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Original Investigation

The Usefulness of Employing an Electronic Traction Table to Determine Flexibility in Adolescent Idiopathic Scoliosis

Erman CEYHAN[1], Onder Murat DELIALIOGLU[2], Kenan BAYRAKCI[2], Bulent DAGLAR[3], Alper DEVECI[4], Ugur GUNEL[1]

[1]Social Security Institution, General Directorate of Universal Health Insurance, Ankara, Turkey
[2]Tiran American Hospital, Orthopaedics and Traumatology Clinic, Tiran, Albania
[3]Guven Hospital, Orthopaedics and Traumatology Clinic, Ankara, Turkey
[4]Ankara Numune Training and Research Hospital, Orthopaedics and Traumatology Clinic, Ankara, Turkey

ABSTRACT

AIM: The aim of the study was to develop new equipment for the assessment of the flexibility of the spine with different forces. This new system should provide a different perspective to adolescent idiopathic scoliosis (AIS) for the selection of fusion levels and surgical success.

MATERIAL and METHODS: Eighteen patients suffering from AIS who were scheduled to undergo posterior instrumented spinal fusion in our clinic were recruited in this study. The Electronic Traction Table (ETT) that was designed in our clinic was used to evaluate the radiogical and clinical parameters of the spine.

RESULTS: The significant prescriptive angle of major Cobb angles between postoperative angles were longitudinal traction and lateral pushing Cobb angles. Longitudinal traction and lateral pushing angles were more correlated with correction ratios. There was a significant difference between longitudinal traction minor Cobb angle, longitudinal traction lateral pushing minor Cobb angle and postoperative minor Cobb angles.

CONCLUSION: The deformity is needed to balance both tractional and rotational forces and useful technique to evaluate curve flexibility before the operation. Electronic traction table is a new device for determining preoperative flexibility with longitudinal traction and lateral pushing radiographs. It can be useful for choosing selective fusion levels at the proximal and distal end of the vertebral column.

KEYWORDS: Adolescent idiopathic scoliosis, Traction table, Fusion levels, Curve flexibility

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is a 3-dimensional spinal deformity that most commonly occurs during growth (1). The success of surgical management depends on the selection of fusion levels due to the importance of preserving motion segments (11,19). The selection of the fusion levels is still a controversial issue (3,6). Several preoperative planning methods have been described in the literature but surgical management is not always sufficiently addressed (18). When creating a template of the fusion levels, preoperative assessment of spinal flexibility is critical. Several techniques are referenced in the literature for assessing spinal flexibility (1), including suspension test, push traction films and traction radiographs (2,8). However, no single equipment exists that offers comparable utility in all patients and positions.

This study aims to present a new piece of equipment developed for assessing spinal flexibility at different force levels,

Corresponding author: Erman CEYHAN
E-mail: ermanceyhan1977@hotmail.com

and to demonstrate its efficacy for the treatment of AIS. This new system should provide a different perspective for the selection of fusion levels and subsequent surgical success in the treatment of AIS.

■ MATERIAL and METHODS

The study included 18 patients with AIS who were scheduled to undergo posterior instrumented spinal fusion at our clinic. An Electronic Traction Table (ETT), internally designed at our clinic, was used to evaluate the radiological and clinical parameters of the spine. A minimum 2–year follow–up period was indicated. Each patient was evaluated physically. Radiographic assessment included preoperative standing posteroanterior (PA) and lateral, supine side bending, supine with ETT and postoperative standing PA and lateral direct radiographs. Sagittal balance was calculated according to thoracic kyphosis (T4-T12), thoracolumbar junction (T12-L2), Lumbar lordosis (L1-L5) using the Cobb method, and frontal balance was calculated based on the line between the central sacral line and C7 spinous process.

Technique

The study was based on the use of an ETT, developed internally at our clinic. The device had a digital control panel and mobile segments that can be calibrated individually for each patient before application. The mobile segments applied longitudinal traction and lateral pushing according to the three-point principle. On the digital control panel, the application force was shown in kilograms. A part of the device was motorized with a piston rod that applied the lateral force. The treadles were made of polyurethane and combined with a motor unit. The section that stabilizes the pelvis was of a soft material that allowed mobility. There was a mobile X-ray cassette system made of hard polyurethane that calculated the patient's body weight (Figure 1A, B). Longitudinal traction applied to the patients avoided exceeding 70% of their body weight. If the patient reported pain during application, traction was released and a lower traction force was applied. The same application was used for the lateral push mechanism and the values were recorded. Lateral pushing was applied to the apical vertebrae of the lumbar curvature and to the costae of thoracic curvatures. For lateral pushing, pain was used as a basic variable. The measure of force being applied at pain onset was recorded in kilograms. At the third stage of the application, both longitudinal traction and lateral pushing radiographs were taken. The entire procedure was performed with the patient in a conscious state. Pain experienced by the patient during the procedure was considered as a limiting factor. At the initial stage of the study, the procedure described was applied to the first 5 patients using the same parameters, but also under general anesthesia. Because the difference between the results was not considered significant, use of general anesthesia for performing the procedure was abandoned for the rest of the study.

The Cobb angles, apical vertebra rotations, stable vertebra, and neutral vertebra were derived from these radiographs. Preoperative bending and ETT radiographs were measured according to Formula 1a (Flexibility rate %=preoperative standing angle-preoperative bending angle/preoperative angle X 100%), and Formula 1b (Flexibility rate %=preoperative standing angle-preoperative ETT angle/preoperative angle X 100%).

The postoperative correction rate and correction index were calculated according to Formulas 2a and 2b (Correction rate %=Preoperative angle-postoperative angle/preoperative angle X100 Correction index %= Correction rate/Flexibility rate

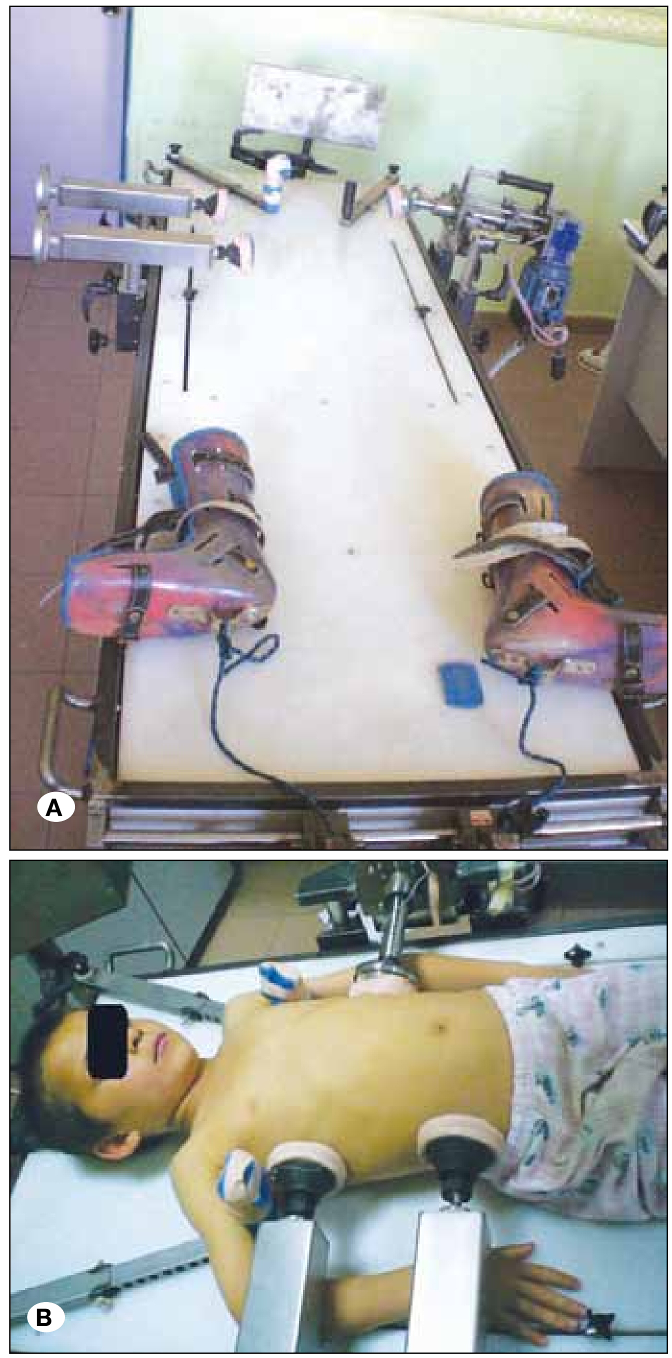

Figure 1: A) Electronic traction table, **B)** Patient application of electronic traction table.

X 100). Correction loss was measured at the 2-year follow-up examination according to Formula 3 (Correction loss =last control angle-postoperative angle/preoperative angle X 100).

Frontal Cobb Angle (FCA), Bending Cobb Angle (BCA), longitudinal traction Cobb Angle (LTCA), Lateral Push Cobb Angle (LPCA), Longitudinal traction and lateral push Cobb Angle (LTLPCA), postoperative Cobb Angle (PCA), Postoperative 2-year Cobb Angle (PC2A), bending flexibility rate (BFR), Longitudinal traction flexibility rate (LTFR), Lateral push Flexibility rate (LPFR), Longitudinal traction and lateral push flexibility rate (LTLPFR), Correction rate (CR), Bending Correction index (BCI), Longitudinal traction correction index (LTCI), Lateral push correction index (LPCI), Longitudinal traction and lateral push correction index (LTLPCI) were measured.

Statistical analyses were performed using SPSS statistical software version 15.0 (SPSS Inc., Chicago, IL, USA). The Pearson correlation coefficient was calculated using bivariate analyses. Bonferroni multiple comparisons and the Wilcoxon test were used. A value of $p<0.05$ was considered statistically significant.

Table I: Major Cobb Angle Mean Values at Different Positions

Major Cobb Angle	Mean	SD
FCA	54.67	7.33
BCA	41.72	9.89
LTCA	35.11	7.51
LPCA	30.89	7.19
LTLPCA	25.39	6.55
PCA	20.67	6.42
PC2A	21.22	6.85

RESULTS

The patient group comprised 13 females and 5 males with an average age at surgery of 14±1.57 years. No bracing was used on any of the patients, for all of them had surgery-indicated scoliosis. The maturity was evaluated according to the Tanner classification and the Risser sign. Deformities were classified as Lenke type 1A in 10 patients, type 1 B in 1, type 3 B in 4, and type 3 C in 3. All of the structural curvatures were mainly thoracic. The minor curvatures were thoracolumbar/lumbar curvatures. Patients with minor curvatures on the bending radiographs $<25^0$ were classified as Lenke type 3. According to the bending radiographs, all of the Lenke type 3 patients except one decreased to $< 25^0$ on longitudinal and lateral pushing. The major Cobb angles for all application runs are shown in Table I. There was a statistically significant difference between all Cobb angles except PCA and PC2A by the Bonferroni test. There was a strong relationship between PCA and PC2A by the Pearson test (p=0.000). The correlations between BCA, PCA and PC2A were not robust (p=0.002 and =0.008) (Table II). Five different preoperative major Cobb angles in different positions were measured. The significant prescriptive angles between the postoperative angles were the Cobb angles for longitudinal traction and lateral pushing. Five different flexibility ratios were calculated. These flexibility ratios were evaluated with the correction index. Longitudinal traction and lateral pushing angles were more correlated with the correction ratios (r=0.83, p=0.000) (Tables II, III). The mean values for the major Cobb angle correction index are shown in Table IV.

The minor Cobb angle was evaluated in 9 patients who had minor curvatures. No significant difference was determined between the frontal minor Cobb angle, the bending minor Cobb angle and the lateral pushing minor Cobb angle. There was a significant difference between the longitudinal traction minor Cobb angle, the longitudinal traction lateral pushing minor Cobb angle and the postoperative minor Cobb angles.

Table II: The Relations Between Major Cobb Angles at Different Positions

Major Cobb Angle	FCA	BCA	LTCA	LPCA	LPLTCA	PCA	PC2A
FCA	-						
BCA	0.83 (p=0.000)	-					
LTCA	0.79 (p=0.000)	0.81 (p=0.000)	-				
LPCA	0.84 (p=0.000)	0.81 (p=0.000)	0.93 (p=0.000)				
LTLPCA	0.82 (p=0.000)	0.76 (p=0.000)	0.83 (p=0.000)	0.94 (p=0.000)			
PCA	0.73 (p=0.000)	0.67 (p=0.002)	0.71 (p=0.001)	0.80 (p=0.000)	0.89 (p=0.000)		
PC2A	0.72 (p=0.000)	0.60 (p=0.008)	0.68 (p=0.002)	0.78 (p=0.000)	0.89 (p=0.000)	0.98 (p=0.000)	

Table III: Major Cobb Angle Flexibility Ratio Bonferroni Test p Values

Flexibility ratio	BFR	LTFR	LPFR	LTLPFR	CR
BFR	–				
LTFR	0.55 (p=0.018)	–			
LPFR	0.51 (p=0.030)	0.83 (p=0.000)	–		
LTLPFR	0.49 (p=0.037)	0.63 (p=0.000)	0.88 (p=0.000)	–	
CR	0.35 (p=0.031)	0.47 (p=0.049)	0.65 (p=0.004)	0.83 (p=0.000)	–

Table IV: Major Cobb Angle Correction Index (%)

Correction Index	Mean	Standart deviation
Bending Correction Index (BCI)	307	129
Longitudinal traction Correction Index (LTCI)	183	37
Lateral push Correction Index (LPCI)	145	22
Longitudinal traction and lateral push Correction Index (LTLPCI)	116	11

Table V: Minor Cobb Angle Flexibility Ratio Bonferroni Test p Values

Flexibility ratio	BFR	LTFR	LPFR	LTLPFR	CR
BFR	–				
LTFR	0.017	–			
LPFR	0.007	0.002	–		
LTLPFR	0.000	0.014	0.000	–	
CR	0.000	NS	0.000	NS	–

***NS:** not significant.*

Five different flexibility ratios of the minor Cobb angles were calculated. In the same way as for the major Cobb angle, the longitudinal traction and lateral pushing minor angles were correlated with the correction ratios. There was no difference between the postoperative minor Cobb angle and the 2-year follow-up minor Cobb angle. The minor Cobb angle flexibility ratios were calculated in 5 different positions. According to the variant analyses, there were significant differences between these 5 values (Table V). The significance of difference of the flexibility ratios of the minor Cobb angle was evaluated with the Bonferroni test, and no difference was determined between the minor Cobb angle correction ratio and the longitudinal traction minor Cobb angle flexibility ratios. There was also no difference between the longitudinal traction lateral pushing minor Cobb angles flexibility and minor Cobb angle correction ratios. The same values as the major Cobb angles were determined on the lateral pushing radiographs; and the difference was statistically significant. The correction index of the minor Cobb angles was evaluated and a correlation was determined between the longitudinal traction lateral pushing correction index and the bending minor Cobb angle correction index (Table VI).

Table VI: Minor Cobb Angle Correction Index (%)

Correction Index	Mean	Standart deviation
Bending Correction Index (BCI)	189	58
Longitudinal traction Correction Index (LTCI)	133	77
Lateral push Correction Index (LPCI)	591	371
Longitudinal traction and lateral push Correction Index (LTLPCI)	99	29

Values for the stable vertebra, the neutral vertebra, the apex of the curvature and vertebra which was within the curvature were derived from the bending and traction radiographs (Table VII). More mobile segments at proximal and distal levels of the vertebral column were achieved with the traction radiographs than with the bending radiographs. Changing the stable and neutral vertebrae, in particular, made this challenging. An average of 0.6 vertebra levels were saved from the proximal and an average of 1.1 vertebrae were saved at the stable vertebra level. Posterior instrumentation and posterior fusion were applied to all patients. Anterior surgery was not used because there was no major Cobb angle up to 40^0 on longitudinal traction and lateral pushing. There were no neurological complications. Only one superficial infection occurred.

Table VII: Parameters of All Patients

Patient	Lenke	Bending graphs		Traction graphs		The number of vertebra in the curvature	Apex	Fusion level level	Screw number	
		Stable vertebra	Neutral vertebra	Stable vertebra	Neutral vertebra				Convex	Concave
1	1NA	L2	T2-L2	L2	T3-L1	9	T8-9 Disc	T3-L2	6	6
2	3NB	L2	T2-L2	L2	T3-L1	8	T9	T3-L2	6	11
3	1NA	L1	T4-L1	T11	T5-T11	8	T9	T5-T11	7	7
4	3NB	L2	T2-L2	L2	T3-L2	9	T8	T3-L4	6	8
5	1NB	L1	T4-T12	T12	T4-T12	7	T8	T4-T12	5	9
6	1NA	L3	T2-L1	L2	T2-L1	7	T8-9 Disc	T2-L2	9	10
7	1NA	L3	T3-L2	L1	T4-L1	8	T9-10 Disc	T4-L1	10	10
8	1NA	L2	T3-L1	L1	T4-L1	8	T8-9 Disc	T4-L1	7	10
9	3NC	L2	T2-L2	L1	T3-l1	10	T8	T3-L1	6	12
10	3NC	L3	T2-L2	L1	T4-L1	8	T8	T4-L3	7	12
11	1NA	L2	T3-L1	L1	T3-L1	7	T8-9 Disc	T3-L1	7	11
12	1NA	L3	T3-L2	L1	T3-L1	8	T9	T3-L1	7	7
13	1NA	L4	T1-L3	L2	T2-L2	9	T10	T2-L2	8	11
14	1NA	L2	T2-L1	T12	T3-T12	7	T8	T3-T12	7	10
15	3NB	L2	T2-L1	L1	T2-L1	8	T8	T2-L1	8	12
16	3NC	L2	T3-L1	L2	T3-L1	7	T9	T3-L2	7	12
17	3NB	L2	T4-L1	L1	T5-L1	7	T9	T5-L1	7	9
18	1NA	L2	T3-L1	T12	T4-T12	8	T9	T4-T12	7	9

■ DISCUSSION

Adolescent idiopathic scoliosis is the most common form of scoliosis (26). The female to male ratio is 8/1 in adolescent idiopathic scoliosis. In this study, the ratio of females to males was 2.6/1.

The goal of surgical management is to select fusion levels (13), and classification systems have been developed to overcome this problem. In this study, the Lenke classification system was used and 61.1% of the patients were Lenke type 1 and 38.9% Lenke type 3. The most controversial aspect of scoliosis surgery is the selection of the fusion levels. The aim of the treatment is to obtain sagittal and frontal balance with minimal fusion levels (9). Flexibility is an important consideration for the selection of fusion levels. Preoperative side-bending films, traction films and push-prone films are used for evaluating fusion levels (7,10,12,15,22,24). The selection of distal levels may prevent the patient from spinal decompensation and adding-on phenomenon (20). In a study by Ni et al. (14), side-bending radiographs were used to determine the distal fusion level with single thoracic curvatures. This method was shown to be effective in the preservation of lumbar motion segments. Takahashi et al. also used bending radiographs to select the optimal lowest vertebrae for selective thoracic fusion in Lenke Type 1B, 1C and Type 3C (21). In this study, the electronic traction table was used to determine the fusion levels. The flexibility and fusion level values in the current study were significantly different from the lateral bending radiographs. The development of modern screw constructs, in particular, provides more powerful corrective forces (14). Therefore, these corrective forces on the lateral bending radiographs are not sufficient to determine distal and proximal fusion levels.

Using the electronic traction table could help to show a higher correction index, more than with other techniques.

Traction radiographs have been used to determine flexibility in many studies. Hirsch et al. used the suspension test to determine flexibility and fusion levels (5). It was emphasized that a low dose technique with suspension avoided radiation of the traction radiographs. Vaughan et al. suggested using traction radiographs in curvatures of >60^0 and showed that it was more useful than bending radiographs in the determination of stable vertebrae. It was reported that using traction radiographs <60^0 may result in the wrong stable vertebra and wrong fusion levels being selected, which in turn may lead to the adding-on deformity and decompensation postoperatively (23). In the current study, an average of 1.1 vertebrae were excluded from the fusion level when determined by the electronic traction table, rather than by lateral bending. The major Cobb angle values were evaluated both above and below 60^0 and longitudinal traction and lateral pushing were more prescriptive than bending radiographs for postoperative correction. When longitudinal traction lateral pushing radiographs were compared with bending radiographs, significant differences were seen between the major Cobb angles, minor Cobb angles, flexibility ratios, correction ratio and correction index values. On the other hand, the strongest correlation with postoperative correction was longitudinal traction and lateral pushing radiographs. The electronic traction table radiographs presented here can be defined as a new method that can be used with visible force application and can be applied independently of the patient.

Hamzaoglu et al. suggested using traction radiographs in general anesthesia in all curvature types. The use of bending and fulcrum radiographs was reported to be appropriate in serious lumbar curvatures. That study had a limitation regarding patient data before the surgery. In the current study, the correction ratio was estimated before the operation and accurate information could be given to the patient's family (4). White and Panjabi stated that if the major Cobb angle was >53^0, longitudinal traction would be best but if it is <53^0, lateral pushing would be the best method for curve correction (27). In the current study, both techniques were used for correction and the results achieved were close to the operative correction. Watanabe suggested that if the apex of the main thoracic curvature was higher than the T9 vertebra, bending radiographs would be better than traction radiographs. In the same study, the same suggestion was made for thoracolumbar/lumbar curvatures. In this study, the apexes of all the curvatures were found to be higher than T9 in all but 2 patients. Nevertheless, the traction radiographs were better than the bending radiographs. The same results were also determined in minor curvatures (25). Another important point of the study by Watanabe was the number of vertebrae included in the main thoracic curvature. If the number of vertebrae is more than 6-7, then bending radiographs are better than traction and conversely, if the number of vertebrae is lower, traction radiographs would give better results than bending radiographs. In the current study, although the mean number of vertebrae included in the curvature was 7.9, traction radiographs were better than bending radiographs.

In a study by Potter et al., better results with posterior fusion than with anterior fusion were reported in Lenke type 1 curvature treatment (16). Puno et al. reported that selective fusion was a good choice for Lenke type 1 curvatures. In the current study, there were 11 Lenke type1 and 7 Lenke type 3 patients based on the bending radiographs (17). When the patients were evaluated according to the electronic traction table radiographs, 2 patients could be classified as Lenke type 3 scoliosis. These 2 patients underwent surgery with posterior instrumentation and posterior fusion. Posterior instrumentation and selective fusion were applied to the other 16 patients. The postoperative results of the current study were similar to those reported in the literature.

An unexpected aspect of this study was the effect of lateral pushing on minor curvatures. Lateral pushing alone did not decrease minor curvature values in the same way as longitudinal traction and it was not successful for flexibility evaluation. The force that was applied to the apex of the major curvature can be considered to have had a disruptive effect on the minor curvature.

■ CONCLUSION

Adolescent idiopathic scoliosis is a 3-dimensional spinal deformity. A useful technique is required to balance both tractional and rotational forces to evaluate flexibility before the operation. The electronic traction table is a new device for determining preoperative flexibility with longitudinal traction and lateral pushing radiographs. The results of this study show that it could be useful when choosing selective fusion levels at the proximal and distal ends of the vertebral column. This would enable the surgeon to give correct information about the surgery and fusion levels to patient and relatives.

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