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LUMBAR LORDOSIS AFTER POSTERIOR SPINAL FUSION IN ADOLESCENT IDIOPATHIC SCOLIOSIS: A RETROSPECTIVE ANALYSIS OF 22 PATIENTS

ADÖLESAN İDİOPATİK SKOLYOZDA POSTERİOR SPİNAL FÜZYON SONRASI LOMBER LORDOZ: 22 HASTANIN GERİYE DÖNÜK DEĞERLENDİRİLMESİ

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SUMMARY:

Study Design: Retrospective single-center clinical study

Objective: We aimed to evaluate lumbar lordosis after posterior spinal fusion and bilateral segmental instrumentation for AIS. We also evaluated patients' satisfaction with treatment.

Methods: Twenty-two AIS patients treated with posterior spinal fusion and followed at least two years after the operation were evaluated retrospectively. Radiographic parameters for changes on frontal and sagittal planes were measured on anteroposterior and lumbar lordosis X-rays, and patients' satisfaction was assessed by Scoliosis Research Society (SRS)-22r Patient Questionnaire preoperatively, at sixth month postoperatively, and at final visit which was at 43.6 months on average (range, 24-66 months).

Results: The mean thoracic or thoracolumbar curve correction rate was 74.6±11.8%. The lumbar lordosis decreased from 51.3°±13.1° to 42.8°±12.6° (p=0.014) and sacral slope angle from 40.9°±5.7° to 27°±8.7° (p<0.001) after the operation. Mean pelvic tilt angle increased from 7.9°±7.6° to 20.2°±9.9° (p<0.001). Thoracic kyphosis was within normal limits and did not change significantly throughout the follow-up. Total SRS-22r score improved from 3.4±0.6 to 4±0.3 after AIS surgery.

Conclusions: AIS surgery had no significant effect on throcal kyphosis and lumbar lordosis on sagittal plane; even insignificant decrease in lumbar lordosis reduces sacral slope, thus keeps sagittal C7 plumbline within normal limits, and as a result provides sagittal balance.

Keywords: Spine; Adolescent idiopathic scoliosis; Posterior spinal fusion; Bilateral segmental instrumentation.

Level of evidence: Retrospective clinical study, Level III

ÖZET:

Amaç: Bu çalışmamızda, AİS tedavisinde posterior spinal füzyon ve bilatarel segmental füzyon sonrasında lomber lordozun ve hastaların memnuniyetinin değerlendirilmesini amaçladık.

Materyal ve metod: AİS nedeniyle porterior spinal füzyon ile tedavi edilen ve operasyondan sonra en az iki yıl takibi olan 22 hasta retrospektif olarak değerlendirildi. Anteroposterior ve lomber lordoz direkt grafilerinde, frontal ve sagittal plandaki radyografik parametrelerdeki değişiklikler ölçüldü. Ameliyat öncesinde, ameliyat sonrası 6. ayda ve son takiplerinde (ortalama 43.6 ay, 22-66 ay) Scoliosis Research Society (SRS)-22r hasta değerlendirme anketi ile hasta memnuniyeti değerlendirildi.

Bulgular: Ortalama torasik ve torakolomber düzeltme % 74.6±11.8 idi. Ameliyat sonrası lomber lordoz 51.3° ± 13.1°'den 42.8° ± 12.6°'ye geriledi (p=0.014) ve sakral slop açısı 40.0° ± 5.7°'den 27° ± 8.7°'ye geriledi (p<0.001). Ortalama pelvik tilt açısı 7.9° ± 7.6°'den 20.2° ± 9.9°'ye yükseldi (p<0.001). Torasik kifoz normal sınırlar içerisinde idi ve takipler sürecinde anlamlı bir değişiklik göstermedi. Ameliyat sonrasında toplam SRS-22r puanı 3.4 ± 0.6 'dan 4 ± 0.3'e yükseldi.

Tartışma: AİS cerrahisi, lomber lordozda bir miktar azalma sakral slopu azaltsa bile, sagittal planda torakal kifoz ve lomber lordoz üzerinde anlamlı bir etki yapmamaktadır. Böylece sagittal C-7 çekül ipi çizgisi normal sınırlarda kalmakta ve sonuç olarak sagittal balansı korumaktadır.

Anahtar kelimeler: Omurga; Adelösan idiopatik skolyoz, posterior spinal füzyon, bilateral segmental enstrümentasyon

Kanıt düzeyi: Retrospektif klinik çalışma, Düzey III

INTRODUCTION:

Adolescent idiopathic scoliosis (AIS) is a three-dimensional torsional deformity of the spine that arises in otherwise healthy children around puberty. It is a complex disorder involving other bony structures such as the rib cage and often characterized by preoperative hypokyphosis[9,15,16]. It may lead to significant pain and functional disability; therefore, surgical correction is often required. In a successful AIS surgery, the main focus is the coronal curvature correction for achievement of shoulder level to have a proper balance of the spine on both the sagittal and coronal planes to prevent further deformity, to improve cosmesis, and to prevent back pain and subsequent cardiac and pulmanory problems[6,10,17,18].

Modern posterior segmental instrumentation systems, using a combination of hooks, wires, and pedicle screws, have enhanced a surgeon's ability to improve thoracic sagittal alignment and to maintain normal sagittal balance compared to previously used Harrington distraction instrumentation[1,3-5,7,11,13,14,19,21-24]. Despite advances in techniques and newer implants, avoiding persistent thoracic hypokyphosis can still be difficult, and posterior instrumentation systems tend to be more lordosing than anterior instrumentation[5,18].

Thoracic hypokyphosis as a surgical outcome of AIS have been well described in literature[4,15,22,23]; however, to our best of knowledge, there is no study evaluating the effect of posterior spinal fusion with segmental pedicle screw instrumentation on lumbar lordosis. Thus, we primarily aimed to evaluate the frontal and sagittal parameters, especially lumbar lordosis, after posterior segmental pedicle screw instrumentation and spinal fusion in AIS. We also evaluated patients' satisfaction with treatment.

MATERIALS AND METHODS:

Study design and patients:

Twenty-two patients with AIS (female/male ratio, 17/5; mean age, 14.2; age range, 12 to 22 years) treated with posterior spinal fusion and bilateral segmental pedicle screw instrumentation between 2010-2012 and followed at least two years after the operation were included in this retrospective study. Patients with neuromuscular scoliosis, congenital scoliosis or with prior scoliosis surgery were excluded.

This study was approved by the Institutional Ethics Committee and conducted in accordance with the Helsinki Declaration. All patients or legal represantatives signed a written informed consent form.

Clinical assessment:

Patients were examined preoperatively, at sixth month postoperatively, and at final visit which was at 43.6 months on average (range, 24-66 months). AIS was classified according to the amount of thoracic kyphosis: hypo, hyper and normokyphotic as described by Lenke et al[11]. The presence of secondary sex characters (axillar and pubic hair, breast development) and limb length discrepancy were recorded. Radiographical maturation was scored according to Risser sign[19]. Shoulder balance, pelvic balance, and 7th cervical vertebra C7-gluteal interval balances were evaluated with plumb line and costal and lumbar gibbosities with forward bending test in follow-up examinations.

Surgical technique:

Two senior surgeons (A.A.U. and M.Y.) performed one-stage posterior surgical correction and fusion with the same surgical correction technique by only posterior approach with derotation maneuver after placement of hybrid (screws/hooks) or all screws construct, without neuromonitorization. Posterior pedicular screws were applied at every level through standard paravertebral approach. Reduction technique was rod derotation, cantilever or simultaneous translation of two rods with spondylolisthesis screws.

Radiographic parameters

The radiographic measurements were obtained by the same orthopedic surgeon for all case (M.Y.) on entire vertebral column anteroposterior and lateral 36" cassette radiographs in standing position. In anteroposterior radiographs, distance of vertical line drawn from the C7 to the midsacral line (C7-midsacral), upper thoracic, thoracic, and lumbar Cobb angle[3], thoracic and lumbar rotation[14], 1st thoracic vertebra (T1) and pelvic parameters in the coronal plane[3] were measured (Figure-1).

The pelvic parameters were pelvic incidence, pelvic tilt angle, and sacral slope. Pelvic incidence is a morphological parameter defined as the angle between the line perpendicular to the middle of the cranial sacral endplate and the line extending from the middle of the cranial sacral endplate to the center of the bicoxofemoral axis (the line between the geometric centers of both femoral heads) (Figure-2).

Pelvic tilt angle is the angle between the vertical line and the line joining the middle of the superior sacral plate and the center of the bicoxofemoral axis. Pelvic tilt angle is a positional parameter acting as one of the regulator of the standing posture; pelvic retroversion (i.e., the posterior rotation of the pelvis) has been demonstrated to correlate with clinical outcomes in the setting of adult with spinal deformities[9]. Sacral slope is also a positional parameter and completes to geometrical relationship among pelvic parameters, where pelvic incidenceis equal pelvic sum of tilt angle and sacral slope, and defined as the angle between the horizontal line and the superior sacral end-plate tangent.

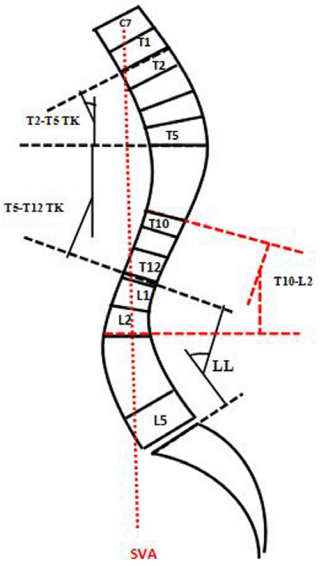

Figure-1. Radiographic pelvic parameters. PT; Pelvic tilt, the angle between the vertical line and the line joining the middle of the superior sacral plate and the center of the bicoxofemoral axis. PI; Pelvic incidence, the angle between the line perpendicular to the middle of the cranial sacral end-plate and the line extending from the middle of the cranial sacral endplate to the center of the bicoxofemoral axis (the line between the geometric centers of both femoral heads). SS; Sacral slope, the angle between the horizontal line and the superior sacral end-plate tangent.

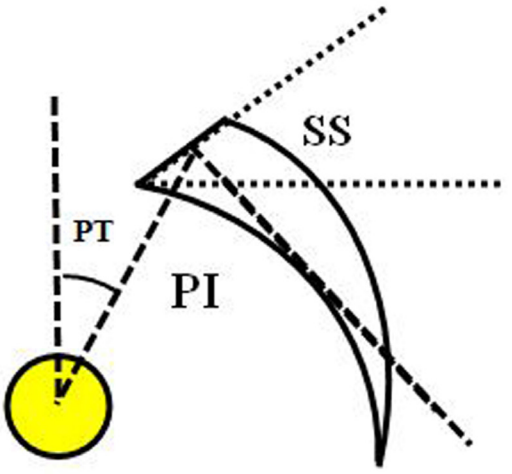

Figure-2. Sagittal spinal radiographic parameters. SVA; Sagittal vertical axis, the horizontal offset from the posterosuperior corner of S1 to the vertebral body of C7. TK; Thoracic kyphosis, is measured from the superior endplate of T4 to the inferior endplate of T12. LL; Lumbar lordosis is measured from the superior endplate of L1 to the superior endplate of S1.

Distance of C7 vertebral body midpoint plumb line to the posterosuperior corner of 1st sacral vertebra (S1) body, angles between T2-T5, T5-T12, T10-2nd lumbal vertebra (L2), and T12-S1 were measured in the sagittal plane and sagittal profile of the patients were generated accordingly[3].

Patient satisfaction

For the assessment of patients' satisfaction with AIS surgery, Scoliosis Research Society (SRS)-22r Patient Questionnaire was used. The SRS-22r is a valid instrument for the assessment of the health related quality of life of patients with scoliosis. It has five domains, each scoring between 1 (worst) and 5 (best): function, pain, self-image, mental health, and satisfaction with management. Turkish version of SRS-22r has been shown to be valid and reliable[21].

Statistical analysis

Statistical analysis was performed by the SPSS software package for Windows (Statistical Package for Social Sciences, version 12.0, SPSS Inc., Chicago, Illinois, USA). Categorical variables of the study groups were given as numbers and percentages and quantitative variables as mean±standard deviation (SD), median, minimum and maximum values. Student's t-paired test was used for parametric variables that followed a normal distribution. Pearson correlation was used to determine the relationship between variables. For comparison of more than two groups, Friedman test followed by post-hoc analysis with Wilcoxon signed rank test were used. The level of significance was set at $p<0.05$.

RESULTS:

Study population

The mean age at the onset of deformity was 12.1±2.5 years. Secondary sex characteristics were found only in one patient. Two female patients did not have menarche at the time of AIS surgery. Physical examination of the study patients showed distribution among several AIS classification types[13] and radiographical maturation grades (Table-1)[19].

Ten patients had type A, two had type B and the other ten had type C lumbar modifier. Five patients were hypokyphotic and one was kyphotic, whereas 72.7% of the patients had 10°-40° of kyphosis. Two patients had leg length discrepancy less than 2 cm and five patients had received orthotic treatment before surgery. Proximal fusion level was T2 in all patients, and distal fusion level was T12 in seven, L2 in seven, L3 in three, T11 in two, L1 in two and T10 vertebrae in one case. Four patients developed pulmonary complications like prolonged ventilation and pneumothorax but no significant relation was noted between development of pulmonary complications and coronal or sagittal parameters.

Table-1. Demographic and clinical characteristics of the study patients

		Total (n=22)
Age (mean±SD, years)		14.2±2.4
Gender (n, %)	Male	5 (22.7%)
	Female	17 (77.3%)
AIS classification (13) (n, %)	Type 1	7 (31.8%)
	Type 2	6 (27.3%)
	Type 3	3 (13.6%)
	Type 4	1 (4.6%)
	Type 5	2 (9.1%)
	Type 6	3 (13.6%)
Radiographical maturation (14) (n, %)	Grade 0	1 (4.6%)
	Grade 1	1 (4.6%)
	Grade 2	5 (22.6%)
	Grade 3	1 (4.6%)
	Grade 4	11 (50.0%)
	Grade 5	3 (13.6%)

Changes in clinical and radiographic parameters after AIS surgery

There were significant improvements in preoperative shoulder balance, pelvic balance, costal gibbosity and lumbar gibbosity values after AIS surgery and at the last follow-up ($p<0.05$ for all, Table-2).

The mean postoperative frontal plane correction compared to preoperative value was 74.6±11.8%, whereas correction percentage at the last follow-up was 75.5±12.5%. No significant correction loss was observed in any study patients. There were significant improvements in the upper frontal, thoracic and lumbar deformity parameters after surgery ($p<0.05$ for all, Table-3).

However, no significant increase in thoracic kyphosis values, all of which were within normal limits, was observed at sagittal plane ($p=0.702$, Table 3). Three patients developed hypokyphosis after surgery. There was no significant difference between preoperative and postoperative kyphosis degrees in either patients with or without hypokyphosis ($p>0.05$ for both).

The mean postoperative lumbar lordosis decreased from a mean of -51.3°±13.1° to -42.8°±12.6° at the final follow-up examination ($p=0.014$). With respect to preoperative pelvic measurements and measurements at the last follow-up, there was a significant decrease in sacral slope angle from 40.9°±5.7° to 27°±8.7° ($p<0.001$), and pelvic tilt angle was found to be significantly increased from 7.9°±7.6° to 20.2°±9.9° ($p<0.001$).

The preoperative total SRS-22r scores of the patients significantly improved in the last follow-up after surgery (3.4±0.6 to 4±0.3, $p<0.001$).

DISCUSSION:

In this retrospective study involving 22 AIS patients treated with posterior pedicle screw instrumentation and fusion, postoperative coronal plane curve correction at the last follow-up examination was found to be about 75%.

Table-2. The change in physical examination findings of the patients before and after AIS surgery

	Preoperative	Postoperative6 months	Last follow-up(24 to 66 months)	p[a]
C7-gluteal space (cm)	1.5±1.8	0.7±0.9	0.5±0.7	0.150
Shoulder balance (cm)	1.3±1.1	0.4±0.8	0.4±0.5	*0.004*
Pelvic balance (cm)	0.3±0.7	0±0	0±0	*0.018*
Costal gibbosity (cm)	3±1.8	0.2±0.4	0.6±1	*<0.001*
Lumbar gibbosity (cm)	0.5±1	0±0	0±0	*0.002*

[a]Friedman test for comparison of preoperative versus postoperative 6 months values.
The results are given as mean±SD.

Table-3. The change in radiographic parameters of the patients before and after AIS surgery

	Preoperative	Postoperative	Last follow-up (24 to 66 months)	p[a]
Frontal C7-midsacral line (cm)	1.9±1.3	1.2±1.2	1±1	0.190
Frontal T1 tilt angle (°)	6.2±6.1	2.3±3.2	2.3±3.7	*0.001*
Frontal upper thoracal curve (°)	16.4±16.2	3.2±7.6	3.3±6.6	*<0.001*
Frontal thoracal curve (°)	59.6±16.6	15.1±7.6	14.1±8.8	*<0.001*
Frontal lumbar curve (°)	33.7±30.2	12.3±12.2	13.6±11.3	*0.002*
Upper thoracal rotation	0.6±0.7	0.2±0.5	0.2±0.4	*0.003*
Thoracal rotation	1.9±0.8	0.8±0.6	0.9±0.5	*<0.001*
Lumbar rotation	1.1±1.1	0.7±0.8	0.6±0.7	*0.013*
T2-T12 kyphosis (°)	31.6°±18.8°	30.5°±10.2°	28.5°±8.5°	0.702
Sagital C7-plumb line (cm)	1.7±2.3	3±2.1	2.2±2.3	0.225
Sagital T2-T5 (°)	10.1°±9.4°	11.4°±7.6°	10.4°±6.9°	0.688
Sagital T5-T12 (°)	21.5°±16.8°	20°±10°	18.1°±6.8°	0.781
Sagital T10-L2 (°)	7.1°±20.2°	1.1±11.8	-1±9.6	0.272
Lumbar lordosis (°)	-54.9±19.4	-51.3±13.1	-42.8±12.6	0.232
Sacral slope angle (°)	40.9±5.7	39.7±4.3	27±8.7	*<0.001*
Pelvic tilt angle (°)	7.9±7.6	8±5.2	20.2±9.9	*<0.001*

[a]Friedman test for comparison of preoperative versus postoperative 6 months values.
The results are given as mean±SD.

Although there was no significant increase in thoracic kyphosis, preoperative, postoperative and the last follow-up kyphosis values of the study patients were in the normal limits. In addition, postoperative T1 tilt angle was significantly improved with AIS surgery.

Maintaining or restoring sagittal balance and sagittal plane parameters within the normal values is important in maintaining the long-term health of the spine[18]. Patients with AIS are characterized by preoperative thoracic hypokyphosis, and it is generally accepted that surgical treatment should aim to improve sagittal plane deformities and to restore thoracic kyphosis to normal values while maintaining lumbar lordosis and good overall sagittal balance[10,18]. The use of pedicle screws with posterior instrumentation construct was shown to allow a stronger correction of spinal deformity[1,7,24].

The main aim of AIS surgery is the correction of trunk distortion, along with the cosmetic deformity[8,12,15]. The unleveled shoulders and costal gibbosity are commonly observed in AIS patients with distorted thoracic curve[16]. In addition, lumbar gibbosity and pelvic imbalance are observed in patients

with defects in lumbar and thoracic lumbar curve. Hong et al.[6] reported that fusion from T1 or T2 including proximal end of the curvature were more effective in correction of T1 tilt angle and postoperative shoulder balance. In the present study, a significant improvement in postoperative shoulder balance was observed in all patients, which resulted from the fusion of T2 and the proximal end of the curvature. However, since thoracic curve was derotated and involved in the fusion, no postoperative improvement was observed in costal gibbosity. The main reason in significant improvement in pelvic balance and lumbar gibbosity was, therefore, the correction of lumbar curve. We also found that sacral obliquity angle was correlated with preoperative sacral gibbosity and lumbar Cobb angle. However, there was no correlation between postoperative values. The extension of the instrumentation to L3 in three patients might have affected the decrease in lumbar lordosis; thus, insufficient number of cases might cause this unexpected observation.

The importance of obtaining a good sagittal alignment in the AIS surgery is well studied, whereas there is only few studies in the literature focusing on the effect of surgical correction of the deformity on spinopelvic parameters, although recent publications reported the importance of considering the sagittal spinal and pelvic alignments in AIS surgery outcome[2,20]. Clément et al.[20] reported a positive correlation between distal lumbar lordosis and sacral slope, and distal lordosis and pelvic incidence, in their study on evaluation of spinal and pelvic sagittal parameters on lateral radiographs of 86 patients with thoracic AIS. The results obtained in a radiographic retrospective study of 76 patients with AIS undergoing posterior only surgical correction and fusion suggested that the increasing amount of pelvic tilt after surgery enables the activation of pelvic compensation mechanism to try to restore the spinal balance[6]. The same study reported a slight further posterior imbalance, especially in Lenke type 1 curves, in AIS patients with hypokyphosis[10]. In this study, we found no increase in thoracic kyphosis despite the decrease in lumbar lordosis and sacral slope. Considering the pelvic compensation mechanism, our results suggested that the decrease in sacral slope consequently resulted an increase in pelvic tilt to balance C7-plumb line in position.

It should be also noted that although there was a lordosing effect of surgery on the thoracalumbar junction at final follow-up compared to preoperative values, the difference was not statistically significant (p=0.272). This lordosis was probably due to the lordosing effect of pedicle screws, since change in T10-L12 angle was more remarkable at early postoperative assessment than at final-follow-up (from 7.1˚±20.2˚ to 1.1˚±11.8˚ vs. from 1.1˚±11.8˚ to -1˚±9.6˚, respectively). Furthermore, lordosis on the thoracalumbar junction at long-term may contribute to the decrease in lordosis in the lumbar region, because both the thoracalumbar junction and the lumbar region include T12-L1-L2 segments.

Limited patient size and retrospective design are the main limitations of this study. The distribution of the study patients in AIS classification (Lenke types) and radiographical maturation (Risser grades) further limits us to reach a definitive conclusion. Additional prospective, large-scale studies are still required to evaluate the improvement in frontal and sagittal profile in patients after AIS surgery by posterior approach with derotation maneuver after placement of hybrid (screws/hooks) or all screws construct.

In conclusion, the AIS management by posterior spinal fusion and bilateral segmental instrumentation provides radiological and clinical improvement on frontal plane and patients' satisfaction. Although AIS surgery had no significant effect on throcal kyphosis and lumbar lordosis on sagittal plane; even insignificant decrease in lumbar lordosis reduces sacral slope, thus keeps sagittal C7 plumbline within normal limits, and as a result provides sagittal balance. For surgical treatment of AIS, the relationship between lumbar lordosis and frontal and sagittal profile parameters should be considered.

CONFLICT OF INTEREST AND FUNDING

Authors declared no conflicts of interests. The study was not funded.

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