Annals of Medical Research
DOI: 10.5455/annalsmedres. 2019.07.375 2019;26(10):2134-8

Original Article

Evaluation of the distal adjacent segment after long-segment posterior instrumentation and fusion for adolescent idiopathic scoliosis

Serdar Demiroz[1], Samet Bayram[2], Tamer Coskun[3], Alper Cirakli[4], Hakan Serhat Yanik[2], Yunus Atici[1], Sevki Erdem[2]

[1]Medicalpark Gebze Hospital, Clinic of Orthopaedics and Traumatology, Istanbul, Turkey
[2]Haydarpasa Numune Education and Research Hospital, Istanbul, Turkey
[3]Koc University, Faculty of Medicine, Department of Orthopaedics and Traumatology, Istanbul, Turkey
[4]Ordu University, Faculty of Medicine, Department of Orthopaedics and Traumatology, Ordu, Turkey

Abstract

Aim: The majority of studies about adjacent segment disease (ASD) in the literature concern adult patients who were operated on because of degenerative process-related diseases, such as lumbar instability or lumbar stenosis.

Material and Methods: We retrospectively reviewed cases of AIS surgically treated in our institution between 2012 and 2015. Patients with an increase in the amount of disc degeneration at adjacent segment (AS) (the ASD group) were compared with those with no increase in degeneration at AS (the non-ASD group).

Results:ASD was observed postoperatively in 24 patients (57.1%), and 18 patients (42.9%) had no increase in disc degeneration at the latest follow-up.The mean follow-up was 13 to 34 months, with an average of 22±7.1 months and the lowest instrumented vertebra for 10 of the patients was L2, and the other 32 patients had L3. The rate of ASD in patients with fusion at T4-L3 was significantly higher than for the other instrumentation levels ($p < 0.05$). All 24 patients in the ASD group had L3 as the lowest instrumented vertebra (LIV) ($p < 0.05$).

Conclusion: We believe that ASD is present even in short-term follow-up in patients who undergo long-segment fusion at a young age due to AIS and leaving as many mobile segments as possible will protect from ASD.

Keywords: Adjacent segment; adolescent idiopathic scoliosis; posterior instrumentation, disc degeneration.

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is the most common type which accounts for approximately 80% of patients with scoliosis and AIS is mostly treated with posterior instrumentation and fusion if the surgery is indicated (1-3).However, there are concerns about long-term outcomes after spinal fusion, especially in young patients(4).

The segment immediately beneath the distal end of the fusion is called the distal adjacent segment (distal AS),and the segment immediately above the proximal end of the fusion is called the proximal AS.Increased mechanical stress and segmental motion in the AS after spinal fusion have been documentedin the literature(5). As a result, pathological findings, such as facet joint arthrosis, segmental instability, spinal stenosis, spondylolysis, and especially acceleration of disc degeneration,have been found in the AS(6).This is called adjacent segment pathology (ASP). If symptoms such as radiculopathy, neurogenic claudication, or back pain are present, the condition is called clinical adjacent segment pathology (CASP). Radiographical adjacent segment pathology (RASP) refers to the condition of asymptomatic patients with radiographical findings.However, in many studies in the literature, ASP is referred to as adjacent segment disease (ASD), regardless of whether it is symptomatic.

Received: 05.07.2019 **Accepted:** 16.08.2019 **Available online:** 21.10.2019
Corresponding Author: Serdar Demiroz, Medicalpark Gebze Hospital, Clinic of Orthopedic Surgery, Istanbul, Turkey
E-mail: serdardemiroz@hotmail.com

The term ASD is also used for patients with increased disc degenerationthat has been evaluated radiologically after surgery.

The majority of studies of ASD in the literature concern adult patients who were operated on because of degenerative process-related diseases, such as lumbar instability or lumbar stenosis. In the present study, we aim to evaluate ASD after long-segment posterior instrumentation and fusion in adolescent patients. To our knowledge, this is the first study to evaluate the AS after long-segment posterior fusion with an all-pedicle screw construct for AIS by comparing the latest follow-up MRI scans with the preoperative ones.

MATERIAL and METHODS

After the approval of the local ethic committee, we retrospectively reviewed all the AIS cases surgically treated in our institution from 2012 to 2015.Patients who underwent revision surgery, had a follow-up less than one year, did not have full follow-up radiographs,or did not agree to perform amagnetic resonance imaging (MRI) scan at the latest follow-up were not included in the study.

We have received informed consent from patients and then they were evaluated with full standing anterior-posterior and lateral radiographs and lumbar MRI at the latest follow-up. The segment below the lowest instrumented vertebra was considered as an adjacent segment(AS). The ASs were evaluated and classified by a radiologist in terms of disc degeneration according to the Pfirrmann classification(7)(Table 1). Coronal Cobb and lumbar lordosis angles were evaluated in the radiographs before surgery and at the latest follow-up.Patients with an increase in the amount of disc degeneration in postoperative MRI scans(whencompared to the preoperative scan), which is called the ASD group, were compared with those with no increase in degeneration at AS, which is called the non-ASD group, in terms of demographic properties,fusion level,fusion length,selection of lowest instrumented vertebra (LIV), short form 36(SF-36) score, body mass index (BMI), and duration of follow-up.

The same senior author performed posterior instrumentation and fusion using the same technique for all patients.The motor-evoked potential (MEP) and somatosensory-evoked potential (SSEP) values of the patients were monitored during surgery.The pedicle screws were placed bilaterally to each level with a free-hand technique under fluoroscopic guidance. The deformity was corrected using the direct rod derotation technique. The laminar and transverse protrusions were decorticated, and bone allografts and autografts,obtained during screw placement, were used for fusion.

Statistical Analysis

For statistical analysis, the Number Cruncher Statistical System (NCSS) 2007 and PASS (Power Analysis and Sample Size) 2008 Statistical Software (Utah, USA) programswere used. The Mann–Whitney U test was used to compare the descriptive statisticalmeasurements (mean, standard deviation, median, frequency, ratio, minimum, and maximum) and the two groups of parameters that did not show a normal distribution in the comparison of the quantitative data. Fisher's exact test and Fisher-Freeman-Halton'stest were used for the comparison of qualitative data. Significance was evaluated at $p < 0.05$.

RESULTS

A total of 42 patients were included in this study,30(71.4%) female and 12(28.6%) male. The mean age ranged from 10 to 20, with an average of 16.1 ± 2.56. The mean follow-up was 13 to 34 months, with an average of 22 ± 7.1 months. The fusion level was T3-L3 for 20 of the patients (47.6%), T4-L3 for 10 patients (23.8 %), T3-L2 for 8 patients (19 %), T2-L2 for 2 patients (4.8 %), and T2-L3 for 2 patients (4.8 %). The fusion length of 16 of the patients (38.1%) was 12 segments,for 22 patients (52.4%) it was 13 segments, and for 4 patients (9.5%) it was 14 segments.Thelowest instrumented vertebrafor 10 of the patients was L2, andthe other 32 patients had L3. The mean BMI of the patients ranged from 14.31 to 22.15, with an average of 18.44±2.01 kg/m2. Mean values for SF-36-P(Physical) and SF-36-M (Mental) were 54.10±3.52 and 43.76±4.21, respectively.

ASD was observed postoperatively in 24 patients (the ASD group, 57.1%), and 18 patients (the non-ASD group, 42.9%) had no increase in disc degeneration at the latest follow-up (Table 2). Disc degeneration increased from grade 1 to grade 2 in all patients in the ASD group. None of the patients with grade 2 disc degeneration in the preoperative MRIhad an increase in disc degeneration. There was no significant difference between the two groups in terms of age, gender distribution, BMI, follow-up period, fusion length,or SF-36 scores. However, the difference between the numbers of the patients with fusion levelat T4-L3 was significantly higher in ASD group when compared to non-ASD group,and all 24 patients in the ASD group had L3 as LIV ($p<0.05$). None of the patients who had L2 as LIV had ASD (Table 2). Thecoronal Cobb and lumbar lordosis angles indicated that the lumbar lordosis angle was reduced by 11.00 ±7.68 in the non-ASD group. There was an average decrease of 5.83±12.14° in the ASD group at the latest follow-up compared to preoperative radiographs. However, these differences between the two groups were not statistically significant ($p>0.05$). Coronal Cobb angle decreased by an average of 29.00±5.36 in the ASD group and 29.89±12.85°inthe non-ASD group. These differences between the two groups were also not statistically significant ($p>0.05$).

DISCUSSION

In this study we reported that degenerative changes were present in the AS even in the early period for patients with thoracolumbar instrumentation and fusion for AIS. We also reported that having fewer moving segments is a risk factor for developing ASD. On the other hand, we did not find statistically significant differences between the two groups in terms of age, gender, length of fusion, SF-36 scoresor BMI values. This is to be expected, because all

Table 1. Pfirrmann classification of disc degeneration

Grade	Structure	Distinction of Nucleus and Anulus	Disc Height	Signal Intensity
I	Homogeneous, bright white	Clear	Normal	Hyperintense
II	Inhomogeneous with or without horizontal bands	Clear	Normal	Hyperintense
III	Inhomogeneous. gray	Unclear	Normal to slightly decreased	Intermediate
IV	Lost	Normal to moderately decreased	Intermediate to hypointense	
V	Lost	Collapsed disc space	Hypoitense	

Table 2. Comparison of two groups

		Non-ASD group (n=18)	ASD group (n=24)
Age	Mean±SD	15.00±2.64	16.92±2.27
	Min-Max (Median)	10-19 (15)	14-20 (16)
Sex n(%)	Male	3 (50.0)	3 (50.0)
	Female	6 (40.0)	9 (60.0)
BMI (kg/m2)	Mean±SD	18.25±2.49	18.58±1.66
	Min-Max (Median)	14.37-22.15 (17.9)	15.54-22.08 (18.7)
Follow -up (day)	Mean±SD	638.55±190.41	725.25±230.97
	Min-Max (Median)	407-911 (549)	454-1044 (700)
SF-36 -P	Mean±SD	54.56±3.12	53.75±3.88
	Min-Max (Median)	51-60 (55)	48-60 (53)
SF-M-36	Mean±SD	44.22±5.06	43.42±3.65
	Min-Max (Median)	35-49 (47)	39-49 (42.5)
Fusion level n (%)	T2-L2	2 (100.0)	0 (0.0)
	T2-L3	0 (0.0)	2 (100.0)
	T3-L2	8(100.0)	0 (0.0)
	T3-L3	6 (30.0)	14 (70.0)
	T4-L3	2 (20.0)	8 (80.0)
Fusion length n(%)	Twelve	8 (50.0)	8 (50.0)
	Thirteen	8 (36.4)	14 (63.6)
	Fourteen	2 (50.0)	2(50.0)
LIV	L2	10 (100.0)	0 (0.0)
	L3	8 (25.0)	24 (75.0)

SD: Standard deviation n :NumberMin:MinimumMax:Maximum
LIV: Lower instrumented vertebra
SF-36 P:Short Form physical component SF-36 M : Short Form mental component

the patients were in the adolescent age group, with similar BMI and similar fusion length.

The long-term consequences of spinal fusions are of great concern,especially in young patients. It has been shown that there is increased mechanical stress and segmental motion in the AS after spinal fusion. We report that 57.1% of the patients in this study had ASD after long-segment fusion for AIS in the short-term follow-up. However, most of the studies in the literatureon ASDfocus on degenerative lumbar diseases, and the incidence of development of ASD is very variable(8). Penta et al. examined MRI scans of patients after ten years follow-up who had undergone lumbar fusion for discogenic back pain.They found that 32% of 81 patients had ASD(9).Etebar and Cahill reported the incidence of ASD as 14% at follow-up after 4.5 years in a group of 125 patients who had been operated on for the treatment of degenerative lumbar instability (10).It is obvious that there are great differences in the incidence of ASDin the literature. This can be attributed tothe absence of clinical and radiological distinctionin the definition of ASD. Harrop et al. reviewed 27 studies on ASD. They found that the incidence ranged from 8% to 100% for studies in which radiological changes were defined as ASD but from 0% to 27% for studies in which clinical findings were required to confirm ASD.Thus, radiological changes in the adjacent segment are more common, although most patients with radiological changes are clinically asymptomatic (11).In this study, we also report similar quality of life scores (SF-36) between two groups(p>0.05).

It is debatable whether the literature shows preoperative disc degeneration to be a risk factor for ASD. In our study, all patients in the ASD group had normal disc appearance in preoperative MRI scans.Edwards et al. examined 34 patients who had undergone spinal fusion from the thoracic

region to L5 and found that 61% showed degeneration of the L5-S1 disc after 5.6 years of follow-up. They reported that the presence of minimal disc degeneration in the preoperative period was a risk factor for ASD (12). However, in a study of 215 patients who underwent lumbar fusion, Ghiselli et al. reported that the presence of disc degeneration before fusion was not a risk factor for the development of ASD(13).We also report that, compared to the Pfirrmann classification in preoperative MR scans, there were no changes in postoperative MR scans in any of the 16 patients with grade 2 degeneration. This leads us to believe that preoperative disc degeneration is not a risk factor for ASD in the shortterm for AIS patients treated with long-segment fusion.

Another issue addressed as a risk factor for the development of ASD is the length of the fusion level. Penta et al. reported that the length of the fusion level had no effect on the development of ASD (9).On the other hand, Jun Young Yang et al. evaluated 217 cases to define the effect of fusion length on developing ASD. Of these patients, 112 had single-level fusion, 62 had two-level fusion,and 43had fusion of three or morelevels. As a result, the incidence of ASD was found to be 11.6% in single fusion, 14.5% in two-level fusion, and 16.3% in fusion of threelevels or more. This shows that there is a relationship between the length of the fusion level and the risk of developing ASD(14). However, Ghiselliet al. found that patients who needed revision due to ASD after lumbar fusion reported three times more ASDif theyhad single-level fusion than if they hadmultiple-level fusion. They explained this result by claiming that, as the level of fusion increases, the amount of moving discs decreases. As a result, the possibility of developing ASD increases with fewer moving discs (13). In our study, there was no statistically significant difference in the development of ASD among the three groups of patients who had 12, 13, and 14-level fusion length. However, the incidence of ASD was significantly higher in patients with fusion level T4-L3 ($p < 0.05$). However, while the fusion level of 10 of the patients was terminated at L2, 32 of them were terminated at L3, and all 24 patients in the ASD group had a fusion level terminated at L3 (Table 2).This suggests that there is a decreased risk of ASD in cases withmore mobile segments.

In a cadaveric study, Akamaru et al. reported that lumbar hyperlordosis and hypolordosisled to increased flexion and extension movements in the lumbar discs, thereby increasing the risk of ASD (15). In our study in the non-ASD group, the average was 41.44°, with a decrease of 11° compared to the preoperative angle. In the ASD group, the average was 40°, with a decrease of5°. As a result, there was no statistically significant difference between average lumbar lordosis angles after the operation in either group($p > 0.05$).On the other hand,when the coronal Cobb angles of the patients were examined, it was observed that there was no statistically significant difference between the Cobb angle decline values in the two groups ($p > 0.05$). We therefore believe that the amount of correction in the coronal plane and the changes in the lumbar lordosis angles do not affect the development of ASD in early-term follow-up after AIS surgery.

Only a limited number of studies have evaluated AS following scoliosis surgery in adolescents, and they have some limitations. Kelly et el. reviewed 18 patients who were treated with thoracolumbar instrumentation and fusion for AIS. They evaluated distal AS, but lumbar MRI results were available for only 6of the patients. They reported that loss of signal intensity was present in AS for all 6 patients(16). Furthermore,the patients were operated on using the anterior approach, which is currently not often used for AIS patients because of the higher risk of complications and morbidity compared to the posterior approach. Green et al. reviewed 20 patients with posterior instrumentation and fusion for AIS, but different instrumentation methods were used: 10 of the patients were treated with hooks, apical wires, and pedicle screws,9 were treated with all-hook constructs, and 1 patient was treated with hooks and apical wires.They reported that only 1 patient of the 20 demonstrated significant degenerative disc disease at the junctional level(17). Danielssonn et al. evaluated 32 patients who had undergone spinal fusion for AIS and reported significantly more degenerative disc changes in the AS. However, all patients were treated with Harrington rods, which are not used today(18). Enercan et al. evaluated 21 patients treated with selective fusion for AIS. They suggested that there was a significant difference between the two groups for disc degeneration in AS and below, except at the L4-L5 level. However, since no preoperative MRI scans were available, they compared the patients with the normal population(19). Enercan et al. also evaluated 37 AIS patients who were treated with posterior fusion using an all-pedicle screw construct. They divided the patients into two groups, one group with LIV at L3 and the other with LIV at L4. After follow-up at a minimum of 5 years, they reported similar disc degeneration rates in both groups, but again they compared the patients with the normal population(20).

The present study also has a number of limitations, in particular the retrospective design and the relatively small number of patients included in the cohort. Although the length of thefollow-up period might appear to be a limitation, it is important to showthat degenerative changescan be found even in a short-term follow-up period.

CONCLUSION

In conclusion, we believe that ASDis present even in short-term follow-up in patients who have undergone long-segment fusion at a young age due to AIS. Leaving as many mobile segments as possible will protect from ASD. However, there is a need for longer follow-up studies to investigate the clinical consequences of early-onset radiological findings in the years that follow.

Competing interests: The authors declare that they have no competing interest.

Financial Disclosure: There are no financial supports.

Ethical approval: After the approval of the local ethic committee, we

retrospectively reviewed all the AIS cases surgically treated in our institution from 2012 to 2015.

Serdar Demiroz ORCID:0000-0002-2403-3750
Samet Bayram ORCID:0000-0003-2647-3386
Tamer Coskun ORCID:0000-0001-5043-2408
Alper Cirakli ORCID:0000-0002-9879-312X
Hakan Serhat Yanik ORCID:0000-0003-2917-8761
Yunus Atci ORCID:0000-0002-9661-4618
Sevki Erdem ORCID:0000-0002-3977-3380

REFERENCES

1. Hazebroek-Kampschreur AA, Hofman A, Van Dijk AP, et al. Prevalence of trunk abnormalities in eleven-year-old schoolchildren in Rotterdam, The Netherlands. J Pediatr Orthop 1992;12:480-4.
2. Hamill CL, Lenke LG, Bridwell KH. The use of pedicle screw fixation to improve correction in the lumbar spine of patients with idiopathic scoliosis. Is it warranted? Spine 1996;21:1241–9.
3. Ogilvie JW. Historical Aspect of scoliosis. Winter RB, Bredford DS, Lonstein JH, Ogilvie JW. MOE'S Textbook of Scoliosis and Other Spinal Deformities. 3rd Ed, Philadelphia: W.B. Saunders Company 1995:1-5.
4. Lehman TR, Spratt KF, Tozzi JE. Long-term follow-up of lower lumbar fusion patients. Spine 1987;12:97–104.
5. Lee CK, Langrana NA. Lumbosacral spinal fusion: a biomechanical study. Spine (Phila Pa 1976)1984;9:574-81.
6. Kumar MN, Baklanov A, Chopin D. Correlation between sagittal plane changes and adjacent segment degeneration following lumbar spine fusion. Eur Spine J 2001;10:314–9.
7. RimDC. Quantitative Pfirrmann Disc Degeneration Grading System to Overcome the Limitation of Pfirrmann Disc Degeneration Grade. Korean J Spine 2016;13:1-8.
8. Park P, Garton HJ, Gala VC, et al. Adjacent segment disease after lumbar or lumbosacral fusion: review of the literature. Spine (Phila Pa 1976)2004;29:1938-44.
9. Penta M, Sandhu A, Fraser RD. Magnetic resonance imaging assessment of disc degen-eration 10 years after anterior lumbar inter¬body fusion. Spine (Phila Pa 1976)1995;20:743-7.
10. Etebar S, Cahill DW. Risk factors for adjacent-segment failure following lumbar fixation with rigid instrumentation for degenerative instability. Division of Neurological Surgery, University of South Florida, Tampa, Florida. J Neurosurg; 1999. 90.pp.163–9.
11. Harrop JS, Youssef JA, Maltenfort M,et al. Lumbar adjacent segment degeneration and disease after arthrodesis and total disc arthro¬plasty. Spine (Phila Pa 1976).2008;33:1701-7.
12. Edwards CC 2nd, Bridwell KH, Patel A,Rinella AS, Jung Kim Y, Berra AB, et al. Thoracolumbar deformity arthrodesis to L5 in adults: the fate of the L5-S1 disc. Spine (Phila Pa 1976) 2003;28: 2122-31.
13. Ghiselli G, Wang JC, Bahtia NN, et al. Adjacent segment degeneration in the lumbar spine. J Bone Joint Surg Am 2004;86-A:1497–503.
14. Yang JY, Lee JK, Song HS. The impact of adjacent segment degeneration on the clinical outcome after lumbar spinal fusion. Spine(Phila Pa 1976) 2008:33;503-7.
15. Akamaru T, Kawahara N, Tim Yoon S, et al. Adjacent segment motion after a simu¬lated lumbar fusion in different sagittal alignments: a biomechanical analysis. Spine(Phila Pa 1976) 2003;28:1560-6.
16. Kelly MP, Mok JM, Frisch RF, et al. Adjacent segment motion after anterior cervical discectomy and fusion versus Prodisc-c cervical total disk arthroplasty: analysis from a randomized, controlled trial. Spine(Phila Pa 1976) 2011:36;1171-9.
17. Green DW, Lawhorne TW 3rd, Widmann RF, et al. Long term magnetic resonance imaging follow up demonstrates minimal transitionallevel lumbar disc degeneration after posterior spine fusion for adolescent idiopathic scoliosis. Spine(Phila Pa 1976) 2011:36;1948-54.
18. Danielsson AJ, Cederlund CG, Ekholm S, et al. The prevalence of disc aging and back pain after fusion extending into the lower lumbarspine. A matched MR study twenty-five years after surgery for adolescent idiopathic scoliosis. ActaRadiol 2001:42;187-97.
19. Enercan M, Kahraman S, Cobanoglu M , et al.Selective thoracic fusion provides similar health-related quality of life but can cause more lumbar disc and facet joint degeneration: a comparison of adolescent idiopathic scoliosis patients with normal population 10 years after surgery. Spine Deform 2015:3;469-75.
20. Enercan M, Kahraman S, Yilar S, et al.Does It make a difference to stop fusion at L3 Versus L4 in terms of disc and facet joint degeneration: An MRI Study With Minimum 5 Years Follow-up. Spine Deform 2016:4;237-44.