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Correlation of reduction and clinical outcome in patients with degenerative spondylolisthesis

K. Wegmann · S. Gundermann · J. Siewe · P. Eysel · K.-S. Delank · R. Sobottke

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Abstract
Study design Prospective cohort study.
Introduction Operative treatment is increasingly implemented for the treatment of degenerative lumbar listhesis, with lumbar fusion the most common intervention. Prediction of clinical outcomes after such procedures is of ongoing relevance, and the correlation of radiologic parameters with clinical outcome remains controversial. In particular, clinical studies have not determined conclusively whether reduction of slipped vertebrae is beneficial.
Methods We performed a monocenter prospective analysis of a comprehensive set of quality of life scores (QLS) (Core Outcome Measure Index, Oswestry Low Back Pain Disability Index, SF-36) of 40 patients, who underwent a standardized PLIF procedure for symptomatic, Spondylolisthesis. Follow-up was 24 months. The correlations between the radiologic parameters (degree of slippage, sagittal rotation) and the clinical scores before surgery as well as 12 and 24 months post-operatively were examined.
Results All QLS showed a statistically significant improvement after 12 and 24 months post-operatively ($p < 0.05$). The mean amount of the anterior slippage was 34.2 ± 14.7 % (minimum 12 %, maximum 78 %). After 12 months, there was an average 19.1 % decrease to 15.1 ± 8.3 % (minimum 2 %, maximum 38 %, $p < 0.000$) and after 24 months it was decreased by 18.0–16.2 ± 9.0 % (minimum 2.9 %, maximum 40 %, $p < 0.000$). Average sagittal rotation measured 67.3° ± 16.6° initially (minimum 35°, maximum 118) and decreased by 4.3° to an average of 63.0° ± 15.2° at 12 months post-surgery (minimum 15°, maximum 101°, $p = 0.065$,), and by 5.7° to an average of 61.6° ± 13.0° at 24 months (minimum 15°, maximum 90°, $p = 0.044$). The data show positive correlations between the amount of reduction of the slipped vertebra as well as the amount of correction of the sagittal rotation and the improvement of the clinical outcomes($r = 0.31$–0.54, $p < 0.05$).
Conclusion The current study indicates a modest advantage for the best possible reposition in respect of the clinical outcome.

Keywords Degenerative spondylolisthesis · Sagittal alignment · Amount of reduction · Quality of life scores · PLIF

Introduction

In industrialized nations, the prevalence of degenerative spondylolisthesis increases along with the life expectancy of the population [1]. However, the etiology of the disease is not fully understood. A number of potential causative factors have been presented, such as pelvic incidence, disc height, lumbar index, age and gender [1–3]. Degenerative spondylolisthesis is typically associated with chronic low back pain, and in severe states, with neurologic dysfunction of the lower extremities. In addition to conservative measures, operative therapy for this pathology has been increasingly implemented, with lumbar fusion the most common

K. Wegmann (✉) · S. Gundermann · J. Siewe · P. Eysel
Centre for Orthopaedic and Trauma Surgery, University Medical Center, Josef-Stelzmann-Str.9, Cologne 50924, Germany
e-mail: kilian.wegmann@uk-koeln.de

K.-S. Delank
Department of Orthopaedic and Trauma Surgery, Martin Luther University Halle-Wittenberg, Halle, Germany

R. Sobottke
Department of Orthopedic and Trauma Surgery, Medizinisches Zentrum StädteRegion Aachen, Würselen, Germany

intervention [4–7]. The clinical outcome of this surgical treatment depends on multiple factors. To predict clinical results after operative treatment of isthmic listhesis, a number of studies have been conducted to identify parameters correlating with outcomes. In a recent prospective study, Bourghli et al. [8] showed that the restoration of the appropriate spino-pelvic parameters was clearly correlated with good clinical outcomes according to the Oswestry Low Back Pain Disability Index (ODI). Bourghli did evaluate the pelvic parameters, but did not, however, correlate the degree of slippage and the sagittal rotation at the defect segment with the clinical outcome.

Concerning degenerative listhesis, Sears [9] analyzed the impact of the reduction of slippage on the clinical outcome in 2005. The author, however, analyzed only 17 patients radiographically and found no correlation between radiological and clinical values. Hence, comparatively little is known about the correlations between the reduction of slipped vertebrae and the corresponding clinical values.

Thus, the aim of the present study was to statistically correlate Core Outcome Measure Index (COMI), ODI and SF36 with specific radiological parameters, and to assess the impact of the amount of pathologic alignment reduction on clinical outcomes for patients after lumbar fusion of degenerative spondylolisthesis. We hypothesized that reduction of anterior displacement and sagittal malrotation would positively correlate with the amelioration of the clinical outcomes. To the best of our knowledge, no study to date has examined the correlation of the amount of reduction with three quality of life scores (QLS).

Materials and methods

Patients

This prospective study focused on patients from one specialty spine unit undergoing instrumented lumbar fusion for single segment degenerative spondylolisthesis, after at least 3 months of conservative therapy yielding no improvement of clinical symptoms. The surgical procedures were conducted between February 2007 and January 2010.

Inclusion criteria: (1) single-level degenerative lumbar spondylolisthesis of L4/5 or L5/S1, (2) treatment with standard posterior lumbar interbody fusion (PLIF procedure: ART I screws©, Wave Cages (PEEK)©, AMT Nonnweiler, Germany), and (3) clinical and radiological follow-up of at least 24 months, (4) participant capable of German language.

Exclusion criteria: (1) multi-segmental lumbar instability, meaning pathology of more than one segment with instability and slippage, (2) previous lumbar spine surgery, and (3) systemic or local infection, (4) malignancy, (5) chemotherapy, (6) immunosuppression, (7) severe osteoporosis, (8) vertebral fracture, (9) paresis, (10) inability to reply to the quality of life forms.

43 patients, with an average age of 55.5 ± 14.9 years met these criteria. There were 28 female and 15 male patients. The patients were enrolled in a monocenter database, set up for Spine Tango-data acquisition. The maximum follow-up was 24 months, including evaluations pre-operatively as well as at 12 and 24 months post-operatively.

Evaluation of clinical and radiological parameters

To evaluate the pre- and post-operative quality of life, the following scores were used: ODI, COMI, SF-36 Physical Component Summary Score, and the SF-36 Mental Component Summary Score. These scores are recommended for the use in the clinical follow-up of patients with spinal disorder and display excellent psychometric characteristics [10–13].

The radiological evaluation was performed by the same examiner, using standing plain radiographs in a lateral and AP view. Two radiological parameters were measured. Sagittal rotation represents the angular relationship between the slipped and resting vertebrae (Figs. 1, 2) [14]. The extent of anterior displacement was measured using Boxall's method, by calculating the percentage of slippage in relation to vertebral body length (Figs. 1, 2) [15].

Post-operative radiographs were also examined for signs of nonunion, i.e. radiolucent lines, changes of implant position and pseudarthrosis.

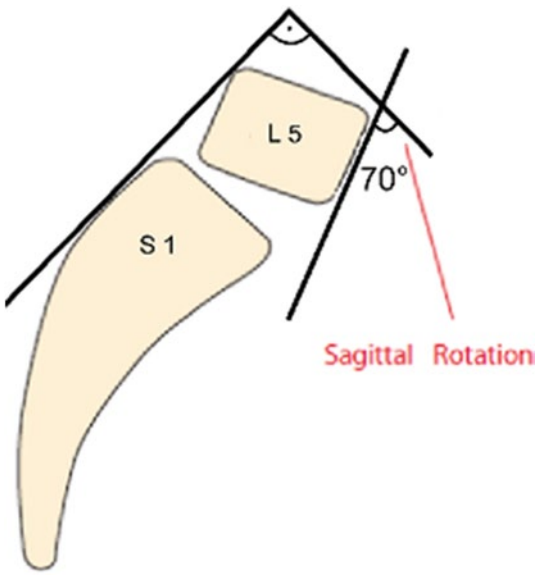

Fig. 1 Schematic illustration of the radiographic parameters that were used in the present study

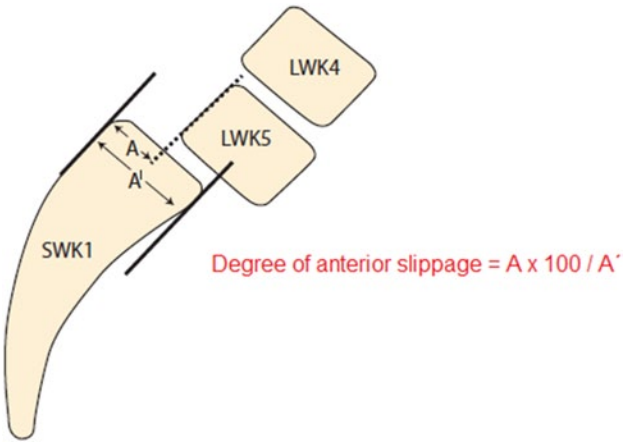

Fig. 2 Schematic illustration of the radiographic parameters that were used in the present study

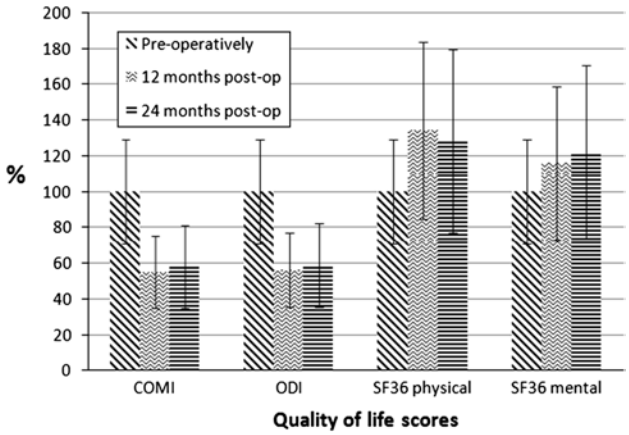

Fig. 3 Quality of life scores before and 12 and 24 months after surgery. Data are given in percent of the pre-operative scores

Statistical analysis

Statistical calculations were performed with SPSS software (SPSS Inc., Chicago, IL, USA). The significance of the changes of the different parameters between pre- and post-OP was calculated using the paired *t* test. The level of significance was set aft $p < 0.05$. To determine which radiologic parameters correlated with the post-operative clinical results, a correlation analysis was performed using the Spearman-Rho bi-serial test. The changes of the values of the radiological parameters before and after surgery were correlated with the corresponding changes in the clinical scores, to display a possible cohesion.

Results

Of the 43 included patients, three were lost to follow-up. 40 patients completed 12 (±0.7) and 24 (±1.8) months of clinical and radiological follow-up.

Within the study group no nonunion/pseudarthrosis was found.

Quality of life scores

The *p* values describe whether the changes of the data from pre- to post-operative were statistically significant. There was a significant ($p < 0.05$) improvement of all QLS after 12 and 24 months (Fig. 3). Before surgery, the average COMI score was 7.7 ± 1.4 points (minimum 2.7, maximum 9.8). At 12 months, the average dropped by 3.3 to a score of 4.4 ± 2.9 (minimum 0, maximum 9.6, $p < 0.000$), and at 24 months it remained at 4.4 ± 3.0 (minimum 0, maximum 9.4, $p < 0.000$). Initially, the ODI averaged 48.3 ± 16.2 (minimum 10, maximum 88). At 12 months post-surgery, the average dropped 20.6 points to 27.7 ± 21.4 (minimum 0, maximum 72, $p < 0.000$) and at 24 months by 19.0 points to 29.3 ± 22.3 (minimum 0, maximum 80, $p < 0.000$). Pre-operatively, the average SF 36 Physical Component Summary Score was 30.2 ± 6.5 (minimum 16.9, maximum 48.9). It increased 9.0 points to 39.2 ± 10.9 at 12 months (minimum 8.1, maximum 65.8, $p < 0.000$), and 8.4 points to 38.6 ± 13.3 at 24 months (minimum 13.6, maximum 60.1, $p < 0.000$). Before surgery, the SF 36 Mental Component Summary Score averaged 39.5 ± 14.3 (minimum 8, maximum 67.8). It increased by 7.1 points to an average 46.6 ± 14.0 at 12 months post-surgery (minimum 5.3, maximum 68.8, $p = 0.003$), and by 7.9 points to 47.4 ± 13.4 at 24 months (minimum 17.1, maximum 73.1, $p < 0.001$).

Radiological parameters

The *p* values describe whether the changes of the data from pre- to post-operative were statistically significant. Regarding the severity of the listhesis, nine patients (22.1 %) presented as Meyerding Grade I and with an anterior slippage measurement less than 25 %. 25 Patients (63 %) were classified as Grade II, 5 (12.3 %) as Grade III, and 1 (2.5 %) as Grade IV. Before surgery, the magnitude of anterior displacement of the slipped vertebra averaged 34.2 ± 14.7 % (minimum 12 %, maximum 78 %). This changed significantly post-operatively. After 12 months, there was an average 19.1 % decrease to 15.1 ± 8.3 % (minimum 2 %, maximum 38 %, $p < 0.000$) and after 24 months it was decreased by 18.0–16.2 ± 9.0 % (minimum 2.9 %, maximum 40 %, $p < 0.000$). This shows a loss of reduction over the 24 month follow-up of 1.1 percentage points, representing a change of 7.3 %, which we explain with tipping of the polyaxial screws. Average sagittal rotation measured 67.3° ± 16.6° initially (minimum 35°, maximum 118°).

That value decreased by 4.3° to an average of 63.0° ± 15.2° at 12 months post-surgery (minimum 15°, maximum 101°, $p = 0.065$,), and by 5.7° to an average of 61.6° ± 13.0° at 24 months (minimum 15°, maximum 90°, $p = 0.044$).

Correlations of clinical and radiological parameters

We statistically analyzed the correlation between the changes of the values of the pre- and post-operative clinical and radiological parameters. The data showed modest correlations between the COMI score and reduction of anterior displacement as well as reduction of sagittal rotation, at 12 months ($r = 0.427$, $r = 0.540$, respectively, $p < 0.01$) and 24 months post-operatively ($r = 0.414$, $r = 0.402$, respectively, $p < 0.025$) (Tables 1, 2). We also identified modest correlations between ODI score and reductions of anterior displacement and sagittal rotation, at 12 months ($r = 0.311$, $r = 0.286$, respectively, $p < 0.02$) and 24 months post-operatively ($r = 0.374$, $r = 0.370$, respectively, $p < 0.02$). There were modest correlations between the SF 36 Physical Component Summary Score and reductions in the anterior displacement and sagittal rotation, at 12 months ($r = 0.382$, $r = 0.290$, respectively, $p < 0.01$) and 24 months ($r = 0.404$, $r = 0.353$, respectively, $p < 0.01$). There was no significant correlation between the SF 36 Mental Component Summary Score and the reductions in anterior displacement and sagittal rotation, at 12 months ($r = 0.026$, $r = 0.081$, respectively, $p > 0.5$) and 24 months ($r = 0.089$, $r = 0.111$, respectively, $p > 0.5$) post-operatively.

Discussion

Summarizing the present data, we conclude that reduction, and not only in situ fixation of the slipped vertebra,

Table 1 Correlations of the clinical and radiological parameters 12 months after surgery ($n = 40$)

COMI 12 months	ODI	SF 36 phys.	SF 36 mental	Anterior displ.	Sagittal rot.
Correlation coeff.	0.608	−0.586	−0.226	0.427	0.540
p	0.000	0.000	0.161	0.006	0.000
ODI 12 months	COMI	SF 36 phys.	SF 36 mental	Anterior displ.	Sagittal rot.
Correlation coeff.	0.608	−0.681	−0.295	0.311	0.286
p	0.000	0.000	0.061	0.048	0.066
SF 36 phys. 12 months	COMI	ODI	SF 36 mental	Anterior displ.	Sagittal rot.
Correlation coeff.	−0.586	−0.681	−0.070	−0.355	−0.417
p	0.000	0.000	0.664	0.025	0.007
SF 36 mental 12 months	COMI	ODI	SF 36 phys.	Anterior displ.	Sagittal rot.
Correlation coeff.	−0.226	−0.295	−0.070	−0.026	0.081
p	0.161	0.061	0.664	0.873	0.615

Table 2 Correlations of the clinical and radiological parameters 24 months after surgery ($n = 40$)

COMI 24 months	ODI	SF 36 phys.	SF 36 mental	Anterior displ.	Sagittal rot.
Correlation coeff.	0.782	–0.655	–0.279	0.414	0.402
p	0.000	0.000	0.090	0.011	0.014
ODI 24 months	COMI	SF 36 phys.	SF 36 mental	Anterior displ.	Sagittal rot.
Correlation coeff.	0.782	–0.514	–0.372	0.374	0.370
p	0.000	0.001	0.020	0.021	0.022
SF 36 phys. 24 months	COMI	ODI	SF 36 mental	Anterior displ.	Sagittal rot.
Correlation coeff.	−0.655	−0.514	0.055	−0.404	−0.353
p	0.000	0.001	0.741	0.012	0.030
SF 36 mental 24 months	COMI	ODI	SF 36 phys.	Anterior displ.	Sagittal rot.
Correlation coeff.	−0.279	−0.372	0.055	−0.089	−0.111
p	0.090	0.020	0.741	0.599	0.513

obviously plays a role in the treatment of degenerative spondylolisthesis. In addition, the correction of sagittal rotation of the slipped vertebra must be considered, as these two values show positive correlations with clinical outcome 12 and 24 months after surgery.

Degenerative spondylolisthesis is a common cause of chronic low back pain, with high demands for both conservative and operative therapy. Regarding surgical treatment of degenerative spondylolisthesis the effectiveness of slipped vertebral reduction remains controversial, one reason being the few number of scientific publications regarding the topic of this specific pathology.

For isthmic and dysplastic spondylolisthesis in contrast, several clinical studies have addressed the effect of reduction and fixation. In 2011, Audat et al. [16] presented a prospective, randomized, double blinded study cohort of 41 patients treated for symptomatic isthmic spondylolisthesis. One group underwent reduction of the slipped vertebra along with fixation and decompression, while the second group underwent fixation and decompression alone. The Oswestry disability index was used to assess clinical outcomes of the two groups over a follow-up period of 36 months, and showed no statistical difference between the two. Based on this data, Audat et al. concluded that reduction is not necessary.

Also there are only few publications actually recommending reduction. In a retrospective clinical study of 24 patients, Ruf et al. [17] displayed good to excellent results according to the SRS-30 questionnaire when treating high-grade spondylolisthesis at the lumbo-sacral junction with reduction and lumbar fusion. The authors recommend complete reduction of high-grade dysplastic spondylolisthesis and of segmental kyphosis to achieve good clinical results and to minimize the risk of nonunion/pseudarthrosis. In a prospective study of 119 patients, Ming-li et al. [18] concluded that reduction correlates with improvements in the post-operative JOA-score when treating low-grade isthmic spondylolisthesis with reduction and fusion. They used multivariate stepwise correlation analysis to evaluate the influence of the post-operative slip on the JOA-scores. Their data showed significant correlation of the post-operative slip to the JOA-score. They did not, however, correlate the amount of slippage reduction to the clinical score.

These findings cannot be properly applied to the treatment of degenerative spondylolisthesis, as it represents a different entity with different patient history and symptoms. Only few reports in the literature refer to the correlation of slippage reduction and clinical outcome in degenerative listhesis. For example, Kim et al. [19] suggested that in the surgical treatment of spondylolisthesis, the clinical outcomes also correlate with the pre- and post-operative radiological parameters of the spine and pelvis. Therefore, the authors retrospectively investigated the clinical outcome in 18 patients after fusion for degenerative listhesis at hand of the VAS and the ODI. According to the differences of the sagittal alignment on roentgenographic images, the patients were divided in two subgroups and showed more significant clinical improvement in the group which featured restoration of sagittal balance on the radiographic images.

In 2002, Kawakami et al. [20] published a retrospective review of 47 patients undergoing posterolateral spinal fusion for degenerative lumbar spondylolisthesis. The authors differentiated between patients with minor slippage and major slippage, whereas the group of major slippage patients was subdivided in two subgroups, in which one was in situ fixated, and one fixated after reduction. After analyzing outcomes with the JOA-score, they concluded that in more severe cases of degenerative spondylolisthesis, posterolateral spinal fusion with reduction offers merely a potential improvement of clinical symptoms. There was no statistical significant correlation found in their data, concerning reduction and the clinical outcome. Their data are based on a retrospective patient questionnaire focusing on pain relief and quality of life improvement over a mean follow-up of 9.9 years post-surgery. However, the authors did not acquire correlations between the amount of the reduction and the clinical outcome, as they only evaluated the post-operative slippage.

The current study indicates the need to restore physiological alignment of instable and slipped vertebrae in degenerative spondylolisthesis as much as possible. Anterior displacement and sagittal malrotation of the affected vertebrae should be addressed during surgery for spondylolisthesis and should be reduced. Still, in cases of severe slippage, possible elongation of neural structures has to be considered and reduction has to be neglected to prevent iatrogenic neural injuries. The current data were acquired using a comprehensive set of QLS. The efficacy of these QLS has already been proven in clinical studies. In respect to the aforementioned publications, no study correlated three QLS with pre- and post-operative radiological parameters focusing on slipped vertebral alignment. The current data indicate an advantage for as much repositioning of anterior slippage and sagittal rotation as possible in degenerative spondylolisthesis prior to fusion, as it is associated with significantly better results on quality of life assessment.

The limitations of the present study are on the one hand the lack of a control group with decompression and fixation alone, to improve the evidence base.

Moreover, adding *T* scores in the study group would also have been beneficial to see if there is a difference in the outcome of osteoporotic and non-osteoporotic individuals. These additions have to be respected in future studies concerning the topic.

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Conflict of interest With the presenting authors, there is no conflict of interest in the making of the study.

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