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ORIGINAL ARTICLE

Failure to maintain segmental lordosis during TLIF for one-level degenerative spondylolisthesis negatively affects clinical outcome 5 years postoperatively: a prospective cohort of 57 patients

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Abstract

Purpose The present study aimed to determine whether obtaining adequate lumbar (LL) or segmental (SL) lordosis during instrumented TLIF for one-level degenerative spondylolisthesis affects midterm clinical outcome.

Methods The study was designed as a prospective one, including 57 patients who underwent single-level TLIF surgery for degenerative spondylolisthesis. Patients were analyzed globally with additional subgroup analysis according to pelvic incidence (PI). Radiographic analysis of spinopelvic sagittal parameters was conducted pre- and postoperatively. Clinical examination including ODI score was performed preoperatively, 1 and 5 years postoperatively.

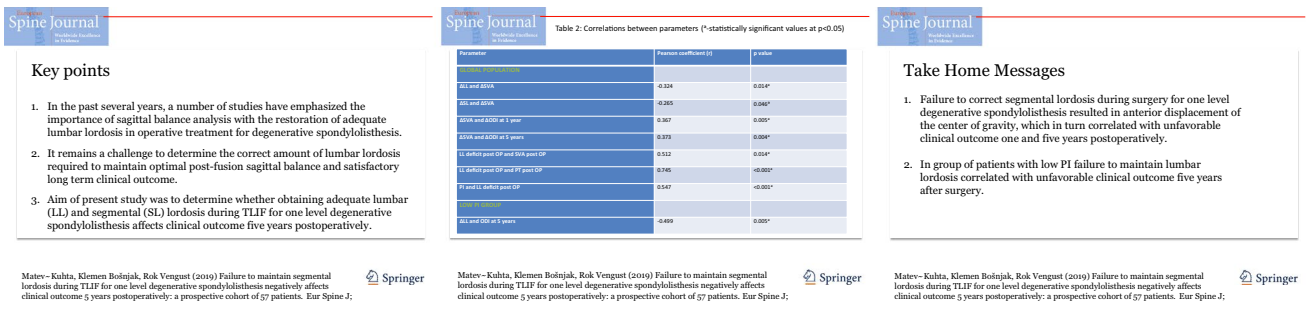
Results Significant improvement in ODI scores at 1 and 5 years postoperatively ($p < 0.001$) was demonstrated. There was a significant correlation between anterior shift of SVA and failure to improve SL ($p = 0.046$). Moreover, anterior SVA shift correlated with increased values of ODI score both 1 and 5 years postoperatively. In low-PI group, failure to correct LL correlated with high ODI scores 5 years postoperatively ($r = -0.499$, $p = 0.005$).

Conclusions Failure to correct segmental lordosis during surgery for one-level degenerative spondylolisthesis resulted in anterior displacement of the center of gravity, which in turn correlated with unfavorable clinical outcome 1 and 5 years postoperatively. In patients with low PI, failure to maintain lumbar lordosis correlated with unfavorable clinical outcome 5 years after surgery.

Level of evidence II.

Graphical abstract

These slides can be retrieved under Electronic Supplementary Material.



Keywords Sagittal balance · TLIF · Degenerative spondylolisthesis · Segmental lordosis · Clinical outcomes

Electronic supplementary material The online version of this article (https://doi.org/10.1007/s00586-019-05890-w) contains supplementary material, which is available to authorized users.

Extended author information available on the last page of the article

Introduction

As the spine ages, it becomes subjected to degenerative changes that can result in progressive loss of lumbar lordosis, forward inclination of the trunk with chronic low back pain and frank sagittal imbalance [1, 2].

In the past several years, a number of studies have emerged that highlight the importance of sagittal balance analysis with the restoration of adequate lumbar lordosis in surgical procedures for different degenerative pathology [3–6]. Failure to reach proper sagittal balance can result in compensatory mechanisms such as increased pelvic tilt (PT), cervical and thoracic segment hyperextension, and knee flexion, which can in turn have adverse effects such as muscle fatigue, leading to chronic back pain and disability [1, 4]. It remains a challenge, however, to determine the correct amount of lumbar lordosis that is required to maintain optimal post-fusion sagittal balance [3, 7, 8].

TLIF is one among several fusion techniques to address single-level lumbar degenerative disease [9, 10]. Several studies have compared sagittal parameters and functional outcomes in single-level TLIF surgery on short term, four of which have been published within the last 2 years [5, 6, 10, 11]. Nevertheless, there is little published information regarding cohorts with long-term evaluation [12, 13]. Moreover, in most literature reports, the fusion was performed at different lumbar levels [5, 6, 11, 12].

With the present study, we aimed to analyze clinical outcomes in patients who underwent a TLIF procedure for single-level degenerative spondylolisthesis limited to levels *L*3/4 and *L*4/5 with a follow-up of 5 years.

Methods

This prospective cohort study was performed between March 2011 and December 2013 in a single institution. Fifty-seven consecutive patients with or without decompression underwent a single-level instrumented TLIF for *L*3/4 (8 subjects) or *L*4/5 (49 subjects) degenerative spondylolisthesis. The mean age of 36 female and 21 male participants at the time of surgery was 66.7 ± 9.8 years. The exclusion criteria were: history of previous spinal surgery or spinal trauma, inflammatory conditions, flexion contractures of the hips or knees, degenerative spondylolisthesis at more than one level, and additional types of adult spinal deformity.

Compliance with ethical standards

All procedures involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Surgical procedure

All patients were operated by three senior spinal surgeons. In knee-chest position, a single-level instrumented TLIF was performed using polyaxial pedicle screws (Xia 3®, Stryker) and crescent-shaped interbody cage (Boomerang®, Medtronic, Minneapolis, MN; T-Plus®, RTI Surgical). Decompression of lateral recess/foramina was performed in case of significant stenosis. Osteotomy of the endplates was performed in anterior portions of endplates followed by insertion of morcellized bone obtained by approach/decompression mixed with bone graft substitute (Actifuse®, Baxter). Interbody cage of maximal feasible height was placed posterior to bone grafts. To complete the procedure, compression over the rods was performed to obtain maximal segmental lordosis.

Clinical and radiographic analysis

Patients were examined clinically preoperatively, at 1 and 5 years postoperatively. At the same checkpoints, ODI questionnaires were administered.

Radiographic parameters were analyzed preoperatively and 2 or 3 days postoperatively. Full-standing lateral radiographs as proposed by Morovan et al. [14] were used for the analysis. Images were imported and analyzed by ArchiCAD v 19.0 software by single surgeon (Fig. 1). The parameters measured were: lumbar lordosis (LL), segmental lordosis (SL), sagittal vertical axis (SVA), pelvic incidence (PI), pelvic tilt (PT) and sacral slope (SS) [15]. To obtain delta values (Δ), preoperative values were subtracted from their subsequent postoperative counterparts (postoperative value minus preoperative value). ΔODI was calculated as a change in ODI score for both 1 and 5 years postoperatively. ΔSL, ΔLL, ΔSVA, ΔPT, and ΔSS were calculated as a change in SL, LL, SVA, PT, and SS, respectively.

The new LL deficit parameter was calculated by subtracting LL from ideal LL (LL = PI + 9) according to Schwab [16].

Analysis comprised global analysis, where all subjects were analyzed, and a subgroup analysis according to patient's PI value. The mean value of PI in total sample was 56.2° ± 11.3°; therefore, this value was used to divide patients in two groups: high- and low-PI group. There were 30 patients in low-PI group and 27 patients in high-PI group.

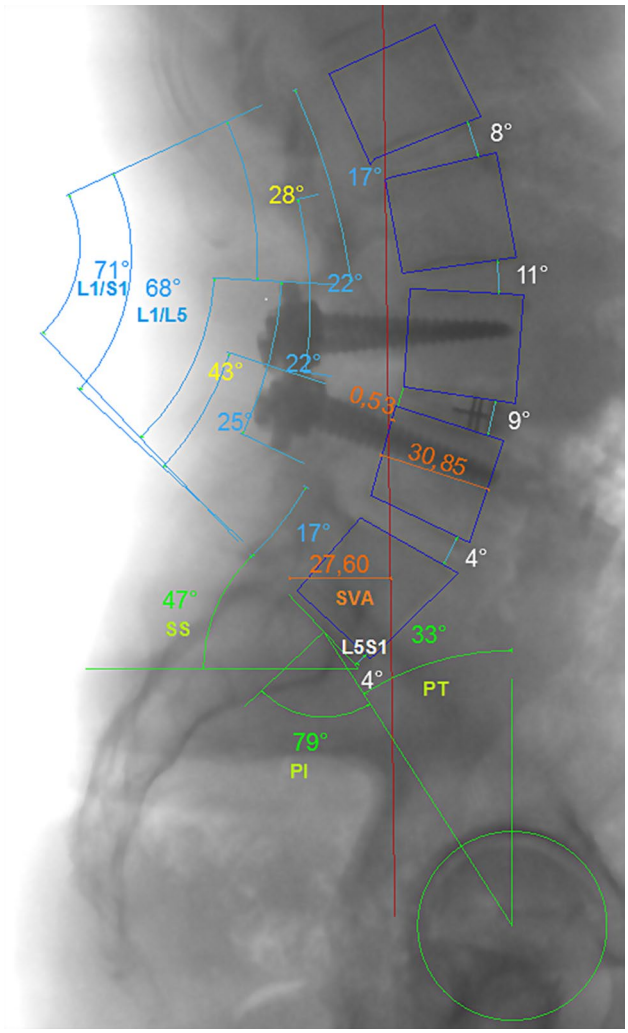


Fig. 1 Example of measured parameters using computer software

Statistical analysis

The analyses were conducted using SPSS for Windows 20.0 software. Paired *t* test and Pearson correlation were used. All statistical tests were two tailed and significance was set at $p < 0.05$.

Results

Global population analysis

After TLIF procedure, there was a significant improvement in ODI scores at 1 and 5 years postoperatively ($p < 0.001$) (Table 1). Mean increase in SL and LL deficit were 0.4° and 1.5°, respectively, while LL was lowered by 1.5°. Neither of the differences was statistically significant. On the other hand, a significant anterior shift of the vertical axis from 3.1 to 18.9 mm was noted postoperatively ($p < 0.002$) (Table 1).

Table 1 Global population spinopelvic and clinical outcome parameters

	Preoperative	Postoperative	*p* value
ODI	52.5 ± 14.0		
ODI at 1 year		32.3 ± 18.2	< 0.001[a]
ODI at 5 years		35.9 ± 18.1	< 0.001[a]
LL	48.5° ± 12.4°	47.0° ± 10.2°	0.071
SL	18.0° ± 8.7°	18.4° ± 7.9°	0.559
SVA	3.1 mm ± 39.2 mm	18.9 mm ± 31.2 mm	0.002[a]
PT	25.1° ± 7.9°	24.9° ± 7.4°	0.784
SS	30.9° ± 9.6°	31.3° ± 9.1°	0.528
LL deficit	16.7° ± 12.1°	18.2° ± 10.6°	0.071

[a]Statistically significant values at $p < 0.05$

Global analysis of correlation

Significant correlations between the anterior shift of SVA and increased values of ODI scores, both 1 and 5 years postoperatively, were found in our series (Table 2). Furthermore, there was a significant correlation between anterior shift of SVA and failure to improve SL ($p = 0.046$) or LL ($p = 0.014$). There was also a significant correlation between LL deficit values and postoperative anterior shifting of SVA ($p = 0.014$) or postoperative increase in PT ($p < 0.001$). Higher PI angle correlated with higher LL deficit values (Table 2).

Subgroup analysis according to PI

Analyses showed significant improvement in ODI scores for both high- and low-PI groups, although without significant differences between them.

In a group with lower PI (Fig. 2a, b), better postoperative values of lumbar lordosis were achieved (with no

Table 2 Correlations between parameters in global population

Parameter	Pearson coefficient (*r*)	*p* value
ΔSVA and ΔODI at 1 year	0.367	0.005[a]
ΔSVA and ΔODI at 5 years	0.373	0.004[a]
ΔSVA and ΔLL	−0.324	0.014[a]
ΔSVA and ΔSL	−0.265	0.046[a]
ΔLL deficit and ΔSVA	0.324	0.014[a]
ΔLL deficit and ΔPT	0.803	< 0.001[a]
ΔLL deficit and ΔSS	−0.771	< 0.001[a]
LL deficit postoperatively and PI	0.547	< 0.001[a]

[a]Statistically significant values at $p < 0.05$

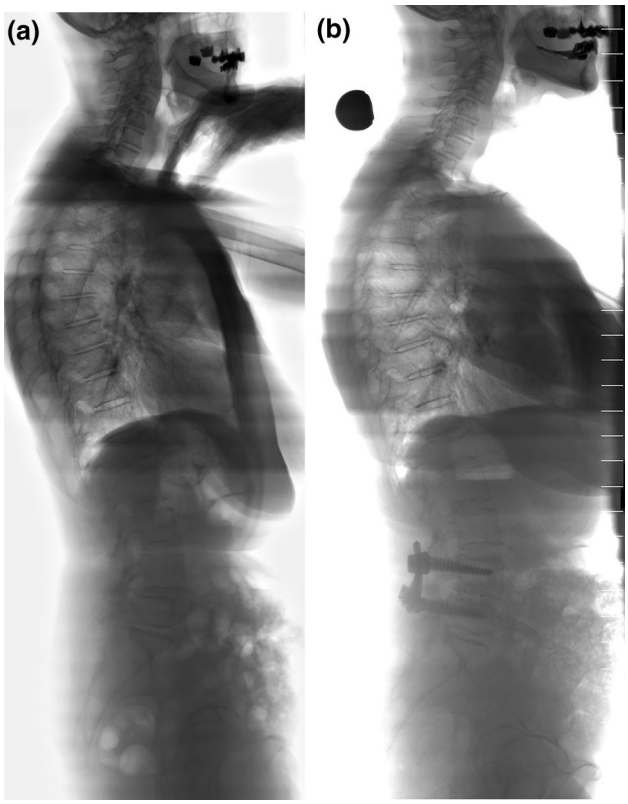


Fig. 2 **a** A patient with *L4L5* degenerative spondylolisthesis from low PI group (PI 47°) before surgery. **b** Same patient after the procedure; LL increased from 30° preoperatively to 37° postoperatively

Table 3 Correlations between parameters in group with low PI

	ΔODI 1 year		ΔODI 5 years	
	Pearson coefficient (*r*)	*p* value	Pearson coefficient (*r*)	*p* value
ΔLL	−0.147	0.437	−0.499	0.005[a]
ΔSL	−0.024	0.889	0.069	0.717
ΔSVA	0.311	0.094	0.240	0.201
ΔPT	−0.072	0.704	0.359	0.052
ΔSS	0.040	0.836	−0.355	0.054

[a]Statistically significant values at $p < 0.05$

change in LL deficit, from 13.9° ± 10.4°, to 14.1° ± 9.1°; $p = 0.82$), when compared to a group with high PI (LL deficit increased from 19.9° ± 13.3° to 22.7° ± 10.3°; $p = 0.03$). Failure to correct LL significantly correlated with anterior shift of SVA ($r = -0.371$, $p = 0.044$) and compensatory increase of PT ($r = -0.831$, $p < 0.001$). Failure to correct LL correlated significantly with high ODI scores 5 years postoperatively ($r = -0.499$, $p = 0.005$) (Table 3).

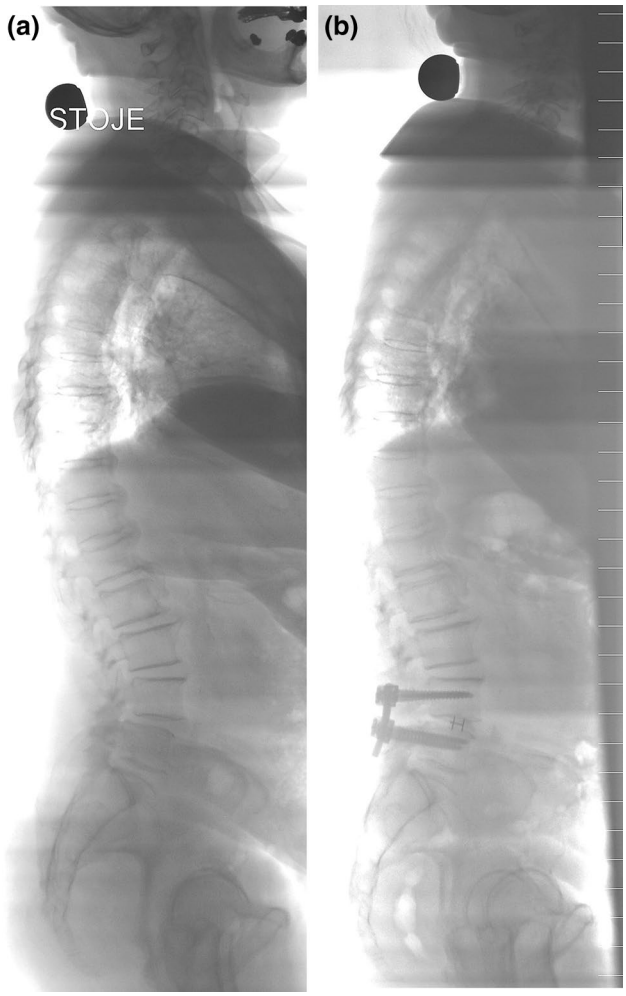


Fig. 3 **a** A patient with *L4L5* degenerative spondylolisthesis from high-PI group (PI 61°) before surgery. **b** Same patient after the procedure; LL decreased from 39° preoperatively to 37° postoperatively

Table 4 Correlations between parameters in group with high PI

	ΔODI 1 year		ΔODI 5 years	
	Pearson coefficient (*r*)	*p* value	Pearson coefficient (*r*)	*p* value
ΔLL	−0.197	0.326	0.003	0.990
ΔSL	0.087	0.667	0.228	0.254
ΔSVA	0.436	0.023[a]	0.510	0.007[a]
ΔPT	−0.027	0.895	−0.303	0.125
ΔSS	0.041	0.837	0.268	0.177

[a]Statistically significant values at $p < 0.05$

In higher-PI group (Fig. 3a, b), anterior shift of SVA correlated with increased ODI scores at 1 year ($r = 0.436$, $p = 0.023$) and at 5 years postoperatively ($r = 0.510$, $p = 0.007$) (Table 4).

Discussion

Present study demonstrated marked clinical improvement after instrumented TLIF for one-level degenerative spondylolisthesis with significant improvement in ODI scores that are comparable to the results published by other studies [6, 12]. Several reports analyzed sagittal balance after lumbar fusion for degenerative spine conditions [5, 8, 10, 11]. There is no study, however, analyzing clinical results after TLIF for one-level degenerative spondylolisthesis by stratifying the population as a function of pelvic incidence as proposed by Le Huec et al. [4]. Using the subgroup analysis, we managed to demonstrate that failure to obtain operative correction of lumbar lordosis in patients with low PI correlates negatively with clinical outcome 5 years after surgery ($p = 0.005$). The tendency toward unfavorable clinical outcome 5 years postoperatively was also demonstrated in global population, but not quite reaching statistical significance ($p = 0.061$). On the other hand, no connection between lumbar lordosis and clinical outcome could be demonstrated in patients with high PI. As shown in literature and additionally confirmed by our series, patients with higher PI are frequently undercorrected [4, 17]. This is consistent with findings of Coignet et al. [18] who demonstrated that it is more difficult to obtain optimal sagittal parameters in patients with larger PI. Presumption could therefore be made, as also suggested by LeHuec [4], that patients with higher PI need more lumbar lordosis correction, but have on the other hand more space for compensatory pelvic retroversion when undercorrected and/or have other variables that affect long-term clinical outcome.

The correlation between operative lordosis correction and clinical outcome in patients with small value of PI could be demonstrated only 5 years after surgery, while no such correlation was noted 1 year postoperatively. This again suggests that lumbar lordosis presents a significant determinant of clinical outcome, which only shows itself after longer periods of time, as already pointed out by other studies [3, 12]. As opposed to global lordosis gain, we were unable to demonstrate any correlation between segmental lordosis gain and clinical outcome 1 or 5 years after surgery. It is estimated that there are other factors, besides operative gain of segmental lordosis, that affect lumbar lordosis after surgery such as remaining spinal stenosis at non-operated levels, mechanical back pain, pathology of the hips and possibly others, which were not controlled in present study.

It is proposed that gain of segmental lordosis in PLIF and TLIF surgery depends on placement of cage relative to anterior annulus; the more anterior a cage is placed the greater is the gain of segmental lordosis that could be achieved [19–21]. Some authors even advocate use of monoaksial screws to obtain more lordosis of a segment [3, 19, 22]. In our series, a cage was put posterior to bone grafts, which precluded creation of optimal segmental lordosis. This is why postoperative increment of SL was comparable to values reported in some studies Cheng et al. [6] at 0.5°, Liang et al. [12] at 0.9° but not with others, which demonstrated higher operative SL gains: Tye et al. [5] at 5.7°, Mourad Olud-Slimane et al. [19] at 8.1°, Galla et al. [11] at 5.7°.

As anticipated, SVA in our series was found a single most important determinant of clinical outcome, with postoperative anterior shift negatively affecting clinical results 1 and 5 years postoperatively. Awareness that failure to correct SL correlates with anterior shift of SVA ($p = 0.046$), once again underlines the importance of surgical correction of segmental lordosis. Based on the results of the study, we changed our clinical praxis in PLIF and TLIF procedures by placing a cage as far anteriorly as possible thereby enabling the creation of maximal segmental lordosis.

There were limitations to the study. A small cohort of patients was included and no thoracolumbar, head-pelvis or lower extremities alignment parameters were evaluated. Amabile et al. [23] recently demonstrated the use of head-pelvic parameters, as they proved to be more specific in the global sagittal alignment evaluation. In this study, no measurements of adjacent segment sagittal parameters were performed nor perioperatively neither at latest follow-up. Long-term radiographic evaluation of neighboring segments compared to operative correction and clinical outcome could pose a further insight into natural history of post-fusion lumbar spine and remains to be a subject of further studies.

Conclusion

Results of present study indicate that operative undercorrection of segmental lordosis leads to anterior shift of SVA which in turn negatively affects clinical results both 1 and 5 years after surgery for one-level degenerative spondylolisthesis. In patients with low PI, postoperative decrease in lumbar lordosis negatively affects clinical results 5 years postoperatively.

Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

Ethical standards All procedures were in accordance with ethical standards of the National ethics committee of Slovenia on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Informed consent Informed consent was obtained from all patients for being included in the study.

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