# INTERRELATION OF SPONDYLOMETRIC PARAMETERS WITH THE OUTCOME OF SURGICAL TREATMENT OF PATIENTS WITH DEGENERATIVE DISEASES OF THE LUMBOSACRAL JUNCTION

**V.A. Byvaltsev[1–4], Yu.Ya. Pestryakov[1], A.A. Kalinin[1, 2]**

[1]Irkutsk State Medical University, Irkutsk, Russia
[2]Road Clinical Hospital at «Irkutsk-Passazhirskiy» station, Irkutsk, Russia
[3]Irkutsk Scientific Center for Surgery and Traumatology, Irkutsk, Russia
[4]Irkutsk State Academy of Postgraduate Education, Irkutsk, Russia

**Objective.** To evaluate the relationship between the radiological and neuroimaging parameters of the spinal motion segment and the clinical outcome of surgical treatment of patients with degenerative diseases of the lumbosacral junction to clarify the indications for dynamic and rigid stabilization.

**Material and Methods.** The study included 267 patients with degenerative diseases of the lumbosacral spine. Depending on the stabilization method, patients were divided into two groups: Group I (n = 83) with dynamic intervertebral disc (IVD) prosthesis; and Group II (n = 184) with interbody fusion and transpedicular fixation. Long-term clinical parameters and biomechanical characteristics before and after surgery were analyzed.

**Results.** A significant nonparametric correlation of the long-term result of surgical treatment assessed by VAS and Oswestry Disability Index with radiological parameters and results of neuroimaging was revealed. It was determined that the use of artificial IVD allows achieving a minimum level of pain syndrome and good functional recovery with effective preservation of the volume of physiological movements in the operated segment and restoration of the total angle of lumbar lordosis.

**Conclusion.** Objective neuroimaging data (grade II–IV of degeneration according to the measured diffusion coefficient) and radiological parameters (linear displacement of vertebrae not more than 4 mm, sagittal volume of movements in the spinal motion segment less than 6°, decrease in the height of intervertebral disc space no more than 2/3 of the superjacent one) make possible using total arthroplasty. It is advisable to perform interbody fusion and rigid stabilization in grade IV–V of degeneration, linear displacement of vertebrae more than 4 mm, sagittal volume of movements of at least 6°, and decrease in the interbody space height over 2/3 of the superjacent one.

**Key Words:** intervertebral disc, facet joint, degeneration, microdiscectomy, spinal fusion.

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Vertebrogenic pain syndrome is an urgent problem of modern medicine, which affects the able-bodied individuals and is accompanied by high risks of primary disability [2, 5]. The development of pain in the lumbar spine in mainly caused by degeneration of intervertebral discs (IVDs), that of facet joints, or their combination [3, 6].

Operations involving junction areas of the spine, in particular the lumbosacral junction, are the most complicated ones in spinal surgery [4]. This segment bears the greatest axial load due to biomechanical, anatomical, and physiological features and, in most cases, it is prone to degeneration [10, 21]. At the same time, surgical treatment of patients with degenerative diseases of the lumbosacral junction is associated with complications in 57 % of cases [1, 16].

The pathogenetic degenerative cascade includes primary IVD dehydration accompanied by decrease in its height and development of segmental instability followed by hypertrophy of the facet joint and ligamentous apparatus, restabilization and stenosis of the spinal canal [19]. Various puncture-based [15, 24], decompression [14, 25], and decompression and stabilization [2, 18] surgical procedures are used at different stages of degenerative disease of the spinal segment.

Extensive experience in decompression and decompression and stabilization surgical treatment of the lumbar spine has been accumulated in recent decades. The outcomes of surgical treatment vary in a wide range, which is, on the one hand, due to the lack of objective criteria for surgery, and, on the other hand, due to a large number of structurally different implants [3, 19, 23]. This circumstance necessitates the development of approaches to prediction of degenerative processes and specification of objective clinical and morphostructural parameters for implementation of patient-specific surgical approaches [3, 5, 8].

This study was inspired by the need for the development of novel tactical and surgical approaches to optimize the results of surgical treatment of patients with degenerative diseases of the lumbosacral junction based on the analysis of clinical and instrumental parameters of spinal motion segments.

The study was aimed at evaluating the relationship between the X-ray and neuroimaging parameters of the spinal motion segment and clinical outcome of surgical treatment of patients with degenerative diseases of the lumbosacral junction in order to specify the indications for dynamic and rigid stabilization.

## Material and Methods

A total of 1342 operations for degenerative diseases of the lumbar spine were carried out at the Neurosurgical Center of the Road Clinical Hospital at the Irkutsk-Passazhirskiy station since January 2009 till December 2013. The study was approved by the ethics committee of the Irkutsk State Medical University. The study included 267 patients who underwent multimodal clinical and instrumental examination followed by decompression and stabilization lumbosacral surgery. In all cases, the list of diagnostic measures included the study of neurological and orthopedic status, spondylography, MRI, MSCT, and electroneuromyography (ENMG) of the lower limbs.

Indications and contraindications to stabilization of the operated spinal motion segment were used as inclusion and exclusion criteria.

Inclusion criteria:

– ineffective conservative therapy, long-term or recurrent pain syndrome, persistent neurological deficit, ranging from radicular neuralgia to radiculopathy with peripheral paresis;

– a combination of radicular and pseudo-radicular clinical symptoms;

– decrease in the interbody space height of no more than 1/3 of the height of the superjacent one;

– grade II or higher degeneration of the lumbosacral spine based on quantitative assessment of apparent diffusion coefficient (ACD);

– single-level symptomatic degenerative disease of the lumbosacral junction according to neuroimaging data.

Contraindications:

– central stenosis of the spinal canal;

– spondylolisthesis with or without spondylolysis;

– severe concomitant pathology;

– clinical symptoms of prevalent pain syndrome in the lower extremities rather than in the lumbar spine;

– significant osteoporosis (decrease in bone mineral density by 2.8 or more according to the WHO T-criterion 1995);

– the need for significant correction of the sagittal balance;

– the need for surgical correction of two or more segments of the lumbosacral spine.

The patients were divided into two groups: 83 patients (Group I) underwent discectomy through the extraperitoneal pararectal approach with implantation of the M-6 disc prosthesis (Spinal Kinetics, USA); 184 patients (Group II) underwent unilateral facetectomy with or without contralateral foraminotomy, transforaminal fusion with Capstone (Medtronic, USA) or Pezo-T (Ulrich Medical GmbH, Germany) cage, and open transpedicular stabilization using the Conmet system (Russian Federation) through the medial approach. All patients were operated on using the original instrumentation by the same surgical team.

Postoperative follow-up was 24 to 48 months with the median of 36 months. Anthropometric data (sex, age, body mass index), clinical parameters (pain level according to VAS, quality of life according to ODI, and patient's satisfaction with the operation as assessed by MacNab scale), instrumental parameters (interbody space height, amplitude of the segmental angle, lumbar lordosis angle, and linear displacement of the vertebrae as assessed by lumbar spondylography; the severity of degenerative changes in IVDs (Pfirrmann score) and facet joints (Fujiwara score) as assessed by MRI), quantitative characteristics of degeneration as assessed by ADC, and the presence of complications.

The data for the ADC were obtained using the Siemens Magnetom Essenza 1.5 T MRI scanner. The following set of MRI parameters was used: diffusion weighted (DW) SE-echo-planar imaging (EPI), 160x128 matrix, TR — 7500, TE — 83, NEX — 6, slice thickness — 4 mm, FOV — 30 x 30. The following values of b were used: 400 and 800 s/mm$^2$, scanning time was 6 minutes 30 seconds. The diffusion coefficient was calculated on T2-weighted images using the OsiriX Lite software, the obtained values were transferred to the functional DWI maps.

Statistical processing of the results was carried out on a personal computer using the Microsoft Excel and Statistica-8 applications for data processing. Nonparametric statistics were used to assess the significance of differences in the study populations, and $p < 0.05$ was used as the lower confidence limit. The data are represented by the median and interquartile range in the form of Me (25; 75).

## Results

*General information about the study groups.* General characteristics of the study groups including sex, age, and constitution type are shown in Table 1. Data analysis showed that the population of operated patients dominated with young and middle aged males (25–50 years).

Radicular symptoms with various severity of neurological deficit and non-compressive clinical manifestations were verified in the study groups.

The presence of lumbosacral junction abnormalities according to instrumental data in the studied groups of patients is shown in Table 2. The absence of lumbosacral stigmas was detected in most respondents in both groups.

The type of the leading pathomorphological substrate in patients with degenerative diseases of the lumbosacral junction as shown by neuroim-

**Table 1**

Distribution of patients by sex, age, and constitution type

| Criteria | Group I (n = 83) | Group II (n = 184) |
|---|---|---|
| Age, years | 29 (26; 44) | 32 (29; 49) |
| Males, n, (%) | 52 (63) | 119 (65) |
| Body mass index, kg/m$^2$ | 23,8 (22,1; 26,2) | 24,9 (23,3; 25,8) |

**Table 2**

Distribution of patients by the presence of lumbosacral junction anomalies, n (%)

| Symptom | Group I (n = 83) | Group II (n = 184) |
|---|---|---|
| Without pathology (true L5—S1 junction) | 79 (95.0) | 128 (70.0) |
| Complete lumbarization (L6—S1 junction) | 2 (2.0) | 16 (9.0) |
| Incomplete lumbarization (L6—S1 junction) | 1 (1.5) | 21 (11.0) |
| Complete sacralization (L4—S1 junction) | 1 (1.5) | 11 (6.0) |
| Incomplete sacralization (L4—S1 junction) | — | 8 (4.0) |

aging is presented in Table 3. Analysis showed that most operated patients (>50 %) had a combined pathology of IVDs and facet joints.

The correlation between the ADC and investigated instrumental and morphological parameters was analyzed (Table 4).

Thus, the ADC value determined using non-invasive diffusion MRI enabled quite reliable assessment of the severity of IVD and facet joint degeneration at the lumbosacral junction and development of possible surgical strategy.

Discriminant analysis was used in patients with degenerative disease of the lumbosacral spine to objectify the classification of the severity of degenerative changes in the spinal motion segment based on the ADC value. The statistical classification matrix was constructed. The conclusion about the sufficient effectiveness of the linear discriminant function was made based on this matrix: high recognition quality (90% or more in each group) was found, which confirms the possibility of implementation of the statistical model based on the proposed classification.

The above data laid the basis for classification including five levels of IVD degeneration at the lumbosacral junction based on the ADC according to DW-MRI data (Table 5).

*Analysis of clinical outcomes.* Significant postoperative decrease in the intensity of the pain was observed; VAS score showed positive dynamics in the form of significant postoperative decrease in pain severity in the lumbar spine: from 76.0 (64.82) to 10.5 (6; 14) mm in Group I; p = 0.004; from 75.0 (62; 82) to 22.0 (16; 30) mm in Group II; p = 0.001 (Fig. 1). Significantly lower level of pain in the lumbar spine in the late postoperative period was observed in Group I as compared to Group II (p = 0.003).

All patients demonstrated significant decrease in pain in the lower extremities after the operation: from 79.5 (66.87) to 8.0 (4.12) mm; p = 0.007 and from 84.0 (67; 89) to 18.0 (12; 25) mm; p = 0.004, respectively (Fig. 2). A comparative analysis carried out on average 36 months later verified the lower level of pain in the lower extremities in Group I (p = 0.005).

Analysis of ODI values showed significant positive dynamics of the functional state after the operation as compared to the preoperative value: from 78 (66; 82) to 10 (8; 14); p = 0.009 in Group I; from 74 (60; 80) to 17 (14; 20); p = 0.001 in Group II (Fig. 3). In the long-term postoperative period, Group I showed significantly better functional outcome compared to Group II (p = 0.002).

The proportion of good and excellent outcomesas assessed by the MacNab subjective satisfaction score on average 36 months after surgery was 93 % (n = 77) in Group I and 63 % (n = 115) in Group II; p = 0.003 (Fig. 4).

*Analysis of postoperative complications.* The complications identified by the retrospective analysis vs verification time and the type of surgical treatment are shown in Table 6.

The relationship between complication and the method of surgical treatment was analyzed in detail. No venous thrombosis and pulmonary embolism were detected in both groups due to strict adherence to the protocol for prevention of vascular complications (elastic bandaging of the lower extremities, anticoagulant therapy).

Various complications characteristic of the type of surgical intervention and approach were observed in patients who underwent surgery at the lumbosacral junction. Thus, the lowest level of postoperative complications was found in the group of patients who were operated on using the dynamic fixation technique, including mainly injury to the main vessels (left common iliac vein) during approach, postoperative wound infection, and heterotopic ossification phenomenon. The absence of conventional complications of anterior approach in the form of retrograde ejaculation can be attributed to the fact that cellular tissue coagulation on the anterior surface of the L5—S1 IVD and adjacent vertebral bodies was not used.

In the group of patients who were operated on using the rigid stabilization method, there were complications associated with adjacent segment degeneration, pseudoarthrosis, and instability of the fixation system.

*Analysis of clinical and biomechanical parameters of involved spinal motion segments and their relationship with* *the outcome of surgical treatment.* The severity of pain as assessed by VAS score and the functional state (ODI) are the most important clinical characteristics that are directly related to the postoperative outcome and the quality of life. We analyzed a correlation between clinical components and parameters characterizing the state of the lumbosacral junction (amplitude of the segmental angle, lumbar lordosis angle, linear displacement of the vertebrae, interbody space height, ADC, and preoperative clinical symptoms).

Significant positive nonparametric correlation was found between the long-term outcome of surgical treatment as assessed by VAS and ODI and studied parameters (Table 7, 8), except for the initial value of the lumbar lordosis angle.

In order to analyze the influence of clinical and instrumental parameters on the clinical outcome and assess the possibility of optimizing the treatment of patients with degenerative diseases of the lumbosacral spine, the obtained data were classified as follows:

– good outcomes: postoperative outcomes characterized by complete or almost complete resumption of the initial (before onset of the disease or the last relapse) level of social and physical activity (with allowance for possible restriction of high physical activity);

– poor outcome: social and daily living activities are not fully restored, ineffective operation or worsening of patient's condition.

A comparative analysis of the clinical and instrumental data of the studied groups of patients is shown in Table 9.

All patients with degenerative diseases of the lumbosacral junction demonstrated preoperative hypolordosis (less than 35°), which did not correlate with the long-term clinical outcome as assessed by VAS ($R = -0.15$, $p > 0.05$) and ODI ($R = 0.08$, $p > 0.05$).

In the group of patients operated on using the dynamic fixation technique, good outcomes with preoperative parameters of the lumbosacral junction are characterized by linear displacement of the vertebrae of no more than 4 mm, sagittal range of motions less than 6°, decrease in the interbody space height no more than 2/3 of the superjacent one, and grade II—IV IVD degeneration as assessed by ADC. In the group of patients who were operated on using rigid stabilization, good outcomes with preoperative parameters of the lumbosacral junc-

**Table 3**

Patient distribution by the type of dominant degenerative morphostructural changes as shown by MRI, n (%)

| Pathology | Morphological sign | Group I (n = 83) | Group II (n = 184) |
|---|---|---|---|
| Intervertebral disc degeneration | Protrusion | 49 (59) | 31 (17) |
| | Extrusion | 25 (30) | 74 (40) |
| | Sequestration | 9 (11) | 7 (4) |
| | Retrolisthesis | 17 (20) | 11 (6) |
| Facet joint degeneration | Spondylarthrosis without spinal canal stenosis | 47 (57) | 35 (19) |
| | Spondylarthrosis with spinal canal stenosis | — | 84 (45) |
| | Grade I spondylolisthesis | 1 (1) | 29 (16) |

**Table 4**

Correlation between the apparent diffusion coefficient (ADC) according to diffuse-weighted images with long-term clinical parameters as assessed by VAS and ODI, degenerative changes in the intervertebral disc (Pfirrmann score) and facet joint degeneration (Fujiwara score)

| Indicator | Group I (n = 83) | | Group II (n = 184) | |
|---|---|---|---|---|
| | R | p | R | p |
| VAS: lumbar spine in 36 months | -0.85 | <0.05 | -0.82 | <0.05 |
| VAS: lower limbs in 36 months | -0.82 | <0.05 | -0.81 | <0.05 |
| ODI in 36 months | -0.78 | <0.05 | -0.83 | <0.05 |
| Pfirrmann | -0.50 | <0.05 | -0.71 | <0.05 |
| Fujiwara | -0.59 | <0.05 | -0.69 | <0.05 |
| Vernon-Roberts | -0.88 | <0.05 | -0.84 | <0.05 |

R — correlation coefficient; p — confidence coefficient.

**Table 5**

Quantitative characteristics of the lumbosacral intervertebral disc degeneration based on the apparent diffusion coefficient (ADC)

| Degeneration grade | ADC value | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| I | 1656 | 1850 | 1730.0 |
| II | 1442 | 1654 | 1523.5 |
| III | 1253 | 1420 | 1332.0 |
| IV | 1070 | 1205 | 1177.5 |
| V | 717 | 988 | 882.5 |

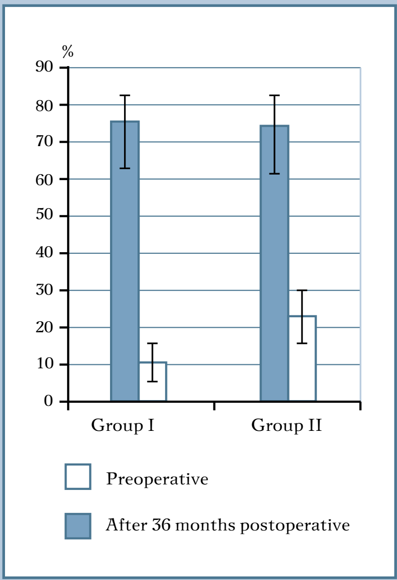


**Fig. 1**
Dynamics of the pain level in the lumbar spine in the studied groups of patients as assessed by VAS

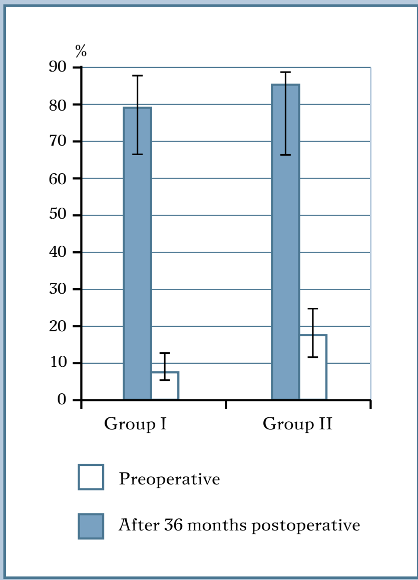


**Fig. 2**
Dynamics of the pain level in the lower extremities in the studied groups of patients as assessed by VAS

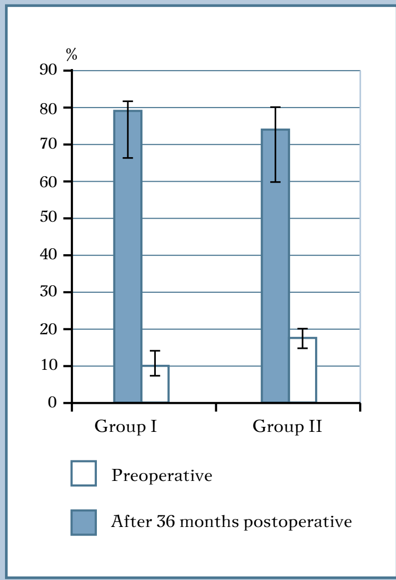


**Fig. 3**
Dynamics of the functional state in the studied groups of patients as assessed by ODI

tion are characterized by linear displacement of the vertebrae of more than 4 mm, sagittal range of motion of at least 6°, decrease in the interbody space height of more than 2/3 of the superjacent one, and grade IV—V IVD degeneration as assessed by ADC.

We developed novel tactical and surgical approaches on the basis of the differentiated preoperative clinical and instrumental algorithm in order to optimize the outcomes of surgical treatment in patients with degenerative diseases of the lumbosacral junction with allowance for elimination of possible adverse effects (Fig. 5).

A clinical example of the use of total arthroplasty is shown in Fig. 6.

A clinical example of the use of interbody fusion and transpedicular stabilization is shown in Fig. 7.

## Discussion

Degenerative changes in the lumbar spine is an indication for the use of various surgical techniques [15]. Optimal

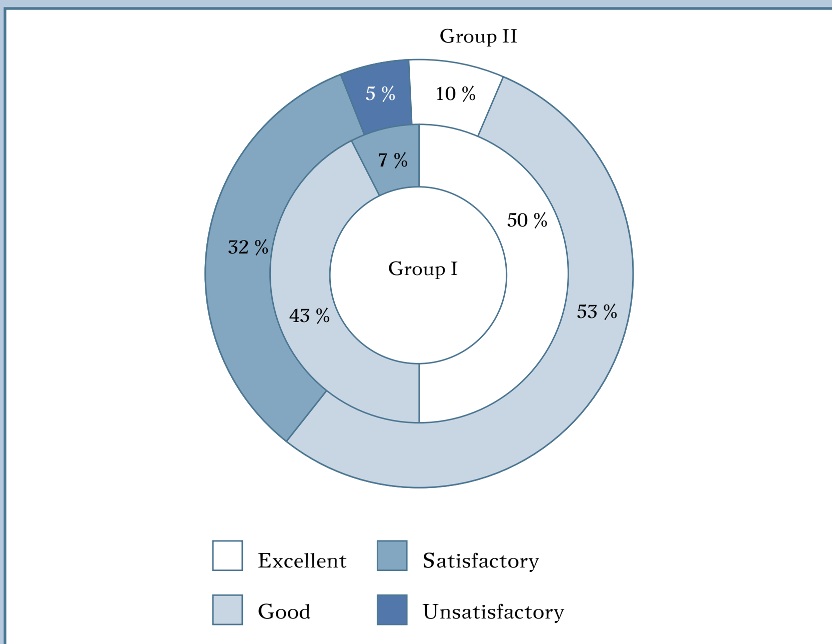


**Fig. 4**
Subjective satisfaction with surgery results in the long-term postoperative period according to the MacNab scale in the studied groups of patients

**Table 6**

Characteristics of detected complications in the study groups

| Complications | Group I (n = 83) | Group II (n = 184) | p |
|---|---|---|---|
| *Intraoperative, n (%)* | 3 (3.60) | 8 (4.30) | 0.037 |
| Injury to the dura mater | – | 3 (1.63) | |
| Injury to the nerve root | – | 3 (1.63) | |
| Instrumentation failure | – | 2 (1.08) | |
| Incorrect level | – | – | |
| Conversion of the method | – | – | |
| Injury to the main vessels | 3 (3.60) | – | |
| *General surgical, n (%)* | 4 (4.81) | 9 (4.89) | 0.024 |
| Postoperative hematoma | 1 | 5 | |
| Postoperative surgical site infection | 3 | 4 | |
| Venous thrombosis, PE | – | – | |
| *Specific, n (%)* | 3 (3.60) | 25 (13.60) | 0.004 |
| Spondylodiscitis | – | – | |
| Worsening of neurological symptoms | 1 | 8 | |
| Disc herniation at the adjucent level | – | 9 | |
| Pseudoarthrosis | – | 7 | |
| Instability of the fixation system | – | 1 | |
| Heterotopic ossification | 2 | – | |

**Table 7**

Correlation between functional state values (ODI) 36 months after the operation and studied characteristics of the lumbosacral segment

| Parameter | Group I (n = 83) | | Group II (n = 184) | |
|---|---|---|---|---|
| | R | p | R | p |
| Preoperative symptoms | 0.90 | <0.05 | 0.87 | <0.05 |
| Preoperative LD | 0.84 | <0.05 | 0.71 | <0.05 |
| Postoperative LD | 0.66 | <0.05 | 0.82 | <0.05 |
| Preoperative FEA | 0.59 | <0.05 | 0.51 | <0.05 |
| Postoperative FEA | 0.77 | <0.05 | 0.70 | <0.05 |
| Total preoperative lordosis | -0.74 | <0.05 | -0.69 | <0.05 |
| Total postoperative lordosis | -0.91 | <0.05 | -0.81 | <0.05 |
| Preoperative disc height | 0.73 | <0.05 | 0.74 | <0.05 |
| Postoperative disc height | -0.88 | <0.05 | -0.73 | <0.05 |
| Apparent diffusion coefficient | -0.88 | <0.05 | -0.70 | <0.05 |

R — Spearman's correlation coefficient; p — confidence coefficient; LD — linear displacement of the vertebrae; FEA — flexion-extension amplitude of the segmental angle.

indications for surgical intervention should be determined in each clinical situation. Popularization of minimally invasive techniques for the treatment of degenerative diseases led to widespread implementation of microsurgical (subtotal) discectomy. However, long-term results of this technique demonstrate the lack of clinical efficacy in some cases [11, 12, 25].

Currently, interbody fusion and rigid stabilization are the most common methods of surgical treatment of degenerative diseases of the lumbar spine and successful clinical outcomes do not correlate with radiographic ones [2, 6]. Rigid stabilization leads to biomechanical stress and accelerated degeneration of adjacent segments, contributes to bone block failure, development of infectious complications, postoperative pain syndrome, instability of fixation elements, and resorption of bone tissue around the implants [3, 6, 22].

The study of technical capabilities aimed at reducing the incidence of unsatisfactory outcomes of rigid stabilization is associated with protection of adjacent segments from biomechanical overloads along with reduction of the risk of fixing structure breakage, elimination of pathological mobility with preservation of the physiological range of motion in the operated segment [6, 18, 26]. It was found that the posterior dynamic (semi-rigid) stabilization restores physiological range of motion in the lumbar spine and reduces degeneration of the adjacent segment [9, 19]. Modern specialized literature sources include the evidence of positive postoperative clinical outcomes, but biomechanical effects of the use of various stabilizing structures are inconsistent [19, 22].

Dynamic fixation using artificial IVDs is aimed at restoring spatial relationships and biomechanics in the operated spinal segments provided that there are no significant morphostructural changes in its supporting elements. In this connection, a detailed preoperative examination of patients, taking into account modern neuroimaging methods, is required [7, 27].

We analyzed the literature and found no fundamental differences in clinical outcomes as assessed by VAS and ODI between surgical correction groups [2, 6, 15, 17]. In our study, we observed lower VAS (pain) and ODI (quality of life) scores in the group of patients who were operated on using artificial IVDs as compared to monosegmental interbody fusion and transpedicular stabilization.

The study confirmed the presence of the most common complications after total arthroplasty, including injury to the main vessels and heterotopic ossification [13, 20], and after rigid stabilization, including degeneration of adjacent segments, pseudoarthrosis, and postoperative scarring [2, 6, 17].

Assessment of prognostic factors and the relationship between long-term postoperative outcomes and clinical and morphological preoperative changes at the area of planned surgical treatment is the topic of current interest. For this reason, the detailed retrospective comprehensive clinical and instrumental preoperative analysis was aimed at specifying the indications for dynamic and rigid stabilization with allowance for individual clinical and instrumental parameters of degenerative changes at the lumbosacral junction.

Table 8

Correlation between the functional state as assessed by VAS 36 months after the operation and studied characteristics of the lumbosacral segment

| Parameter | Group I (n = 83) | | Group II (n = 184) | |
|---|---|---|---|---|
| | R | p | R | p |
| Preoperative symptoms | 0.72 | <0.05 | 0.89 | <0.05 |
| Preoperative LD | 0.86 | <0.05 | 0.68 | <0.05 |
| Postoperative LD | 0.84 | <0.05 | 0.86 | <0.05 |
| Preoperative FEA | 0.76 | <0.05 | 0.51 | <0.05 |
| Postoperative FEA | 0.84 | <0.05 | 0.67 | <0.05 |
| Total preoperative lordosis | -0.21 | <0.05 | -0.62 | <0.05 |
| Total postoperative lordosis | -0.57 | <0.05 | -0.80 | <0.05 |
| Preoperative disc height | 0.67 | <0.05 | 0.69 | <0.05 |
| Postoperative disc height | -0.65 | <0.05 | -0.78 | <0.05 |
| Apparent diffusion coefficient | -0.81 | <0.05 | -0.82 | <0.05 |

R — Spearman's correlation coefficient; p — confidence coefficient; LD — linear displacement of vertebrae; FEA — flexion-extension amplitude of the segmental angle.

## Conclusion

Comprehensive clinical and instrumental examination including lumbar spondylography, T1, T2, and DW-MRI is indicated to all patients with degenerative diseases of the lumbosacral junction for a full-scale study of morphostructural changes in IVDs and facet joints.

Arthroplasty can be used in patients with grade II—IV degeneration according to ADC, linear displacement of vertebrae of no more than 4 mm, sagittal range of motion in the spinal motion segment less than 6°, decrease in the interbody space height of no more than 2/3 of the superjacent one.

Table 9

Comparative analysis of clinical data of patients depending on postoperative outcome

| Parameter | Group I (n = 83) | | p | Group II (n = 184) | | p |
|---|---|---|---|---|---|---|
| | Good outcomes (n = 79) | Poor outcomes (n = 4) | | Good outcomes (n = 101) | Poor outcomes (n = 83) | |
| ODI in 36 months. | 8 (6; 10) | 12 (10; 14) | <0.01 | 14 (12; 18) | 30 (24; 36) | <0.01 |
| VAS: lumbar spine in 36 months | 6 (4; 8) | 13 (10; 18) | <0.01 | 12 (10; 16) | 32 (20; 34) | <0.01 |
| VAS: lower limbs in 36 months | 2 (2; 4) | 10 (6; 16) | <0.01 | 10 (6; 12) | 28 (20; 36) | <0.01 |
| Preoperative LD | 2 (1; 4) | 6 (5; 7) | <0.01 | 7 (4; 11) | 3 (2; 3) | <0.01 |
| Postoperative LD | 1 (1; 2) | 2 (1; 2) | >0.05 | 2 (1; 3) | 5 (4; 7) | <0.01 |
| Preoperative FEA | 4 (3; 5) | 7 (6; 8) | <0.01 | 8 (6; 9) | 3 (2; 3) | <0.01 |
| Postoperative FEA | 4 (4; 5) | 3 (3; 5) | >0.05 | 4 (2; 6) | 3 (3; 4) | >0.05 |
| Total preoperative lordosis | 30 (28; 36) | 30 (26; 38) | >0.05 | 32 (28; 36) | 32 (23; 38) | >0.05 |
| Total postoperative lordosis | 54 (48; 64) | 34 (32; 36) | <0.01 | 52 (44; 66) | 37 (32; 38) | <0.01 |
| Preoperative disc height | 10 (9; 13) | 6 (5; 9) | <0.01 | 6 (5; 8) | 10 (9; 12) | <0.01 |
| Postoperative disc height | 12 (10; 12) | 10 (10; 12) | >0.05 | 12 (10; 14) | 11 (10; 13) | >0.05 |
| Apparent diffusion coefficient | 1540 (1280; 1760) | 1050 (800; 1150) | <0.01 | 1180 (980; 1230) | 1320 (1240; 1520) | <0.01 |

R — Spearman's correlation coefficient; p — confidence coefficient; LD — linear displacement of vertebrae; FEA — flexion-extension amplitude of the segmental angle.

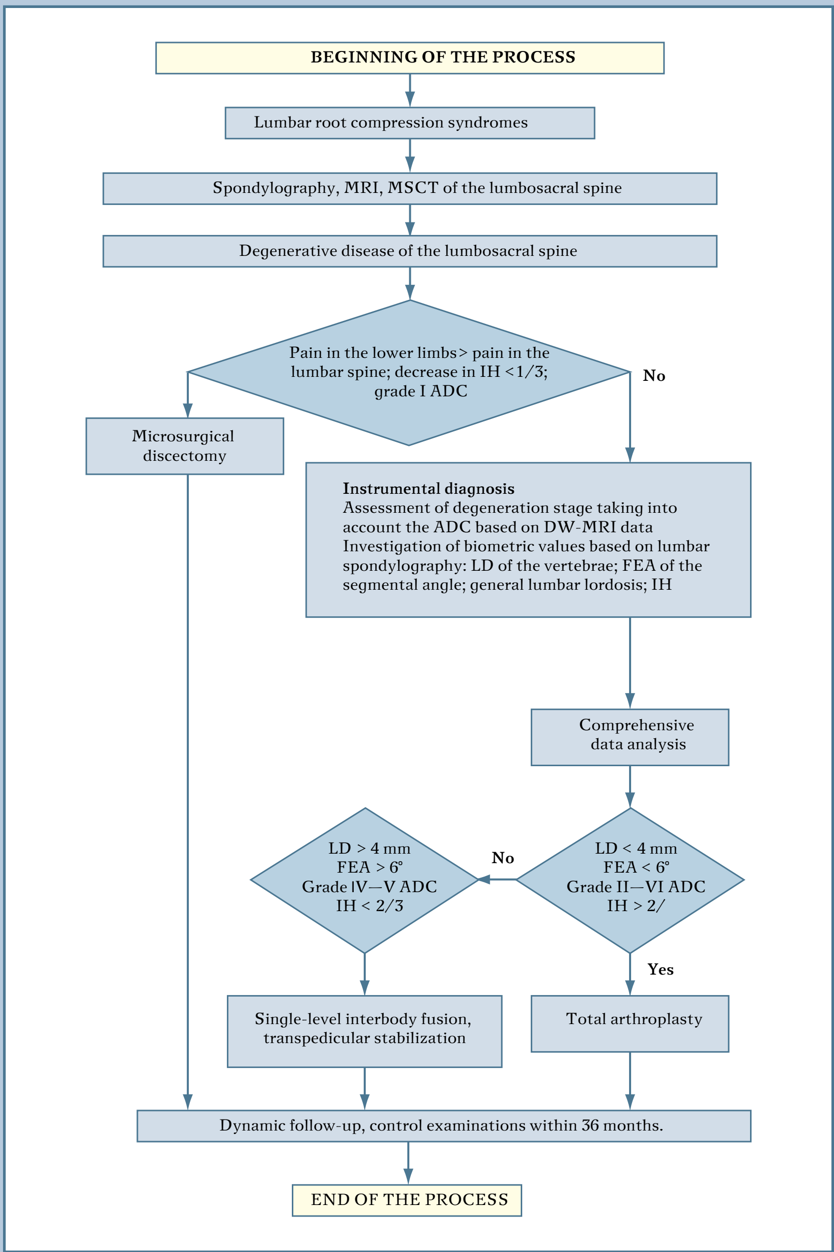


**Fig. 5**
Novel tactical and surgical approaches based on the differentiated preoperative clinical and instrumental algorithm in the treatment of patients with degenerative diseases of the lumbosacral junction: IH — interbody height; ADC — Apparent diffusion coefficient; LD — linear displacement; FEA – flexion-extension amplitude

Interbody spinal fusion and rigid stabilization are advisable in patients with grade IV—V degeneration according to ADC, linear displacement of the vertebrae of more than 4 mm, sagittal range of motion in the spinal motion segment of at least 6°, decrease in the interbody space height of more than 2/3 of the superjacent one.

Implantation of artificial IVDs can be used in patients with a wide range of degenerative diseases of the lumbosacral spine, which results in minimum level of pain as assessed by VAS, good functional state according to ODI, and mostly good outcomes as assessed by MacNab subjective satisfaction scale (as compared to rigid stabilization in this group of patients).

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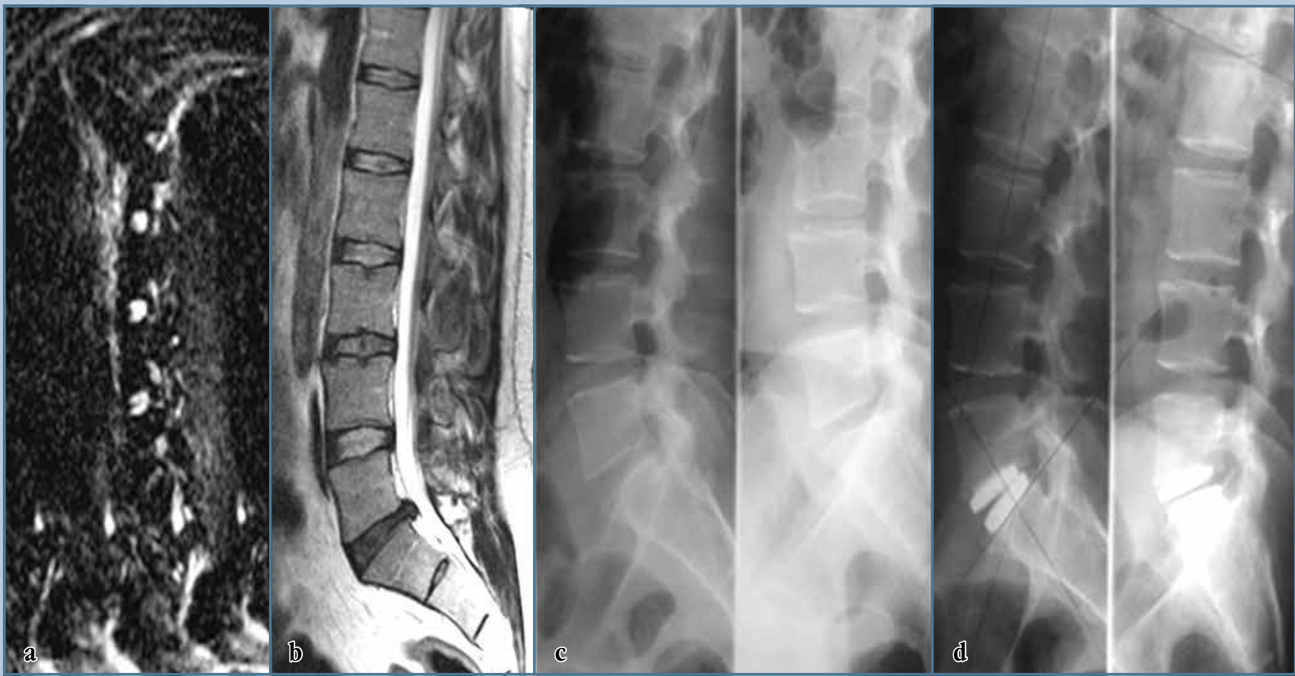


**Fig. 6**
Patient R., 37 years old, with degenerative disease of the lumbosacral junction: **a** — DW-MRI, apparent diffusion coefficient — 1392; **b** — sagittal MRI of the lumbar spine: right-sided herniation of the L5—S1 intervertebral disc; **c** —preoperative lumbar spondylography with functional tests: flattening of lumbar lordosis (29°), linear translation — 3 mm, sagittal angulation — 5°; **d** —postoperative lumbar spondylography with functional tests: lumbar lordosis angle 47°, no signs of segmental instability; preoperative VAS: lumbar spine — 72 mm, lower limbs — 84 mm, preoperative ODI — 68 points; VAS in 36 months: lumbar — 8 mm, lower limbs — 2 mm, ODI in 36 months — 6 points, MacNab score — excellent outcome


**Fig. 7**
Patient B., 49 years old, with degenerative disease of the lumbosacral junction: **a** — DW-MRI, apparent diffusion coefficient — 1052; **b** — sagittal MRI of the lumbar spine: left-sided herniation of the intervertebral L5—S1 disc; **c** — preoperative lumbar spondylography with functional tests: flattening of lumbar lordosis (23°), linear translation — 7 mm, sagittal angulation — 6°; **d** — postoperative lumbar spondylography with functional tests: angle of lumbar lordosis — 46°, no signs of segmental instability; preoperative VAS: lumbar spine — 78 mm, lower limbs — 82 mm, preoperative ODI — 62 points; VAS in 36 months: lumbar spine — 18 mm, lower limbs — 8 mm, ODI in 36 months— 16 points, MacNab score — good outcome

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**Address correspondence to:**
Byvaltsev Vadim Anatolyevich
P.O.B. 62, Irkutsk, 664082, Russia,
byval75vadim@yandex.ru

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*Vadim Anatolyevich Byvaltsev, DMSc, Head of the Centre of Neurosurgery, Road Clinical Hospital at «Irkutsk-Passazhirskiy» station of JSCo «Russian Railways», Botkin str., 10, Irkutsk, 664005, Russia; Head of Scientific and Clinical Department of Neurosurgery, Irkutsk Scientific Centre of Surgery and Traumatology, Bortsov Revolyutsii str., 1, Irkutsk, 664003, Russia; director of the course of neurosurgery, Irkutsk State Medical University, Krasnogo Vosstaniya str., 1, Irkutsk, 664003, Russia; Professor of the Department of Traumatology, Orthopaedics and Neurosurgery of Irkutsk State Medical Academy of Postgraduate Education, Yubilejnyj microdistrict, 100, Irkutsk, 664049, Russia, byval75vadim@yandex.ru;*

*Yury Yakovlevich Pestryakov, postgraduate student in neurosurgery, Irkutsk State Medical University, Krasnogo Vosstaniya str., 1, Irkutsk, 664003, Russia; neurosurgeon, head of the Neurosurgical department, Regional Clinical Hospital, Partizana Zheleznyaka str., 3a, Krasnoyarsk, 660022, Russia, pestryakov-nho@mail.ru;*

*Andrey Andreyevich Kalinin, MD, PhD, neurosurgeon, Centre of Neurosurgery, Road Clinical Hospital at «Irkutsk-Passazhirskiy» station, Botkin str., 10, Irkutsk, 664005, Russia; researcher, Irkutsk Scientific Centre of Surgery and Traumatology, Bortsov Revolyutsii str., 1, Irkutsk, 664003, Russia; teaching assistant of the course of neurosurgery, Irkutsk State Medical University, Krasnogo Vosstaniya str., 1, Irkutsk, 664003, Russia, andrei_doc_v@mail.ru.*