Clinical, Functional, and Radiologic Outcome of Single- and Double-Level Transforaminal Lumbar Interbody Fusion in Patients with Low-Grade Spondylolisthesis

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Abstract

Objective: The main objective is to determine the functional, clinical, and radiological outcome of patients with low-grade spondylolisthesis undergoing single- or double-level transforaminal lumbar interbody fusion (TLIF). **Materials and Methods:** This quasi-interventional study was conducted during a 2-year period from 2016 to 2018 in Shiraz, Southern Iran. We included all the adult (≥18 years) patients with low-grade spondylolisthesis (Meyerding Grade I and II) who underwent single- or double-level TLIF in our center. The spinopelvic parameters including pelvic incidence (PI), pelvic tilt (PT), sacral slope (SS), lumbar lordosis (LL), and segmental LL (SLL) were measured. The pain intensity and disability were measured utilizing the visual analog scale (VAS) for back and leg pain and Oswestry Disability Index (ODI), respectively, after 1 year. **Results:** Overall, we included a total number of 50 patients with mean age of 54.1 ± 10.48 years. After the surgery, the PI ($P = 0.432$), PT ($P = 0.782$), and SS ($P = 0.466$) were not found to be statistically changed from the baseline. However, we found that single- or double-level TLIF was associated with increased LL ($P < 0.001$) and SLL ($P < 0.001$). Regarding the clinical outcome measures, both back ($P = 0.001$) and leg ($P < 0.001$) VAS improved after the surgery significantly. In addition, we found that improved leg VAS was positively correlated with improved ODI ($r = 0.634$; $P < 0.001$). **Conclusion:** Single- or double-level TLIF is associated with increased global and SLL along with improved leg and back pain and disability in patients with low-grade spondylolisthesis. Interestingly, improved leg pain is correlated to improved disability in these patients.

Keywords: *Lumbar lordosis, pelvic incidence, sacral slope, spondylolisthesis, transforaminal interbody lumbar fusion*

Introduction

Lumbar spondylolisthesis is a relatively common condition that is recognized as a potential cause of low back, radiculopathy, and lower extremity paresthesia.[1,2] The incidence of degenerative spondylolisthesis was reported to be 2.7% in males and 8.4% in females.[1] In men, only age was a risk factor while in women, increased lordosis, body mass index, ethnicity (black), and age were all found to be risk factors.[1,3] Currently, the spondylolisthesis is classified as dysplastic, isthmic, traumatic, pathologic, and degenerative of which the degenerative and isthmic are the most common.[4,5] A wide variety of radiologic changes have been reported in degenerative spondylolisthesis including decreased disc space, foraminal stenosis, vertebral translation, and decreased lumbar lordosis (LL).[6] In low-grade spondylolisthesis, the spine and pelvic parameters change in order to compensate for the variations of the spine mobility.[6-8] In those with low-grade spondylolisthesis, decreased LL is followed by a reversed ratio of extensors/flexors muscle power compared with normal controls.[2,9] It has been demonstrated that the segmental and global LL are reduced resulting in increased pelvic incidence (PI) and thus transferring the tension to the posterior elements resulting in aggravated deformity, pain, and disability.[10,11] Thus, evaluation of the spine biomechanics and measurement of spinopelvic parameters is recommended before surgical correction of the low-grade spondylolisthesis.[4,6,7,10]

Currently, posterior pedicular screw fixation augmented by the interbody fusion remains the mainstay of treatment choice for low-grade spondylolisthesis.[12,13] There

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Access this article online

Website: www.asianjns.org

DOI: 10.4103/ajns.AJNS_156_18

Quick Response Code:

How to cite this article: Eghbal K, Pourabbas B, Abdollahpour HR, Mousavi R. Clinical, functional, and radiologic outcome of single- and double-level transforaminal lumbar interbody fusion in patients with low-grade spondylolisthesis. Asian J Neurosurg 2019;14:181-7.

are several approaches for interbody fusion including anterior (ALIF), posterior, lateral, and transforaminal lumbar interbody fusion (TLIF) with specific advantages and disadvantages for each procedure.[2] The TLIF is among the most common performed procedure because compass several advantages including the minimal traction on the nerve root and the dura, lower risk of postoperative radiculitis, availability of the instruments, and familiarity of the surgeons with the approach.[12,14-16] Several studies have demonstrated the effects of TLIF on lumbar and pelvic parameters and the amount of correction in different ethnic groups.[17-20] However, data on the Iranian population are scarce. Thus, the aim of the current study was to determine the effects of single- or double-level TLIF on spinopelvic parameters of the patients with low-grade spondylolisthesis.

Materials and Methods

Study population

This prospective quasi-experimental study was conducted during a 2-year period from March 2016 to February 2018 in Neurosurgery and Orthopedic Surgery Department of Shahid Chamran Hospital, a Tertiary Health-care Center and Referral Center for Spine Surgery affiliated with Shiraz University of Medical Sciences, Shiraz, Southern Iran. We included all the adult (≥18 years) patients with low-grade degenerative or isthmic spondylolisthesis. Low-grade spondylolisthesis was defined as Meyerding classification of 1 or 2 (a slip of 0%–50%). We excluded those patients who had undergone multilevel operation (≥3 levels), previous spine surgery, degenerative scoliosis, or preoperative coronal imbalance. Those who underwent pedicle subtraction osteotomy combined with TLIF and those who underwent surgery for trauma, infection, or malignancy were excluded from the study. The study protocol was approved by the Institutional Review Board and Medical Ethics Committee of Shiraz University of Medical Sciences. All the patients provided their informed written consents before being included in the study.

Study protocol

All the included patients were examined by an attending spine surgeon and a fellowship of spine surgery and the positive findings of the history and physical examination were recorded in a data gathering form. The demographic, comorbidities, past medical history, presenting symptoms, and the clinical findings were all recorded. All the patients underwent a complete preoperative radiological evaluation of the spinopelvic parameters and the assessments were all repeated after the operation. The patients were followed for at least 1 year and the parameters and the pain intensity were measured.

Surgical technique

The patients were all operated by the same surgical team in our center under the general anesthesia in the prone position. Two rolls were placed under the chest and the pelvis in order to avoid pressure injury during the operation. Posterior approach was utilized and the levels were cleared using intraoperative fluoroscopy. Pedicular screw fixation of the involved levels was performed under guide of anatomical landmarks and fluoroscopy using the polyaxial screws. Then, the interspinous ligament at the desired levels was removed, and a distractor was placed to distract between the spinous processes above and below. Bilateral laminectomy and total medial facetectomy of the superior level is performed using the Rongeur and Kerrison punch. The thick ligamentum flavum was gently dissected from the dural sac and was removed. Then, the dural sac and the above and below nerve roots were retracted and the disc space was completely identified. Unilateral total discectomy was conducted at the listhesis level using a combination of pituitary Rongeur and curette. With additional interbody distraction, the interspace was held open with the temporary distractor as additional disc material was removed. The disc space and wound were then copiously irrigated. Then, a trial spacer was introduced to the disc space and the largest possible cage was chosen. The cage was filled with autograft and allograft (Tissue regeneration Inc., Kish, Iran) and was then carefully impacted into position. The cage was pushed as anterior as possible and the location was checked with fluoroscopy. The distraction was released and the screws were fixed by two bilateral lordotic rods. Compression was then placed across the construct. Bilateral posterolateral fusion with transverse process osteotomy and allograft was done. The wound was copiously irrigated and closed with a Hemovac drain in place.

Radiologic and clinical assessment

Before surgery, all patients had a radiographic assessment of the lumbosacral spine, including standing neutral, flexion, and extension plain lumbar radiographies, computed tomography (CT) imaging, and magnetic resonance imaging of the lumbosacral spine. The dynamic radiography of the lumbosacral area was performed in standing position in the lateral plain. The patient was asked to flex and extend as much as possible actively [Figure 1]. We also obtained standing anteroposterior and lateral lumbosacral radiographies to calculate the spinopelvic parameters. In the follow-up, we obtained standing anteroposterior and lateral lumbosacral radiographies. All the measurements were performed by two assessors independently using the PACS software (Virtual Expo Group, Hamburg, Germany). We measured segmental LL (SLL) defined as lordosis measured between the lower endplate of the vertebra above the instrumented disc and the upper endplate of the vertebra

Figure 1: The preoperative standing dynamic lateral radiography of the lumbosacral spine in flexion (a) and extension (b). The images demonstrate the degenerative L4/L5 spondylolisthesis with angular discplacement (sagittal rotation) and anterior translation of L4 vertebral body over L5 in flexion when compared with extension

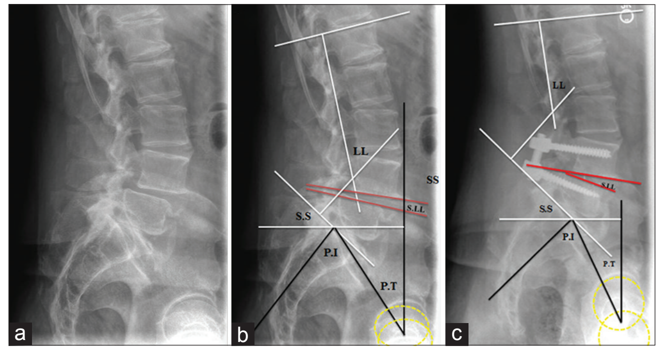

Figure 2: The preoperative standing lateral radiography of the lumbosacral region in a patient with isthmic spondylolisthesis of L4/L5 (Meyerding grading 2) (a). Preoperative measurement of different spinopelvic parameters including lumbar lordosis, segmental lumbar lordosis, sacral slope, pelvic incidence, and pelvic tilt in the mentioned patient (b). Postoperative image of the same patient and measurement of the same spinopelvic parameters in lateral standing lumbosacral radiography (c). LL: Lumbar lordosis, SLL: Segmental lumbar lordosis, SS: Sacral slope, PI: Pelvic incidence, PT: Pelvic tilt

below the instrumented disc; LL, the angle between the upper endplate of L1 and the upper endplate of S1; PI, the angle between the perpendicular of the sacral endplate and the line joining the middle of the sacral endplate and the midpoint of the axes of both femoral heads; pelvic tilt (PT), the angle between the vertical line and the line joining the middle of the sacral endplate and the hip axis; and sacral slope (SS), the angle between the superior plate of S1 and a horizontal line [Figure 2]. Visual analog scales (VASs) for back and leg pain and Oswestry Disability Index (ODI) were used for preoperative and postoperative evaluation of the clinical outcomes.

Statistical analysis

All the statistical analyses were conducted using the Statistical Package for Social Sciences (SPSS Inc., Chicago, Illinois, USA) version 22.0. Data are presented as mean ± standard deviation and proportions as appropriate. The nonparametric and parametric variables without normal distribution were compared before and after surgery using the Kruskal–Wallis test. The parametric variables were compared before and after surgery using paired *t*-test. The variations of each parameter (postoperative subtracted by preoperative and reported as Δ) were compared between isthmic and degenerative spondylolisthesis using independent *t*-test. The parametric variables without normal variations were compared using Mann–Whitney U-test. In order to determine the correlation between the changes in spinopelvic parameters and the clinical outcome, a univariate Pearson's correlation analysis was performed. The correlation coefficient (*r value*) was also reported. A two-sided $P < 0.05$ was considered statistically significant.

Results

Overall, we included a total number of 50 patients with low-grade spondylolisthesis who underwent single- or double-level TLIF. The mean age of the patients was 54.1 ± 10.48 (ranging from 25 to 71) years, and there were 42 (84%) women and 8 (16%) men among the patients. Only 14% had a history of diabetes mellitus and none were smoker. Most of the patients (58%) suffered from degenerative spondylolisthesis and most of them (62%) were in Grade I according to the Meyerding classification. L4/L5 was the most common level of the spondylolisthesis and only 11 (22%) patients underwent double-level TLIF. The baseline characteristics of the patients are summarized in Table 1.

After the surgery, the PI ($P = 0.432$), PT ($P = 0.782$), and SS ($P = 0.466$) were not found to be statistically changed from the baseline. However, we found that single- or double-level TLIF was associated with increased LL ($P < 0.001$) and SLL ($P < 0.001$). Regarding the clinical outcome measures, both back ($P = 0.001$) and leg ($P < 0.001$) VAS improved after the surgery significantly. The disability measured by ODI was also significantly improved after the surgery ($P < 0.001$). The changes in spinopelvic parameters and the clinical outcome measures are summarized in Table 2.

We also compared the changes of the spinopelvic parameters and the clinical outcome measures between those with degenerative and isthmic spondylolisthesis [Table 3]. We found that there was no statistically significant difference between these two types of spondylolisthesis regarding the improvement in spinopelvic parameters and clinical outcome measures. The correlation analysis revealed that the changes in none of the spinopelvic parameters were associated with improved clinical outcome [Table 4]. In addition, we found that improved leg VAS was positively correlated with improved ODI ($r = 0.634$; $P < 0.001$).

Overall, we recorded three (6%) patients with complications. One (2%) developed postoperative

Table 1: The baseline demographic and clinical characteristics of the 50 patients with low-grade spondylolisthesis included in the current study

Variables	Values
Age (years)	54.1±10.48
Gender (%)	
Men	8 (16.0)
Women	42 (84.0)
Diabetes mellitus (%)	7 (14.0)
Presenting symptom (%)	
Low back pain	46 (92)
Radicular pain	43 (86)
Neurogenic claudication	7 (14)
Neurologic deficit	5 (10)
Spondylolisthesis type (%)	
Degenerative	29 (58.0)
Isthmic	21 (42.0)
Spondylolisthesis grade (%)	
I	62 (31)
II	38 (19)
TLIF level (%)	
L2/L3	3 (5.8)
L3/L4	8 (15.1)
L4/L5	23 (43.3)
L5/S1	19 (35.8)
Number of TLIF levels (%)	
Single level	47 (93.0)
Double level	11 (22)
Follow-up period (months)	17.1±4.66

TLIF – Transforaminal lumbar interbody fusion

Table 2: Comparing the radiologic spinopelvic parameters and the clinical determinants before and after single- or double-level transforaminal lumbar interbody fusion in 50 patients with low-grade spondylolisthesis

Parameters	Before surgery	After surgery	*P*
PI	60.1±14.9	60.5±14.5	0.432
PT	21.6±8.7	21.8±7.2	0.782
SS	37.1±10.5	37.8±9.5	0.466
LL	−43.1±19.8	−48.1±20.5	<0.001
SLL	−7.7±1.9	−12.7±8.5	<0.001
Back VAS	6.4±1.6	3.4±1.6	0.001
Leg VAS	8.5±1.4	2.9±2.2	<0.001
ODI	69.7±16.8	32.1±16.4	<0.001

ODI – Oswestry Disability Index; VAS – Visual analog scale; LL – Lumbar lordosis; SLL – Segmental lumbar lordosis; PI – Pelvic incidence; PT – Pelvic tilt; SS – Sacral slope

Table 3: Comparing the changes in spinopelvic parameters and the clinical determinants in single- or double-level transforaminal lumbar interbody fusion between those with degenerative and isthmic low-grade spondylolisthesis

Parameters	Degenerative (*n*=29)	Isthmic (*n*=21)	*P*
Age (years)	56.4±8.8	50.7±11.8	0.059
Δ.0	0.24±4.6	0.80±3.8	0.537
Δ.5	−0.51±8.4	1.42±6.3	0.431
Δ.4	1.34±8.3	0.04±6.8	0.701
ΔLL	−4.3±10.4	−5.9±11.6	0.783
Δ.78	−5.8±5.5	−3.9±6.8	0.222
Δ.222.868	−2.9±2.0	−2.9±1.7	0.592
Δ.592.76	−5.4±3.2	−5.8±2.2	0.912
ΔODI	−36.3±26.6	−39.5±21.7	0.648

ODI – Oswestry Disability Index; VAS – Visual analog scale; LL – Lumbar lordosis; SLL – Segmental lumbar lordosis; PI – Pelvic incidence; PT – Pelvic tilt; SS – Sacral slope

Table 4: The univariate correlation analysis between the changes in spinopelvic and the clinical outcome measures in 50 patients with low-grade spondylolisthesis undergoing single- or double-level transforaminal lumbar interbody fusion

Outcome measure	Correlation coefficient	*P*
ODI		
ΔDI	−0.058	0.688
Δ.6	−0.049	0.736
Δ.7	−0.009	0.951
Δ.9	−0.029	0.841
Δ.84	0.049	0.735
Δ.735lati	0.194	0.176
ΔLeg VAS	0.634	<0.001
Back VAS		
Δac	−0.109	0.452
Δ.4	−0.046	0.750
Δ.7	0.040	0.783
Δ.7	−0.045	0.754
Δ.75	0.071	0.625
Δ.625VAS	0.194	0.176
Leg VAS		
Δeg	0.012	0.932
Δ.9	0.203	0.157
Δ.1	−0.211	0.141
Δ.1	0.156	0.278
Δ.27	−0.174	0.227

ODI – Oswestry Disability Index; VAS – Visual analog scale; LL – Lumbar lordosis; SLL – Segmental lumbar lordosis; PI – Pelvic incidence; PT – Pelvic tilt; SS – Sacral slope

epidural hematoma presenting as back pain and paraparesis 48 h after the operation. He was on antiplatelet agents (Aspirin and Plavix) which were discontinued 5 days before surgery. The patient underwent emergency reoperation and the hematoma was evacuated and he recovered partially after 6 months of physiotherapy and conservative management. In addition, 2 (4%) patients developed ipsilateral weakness of extensor hallucis longus. The muscle power recovered completely after 4 months of physiotherapy and conservative care. It should be also noted that none of the patients had sphincter problems before the surgery and also after the operation.

Discussion

Several studies have addressed the spinopelvic parameters in those with different grades of spondylolisthesis undergoing TLIF.[12-15,19] In the current study, we demonstrated that TLIF in those with low-grade spondylolisthesis is associated with increased global and SLL without any effect on the PI, SS, and the PT. The leg and back pain measured by VAS decreased significantly after the operation followed by the improved disability measured by ODI. Interestingly, the improved ODI was correlated with decreased leg pain. The results of the current study are in concordance with many previous reports in the same field demonstrating improved segmental and global LL after TLIF.[12,14,18,20,21]

Although we found that LL (global and segmental) was increased postoperatively which is in consistent with the previous reports,[18,21,22] however, some others have reported no change in the corresponding variables after TLIF.[15,23-25] Theoretically, the TLIF primarily restores LL through its effects on the lower lumbar spine. In practice, however, there have been mixed reports on the efficacy of the TLIF in restoring lordosis. Hsieh *et al*.[24] compared 25 patients who underwent a TLIF operation with 32 who had an ALIF. The authors noted that the TLIF was inferior to the ALIF in restoring normal LL. Most recently, Cheng *et al*.[15] demonstrated that for patients with neurogenic leg symptoms owing to single-level lumbar degenerative disease, whole LL was improved after TLIF as a result of the spontaneous restoration of lordosis at the unfused lumbar levels. Jagannathan *et al*.[18] demonstrated that improvement in LL may be attributable to two factors; performing bilateral facetectomies and permitting improved lordosis intraoperatively in a method analogous to a chevron osteotomy. Second, improved lordosis may be obtained using a larger interbody graft, which acts as a fulcrum at the junction of the anterior third and middle third of the vertebral body. Our general practice is to place the interbody graft as anteriorly as possible, to maximize the lordotic potential, increase the overall stiffness of the construct, and decrease strain on the rods.[26]

The unchanged LL in some reportes[15,23] might be due to several factors. First, the main indication for TLIF was spondylolisthesis in the current study and those reporting significant improvement of LL,[18,21] while those without any positive results included a heterogeneous group of patients including lumbar disc disease and discogenic low back pain. Liang *et al*.[27] found that one-level TLIF did not change LL when treating lumbar degenerative disease except for spondylolisthesis. Second, those studies without significant improvement in the LL have utilized the routine unilateral facetectomy.[15,23] The intact contralateral facet limits compression and the capacity to restore lordosis.[18,24] Third, the shape and location of cage are also important factors affecting the improvement of LL.[28,29] Fourth, *in situ* contouring of the rods and compression between the pedicle screws could further facilitate restoration of LL after insertion of the cage. In the series by Cheng *et al*.,[15] the pedicle screws were loosened and then retightened *in situ* after inserting the cage without application of compression over the pedicle screws because they believed that the compression would make the posterior spinal structures fixed at a nonphysiologic location generating abnormal stress concentration. The compression of the pedicle screws combined with the retained facet can also lead to contralateral foraminal stenosis.[30,31] Finally, we used polyaxial screws to fix the fusion segment in all cases. When using the polyaxial screws, the connection between the screw and the rod is angulated with the lumbar spine less lordotic compared with the precontoured rod. However, we finalized all the screws in compression which makes the screws monoaxial finally. The variable angle between the polyaxial screw and the rod makes the posterior instrumentation hard to prevent the loss of intervertebral height.[15]

We note some limitations to our study. First, we included a limited number of patients with low-grade spondylolisthesis and measured the spinopelvic parameters accordingly. The final power of the study was 80% to detect a 5% difference in any of the corresponding variables. Thus, the results are reliable. The low number of included patients might be responsible for the lack of association between spinopelvic parameters and the clinical outcomes. Second, the follow-up period was limited and we included those with at least 1-year of follow-up while most studies have included those with at least 2 years. This is because we are a referral center and most of the patients are referred to us from other provinces and the patients do not follow the instructions after the pain alleviated. Further larger studies with longer follow-up periods are needed to shed light on the issues. The other limitation was that we did not evaluate the fusion rate in these patients and groups. Actually, the fusion rate was not among the primary end-points of the study and correction of the spinopelvic parameters were the main aim. For evaluation of the fusion rate we need to performed high-resolution thin-cut CT-scan which was not performed in the current study.

Conclusion

Single- or double-level TLIF is associated with increased global and SLL along with improved leg and back pain and disability in patients with low-grade spondylolisthesis. Interestingly, improved leg pain is correlated to improved disability in these patients.

Acknowledgment

The authors would like to thank all the patients and their families who participated in this study. We would also like to acknowledge the editorial assistance of Diba Negar Research Institute for improving the style and the use of English throughout the manuscript.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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