Eur Spine J (2011) 20:1141–1148
DOI 10.1007/s00586-011-1837-z

ORIGINAL ARTICLE

Cervical spine sagittal alignment variations following posterior spinal fusion and instrumentation for adolescent idiopathic scoliosis

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Received: 1 August 2010 / Revised: 8 March 2011 / Accepted: 25 April 2011 / Published online: 11 May 2011

Abstract The aim of this study is to quantify the changes in the sagittal alignment of the cervical spine in patients with adolescent idiopathic scoliosis following posterior spinal fusion. Patients eligible for study inclusion included those with a diagnosis of mainly thoracic adolescent idiopathic scoliosis treated by means of posterior multi-segmented hook and screw instrumentation. Pre and post-operative anterior–posterior and lateral radiographs of the entire spine were reviewed to assess the changes of cervical sagittal alignment. Thirty-two patients (3 boys, 29 girls) met the inclusion criteria for the study. The average pre-operative cervical sagittal alignment (CSA) was 4.0° ± 12.3° (range −30° to 40°) of lordosis. Postoperatively, the average CSA was 1.7° ± 11.4° (range −24° to 30°). After surgery, it was less than 20° in 27 patients (84.4%) and between 20° and 40° in 5 patients (15.6%). The results of the present study suggest that even if rod precontouring is performed and postoperative thoracic sagittal alignment is restored, improved or remains unchanged after significant correction of the deformity on the frontal plane, the inherent rigidity of the cervical spine limits changes in the CSA as the cervical spine becomes rigid over time.

Keywords Sagittal alignment · Cervical spine · Adolescent idiopathic scoliosis

Introduction

Scoliosis is a three-dimensional deformity of the spine [1–3] and idiopathic cases of scoliosis usually exhibit a flattening of the sagittal profile. Frontal and sagittal plane correction is critical to the long-term success of scoliosis surgery. The sagittal profile often deteriorates when the Harrington technique is used. The consequences include a flat back, an angular increase of lumbar lordosis below the fusion level and low back pain [4–9].

Restoration of normal sagittal alignment is one of the fundamental goals in scoliosis correction surgery and rod precontouring is a standard procedure in almost all modern correction techniques for sagittal alignment control. In particular, the Cotrel-Dubousset technique restores thoracic kyphosis for patients with hypokyphotic spines and preserves or restores normal lumbar lordosis in a considerable percentage of patients [10–12]. Studies evaluating the effects of scoliosis surgery on cervical spine sagittal alignment are scarce and it is possible that scoliotic patients treated with surgery have a greater incidence of cervicodorsal pain when compared with normal subjects [13]. Recent publications have shown correlations between cervical kyphosis and axial neck pain, and between the loss of thoracic kyphosis and the development of cervical kyphosis in pre-operative radiographs of patients with adolescent idiopathic scoliosis [14–17].

Therefore, the specific aim of this study was to quantify the changes in the sagittal alignment of the cervical spine in patients with adolescent idiopathic scoliosis following posterior spinal fusion using the multisegmented hook and screw instrumentation.

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Materials and methods

Following approval by the institutional review board of our Institution, we performed a retrospective chart and radiographic review on 32 patients (3 boys, 29 girls) with adolescent idiopathic scoliosis who had undergone posterior fusion with the multisegmented hook and screw instrumentation. All patients were followed at our institution between 1990 and 2000. Data were collected on age, gender, curve patterns, Risser stage, type of surgery performed, as well as the number of spinal segments fused (Tables 1, 2).

Clinical information and follow-up data were also obtained from medical records. Patients eligible for study inclusion included those with a diagnosis of mainly thoracic adolescent idiopathic scoliosis treated by means of posterior multisegmented hook and screw instrumentation (CD-Horizon; Medtronic Sofamor Danek, US).

Table 1 Patients included in the study

Main curve (°)									Compensatory curve (°)					
Patient	Gender	Age	Risser	Examiner 1		Examiner 2			Examiner 1		Examiner 2			
				Pre-op	Post-op	Pre-op	Post-op	Levels	Pre-op	Post-op	Pre-op	Post-op	Levels	Fusion
1	F	14	2	77	31	79	34	D4–D11	37	13	38	17	D12–L4	D3–L4
2	M	16	2	60	32	61	35	D4–L1						D3–L1
3	F	15	3	68	20	68	21	D7–L1						D4–L2
4	F	15	3	50	10	50	3	D5–D12						D3–L1
5	F	13.5	1	36	6	35	6	D5–D12						D3–L1
6	F	16	3	55	29	55	32	D3–D12	40	22	40	22	D12–L4	D3–L3
7	F	12	0	49	20	46	20	D5–L1						D4–L1
8	F	14.75	2	46	7	44	10	D11–L5	30	19	29	19	D4–D10	D7–L4
9	F	14.75	2	44	26	46	28	D5–D11	53	24	55	28	D12–L4	D6–L4
10	F	13	1	54	20	55	26	D4–D11	38	17	40	15	D12–L4	D3–L2
11	M	17.5	4	49	25	50	25	D5–D12	32	4	30	5	D12–L4	D3–L4
12	F	14.25	2	46	16	45	18	D5–D12	36	25	35	25	D12–L4	D5–L1
13	F	14.75	2	52	19	52	23	D4–D11	37	17	34	20	D12–L4	D3–L1
14	F	15	3	88	40	90	40	D4–D11	63	30	63	25	D12–L4	D3–L3
15	F	11	0	60	19	58	20	D5–D12	40	13	40	12	D12–L4	D5–L3
16	F	11.5	0	52	17	55	22	D5–L2						D4–L1
17	F	18	5	84	26	84	25	D5–D11	40	21	44	22	D12–L4	D2–L3
18	M	13	1	85	30	88	30	D6–D12	45	18	40	16	D12–L4	D2–L4
19	F	13	0	62	20	61	20	D5–D12	40	16	40	15	D12–L4	D2–L1
20	F	14	2	54	16	56	16	D4–L2						D4–L2
21	F	16	3	74	24	62	20	D3–D11	40	13	40	16	D12–L4	D3–L1
22	F	16	3	65	35	54	16	D5–D11	50	32				D3–L4
23	F	14.5	2	67	40	74	24	D4–D12	57	36	40	13	D12–L4	D3–L3
24	F	16.5	4	41	17	45	35	D6–D12	49	18	50	32	D12–L4	D5–L4
25	F	15.5	3	53	18	53	18	D3–D12	35	10	35	10	D12–L4	D4–L2
26	F	16	4	50	20	50	20	D6–D12	41	14	41	14	D12–L4	D4–L4
27	F	15	3	52	13	52	13	D5–D11	37	11	37	11	D12–L4	D4–L1
28	F	12.5	0	60	17	58	17	D4–D12	40	20	40	18	D12–L4	D4–L2
29	F	14	2	52	20	52	20	D5–D11	46	17	46	17	D12–L4	D4–L3
30	F	13	1	58	20	57	20	D6–D11	40	22	40	22	D12–L4	D4–L2
31	F	13.5	1	70	35	70	35	D5–L1						D5–L2
32	F	18	5	42	16	42	13	D9–L2	27	7	27	9	D4–D8	D3–L2
Mean		14.6	2.2	58.0	22.0	57.7	22.0		41.4	18.3	40.2	17.5		
SD		1.4	1.1	10.4	6.8	10.0	6.6		6.1	5.7	5.0	5.0		

Ages are expressed in years and angles are expressed in degrees. All measurements were performed by two examiners experienced in spinal deformities. Values are expressed in degrees

Table 2 Cervical sagittal alignment (CSA), thoracic sagittal alignment (TSA) and lumbar sagittal alignment (LSA) of operated patients

Patients	Cervical sagittal alignment (CSA)						Thoracic sagittal alignment (TSA)						Lumbar sagittal alignment (LSA)					
	Examiner 1			Examiner 2			Examiner 1			Examiner 2			Examiner 1			Examiner 2		
	Pre-op	Post-op	Evolution	Pre-op	Post-op	Evolution	Pre-op	Post-op	Evolution	Pre-op	Post-op	Evolution	Pre-op	Post-op	Evolution	Pre-op	Post-op	Evolution
1	−30	−24	6	−28	−21	7	10	20	10	10	21	11	26	42	16	27	42	15
2	−7	−16	−9	−7	−18	−11	14	25	9	10	24	14	44	50	6	50	55	5
3	−12	−7	5	−11	−6	5	16	20	4	15	22	7	33	40	7	35	40	5
4	−6	−6	0	−7	−7	0	16	23	7	14	22	8	26	47	11	33	46	13
5	−6	−17	−11	−6	−16	−10	16	19	3	15	20	5	53	58	5	50	57	7
6	−3	−5	−2	−2	−6	−4	16	20	4	16	22	6	36	32	−4	36	32	−4
7	0	−7	−7	0	−6	−6	18	17	−1	17	20	3	40	29	−11	42	31	−11
8	3	3	0	4	3	−1	24	27	3	26	29	3	40	48	8	41	44	4
9	8	10	3	7	10	3	28	30	2	26	30	4	40	30	−10	40	32	−8
10	5	9	4	5	5	0	30	30	0	30	30	0	57	49	−8	57	62	5
11	−12	−10	2	−12	−10	2	30	46	16	30	46	60	46	42	−4	46	42	−4
12	−14	−5	9	−14	−5	9	30	30	0	30	30	0	54	50	−4	54	50	−4
13	−25	−6	19	−13	8	21	32	22	−10	25	30	5	42	32	−10	40	28	−12
14	5	23	18	5	18	13	33	45	12	33	43	10	30	40	10	28	39	11
15	0	−13	−13	0	−13	−13	33	20	−13	37	20	−17	60	44	−16	62	45	−17
16	0	5	5	0	5	5	33	22	−11	35	25	−10	27	23	4	27	25	2
17	40	32	−8	40	32	−8	34	30	−4	35	30	−5	40	36	−4	40	35	−5
18	40	30	−10	40	30	−10	36	43	7	36	43	7	37	46	9	36	45	9
19	−10	−7	3	−8	−4	4	36	30	−6	28	30	2	33	33	0	34	34	0
20	7	4	−3	7	4	−3	36	24	−12	36	24	−12	18	42	24	18	42	24
21	15	23	8	15	23	8	36	36	0	36	36	0	56	54	−2	56	54	−2
22	0	−16	−16	0	−16	16	40	39	−1	40	39	−1	50	48	−2	50	48	−2
23	28	24	−4	28	24	−4	42	37	−5	42	37	−5	42	40	−2	42	40	−2
24	7	12	5	5	12	7	44	50	6	43	50	7	48	42	−6	45	47	−2
25	27	0	−27	27	0	−27	45	44	−1	45	44	−1	40	44	4	40	44	4
26	7	3	−4	7	3	−4	48	40	−8	48	40	−8	56	37	−19	56	37	−19
27	40	12	−28	40	12	−28	48	38	−10	48	36	−12	44	42	−12	44	48	4
28	0	13	13	3	18	15	50	27	−23	50	30	−20	60	28	−32	62	33	−29
29	0	−20	−20	0	−20	−20	50	33	−17	50	33	−17	37	30	−7	37	30	−7
30	11	10	−1	9	10	1	50	38	−12	50	38	−12	36	25	−11	37	20	−17
31	14	0	−14	15	5	−10	50	27	−23	50	28	−23	53	47	−6	52	40	−12
32	−3	0	3	−4	0	4	8	20	12	12	21	9	44	52	8	44	51	7
Mean	4.0	1.7	−2.2	4.5	2.3	−2.2	32.3	30.4	−1.9	31.8	31.0	−0.8	42.4	40.7	−1.5	42.5	41.2	−1.3
SD	12.0	11.4	8.6	11.3	11.1	8.5	9.9	7.5	7.8	10.5	6.8	8.0	7.9	6.9	8.0	8.0	7.4	8.2

Values are expressed in degrees. All measurements were performed by two examiners experienced in spinal deformities

Table 3 Cervical sagittal alignment (CSA), thoracic sagittal alignment (TSA) and lumbar sagittal alignment (LSA) of normal subjects

Patients	Gender	Age	Risser	Cervical sagittal alignment (CSA)	Thoracic sagittal alignment (TSA)	Lumbar sagittal alignment (LSA)
1	M	12.5	0	18	35	30
2	F	13	2	−5	35	36
3	F	17.25	5	6	39	46
4	F	13	0	3	46	31
5	F	12	2	8	32	36
6	F	12.5	0	−12	36	50
7	F	13.5	2	−1	34	32
8	F	13	0	0	29	36
9	F	12	0	21	53	42
10	F	13	2	12	44	58
11	F	13	0	1	35	37
12	F	15.25	4	11	30	31
13	F	14	3	35	49	51
14	F	15	4	5	34	53
15	F	12.5	0	2	38	50
16	F	14.75	3	−3	47	40
17	F	14.5	2	4	38	33
18	F	13.25	3	0	29	26
19	F	11.75	0	2	34	32
20	F	16.75	5	−7	23	43
21	F	14	3	−8	47	40
22	F	16.75	5	−6	24	45
23	F	12	0	4	29	40
24	F	14.25	1	4	36	50
25	F	14.75	2	9	36	55
26	F	12.75	2	−1	30	26
27	F	14.5	5	−3	23	20
28	F	13	0	−2	28	47
29	F	15	3	1	46	45
30	F	12	0	17	42	49
31	F	15.5	3	−1	37	38
32	F	16	5	−2	27	44
Mean		13.8	2.1	3.5	35.8	40.4
SD		1.3	1.5	6.8	6.1	7.6

Values are expressed in degrees

All patients were operated in the prone position. A standard rod rotation maneuver was used for scoliosis correction in all patients; additional distraction was applied on the concavity, while the implants on the convexity were compressed. No in situ rod contouring was performed in any of the patients. The rod was pre-contoured based on the surgeon's experience aiming to restore appropriate thoracic kyphosis and thoraco-lumbar junction lordosis. In particular, we over bent the rod and used a three point system in order to obtain as much kyphosis correction as possible.

A group of 32 adolescent (1 boy, 31 girls) age matched with the group of patients was also included as the control group for reference data (Table 3).

Radiographic analysis

Two experienced examiners evaluated pre and post-operative anterior–posterior (AP) and lateral radiographs of the entire spine to assess the changes of cervical sagittal alignment (CSA), thoracic sagittal alignment (TSA) and lumbar sagittal alignment (LSA) in eligible patients (Table 2). Radiographs were all taken in a standard standing position. Patients had AP radiographs of the entire spine, including the pelvis and all individuals underwent lateral radiographs with their spine in the neutral position (they were given instructions to look straight ahead in a relaxed position). All patients had both upper extremities supported at 70° of extension by an arm rest.

Measurements of the spinal curvature were performed in the coronal and sagittal plane using Cobb's method [18]. In particular, measurements of sagittal alignment of the 2nd to 6th cervical vertebrae (C2–C6), of the 2nd to 12th thoracic vertebrae (T2–T12) and of the 1st to 5th lumbar vertebrae (L1–L5) were performed for each patient on lateral radiographs.

Cervical measurements were obtained by measuring from the lower border of C2 to the lower border of C6. C6 was chosen as the distal endpoint for total CSA because this vertebra could not be adequately visualized for all of the patients. The occasional failure to properly visualize C7–T1 in some patients resulted in choosing C6 as the distal level for CSA evaluation. Cervical lordosis between 20° and 40° was considered as normal [19–23].

Thoracic and lumbar measurements were obtained by measuring from the upper border of T2 to the lower border of T12, and from the upper border of L1 to the lower border of L5, respectively. The occasional failure to properly visualize C7–T1 in some patients resulted in choosing T2 as the proximal level for TSA evaluation. Thoracic kyphosis and lumbar lordosis were considered normal if measuring between 17° and 57° and 30° and 50°, respectively [19–23].

The CSA, TSA and LSA were also measured on control subjects for reference data (Table 3).

Statistical analysis

Data was expressed as frequencies and percentages, and means and standard deviations as appropriate. The inter-observer reliability was evaluated using two-way random Intraclass Correlation Coefficients ($ICC_{2,1}$). Repeated measured ANOVA and Tukey post hoc tests were used to evaluate difference between pre and post evaluations. The comparison between the group of patients and control subjects was performed using unpaired *t* tests. Statistical significance was set at $P < 0.05$.

Statistical analysis was performed using STATISTICA 8.0 (StatSoft Inc., 8.0, USA).

Results

Demographic results

The mean age and Risser stage of patients at surgery were 14.6 ± 1.4 years (range 11–18) and 2.2 ± 1.1 (range 0–5) respectively. The mean age and Risser stage of control subjects were 13.8 ± 1.3 years (range 12–17) and 2.1 ± 1.5 (range 0–5) respectively. No significant difference was found between groups.

Based on King's classification [24] there were 22 type II, 8 type III, 1 type V and 1 type I. According to Lenke's classification [25] there were 9 type I, 10 type II, 11 type III, 1 type V and 1 type VI.

All patients underwent posterior spinal fusion and multisegmented hook and screw instrumentation (Cotrel-Dubousset technique). All procedures were performed by the same surgical team.

Radiographic results

Radiographs were reviewed at an average of 72.0 ± 16.7 months after surgery (range 51–144). All measurements were performed by two examiners experienced with spinal deformities. Inter-observer reliability demonstrated excellent reliability with an average $ICC_{2,1}$ of 0.95, ranging from 0.76 to 1.00 (Table 4). Therefore, the results obtained from the first examiner will be reported in the text; refer to Tables 1, 2 and 3 for a complete overview of data.

The proximal fusion level was at T2 in three patients, T3 in 13 patients, T4 in 10 patients, T5 in 4 patients, T6 in 1 patient and T7 in 1 patient. The distal fusion level was at L1 in 10 patients, L2 in 8 patients, L3 in 6 patients and L4 in 8 patients.

Results show difference between pre and post-radiographic data with a significant main effect ($P < 0.0001$).

The index curve show a significant reduction postoperatively ($P < 0.0001$). The average pre-operative index curve was 58.0° ± 10.4° (range 41° to 88°). Postoperatively, it was 22.0° ± 6.8° (range 6° to 40°). The average compensatory curve measured 41.4° ± 6.1° (range 27° to 63°) preoperatively and 18.3° ± 5.7° (range 4° to 36°) postoperatively ($P < 0.0001$). The average number of motion segments fused was 11.6 ± 1.2 (range 9–14).

Table 4 Inter-observer intraclass correlation coefficient (ICC) and confidence interval (IC) of pre and post-operative measurements

	ICC (2, 1)	IC (95%) low	IC (95%) up
Pre-operative			
Index curve	0.99	0.98	0.99
Compensatory curve	0.91	0.83	0.95
Cervical sagittal alignment	0.99	0.99	1.00
Thoracic sagittal alignment	0.99	0.98	1.00
Lumbar sagittal alignment	1.00	1.00	1.00
Post-operative			
Index curve	0.86	0.74	0.93
Compensatory curve	0.76	0.57	0.87
Cervical sagittal alignment	0.98	0.96	0.99
Thoracic sagittal alignment	0.99	0.98	1.00
Lumbar sagittal alignment	0.98	0.96	0.99

Cervical sagittal alignment

No difference between pre and postoperative results for the CSA was found ($P = 0.51$). The average pre-operative CSA was 4.0° ± 12.3° (range −30° to 40°). The CSA was less than 20° in 27 patients (84.4%) and between 20° and 40° in 5 patients (15.6%). Among the 27 patients with CSA less than 20°, 11 had an average kyphosis of 11.6° ± 6.3° (range 3° to 30°) and 16 had an average lordosis of 5.1° ± 4.1° (range 0° to 15°).

Postoperatively, the average CSA was 1.7° ± 11.4° (range −24° to 30°) of lordosis. After surgery, CSA was less than 20° in 27 (84.4%) patients and between 20° and 40° in 5 (15.6%) patients. Among the 27 patients with CSA less than 20°, 14 had an average kyphosis of 5.1° ± 4.1° (range 5° to 24°) and 13 had an average lordosis of 6.2° ± 4.4° (range 0° to 13°) (Table 2).

Thoracic sagittal alignment

The mean pre-operative thoracic kyphosis (thoracic sagittal alignment, TSA) was 32.3° ± 9.9° (range 8° to 50°). Postoperatively, it was 30.4° ± 7.5° (range 17° to 50°. The mean difference between pre and postoperative values was 1.9° ± 8.0° (range −23° to 11°).

Preoperatively, thoracic kyphosis was less than 17° in 7 cases (21.9%) and between 17° and 50° in 25 (78.1%). Postoperatively, none of the patients had a thoracic kyphosis less than 17° (Table 2).

Lumbar sagittal alignment

The mean pre-operative lumbar lordosis (lumbar sagittal alignment, LSA) was 42.4° ± 7.9° (range 26° to 60°). Postoperatively, it was 40.7° ± 6.9° (range 25° to 58°). The mean difference between pre and postoperative values was 1.5° ± 8.0° (range −32° to 24°. Preoperatively, lumbar lordosis was less than 30° in three cases (9.4%), between 30° and 50° in 21 cases (65.6%) and over 50° in 8 cases (25.0%). Postoperatively, lumbar lordosis was less than 30° in four cases (12.5%), between 30° and 50° in 25 cases (78.1%) and over 50° in 3 cases (9.4%) (Table 2).

Moreover, no significant difference between control subjects and patients pre and postoperatively was found for CSA measurements (Table 3).

Discussion

Thoracic hypokyphosis can be improved with posterior segmental instrumentation. Within the literature, however, there is no extensive investigation of whether this treatment has a significant impact on the cervical spine above or the lumbar spine below. In particular, studies evaluating the effects of scoliosis surgery on cervical spine sagittal alignment are scarce and it is not clear if scoliotic patients treated with surgery have a greater incidence of neck pain as compared to normal subjects [13]. Recent publications have shown a correlation between cervical kyphosis and axial neck pain or new-onset neurologic symptoms [14–16]. In particular, Edgar and Metha [13], in their long-term follow-up of fused and unfused idiopathic scoliosis patients, found an incidence of cervicodorsal pain in 17.6% of the patients who had undergone fusion and 7.8% of the patients who had not.

The current study aimed to quantify the changes in the sagittal alignment of the cervical spine of scoliotic patients surgically treated and to evaluate if the CSA was altered following surgical modification of preoperative TSA and LSA. The T6–T12 intervertebral joints contribute up to 10% of cervical spine movement [26] and the postural alignment of the cervical spine and the head in the sagittal plane is related to the curvature of the thoracic spine [20]. In addition, the standing posture results from an accurate sagittal alignment of the various body segments with respect to gravitational forces [27–29].

Cervical kyphosis in patients with scoliosis is frequent. Helliwell et al. [30] performed a cross-sectional study of the prevalence of hypolordotic cervical spines in three groups of patients: 83 presenting with acute neck pain, 83 with chronic neck problems, and 80 normal subjects. The authors could not find any difference in the prevalence of loss of cervical lordosis between films of patients with acute neck pain, and those from patients with more chronic symptoms. They concluded that loss of cervical lordosis might be influenced by variations in radiographic positioning.

Kimura et al. [31] found that 70.0% of patients (77 out of 110) with thoracic scoliosis developed cervical kyphosis and reduction of cervical lordosis is correlated to a reduction of thoracic kyphosis. Our data confirmed the high incidence of reduced CSA in patients with adolescent idiopathic scoliosis as 50% of our patients had an average cervical lordosis of 5° and 34.4% had an average cervical kyphosis of 11°.

Furthermore, in their review of 110 patients, Kimura et al. reported the average sagittal alignment for the cervical spine was 5.6° of kyphosis, 22.3° of kyphosis for the thoracic spine and 39.8° of lordosis for the lumbar spine. The average magnitude of the scoliosis curve was 25.9°. However, in their study they could not evaluate the effects of scoliosis surgery as none of their patients received an operation.

Restoration of normal sagittal alignment is one of the fundamental goals in scoliosis correction surgery. Rod precontouring is a standard procedure in almost all modern correction techniques for sagittal alignment control. In particular, we over bent the rod and used a three points system to obtain as much kyphosis correction as possible.

In our study, the average preoperative CSA, TSA and LSA was 4.0° of lordosis, 32.3° of kyphosis and 42.2° of lordosis, respectively. Postoperatively, the average CSA was 1.7° of lordosis and none of the patients had a TSA under 17° of kyphosis. In our group of patients, despite seeing an improvement of TSA, the CSA worsened in 50% of our patients. After surgery, the CSA improved in 16 cases (50.0%), and worsened or remained unchanged in 16 (50.0%) cases. The mean difference between pre and postoperative values was 2.3° ± 8.6° (range −28° to 19°). A proximal fusion level at T2–T3 had a similar effect on CSA to a proximal fusion level at T4 or below.

In 1983 Cochran et al. reported on 100 patients treated with Harrington rod fusion for idiopathic scoliosis with a minimum 5-year follow up. Lateral roentgenograms demonstrated that the 52% of patients with flattened or kyphotic cervical spines had no significant complaint, non-significant flattening of the thoracic kyphosis, but significant lowering of the lumbar lordosis [9]. In 1995, Hilibrand et al. published a radiographic study on the sagittal alignment of the cervical spine in patients with adolescent idiopathic scoliosis. They found that the less kyphotic the TSA, the more lordotic the cervical spine. They noted there was no progression of cervical kyphosis if thoracic kyphosis remained under 20° after surgery. On the contrary, cervical kyphosis worsened, despite preservation of thoracolumbar sagittal contour, in patients with thoracic kyphosis of more than 20° after surgery they suggested that moderate thoracic hypokyphosis may predispose to cervical kyphosis and that correction of thoracic hypokyphosis did not necessarily lead to changes in the cervical sagittal plane [32].

Our findings confirm those previously published. In addition, we found that patients with postoperative improvement of TSA experienced a reduction of CSA, regardless of the presence of cervical lordosis or kyphosis. We hypothesize that the cervical spine is affected by the thoracic deformity in the sagittal plane as we observed a high percentage of patients with a reduction in cervical lordosis. This reduction of cervical lordosis was proportional to the reduction of thoracic kyphosis. Although spinal surgery can improve and/or restore thoracic sagittal coronal alignment, its effects on CSA are limited.

In conclusion, we found that CSA was affected by the thoracic deformity in the sagittal plane as there was a reduction in cervical lordosis. The results of the present study suggest that even if rod precontouring is performed and postoperative TSA is restored, improved or remains unchanged after significant correction of the deformity on the frontal plane, the inherent rigidity of the cervical spine limits changes of CSA as the cervical spine tends to become more rigid over time.

Acknowledgments None of the authors received financial support for this study.

Conflict of interest None.

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