldeveloped vertebrae, spinal trauma with the involvement of the relatively neutral thoracolumbar junction by compression fractures leading to a kyphotic vertebral body deformity, degenerative lumbar kyphosis due to either degenerative process of multiple vertebral**(1)**

discs causes loss of motion and height in those segments or iatrogenic fixation of lumbar segments in kyphosis, inflammatory diseases as ankylosis spondylitis that cause degenerative fixed changes of the spine and idiopathic conditions as Scheurmann's disease related to idiopathic wedging of multiple vertebrae. **(2)**

Various regional and global parameters help define "normal" sagittal alignment. The C7 sagittal vertical axis (SVA) is determined by the C7 plumb line drawn caudally from the center of the body of C7. The line should theoretically intersect the posterosuperior aspect of the S1 endplate on a full-length standing X-ray. By definition, if the line passes anteriorly, the patient has positive global sagittal balance, and if the line passes posteriorly, the patient has negative balance. Typically, in patients with normal or neutral sagittal balance, the C7 plumb line should fall within 4 cm, either anterior (4 cm positive) or posterior (4 cm negative), to the posterosuperior aspect of the S1 endplate. **(3)**

Thoracic kyphosis (TK) is measured from the upper endplate of T2 to the lower endplate of T12. Due to the radiographic shadow -of the shoulders, a surrogate for TK can be estimated from the T5 upper endplate to the T12 lower endplate. Normal TK is estimated to be 20–50 degrees. **(4)**

Thoracolumbar kyphosis (TLK) (normal 0 degree) is measured by the Cobb angle between the upper end-plate of T10 and lower end-plate of L2. Lumbar lordosis is the angle between the lower endplate of the T12 vertebral body and the upper endplate of sacrum. The lumbar spine has approximately 60 degrees of lordosis from T12–S1. Up to two thirds of this lordosis routinely arises between L4 and S1. **(5)**

Sacral slope (SS) describes the angle between the sacral endplate and the horizontal reference line, and is normally about 40 degree. Pelvic tilt (PT) describes the spatial orientation of the sacrum and the femoral head. PT is the angle between a vertical reference line and the line connecting the midpoint of the sacral end plate and the center of the femoral head, which is normally 11 degrees. **(6)**

Pelvic incidence (PI) describes the relationship of the sacrum to the pelvis. It is defined as the angle between a line perpendicular to the center of the sacral endplate and a line between the center of the sacral endplate and the center of the femoral heads. Unlike other measures, PI is a fixed anatomic parameter that is not position-dependent; normal ranges have been described as about 52±9 degrees. **(7)**

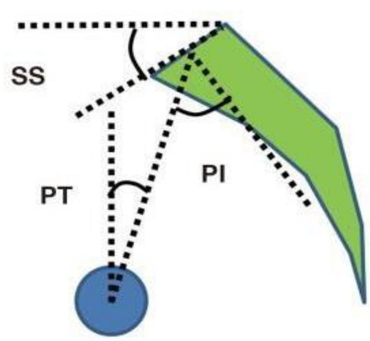

Figure (2): Measurements of PI, SS and PT. **(7)**

Sagittal imbalance in spine deformity has shown more association with negative health related quality of life and worse disability. **(8)** Increased sagittal vertical axis (SVA) and pelvic incidence – lumbar lordosis (PI-LL) mismatch highly relate to bad functional outcomes. The PI-LL mismatch correlates strongly with SVA and is a target of correction during planning. One of the main targets of surgical correction is optimizing PI-LL and SVA to achieve global sagittal balance. **(9)**

The change of the compatible relationship between cervical lordosis (CL), thoracic kyphosis (TK), lumbar lordosis (LL), and pelvic parameters, that leads to loss of mechanical balance, will result eventually in overstress of the muscles responsible for the trunk upright posture and will lead to agonizing back pain as the body struggles to keep the head above the pelvis during walking or standing. **(10)**

The increasing SVA and subsequent increase in the PI-LL mismatch start compensatory mechanisms of increased pelvic retroversion, reduced thoracic kyphosis (TK) and increased knee flexion to balance the SVA. Good perception of which segments of the spine help to achieve a normal SVA when there is a high PI-LL mismatch (>11 degrees), and how the sagittal spinal parameters changes with the postoperative change of SVA, is necessary for effective surgical planning.**(11)**

***Types of sagittal imbalance:**

- Type 1, Balanced
- Type 2, Compensated balanced: the patient compensate by making changes at the unaffected vertebral segments above and below the fused kyphotic segments.
- Type 3, Unbalanced (decompensated).

Compensated or not refer to the spine compensation by the remaining mobile segments above and below the fixed kyphotic segment to keep the head over pelvis. **(12)**

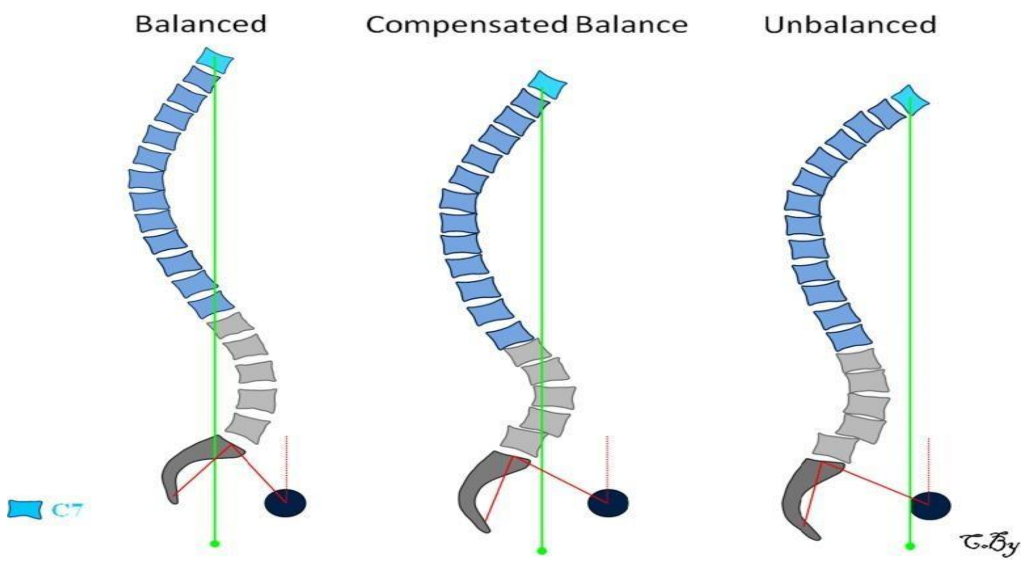

Figure (3): Types of sagittal imbalance. **(12)**

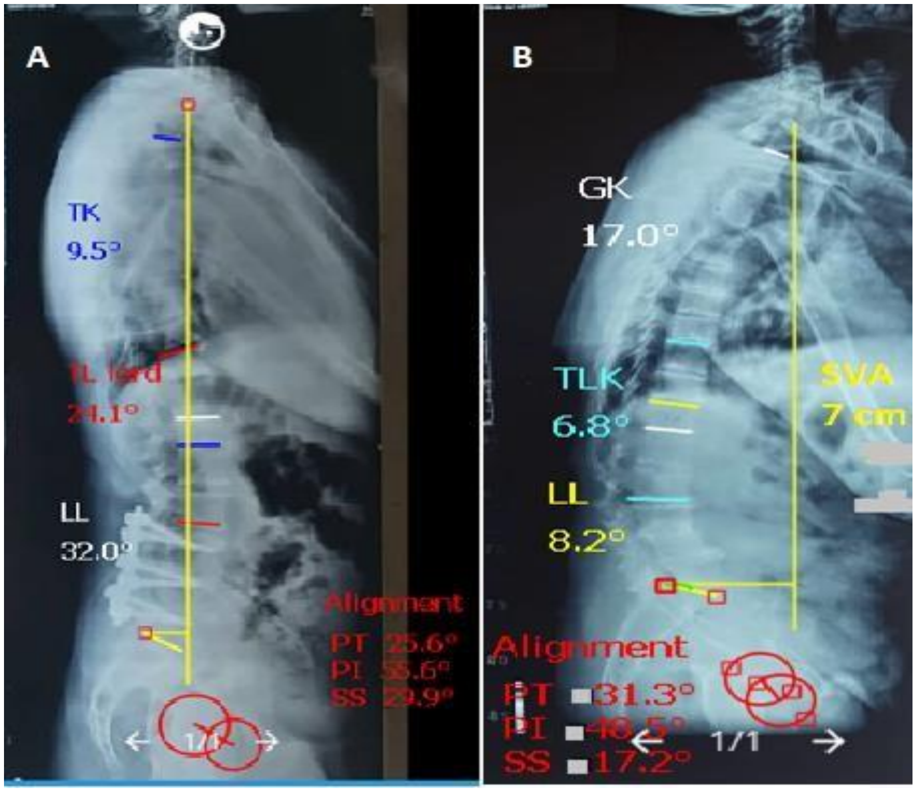

Figure (4): Compensated VS Decompensated**: A)** PI-LL mismatch of 23° compensated by TL lordosis to keep patient balanced. **B)** Unbalanced due to failure of compensation of 40° (PI-LL) mismatch with SVA= 7 cm

Diebo et al examined patients with sagittal spinal imbalance and divided them into groups with PI–LL mismatch as follow: 0 to 10,° 10° to 20°, 20° to 30°, and 30° to 40°. They found that increasing PI-LL mismatch was associated with increased pelvic retroversion, reduction of TK and increased knee flexion. They also showed that compensation for positive sagittal imbalance via pelvic parameters and TK change became exhausted after about 20° and 30° of PI-LL mismatch, respectively. **(13)**

Roussouly and Pinheiro-Franco described how the biomechanical relationship between Sacral slope (SS), LL, and TK affects SVA. High SS correlates with increased LL, TK, and CL to balance the SVA, and if the LL is low, TK must decrease to align the SVA. So, a high PI pushes the SVA forwards, LL pulls the SVA backwards, PT pulls the SVA backwards and TK pushes the SVA forwards. **(14)**

Merrill et al stated that the interaction between different spine parameters should be put in mind when planning deformity correction and the whole spine should be focused on. Regression analysis with SVA as the independent variable and ((PI-LL) - PT + TK) as the dependent variable shows that when SVA = 50mm, the value of ((PI-LL) - PT + TK) = 16.22°. Thus, the target postoperative value for ((PI-LL) - PT + TK) should be less than <16° to improve sagittal balance, and should take into account PT and TK as they are critical to achieving an SVA < 50mm.**(15)**

It is mentioned also that PT should not increase more than 20° to 22° because of associations with negative health related quality of life reported in other studies. A good balance between sagittal spinopelvic parameters should be maintained to achieve the best outcome.**(16)**

Obeid et al defined global tilt as the summation of C7 vertical tilt and pelvic tilt. They aimed to obtain a measurement that is minimally affected by

patient position and would therefore make it easier to understand sagittal balance.**(17)**

Diebo et al took it to another level by including the lower extremities parameters when investigating radiographic parameters of the spine and pelvis. They calculated a new parameter and called it the global sagittal axis. It is the angle between a line from the C7 vertebral body to the femoral condyles and another line from the femoral condyles to the posterosuperior corner of the first sacral vertebra. They stated that this angle to correlate more strongly with health related quality of life than any other sagittal parameters **(18**)

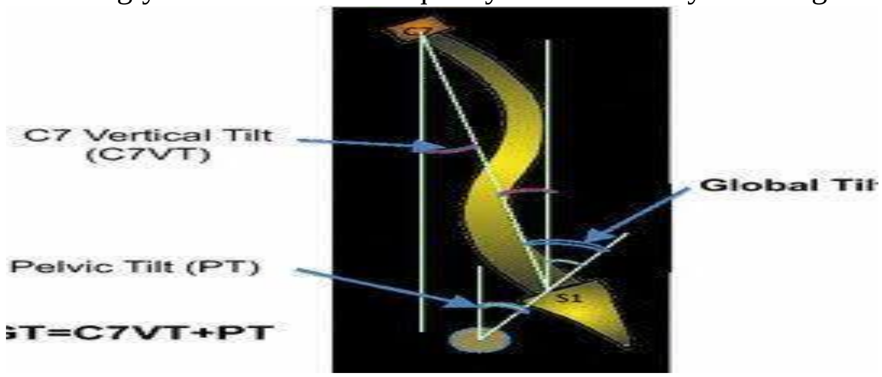

Figure (5): Global tilt as described by Obeid et al. **(17)**

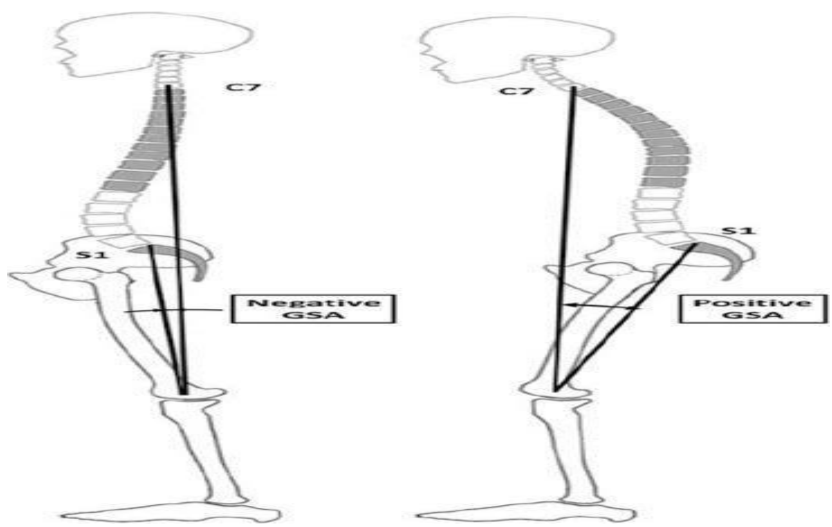

Figure (6): Global sagittal axis as defined by Diebo et al. **(18**)

This attention to the spinopelvic parameters and their relation to the Health related quality of life (HRQOL) has been increasing for over the last two decades. One of those studies for more understanding of the human sagittal profile was when Roussouly published the famous spinal sagittal alignment patterns of normal population. It is suggested that Pelvic Incidence (PI), a constant parameter, can be used to classify patients more accurately and guide the design of any deformity correction plan. The normal population was classified into four types according to the degree of the PI and sacral slope (SS) . Low PI types (<45°) are types one and two while the high PI types (>45°) are types three and four. Type 1 with SS<35° with apex of lordosis is at L5 and some degrees of thoracolumbar kyphosis (about 15)° . Type 2 with SS <35° is charachterized by hypokyphotic thoracic spine and hypolordotic lumbar spine with the apex of lordosis at the base of L4. Type 3 with 35° < SS < 45°, is called the harmonic variant with apex of lordosis at lower part of L3. Type 4 with SS>45° , is charachterized by thoracic hyperkyphosis and lumbar hyperlordosis with apex of lordosis at L3. **(19**)

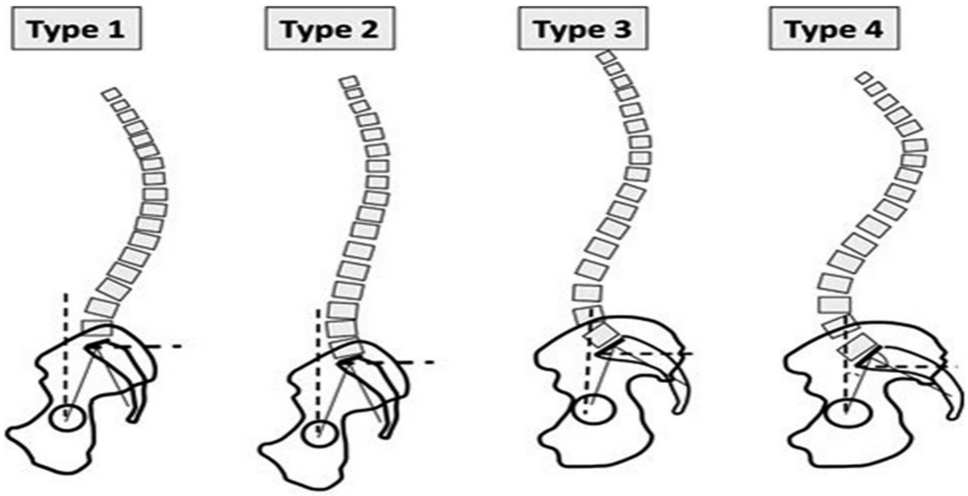

Figure (7): Roussuly classification of the normal variations of sagittal alignment of normal population.

In a study by Li et al for the Roussuly spine types clinical application, it was proved that Roussouly spine patterns mismatch before or after operation leads to increased risks of PI-LL mismatch postoperatively which significantly worsens the clinical symptoms and prognosis of patients. So restoring the Roussouly type positively is recommended to improve patients' quality of life. **(20**)

Thoracolumbar kyphosis types show many variations. According to the rigidity of the deformity, it may be postural or structural. Postural kyphosis which is mainly caused by poor posture can be corrected with exercises to strengthen the back muscles to improve posture. Structural kyphosis refers to deformities that does not correct with the change of posture due to abnormalities within the structure of the spine. Those abnormalities may be congenital as fused vertebra, idiopathic like Scheuermann's disease or acquired as malunited fractured vertebra and degenerative changes of spine segments. Those structural types require different strategy for management according to the cause and degree of the deformity. **(20)**

A. Role of conservative treatment in different types of thoracolumbar kyphosis:

Conservative treatment in the thoracolumbar kyphosis is of limited only to special types. In cases of hyperkyphosis confirmed as Scheuermann's kyphosis by radiology, but with thoracic kyphosis (TK) degrees lower than 65 ̊, conservative treatment has the upper hand over surgical intervention. Anti-gravity brace is the ideal choice in those adolescents as it leads the growth of affected vertebrae till maturity preventing exaggeration of the deformity and correcting the some degrees of the deformity itself. The brace may be continued till full vertebral geometry restoration of the affected apical vertebrae. Aulisa et al stated that conservative treatment of low degrees scheuermann's kyphosis during skeletal growing by bracing is effective and leads to remodelling of the deformed vertebrae while the physiotherapy has no role. (**21)**

The vertebral geometry restoration is confirmed radiologically by: thoracic kyphosis magnitude, anterior wedging angles of the apical vertebrae formed by the intersection of the lines tangential to the upper and lower endplates and the posterior wall inclination angle of the apical vertebrae measured between the line perpendicular to the inferior plate and the line passing through superior and inferior limit of posterior wall. (**22)**

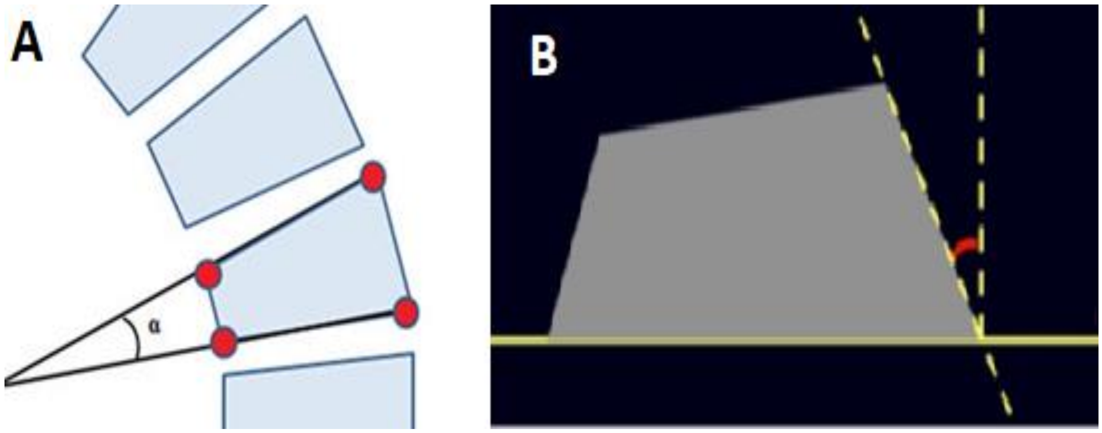

Figure (8): A) anterior wedging angel of apical vertebra,
B) Posterior wall inclination angle (**22)**

The conservative treatment by braces or only physiotherapy by exercises may apply also to congenital and posttraumatic kyphosis with mild local deformity degrees especially in the thoracic region which is already a kyphotic region. This tolerance of the deformity decreases as we go distal to the thoracolumbar region which is usually straight and can accommodate lower degrees of kyphotic deformity up to 15 degrees. However in the lumbar region it is a completely different issue as it is a normally lordotic segment and any kyphotic deformity will lead to disturbance of the biomechanics of this region ending eventually in handicapping degenerative lumbar spine.**(23)**

The spondyloarthropathies like Ankylosing Spondylitis follows the same mentioned rules of better accommodation of kyphotic deformities in the thoracic region than in the lumbar region. The only difference of this type than any other kyphosis type is the response to medical treatment due to the destructive inflammatory etiology of the disease which can be halted by new medications. Over the last decade, there was massive improvement of the medical treatment of AS. The anti-tumor necrosis factor a (TNFa) therapies, infliximab and etanercept, target the specific inflammatory processes of the disease, and thus, may potentially influence disease progression subsequently decreasing the deformity progression and eventually the need for surgical intervention. It was proved that those drugs also decrease the debilitating effect of the disease on the bone density and decrease the incidence of osteoporosis in AS patients. However, some severe forms of the disease do not respond well to the treatment requiring surgical correction lately.**(24)**

The degenerative lumbar kyphosis is considered as a special category as it is already a kyphosis of a normally lordotic area leading to changing the force loading of that area causing more degeneration of already degenerated segments like a vicious circle that need to be broken. Conservative treatment has nearly no role in breaking that circle and managing the stenotic canal and foramens or restoring the height of the collapsed degenerated or even calcified discs.**(25)**

B. Role of operative treatment in different types of thoracolumbar kyphosis:

In cases where the conservative treatment is not indicated, spinal osteotomies are the way to correct the deformities. Putting in consideration that the thoracolumbar kyphosis can be classified according to the shape of the deformity into global rounded as in Scheurmann's disease, degenerative lumbar spine and Ankylosing Spondylitis or sharp angular as in congenital and posttraumatic kyphosis, there are many types of osteotomies to deal with each pattern of deformity as: Smith-Peterson osteotomy, transpedicular decancellation, pedicle subtraction osteotomy and vertebral column resection. **(25)**

A) Smith-Peterson osteotomy: a single-level posterior closing wedge osteotomy, in which the posterior ligaments and the facet joints are removed and correction is performed through the disc space. A mobile anterior disc is essential. It gives a 10 degrees correction per level and one degree correction for each one mm of posterior structures removed. **(26)**

B) Transpedicular decancellation: it is best indicated in low lumbar kyphosis then high thoracic deformities. Decancellation can be used at all levels but it is difficult to get a satisfactory correction over 30̊ by its use only. **(27)**

C) Pedicle subtraction osteotomy (PSO): it includes removal of the posterior elements, facet joints and pedicles. Then a triangular wedge through the pedicles into the body of the vertebra is removed and the posterior spine is shortened using the anterior cortex as a hinge. It can produce 35° of correction restore global sagittal balance up to an average of 7 cm per level. **(28)**

D) Extended PSO: a modification of the classic PSO was done by Liu et al, in which in addition to the classic PSO the upper end plate of the deformed vertebra with the above damaged disc are removed up to the lower endplate of the above vertebra then bone graft is inserted into the osteotomy site, which is the gradually closed to correct the deformity. **(29)**

E) Vertebral column resection (VCR): it involves the complete resection of one or more vertebral segments and can be performed using either combined anterior and posterior approaches or a posterior-only approach. VCR enables translation of the spinal column and offers the advantage of controlled manipulation of both the anterior and posterior columns with active reconstruction. It allows for massive correction up to 45 degrees for single level osteotomy**. (30)**

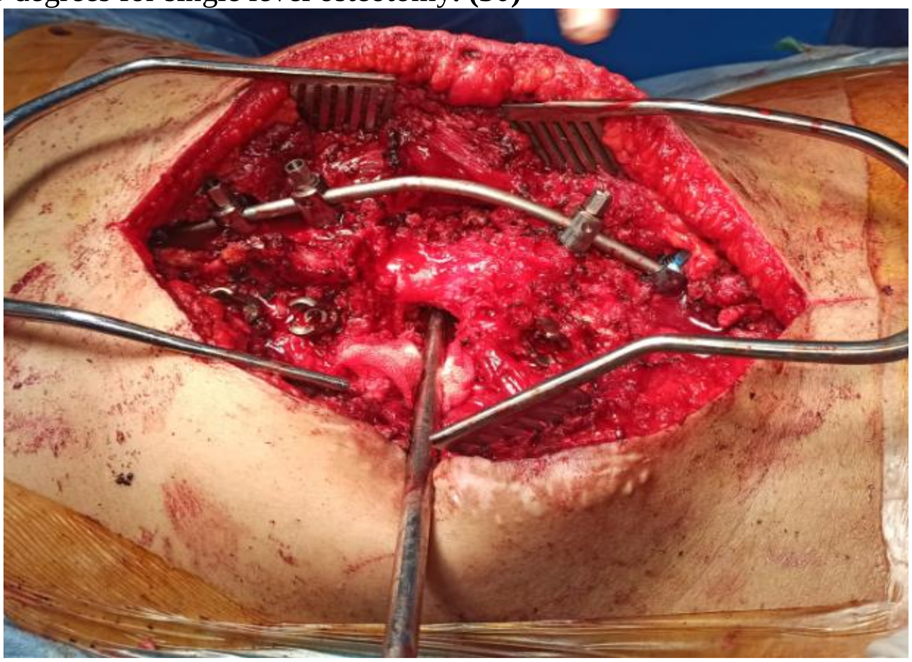

Figure (9): Clinical photo showing the cord after complete vertebral resection with temporary rod fixation.

Schwab osteotomies classification:

Schwab et al proposed an anatomical descriptive classification, offering a common language for osteotomy description. The osteotomies were classified into six grades.

(Grade 1): is bilateral resection of the inferior articular process of the facet joints at a certain spine level. It gives minimal correction of 5-7 degrees and provides a bed for fusion.

(Grade 2): includes bilateral removal of the whole facet joints at certain spine level (both superior and inferior articular processes). This is accompanied by removal of the ligamentum flavum with parts or all of the posterior structures like the spinous processes and lamina. It gives 10 ̊ of correction. Both grades 1 and 2 need anterior column mobility for the correction to occur.

(Grade 3): is a partial wedge resection of the posterior vertebral body and the posterior elements (spinous processes, lamina and ligamentum flavum) with pedicles resection. A portion of the vertebral body and the discs above and below the level of the osteotomy are not touched. This osteotomy gives about 30-35 degrees of correction per level. There is no elongation of the anterior column in this grade.

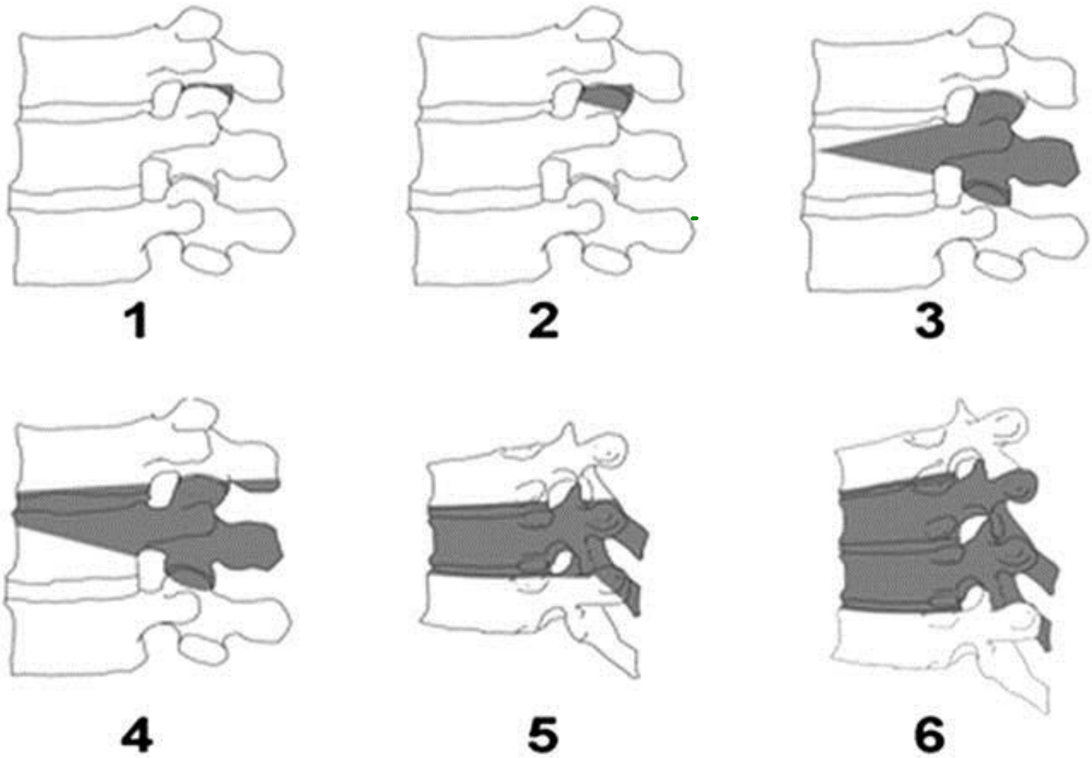

Figure (10): Schwab osteotomy classification. **(30)**

(Grade 4): is like grade 3 with resection of the upper end plate and disc above and more resection of the vertebral body sufficient enough to correct the deformity, but part of the body remains not removed. There may be too much bone resection to prevent excessive shortening and anterior support by cages may be needed. This correction may give about 40 degrees of correction.

(Grade 5): includes complete vertebral body resection at a level with the disc above and disc below. This grade gives enormous amount of correction reaching up to 50 degrees.

(Grade 6): represents extending the osteotomy beyond grade 5 into vertebral body above or below. This extension may be partial or complete resection of the other vertebra. Grades 4,5 and 6 usually need rib resection to aid the exposure and osteotomy at the thoracic level. **(30)**

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