Volume: 29, Issue: 2, April 2018 pp: 97-102 ORIGINAL ARTICLE

COMPARISON BETWEEN THE PRE- AND POSTOPERATIVE RADIOLOGICAL FINDINGS AND CLINICAL OUTCOMES EVALUATION OF THE PATIENTS WHO UNDERWENT SURGERY FOR LUMBAR SPONDYLOLISTHESIS

Meliha GÜNDAĞ PAPAKER[1],
Erhan EMEL[2],
Anas ABDALLAH[1],
M. Hakan SEYİTHANOĞLU[1],
Tolga Turan DÜNDAR[1],
Serkan KİTİŞ[1]

[1]*University of Bezmialem Foundation, Department of Neurosurgery, İstanbul, Turkey.*

[2]*University of Health Sciences, Bakırköy Prof. Dr. Mazhar Osman Research and Training Hospital, Department of Neurosurgery, İstanbul, Turkey.*

ORCID Numbers:
-Meliha GÜNDAĞ PAPAKER: 0000-0003-1271-9023
-Erhan EMEL: 0000-0002-0584-9164
-Anas ABDALLAH: 0000-0003-3600-089x
-M.Hakan SEYİTHANOĞLU: 0000-0002-6072-0347
-Tolga Turan DÜNDAR: 0000-0003-0030-2618
-Serkan KİTİŞ: 0000-0002-9119-5899

Address: Karagümrük mh. Çorapsız Kadıasker sokak. 116 ada no:7 D:7 Fatih-İSTANBUL
Phone:+90 212 295 76 27
GSM: +90 533 651 50 20
E-Mail: melihagundag34@gmail.com
Received: 3rd January, 2018.
Accepted: 4th March, 2018.

ABSTRACT

Aim: We aimed to evaluate the surgical outcomes in the patients who underwent surgery for lumber spondylolisthesis by evaluation pre- and postoperative clinical results, radiological fusion and adjacent segment disease rates.

Material and Methods: Pre- and postoperative clinical evaluations using pre- and postoperative Visual Analog Scale (VAS) were performed in 48 patients who operated on for Grade 1, 2 and 3 spondylolisthesis. Radiological evaluation was retrospectively performed using direct radiographs, three-dimensional lumbar tomography (CT), and lumbar magnetic resonance imaging (MRI). The presence of pars defect, the presence of instability, Meyerding slip rate, slip percentage, slip angle, sacral slope (angle of inclination), sagittal range of motion, sacrohorizontal angle (pelvic tilt), and lumber lordosis angle were measured on direct radiographs. Dynamic radiographs and Lumbar CT were used for fusion detection. Lumber MRI was used to assess adjacent segment degeneration.

Results: 48 (43 female and 5 male) spondylolisthesis patients were operated on, with a mean age of 49.1 years and an average follow-up of 4.5 years. There was a significant decrease in postoperative back VAS ($p = 0.01$), and leg VAS ($p = 0.02$) values of the cases. The mean slippage percentage of the cases was 19.2 % in the preoperative period versus 13.2 % in the postoperative period. The mean slip angle was 10.18^0 in the preoperative period versus 6.64^0 in the postoperative period. The mean lumbar lordosis angle was 34.17^0 in the preoperative period versus 32.51^0 in the postoperative period. The mean sacral slope was 45.82^0 in the preoperative period versus 44.59^0 in the postoperative period.

Conclusion: Good clinical outcomes can be obtained with posterior instrumentation and fusion in the long-term instability patients.

Key Words: Spondylolisthesis, fusion, lumbar lordosis, sacral inclination.

Level of Evidence: Retrospective clinical study, Level III

INTRODUCTION

Spondylolisthesis is the forward slip or displacement of one vertebrate over the other. Andre was the first one who described spondylolisthesis in 1741 as a result of the inward slip of the vertebral column, resulting in a "trough waist" which is difficult to bear a child [15]. Paul Harrington was the first who used the posterior distraction instrument. In 1941, pedicle screws and facet screws were introduced for the first time [1]. Meyerding classified spondylolysis according to the percentage of slip in 1932 (11). This classification was expended and reformed by Wiltse, Newman, and McNab, in 1976, which is still being used today [18].

Conservative treatment such as pain killers, braces, physical treatment and epidural steroid injections may be useful for some of the first-grade spondylolisthesis patients who were presented without neurological deficits. Aim of treatment is usually to relieve short-term symptoms, since symptoms tend to improve following acute exacerbations. In conservative treatment requiring multidisciplinary approach; bed rest, weight loss in overweight patients, smoking cessation, nonsteroidal anti-inflammatory medications and muscle relaxant drug therapy, foraminal and epidural steroid injections, flexion exercises, restriction of pain and slip enhancing movements and bracing are

essential. Stretching and strengthening exercises as well as special education practices also take place in the treatment [6,10,14].

The current study aims to evaluate surgical outcomes in the patients who surgically treated for lumbar spondylolisthesis, by evaluating fusion and adjacent segment disease rates radiologically and by comparing preoperative and postoperative clinical evaluations.

MATERIAL AND METHOD

Patient Population:

48 patients who underwent lumbar laminectomy, transpedicular screw-rod system insertion as posterior instrumentation and posterolateral fusion due to Grade 1, 2 and 3 spondylolisthesis were reviewed retrospectively.

Evaluation of Subjective Complaints of Patients:

Pre- and postoperative VAS (Visual analog scale) was used to evaluate back and leg pain. For VAS measurement, a line which is vertically or horizontally drawn as 10 cm in long, is utilized. There are two extreme descriptive words subjectively at each side of this line. No pain is written on one side of the line and the worst intolerable pain on the other side. The patient is told to place a sign on this line to match the severity of his/her pain, so that this line will break. The distance from the lowest VAS level to the patient's sign is measured with a ruler to obtain the numerical index of the patient's pain severity in cm [2].

Parameters of Radiological Findings:

Preoperative and postoperative direct radiographs were used to measure the presence of pars defect and instability, and Meyerding slip rate, slip percentage, slip angle, sacral inclination, sagittal rotation, sacro-horizontal angle and lumber lordosis angle were measured. In Meyerding slip rate; the distance from the posterior cortex of the superior vertebra to the posterior cortex of the lower vertebra was measured and calculated as the ratio to the anteroposterior distance of the lower vertebra. The angle at which the slip angle intersects the lower end plate of the upper vertebrae and the vertices passing through the upper end plate of the lower vertebrae are calculated. In the lateral radiograph taken to detect sacral inclination, we recorded the straight line drawn along the S1 posterior border and calculating the angle formed by the vertical plan. For sagittal rotation, the line drawn along the S1 posterior face was based on the angle formed by the line drawn along the L5 anterior face. Angle between the line drawn from the sacro-horizontal angle S1 upper end plate and the horizontal axis was recorded. Angle between the lines drawn from the upper end plate of L1 at the angle of the lambs and the line drawn at 90^0 is taken as the angle between the lines drawn at the line 90^0 drawn from the upper end plate of L5.

Fusion and Adjacent Disease Assessment:

Dynamic graphics and three-dimensional lumbar CT were used in the fusion evaluation. However, it is reported that these tests may give pseudo-positive results and the radiological diagnosis of pseudoarthrosis is still difficult and uncertain. Successful fusion criteria were recorded to be the absence of motion on dynamic graphs, the presence of bilateral continuous trabecular bone between fused segments, and the absence of halo around the implant [16]. Three-dimensional tomography has 96 % sensitivity. In three-dimensional CT, cortical ring presence around the graft is the most accurate evidence of anatomic fusion [8,12]. Adjacent segment degeneration was recorded with lumbar MRI.

Statistical Evaluation:

Statistical Package for Social Sciences (SPSS) for Windows 21.0 program was used for the statistical evaluations. Chi-square test was used for comparison of qualitative data between groups, Mann-Whitney U and Kruskal Wallis tests were used for quantitative data. Wilcoxon Signed Ranks test was used to compare quantitative data before and after surgery. When the data were evaluated, descriptive statistical methods, Mean and Standard Deviation, were used. Results were evaluated in a 95 % confidence interval and a significance level of $p < 0.05$.

RESULTS

Demographic Characteristics of Patients:

Of the 48 cases who underwent surgery due to spondylolisthesis, 43 (90.0%) were female and 5 (10.0%) were male. Their ages ranged from 17 to 69 and the average age was 49.1. The majority of cases are at L_5-S_1 level and the number of spondylolisthesis type and cases are shown in Table-1.
Complaint period of the cases ranged from 1 month to 35 years with an average of 5.7 years. Follow-up period of the cases ranged from 1 to 8 years with a mean of 4.5 years.

Findings of Subjective Complaints of Patients:

The preoperative VAS averages were 8.02 for back and 8.79 for leg while the final postoperative VAS averages at last follow-up visits were 1.83 for back and 1.72 for leg (p 0.01 and 0.02, respectively). (Figure-1).

Clinical findings of the cases were found as claudication of 31, flat leg lift test (Laseque) positivity of 32, loss of sensation in 20, motor deficit of 9, reflex abnormality of 11, and sphincter dysfunction of 4 cases. Neurological examination was normal in 10 cases (Figure-2).

Radiological Findings:

39 of the cases (81.3 %) were determined as Grade I, 8 (16.7 %) were Grade II and 1 (2 %) was Grade III. The mean preoperative slip percentage of the cases was 19.2 %, versus 13.2 % postoperatively. The mean preoperative slip angle was 10.18^0 versus 6.64^0 postoperatively. The mean preoperative sacral inclination was measured as 45.82^0 versus 44.59^0

postoperatively. The mean preoperative sagittal rotation was measured as 20.76^0 versus 23.12^0 postoperatively. The mean preoperative sacro-horizontal angle was measured as 49.82^0 versus 47.41^0 postoperatively. The mean lumbar lordosis angle was preoperatively measured as 34.17^0 versus 32.51^0 postoperatively. There was no statistically significant difference between the preoperative and postoperative angular comparisons ($p > 0.05$). Adjacent segment degeneration assessed by Lumber MRI was detected in 14.6 % of our cases. In x-rays, fusion was detected in 27 of the patients, suspicious fusion in 10, no fusion in 9, and pseudarthrosis in 2 patients. In three-dimensional lumbar CT fusion was detected in 36 cases and 12 cases were not fused (Figure-3.a-ı).

Perioperative Findings:

In our cases, the average amount of bleeding during surgery was 910 cc, the average blood transfusion was 1.2 units, and the average operation time was 3.4 hours.

Postoperative Complications:

During the operation, intended dural tear was occurred in two of our patients in which were repaired surgically. In the early postoperative period, two cases underwent revision surgery due to screw malposition. In one case monoparesis was developed in the lower extremity and the motor power recovered completely within one week after steroid treatment. In the late postoperative period, one case was treated using parenteral antibiotics after presentation with surgical site infection. Another case was operated on for incisional hernia which was developed in the iliac graft site. Screw fracture was observed in four patients. Fusion was seen in two of them, in which had no symptoms, therefore no needed to additional surgical treatment. The third patient was re-operated after spondylopytosis was developed. The fourth patient was re-operated for pain in her legs after detected that no fusion. In one patient, one of the connected rods was observed to be loosen in his yearly control visit, but he has no symptom, so there was no additional surgical intervention recommended.

Table-1. Vertebral levels and the spondylolisthesis type of the patients.

	Degenerative		Isthmic		Dysplastic		Iatrogenic		Traumatic	
Level	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
L_5-S_1	**1**	3.3	13	81.25	2	100	1	50	1	100
L_4-L_5	19	63.4	3	18.75			1	50		
L_3-L_4	**7**	23.4								
L_2-L_3	1	3.3								
L_1-L_2	**1**	3.3								
T_{12}-L_1	1	3.3								

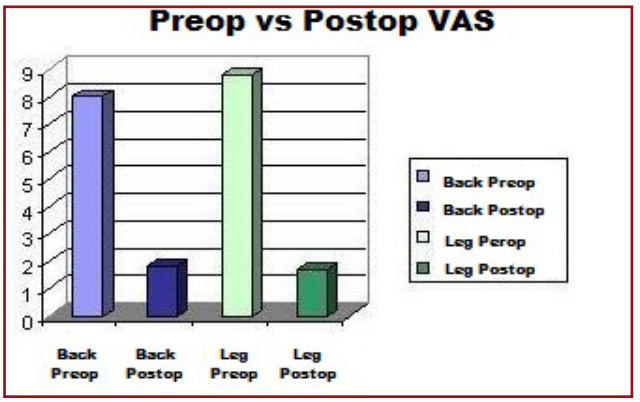

Figure-1. Preoperative and postoperative VAS scores.

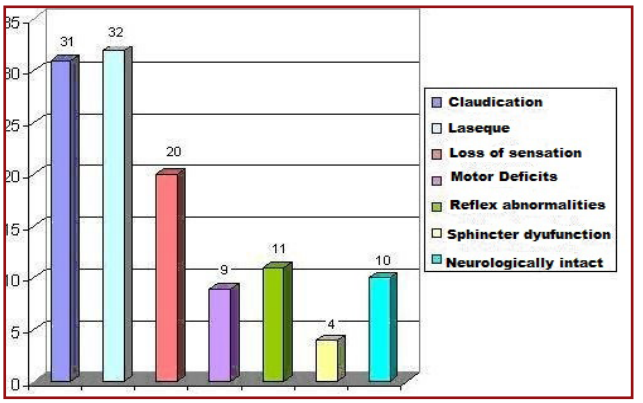

Figure-2. The results of neurologic examination of the patients.

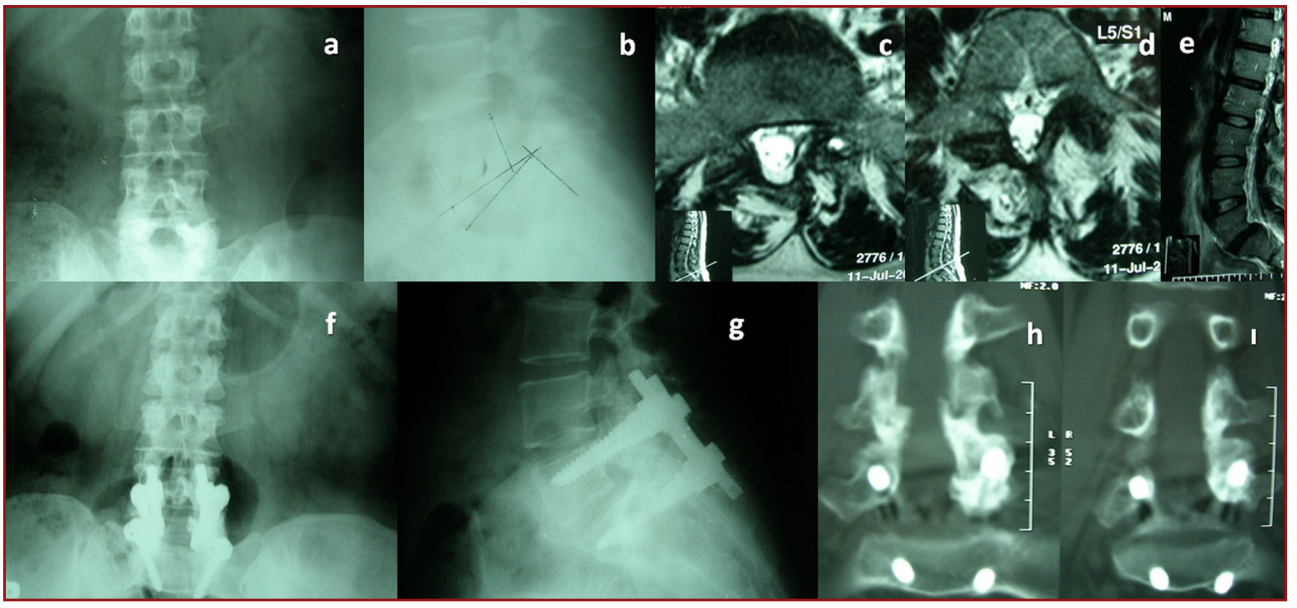

Figure-3. a-ı. A 44-year-old female patient had referred to our outpatient clinic with a 3-year back pain, which was alleviated painkillers and exacerbated with leaning. Except for a claudication at about 20 meters, the patient was neurologically intact. The patient received medication and physical therapy rehabilitation during preoperative period but her pain did not relieve. MRI, CT and x-rays were confirmed diagnosis of L_5-S_1 spondylolisthesis. Total L_5 laminectomy and insertion of bilateral transpedicular screw-rod posterior instrumentation were applied. The screws placement was control with performing x-rays on postoperative first day. The patient was discharged after relieve her symptoms. Postoperative 4th year lumbar CT showed that fusion developed.

DISCUSSION

Surgical intervention for patients were diagnosed with spondylolisthesis success rate is very high when patients are carefully selected and when the criteria of indications are appropriate. One of the most important of the surgical indications is intolerable pain which is resistant to physical therapy and causes activity restriction. In all of our cases, there is complaints of conservative treatment-resistant pain. In our patients, to select the appropriate surgical intervention, we aimed to evaluate the mechanisms of pain formation.

Therefore, we added interbody fusion in some cases in which the patients have scoliosis or/and malformation that lead to sagittal imbalance. But when the patients have spondylolisthesis with intact disc only posterior instrumentation was applied. In the literature, conservative methods have been applied for a long time in the treatment of this deformity and it is seen that the activities of the patients are restricted in this period[14]. Aim of spondylolisthesis surgical treatment is to reduce existing neurological deficits, to prevent deficits, to provide stability, to stop the progress of the slip and to improve the quality of life of the patient by relieving pain.

Various methods are used in the surgical treatment of spondylolisthesis. These include transpedicular fixation, bone or cage anterolateral interbody fusion (ALIF), posterolateral interbody fusion (PLIF), transforaminal lumber interbody fusion (TLIF), extraforaminal lumber interbody fusion (ELIF), facet screw fixation and combined procedures [3,4,7,19].

Success rate increases by adding posterolateral fusion (PLF) and PLIF, ALIF, ELIF, TLIF to the transpedicular screw fixation. The interbody fusion applied with the instrumentation provides a 360° fusion in the moving spine segment. With decompression, the risk of pseudoarthrosis, nonunion will decrease considerably when PLF and interbody fusion are applied. Intervertebral fusion is recommended to be used in situations where the anterior column should be more supported, such as those with high physical activity, obesity, and frontal / sagittal imbalances [3,19].

Currently, most segmental transpedicular screw fixation methods are used. In this method, anatomic changes due to spondylolisthesis are corrected, moving lumbar segments are immobilized, lumber opening is corrected, and fusions are added by reducing shear forces causing anterior sliding. In addition, three columns are stabilized by this method. Biomechanically, pedicle screw systems provide stronger grip than other posterior screw systems and do not require intact posterior elements. It prevents progression of deformity and reduces mechanical pain syndromes to provide early ambulance and increase fusion rate [9,17].

Decompression by laminectomy with transpedicular screw fixation by transpedicular screw-rod method and applying PLF increase the operation time and intraoperative bleeding. In cases when PLIF is added, it is inevitable that this amount of time and bleeding will be higher. In our cases, the average amount of bleeding during surgery was 910 cc, the average blood transfusion was 1.2 units, and the average operation time was 3.4 hours.

Additional PLIF can provide optimal conditions to maintain high disc height and sagittal equilibrium to provide a high fusion rate by providing dense blood flow from adjacent vertebral end plates under compression. However, 3 to 10 % of collapse, slip and graft migrations have been reported in patients underwent PLIF [3,20]. In our cases, we have not seen slip and graft migrations complications.

Spinal fusions provide stability and improves functions by pain relief. Solid fusion failure leads to painful pseudarthrosis. Pseudoarthrosis is the cause of unsuccessful spinal fusion. The most common causes of the pseudoarthrosis are inadequate surgical technique, excessive stress on fusion area, insufficient internal or external stabilization, and metabolic abnormalities. The presence of excessive segmental motion on dynamic flexion-extension graphs is diagnostic criterion for pseudoarthrosis. The other criteria for pseudoarthrosis are absence of trabecular bone in fusion area, loss of autograft height, fracture and/or of any instrumentation (rod, screw, and/or hook) after the expected improvement period. There is excessive movement if slip is more than 2 mm; but if slip be more than 4 mm slip and greater angulation more than 10^0 are diagnostic criteria for pseudoarthrosis. 3D tomography is quite meaningful in evaluating fusion and pseudarthrosis. In three-dimensional CT, cortical ring presence around the graft is the most accurate evidence of anatomic fusion. In our study, we based on dynamic graphs and lumbar CT to detect fusion. According to this, with the use of a roentgenogram, 27 patients were detected to have fusion, 10 had suspicious fusion, 9 had no fusion, and 2 had pseudoarthrosis. We found fusion in 36 cases, 12 cases of fusion, 11 cases of bone scintigraphy out of 34, 22 cases of no fusion and 1 case of pseudarthrosis. In pseudoarthrosis, there is constant movement on the bone surfaces with loading.

Degenerative spondylolisthesis is usually accompanied by spinal stenosis, caudal and radicular symptoms, and neural decompression of these patients with persistent neurogenic symptoms is recommended [6]. We performed decompression to all our cases with degenerative spondylolisthesis. We also performed partial/total laminectomy when all spondylolisthesis had a relative spinal stenosis.

In a study conducted by Wenger and colleagues on 132 cases, 65.3 % of the patients had low back and leg pain, 26.3 % had leg pain, 18 % had neurological dysfunction, 8.4 % had back pain [17]. Kaneda et al. reported that the postoperative lumbalgia has been completely resolved in most of their patients. They reported that lumbalgia was seen in 87 % of their patient preoperatively versus only 7.5 % of their patients were postoperatively suffered from lumbalgia.

Similarly, sciatica was preoperatively seen in 66.7 % of their patients versus only 5.6 % of their patients were suffered from sciatica. In the same study the authors reported that all their patients who preoperatively experienced neurogenic claudication (63 % of their patients) and neurogenic bladder (11 % of their patients) were fully recovered. They also reported that 80 % of the patients who preoperatively suffered from the motor deficits were totally, and 20 % of them partially resolved. The same study reported that 59 % of the patients who preoperatively presented with loss of sensation were completely and 41 % partially resolved [5].

According to our results, 28 out of 32 patients who were presented with preoperative sciatic pain were totally recovered postoperatively. 28 out of 31 patients who were suffered from neurogenic claudication were relieved postoperatively. Eight out of nine patients presented with motor deficit were fully recovered. Eight patients out of eleven who were diagnosed with abnormal reflexes were taken normally in postoperative period. Similarly, three out of four patients who suffered from preoperative sphincter dysfunction were fully recovered (Table-2).

Table-2. Preoperative and postoperative neural problems of the patients.

	Preoperative	Postoperative
Sciatalgia	32	4
Claudication	31	3
Motor deficit	9	1
Loss of sensation	20	4
Reflex changes	11	3
Sphincter dysfunction	4	1

In the study conducted by Wenger et al. for the patients who received surgical intervention with spondylolisthesis reported that the mean postoperative VAS values were 2.13 for low back and 1.59 for leg [17]. In our cases, the preoperative VAS averages were 8.02 for back and 8.79 for leg while the final postoperative VAS averages at last follow-up visits were 1.83 for back and 1.72 for leg.

Complications such as screw malposition, screw fracture, rod fracture, instrumentation failure, dura and root injury, neurological deficit and infection have been reported after insertion of the transpedicular screw-rod systems [5]. Dura injury occurred in two of our cases during the operation. In the early postoperative period, 2 cases underwent revision surgery due to screw malposition. Screw fracture was observed in 4 patients. Wenger et al. reported a 2.3 % surgical site infection in a study of 132 patients [17]. We detected surgical site infection in 1 of our cases (2.1 %). In the same study, adjacent segment degeneration was reported in 9.9 % [17]. In the study of Okuda et al., degeneration of the adjacent segment was reported as 1.4 - 16.8 % [9]. In our study with 48 cases, adjacent segment degeneration was detected in seven of our patients (14.6 %). Adjacent segment degeneration generally develops damage to the superior segment and with the same characteristics as the first operation.

Factors such as adjacent facet joint damage, unnecessary instrumentation, unnecessary fusion length, disruption of the sagittal balance, facet tropism, and horizontalization in the

adjacent lining of the fused segment are predisposed factors for adjacent segment degeneration disease [13,17].

Pseudoarthrosis was reported in 53 % of the cases in the study conducted by Wenger et al. [17]. We detected pseudoarthrosis in 2 (4.2 %) of our cases. One early published study supposed that 43 % of the patients with pseudoarthrosis was found to be asymptomatic [18]. Since spondyloptosis developed in 1 case of 2 pseudoarthrosis-developed cases, reoperation was performed. Our other case was a male patient who had surgical site infection and smoked for a long time. We did not perform surgery since this patient was asymptomatic.

Our work has several limitations; first its retrospectivity nature which may has bias, small number of patients, single center study and follow-up periods of some patients were one year. Our work needs to be supported by prospective, multi-center studies with longer follow-up and more patients.

In conclusion, well-selected patients who describe long-term instability and who do not benefit from conservative treatment, good clinical results may be obtained with posterior instrumentation and fusion.

REFERENCES

1. Boden SD, Schimandle JH. Biologic enhancement of spinal fusion. *Spine* 1995; 20: 113-123.
2. Emel E, Abdallah A, Özer AF. Taking history and patient assessment in spinal surgery. In: Özer AF, Arslantaş A, Dalbayrak S (Eds.), *Principles of Spine Surgery*, Volume-1. İntertıp Yayınevi, İzmir 2017; pp: 99-108.
3. Joseph JR, Smith BW, La Marca F, Park P. Comparison of complication rates of minimally invasive transforaminal lumbar interbody fusion and lateral lumbar interbody fusion : a systematic review of the literature. *Neurosurg Focus* 2015; 39(4): E4.
4. Keorochana G, Setrkraising K, Woratanarat P, Arirachakaran A, Kongtharvonskul J. Clinical outcomes after minimally invasive trasforaminal lumbar interbody fusion and lateral lumbar interbody fusion for treatment of degenerative lumbar disease: a systematic review and metaanalysis. *Neurosurg Rev* 2016; doi: 10.1007/s10143-016-0806-8.
5. La Rosa G, Conti A, Cacciola F, Cardali S, La Torre D, Gambadauro NM, Tomasello F. Pedicle screw fixation for isthmic spondylolisthesis: does posterior lumbar interbody fusion improve outcome over posterolateral fusion? *J Neurosurg* 2003; 99 (Suppl.-2): 143-150.
6. Machado GC, Ferreira PH, Yoo RI, Harris IA, Pinheiro MB, van Tulder MW, Rzewuska M, Maher CG, Ferreira ML. Surgical options for lumbar spinal stenosis. Cochrane *Database Syst Rev* 2016; 11: CD012421.
7. Mobbs RJ, Phan K, Malham G, Seex K, Rao PJ. Lumbar interbody fusion: techniques, indications and comparison of interbody fusion options including PLIF, TLIF, MI-TLIF, OLIF/ATP, LLIF and ALIF. *J Spine Surg* 2015; 1(1): 2-18.
8. Mundis GM Jr, Turner JD, Deverin V, Uribe JS, Nunley P, Mummaneni P, Anand N, Park P, Okonkwo DO, Wang MY, Bess S, Kanter AS , Fessler R, Nguven S, Akbarnia BA: International Spine Study Group. A critical analysis of sagittal plane deformity correction with minimally invasive adult spinal deformity surgery: a 2-year follow-up study. *Spine Deform* 2017; 5(4): 265-271.
9. Okuda S, Miyauchi A, Oda T, Haku T, Yamamoto T, Iwasaki M. Surgical complication of posterior lumbar interbody fusion with total facetectomy in 251 patients. *J Neurosurg Spine* 2006; 4: 304-309.
10. Resnick DK, Choudhri TF, Dailey AT, Choudhri TF, Eck JC, Sharan A, Groff MW, Wang JC, Ghogawala Z, Dhall SS, Kaiser MG. Guidelines for the performance of fusion procedures for degenerative disease of the lumbar spine. Part 13: injection therapies, low-back pain, and lumbar fusion. *J Neurosurg Spine* 2005; 2: 707-715.
11. Schoenecker PL. Congenital Spondylolisthesis. In: Bridwell KH, DeWald RL (Eds.). *The Textbook of Spinal Surgery*. Vol. I, Lippincott, Philadelphia 1991; pp: 557-562.
12. Steinmetz MP, Rajpal S, Trost G. Segmental spinal instrumentation in the management of scoliosis. *Neurosurgery* 2008; 63 (Suppl.-3): 131-138
13. Sudo H, Oda I, Abumi K, Ito M, Kotani Y, Takahata M, Sudo H, Hojo Y, Minami A. Biomechanical study on the effect of five different lumbar reconstruction techniques on adjacent-level intradiscal pressure and lamina strain. *J Neurosurg Spine* 2006; 5: 150-155.
14. Suh PB, Esses SI, Kostuik JP. Repair of pars interartikülaris defect. The prognostic value of pars infiltration. *Spine* 1991; 16: 445-448.
15. Tachdijan, MO (Ed.). Pediatric Orthopaedics, 2nd ed., WB. Saunders Co., Philadelphia 1990; pp: 2183-2379.
16. Turner JA, Ersek M, Heron L, Haselkorn J, Kent D, Ciol MA, Deyo R. Patient outcomes after lumbar spinal fusions. *JAMA* 1992; 268: 907-911.
17. Wenger M, Sapio N, Markwalder TM. Long-term outcome in 132 consecutive patients after posterior internal fixation and fusion for Grade I and II isthmic spondylolisthesis. *J Neurosurg Spine* 2005; 2: 289-297.
18. Wiltse LL, Newman PH, MacNab I. Classification of spondylolisis and spondylolisthesis. *Clin Orthop* 1976; 117: 23-29.
19. Xu DS, Bach K, Uribe JS. Minimally invasive anterior and lateral transpsoas approaches for closed reduction of grade II spondylolisthesis: initial clinical and radiographic experience. *Neurosurg Focus* 2018: 44(1):E4.
20. Zileli M, Kepoğlu Ü. Lomber Spondilolistezis. In: Zileli M, Özer F (Eds). *Omurilik ve Omurga Cerrahisi.* İkinci baskı. Cilt-1. Meta. İzmir 2002; pp: 769-782.