A comparative study of L4-L5-S1 and L5-S1 vertebral fusion in high-grade L5-S1 spondylolisthesis

ABSTRACT

Introduction: One of the most common types of spinal diseases is spondylolisthesis, which in advanced cases requires surgical intervention. This study aimed to compare the results of L4-L5-S1 and L5-S1 vertebral fusion treatment in high-grade L5-S1 spondylolisthesis.

Methods: A study design that randomized controlled trial. A total of 70 consecutive patients who underwent surgery for the treatment of spondylolisthesis at Al-Zahra Hospital in Isfahan, Iran, were evaluated from July 2020 to February 2021 (35 patients underwent L4-L5-S1 and 35 received L5-S1 vertebral fusion treatment). The radicular and low back pain (LBP) intensity (Vanguard Australian Shares), blood loss, wound infection, reduction, and quality of life (SF-12 scores) were quantified before the surgery, 1, 3, and 6 months after surgery in two groups.

Results: Patients involved in the two groups had similar baseline demographic characteristics. The percent slip in L4-L5-S1 and L5-S1 group, respectively, postoperative 81.11% and 57.89%, P = 0.0001. Intraoperative blood loss and postoperative were higher in the L4-L5-S1 group when compared to the L5-S1 group (P < 0.05). The wound infection rate of the L4-L5-S1 group was similar to that of the L5-S1 group (8.6% vs. 2.9%, P = 0.303). There was no difference in radicular and LBP intensity, SF-12 scores among patients with L4-L5-S1 and L5-S1 groups (P < 0.05).

Conclusion: Both L4-L5-S1 and L5-S1 were equally beneficial in improving short-term functional outcomes for patients with high grade L5-S1 spondylolisthesis. However, L4-L5-S1 was associated with statistically significant higher incidences of blood loss, but it was accompanied by a better reduction. Therefore, caution should be exercised when considering L4-L5-S1.

Keywords: Back pain, high-grade L5-S1 spondylolisthesis, radicular pain, reduction, surgical technique, vertebral fusion

INTRODUCTION

Low back pain (LBP) is one of the most common musculoskeletal disorders in different communities.[1] The prevalence of LBP is estimated to be between 30 and 80% among the general population and has been found to increase with age;[2] approximately 85% of these people are in the category of nonspecific LBP and 15% of them have a specific pathoanatomical origin for LBP and are in the group of patients with specific LBP.[3-5]

One of the pathobiomechanical and pathoanatomical causes of LBP is spondylolisthesis, which directly affects the vertebrae and is most often seen in the lumbar spine.[4] Spondylolisthesis is an anatomical defect or fracture of the pars interarticularis of the vertebral arch. It occurs at the L5 vertebrae between 85% and 95% of the time and occurs at the L4 vertebrae 5%-15% of the time.[7]
Spondylolysis has been shown to be absent at birth, and generally develops at a young age.\[^8\] Lemoine et al.\[^9\] performed a prospective study on 532 patients under 8 years of age, finding 3.7% with a prevalence of spondylolysis. Ko and Lee\[^10\] found that prevalence of LBP was 36.37% and the prevalence of lumbar spondylolysis in a selected population, who visited hospital for abdominal or urological lesions except LBP, was 9.12% based on computed tomography (CT) imaging. Males demonstrated a similar presence of LBP to females but a significantly higher incidence of spondylolysis. The prevalence of spondylolysis was not associated with the presence of LBP and age in adulthood.

Spondylolisthesis refers to degenerative changes in the spine that are characterized by lumbosacral deformity, dislocated vertebrae, fractures, or other deformities of the pars interarticularis and is generally the anterior displacement of one vertebra over another vertebra. In all cases, there is a defect in the posterior part of the vertebra. Spondylolisthesis may be completely asymptomatic. Chronic, mild back pain is the most common complaint that may be accompanied by intermittent radicular pain or lameness. In case of mild chronic back pain, supportive treatments, including rest, prescribing painkillers, and wearing a medical belt are recommended, but in severe and progressive cases or intermittent neurological symptoms and lameness, surgery is recommended.\[^11\]

Different imaging methods such as plain radiography, CT scan, and MRI can be used to diagnose spondylolisthesis.\[^12\] The traditional method of surgical treatment of high-grade spondylolisthesis is the Gill method, which slips by removing the posterior and loose parts of the vertebrae and is a posterolateral fusion without instrumentation,\[^13\] but it was later determined if this method uses pedicular screws, the vertebral fusion will be more resistant.\[^14\]

The Cotrel-Dubousset system was developed in the 1980s, and the benefits of using pedicular screws have been reported by Cotrel, Roy Camille, and Steffee since the mid-1980s.\[^15\] Although many studies have been conducted on the advantages and disadvantages of vertebral fusion with instrumentation compared to the traditional method (without instrumentation), the physical and biomechanical properties of the spine in improving spondylolisthesis have received less attention and such expression. It has been found that in vertebral fusion using pedicular screws, fewer segments of the spine are involved and in terms of stability, it creates more strength in rotation and translation positions.\[^16,17\]

The use of this method causes the patient to return to normal and daily activities faster and also reduces the length of hospital stay and immobility.\[^16\] However, this type of technique is safer, more effective, and has a better fusion rate.\[^18\] Furthermore, the biomechanical properties of fusion with pedicle screws (PSs) are excellent, but this technique is associated with significant surgical risk\[^19\] and necessary measures must be taken to minimize postoperative complications.

Surgical management of high-grade spondylolisthesis involves various techniques such as instrumentations, reductions, and decompressions. Instrumentation plays a more significant role in adults than children as uninstrumented in situ circumferential fusion is considered more viable in treating pediatric high-grade spondylolisthesis.\[^20\]

A method of lumbosacral fixation that has been used successfully in moderate grades of spondylolisthesis at our institution involves the use of translateral S1 PSs. With this technique, S1 PSs are placed through the S1 pedicle, through the superior endplate of S1, through the inferior endplate of L5, to terminate in the L5 body. Transpedicular screw L4-L5-S1 fixation is an established, common procedure performed by spine surgeons that requires correct placement of PSs to provide biomechanical stability and to avoid injuries in neighboring neurovascular structures.\[^21\]

Postoperative care is one of the most important measures in the success of the treatment of spondylolisthesis, and in addition to educating the patient and companions about adhering to the standards of care, taking measures that help make the spine more stable and the spine return faster is very important. Therefore, in this study, the effect of fusion of L4-L5-S1 vertebrae compared to L5-S1 vertebral fusion on healing and reduction of pain and other symptoms of high-grade L5-S1 spondylolisthesis will be investigated.

**METHODS**

The present study was performed as a randomized clinical trial study and as a 6-month follow-up period from July 2020 to February 2021 in Al-Zahra Hospital in Isfahan, Iran. (IRCT Registration Reference: IRCT20201130049541N1). The target population included patients with high-grade L5-S1 spondylolisthesis who were admitted to the center for spinal fixation with fusion surgery.

Inclusion criteria included patients with high-grade spondylolisthesis L5-S1 (The spondylolistheses are divided into high (slippage > 50%) and low (slippage < 50%) grade).\[^22\]
Candidate for vertebral fusion with instrumentation, slip on the surface of a vertebra, age <80 years and patients consented to participate in the study. Exclusion criteria included patients who suffer from complications of surgery (root injury, rupture of the sac, etc.), patients with neurological defects who need emergency surgery, patients with a history of underlying diabetes, who have neuropathy, patients with a history of severe heart disease and preoperative anticoagulant use, as well as patients who are smokers or addicted to alcohol and drugs, and bone metabolic diseases.

According to the entry and exit criteria and the study of Zhang et al.,[23] in 2017 and based on the formula of the following sample volume at a significant level of 0.05, the test power is 80% and considering 5% of the sample drop, 70 samples of this study were selected.

\[
\frac{n}{\text{(mean_1 - mean_2)}^2} = \frac{(Z_{1-\alpha/2} + Z_{1-\beta})^2 \times (S_1^2 + S_2^2)}{(5^2 - 4.3^2)} = \frac{31.86}{0.49} = 69.12 \pm 70
\]

The research samples were divided into two groups of 35 people using random number generation software and the random allocation method. The work of vertebral fixation in the first group (L4-L5-S1) was performed on the surface of L4-L5-S1 vertebrae using PSs and the instrumentation method by which three lumbar vertebrae were fixed [Figure 1].

In the second group (L5-S1), the device was placed on the surface of the L5-S1 vertebrae using pedicular screws and two lumbar vertebrae were fixed. L5-S1 interbody fusion was performed for all groups of patients using allograft bone [Figure 2].

At the beginning of the patients’ study, the demographic information of the disease, including age, sex, height and weight, and information about the disease, including slippery vertebrae, cause of vertebral slip, body mass index, and duration of the disease were recorded in the data collection form. Preoperatively, the severity of LBP and radicular pain in patients was assessed using the Vanguard Australian Shares (VAS) Index (score zero: painless to score 10: most severe pain) [Table 1].

Reduction was assessed according to The Meyerding classification [Figure 3].[24]

The Meyerding classification defines the amount of vertebral slippage on X-ray in reference to the caudal vertebrae.

There are five grades of spondylolisthesis in the Meyerding classification. Grade I is <25% slippage, Grade II is 26%–50% slippage, Grade III is 51%–75% slippage, grade IV is 76%–100% slippage, and Grade V is over 100% slippage and is referred to as spondyloptosis.
Other symptoms of the disease were determined in the examination of patients and the result was recorded in the data collection form. After surgery and completion of the hospitalization period and after providing care training to the patient and his companions, patients were asked to come at the specified time intervals (1 month, 3 months, and 6 months after the surgery) for re-evaluation and additional examinations. After referral at the mentioned time intervals, the severity of LBP and radicular pain and complications of the operation such as infection and bleeding and the percentage of reduction were assessed by X-ray. Finally, patients’ Quality of life was determined by a Health Survey Short Form (SF-12) from questionnaire the patients before and 6 months after the operation.

The SF-12 is a self-administered questionnaire, which measures health status. Responses to questions are dichotomous (yes/no), ordinal (excellent to poor), or expressed by a frequency (always to never). The answers to this 12-item questionnaire allow calculation of Physical Component Summary and a Mental Component Summary scores. In the absence of response to a single question of these subscales, the score cannot be calculated. The higher the score, the better the health status.\textsuperscript{[25]}

To determine the frequency tables, number and percentage indices were used for qualitative variables, and for quantitative variables mean and standard deviation were used. Due to the normal distribution of quantitative variables, repeated measure ANOVA, paired sample t-test, and independent samples t-test and to determine the relationship between qualitative variables, the Pearson Chi-squared test and Fisher’s exact test were used. Statistical analyses were performed using SPSS software version 21. In this study, a statistically significant level of 0.05 was considered.

**RESULTS**

In this clinical trial study, 70 patients were randomly assigned to the two groups of vertebral fusion treatment L4-L5-S1 and L5-S1. Twelve men (34.3%) and 23 women (65.7%) were in the L4-L5-S1 group and 13 men (37.1%) and 22 women (62.9%) were in the L5-S1 group. The mean age in the L4-L5-S1 group is 61.28 with a standard deviation of 7.94 years and in the L5-S1 group is 58 with a standard deviation of 7.13 years. Furthermore, the body mass index in L4-L5-S1 group is 25.40 with a standard deviation of 5.41. In this study, BMI, gender, age, heights, and weight were homogeneous in both groups [Table 2].

According to independent t-test regarding the Intensity of radicular pain before the intervention, there was no significant difference between the two groups ($P = 0.342$). As well as 1 month ($P = 0.195$), 3 months ($P = 0.593$), and 6 months after the intervention ($P = 1.000$), the Intensity of Radicular Pain was not significantly in two groups. Repeated measures ANOVA showed that the mean Intensity of Radicular Pain differed significantly between different times in two groups ($P = 0.0001$) [Table 3].

The results showed according to independent t-test regarding the severe back pain before the intervention, there was no significant difference between the two groups ($P = 0.506$). As well as 1 month ($P = 0.865$), 3 months ($P = 0.860$), and 6 months after the intervention ($P = 0.337$), the Severe Back Pain was not significantly in two groups. Repeated measures ANOVA showed that the mean Severe Back Pain differed significantly between different times in two groups ($P = 0.0001$) [Table 3].

Furthermore, bleeding during and after surgery in L5-S1 group was significantly less than L4-L5-S1 group ($P < 0.05$).
Meanwhile, the percentage of reduction in L4-L5-S1 treatment group is significantly higher than the percentage of reduction in L5-S1 treatment group \( (P < 0.05) \) [Table 4].

Of patients, 8.6% in the L4-L5-S1 treatment group and 2.9% in the L5-S1 treatment group became infected. The results of statistical tests showed that the type of group therapy and the prevalence of infection in patients were not significantly related \( (P > 0.05) \) [Table 4].

Results of numeric mental and physical scores of the SF-12 in patients with two groups are presented in Table 5. There were no significant differences in both mental and physical numeric scores \( (P > 0.05, \text{ for both scores}) \) between patients with L4-L5-S1 and L5-S1 treatment group. However, there were a significant differences in both mental and physical numeric scores \( (P < 0.05, \text{ for both scores}) \) between score before and after 6 months in two groups.

**DISCUSSION**

Spondyloolisthesis refers to degenerative changes in the spine that are often treated with supportive therapies...
and in severe cases requires surgical intervention\textsuperscript{[26]} and remains a challenge for orthopedic surgeons, neurosurgeons and pediatrics\textsuperscript{[27]}. The optimal treatment of high-grade spondylolisthesis is a controversial issue. It is well known that symptomatic high-grade slip, resistant to conservative management requires surgical stabilization.\textsuperscript{[28]}

The classification system proposed by Spinal Deformity Study Group is practical and easy to apply and should be used and more studied in our country. The purpose of this classification emphasizes that patients with spondylolisthesis L5/S1 form a heterogeneous group with several postural adjustments and that this should be considered by physicians when indicating any type of treatment.\textsuperscript{[29]}

Minamide et al., 18 fresh human cadaveric (age 59–88 years) L5–S1 motion segments were obtained. There were no differences in stiffness between transdiscal fixation and combined interbody/PS fixation. Spondylolisthesis was then simulated by displacing L5 on S1 (% slip average = 41.3%) were more likely to present research (57.89%) findings.\textsuperscript{[30]}

Thomas et al., the rate of failure of indirect decompression in lateral single-position surgery from L4 to S1 is exceedingly low. This low risk of failure should be weighed against the risks associated with direct decompression as well as the risks of the extra operative time needed to perform this decompression.\textsuperscript{[31]}

In the study of Wang et al.,\textsuperscript{[32]} the fixation of two vertebral surface with the fixation of three vertebral surfaces in fusion operation by the spinal device in groups of patients with spondylolisthesis grades 1 and 2 was examined and compared. Recovery time in the two-level stabilization group was significantly longer than one-level fixation. In our study, the recovery time was the same in both methods.

In the study of Ames et al.,\textsuperscript{[33]} the effect of vertebral device level in improving the symptoms of spondylolisthesis was studied. Implantation of pedicular screws did not have a significant effect on the amount and duration of recovery.

In his study, Farzanegan\textsuperscript{[34]} evaluated 48 patients with spondylolisthesis who underwent fixation surgery with CD-type pedicular screws over a period of 3 years for the improvement of symptoms as well as postoperative complications and stated that lumbar fusion in the above method resulted in proper performance, patient satisfaction and a low percentage of complications, which is consistent with the results of our study.

The goals for surgical correction of high-grade spondylolisthesis are to arrest the progression of listhesis, achieve decompression of neural elements, and prevent a worsening slip angle. Any reductive technique of high-grade spondylolisthesis is controversial.

All reported that although fusion and reduction achieve a higher rate of fusion, this does not necessarily lead to better clinical or functional outcomes.

To the best of our knowledge, no other studies have been published reporting the use of L4-L5-S1 and L5-S1 vertebral fusion in adolescents with high-grade L5-S1 spondylolisthesis and the patient in our report demonstrated Decrease low-back pain and radicular pain in two groups.

This study has several limitations. A possible reason was that follow-up periods were not long enough to confirm the results. Further multicenter studies with more patients and longer follow-up should be performed.

CONCLUSION

According to the results of this study, the intensity index of radicular pain and the severity of LBP and infection rate were almost the same in L4-L5-S1 and L5-S1 vertebral fusion at each time, and there was no significant advantage in either group. Bleeding during and after surgery in L5-S1 group was significantly less than L4-L5-S1 group. Furthermore, the percentage of reduction in L4-L5-S1 treatment group is significantly higher than the reduction rate in L5-S1 treatment group. Finally, there were no significant differences in both mental and physical numeric scores between patients with two groups.

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Conflicts of interest

There are no conflicts of interest.

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