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RESULTS OF PONTE'S OSTEOTOMY IN THE TREATMENT OF RIGID ADOLESCENT IDIOPATHIC SCOLIOSIS

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ABSTRACT

Purpose: To evaluate the effectivity of Ponte's osteotomy in the patients of adolescent idiopathic scoliosis (AIS) with rigid curvature.

Method: From 74 patients having severe structural scoliosis, the patients who have curvature above 50° and in whose curvature graphies recovery less than 45 % was ensured and Ponte's osteotomy was applied to different number of levels. From these patients, 23 patients who were followed up for 2 years and above and were included to the study. The surgical details, the complications and the estimated blood loss were recorded. The corrections on the coronal and sagittal plane were radiologically measured and the Scoliosis Research Society-22 survey was applied to the patients.

Results: According to the measurements made preoperatively, the Cobb angle of the main thoracic curvature on the coronal plane was measured as 70.9o (45°-93°) in average and the Cobb angle of the thoracolumbar/lumbar curvature was measured as 520 (16°-99°) in average; in the fulcrum curvature graphies, the flexibility rate was calculated as 36.8 % in the thoracic curvatures and as 32.4 % in the thoracolumbar/lumbar curvatures. In the coronal measurements made after Ponte's osteotomy was applied to our patients at the level of 3.1 (2-7) in average, the main thoracic curvature was calculated as 23.4° and the thoracolumbar curvature was calculated as 18.6° ($p<0.001$). In the measurements made on the sagittal plane, on the other hand, the values found are not statistically significant even though they are successful.

Conclusions: In the rigid AIS patients, Ponte's osteotomy helps to the correction procedure made with pedicle screws. It is an effective and reliable method that can be used in order to increase the correction amount in the rigid AIS patients even though it increases the bleeding amount and the operation period.

Key words: Ponte's osteotomy, adolescent idiopathic scoliosis, pedicle screw.
Level of Evidence: Retrospective clinical study, Level III.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is the most frequently seen scoliosis type and the most frequently seen pediatric deformity [12]. Although considerably good results are obtained since the use of the pedicle screws, many methods are still tried in order to increase the correction amount. For more correction by release especially the hardened vertebra from the anterior or posterior, it is tried to obtain a more flexible spinal column. Within the recent periods, the posterior release surgeries are frequently used.

Firstly, Smith-Petersen described the posterior column osteotomy that he applied from one level for the purpose of correcting the lumbar kyphosis [10]. In this way, it was possible to correct the spinal column in which fusion developed due to ankylosing spondylitis or rheumatoid arthritis even if partially. Alberto Ponte's, on the other hand, applied the procedure in the form of wide posterior release and total facet resection in flexible spines by applying at multiple levels in 1984 [6]. In this way, in Scheuerman Kyphosis patients, the deformity correction was applied successfully by shortening the posterior column.

Ponte's osteotomy is considerably frequently used in the treatment of AIS

within the recent years. Although there are publications stating that it is considerably successful in the coronal and sagittal plane [3,7-8], there are studies arguing that it is ineffective [4]. For this reason, we consider that different studies are still needed in order to prove the effectiveness of Ponte's osteotomy.

In this study, the patients having adolescent idiopathic scoliosis who has severe curvature and in whose fulcrum graphies the flexibility is less than 45 % were evaluated by the same surgery team at the same center for three years. Ponte's osteomoty in the form of total facet resection was applied to the patients along with the wide posterior release. As the instrument, only the pedicle screw was applied. From these patients, those who were followed up for at least 24 months were included to the study. Our hypothesis in this study is that Ponte's osteotomy ensures advanced correction on the sagittal and coronal plane in the AIS patients with rigid curvature. Furthermore, in our study, the surgical details, the complications and the estimated blood loss were recorded. The corrections on the coronal and sagittal plane were radiologically measures and the clinical evaluations of the patients were made by the Scoliosis Research Society-22.

MATERYAL METOD

In this study, 74 Adolescent Idıopathic Scoliosis (AIS) patients with minimum 2-years follow-up after surgical treatment at our clinic were evaluated. From these patients, Ponte's osteotomy was applied to 37 patients whose main curvature is more than 50 degrees and in whose curvature graphies correction less than 45% was ensured. From the patients to whom Ponte's osteotomy was applied, 23 patients who were followed up for 12 months and above and who had preoperative, postoperative and follow-up x-rays taken at good quality were included to the study.

For the posterior enstrumentation of all patients, only the pedicle screws were used. The pedicle screw was tried to be bilaterally placed to all vertebras. In the patients, no sublaminar wire or hood was used. In all patients, the enstrumentation systems of the same company were used and the titanium rod at the thickness of 5,5 mm was used in all patients.

While applying Ponte's osteotomy, the apex and the vertebras in its surrounding were intervened. After the spinous processes were completely taken, the supra and inferior ligament and ligamentum flavum were taken. As the superior facets were already taken during the screwing, the inferior joint was carefully taken with kerrison ronger by inclining towards to the lateral after reaching to durameter and the wide resection was continued until it was seen that the vertebra moved (Figure-1).

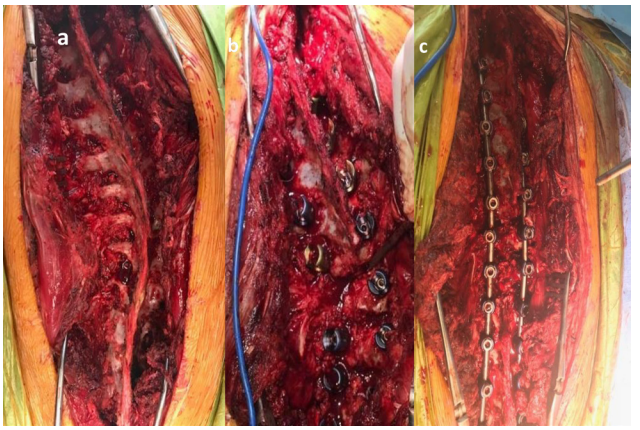

Figure-1. (a) Intraoperative views: after the exposure, **(b)** the ponte osteotomies and **(c)** after the reduction.

In all patients, intraoperative cord monitoring was used. In all patients, somatosensory evoked pottentialis (SSEPs) and transcranial motor evoked potentialis (TcMEPs) were used.

In all patients, the same reduction maneuvers were used: after the rod with appropriate inclination was placed on the concave side, the rod was turned by global rotation. After the rod was fixed from the apex, the curvature was tried to be corrected by making the segmenter derotation, compression and distraction maneuvers.

The surgical intervention of all patients was made by S.Y. and their measurements were made by A.A.U. The data was obtained by examining the anesthesia follow-up chart, the patient medical history form and the survey records in the patient file and by measuring from the PACS system integrated to the hospital data evaluation application.

The bleeding amount during surgical period , the number of vertebras in which fusion was made, the hospitalization period, the complications and the levels at which osteotomy was applied were recorded. The graphies taken preoperatively and postoperatively were recorded by being measured by one physician. The postoperative radiological examinations were evaluated with XR graphies taken 3 days after the initial mobilization of the patient, in the first month after the operation and after the 18th month. On the coronal plane, the Cobb angle of the main thoracic curvature and the thoracolumar/lumbar curvature, the recovery rate of these values and the translation amounts of the apical vertebra were measured. On the sagittal plane, on the other hand, the thoracic kyphosis measurements were made from the range of T5-T12, the lumbar lordosis measurements were made from the range of T12-S1 and the sagittal balance measurements were made according to the distance of the vertical line drawn from the C7 center to the sacrum superior corner. The

flexibility of the curvature was evaluated with the bending graphies taken preoperatively.

In the case of correction loss more than 10° as compared with the postoperative graphies or implant insufficiency, psodoarthrosis research was made with the routine tomography controls. For each case, the possible blood loos amounts, the operation periods, the curvature correction on both planes, the neuromonitor signal changes, the postoperative complications and the SRS-22 and survey records were taken. The SRS-22 survey was applied to all of our cases preoperatively, in the 2nd month postoperatively and at the final controls.

For the statistical analysis, the IBM SPSS version 20.0 program was used. While the study data was being evaluated, the Wilcoxon test was used in the comparison of the quantitative data as well as the descriptive statistical methods (average, standard deviation, median, frequency, rate, minimum, maximum). The significancy was evaluated at the levels of $p<0.001$ and $p<0.05$.

For this study, the approval of the ethical committee of our university was obtained.

RESULTS

23 patients complying with the study criteria were included to our study. From these patients, 17 patients (74 %) were female and 6 patients (26 %) were male. The age average was 18.1 (12-35). According to the Lenke classification, there were 12 patients who were Lenke-1, 2 patients who were Lenke-2, 3 patients who were Lenke-3, 3 patients who were Lenke-5 and 3 patients who were Lenke-6. Risser grades were determined as grade-3 in 2 patients; grade-4 in 6 patients; and grade-5 in 15 patients. Lumbar modifier was A in 12 patients, B in 4 patients and C in 7 patients. The thoracic sagittal variable were noted (-) in 6 patients, (N) in 10 patients and (+) in 7 patients. According to the marking made in the patient medical history forms, the reason for the preoperative application was substantially (91 %) the problems related to deformity (posture, walking disorders) and the back-belly pain and the neurological problems (9 %) were less. According to the measurements made preoperatively, the Cobb angle of the coronal main thoracal curvature was measured as 70.9° (45°-93°) in average and the Cobb angle of the thoracolumbar/lumbar curvature was measured as 52° (16°-99°) in average. The flexibility rate in the fulcrum curvature graphies was calculated as 36.8 % in the thoracal curvatures and as 32.4 % in the thoracolumbar/lumbar curvatures. In all of the cases, the secondary sex characters developed and all of the female patients, menarch occurred (Table-1).

Table-1. Patients demographics

Patients	23
Males	6(26(%)
Females	17(74%)
Age at the surgery	18,1(12-35)
Lenke clasification	
Lenke 1	12
Lenke 2	2
Lenke 3	3
Lenke 5	3
Lenke 6	3
Risser clasification	
Risser 3	2
Risser4	6
Risser 5	15
Lumber modification	
A	12
B	4
C	7
Thoracal sagittal modification	
(-)	6
N	10
(+)	7
Coronal mainthoracal cobb angle	70.9° (45°-113°)
Coronal thoracolumbar / lumbal cobb angle	52° (16°-99°)
Flexibility	
Thoracal	36.8 %
Lumbar	32.4 %

Ponte's osteotomy was applied at the level of 3.1 (2-7) in average. The average operation period was 378 (255-512) minutes. Fusion was applied at the level of 11.4 (6-15) in average. The estimated blood loss amount was calculated by counting the aspirates and dirty sponges (less dirty 5, medium dirty 10, wet 15 cc) and is 1571 (524-2829) cc. The intraoperative autotransfusion systems were not used in any case. The patients were followed up for 10.3 (5-17) days in average with the first 24 hours in the intensive care postoperatively.

In all patients, the intraoperative cord monitoring was used. The significant signal changes were seen at the correction stage in only 3 cases and at the screwing stage in 1 patient. These

problems were overcome by the restitution of the procedure that was finally applied and by resending the relevant screw. In a patient with curvature of 99° preoperatively, the T2-L4 posterior segmental instrumentation was made, Ponte's osteotomy was applied at the level 4 to the range of T8-T12 AND signal decrease above 80 % was seen bilaterally during the reduction. After the removal of the rods, the signals reached to the normal level and for this reason, the case was ended to make correction again in the next session by placing only short rods to the patient. In the postoperative scoliosis graphy taken, it was seen that the recovery was sufficient and balanced. The patient was taken to the operation again after 2 weeks and the operation was completed by placing the long rods (Figure-2).

The patients whose lateral plane measurements were hypokyphotic, normokyphotic and hyperkyphotic in the preoperative period were compiled in separate groups and their average was taken. As T2 is not suitable for healthy measurement due to the graphy quality and other reasons in many patients, the thoracal sagittal kyphosis value was calculated by using only the range of T5-T12. There was no significant difference between the preoperative kyphosis angle (27.4°) and the postoperative kyphosis angle (25.1°) of all patients ($p>0.05$). In the hypokyphotic patients (<20°), the lateral cobb angle increased at advance level (10.4°-20.1°). In hyperkyphotic patients, the lateral cobb angle decreased from to 44.8° to 31.1°, in normol kyphotic patients, the lateral cobb angle minimal decreased from 32.1° to 28.8°($p>0.05$) and the main sagittal balance improved from -4.1mm to 6 mm.

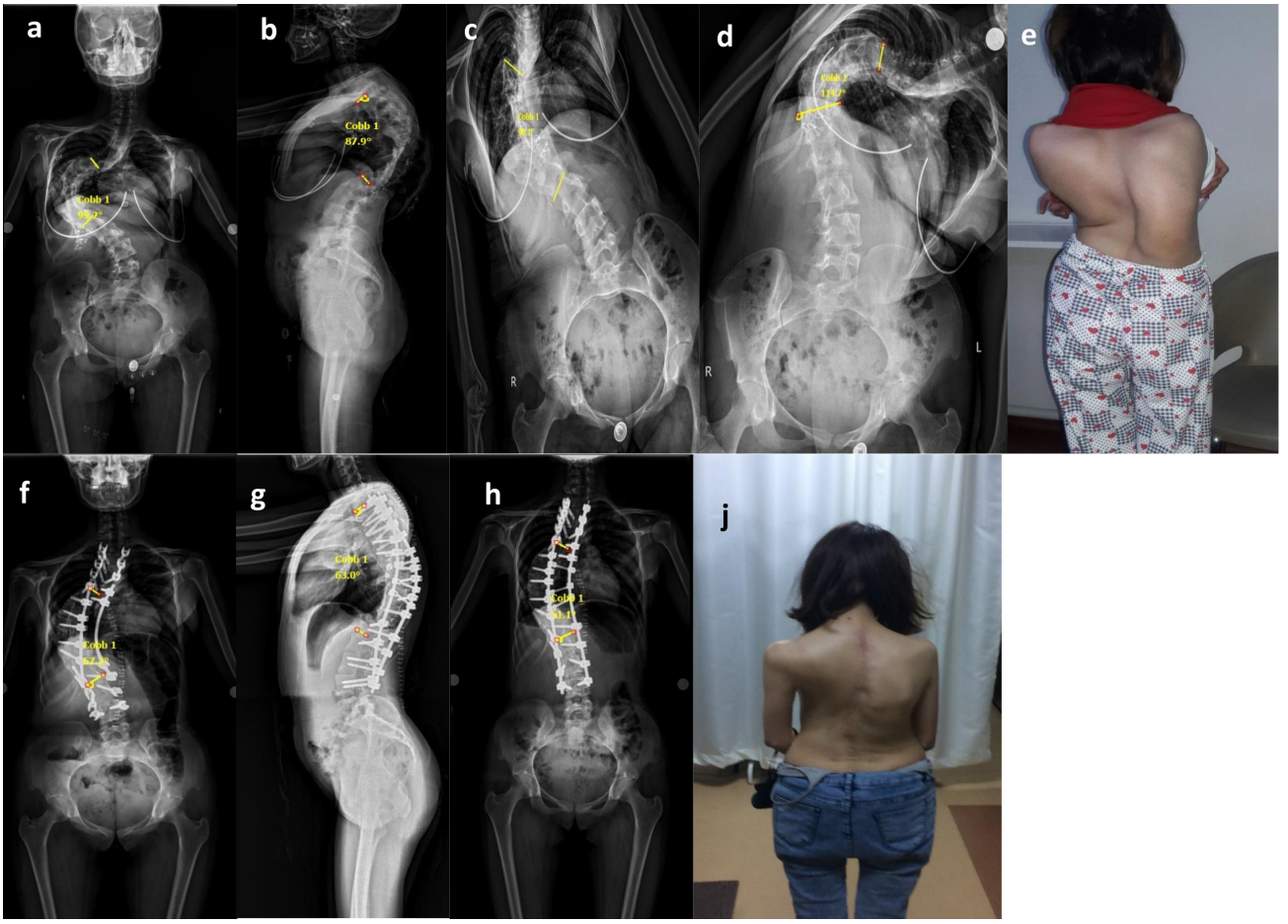

Figure-2. (a) Preoperative posteroanterior (Cobb angle was 99°), and **(b)** preoperative sagittal (T2-T12 kyphosis angle was 87°), **(c-d)** preoperative bending graphies, **(e)** preoperative back photograph of the patient, **(f)** postoperative posteroanterior (T2-L4 posterior segmental instrumentation was made, ponte osteotomy was applied at the four levels to between T8 and T12 at the first operation), **(g-h)** postoperative posterior-anterior and sagital radiographies after the 2nd operation, (Postoperative Cobb angle was 51° and kyphosis angle was 63°) and **(j)** postoperative 2nd years back photo of the a 19 year-old girl with adolescent idiopathic scoliosis were seen in the figures.

Table-2. Coronal radiological measurements

	Preoperatively	Postoperatively	Fist control	Last control	p
Coronal main thoracic cobb angle (°)	70.9	23.4	24.1	27.9	<0.001
Thoracic % Cobb correction	-	% 66.9	% 66	% 60.6	<0.001
Thoracic apical C7 plumbline translation (mm)	47.8	21.3	22.6	23.1	<0.001
Thoracolumbar/lumbar Cobb angle (°)	52	18.6	19.7	20.3	<0.001
Thoracolumbar/lumbar % Cobb correction	-	% 64	% 62.1	% 60.9	<0.001
Thoracolumbar/lumbar apical C7 plumbline translation (mm)	23	12	11	9	<0.001

Table-3. Sagittal radiological measurements

	Preoperatively	Postoperatively	Fist control	Last control	P
Lateral T5-T12 Cobb angle (°)	27.4°	25.1°	25.7°	26.1°	0.301
Lateral T5-T12 Cobb angle (hypokyphosis group< 20°)	10.4°	20.1°	20.3°	21.2°	<0.001
Lateral T5-T12 Cobb angle (normal kyphosis group 20-40°)	32.1°	28.8°	29.1°	29.6°	0.233
Lateral T5-T12 Cobb angle (hyperkyphosis group > 40°)	44.8°	31.1°	31.6°	33.4°	<0.05
Lumber lordosis (T12-S1) (°)	-51.5°	-47°	-47.4°	-46.7°	<0.001
Sagittal balance (C7 plumbline to sacrum) (mm)	-4.1	6	6.8	12.3	0.053

The SRS-22 survey was applied to the cases before the operation and during the follow-ups. The average values of the question subgroups the SRS-22 survey results of which were specified in advance were calculated as listed below. According to these values, whereas there was not significant healing in the initial controls of the patients in the total values, it was seen that the satisfaction values and pains of the patients healed in the second controls (Table-4).

In none of the cases, the late period infection was found. In two patients, superficial wound area infection was considered in the early period and it was folowed up without going beyond the routine antibiothreapy when no reproduction occurred in the cultures taken. None of our cases was taken to a secondary operation due to revision and other reasons during the follow-up period.

Tablo-4. Scoliosis Research Society(SRS)-22questionary results

Pain (1, 2, 8, 11, 17)		p
Preoperative	3.72	
First control	3.64	>0.05
Last control	4.16	<0.05
Mental Health (3, 7, 13, 16, 20)		
Preoperative	3.32	
First control	3.92	>0.05
Last control	4.13	<0.05
Self İmage (4, 6, 10, 14, 19)		
Preoperative	3.22	
First control	4.13	<0.05
Last control	4.43	<0.05
Function (5, 9, 12, 15, 18)		
Preoperative	3.61	
First control	3.12	>0.05
Last control	4.23	>0.05
Satisfaction (21, 22)		
Preoperative	4.05	
First control	4.75	<0.05
Last control	4.85	<0.05
Totaly		
Preoperative	3.52	
First control	3.79	>0.05
Last control	4.29	<0.05

The purpose in the surgical treatment is to obtain a balanced spinal column on the coronal and sagittal planes. The array ensured with the instrumentation systems for this purpose is tried to be maintained by constituting fusion. However, it might be necessary to make the spinal column structure more flexible in order to ensure the required array in certain rigid spinal columns. To ensure the highest correction with the least force possible without causing damage to the neurological and bone structures is possible by making the rigid spinal column bendable. For this purpose, various ligament loosening procedures and osteotomies are applied on the spinal column [2].

The osteotomy techniques described in the correction of the spinal deformities have become one of the important milestones in the achievement of the surgical treatment. Smith Petersen osteotomy which was described by Smith Petersen in 1945 for the first time and which was used in the lumbar kyphosis became widespread by being used in the thoracal kyphosis by Alberto Ponte's. Many studies which were subsequently carried out showed that the osteotomies applied in rigid idiopathic curvatures are effective also on the coronal plane [2-3,8]. In this way, the auxiliary osteotomies applied from posterior have become widely usable in the patients in whom the balance cannot be ensured with the soft tissue manipulations and who have lost their flexibility. The most known osteotomy techniques are Ponte's osteotomy, pedicle substraction osteotomy and posterior vertebral column resection [2].

Ponte's osteotmoy is considerably frequently used in the treatment of AIS within the recent years. Although there are publications expressing that it is considerably successful on the coronal and sagittal planes [3,7-8], there are also studies arguing that it is ineffective [4]. For this reason, we consider that different studies are still necessary in order to prove the effectiveness of poste osteotomy. Halanski et al. [4] applied only inferior facetectomy to 19 patients whereas they applied Ponte's osteotomy to 18 patients. They did not report any significant difference except for that the bleeding amount was higher in the first group. However, their study was carried out with less number of patients who was followed up in short period and there was no randomization between the groups. The use of Ponte's osteotomy in the scoliosis surgery, in contrary to the use of kpyhosis, aims at correcting the hypokyphosis, not shortening the posterior column. It contributes also to the correction on the coronal plane as well as the sagittal balance.

Ponte's osteotomy is a surgical technique that is applied in the form of resection of the soft tissues and bone structures. It starts with the removal of the interspinous ligament together with the spinous protrusions and it is applied with the partial lamina excision over the ligamentum flavum and the removal of the facet joint together with the adjacent structures. The effectiveness of this osteotomy which was already proven in the kyphosis surgery was demonstrated also in the different studies subsequently carried out [7-9]. However, the indication limits are not fully specified in the thoracal scoliosis. The current application is the use of the osteotomy techniques for the patients who have main curvature more than 70° and who showed recovery less than 45 % in the curvature graphies. The certain surgeons, on the other hand, use this technique in all AIS cases routinely. In our study, it was aimed to help to the spine surgeons at the decision-taking stage with evidence-based information. Although there are many techniques for obtaining the curvature graphies, the curvature graphies taken on foot were used because they are practical and there is not need for using auxiliary personnel. By means of these graphies, the flexibility measurements were made. The average flexibility of the thoracic curvatures was measured as 36.8 % and the flexibility of the lumbal area was measured as 32.4 %.

While evaluating the patient on the sagittal plane, the fact that the AIS patients are presented by lordosis in the thoracic area should be remembered. For this reason, while the data was being shared, the data was given in 3 separate groups. While it is possible to intervene by closing the osteotomy line for the hyperkyphotic patient, the distraction needs in the hypohpyhotic patient group strains the cord and increases the psodoartrosis risk. In these patients, it is necessary to be more careful while correcting the deformity.

In the study carried out by Lehman et al., fusion was applied at 10 levels in average to 114 AIS patients at the age of 14.9 in average. It reduced the coronal main curvature from 59.2° to 16.8° in average (71.7 % correction rate) [5]. In this study, they used monoaxial screw in the corrections made with 5.5 mm steel rods. There are also the publications which recommend using 7 mm steel rods for the purpose of ensuring and maintaining the sagittal balance without using osteotomy. We obtained stable balanced spinal column by using titanium rod at the thickness of 5.5 mm after making the corrections on the coronal and sagittal plane. We reduced the thoracal curvature rate which was 70.9° in average to 23.4° postoperatively (66.9 % correction rate). We consider that this result which we obtained by using poliaxial screws was ensured by osteotomy. We saw that there occurred correction loss even if in less amount in the measurements that we made during our follow-ups as in the different studies. However, in order to understand whether this is related to the rod diameter, the long-term studies in which the different rod diameters are compared are required. Another discussion is the possibility of increase in the pseudoarthrosis rate due

to Ponte's osteotomy because wide bone resection, spinous process excision and lower and upper facet resection are made with Ponte's osteotomy and this will reduce the possibility of fusion in the long period. If pseudoarthrosis occurs, this may cause implant fatigue and correction loss in the long period. In order to understand this, the comparative publications with long follow-up period are necessary.

Ponte's osteotomy may cause an increase in the operation period and the bleeding amount. This increase was demonstrated with the comparative publications [3,7,11]. However, in these studies, no serious complication depending on bleeding was reported. At our clinic, we calculated the estimated blood loss by classifying the gauze bandages as less dirty, dirty and very dirty. The average blood loss was 1571 (524 - 2829) cc and we did not encounter any complication depending on bleeding. Also, in the same studies, it was demonstrated that the operation time increased as well. However, in these studies, the rigidity and the curvature degree of the group on which Ponte's osteotomy was applied were higher than the other group and this may increase the operation time by increasing the time necessary for the reduction. In order to be able to understand this, two groups having rigidity and cobb angle at the same degree should be compared because the time lost with osteotomy may provide the surgeon with time at the deformity correction stage.

One complication related to Ponte's osteotomy, on the other hand, is the neurological complications that can develop depending on the increased recovery possibility. Buckland et al. [1] stated that they recorded more intraoperative electrical changes in the patients with Ponte's osteotomy in 2210 disease multicenter studies. We also saw intraoperative electrical changes at the deformity correction stage in only 3 patients. We saw that the electrical changes reached to the normal state a while after withdrawing the final maneuver made and increasing the tension of the patient. In our study, we did not see any change during the deformity correction in our other AIS patients on whom we don't applied Ponte's osteotomy even though we did not compare.

In the osteotomy procedure that we started from the segments adjacent to the apical vertabra, we intervened to both facet joints without making concave/convex side discrimination. Although certain authors argue that the unilateral facet excision is sufficient, we consider that the facet ignored on the concave side will constitute tight band effect at the correction stage. However, the close adjacency of the cord should be paid attention while intervening to the concave side in the apex of the curvature. Especially in the hypokyphotic or lordotic backbones, the attention was drawn to that it is closer to the lamina. In this area, the surgical tools should be carefully used.

Although we consider that our study will help to eliminate the conflicts related to Ponte's osteotomy, we consider that we have certain important deficiencies. The most important one is that we have no control group with which we can compare our results. The second one is that all data cannot be kept in sufficient meticulousness. The third one is that we have no sufficiently long follow-up period for the pseudoarthrosis and correction loss to be able to be sufficiently evaluated.

As a conclusion, in the rigid AIS patients, Ponte's osteotomy helps to the correction procedure made with pedicle screws. It is an effective and reliable method that can be used in order to increase the correction amount in the rigid AIS patients even though it increases the bleeding amount and the operation period. However, the studies which include a control group in which the number of the patients is higher for the purpose of evaluating the complication rates and the results are required.

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