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ORIGINAL ARTICLE

FUNCTIONAL AND RADIOLOGICAL RESULTS OF THORACOLUMBAR / LUMBAR ADOLESCENT IDIOPATHIC SCOLIOSIS (AIS) TREATMENT WITH POSTERIOR PEDICLE SCREWS

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ABSTRACT

Aim: Correlation between coronal imbalance and radiological parameters in Lenke type 5C curves treated with posterior pedicle screws were studied and effects on the clinical results were evaluated.

Material and methods: Sixteen patients with Lenke type 5C AIS operated between years 2008-2015 were included in this study. Ten patients (62.5%) were female and 6 (37.5%) were males. The average age of patients were 15.5 years and mean follow-up duration was 37 months. The parameters affecting coronal and sagittal balance were measured on patients' pre-operative, post-operative and last control X-rays. SRS-22 questionnaire was applied to the patient for the clinic satisfaction of the patients postoperatively.

Results: Patients were divided to 2 groups. Group 1 consisted of 8 patients with preserved coronal balance, and group 2 consisted of 8 patients with coronal imbalance. Radiological and clinical parameters of the groups were compared statistically in the early and late postoperative period. When patients' demographic data and radiological parameters were compared preoperatively and early postoperatively, no statistical differences were observed between two groups. In the last control assessment in group 2, the major TL/L curvature, minor thoracic curvature, SVL, thoracic apical vertebrae (TAV) translational amount and L4/5 disc angle were found to be significantly different ($p<0.05$). No statistical difference in terms of clinical outcomes were observed between 2 groups.

Conclusion: We found that minor thoracic curvature, TAV translation and L4 / 5 disc angle have an impact on coronal balance in long-term, however no correlation was found between radiological coronal imbalance and clinical outcomes.

Key words: Thoracolumbar/lumbar scoliosis; adolescent idiopathic scoliosis; coronal balance; L4/5 disc angle; posterior selective fusion.

Level of evidence: Retrospective clinic study, Level III.

INTRODUCTION

Lenke type 5C curvatures include compensatory non-structural thoracic curves, along with main structural thoraco-lumbar and lumbar curvature. Aims of surgical treatment of these spinal deformities include obtaining maximal correction, establishment of good spinal balance, and obtaining maximal function. Surgical options include anterior, posterior and combined approaches. Anterior surgical technique which became popular with Dwyer was considered as standard treatment of cases with Lenke type 5C curves till the last 10-20 years. A more mobile spine with better balance and correction is obtained by adding a shorter segment to fusion with anterior surgery. However, observation of high rates of pseudo-arthrosis, thoracic and vascular injury, and unacceptable surgical scar in the patients, with kyphosis development on the upper level of segment on which fusion was done on follow-up of anterior surgical approach have led to predominance of posterior surgical approaches in recent years. Emergence of systems which facilitate correction of spinal rotation with pedicle screws after instrumentation by hook by Shufflebarger and described by Harrington have resulted in routine use of posterior surgical intervention for Lenke type 5C curves currently. Debate continue on determination of proximal and distal instrumentation levels aiming to prevent decompensation that may occur after correction of this type of curvatures from posterior.

We aimed to investigate the correlation between radiologic parameters and coronal balance disorders that develop during follow-up of Lenke type 5C curves which we had treated by correcting with posterior pedicle screws and fusion and its impact on clinical outcomes.

MATERIAL AND METHODS

A total of 16 patients with Lenke type 5C curves who were operated at Akdeniz University Medical School, Clinic of Orthopedics and Traumatology between 2008-2015, and whose medical records could be obtained were included in this study. Inclusion criteria included patients between 11-21 years old, deformities with Cobb's angle between 30-60 degrees, in whom single-step correction with double rod was performed from posterior, who were followed-up for at least 5 months, whose x-rays were taken pre-operatively, at the early post-operative period (week 1) and at follow-up, who had SRS-22 record forms for early post-operative (month 1) and last control examination. Exclusion criteria were as follows: a history of past spinal surgery, deformities with Cobb's angle higher than 60°, patients younger than 10 years of age, Risser stage 0 patients, those with spinal instrumentation extended beyond T3-4-5 levels, and those with lumbar or thoraco-lumbar kyphosis.

PA and lateral scoliosis x-rays were obtained in all patients who would undergo surgery. Bending radiographs were taken between the years 2008-2010, and traction radiographies under general anesthesia were obtained after 2010, in order to evaluate the flexibility of curvature and determine the instrumentation level. Turkish version of SRS-22 questionnaire form was used in evaluation of functional status of all patients. Control x-rays at early post-operative period were obtained on the mean 3rd day, as standing PA and lateral scoliosis x-rays. Post-operative controls were done on the day 15, day 45 , month 3, month 6, month 9, month 12 and month 18, and yearly afterwards. Radiologic parameters were determined according to Spinal Deformity Group Guidelines and manually measured [1]. Angles of major and minor curvatures were measured with Cobb method, with Risser stages, vertebral rotations according to Nash-Moe, Global Coronal Balance), Regional Coronal Balance , truncal shift, vertebral translation , upper instrumental vertebral tilt (UIV) and disc angle, lower (L-3 or L-4) instrumental vertebral (LIV) tilt and disc angles, while Thoracic Kyphosis (TK), Lumbar lordosis (LL), SVL, proximal junction kyphosis(PJK) were measured from lateral x-rays. Global Coronal Balance was determined by measurement of the distance between CSVL and C7 vertebral midline in millimeters. The upper limit of this value was accepted as 20 mm in some studies, while in our study a displacement of 15 mm from the midline was considered coronal imbalance [2]. Regional Coronal Balance is the measurement of the distance in millimeters between L3, L4 and apical vertebral center and CSVL. Lumbar Coronal Balance was determined as the distance between CSVL and midline of lower instrumental vertebrae. Truncal shift is the distance between CSVL line and the midline of lateral margins of ribs in the mid-thoracic region in millimeters. Apical vertebra translation was evaluated by measuring the distance of C7 plumb line and thoracic and lumbar apical vertebrae (TAV, LAV). LIV tilt was defined as the angle between inferior end-plate of the lower instrumented spine and horizontal line. UIV tilt was defined as the angle between upper end-plate of upper instrumented spine and horizontal line. LIV-Disc Angle was defined as the angle between LIV inferior end plate and upper end-plate of the lower level spine. UIV-Disc angle was measured as the angle between UIV upper end-plate and adjacent upper vertebra lower end-plate. The angle between upper end-plate of T5 vertebrae and lower end-plate of T12 vertebrae was measured for thoracic kyphosis, and the angle between upper end-plate of L1 vertebrae and lower end-plate of L5 vertebrae for lumbar lordosis was measured by Cobb's method [3].

The angle between lower end-plate of upper instrumented vertebra and upper end-plate of the vertebra 2 levels above was measured post-operatively, and it was considered proximal junction kyphosis (PJK) if it is above 10° and there is an increase more than 10° in comparison with pre-operative values [4]. Fusion criteria in x-rays of patients at post-operative controls included absence of clinical complaints, absence of segmental movement, presence of radiologic fusion findings and absence of implant insufficiency or absence of radioluscent line around the implant. SRS-22 forms were filled at all control examinations and recorded. Functional outcomes of patients were evaluated by means of data obtained at last evaluation. questions in SRS -22 forms were separated into four groups and were evaluated based on mean values.

Surgical Method

All patients were administered prophylactic cefazoline sodium IV 1 hour before the surgery. Antibiotic prophylaxis was continued till the 3rd post-operative day. All patients were operated under general anesthesia. After invasive monitorization and placement of urinary catheter, traction x-rays were taken manually under general anesthesia.. Before the patients were put in the prone position, silicon supports were placed, leaving the mid portions empty, in order to prevent the abdomen and thorax being exposed to pressure and to prevent development of fat necrosis in the breasts.

Regions adjacent to the bone such as elbow and patella were supported with cotton. Surgical incision was done in the midline, and posterior elements were reached with help of cautery subperiostally till the transverse processes. The capsule of facet joints, and all soft tissues including interspinous and supraspinous ligaments were exposed. Capsule and soft tissues surrounding facet joint were cleaned with cautery and rongeur. The next step was excision of facet joints that would be included in the fusion area.

Osteotome was used in case when needed, in order to excise superior joint process of the inferior vertebra at all levels. Leksell ronguer was used to clean all joint cartilage before excision of joint processes.

Ligamentum flavum was excised at the next step with Kerrison ronguer and, polyaxial segmental pedicle screws (Johnsons&Johnsons and Medtronic) were inserted between proximal and distal end vertebrae and at every level that insertion was possible with free-hand technique.

Pedicle orientation was verified under fluoroscopy control when necessary. After placement of pedicle screws were controlled, next step of the intervention was placement of rod. Titanium rod of 5.5 mm with lordotic shape was placed at the convex side of curvature to obtain lordosis and correct the coronal deformity. Fixation of this rod on the most distal instrumented vertebra first facilitated rod placement. Placement of convex rod was completed with Cantilever maneuver. Concave rod was given less lordosis than the first rod. Less lordosis of this concave rod enabled de-rotation as a block as the rod was being pulled by screws on the concave side. This rod was fixated to the most proximal and distal screws preferentially. After that, middle portion of deformed curve was pulled towards the posterior rod. After placement of two rods, direct vertebral rotation was done. In order to obtain optimal balance, lower instrumented vertebra was tried to be put parallel to sacrum, and rotation was tried to be lowered to 0-1 level with compression and distraction maneuvers, and intra-operative control x-rays and fluoroscopic images were evaluated for this aim. When necessary, these maneuvers were repeated. Cross-link was not used routinely.

Decortication was done till the tips of transverse processes, in addition to facet excision for posterior arthrodesis. Afterwards, autogenous and allogeneic bone grafts were used. Neuromonitorization was used in 7 patients during surgery, while wake-up test was used in all other patients. After correction and arthrodesis procedure, subfascial hemovac drains were placed and structures were closed in accordance with the procedure. After the intervention was completed, x-rays were taken at supine position at the operating room and the patients were taken to the intensive care unit. After the operation, remaining part of the 48 hours extended prophlactic antibiotherapy (Cefazoline Na IV 3x1 g) was continued. When the patients recovered at the intensive care unit, neurological examination was done. As the patients were taken to the ordinary ward from the intensive care unit, urinary catheters were removed. On the post-operative 2nd day, drains were pulled and all patients were mobilized. No corset or casts were used in any patients. Sedentary activities were permitted as tolerated and most sports activities were permitted after 3-6 months from surgery. Post-operative standing PA and lateral control x-rays were taken in all patients. The patients were discharged after a mean 6 days, and sutures were removed on the day 15 . The patients were followed-up on week 6,month 3, 6, 12 and 18 , and yearly afterwards with standing PA and lateral x-rays.

Early superficial or deep wound site infections, opening of incision, atelectasis or other pulmonary complications were not seen. Implant failure, late infections were not seen in the long term. Proximal junctional kyphosis was seen in 3 patients but they did not require treatment.

RESULTS

Among 16 patients included in this study, 10 were females (62,5%) and 6 (37,5%) were males. Their age varied between 11 – 21 years, a mean of 15,5 years at surgery. The duration of follow-up was between 5 - 95 months (Mean 37 months). Risser staging at time of surgery was as follows: 1 patient at stage 1, 1 patient at stage 2, 2 patients at stage 3, 10 patients at stage 4 and 2 patients at stage 5.

Instrumentation and fusion was applied to mean 6 levels (between 3-7). Two opposing pedicle screws were placed at every level in 12 patients, while one instead of two screws due to pedicle conformity problems at one level in four patients.

Early post-operative phase and last control SRS-22 questionnaire forms were evaluated in all patients. Clinical satisfaction scores were between 3,36 and 4,91 in the early post-operative period (mean 3,94). Clinical satisfaction scores at last control was between 3,05 and 5 (mean 4,12).

The pre-operative TL/L Cobb Angle was between 23º - 45º (mean 36º). It was between 2º - 16º at the early post-operative period (mean 7º) and correction was measured as 81%. It was between 1º - 14º at the last control (mean 7º) and the correction was 81%. Pre-operative Thoracic cobb Angle was between 6º - 28º (mean 15º). Thoracic Curve was between 1º- 18º at the post-operative early period (mean 8º) and spontaneous correction was 47%. It was between 1º - 35º at the last control (mean 7º) and correction was 53%.

Preoperative vertebral rotation that was measured with Nash – Moe method was stage 3 in 2 patients, and stage two in 14 patients. In the early post-operative and last control, it was stage 2 in only 1 patient, and stage 1 in 15 patients. Tilt angles of L3 and L4 vertebra were measured in all patients. Pre-operative L3 tilt was between 9º - 29º (mean 20º). It was between 1º - 8º in the early post-operative period (mean 5º). In the last control, it was between 1º - 10º (mean 4º). L4 tilt angle was between 9º - 26º (mean 18º). It was between 2º - 11º in the early post-operative period (mean 6º). In the last control, it was between 2º - 9º (mean 5º).

The pre-operative thoracic kyphosis angle was between 6º - 38º (mean 28º). In the post-operative early period, it was between 12º - 48º (mean 26º). At the last control, it was between 15º - 51º (mean 32º). The pre-operative lumbar lordosis angle was between 7º - 60º (mean 38º). In the post-operative early period, it was between 20º - 61º (mean 41º). At the last control, it was between 22º - 68º (mean 45º). The pre-operative truncal shift amount was between 3 mm - 38 mm (mean 14 mm). Post-operative early period values were between 1 mm - 33 mm (mean 11 mm). At the last control, these were between 1 mm - 25 mm (mean 8 mm). PJK development was observed in 3 patients during follow-up, but these did not require treatment as they did not cause any complaints.

The patients were evaluated in terms of coronal balance.. Patients with a distance longer than 15 mm were considered to have coronal imbalance, which was present in 8 of 16. The patients were classified in two groups according to coronal balance (CB). Group 1 included patients with good coronal balance and Group 2 included patients with coronal imbalance, both groups consisting of 8 patients **(Figure-1 and 2).**

In the comparison of Group 1 patients and Group 2 patients, measurement values were calculated as means and standard deviations in statistical methodology. Mann Whitney U test was used in order to detect whether measurement times differed between groups or not. Friedman test was used in the investigation of differences in measurement times of the patient groups. Bonferroni dual comparison test was used to detect different measurement times (post hoc test). Values of <0,05 were considered as statistically significant. The analysis were done with SPSS 22.0 software.

The pre-operative TL/L curve, minor thoracic curve, apical rotation, TAV translation, coronal balance, lumbar coronal balance, truncal shift, thoracic kyphosis, PJK, lumbar lordosis, SVL, LAV translation, age at surgery, UIV tilt, L3 vertebra tilt, L3/4 Disc Angle, L4 vertebra tilt, L4/5 Disc Angle, LEV level and CSVL level at Lumbar vertebra measurements were similar in patients in Group 1 and Group 2, without statistically significant differences (p>0,05) **(Table-1).**

Mann. Whitney U test was used in investigation of differences between groups in terms of early post-operative measurements and the results are presented in Table-2. Coronal balance and truncal shift measurements were different in Groups in early post-operative measurements (Mann U *z*=-3,82,-3,35, p<0,05) **(Table-2).**

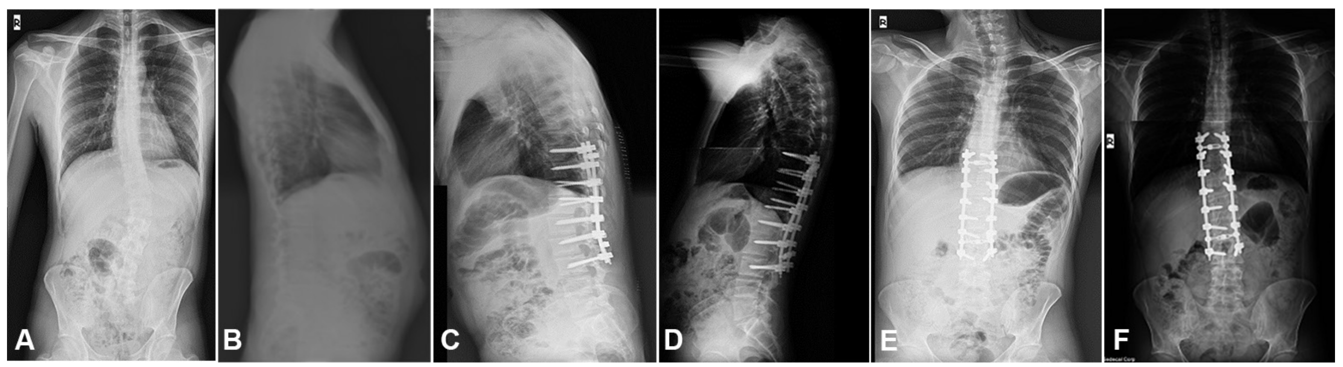

Figure-1. Male case aged 21 years from Group 1 patients. PA and lateral control x-rays in the pre-operative, early post-operative period and at month 27. Coronal balance is seen to be preserved at the early phase and at the last control.

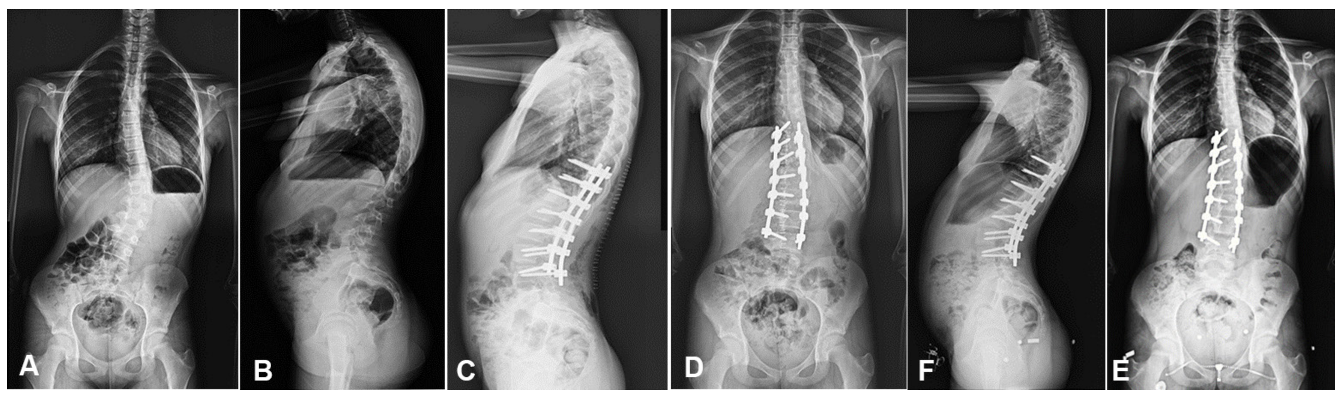

Figure-2. Female patient aged 14 years from Group 2. PA and lateral x-rays in the pre-operative and early post-operative period and at the month 14 control.

Mann. Whitney U test was used in investigation of differences in last control measurements according to groups and the results are presented in Table 3. Differences were found between last control measurements of patients in Group 1 and Group 2 in terms of major TL/L Curve, minor thoracic curve, SVA, TAV translation amount, and L4 disc angle. The cause of differences was found to be higher values of major TL Curve, minor thoracic curve, SVA, TAV Translation, L4 disc angle measurements of patients in Group 2 in comparison to Group 1 (Mann U *z*=-2,86,-4,61, 2,60 2,84,-3,14,p<0,05) **(Table-3).**

Table-1. Investigation of differences in preoperative measurements according to groups

Measurement	Group	N	Mean	s.ds	Mann U *z*	P
Major TL/L Curve	Group1	8	34,88	6,33	-0,59	0,57
Group 2	8	36,50	4,60			
Minor Thoracic Curve	Group1	8	13,25	5,63	-1,04	0,32
Group 2	8	16,88	8,10			
Apical Rotation (Nash-Moe)	Group1	8	2,25	0,46	1,53	0,15
Group 2	8	2,00	0,00			
Thoracic Apical Vertebra (TAV) Translation	Group1	8	14,75	7,59	-2,17	0,05
Group 2	8	21,50	4,44			
Coronal Balance	Group1	8	14,13	12,47	-1,73	0,10
Group 2	8	24,13	10,51			
Lumbar Coronal Balance	Group1	8	43,63	20,49	0,03	0,98
Group 2	8	43,38	19,06			
Truncal Shift	Group1	8	12,75	10,90	-0,29	0,78
Group 2	8	14,38	11,46			
Thoracic Kyphosis	Group1	8	28,13	7,99	0,88	0,39
Group 2	8	24,00	10,56			
PJK	Group1	8	10,00	5,04	-0,10	0,92
Group 2	8	10,25	4,74			
Lumbar Lordosis	Group1	8	37,88	16,06	-0,21	0,83
Group 2	8	39,50	14,42			
SVA	Group1	8	10,38	23,63	-1,56	0,14
Group 2	8	51,25	70,42			
Lumbar Apical Vertebra (LAV) Translation	Group1	8	30,75	10,44	0,95	0,36
Group 2	8	25,13	13,10			
Age at surgery (Months)	Group1	8	199,38	32,52	1,79	0,09
Group 2	8	175,00	20,59			
UIV Tilt Angle	Group1	8	8,88	3,27	0,19	0,85
Group 2	8	8,50	4,63			
UIV Disc Angle	Group1	8	4,00	2,39	1,19	0,25
Group 2	8	2,75	1,75			
L3 Tilt Angle	Group1	8	19,63	6,50	0,08	0,93
Group 2	8	19,38	5,21			
L3 Disc Angle	Group1	8	3,38	2,39	-1,33	0,21
Group 2	8	5,75	4,46			
L4 Tilt Angle	Group1	8	20,38	3,16	2,19	0,05
Group 2	8	16,25	4,30			
L4 Disc Angle	Group1	8	9,38	3,66	2,02	0,06
Group 2	8	5,13	2,90			
CSVL Lumbar Level	Group1	8	4,63	0,52	0,97	0,35
Group 2	8	4,38	0,52			

Table-2. Investigation of differences in early post-operative measurements according to groups

Measurement	Group	n	Mean	S.D	Mann. U z	P
Major TL/L Curve	Group1	8	7,25	5,65	-0,05	0,96
	Group 2	8	7,38	5,37		
Minor Thoracic Curve	Group1	8	7,25	4,80	-0,69	0,50
	Group 2	8	9,13	5,96		
Apical Rotation	Group1	8	1,13	0,35	1,00	0,33
	Group 2	8	1,00	0,00		
TAV Translation	Group1	8	15,63	5,66	-2,04	0,05
	Group 2	8	24,25	9,66		
Lumbar Coronal Balance	Group1	8	24,88	13,54	-1,40	0,18
	Group 2	8	33,13	9,76		
Truncal Shift	**Group1**	**8**	**3,63**	**2,00**	**-3,35**	**0,01***
	Group 2	**8**	**19,13**	**12,94**		
Thoracic Kyphosis	Group1	8	23,13	4,12	-1,22	0,24
	Group 2	8	28,63	12,06		
PJK	Group1	8	10,13	4,91	-0,26	0,80
	Group 2	8	11,00	8,23		
Lumbar Lordosis	Group1	8	99,13	180,95	0,85	0,41
	Group 2	8	44,63	9,18		
SVA	Group1	8	-34,50	40,31	-2,16	0,06
	Group 2	8	17,38	28,72		
LAV Translation	Group1	8	27,13	8,32	-1,12	0,28
	Group 2	8	33,13	12,64		
SRS-22	Group1	8	3,89	0,37	-0,53	0,60
	Group 2	8	3,99	0,43		
UIV Tilt	Group1	8	3,38	1,51	0,79	0,44
	Group 2	8	3,63	1,19		
UIV Disc	Group1	8	2,25	0,89	-1,14	0,27
	Group 2	8	2,00	1,31		
L3 Tilt	Group1	8	5,00	2,45	-0,89	0,39
	Group 2	8	4,13	1,96		
L3 Disc	Group1	8	2,13	0,64	-1,99	0,07
	Group 2	8	3,25	2,71		
L4 Tilt	Group1	8	5,25	2,71	0,59	0,56
	Group 2	8	6,63	3,42		
L4 Disc	Group1	8	1,75	0,89	-0,71	0,49
	Group 2	8	3,38	2,13		
LEV Lumbar Level	Group1	8	3,00	0,00	-2,05	0,06
	Group 2	8	3,38	0,52		

Table-3. Investigation of differences in last follow-up control measurements according to groups

Measurement	Group	n	Mean	s.d	Mann U z	P
Major TL Curve	**Group1**	**8**	**6,13**	**0,85**	**-2,86**	**0,01***
	Group 2	**8**	**7,25**	**0,76**		
Minor Thoracic Curve	**Group1**	**8**	**5,63**	**5,37**	**-4,61**	**0,01***
	Group 2	**8**	**8,75**	**11,31**		
Apical Rotation	Group1	8	1,13	0,35	-1,62	0,13
	Group 2	8	1,00	0,00		
TAV Translation	**Group1**	**8**	**15,13**	**6,85**	**-2,60**	**0,02***
	Group 2	**8**	**32,25**	**15,50**		
Lumbar Coronal Balance	Group1	8	27,50	14,13	-0,67	0,51
	Group 2	8	36,13	5,17		
Truncal Shift	Group1	8	4,50	2,56	-1,43	0,17
	Group 2	8	12,25	8,03		
Thoracic Kyphosis	Group1	8	31,63	10,06	-0,42	0,70
	Group 2	8	33,13	11,43		
PJK	Group1	8	13,88	7,49	-1,66	0,12
	Group 2	8	17,13	11,43		
Lumbar Lordosis	Group1	8	41,38	10,13	-1,61	0,13
	Group 2	8	49,25	11,78		
SVA	**Group1**	**8**	**-46,60**	**30,69**	**-2,84**	**0,01***
	Group 2	**8**	**-36,00**	**29,70**		
LAV Translation	Group1	8	25,63	11,15	0,03	0,98
	Group 2	8	34,13	9,23		
SRS-22	Group1	8	4,12	0,40	0,56	0,58
	Group 2	8	4,11	0,55		
UIV Tilt	Group1	8	3,38	1,77	-1,65	0,12
	Group 2	8	3,50	2,45		
UIV Disc	Group1	8	2,25	0,89	0,55	0,59
	Group 2	8	2,13	1,55		
L3 Tilt	Group1	8	4,88	2,85	0,20	0,85
	Group 2	8	4,00	3,34		
L3 Disc	Group1	8	2,63	2,00	0,56	0,58
	Group 2	8	4,00	3,78		
L4 Tilt	Group1	8	4,00	1,85	-0,91	0,38
	Group 2	8	6,88	1,81		
L4 Disc	**Group1**	**8**	**2,13**	**1,36**	**-3,14**	**0,01***
	Group 2	**8**	**3,50**	**1,93**		

DISCUSSION

Our aim in Lenke type 5C curves is to obtain a more mobile spine with coronal and sagittal balance, by fusion of smaller number of segments. Thus, selective posterior spinal fusion applications are becoming more popular.

Okada et al have divided 29 patients with Lenke type 5C curves on whom they had performed selective posterior fusion in two groups retrospectively. In 10 patients, UIV was left at UEV level, and it was left one level below in 19 patients. In follow-up, significant differences were found in Cobb angle of major curve, correction rate of curvature, operation duration and blood loss, while SRS-22 scores, Coronal and sagittal balances were similar. The authors have concluded that an approach one segment shorter may be an alternative treatment to classic approach in which UEV level is the UIV level, while they admit limitations of their study as small sample size, short follow-up duration and its retrospective nature [5]. In our study, UIV level was UEV in 13 patient's, and UEV was 1 level lower in 3 patients. These 3 patients were from Group 1, with normal coronal balance; thus, we believe that there is no significant relationship between coronal imbalance and UIV level.

When the medical literature is examined, LIV level was more extensively investigated than UIV level on coronal balance in Lenke type 5C curvatures. Li et al have retrospectively examined 27 patients with Lenke type 5C curvature on whom they had performed surgery. A difference of 15 mm was considered significant for coronal imbalance and coronal imbalance was found in 4 patients during 2 years of follow-up. LIV level was L3 in 18 patients, L4 in 8 patients, and L5 in one patient. They have found pre-operative coronal imbalance, pre-operative LIV tilt and post-operative LIV tilt to be effective on post-operative coronal imbalance. If the pre-operative LIV tilt is 25° or more or if it does not fall below 8° post-operatively, these patients may have coronal imbalance[2]. We considered 15 mm as threshold for coronal imbalance. Pre-operative TAV translation and coronal balance measurements were higher in Group 2 in comparison with Group 1, but including these parameters, there were no significant pre-operative differences.

In a study by Wang et al in patients with Lenke type 5C curvatures for LIV selection, there were important results and suggestions. But the fact that 10 of the 30 patients in this study were treated with anterior spinal fusion is an important limitation. 20 mm was considered threshold for coronal imbalance and coronal imbalance was found in 4 patients in 2 years of follow-up. Pre-operative LIV and CSVL distance and LIV +1 vertebra tilt, lumbar Cobb angle, lumbar AV-CSVL distance during 2 years of follow-up were significantly effective in general and on thoracic balance. Additionally, pre-operative LIV level selection was shown to be significantly effective on correction and balance in 2 years of follow-up [6]. They did not find significant increases in major TL/L curvatures in 2 years of follow-up of Lenke 5C curvatures, which is in concordance with our study.

LIV tilt was found to be the most important factor for coronal balance in the study by Li et al, while LIV vertebral tilt higher than 25° and LIV translation over 28 mm were found to be significantly effective on coronal balance in the study by Wang et al [2,6].

In our study, LIV level was 1 level above LEV level in 2 patients, LIV level was at LEV level in 12 patients and LIV level was 1 level below LEV level in 2 patients. When the LIV tilt angles of our patients were compared with the literature, they were found to be similar **(Table-4).** Significant differences were found between pre-operative measurement and early post-operative measurement or last control measurements, while measurements at early post-operative period and last control measurement were similar. We couldn't confirm significance of 25° as a criteria for pre-operative LIV tilt angle in our study. When we examined the last control results of 4 patients with LIV tilt angle higher than 25°, coronal imbalance was not present in 3 of them, with only one with coronal imbalance.

Lee et al have investigated 229 patients with Lenke 3C, 5C, 6C types with major TL/L curvatures. They have divided these patients in two non-equal groups, and compared stopping instrumentation at L3 level distally and L4 level. Instrumentation was stopped at L3 level in 196 patients and L4 level in 33 patients. In this study, 82 patients had Lenke 5C curvature, 73 of which was in L3 and 9 was in L4 groups. While all patients had undergone posterior instrumentation, threshold for coronal balance was considered as 20 mm. Decompensation had developed in post-operative follow-up in 12 patients. While 9 of these patients were from L3 group, when the ratios were compared, ratio of patients with coronal imbalance was twice as higher, but without statistical significance. An insignificant difference was found between the two groups in terms of adjacent disc disease, and no significant differences were seen between staying at L3 level or extending to L4 level in any aspects, including SRS-22 results. After this, the L3 group was divided in two sub-groups, one with LEV level at L3 or higher and the other at L4 and below. In this study also, a significant difference was not observed. For this reason, they have recommended leaving a longer mobile segment by staying at L3 level in patients with major TL/L curvatures [7]. In our study, we had 13 patients in whom LIV level was at L3 and 3 patients at L4. One of these 3 patients was in the group with normal coronal balance, and 2 were in the other group. In analysis on these patients, no significant differences were found.

Sun et al have evaluated the results in 37 patients with TL/L curvatures whom they had operated LIV level according to LEV level. In 3 patients with major TL/L Cobb angle between 30° - 60° who had undergone posterior spinal instrumentation, level was LEV -1, in 22 patients level was LEV and in 12 LEV +1 **(Table-5).** In these patients with similar preoperative demographic characteristics, those in whom LIV level was LEV and LEV+1 were compared. Pre-operative LIV Translation was significantly lower in LEV +1 group; and LIV disc angle was significantly lower in LEV group. Except for these two parameters, all of the other parameters of these two groups were similar. In the post-operative evaluation, one patient from each group showed coronal imbalance (>20 mm) and these patients were not consistent with criteria described by Li et al and Wang et al. For this reason, the authors reported that these criteria should not be included into the guidelines. In post-operative measurements, significant difference was found only in LIV translation, and this was attributed to similar pre-operative differences. They have concluded that fusion one level lower in curvatures with major TL/L Curve Cobb Angle between 30° - 60° does not contribute significantly to curvature restoration, and that this may only be significant in patients with curvatures higher than 60° [8].

Liu et al had operated 40 patients with Lenke type 5C curve and they have later investigated the importance of UIV or LIV levels and other parameters in coronal balance in these patients. In conclusion, these authors recommend that when pre-operative UIV translation is over 25 mm UIV level should be one step upper, and when pre-operative LIV tilt angle is over 25° LIV level should be one step lower. During follow-up period, the most important parameter on coronal balance was also reported to be UIV tilt [9]. But we did not observe a significant difference between pre-operative LIV tilt angle and UIV tilt in our study.

Ando et al. have done a retrospective study in order to determine the parameters for prediction of distal adjacent disc disorder when LIV level is taken as L3 in 16 patients with Lenke 5C curvature. In this study, they have applied ASF in 5 patients, and PSF in others with L3 accepted as LIV level. After that, in follow-up of patients L3 vertebra tilt, L4 vertebra tilt and L3/4 Disc Angle more than 10 degrees were considered as DAD+. Seven patients were found to be DAD+. When DAD+ and DAD- patients were compared, a significant difference was found between LEV levels; which was L4 in most of DAD+ patients, and L3 in the other group, and that the difference was significant. There was no significant difference between these patients in terms of SRS-22 clinical results, coronal and sagittal balances. When the L3/4, L4/5 Disc angles of these patients were measured, those that were on pre-operative convex side were considered as negative, and those on pre-operative concave side were considered as positive. They report that patients with pre-operative negative L3/4 Disc angles had a higher risk of Coronal imbalance (**Figure 3**). In their study on coronal balance, they have reported that translation of standing pre-operative LIV and LIV+1 levels, and translation of L3/4 disc angle and LIV +1 levels at traction x-rays were found to be significant. [10]. When we evaluate our patients in terms of the direction of disc angles, 6 were found to have pre-operative negative disc angles. On the other hand, the fact that half of these patients had coronal imbalance and the other half had normal coronal balance, implicates absence of such a relationship.

In summary, pre-operative coronal balance, TAV translation and LEV levels were better in Group I patients, albeit insignificantly. Later, coronal balance and truncal shift at SRS-22 measurements and early post-operative x-rays were significantly better in Group 1 patients, and TAV translation, lumbar coronal balance, L3/4 disc angle and L4/5 disc angles were also better in Group 1 patients, but insignificantly. A significant difference in favor of Group 1 was observed at major TL/L curve and thoracic curve angles at last control. L4/5 disc angle measurements were significantly different at last control between measurements of 2 groups, while no differences were observed between patients with LIV level L3 and L4, in terms of being effective on L4/5 disc.

Limitations of our study include small sample size in comparison to other studies in the literature, and the fact that not all patients had completed their second year at their last control.

In conclusion, use of pre-operative LEV level in determination of LIV level in order to prevent more mobile segments while obtaining coronal and sagittal balance in patients will be beneficial.

Table-4. LIV Tilt Angle Change

	Preoperative	Early Postoperative	Last Control
Li et al.[2]	18 ± 5.6	5 ± 3.2	5 ± 3.1
Wang et al.[6]	25.9 ± 9.4	8.0 ± 5.9	8.5 ± 8.4
Present Study	19.4 ± 5.8	4.6 ± 2.2	4.6 ± 3

Table-5. LIV – LEV relationship in the medical literature

Study	LIV = LEV-1	LIV = LEV	LIV = LEV+1	Total Patients
Li et al.[2]	12	10	5	27
Sun et al.[8]	3	22	12	37
Our study	2	12	2	16

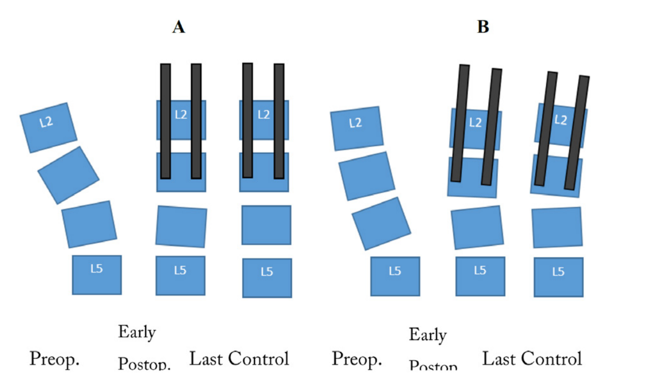

Figure-3. Schematic presentation of Positive Disc Angle **(A)** and negative Disc angle **(B)** in pre-operative, early post-operative and last follow up control x-rays.

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