The Prevalence of Distal Junctional Kyphosis Following Posterior Instrumentation and Arthrodesis for Adolescent Idiopathic Scoliosis

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Abstract- Distal junctional kyphosis (DJK) is a radiographic finding in patients that undergo spinal instrumentation and fusion, since there is an abrupt transition between fixed and mobile spinal segments.The true incidence of DJK is variable in literature and seems that has a multifactorial etiology. A consecutive series of 130 patients (mean age 15.6 years) with Adolescent Idiopathic Scoliosis who underwent posterior spinal fusion and instrumentation were evaluated by analyzing coronal and sagittal angulation and balance measurements from standing radiographs obtained pre-operatively, within 6 weeks post-operation, at two years postoperative and at the latest follow-up. There was 35 male and 95 female. The mean time of follow-up was 36 months. The incidence of DJK at latest follow-up was 6.9% (9 patients). In DJK group ,distal junctional angle from pre-operative of -12.5˚ lordosis (-30 to 0) reached to -5.5˚ (*P*=0.015) at 6 weeks postoperation and to -1.4˚ (-20 to 12˚) (*P*=0.000) at 2 years follow-up,with mean of 12.1˚ kyphotic change (10-20˚). In non DJK group, distal junctional angle from pre-operative angle of -7.5˚ reached -8.1˚ at 2 years follow-up (*P*=0.43). The mean age of DJK group at surgery was 17 years and for non-DJK group was 15.4 years (*P*=0.022). Distal junctional kyphosis was less common in this study than previous reports and stabilized after two years. The magnitude of coronal cobb angles or multiplicity of coronal curves had no effect in developing DJK that may be prevented by incorporation of the first lordotic disc into the fusion construct.

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Introduction

Junctional kyphosis may be a radiographic finding in patients that undergo spinal instrumentation and fusion since there is an abrupt transition between fixed and mobile spinal segments. Previous studies reported different incidence of distal junctional kyphosis (DJK) in posterior instrumentation and arthrodesis of adolescent idiopathic scoliosis (AIS) (1,2).

DJK may result in imbalance and unacceptable deformity, is not detectable clinically and is not predictable in review of preoperative radiographs (1,2).

With the development of segmental instrumentation systems, coronal spinal correction improved from 18% to 67% with preserving more normal sagittal alignment, however, the sagittal plane has become an important area of focus in the surgical treatment of AIS. The first purpose of this study was to determine the incidence of postoperative DJK in AIS cases undergoing posterior spinal fusion and instrumentation, also possible contributing factors to the development of distal junctional kyphosis were studied (1-8).

Materials and Methods

Clinical charts and radiographs of the 181patients who had surgical treatment for adolescent idiopathic scoliosis at Shafa Yahyaiian Hospital in Tehran were retrospectively reviewed from 1991 to 2006. Of these, 130 who underwent posterior spinal fusion (PSF) and instrumentation with a minimum two years follow-up with radiographs available were included. There were 95 female and35 male patients. The average age at time of surgery was 15.4 years (10.5-20 years).

Anterior spinal fusion (ASF), discectomy and release without instrumentation was done in 62 cases in whom there was rigid curves above 70 degrees with a correction less than 50% in the bending film. Those with

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only ASF, with pseudoarthrosis or device failure were excluded from the study. According to the classification of Lenke, the numbers of patients were: 75 (type 1), 6 (type2), 19 (type 3), 5 (type 4), 21 (type 5) and 4 (type 6).

Instrumentation which used including: Multihook for 96 cases, Harrington for 22, Harrington + sub laminar wiring for 7, Hybrid (proximal hook ,distal screw) for 3 and all screw for 2 cases. Lowest instrumented vertebra was T12 in 8 cases, L1 in 28, L2 in 27, L3 in 34, L4 in 31 and L5 in 2 cases.

Clinical and radiographic measures of the spinal deformity were collected from medical charts and radiographs at four stages including: at before surgery, within 6 weeks post operation, at two year follow-up and at final follow-up. Several radiographic variables were evaluated: coronal measures included the cobb angles of the proximal thoracic (PT), main thoracic (MT), thoracolumbar/lumbar (TL/L), amount of correction in bending radiographs for coronal curves, The trunk shift (coronal deviation of C7 plumb line from the central sacral vertebral line), thoracic apical translation and TL/L apical translation.

Sagittal measures included thoracic kyphosis angle (T2-T5 andT5-T12), sagittal alignment of the thoracolumbar junction (T10-L2), lumbar lordosis (T12-S1), levels instrumented and distal junctional angle. DJK was defined as the angle between the superior endplate of the lowest instrumented vertebra and the inferior endplate of the adjacent distal vertebra when increased ≥10 degrees in relation to preoperative angle (2).

The stable vertebra which was the most nearly bisected by the central sacral vertebral line (CSVL) was the distal level of instrumentation but if there was distal junctional kyphosis in standing lateral roentgenogram then implant ended at one vertebra below . For the 130 patients PSF was performed over 1353 levels from T1 to L5, mean 10.3 levels (6-14 levels).

In groups which instrumented by Harrington ± wiring, body cast applied for six months and then standard thoracolumbar spinal orthosis applicated for next six months but in other instrumented groups, only orthosis used for six months.

Statistical analysis were performed using spss 10, All probability (P) values in this study were calculated within a confidence interval of 95%.Independent t-test was used for analysis between the groups.

Results

Mean age at surgery was 15.6 years (10.5-20 years), follow-up period ranged from 2 to 7 years (mean,35.8 months). Thoracoplasty was done in four cases, none in DJK group. The amount of curve correction is shown in Table 1,2.

The overall incidence of postoperative DJK was 6.9% (9 patients, 6 female and 3 male). Postoperative DJK developed in four patients with lenke type 1 (one A+, two AN and one BN), two in type 2 (one AN, one C+), one in type 3CN and two in type 5 CN. From 9 patients with DJK, 6 underwent anterior spinal release in addition to posterior spinal fusion and instrumentation, distal instrumented vertebra was L1 (5 cases), L3 (2 cases) and L4 (2 cases) with mean follow-up of 36 months (24-47 months) and it was not detectable clinically.

Table1. Coronl details of our patients with idiopathic scoliosis.Angles in degrees with mean, range in bracket.AVT (apical vertebral translation).pts(patients)

Lenke groups	No Of Pts	preoperative					Post operative (at 2nd year)				
		Thoracic			Lumbar		Thoracic			Lumbar	
		PT	MT	AVT (cm)	TL/L	AVT (cm)	PT	MT	AVT	TL/L	AVT
Entire	130	20 (0-50)	61 (0-132)	6.8 (0-14)	38 (0-86)	3.9 (0-11)	11 (0-50)	29 (0-88)	2.8 (0-10)	16 (0-60)	1.4 (0-6)
Lenke A	60	21 (0-50)	62 (40-100)	6.9 (4.5-13)	27.5 (0-50)	2.1 (0-6)	11 (0-36)	30.4 (12-60)	2.6 (.5-9)	10 (0-34)	0.6 (0-2)
Lenke B	21	26 (0-50)	77 (10-128)	9.3 (5-13)	41 (27-58)	4.6 (1-8)	18 (0-30)	47 (36-60)	4.2 (1-10)	20.4 (0-40)	1.6 (0-3)
Lenke C	49	16 (0-42)	53 (0-132)	5.5 (0-14)	49 (0-96)	5.2 (0-11)	9 (0-50)	22.5 (0-88)	2.5 (0-10)	22 (0-60)	2 (0-6)

Table 2. Pre- and postoperative sagittal alignment, mean values are given in degrees. Range is given between brackets. Mean and range of posterior fused levels in number

Lenke	T5-T12		T10-L2		T12-S1		Distal junctional angle		fused
Groups	Pre op	Post op	Pre op	Post op	Pre op	Post op	Pre op	Post op	levels
Entire	34	30	5.7	3.5	-47	-44	-7.8	-7.4	10.4
	(0-80)	(12-45)	(-16-32)	(-12-30)	(-80-20)	(-64-20)	(-30-8)	(-30t-11)	(6-14)
Lenke A	34	28	3.4	3.2	-46.6	-42	-5.2	-3.1	9.8
	(0-80)	(13-42)	(-16-22)	(-12-20)	(-80-20)	(-61-20)	(-20-8)	(-15t-20)	(7-13)
Lenke B	39	31	8.2	4.4	-48	-47	-5.8	-8	10.6
	(18-70)	(12-44)	(-3-30)	(0-22)	(-67-30)	(-60-40)	(-14-7)	(-20-0)	(8-13)
Lenke C	32.5	31	7.6	3.5	-48	-49	-11.9	-12	10.7
	(0-68)	(12-45)	(-6-32)	(-12-30)	(-68-30)	(-64-27)	(-30-0)	(-30-0)	(6-14)

The average correction in bending film preoperatively in DJK group was 54% for the PT curve, 48% for the MT curves and 51% for the TL/L curves and in total group was 55% for PT curves , 41% for MT curves and 58% for TL/L curves. There was no significant difference in bending correction between DJK and Non-DJK group.

In DJK group, distal junctional angle from the mean of -12.5˚ (lordotic angle) pre-operatively reached -5.5±10.5 (*P*=0.015) until 6 weeks post-operation and to -1.4˚ (*P*=0.000)at 2 years follow-up, with the mean of 11.1 kyphotic change. The pre and postoperative sagittal, coronal and distal junctional angles of both groups are shown in Table 3.

The trunk shift (coronal decompensation) in DJK group improved from 27 ±13 milimeters at pre-operative to 11±11 mm at 2 years follow-up (p=0.000) ,the mean pre-operative coronal decompensation of 27 mm in DJk group correlated positively with development of DJK in this group (*P*=0.044). Coronal decompensation in non DJk group improved from 16 ± 12 mm to 5 ± 5.5 mm (*P*=0.000). Sagittal balance changed in DJK group from -4 ± 24 mm (-30to41 mm) pre-operatively to 4 ± 22 mm (-28to 33 mm) at 2-year follow-up and there was no significant difference in relation to non DJK group.

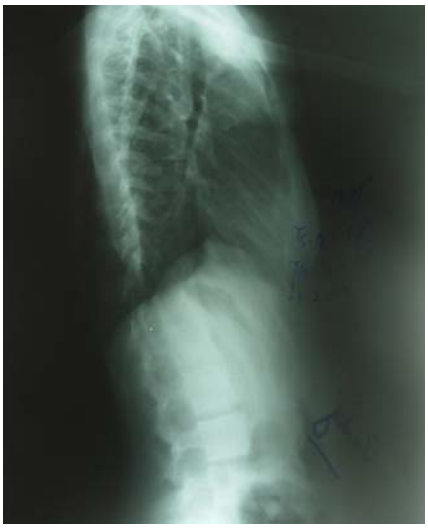
The cobb angle of TL/L curve at 2 years postoperation had significant correlation with incidence of DJK (*P*=0.028) but this value for pre-operative TL/L cobb angle was *P*=0.07.Of the parameters analyzed, there was no correlation between preoperative or postoperative sagittal angle of T5-T12, T10-L2 and T12-S1measurements, coronal cobb angles except TL/L at 2 years, sex, fusion device, number of fused levels and proximal or distal level of fusion and the development of DJK. DJK did not lead to significant change in global sagittal alignment and the c7 sagittal plumb-line was not significantly different before or after surgery between patients with or without DJK.

Table 3. Pre and postoperative age, sagittal and coronal measurements for DJK and non DJK groups. Angles in degrees with mean ± standard deviation , range in brackets

	With post op DJK (n=9)		No post op DJK (n=121)	
	Pre op	post op (2year)	pre op	post op (2-year)
T2-T5	9.8 (6-17)	10.8 (7-18)	6.2 (0-22)	8.7 (0-30)
T5-T12	35 ± 9 (19-46)	30 ± 7 (17-42)	34 ± 15 (0-80)	30 ± 11 (5-63)
T10-L2	3.1 ± 13 (-15-30)	6.4 ± 13 (-8-32)	6 ± 9 (-16-32)	3 ± 9 (-4-30)
T12-S1	-53 ± 7 (-63--45)	-48 ± 9 (-64-36)	-47 ± 11 (-80-20)	-42 (-66-21)
DJA •	-12.5 ± 10 (-30-0)	-1.4 ± 10 (-20-20)	-7.5 ± 6 (-27-8)	-8.1 ± 8 (-30-12)
Age (yr)	17 ± 3 (13-20)	20 (15-23)	15.4 ± 2 (10.5-20)	18.5 (12.5-26)
MT	64 ± 24 (0-90)	34 ± 20 (10-43)	61 ± 26 (0-132)	31 ± 18 (0-88)
TL/L	50 ± 18 (32-86)	26 ± 17 (0-60)	37 ± 17 (0-96)	15 ± 13 (0-43)
PT	22 ± 18 (0-44)	11.4 (0-30)	19 ± 13 (0-50)	9 ± 11 (0-50)
Trunk shift (mm) *	27±13 (10-50)	11±11 (0-30)	16±12 (0-50)	5±5 (0-30)

• Distal junctional angle * mm (milimeter)

1A1



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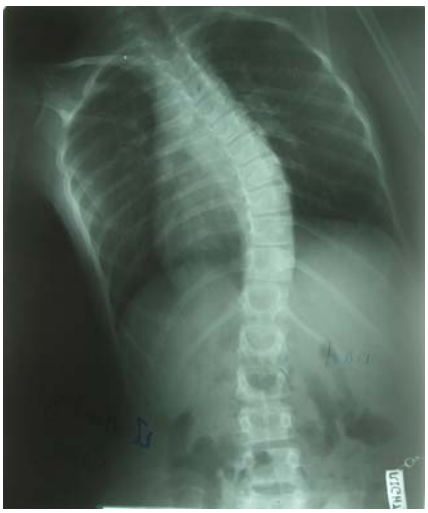

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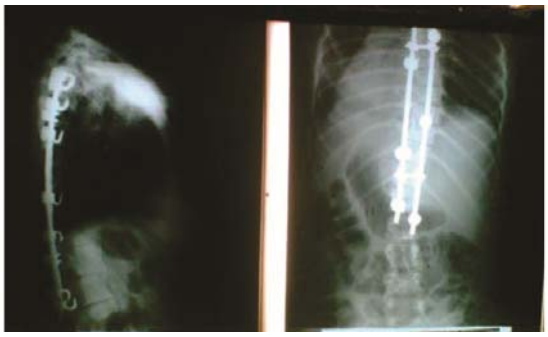

1C1

1C2

Figure 1. A 14 year-old female patient with AIS lenke type 1AN curve who posteriorly fused with multi-hook system from T3 toL1. A, preoperative cobb angle of the thoracic curve was 50°, lumbar curve 35° with 51 milimeter coronal imbalance, Lateral radiograph with distal junctional angle at L1-L2= 0° . B, In Bending film ,the cobb angle of the thoracic curve was 35° and the lumbar curve was 10°. C, At 6 weeks Post-operation ,the cobb angle of the thoracic curve was 20° , the cobb angle of the lumbar curve 14° with spontaneous correction ,the coronal contour was normal. ln lateral radiograph, distal junctional angle was 11° D, 2 years post-operation, thoracic cobb angle progressed to 26°, lumbar cobb angle to 35° and distal junctional angle to 18°.

Table 4. Posterior spinal fusion in patients with lenke 1; Multihook versus Harrington. Angles in degrees with mean, range in bracket. Trunk shift in milimeter

Spinal parameters	Harrington (n=11)		Multihook (n=56)		*P* value
	Pre op	Post op (2year)	Pre op	Post op (2year)	
MT	61 ± 14 (40-86)	37 ± 13 (23-70)	63 ± 15 (40-95)	29 ± 12 (10-60)	0.05
T5-T12	30 ± 13 (10-52)	22 ± 10 (5-39)	34 ± 12 (17-70)	29 (16-46)	0.72
T10-L2	1.7 ± 3 (-2to8)	-0.6 ± 4.8 (-10-7)	3.7 ± 8 (-16-22)	3.3 ± 9 (-14-32)	0.16
T12-S1	-42 ± 15 (-80-20)	-38 ± 9 (-60-21)	-48 ± 9 (-68-30)	-43 ± 8 (-64-31)	0.23
DJA •	-5.9 ± 4 (-12-0)	-6.5 ± 14 (-12-0)	-5.6 ± 5.6 (-17-8)	-4.2 ± 7 (-16-20)	0.047
Trunk Shift	13 ± 10 (0-40)	5 ± 6 (0-20)	16 ± 13 (0-50)	4 ± 5.6 (0-30)	0.15

•Distal junctional angle

We analyzed patients with Lenke type 1 who instrumented by multihook or Harrington separately , Results showed that distal junctional angle in the Harrington group from the mean of -5.9 pre-operatively reached -5.5 (*P*=0.18)at 2 year follow-up but in the multihook group from the mean of -5.4° pre-operatively reached -4.3° at 2 year follow-up. (*P*=0.03) but there was no significant correlation in development of DJK between two implants (*P*=0.18). Pre and postoperative coronal and sagittal measurements of the fusion in Lenke type 1 by Harrington and multihook system are shown in Table 4.

We also analyzed coronal and sagittal measurements according to the Lumbar modifier in sub groups of A,B and C that there was no difference in incidence of DJK .coronal measurements of spinal deformities of subgroups are in table 3 and of sagittal spinal deformities are in table 4. Figure 1 and 2 show the development of postoperative DJK following PSF with multihook system.

Discussion

When approaching the adolescent idiopathic scoliosis (AIS), the major goal is to achieve a balanced spine rather than maximal instrumented curve correction alone (4). Richards *et al.* (2), reported DJK in 16 of 53 patients with AIS following posterior fusion with cotrel-dubousset instrumentation in which they were unable to identify any risk factor for it and MC Cance *et al.* (6) in series of 67 patients with AIS noted DJK in only one patient , also Thomas G (1) reported 14.6% DJK for the posterior fusion in 137 thoracic AIS. In our study DJK developed in 9 patients, that there was no difference between short or long spinal instrumented fusions and incidence was scattered in different levels from L1 to L4 and no failure at caudal instrumented level detected. In Richard study on thoracic curves, DJK was more in the thoracolumbar junction (2,3,9).

For determination of DJK, other studies focused on the thoracic fused curves with report of DJK at the level of Thoracolumbar junction and they did not compared postoperative distal junctional angle with preoperative, but we reported results according to changes in distal junctional angle in relation to preoperation , because this kyphotic change has advese effects on distal junctional disc degeneration, implant failure and on sagittal balance not merely distal junctional kyphosis ≥10 as others defined (1,2).

To achieve a normal sagittal profile over the thoracic and thoracolumbar junction , the distal instrumented vertebra was the same as the stable vertebra in majority in this series but in one case distal instrumented vertebra was the level above stable vertebra which developed DJK , in this case with correction of lumbar curve in bending film to 10°, with selective thoracic fusion , lumbar curve was14 immediate post operation but gradually progressed to 35 degrees at latest radiographs at 2 years, so this progression in cobb angle of lumbar curve probably caused kyphotic change in distal junctional segment as we found that cobb angle of lumbar curve had correlation with development of DJK. (*P*=0.028) (Figure 1) (10-12).

In DJK groups disc space degenerated mildly (less than 25% disc space narrowing more in anterior) in distal junctional segment in four cases but there was no any sagittal imbalance probably due to compensatory increase in more distal lordosis (9,13).

Anterior spinal release may increase main thoracic curve correction by 14% but was not a risk factor for DJK. (5). Curve type distribution was similar to other studies for lenke types (14,15).

Several reports noted the issue of third-generation instruments as causative of postoperative decompensation (4,6,10,12,16-19), but we did not consider this issue because Coronal decompensation significantly improved . We found all DJK in multihook instrumented fused, but there was no correlation with

development of DJK (P=0.48), otherwise large value of pre-operative coronal decompensation had significant correlation with development of DJK, that this may be due to more correction in decompensation by multi-hook implants.

we found that previously reported risk factors for junctional kyphosis include improper end vertebrae selection,curve correction greater than 50% or excessive junctional soft tissue dissection, had no role as risk factor in this study (16,17).

Thomas reported that the presence of increased kyphosis after surgery in the T10-L2 region was a risk factor for DJK, but we noticed no significant correlation between sagittal and coronal parameters preoperative or postoperative for development of DJK (1). Despite the heterogeneity of cases and of the follow-up, there were no significant changes in coronal, sagittal and DJK between two years and at final follow-up. In conclusion, junctional load between fixed fused spinal segments and distal mobile segments may be the reason for kyphotic change of distal junctional segment. The magnitude of thoracic curve or multiplicity of curves had no effect in development of DJK. The purpose of the study was not to determine the exact cause of DJK but to consider possibility of this complication and preventing by including abnormal curves in fusion. Prediction is not possible by review of the preoperative radiographs and diagnosis is impossible clinically, however in majority of cases is asymptomatic and there is no necessity for treatment.

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