Review

Idiopathic Scoliosis

İdiopatik Skolyoz

Onur YAMAN[1], Sedat DALBAYRAK[2]

[1]*Tepecik Education and Research Hospital, Clinic of Neurosurgery, Izmir, Turkey*
[2]*Neurospinal Academy, Istanbul, Turkey*

Corresponding Author: Sedat DALBAYRAK / E-mail: sedatdalbayrak@gmail.com

ABSTRACT

Measurement of a curvature angle higher than 10 degrees on anterior-posterior X-rays is known as scoliosis. Idiopathic scoliosis forms 80% of coronal structural deformities. Deformity causes coronal, sagittal and axial plane imbalance. Idiopathic scoliosis is divided into three sub-groups by age; infantile (0-3 years), juvenile (4-9 years), and adolescent (10 years of age to maturity). Surgery should be considered for progressive deformities and progressive neurological deficits despite conservative treatment. Patients with idiopathic scoliosis should be evaluated according to the patient's age, degree of curvature, and present condition.

KEYWORDS: Deformity, Scoliosis, Idiopatic scoliosis, Cobb angle

ÖZ

Ön-arka direkt grafide 10 derecenin üzerindeki eğriliklere skolyoz denir. Yapısal koronal deformitlerin yaklaşık %80 ini idiopatik skolyoz oluşturur. Ortaya çıkan deformite sagital, koronal ve axial planda balans bozukluğuna neden olmaktadır. Yaş grubuna göre; infantil (0-3 yaş), juvenil (4-9 yaş), adolesan (10 yaş - matüriteye kadar) üç alt gruba ayrılır. Konservatif tedaviye rağmen ilerleyen ve nörolojik hasara neden olan hastalarda cerrahi tedavi düşünülmelidir. İdiopatik skolyozu olan her hasta yaşı, eğriliğin derecesi ve hastanın mevcut koşulları içinde değerlendirilmelidir.

ANAHTAR SÖZCÜKLER: Deformite, Skolyoz, İdiopatik skolyoz, Cobb açısı

Despite the new developments in surgical techniques and technology, Cobb's 'Scoliosis is always an interesting but intricate problem' statement nearly a century ago is still applicable today. Hippocrates was the first to describe scoliosis (18,34), and Galen (131-201 A.D.) was the first to mention the terms kyphosis, lordosis and scoliosis (18, 34).

Scoliosis shall refer to curves exceeding 10 degrees observed through direct radiography from both the anterior and the posterior (11). Scoliosis forms a complex curve that leads to deformities not only in the coronal plane but also at all three planes, which is caused due to the self-rotating movement of the spine. Scoliosis accounts for the most common deformity of the spine. Idiopathic scoliosis corresponds to around 80% of the structural coronal deformities (19). In fact, idiopathic scoliosis is diagnosed to rule out existing causes. Idiopathic scoliosis may develop at any stage of growth period. It can be classified into three sub-groups according to age: infantile (0 to 3 years), juvenile (4 to 9 years), adolescent (10 years to maturity)

INCIDENCE

Incidence rate of curves at 10 degrees and above varies between 1 to 3%, whereas the incidence rate of curves at 30 degrees and above, which require treatment, is as low as 0.15 to 0.3%. The ratio of women to men is 1.4/1 for curves of 10 degrees and above, while this ratio increases up to 5/1 in the case of curves greater than 30 degrees (20).

ETIOLOGY

The main hypothesis for etiology includes genetic factors, hormonal factors, abnormal bone and connective tissue structures and autonomic nervous system dysfunctions. All the above-mentioned causes are inter-connected and inter-influential.

Genetic-Hormonal Causes

Idiopathic scoliosis observed in identical twins makes us consider the fact that the causes may be of genetic origin (49). IS related zones are spotted in 6q, 10q and 18q, 17p11.2, 19p13.3, 8q11, Xq23–26.1, 9q31.3–q34.3, 5q13–q14 and 3q11–q13, 9q31.2-q34.2, 17q25.3-qtel chromosomes (3, 9, 49).

Lebouf et al. indicated that oestrogen had some impact not on the develop-ment of idiopathic scoliosis but on the degree of the curve. Later on it was discovered that such impact was more due to the insufficiency on receptor level rather than decreasing levels of hormone secretion. Core receptors in bone cells, namely oestrogen receptor alpha and beta, were shown to have an impact on AIS curves (38).

Melatonin hormone causes an increase in osteoblasts and a decrease in osteoclasts. Thillard was the first to exhibit that scoliosis developed in experiments after removal of the pineal glands (45). Decreasing melatonin levels were held responsible for such a consequence (29). Melatonin receptor-2

(MT-2) levels were observed to be lower in AIS patients with accompanying lower melatonin responses.

It is known that osteopenia develops in the spinal bone structure during idiopathic scoliosis. One reason for osteopenia is the Bsm I polymorphism in Vitamin D receptor (VDR) gene (44).

Biomechanical Causes

It was Adams who first discovered that the existing deformity increased by bending forward (1). The spine has a fixed rotational direction. Posterior ele-ments make an attempt to rotate towards the concave side, and they try to make the shortest advancement just like an athlete running at the extreme interior lane of a marathon course. Therefore, perpendicular distance is shorter on the posterior side of the vertebrae compared to the relevant distance on the anterior side (43).

In a normal spine, rotational axis crosses the thoracic region from the anterior. This prevents bending of the thoracic region when compressed. However, lordosis development in this area forces the vertebrae to transcend the rotational axis, whereby the area is made susceptible to bending. This is the reason why patients have an increased deformity by bending forward. The vertebra shall move in two ways under compression. Either kyphosis or lordo-scoliosis will develop. Furthermore, biomechanical studies showed that in order to ease the load, the loaded vertebrae shall 1) increase the existing curve 2) extend its length and 3) increase its inner load (32).

Anatomical studies explained that corpus vertebrae developed deformity at the axial sections of T4-T9 due to the descending thoracic aorta, as a result of which thoracic curves bent towards the right hand side (43).

Causes Related to Neurologic Disorders

Disorders of vestibular, ocular and proprioceptive systems impair the balance. It was demonstrated that the response of scoliotic patients to vibration stimulus decreased significantly compared to the control group and an asymmetry existed between the left and right side (18,48).

It was claimed that the organization of the entire brain is asymmetric in scoliotic patients and this caused motor and sensory impairments (16). Another neurologic cause of idioapthic scoliosis is the regulatory role of melatonin in the normal spinal development. This neurohormone secreted by pineal gland controls the daily rhythm. Melatonin rather plays a protective roles against the progression of the curvature. Scoliosis was observed in chickens after pinealectomy in some trials. They thought this was because melatonin deficiency inhibited the normal symmetrical growth of proprioceptive system and affected the spine by paraspinal muscles.

Causes Related to Connective Tissue Anomalies

Histological analysis of ligamantum flavum fibers in scoliotic patients showed that fiber density decreased and had a nonuniform distribution in fibroelastic system. Based on these findings, it is thought that elastic fibrous system (especially fibrillin) plays a role in the patogenesis of idiopathic scoliosis

Figure 1: Physical examination of scoliosis. Distance of the plumb line drawn straight from inion to the sacrum (natal cleft), distance of the apex of the deformity, shoulder imbalance and rib hump.

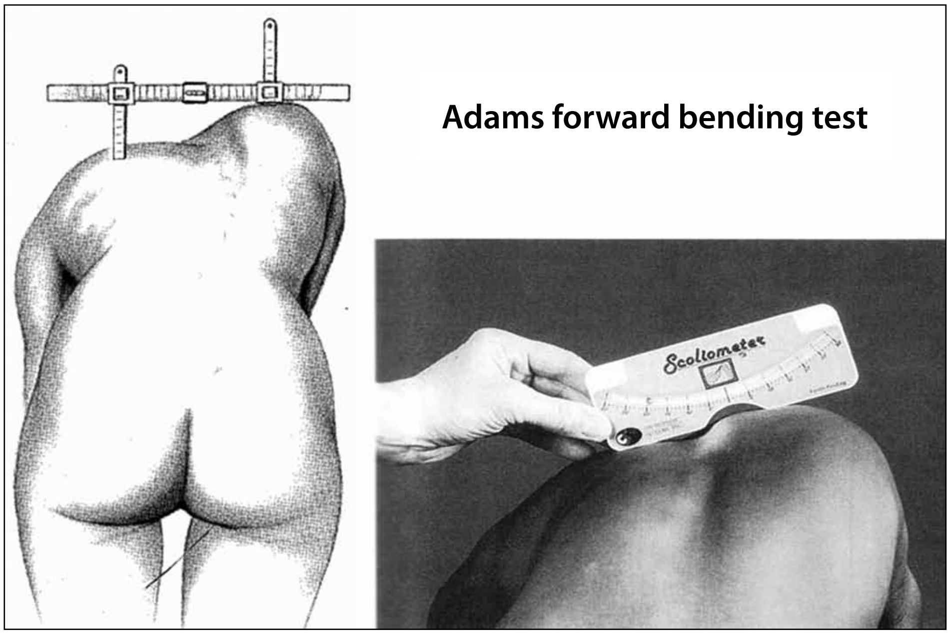

Figure 2: Adams forward bending test and clinical measurement of rotation by scoliometer.

(14). There are defects in the actin and myosin systems of the contractive cells such as skeletal muscles and platelets in patients with idiopathic scoliosis. Impairment of cell membranes increases intracellular calcium and phosphorus levels and decrease contractile structures and platelet aggregation (22).

CLINICAL EVALUATION

Adolescents with scoliosis usually present with symptoms due to deformity such as a curvature on back, high shoulder, rib hump, asymmetric body, one hip being higher than the other and poor posture. Except cases when the adolescent notices this, scoliosis might be diagnosed through school scanning programs or examinations at schools. It is sometimes coincidentally diagnosed in lung radiographs or intravenous (15, 26). The history of patients presenting with these symptoms should be investigated thoroughly, detailed physical examination and necessary radiologic evaluations should be performed to determine the cause of the deformity and treatment plan.

History

Age and gender of the patient is recorded, the age when the deformity was noticed and how it was noticed, whether it increases, family history, second-ary sex characteristics should be investigated to identify the risk of progres-sion. Presence of deformities, pain, neurologic symptoms, cardiopulmonary problems and functional complications are investigated (26). Pain is not common in patients with adolescent idopathic scoliosis. However, pain may develop due to muscle weakness and fatigue in patients with very severe lumbar idiopathic scoliosis. If the pain is in the forefront, it should make one first suspect spondylolysis, spondylolisthesis, Scheurmann's disease, tethered cord, bone or spinal cord tumors (15). Respiratory symptoms are often not common in these patients. Neurologic deficits are rare. If a neurologic deficit is found or if there is a left thoracic curvature, advanced radiologic examinations should be performed to evaluate the neural structures (40, 46). The apex of the adolescent idiomatic scoliosis is normally on the right. The first menstural period and pubic and axillary hair development are investigated to assess maturity. Pubic hair and breast development in girls is just before the start of fast growth. Axillary hair development shows that growth rate decreases in both gender. Menarche is also an indication go slowing growth. Pubic hair development in boys happens far before the fast growth period. Axillary hair development indicates slowing growth in both gender (47).

Physical Examination

The patients with adolescent idiopathic scoliosis should be examined in a way to see the entire back, shoulders and both iliac crests and preferably when the patient is naked (18). Overall status and posture of the patient is inspected. "Cafe au lait" macules on the skin and subcutaneous nodules should make one suspect neurofibromatosis. Excessive hairiness localized on the back favors dimpled appearance, hamngioma, tethered cord or diestematomyelia. Facial asymmetry points to scoliosis due to torticollis. The breast on the convex side in girls is smaller and higher, while the other one on the concave side is bigger and lower (18, 26, 27).

The examiner should definitely check whether the iliac crests are at the same level. If they are not at the same level, it means the length of lower limbs is different. Scoliosis might be caused by the shorter leg, which should not be overlooked. The height of the patient should be measured in sitting and standing positions after the inspection. The direction and localization of the curve is determined. Then the patient is evaluated from the lateral to assess the sagittal contour (15). The level of the shoulders, position of the scapula, balance of head, neck and shoulders according to pelvis. The level difference between the acromioclavicular joints is measured by looking at the shoulders from the back. Shoulder is higher at the convex side of the curve.

Position of head on pelvis is evaluated to assess the spinal balance. A plumb line is drawn from the skul base or C7 spinous process downward. If the plumb line passes through gluteal sulcus, it is a balanced scoliosis. If ıt passes 1 to 2 cm lateral to the gluteal space, it is a decompansated curve and the distance of the plumb line to the gluteal space is recorded in centimetre (13).

Rotation degree of the vertebra and the direction of the curve are best evalu-ated by the Adams forward bending test (1). The examiner observes the patient from the back until the patient comes to a horizontal position. The knees of the patient should not be bent, feet should be kept together, arms should hang down and pals should face each other. Spinal rotation causes a unilateral rising on the back. Rotational asymmetry can be measured by scoliometer. Furthermore, rib hump can be measured by calculating the distance of the highest process by using a ruler placed parallel to the ground (Figure 1, 2).

Neurologic Examination

Possible neurologic causes of deformity should be ruled out to diagnose idiopathic scoliosis. First reflexes are examined. Abdominal reflexes should be checked. If reflexes are present on one side but absent on the other side, it should be investigated further, this sign is not observed in patients with normal scoliosis. Reflexes may be absent on all quadrants. Patellar and achilles tendon reflexes should be symmetrical. Muscle strength and range of motion in four limbs should absolutely be examined. All limbs should be examined against abnormal posture and sensation.

RADIOLOGIC EVALUATION

Direct Radiography

Radiologic examination of the spine starts with standing anterior-posterior and lateral radiographs taken on 90×35 cm (36×14 inch) film cassettes from a distance of 2 metres. Radiography forms the basis to evaluate the patient during treatment and follow-up. Routine radiographs should be taken in standing AP and lateral positions. If conservative treatment or surgery is indicated as a result of the first radiograph taken for diagnosis, traction, bending and hyperextension radiographs, in case of increased kyphosis, should be taken to assess the flexibility of the curve (Figure 3). All patterns can be viewed on a single film if a long film cassette is used. Pattern of the curve, type of scoliosis, spinal and body balance, skeletal maturity and length difference in lower limbs can be assessed on anterior-posterior radiographs. On lateral radiographs, thoracic hypokyphosis in the sagittal contour of the thoracic and lumbar spine can be diagnosed and spondylolysis and spondylolistesis can be viewed (15). Breast and thyroid cancer risk has been demonstrated to slightly increase in scoliotic patients who have been frequently exposed to radiologic examination. For this reason, unnecessary positions and repeated procedures should be avoided (25).

Measurement of the Curve

Cobb method is used as the standard method of measurement for measuring the degree of the curve. The end vertebrae need to be fixed to start measurement. The superior surface of the cephalic end vertebra and inferior surface of the caudal end vertebra have the greatest amount of tilt in the curve. The intervertebral space on the concave side of the curve is wider above the cephalic end vertebra and lower below it. The opposite applies to the caudal end vertebra. After fixing the end vertebrae, lines are drawn perpendicular to the top vertebra's superior surface and the bottom vertebra's inferior surface. Angle formed by the intersection of these lines is the Cobb Angle (13) (Figure 4).

Measurement of Vertebral Rotation

The Perdriolle method and the Nash-Moe method are the two most common means of assessing vertebral rotation on plain anterior-posterior radiograph. The Perdriolle method uses a transparent torsionometer overlaid on a radiograph. The edges of the curve's apical vertebra and its rotated pedicle constitute the landmarks. Even the rotations smaller than 30 degrees can be measured accurately using this method. However, after instrumentation surgery landmarks of the apical vertebra may be obstructed by shadows of rods or hooks, and it may be difficult to obtain accurate measurement (26, 27) (Figure 5).

In the Nash-Moe method the relationship of the pedicle to the center of the vertebral body is observed on anterior-posterior radiography, and the rotation is divided into 5 grades:

Grade 0 : when both pedicles are symmetric. Grade I : when the convex pedicle has moved away from the side of the vertebral body. Evre II : rotation is between grade I and III. Grade III : when the convex pedicle is in the center of the vertebral body. Grade IV : when the convex pedicle has moved past the midline (Figure 6).

School Screening Programs

Skolyoz Research Society (41) suggested screening for children of 10 to 14 years of age, while American Academy of Orthopedic Surgeons (4) suggested screening for girls at age 11 to 13 and boys at 13 to 14 (4, 41). American Academy of Pediatrics suggested screening at routine health checks at ages 10, 12, 14 and16 (5). Screening is the most accurate and reliable way of detecting scoliosis. Early diagnosis may prevent many health problems. Screening results indicated 1.5-3.0% prevalence for scoliosis of 10° and above, 0.3-0.5% for scoliosis exceeding 20°, and 0.2-0.3% for scoliosis exceeding 30° (18). The prevalence of scoliosis was indicated as 1,5%, revealed by the study conducted in 2008 by Tevfik Yılmaz et al. on the Turkish case, and as 1.3% revealed by the screening conducted by Lök et al. (28, 50) (Figure 7).

There is an absolute relationship between the idiopathic scoliosis and gender. This relationship becomes more obvious

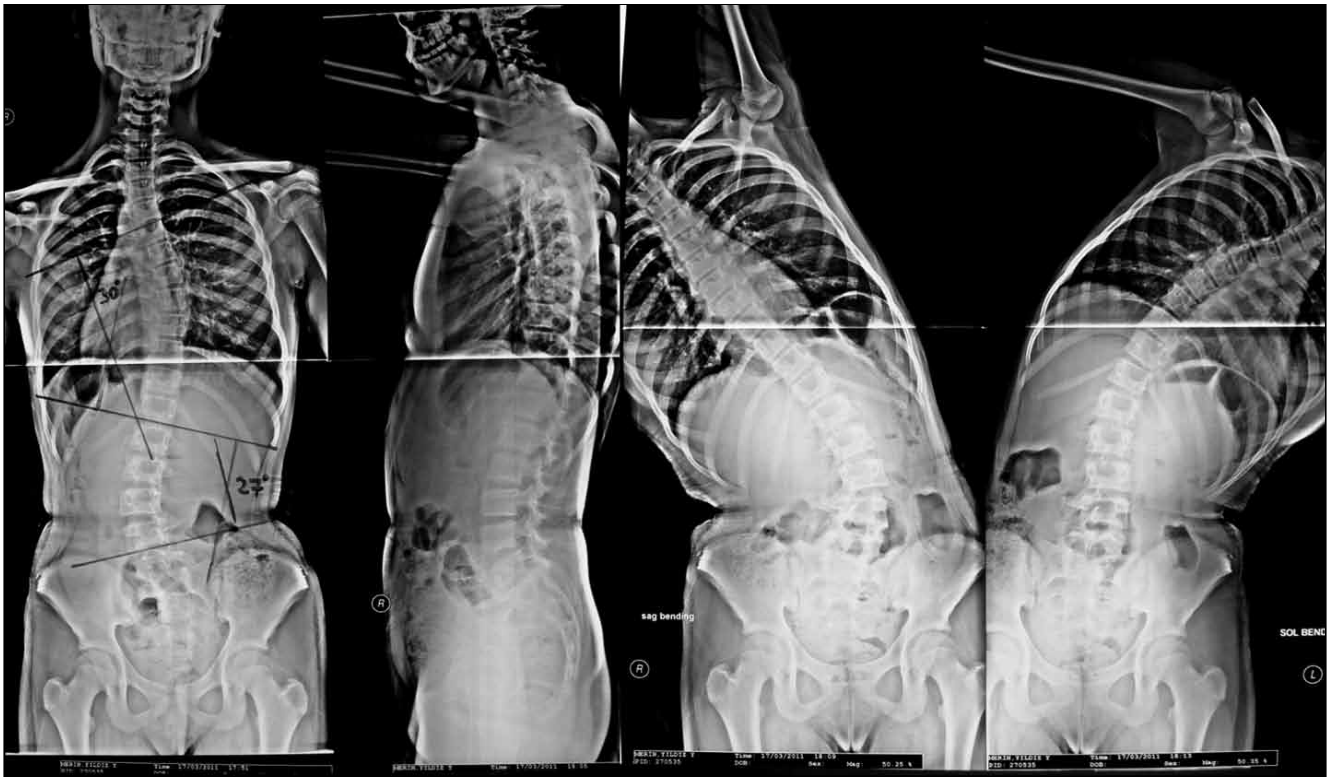

Figure 3: Scoliosis radiograph taken at stance, lateral bending for determining the flexibility of deformity.

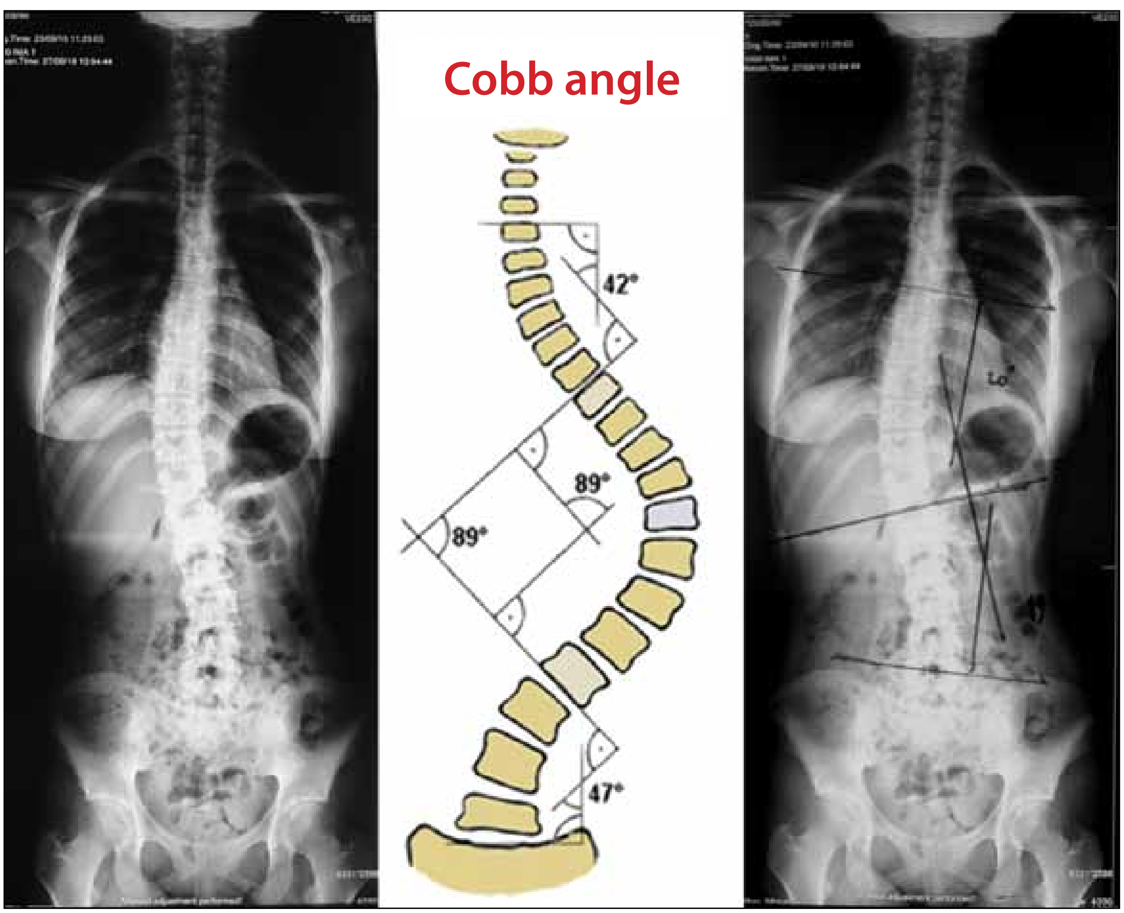

Figure 4: Measuring the Cobb angle.

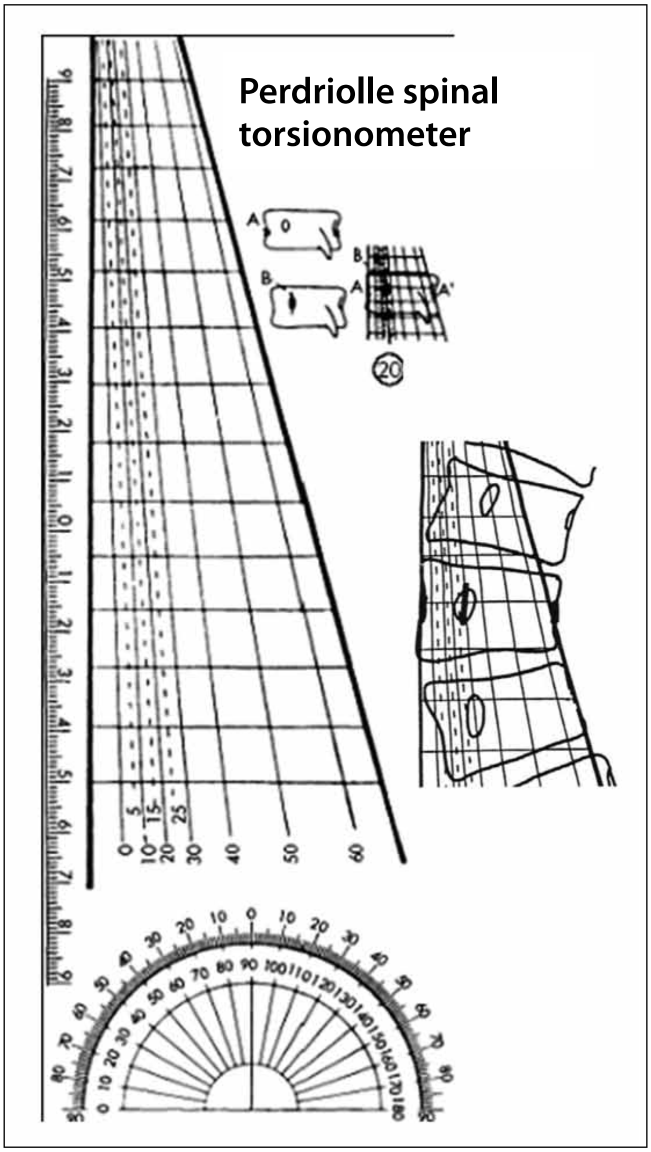

Figure 5: Measuring the rotation of vertebrae with perdriolle torsionometer.

as the degree of the curve increases. In their study Rogala et al. found the ratio of girls to boys as 1:1 between 6° and 10°, 1.4:1 between 11° and 20°, above 21° 5.4:1 for patients, who does not need treatment, and 7.2:1 for patients requiring orthopedic intervention. Higher progression rates in girls are thereby confirmed as a result of clinical observation (18). The risk of curve progression and factors influencing progression are important to know for selecting the method of treatment. Knowledge on progression factors will prevent unnecessary treatment since only 0,2% of the deformities spotted through community screening require treatment.

Natural History of Idiopathic Scoliosis

It is important to know the natural history of idiopathic scoliosis for treatment planning. There must be 5 to 10 degrees increase in the curves to define progression. The degree of the curve and the remaining growth potential of the patient should be known prior to the treatment planning. Risser sign is used for the radiological assessment of skeleton maturity. Risser sign is based on ossification of the iliac apophysis. Beginning on the lateral aspect of the iliac apophysis and the ossification progresses medially. Accordingly, the iliac apophysis is divided into four equal quadrants. Risser 0 has no ossification, while in Risser 4 all four quadrants of the apophysis show ossification. Risser 5 is observed when the ossified apophysis fuses completely to the ilium. Risser 4 indicates the end of spinal growth, whereas Risser 5 indicates full skeletal maturity. Patients at Risser 0 and 1 are at great risk due to their growth reserves (Figure 8). Particularly peak height velocity in girls should be taken into account. This period corresponds to the time, which is 6 months before the menarche in girls. This is the period when the progression in scoliosis is the fastest. The peak growth velocity terminates with the menarche and growth decelerates gradually following this period.

According to Bunnel and Lonstein, 70% of the patients with Risser sign 0, and curves of 20-30 degrees progressed 5 degrees and more (7). Weinstein stated that the curve might still progress although the patients he had followed-up for 40 years completed their maturation process (47). Nachemson reported that the curve might progress by up to 6 degrees in 66% of the patients with a curve between 20 to 30 degrees (33). Large curves (30-40 degrees) progress more than the minor curves (20-29 degrees). Curve type has an impact on progression as much as the curve degree does. Double curves progress more than the single curves. The lowest progression is in the curves in the lumbar region (26, 27). The curve progression rate in girls is higher than that in the boys (47).

Classification of Idiopathic Scoliosis

King Classification

King-Moe was the first classification of the idiopathic scoliosis in the chronological order (23). King et al. classified scoliosis into 5 sub-groups according to the location of the curve (Table I). The terminology adopted include structural and compensatory (secondary) curve, and the flexion index was defined as the difference between the rate of correction in the lumbar curve and the rate of correction in the thoracic curve at lateral bending direct radiography. King classification initially considered that lumbar curve was compensatory and argued that selective fusion would be adequate. Based on this argument, in their series, 405 patients with thoracic scoliosis received selective thoracic fusion by the help of a Harrington rod system. Richards et al. discovered that, in patients with a lumbar curve of 40 degrees and above, spinal imbalance developed in the post-surgery period of selective thoracic fusion.

Lenke Classification (Two-Dimensional Classification)

While the structural curve is considered as the biggest (major) curve, the other two curves are considered minor. There are some criteria according to which one can determine whether the minor curves are structural (Table II). In addition to the 6 types of curves (I-VI), Lenke classification also provides

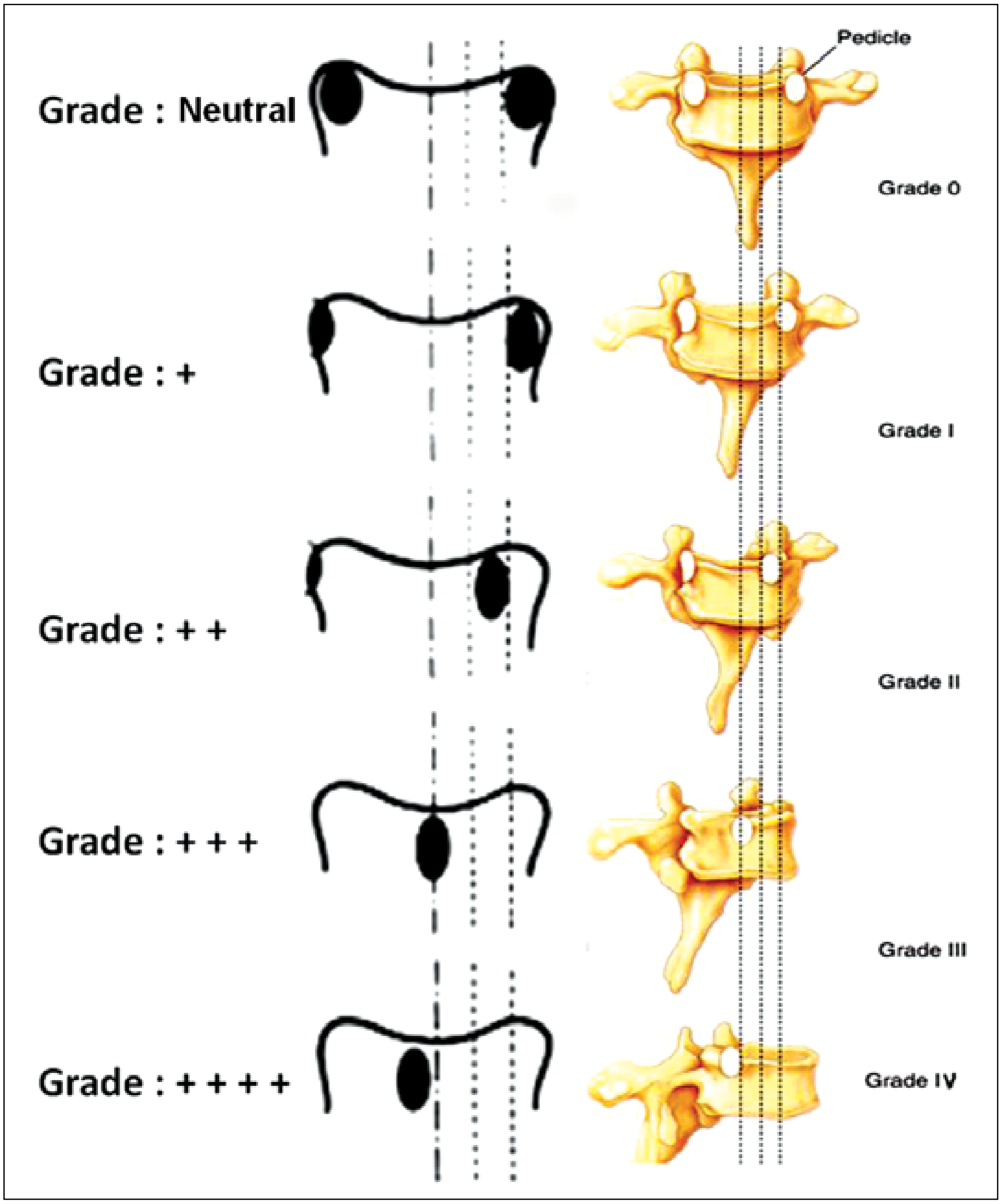

Figure 6: Vertebral rotation measurement according to Nash-Moe method.

for definitions of lumbar spine modifier and sagittal spine modifier (Table III) (24). Lenke Type I curve features a major curve in the main thoracic region. Curves in proximal thoracic (PT) and lumbothoracic (LT/L) regions are minor and non-structural. Lenke Type II curve features a double thoracic curve. Curves in proximal thoracic (PT) and main thoracic (MT) regions are structural, but the curve in the lumbothoracic region is non-structural. Lenke Type III curve features a major curve in the main thoracic region and a structural curve in the thoracolumbar region. Triple curves are defined at Lenke Type IV. In Lenke Type V, major curve is in the thoracolumbar (TL) junction. Curves in the proximal thoracic (PT) and main thoracic (MT) regions are non-structural. Lenke Type VI features a structural curve in the main thoracic (MT) and thoracolumbar /lumbar regions. The curve in TL /L is bigger than the curve in the MT (Table IV).

Limitations of Lenke Classification

Lenke classification does not clearly state the lowest and highest limit of fu-sion; neither does it indicate the extent to which the structural curve should be included in the fusion. The classification does not consider shoulder imbalance, patient maturity or body balance. However, compared to the King classification, the Lenke classification is useful for the surgeon to use a common vocabulary while describing the curve.

Figure 7: School screening for scoliosis.

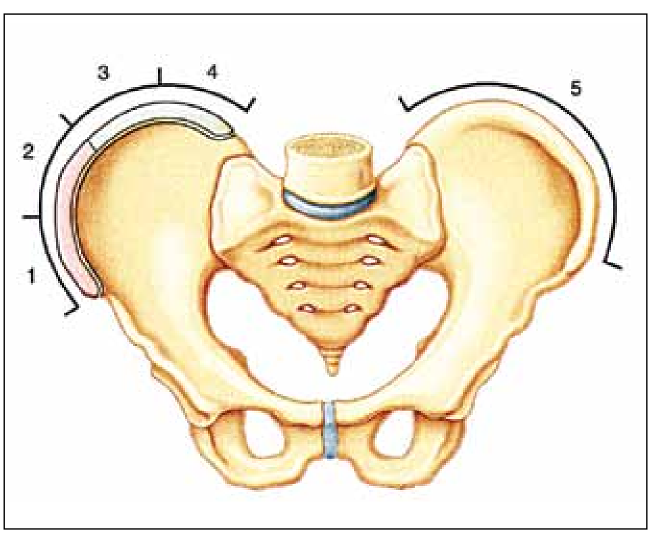

Figure 8: Risser sign.

TREATMENT

Follow-up and Exercise Therapy

Patients presenting with curves lower than 25 degrees and incomplete maturity are eligible for follow-up. Exercise therapy should be applied during the follow-up period.

Weiss et al. followed the lateral deviation surface rotation and kyphotic angle of a patient group by applying the 4-week Scoliosis Intensive Rehabilitation (SIR) program. It was observed that the lateral deviation and surface rotation decreased in the treatment group compared to the control group (49).

The Cobb angles of 107 patients treated by the Schroth method fell from 43.06 to 38.96 degrees compared to the pre-treatment values (49). McIntire et al. treated 15 patients with a mean age of 13.9 years, with Cobb angles ranging between 20-60 degrees, Risser sign III and below with physiotherapy by means of the MedX Rotary Torso Machine. It was reported

Table I: King Classification: 5 Sub-Groups According to the Primary Curve and Compensatory Curve

King Classification			
Type	**Primary Curve**	**Secondary Curve**	**Lateral Bending**
I	Lumbar, crossing the midline	Thoracic, crossing the midline	Lumbar curve is larger
II	Thoracic, crossing the midline	Lumbar, crossing the midline	Thoracic curve is larger
III	Thoracic	Lumbar, not crossing the midline	-
IV	Long Thoracic	Where L5 is centered over the sacrum	-
V	Double Thoracic T1 is tilted to the up-per thoracic curve	-	-

Table II: Structural Criteria for the Minor Curve

Structural Criteria (for Minor Curves)	
Proximal Thoracic	Cobb > 25 at lateral bending T2-5 kyphosis > +20
Main Thoracic	Cobb > 25 at lateral bending T10-L2 kyphosis > +20
Thoracolumbar/lumbar	Cobb > 25 at lateral bending T10-L2 kyphosis > +20

that six patients with curves between 20 to 40 degrees did not progress during 8-month follow-up period but progression could not be avoided by the end of 24-month follow-up (31).

Bracing

Bracing is indicated in immature patients with curves of 25 to 40 degrees (< Risser 3). For successful bracing, the existing curve should be preserved below 45 degrees until the patient reaches full maturity (42). Bracing is suggested for patients with Risser sign from 0 to 2, and current curve at 25-40 degrees.

Lonstein found a reduction by 1-4 degrees in 78% of 1020 patients with adolescence idiopathic scoliosis using Milwaukee braces, while it was reported that 22% of the cases required surgery (26, 27). In the Katz series, where 51 cases with curves between 36 to 45 degrees were followed up using Boston braces, bracing was successful in 61% of the patients, while 31% of the cases required surgery (21).

Milwaukee, Wilmington, Spine-Cor and Boston braces appear to be superior to the other types of braces. Price reported that the outcomes of 98 patients using Charleston braces were excellent in 63%. He reported that the major curves were corrected by 85% and the minor curves by 33% (36) (Figure 9).

Braces should be used for 18-23 hours a day on average. Braces were re-ported to be effective for patients with curves less than 35 degrees when used part-time or at night (36). Patients with curves equal to or greater than 35 degrees should use full-time braces. Braces should be used until the end of full growth. Bracing should be continued until the end of 6th month following the end of growth, up to Risser sign 4 in girls, Risser type 5 in boys, and for 18-24 months following the menarche in girls (42).

Surgical Treatment

Indications for Surgical Treatment

In general, curves greater than 45 and 50 degrees should be treated by sur-gery. Studies have indicated that curves greater than 50 degrees still progress even after reaching the full maturity (47). In another study where patients were followed for 50 years, it was reported that the thoracic curves progressed from 60.5 degrees to 84.5 degrees on average. One should not wait for the curve to progress since surgical treatment of greater degrees of curves would increase

Table III: Lumbar Spine Modifier is Defined According to the Central Sacral Vertical Line (CSVL). Types A, B and C are Determined Depending on the Central Sacral Vertical Line's (CSVL) Position to the Apical Vertebrae. Thoracic Spine Modifier is Determined as Hypokyphotic, Normokyphotic or Hyperkyphotic Ac-Cording to the Cobb Angle at the Sagittal Plane

Lumbar Spine Modifier	
Type A	CSVL passes between pedicles of apical lumbar vertebrae.
Type B	CSVL touches pedicle of apical lumbar vertebrae.
Type C	CSVL does not touch apical lumbar vertebrae.
Thoracic Spine Modifier	
	Sagittal Cobb Angle at T5 to T12
Hypo (-)	< 10 degrees
Normo N	10-40 degrees
Hyper (+)	> 40 degrees

Tablo IV: Lenke Classification

Lumbar spine modifier	Type 1 Main thoracic	Type 2 Double thoracic	Type 3 Double major	Type 4 Triple major	Type 5 TL/L	Type 6 TL / L - MT
A No to Minimal Curve	1A*	2A*	3A*	4A*		
B Moderate Curve	1B*	2B*	3B*	4B*		
C Large curve	1C*	2C*	3C*	4C*	5C*	6C*
Possible sagittal structural criteia (to determine spesific curve type)		≥ +20°	≥ +20°	≥ +20° ≥ +20°		

T5–12 sagittal aligment modifier: (-), N, or (+) (-): < 10^0 N: $10–40^0$ (+): > 40^0

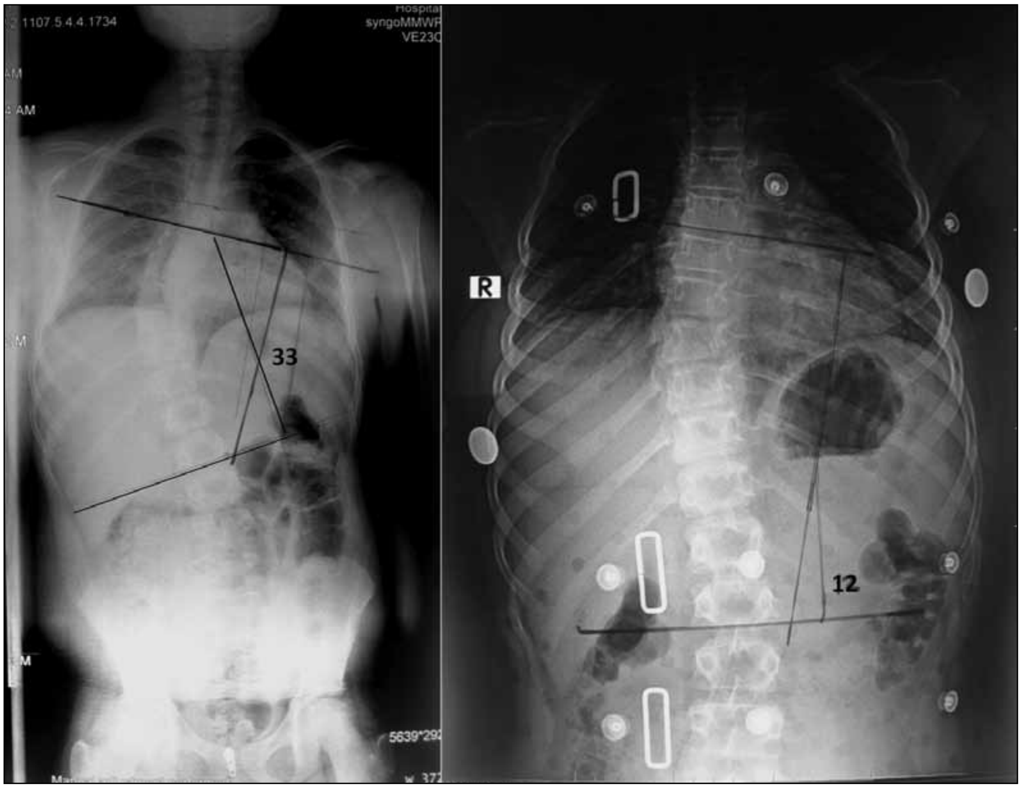

Figure 9: Deformity correction by bracing. Reduction from 33 degrees to 12 degrees.

complication rates and cause more intraoperative blood loss (Figure 10).

1. Fusion Surgery

Posterior instrumentation

Instrumentation was first used by Paul Harrington in the surgical treatment of scoliosis (17). Harrington attempted to correct the curves by distraction from the concave side using the rods. The second generation instrumentation system was developed by Cotrel and Dobousett.

They tried to achieve correction using rod rotation manoeuvres (12). The spine can be attached tightly to the rods by pedicle screws or hybrid systems thanks to today's advanced technology.

It was Suk who first used the pedicle screws in the surgical treatment of de-formities. He reduced the curves from 51 to 16 degrees on average (69% correction) (44). Asher et al reported to have achieved 63% correction using the hybrid system they applied with hooks and pedicle screws (6). Cheng et al. compared the hooks and transpedicular screws and reported no difference between both systems in terms of correction rates (10).

Determining the fusion levels (according to Lenke Classification)

Lenke Type 1: Main Thoracic Curve

All curves in this type can be treated by posterior instrumentation and fusion. It is the upper vertebrae T3, T4 or T5 that will be instrumented while lower instrumented vertebrae (LIV) depend principally on the lumbar spine modifier (24) (Figure 10).

Lenke Type 2: Double Thoracic Curve

The upper instrumented vertebrae (UIV) should be T2 or T3. On the other hand, LIV should be selected according to the procedure applied to Lenke Type I depending on the lumbar spine modifier. One of the basic rules to take into account in proximal thoracic (PT) curves is to preserve the shoulder balance (24).

Lenke Type 3 (Double Major Curve)

The UIV should be T3, T4 or T5 depending on the non-structural PT curve with shoulder imbalance just like in Lenke Type 1. LIV should usually be ex-tended to L3 or L4 (24) (Figure 11).

Lenke Type 4 (Triple Major Curve)

Since the proximal thoracic (PT), main thoracic (MT) and thoracolum-bar/lumbar (TL/L) curves are structural, three curves should be contained in the fusion. UIV should be selected as in Lenke Type 2 while LIV should be selected as in Lenke Type 3 (24).

Lenke Type 5 (Thoracolumbar and Lumbar Curves)

UIV should be the vertebrae one level or two level above the USV, whereas the vertebrae one level or two level below the LSV should be selected as the LIV (24) (Figure 12).

Lenke Type 6 (Main Thoracolumbar / Lumbar Curve)

The curve in the thoracolumbar/lumbar region is larger than the one in the main thoracic region. Both curves should be contained in the fusion. The surgical limits should be determined according to the principles applying to the Type 3 curves (24).

Anterior instrumentation

Anterior approach can be preferred as it can achieve correction with shorter fusion levels in the scoliotic thoracolumbar and lumbar regions. Postoperative pain and scar formation have decreased in patients with the introduction of the video-

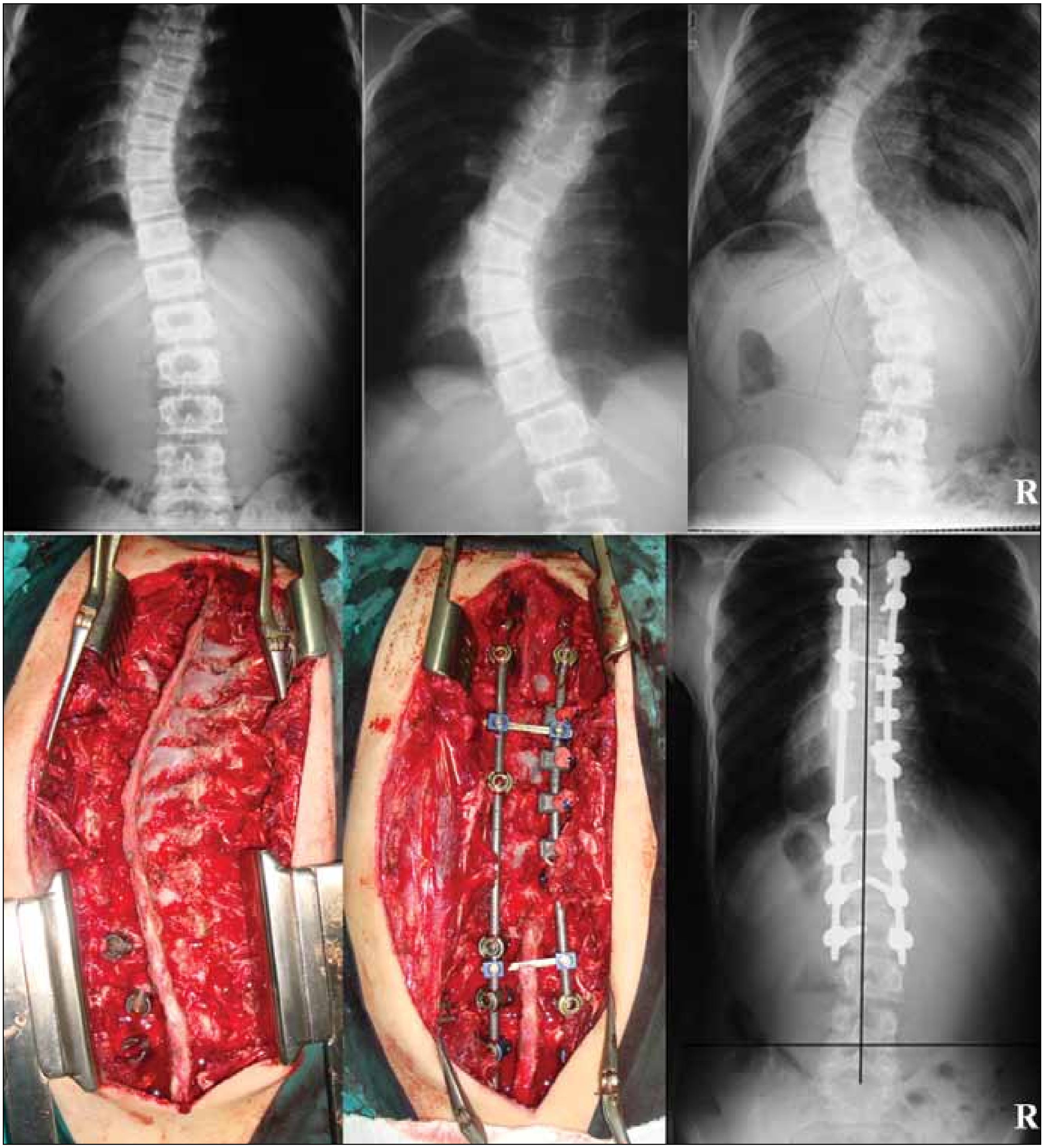

Figure 10: Progression of deformity during the follow-up of idiopathic scoliosis, thoracic main curve (Lenke Type 1B). Pictures of surgery and post-op correction of deformity (below).

Figure 11: Adolescent idiopathic scoliosis case with double major curve (Lenke Type 3B) and post-op pictures.

Figure 12: Adolescent idiopathic scoliosis case with main thoracolumbar curve (Lenke Type 5C) and post-op pictures.

assisted thoracoscopic surgery (37). Potter compared anterior and posterior fusion for thoracic curves and reported that the posterior approach achieved better correction compared to the anterior approach (35). Hee et al. reported no difference in the coronal plane between the anterior instrumentation and pedicle screws in patients with adolescence idiopathic scoliosis (17).

2. Non-Fusion Surgery

Non-fusion surgery is another option to control growth in the treatment of idiopathic scoliosis. Progression of the curve might be avoided by means of instrumented or non-instrumented epiphysiodesis on the convex side of the curve.

Betz et al. stated that preventing the growth in front of the vertebral column will also prevent the progression of adolescence idiopathic scoliosis whereas Marks argued that preventing the anterior and posterior growth in infantile scoliosis alone cannot stop the progression of the deformity (30).

After the fusion surgery at younger ages, the body remains shorter than the limbs. Shorter body prevents the development of lungs. Some techniques for the correction of the existing curve while also allowing the growth of the spine have been developed. The upper and lower parts of the curve can be fixed by the Isula double rod system developed by Akbarnia and attached to the rods, and the rods are attached to one another with an additional rod. The rods are extended in 6-month follow-up. After reaching full growth, fusion is completed with instrumentation. The degree of the curves that was preoperatively 82 on average was reduced to 38 degrees and then 36 degrees following an average 6.6 extension surgeries as a result of this method applied on 23 patients between 1993 and 2001 (2).

Vertical expandable prosthetic titanium ribs (VEPTR) were developed to treat the thoracic insufficiency syndrome that is caused by combination of ribs and curves (8). The deformity can be corrected acutely by means of VEPTR following the wedge thoracostomy. VEPTR device is expanded in 4-6 months time. Seventy two patients with a mean age of 3.2 years were treated with this device for 5.7 years and it was reported that the vital capacity increased and the curve degree was also reduced from 72 on average to 49 (8).

CONCLUSION

Each idiopathic scoliosis case should be assessed independently with regard to the patient's age, degree of the curve and patient's circumstances. The basic goal in the treatment of scoliosis is to make an attempt to stop the curve until the end of maturation. Once maturation is completed, the goal is to correct the curve as much as possible while avoiding neurologic complications. Surgery should also meet the patient's cosmetic expectations as much as possible. While trying to ensure body balance, it is essential to achieve shoulder balance and avoid breast asymmetry especially for girls.

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