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Augmentation of Third Generation Instrumentation with Sublaminar Titanium Wiring in Late Onset Idiopathic Scoliosis

The Surgical Results and Analysis of Trunk Balance.

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In recent years, 3rd generation instrumentation systems which achieve correction by maneuvers like derotation and translation, have been widely used in the treatment of idiopathic scoliosis. To increase correction, additional procedures that increase stability, such as screw application for every segment, have been used. In this study, as a new technique, the effects of combined translation and derotation maneuver with augmentation by using titanium double crimp Songer cable applied on apical region, on trunk balance, sagittal and frontal planes have been examined. 45 idiopathic scoliosis patients operated between 1996 and 2002 have been included in the study. Mean age was 14.5±1.7 years and female/male ratio was 30/15. Mean follow up time was 51.9±22.7 months. According to King Classification, 15 patients had Type II, 18 patients Type III and 12 patients had Type IV curves. One of the apical cables has been tensioned and translation has been performed. At the second step, derotation has been applied to the vertebra, which is firmly attached to the rod. Sagittal and frontal Cobb angles have been measured in preoperative, postoperative and recent radiographic examinations. Trunk balance has been examined both clinically and radiographically. Also, secondary curves have been measured in every examination for decompensation findings. In overall frontal plane measurements, postoperative correction was 79.9±13.5 %, loss of correction 2.9º±3.2º and final correction 74.3 % ± 14.3 %. In postoperative measurements, normal physiological contours have been achieved in 97.8 % of the patients for the thoracic region (30º-50º) and 80.7 % of the patients for the lumbar

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region (40º-60º). In secondary curves, 75.2±34.4 % postoperative correction has been observed. No decompensation findings have been observed in the last examination. In postoperative and last follow up examinations, balanced and totally balanced vertebral column has been achieved in every patient of the study group. Solid fusion mass has been observed in every patient. No early or late, local or systemic postoperative complications have been observed. Given these findings, we conclude that derotation-translation combined maneuver performed with 3rd generation instrumentation reinforced sublaminar wires is a good choice in the treatment of the late-onset idiopathic scoliosis.

As the three dimensional pathology of idiopathic scoliosis has been understood better, significant improvements have been obtained in surgical treatment. In the last two decades, third generation modern instrumentation systems, using multiple hooks, pedicle screws and double rods, have been widely used and many successful results have been published with these systems. (2,14,27,32).

The revolutionary development in the treatment of idiopathic scoliosis was, unquestionably, definition of strategic vertebrae by Cotrel and Dubousset and introduction of derotation maneuver as a corrective procedure for the rotational deformity of apical vertebra in the axial plane (20). This system has become popular worldwide and many papers have been published, emphasizing the success of the system in correction of the deformity in three planes (1,8-9,31,35,44,46). Also high correction rates have been published for the Texas Scottish Rite Hospital System (actually a modification of Cotrel-Dubousset Instrumentation), which differs from Cotrel-Dubousset Instrumentation with the “three point locking “ rod-hook connection mechanism (6,10,48). Afterwards, it was proposed that imbalance and decompensation arises because of transmission of derotational effect on healthy vertebral column (22,25,28,41,47,53-55,60-61). However, in many researches about trunk balance, it was emphasized that the main factors causing the problem were over correction or inappropriate preoperative planning in Type II and Type IV curves (8-10,28,36). In order to avoid these adverse effects, translation maneuver has been preferred as the main corrective procedure in modern systems like ISOLA developed by Asher and USS by AO Group (3-5,34). Imbalance problems have been reported to be minimum in systems using translation (11,23,43,45).

In recent years, in addition to this discussion, the cosmetic aspects of the disease have attracted attention and enlarging the surgical indications, correction at a higher percent has been suggested (14,21). In view of these results, in this study, third generation instrumentation systems which combine derotation and translation partially and augmented by sublaminar wiring with titanium, multifilament, double crimped Songer cable, have been used. It was questioned if it was possible to get higher rates of correction with respect to traditional instrumentation techniques. Nevertheless, although minimal translation has been performed, the principal corrective effect has been due to reinforced derotation maneuver. It is also questioned if imbalance and decompensation problems arise after derotation as reported in the literature and for all patients; trunk balance analysis has bee performed postoperatively and at least 2 years after.

PATIENTS AND METHODS

- Preoperative Evaluation:

Our first case of idiopathic scoliosis which was treated with sublaminar wire augmented 3rd generation instrumentation system was in April 1994. Since that date, 45 idiopathic scoliosis patients, operated consecutively with the same technique, have been included in the study. The last case included in the study was operated in June 2004. Mean follow up period was 51.9±22.7 (24-98) months, and mean age was 14.5±1.7 (11-18). There were 30 girls and 15 boys (female/male=2/1).

In all of the patients, the main complaints at admission were hump, trunk shift and shoulder asymmetry, which were noticed by the family. In addition, 5 patients complained of back pain. Three of the patients were operated in other centers with the same indication, but the results were unsatisfactory. The first of these patients was operated with Harrington Rod System and the second with CD Instrumentation. Both of them had adolescent idiopathic scoliosis. The third had juvenile idiopathic scoliosis and subcutaneous CD Instrumentation and Moe Technique has been performed.

Preoperatively, besides standing posterioanterior and lateral radiographs, bending and standing traction radiographs were taken lying on right and left sides. In these radiographs, the most rigid curve with the highest rotation at the apical vertebra and wide angle was considered as the major curve and the angles of the curves were measured by the Cobb method. The Cobb angles of the upper and lower secondary curves were also measured with a similar method. On lateral radiographs, sagittal contours between T2 and T12 and the L1 and L5 vertebra were measured, again using the Cobb method. Normal thoracic physiological kyphosis and physiological lumbar lordosis were regarded to be between 30° and 50° and between –40° and –60°, respectively (13). All measurements were made in collaboration with radiologists. Sagittal contour were given positive (+) and negative (-) angle values if they had kyphotic and lordotic patterns, respectively. In addition, the patients were evaluated with magnetic resonance imaging (MRI) to detect any neural axis and congenital spinal abnormality.

Curves were grouped according to King Classification (30). There were rigid thoracic curves (Type II) in 15 of 45 patients whose mean age was 15.1±1.6 (12-17). There were flexible thoracic curves (Type III) in 18 patients whose mean age was 14.4± 1.7 (11-18). Remaining 12 patients had thoracolumbar (Type IV) curves and their mean age was 13.9±1.8 (11-17). The ratios of girls/boys in these groups were 10/5, 11/7, and 9/3 respectively. There were no Type I and Type V patients.

The fusion areas have been selected according to King's criteria and instrumentation has been planned according to strategic vertebrae suggested by Herring. Posterior surgical procedure alone has been performed in 1 Type II patient, 18 Type III patients and 12 Type IV patients.

- Surgical Procedure:

The same team, headed by Dr. Benli, carried out all operations. Anterior discectomy and release was performed in patients with major curves above 70°, which was corrected less than 50 % in the bending radiograms and in patients who had spontaneous fusion and severe vertical structural changes. 14 of these patients had Type II curves and one had Type IV curve. Disc space at the planned number (minimum 3, maximum 6) was excised and anterior release performed. Prior to operation, it was decided that as well as discs in the proximity of curve, discs found to be fixed in bending radiographs, i.e. discs with marked asymmetrical narrowing and those between the vertebra, were to be released. The number of discs planned for release was related to the angle of rigidity of the curve. At each level of release, after the anterior longitudinal ligament was dissected and fine bone chip removed from the end plate with a fine chisel, discs were completely excised. In some patients (n: 2), in whom release was considered inadequate with manual manipulation, posterior ligament was excised by a punch with a very fine end. Bleeding was not seen in any of these patients. In order to prevent the graft shifting to the spinal channel, tricortical rib grafts were securely fitted in to vertebral space. Vertebral arteries at these levels were not ligated. If the rib deformity was significant (>4 cm) thoracoplasty was added to the levels by resecting 2-3 cm of the costa on which discectomy was performed and one or two-stage posterior instrumentation was conducted.

Implant removal anterior release, posterior instrumentation and fusion have been performed in the same session for 3 patients who were previously operated. Posterior instrumentation has been performed for all patients. 3 of the patients with type II curve have been operated using ISOLA and remaining 12 using TSRH System. 2 of the patients with type III curve have been operated using ISOLA, one using AO Universal Spinal System (USS) and remaining 15 using TSRH. 5 of the patients with type IV curve have been operated using ISOLA and remaining 7 using TSRH. Overall, 10 patients have been treated with ISOLA, one with USS and remaining 34 with TSRH.

In Type III curves, distal neutral vertebra was instrumented with a reverse transpedicular screw with compression on the concave side to prevent decompensation and preserve lumbar lordosis. No hook has been placed on concave side of the apex. 3 sublaminar double crimp multifilament titanium Songer cables have been placed for curves that have single vertebra as apex and 4 cables have been placed for curves that have intervertebral disc as apex. Then, rods bent according to sagittal contours have been placed, connectors for hooks and screws have also been placed. One of the two-sublaminar cables, placed on every segment, has been tensioned and the other has been left loose. Derotation has been performed with one of the apical wires being tight and compression has been applied to the distal thoracolumbar screws and slight distraction has been applied to the proximal intermediate hook just to prevent dislodgement. Rigid rods have been used to prevent change in contours of the rod during derotation. Derotation maneuver has been continued until the contour of the rod fits to sagittal plane. Following derotation, crimps of the second sublaminar wires have been locked and the connectors of the hooks and screws have been secured.

Technical note: *In application of ISOLA System, when double wires are used, the first tensioned wire may get loose after the second one is tensioned. For that reason, the first cable must be tensioned as much as possible before derotation. So, we did not see any loosing of wires in this study. The main purpose is not translation of vertebra to the pre-bended rod followed by derotation of the rod, but segmental derotation while vertebra is firmly attached to the rod. An additional translation occurs during the tensioning of the second wire. Following the placement of the first rod, as Herring suggested, on the convex side, second rod is placed with the help of proximal transversopedicular claw using hooks, apical hook and distal screws. After a rigid frame is formed with two transverse connectors, posterior fusion is performed following decortication including all facets.*

In Type II curves, it is very important to make rigid thoracic curve completely flexible. For a patient whose thoracic curve was larger than lumbar one (however a flexible real major curve) and the Cobb angle was below 45º, it was preferred to perform posterior selective fusion without anterior release. Also for two patients having Type II curves, anterior release have been performed for rigid thoracic curves that are greater than 70º but for the lumbar curves less than 45º, selective fusion has been preferred. For all other patients, long instrumentation including lumbar area by using lumbar transpedicular screws has been performed. Augmentation has been carried out with sublaminar wires in the apical region of the major thoracic curve.

Among the Type IV patients, one who had rigid curve (over 70º), which was at 88º, underwent anterior release. In Type IV patients there is very difficulty to bend the rod according to normal physiologic contours. The vertebrae below the apical region conforms to the lordotic pattern with the translation performed before derotation with the help of sublaminar wires placed at the apex, which is situated in the thoracolumbar junction. During derotation, as kyphosis and lumbar lordosis are formed, normal physiologic sagittal contours are obtained at the thoracolumbar junction. In Type IV curves, whole curve is instrumented. For the curves that last in mid-thoracic region (T6-7), it is preferred to extend the instrumentation up to T2 in order to prevent additional kyphosis above the instrumentation.

All patients underwent a posterior fusion with a mixture of their local and iliac autologous grafts and allogenic bone grafts (cadaver tutoplast bone graft: 13, University of Florida Bone Bank graft: 32).

Autologous blood transfusion was done in all patients using the “cell saver” (Electromedics) system. Intraoperatively, the autotransfusion unit saved an average of 840±135 cc of blood, and an average of 1.8±0.7 units of saved blood was transfused. None of these patients needed homologous blood transfusion. The hematocrite value was decreased by on average 0.8±0.7 mg/dl, despite the decrease drainage was applied and layers were closed. The mean operation time was 2.4±1.1 h. For all patients in this study, “Somatosensory evoked potentials” (SSEP) and “Transcranial cortical magnetic stimulation-motor evoked potentials” (TkMMEP) were combined for neurological intraoperative monitoring.

- Postoperative Management:

Antibiotic prophylaxis was administered in all patients preoperatively with 2 gr first generation cephalosporine or 1 gr sulbactam amphycilline and maintained during postoperative 3 days, dose being reduced to 0.5 gr daily. The patients were turned to their sides during the first postoperative day and were seated on the second day. On the third day, they were encouraged to walk. No postoperative cast or brace was utilized. Average discharge time was 10 days.

- Clinical and Radiological Evaluation:

All patients were invited for control at the 1st, 3rd, 6th, 12th, 18th and 24th postoperative months for clinical and radiological evaluation.

Balance analysis of patients was made clinically and radiologically. Shoulder asymmetry and distance between centers of gravity were determined by a plumb line swinging from C-7 and intergluteal crisis was determined. In addition, the subjective complaints of the patients were sought. Additionally, lateral trunk shift (LT), shift of stable vertebra (SS) and shift of head (SH) were recorded preoperatively and postoperatively (Figure-1) (8-11). The values measured by this method were divided into radius of the vertebrae, determining the distance, and values were expressed as vertebral units (VU) not metrically. This was done in order to prevent possible magnifications due to the age of patients and variations in position of patients when taking the radiographs. LT shows to what extent the apex of the curve can be shifted to the middle line, and reflects the correction obtained in frontal plane. If SH and SS values are 0 VU, i.e. if the vertebra is in the middle line, that curve is considered a *“completely balanced”* one. If SH and SS are higher than 0 VU but equal 0.5 or lower than

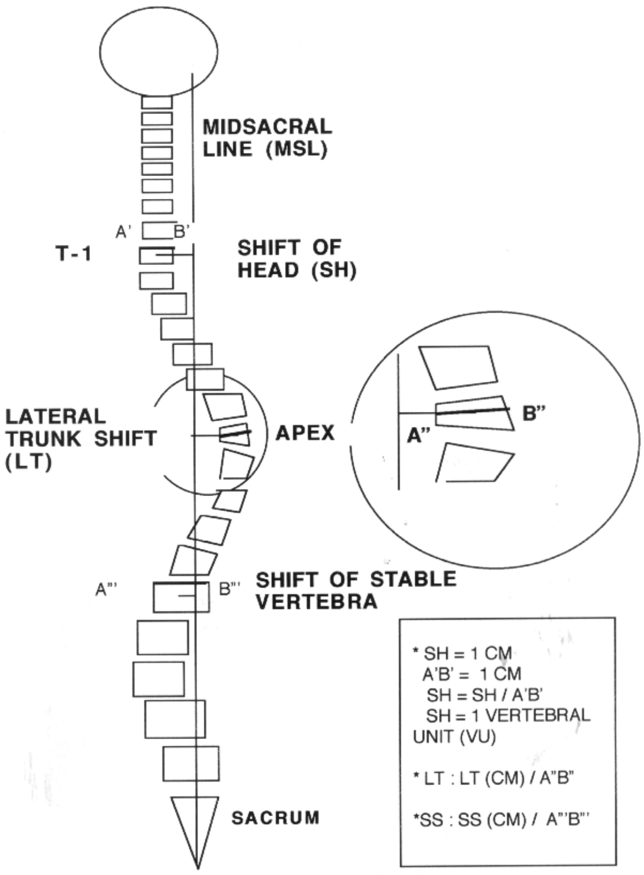


Figure - 1.

Radiological parameters of trunk balance. Lateral trunk shift (LT) is the distance between the midpoint of apical vertebra and mid-sacral line. Shift of stable vertebra (SS) is the distance between midpoint of stable vertebra and mid-sacral line. Shift of head (SH) is the distance between mid-sacral line and mid-point of seventh cervical vertebra.

0.5 VU, there is no clinically recognizable imbalance, and such curves were regarded as *"balanced"*. Curves with SH and SS values higher than 0.5 VU were considered to be imbalanced. The Cobb angles of secondary curves below and above curves were measured to determine decompensation. In addition, the effect of surgical treatment on these curves was also investigated.

Final evaluation was done June 2004 and patients with a minimum follow-up of two years were included in this study. At the last visit, the patients were evaluated clinically, radiologically and frontal and sagittal plane Cobb angles and correction loss in balance values were noted. Additionally, subjective complaints of the patients related to balance, implant failure, and other complications were recorded.

Radiologically, the presence of significant consolidation and absence of implant failure and correction loss and clinical pain relief were considered as proof of a posterior solid fusion mass. When the frontal plane correction rate, loss between the postoperative and the last visit measurements was greater than 10° and/or there was implant failure with serious pain this was considered to be "nonunion" or "pseudoarthrosis". The statistical evaluation was made using the "Difference Between Mean For Paired observations" test and the "Chi-Square" test in SPSS for windows programs (t: 0.05).

RESULTS

Overall mean follow up time was 51.9±22.7 months (Type II patients: 49.5±16.9 months, Type III patients: 54.5±26.2 months, Type IV patients: 50.8±13.4 months). The average values of the preoperative and postoperative Cobb angles in the frontal plane and correction rates are seen in Table-1 and Table-2. Overall, the preoperative average Cobb angle of the major curves was 58.8°±16.6° and the correction rate was 40.7±17.1 % in the bending studies and 79.9±13.5 % postoperatively. In the frontal plane, the correction rates of the Cobb angles of major curves in the patients with King-Moe Type II, III and IV curves were 66.4±9.5 %, 89.1±6.3 % and 83.2±12.6 % respectively. The postoperative correction values of Cobb angles in the frontal plane for all types of curves were statistically significant ($p< 0.01$). The postoperative correction rates were also greater than the preoperative bending radiography values ($p< 0.01$) (Figure-2,3,4).

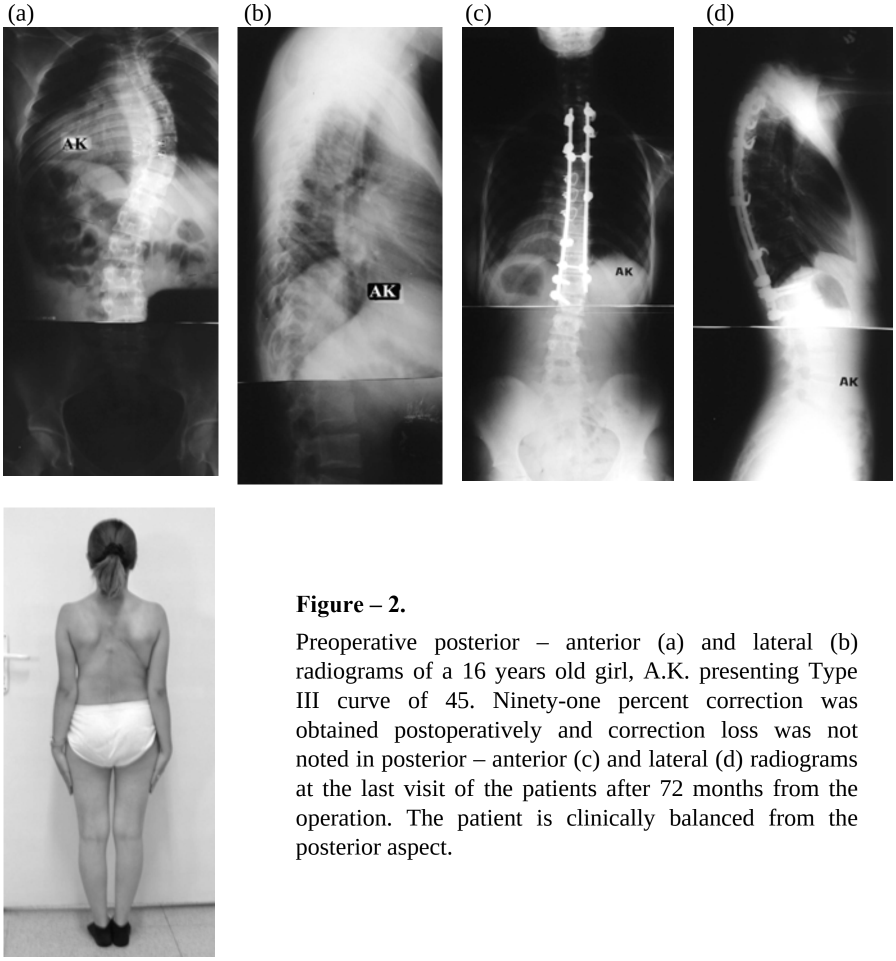
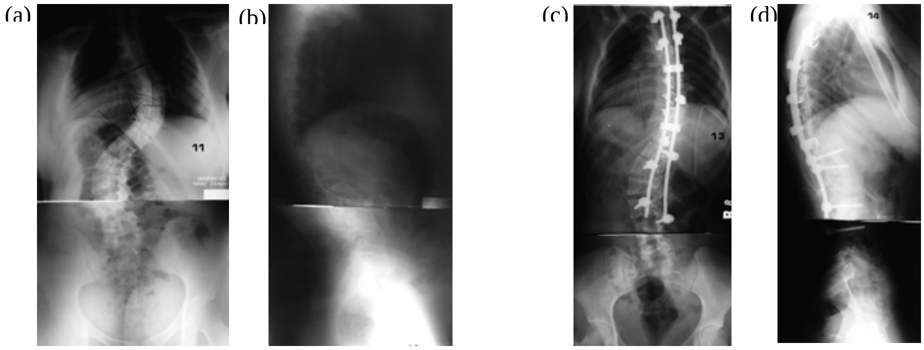


Figure – 2.

Preoperative posterior – anterior (a) and lateral (b) radiograms of a 16 years old girl, A.K. presenting Type III curve of 45. Ninety-one percent correction was obtained postoperatively and correction loss was not noted in posterior – anterior (c) and lateral (d) radiograms at the last visit of the patients after 72 months from the operation. The patient is clinically balanced from the posterior aspect.



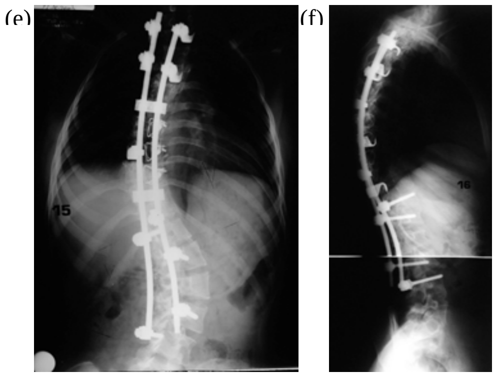
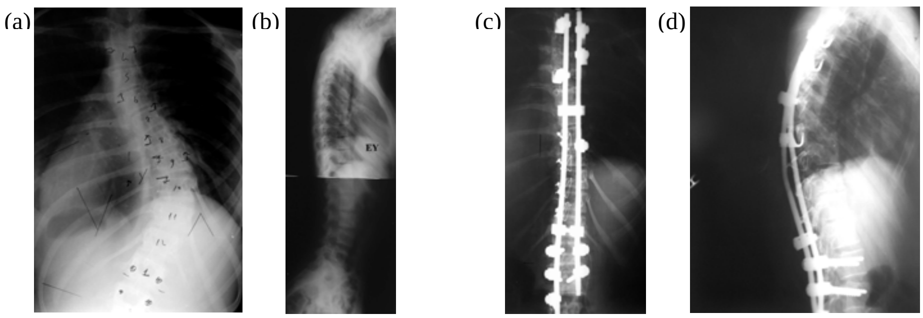


Figure – 3.

Preoperative posterior – anterior (a) and lateral (b) radiograms of 17 years old girl, M.T. revealed 74° of rigid thoracic and 60° of lumbar curves. Postoperative posterior – anterior (c) and lateral (d) radiograms showed 54.1 % of correction rates at the frontal plane and physiological sagittal contours were provided. A minimal correction loss of 6° was noted after 48 months and a solid fusion mass was obtained in posterior – anterior (e) and lateral (f) radiograms.



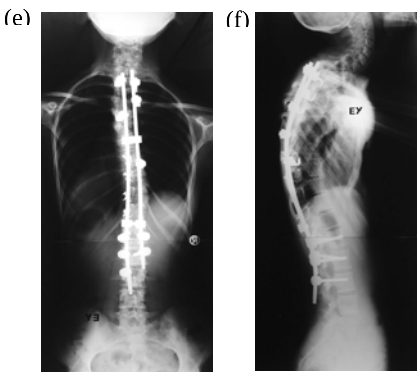


Figure – 4.

Hypokyphosis and 50° of Type IV curve were noted in 14 years old girl E.Y. at the preoperative posterior – anterior (a) and lateral (b) radiograms. Postoperative 96 % of correction was obtained in postoperative posterior – anterior (c) and lateral (d) radiograms and any correction loss were not noted at the last visit after 72 months in posterior – anterior (e) and lateral (f) radiograms.

At the last follow-up visit, there was 4.8°±2.3°, 1.6°±1.3° and 2.7°±2.3° loss of correction for type II, III and IV curves, respectively, overall, the correction loss was 2.9°±3.2°. In the last follow – up visit it was observed that final correction rates of Type II, III and IV curves were preserved and the difference between the preoperative and postoperative mean of Cobb angles was statistically significant (p< 0.01) (Table-2). All patients had less than 10° correction loss. No implant failure was observed, and a solid fusion mass with radiological consolidation was determined in all patients.

Table - 1. Frontal plane analysis of the patients with AIS (n: number of the patients)

Curve Type		Preoperative Cobb	Bending Cobb	Postoperative Cobb	t	p	Final Cobb
Type II	**n: 15**	77.7°±9.7°	62.4°±14.9°	26.7°±6.5°	20.2	**< 0.01**	31.5°±7.8°
Type III	**n: 18**	47.4°±5.9°	23.4°±5.4°	5.2°±3.1°	30.9	**< 0.01**	6.8°±3.3°
Type IV	**n: 12**	52.1°±13.4°	27.4±11.1°	10.0°±10.5°	20.7	**< 0.01**	12.7°±10.1°
Total	**n: 45**	**58.8°±16.6°**	**37.5°±20.8°**	**13.6°±11.6°**	**38.7**	**< 0.01**	**16.6°±12.9°**

Table - 2. Preoperative, postoperative and final correction rates (CR) of the Cobb angles in the frontal plane (n: number of the patients)

Curve Type		Bending CR (%)	Postoperative CR (%)	Final CR (%)
Type II	**n: 15**	21.3±12.6	66.4±9.5	59.7±8.3
Type III	**n: 18**	50.8±8.9	89.1±6.3	86.0±6.4
Type IV	**n: 12**	49.6±8.9	83.2±1.26	77.3±11.9
Total	**n: 45**	**40.7±17.1**	**79.9±13.5**	**74.9±14.3**

Preoperative and postoperative sagittal contours of the patients according to the curve types are given in Table-3. The distribution of the patients with normal physiological sagittal contours and the deviation from these limits are given in Table-4. The preoperative overall thoracic and lumbar sagittal contours were 20.6°±14.3° and -26.1°±12.4°, respectively while the postoperative values were 10.8°±4.5° and –40.7°±13.3°. These improvements were statistically significant, and 97.8 % of the thoracic and 86.7 % of the lumbar contours were corrected in to the normal range.

In patients with Type IV curve, the thoracolumbar junction (TLJ) angles were outside normal range except one (0º). The mean TLJ angle was 6.4º±3.5º preoperatively and 0.7º±1.6º postoperatively. TLJ angle has been reduced to 0º in 10 (83.3 %) patients and below 5º in 2 (16.7 %) patients. Thus, TLJ angle has been reduced to normal physiological range, which is between 0º and 5º. In the last control visit, TLJ angles have been preserved in all patients (1.0º±1.8º) except one (6º).

Table - 3. Sagittal plane analysis of the patients.

Type	Preoperative Thoracic Kyphosis	Postoperative Thoracic Kyphosis	Final Thoracic Kyphosis	Preoperative Lumbar Lordosis	Postoperative Lumbar Lordosis	Final Lumbar Lordosis
Type II (n: 15)	27.3°±18.9°	42.2°±4.3°	43.3°±6.0°	-29.1°±14.7°	-42.5°±29°	-41.3°±5.1°
Type III (n: 18)	16.5°±8.6°	39.6°±4.4°	38.9°±4.3°	-20.7°±10.1°	-40.4°±5.4°	-38.4°±5.6°
Type IV (n: 12)	18.3°±12.4°	41.1°±6.8°	40.3°±7.5°	-30.3°±10.3°	-43.7°±6.9°	-44.3°±6.6°
Total (n: 45)	20.6°±14.3°	40.8°±4.5°	40.6°±5.5°	-26.1°±12.4°	-40.7°±13.3°	-40.9°±6.1°

Table - 4. Distribution of the patients according to sagittal contours.

	THORACIC			LUMBAR	
Type	Hypokyphosis (Below 30°)	Normal (30°-50°)	Hyperkyphosis (Upper 50°)	Hypolordosis (Below 40°)	Normal (40°-60°)
Type II (n : 15)					
Preoperative	10 (% 66.7)	3 (% 20)	2 (% 13.3)	11 (% 73.3)	4 (% 26.7)
Postoperative	0 (% 0)	15 (% 100)	0 (% 0)	0 (% 0)	15 (% 100)
Final	0 (% 0)	14 (% 93.3)	1 (% 6.7)	2 (% 13.3)	13 (% 86.7)
Type III (n : 18)					
Preoperative	15 (% 83.3)	3 (% 16.7)	0 (% 0)	16 (% 88.9)	2 (% 11.1)
Postoperative	0 (%0)	18 (% 100)	0 (% 0)	5 (% 27.8)	13 (% 72.2)
Final	0 (%0)	18 (% 100)	0 (% 0)	6 (% 33.3)	12 (% 66.7)
Type IV (n : 12)					
Preoperative	9 (% 75)	3 (% 25)	0 (% 0)	10 (% 83.3)	2 (% 16.7)
Postoperative	0 (%0)	12 (% 100)	0 (% 0)	10 (% 93)	11 (% 94.7)
Final	3 (% 25)	9 (% 75)	0 (% 0)	1 (% 8.3)	11 (% 91.7)
Total (n : 45)					
Preoperative	34 (% 75.6)	9 (% 20.0)	2 (% 4.4)	37 (% 82.2)	8 (% 17.8)
Postoperative	0 (%0)	44 (% 97.8)	1 (% 2.2)	6 (% 13.3)	39 (% 86.7)
Final	3 (% 6.7)	41 (% 91.1)	1 (% 6.7)	9 (% 20.0)	36 (% 80.0)

Clinically, the shoulder asymmetry became less in all patients, and there was no complaint in this respect. The distance between the plumb line and the intergluteal crisis was brought to 0.4 ±0.3 cm postoperatively, while it was 2.8±1.4 cm preoperatively ($p< 0.05$). The preoperative, postoperative and final values of the radiological balance analysis and correction rates are given in Table-5 and Table-6. There was a significant correction rate in the secondary curves for all types of curves ($p< 0.05$). Overall, secondary compensatory curves which were 25.7º±11.8º preoperatively, have been corrected and brought to 5.2º±34.4º and in the last examination, these high correction rates have been preserved with a minimum loss. Correction rates of the Cobb angles in the frontal plane correlated with those of the LT values. Overall, the average postoperative correction in SS and SH values was 87.5±14.2 % and 88.7±14.3 % respectively. In the last examination high correction rates of SS and SH values have been preserved with a minimum correction loss of 0.07±0.14 VU and 0.08±0.16 VU respectively.

None of the patients were completely balanced preoperatively. Totally 4 (9.9 %) patients had balanced curves, while 41 (91.1%) patients had abnormal balance pattern. Postoperatively the patients with Type II, III and IV curves were balanced or completely balanced with a rate of 100 %.

Overall 19 (42.2 %) patients were found to be balanced, while 26 (57.8 %) patients had a complete balance in which SS and SH values were brought to 0 VU. The best results were obtained with type III curves. In the last examination, it was observed that, no patient had imbalance or decompensation problems and in all patients the trunk balance have been preserved.

There were no intraoperative, early or late postoperative systemic and local complications such as pseudoarthrosis, neurological deficit, infection, and implant failure in patients.

Table - 5. Trunk balance analysis of the patients.

Type	Preoperative Cobb (Secondary Curve)	Postoperative Cobb (Secondary Curve)	t	p	Final Cobb (Secondary Curve)	t	p
Type II	30.9°±13.2°	14.1±11.3	3.1	**< 0.01**	16.1±11.6	2.8	**< 0.01**
Type III	18.8°±0.9°	0.0°	17.1	**< 0.01**	0.0	17.1	**< 0.01**
Type IV	28.4°±12.6°	10.0°±10.2	2.6	**< 0.01**	11.1±9.6	3.1	**< 0.01**
Total	25.7°±11.8°	9.2°±11.4°	11.2	**< 0.01**	10.1±9.8	9.4	**< 0.01**
Type	**Preoperative Lateral Trunk Shift (LT) VU**	**Postoperative Lateral Trunk Shift (LT) VU**	**t**	**p**	**Final Lateral Trunk Shift (LT) VU**	**t**	**P**
Type II	1.88±0.52	0.60±0.21	12.2	**< 0.01**	0.71±0.27	9.9	**< 0.01**
Type III	1.26±0.30	0.22±0.15	13.8	**< 0.01**	0.29±0.23	12.7	**< 0.01**
Type IV	1.49±0.56	0.57±0.37	7.6	**< 0.01**	0.63±0.38	6.6	**< 0.01**
Total	1.53±0.52	0.44±0.29	18.3	**< 0.01**	0.52±0.34	17.4	**< 0.01**
Type	**Preoperative Shift of Stable Vertebra (SS) VU**	**Postoperative Shift of Stable Vertebra (SS) VU**	**t**	**P**	**Final Shift of Stable Vertebra (SS) VU**	**t**	**P**
Type II	1.20±0.23	0.19±0.18	15.6	**< 0.01**	0.31±0.19	15.6	**< 0.01**
Type III	0.72±0.28	0.07±0.12	11.7	**< 0.01**	0.72±0.27	11.6	**< 0.01**
Type IV	0.84±0.29	0.13±0.12	9.1	**< 0.01**	0.25±0.29	2.7	**< 0.01**
Total	0.91±0.34	0.12±0.15	18.4	**< 0.01**	0.19±0.22	16.0	**< 0.01**
Type	**Preoperative Shift of Head (SH) VU**	**Postoperative Shift of Head (SH) VU**	**t**	**P**	**Final Shift of Head (SH) VU**	**t**	**P**
Type II	1.24±0.36	0.17±0.20	12.3	**< 0.01**	0.26±0.20	9.9	**< 0.01**
Type III	0.72±0.27	0.05±0.05	11.1	**< 0.01**	0.07±0.07	10.2	**< 0.01**
Type IV	0.90±0.29	0.13±0.16	13.7	**< 0.01**	0.19±0.14	12.1	**< 0.01**
Total	0.94±0.37	0.11±0.16	17.3	**< 0.01**	0.17±0.18	15.5	**< 0.01**

Table - 6. Correction rates (%) of the balance values of the patients.

Type	Postoperative Mean Correction Rate of Secondary Curve	Final Mean Correction Rate of Secondary Curve	Postoperative Mean Correction Rate of Lateral Trunk Shift (LT)	Final Mean Correction Rate of Lateral Trunk Shift (LT)	Postoperative Mean Correction Rate of Shift of Stable Vertebra (SS)	Final Mean Correction Rate of Shift of Stable Vertebra (SS)	Postoperative Mean Correction Rate of Shift of Head (SH)	Final Mean Correction Rate of Shift of Head (SH)
Type II	54.4±32.6	54.8±10.8	67.8±7.7	62.5±9.5	83.7±14.6	74.0±16.6	80.8±16.2	77.3±17.4
Type III	100.0±70.0	100.0±0.0	81.9±15.2	76.4±17.7	95.1±8.9	91.0±11.5	90.2±14.5	90.2±14.5
Type IV	64.8±46.2	63.2±39.1	64.6±16.4	60.7±18.9	80.8±15.7	80.8±15.7	88.5±13.2	80.8±15.9
Total	75.2±34.4	74.3±33.1	72.6±15.3	67.6±17.1	87.5±14.2	82.6±15.9	0.94±0.37	88.7±14.3

DISCUSSION

Third-generation systems are technologically and metallurgical improved systems and also have developed application strategies. Multiple hook applications to the strategic vertebra, “claw” applications to the proximal and distal part of the curve, new locking mechanism and improved transverse connectors rendered these systems biomechanical safer and led higher correction rates to be achieved (16, 49-50). Cotrel-Dubousset system has found a wide utilization in spinal surgery in the recent years and there are a lot of reports suggesting its high correction potential in all planes when compared to other systems (16,19,44). With derotation maneuver, correction of rotational deformity in the transverse plane, which is a revolution in spinal surgery, can be achieved (1,8-9). In the literature, there are reports on the correction of frontal plane major curves by 30 % - 70% with CDI (8-9). Richards et al. reported a 65 % correction rate with similar techniques using the Texas Scottish rite Hospital system (48).

In recent years, as the cosmetic aspects of the disease have been considered more than they were in the past, the concept of augmentation has been introduced to obtain better correction rates with the third generation instrumentation systems (2,28). With this purpose, in the beginning, the third generation instrumentation systems have been tried to be augmented with screws instead of hooks in the lumbar region. These trials have been followed by screw placement on every segment and wire fixation through the processes or sublaminar (15,18,29,39). The technique used in this study is different from the modern systems in a lot of ways. In this manner the translation and derotation maneuvers are combined as the vertebral column is derotated after being transferred to the midline by a translation maneuver. The study aims to evaluate the correctional effect in the frontal and sagittal planes of this new strategy and the technique which basicly is an application of augmentation with sublaminar wiring.

In this study, augmentation is achieved with 3-4 multifilament titanium Songer cables placed sublaminar. The rods are bended in the sagittal plane in accordance with the patient, attached to the hooks proximally and to the screws distally. However, unlike suggestions of Asher and the Isola System concept, the rod is placed with the curved part left at frontal. After the first cable was tensioned, unlike CDI technique, the derotation maneuver was applied not to the rod but to the vertebral column. The operation was completed with the tensioning of the second wire. To increase correction rates, anterior complete release was performed if thoracoplasty was necessary.

Kim and Lenke have reported the results of instrumentations with pedicle screws and hooks in which correction rates were 76 % and 50 % respectively. They have reported that screw fixation enabled better correction (29). Girardi et al. published the results of CDI augmented with screws and wires versus CDI construct only with hooks and reported better correction rates (66 % and 52 % respectively) with augmentation (24). Bridwell et al. have reported a decrease in major curve from 56º to 31º using CD-Horizon instrumentation augmented with Wisconsin wires (15). While Us et al. used augmentation wires through transverse processes, Yazar et al used them sublaminar and both authors have reported good results with augmented posterior instrumentation in idiopathic scoliosis (56,62).

In this study, postoperatively a high correction rate of 79.9±13.5 % has been obtained in overall patients. In the last examination, loss of correction has been measured to be 2.9º±3.2º and the final correction calculated to be 74.3±14.3 %. In Type II, III and IV curves, the correction rates of the deformity in the frontal plane have been calculated as 66.4±9.5 %, 89.1±6.3 % and 83.2±6.3 % respectively. Solid fusion has been obtained in all patients in the mean follow-up period of 51.9±22.7 months. In all patients high correction rates have been preserved with minimum loss of correction.

For Type II patients whose lumbar curve was below 40º, selective fusion has been performed as Lenke et al., Edwards et al., Benli et al. and Large et al. have been suggested (8-10,21,33,36). Morrey and Kealin have reported that short segmental instrumentation in Type IV curves has been a successful method in restoration of sagittal contours and frontal correction (42). In our study, short segmental instrumentation with sublaminar wiring has been performed in some Type II and Type IV patients and satisfactory results have been obtained. We observed no decompensation in secondary curves especially in lumbar secondary curves of Type II patients.

There are reports claiming high correction rates in sagittal contours and effectiveness of the derotation maneuver with CDI (1,16). However, according to Bridwell with the combination of a rod rotation maneuver, the problem of flat back syndromes can be reduced markedly. He also reported that especially in Type II patients, some complications may occur, and minimal correction may be obtained with derotation in thoracic kyphosis in hypolordotic patients (14-15). Asher reported that the preoperative thoracic kyphosis was corrected from 32° to 28° and lumbar lordosis from 63° to 57° with Isola spinal instrumentation, with 13° loss of correction in both sagittal contours (3-4). Benli et al. have reported correction of sagittal contours in thoracic region to be 31.4º±11.6º and in lumbar region 30.6º±10.9º with TSRH instrumentation and also reported restoration of normal physiologic contours in the thoracic region in 83.3 % of the patients and in the lumbar region in 66.7 % of the patients (10).

In this study, in all patients operated with the sublaminar wire augmented third generation systems, the preoperative contours which were 20.6º±14.3º in thoracic region and 26.1º±12.4º in lumbar region have been calculated to be 40.8º±4.5º and 40.7º±13.3º respectively after operation. Normal physiologic sagittal contours have been restored in 97.8 % of the patients for thoracic region and in 80.7 % of the patients for lumbar region and have been preserved until the last examination. Thoracolumbar junction (TLJ) angles of Type IV patients were outside normal range except in one patient (0º). Postoperatively, TLJ angle of 83.3 % of the patients have restored to 0º and of 16.7 % of the patients to below 5º. Thus, TLJ angle has been restored to normal values (0º-5º) in all patients and preserved until the last examination except in one patient.

With the derotation maneuver, correction of rotational deformity in transverse plane was achieved, which is a revolution in spinal surgery (1,16). Later on, many authors reported decompensation problems and imbalance with the use of the derotation maneuver with CDI especially in type II and IV curves (22,25,28,36,41,47,49,53-55,60-61). Steib et al reported that derotational effect corrected intervertebral rotation extensively but had minimal effect on segmental rotation (51). Bridwell put forth the idea that the major causes of decompensation in Type II curves were: (1) inability to detect double major curves, (2) inappropriate selection of fusion and instrumentation levels, (3) progression of the lumbar secondary curve in skeletally immature patients, (4) insufficiency of structural superior thoracic curve (14). Benli et al. suggested that the main reasons for imbalance and decompensation were inappropriate preoperative planning and over correction in their CDI and TSRH instrumentation studies (9,10).

Asher developed an alternative method to CDI, called the Isola system, which used the translation maneuver as the corrective force, as in the Luque technique (3-5). Webb et al. and Laxer applied an alternative technique using the universal spinal system (USS) (34,57). Asher and Benli et al. have reported high correction rates in idiopathic scoliosis patients treated with isola instrumentation (2-4,11). Delorme et al. have reported that they have obtained similar correction rates with Colorado System and CDI Instrumentation (17). Some authors reported translation systems had better apical vertebral translation and hence was associated with fewer balance problems (11,22,24). Muschik et al. studied the effect of rod rotation and translation was more helpful in spinal balance while the decompensation risk in the uninstrumented region was equal in both methods (43).

In this study, derotation which was augmented and combined with translation has been performed as a new manner. It has been observed that apical vertebrae have been drawn to central line in a high rate in all patients. In secondary curves, postoperatively, 75.2±34.4 % correction has been achieved with a minimum loss of correction observed in the last examination. In all patients, postoperatively, a totally balanced or balanced vertebral column has been obtained and even in the last examination, no imbalance and decompensation have been observed.

Neurological deficit rates up to 17 % have been reported with sublaminar wiring (11,26,58-59). The risk has been reported to be 1.5 % in transpedicular screw fixation (20,59). The SRS Committee has reported neurological deficit risk to be 0.03 % (40). Asher has reported neurological deficit score as 0.03 % in series of 355 patients (5). Benli et al. have reported no neurological deficit in patients operated with ISOLA Instrumentation (11). Asher et al. and Girardi et al. have reported no neurological deficit and pointed out that sublaminar wiring was a safe method (3,23). In this study no neurological deficit has been observed with titanium, double crimp, multifilament sublaminar wiring.

Richards et al. reported a 10 % late infection rate that healed primarily or late with antibiotic therapy and debridement (48). Asher reported 1-2 % early, 0.5 % acute superficial and 1 % late infection rate in his series (5). In this study, we have observed no early or late infection, implant failure, pseudoarthrosis and other systemic complications.

In conclusion, satisfactory correction rates have been obtained in both sagittal and frontal planes with multifilament, titanium, and double crimp sublaminar wire augmented third generation instrumentation systems. No decompensation and imbalance have been observed and in the last examination a totally balanced or balanced vertebral column has been obtained in all patients. Given these results, in our opinion, this technique is a successful alternative in the treatment of idiopathic scoliosis.

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