COMPARATIVE ANALYSIS OF SURGICAL METHODS FOR THE TREATMENT OF GRADE I AND II SPONDYLOLISTHESIS OF THE L5 VERTEBRA

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Objective. To analyze clinical and radiological results of surgical treatment of patients with isthmic spondylolisthesis of the L5 vertebra using anterior axial fusion and transpedicular stabilization with interbody fusion performed through the posterior approach.
Material and Methods. The study involved 71 patients with isthmic grade I and II spondylolisthesis of the L5 vertebra. The patients were divided into two groups: the study group included 25 patients, and the control group — 46. All patients of the study group underwent presacral axial fusion. Patients in the control group underwent transpedicular stabilization combined with TLIF. The results of surgical treatment of patients were assessed using the MacNab scale, the ODI questionnaire and the VAS scale, and the severity of neurological disorders was assessed using the Francel scale.
Results. The duration of surgical intervention in the study group averaged 67 ± 23 min, and in the control group — 135 ± 45 min. The length of hospital stay in the study group was 3 ± 1 days, and in the control group — 5 ± 2 days. Good results were obtained in all cases. In the postoperative period, the average indicators of pain syndrome in the study group after 14 days were 2.0 ± 1.0 points, after 1 month — 1.0 ± 0.7 points and after 1 year — 0.5 ± 0.5 points, and in the control group 2.5 ± 0.5 points, 2 ± 1 points and 0.5 ± 0.3 points, respectively. The average indicators of the general condition in the study group according to the ODI after 14 days was 32.3 ± 8.1 %, after 1 month — 8.1 ± 4.4 % and after 1 year — 4.3 ± 1.8 %, and in the control group 30.2 ± 5.2 %, 6.3 ± 2.2 % and 2.1 ± 1.9 %, respectively. When assessing the duration of the surgical intervention, it turned out that performing presacral axial fusion reduced the duration of the operation by 2 times, and the length of the hospital stay — by 1.5 times.
Conclusion. The results of surgical treatment of patients with grade I and II isthmic spondylolisthesis without sagittal imbalance using transpedicular fixation combined with TLIF and those using presacral axial fusion are comparable. However, due to reducing intraoperative trauma, the method of presacral axial fusion allows to reduce the surgery duration and the length of hospital stay.
Key Words: isthmic spondylolisthesis of the L5 vertebra, anterior axial fusion of the lumbosacral spine, transpedicular fixation of the lumbosacral spine.
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Spondylolisthesis is a spinal pathology that occurs in 4–7 % of people. The development of spondylolisthesis results in a reduced working capacity and quality of life even at a young age, causing the complexity of social and psychological adaptation. [2–4]. The most common localization of spondylolisthesis is the L5 vertebra. The most common types of spondylolistheses are isthmic and degenerative, among which, in turn, the most frequent are grade I and II spondylolisthesis according to the Meyerding classification, less often grade III, IV, and V [2–5, 8–9].

Despite the intensive improvement of surgical techniques for the treatment of spinal diseases and the successes achieved in this area, the surgical treatment of isthmic spondylolisthesis is associated with a rather large surgical trauma. Patients should be prepared for long-term postoperative rehabilitation. It makes surgeons look for new ways of surgical treatment and rehabilitation for patients in this category. These are the main issues in the surgical treatment of pathology: elimination of compression of nerve structures, restoration of normal anatomical relationships of the L5 and S1 vertebrae, and ensuring reliable stabilization of the spinal motion segment of the lumbosacral spine. In treatment planning, the following indicators should be considered: the type and grade of spondylolisthesis, the stability of the spinal motion segment, the grade of the S1 endplate deformation, the severity of lumbar lordosis (LL), the pelvic tilt (PT) from 10 to 25°, the sacral slope (SS) from 30 to 60°, the pelvic incidence (PI) from 40 to 65°, the Boxall's slip angle (SA) (less than 45°), and Dubousset's lumbosacral angle (LSA).

Until now, there is no general approach to the surgical treatment of isthmic spondylolisthesis of the lumbosacral spine. Some surgeons use posterior surgical approaches such as PLIF and TLIF [1–7, 12–14], while others use anterior approaches such as ALIF [3, 8, 9, 11, 14]. The anterior approach is quite trau-

matic and is associated with the risk of severe intraoperative complications from the intestines, great vessels, and ureters. Anterior surgical approaches in the treatment of this category of patients provide appropriate anterior fusion with the use of a variety of implants. Nevertheless, the posterior ligamentous complex remains unfixed [1, 4, 10, 12]. Posterior surgical approaches provide appropriate primary posterior stabilization of the L5-S1 spinal motion segment with the use of transpedicular fixators. Transpedicular fixation is complemented by anterior interbody fusion performed by the TLIF or PLIF technique. Supporters of anterior approaches tend to believe that transpedicular fixation together with interbody fusion is very traumatic and is associated with the risk of neurological complications and the development of the scar formation process. [1, 3, 7–9, 11, 12].

The main tasks in the planning of surgical interventions are:

1) selection of a minimally invasive and maximally safe surgical approach [1–4, 10];

2) ensuring reliable primary fixation of the spinal motion segment and creating conditions for bone block formation [1–9];

3) appropriate decompression of nervous structures;

4) correction of sagittal balance and reduction of displaced vertebrae;

5) biocompatibility of instrumental stabilizing systems, providing early activation of the patient [2, 5, 6, 10, 14].

The objective is to analyze the clinical and radiological results of surgical treatment of patients with isthmic spondylolisthesis of the L5 vertebra using anterior axial fusion and transpedicular stabilization with interbody fusion performed through the posterior approach.

Material and Methods

In 2007–2021, a total of 71 patients with grade I and II isthmic spondylolisthesis of the L5 vertebra underwent surgical treatment. A retrospective intra-group comparison with an abnormal distribution of the effectiveness of various surgical techniques was performed.

Inclusion criteria: the presence of isthmic spondylolisthesis of the L5 vertebra of grade I and II; the absence of true radicular syndrome and a sagittal balance disorder.

Exclusion criteria: degenerative spondylolisthesis, radicular syndrome, osteoporosis, infectious diseases, oncological diseases, traumatic injuries, and sagittal imbalance (according to the SRS-Schwab ASD Classification). Patients were excluded from the study, if PI-LL was more than 10°, SVA was more than 5 cm, PT was more than 20°.

Patients

The general group included patients aged 18–56 years (mean age: 38 years; 36 men and 35 women) only with isthmic spondylolisthesis without radiculopathy. Grade I spondylolisthesis, according to the Meyerding classification, was found in 48 (67.6 %) patients, grade II in 23 (32.4 %) patients. The distribution of patients according to the grade of the L5 vertebra displacement relative to the S1 endplate is given in Table 1.

All patients were divided into 2 groups: the study group included 25 people; the control group included 46 patients. The distribution of patients was random.

Techniques

Patients were assessed according to the following parameters:

– general condition according to the ODI questionnaire;

– the pain severity according to the VAS scale;

– degree of neurologic impairment according to Francel (absence of paresis, hyposthesia, assessment of reflexes);

– the grade of spondylolisthesis according to radiography using the Meyerding classification;

– sagittal balance on lateral radiography according to the SRS-Schwab ASD Classification (SVA < 4.5 cm; PT: from 10 to 20°; SS: from 30 to 60°; LL: from 45 to 87°; PI-LL < 10°);

– the degree of stability according to stress lateral radiography in the standing position (the instability criteria were deemed to be translation >4.5 mm L5–S1 and rotation during flexion and extension >10° on L5–S1, using RadiAnt DICOM, Surgimap);

– narrowing of the spinal canal and intervertebral foramen according to MRI data.

When analyzing the plain spondylograms performed in direct and lateral projections, diastasis in the interarticular area of the vertebral arches was found in all patients.

When analyzing the stability of the spinal motion segment, translation and angulation were assessed (Fig. 1). The study data are shown in Table 2.

The analysis of the sagittal balance of patients is given in Table 3.

According to MRI findings, 71 (100.0 %) patients had L5–S1 intervertebral disc protrusion with compression of the dural sac; 42 (59.1 %) patients had unilateral or bilateral narrowing of the intervertebral foramen.

The main symptom in the clinical picture in patients of both groups before surgery was a pronounced lumbar spine pain, which increased with exercise, extension, and rotational movements.

All patients underwent surgical treatment: it was L5–S1 anterior axial fusion in the study group; and transpedicular fixation combined with TLIF in the control group.

The L5–S1 anterior axial fusion is a retrorectal presacral axial approach to the anterior surface of the first sacral vertebra (S1); lumbosacral spine fusion is performed by inserting a cage-screw in the axial direction through the S1 vertebral body and the L5–S1 disc into the L5 vertebral body.

The surgery consisted of the following stages: anesthetic support (endotracheal anesthesia), laying the patient (standard knee-elbow position), identification of the place of surgical approach in the sacrococcygeal joint, access using a wound dilator along the anterior surface of the sacrum in the axial direction to the body of the S1 vertebra under an image intensifying tube, formation of a canal in the axial direction through the S1 vertebral body, L5–S1 intervertebral disc into the L5 vertebral body, threading for an implant, insertion of an implant (cage-screw), and layered closure of the surgical wound. During the canal formation in the L5 vertebral body, pelvic ret-

roversion can be corrected by changing the angle and trajectory of the canal and the insertion of the implant (Fig. 2, 3).

Transpedicular fixation with interbody fusion (TLIF) of the lumbosacral spine was performed in patients in the control group. The technique of execution followed the classical scheme.

Statistical analysis

Data processing was performed using descriptive statistics. For ordinal variables, the frequency of the value is presented, indicating the percentage of valid observations; for quantitative variables, the mean value with a standard deviation of M ± m. The frequency characteristics of numerical criteria were compared using Fisher's exact test. The Mann – Whitney U Test was used to evaluate the significance of the differences in the sample populations when comparing groups. Statistically significant differences were evidenced by $p < 0.05$. Statistical analysis was performed in the SPSS 22.0 software.

Results

A retrospective analysis of the surgical outcomes of 71 patients was performed. There was a shorter surgery duration (67 ± 23 minutes) and length of hospital stay (3 ± 1 day) in the study group than in the control one (135 ± 45 minutes, 5 ± 2 days, respectively). The mean blood loss volume in the study group was 200.0 ± 100.0 ml; and in the control group – 400.0 ± 200.0 ml.

Clinical data in the postoperative period were evaluated according to the MacNab subjective rating scale and the ODI questionnaire (Tables 4, 5).

The dynamicsof pain syndrome which was the main one in the clinical picture of the disease, are shown in Table 6.

The severity of neurological disorders before and after surgery was evaluated on the Francel scale, that corresponded to group E.

There were no signs of instability on stress radiography in the postoperative period in the patients of both groups.

Since the stabilization of the lumbosacral spine was performed in situ, there were no statistically significant differences in sagittal balance before and after surgery.

In the postoperative period after presacral axial fusion, there were no changes in the MRI findings. After transpedicular fixation with TLIF, an expansion of the spinal canal and intervertebral foramen was determined on the MRI scans at the side of TLIF execution.

Complications. Facet syndrome was found in three (12 %) cases in the postoperative period in patients who underwent surgery with the use of L5–S1 anterior axial fusion, which required further radiofrequency denervation of facet joints. After 4 years, one patient (4 %)

Table 1
Distribution of patients depending on the degree of displacement of the L5 vertebra according to Meyerding, n (%)

Group	Grade I		Grade II	
	10–14 %	15–24 %	25–37 %	38–50 %
Study	10 (40.0)	7 (28.0)	8 (32.0)	0 (0.0)
Control	14 (30.4)	17 (36.9)	15 (32.7)	0 (0.0)
Total	48 (67.6)		23 (32.4)	

Fig. 1
Calculation of indicators of sagittal balance and stability: **a** – calculation of PT, PI, SS; **b** – calculation of LL; **c** – definition of angulation and translation

Table 2
Distribution of patients according to radiological indicators of mobility of the lumbosacral spine, n (%)

Indicator		Study group	Control group
Angulation	0–10°	15 (60.0)	29 (63.0)
	11–20°	8 (32.0)	15 (32.6)
	21–30°	2 (8.0)	2 (4.3)
Translation	0.0–2.0 mm	10 (40.0)	15 (32.6)
	2.1–4.5 mm	9 (36.0)	21 (45.6)
	4.6–6.0 mm	4 (16.0)	4 (8.7)
	6.1–7.0 mm	2 (8.0)	6 (13.1)

was diagnosed with an adjacent segment disease. In the clinical picture, there was a facet syndrome. According to the MRI findings, there were signs of degeneration of the adjacent disc and signs of L4–L5 spondyloarthrosis. There were no signs of nerve compression syndrome. Myofascial pain syndrome was found in four (8.7 %) of the patients who underwent TLIF transpedicular fixation with interbody fusion. Three (6.5 %) patients were diagnosed with adjacent segment disease. The follow-up period was 2–3 years after the surgery. In the clinical picture there was a facet syndrome. According to the MRI findings, there were signs of degeneration of the adjacent disc and signs of L4–L5 spondyloarthrosis. There were no signs of nerve compression syndrome.

Case 1. Patient L., male, 27 years old, was admitted to the hospital complaining of severe low back pain, which increases with exertion. The clinical picture consisted of a muscular defense, restriction of movements in the lumbar spine, and a positive Murphy's punch sign. The patient underwent presacral axial fusion.

In the postoperative period, there was a smooth regression of lumbosacral pain within 2 months after surgery (Fig. 4).

Case 2. Patient O., female, 45 years old, was admitted to the neurosurgical unit complaining of severe lumbosacral pain with periodic radiation to the legs, increasing with physical exertion. The clinical picture consisted of a muscular defense, restriction of movements in the lumbar spine, a positive Murphy's punch sign. The patient underwent presacral axial fusion.

Lumbosacral pain and pseudoradicular pain regressed within one month after surgery (Fig. 5).

Case 3. Patient Ch., female, 40 years old, was admitted to the hospital complaining of pronounced lumbosacral pain with periodic radiation to the posterolateral surface of the legs from both sides. The clinical picture consisted of a muscular defense, restriction of movements in the lumbar spine, and a positive Murphy's punch sign. The patient underwent TLIF with transpedicular stabilization.

Lumbosacral pain and pseudoradicular pain regressed in the postoperative period (Fig. 6).

Table 3
Sagittal balance indicators

Indicator	Study group	Control group
SVA, sm	3.84 ± 1.40	3.15 ± 1.90
SS, degree	43.40 ± 12.30	39.60 ± 4.60
PT, degree	14.60 ± 4.30	15.30 ± 4.60
PI, degree	58.70 ± 9.40	56.70 ± 7.30
LL, degree	50.20 ± 8.90	52.90 ± 10.20
PI–LL, degree	8.50 ± 5.30	3.80 ± 7.10

$p < 0.05$.

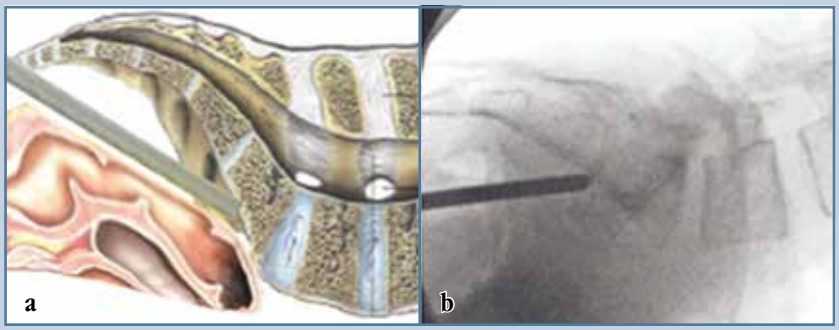

Fig. 2
Approach to the S1 vertebral body: **a** – approach scheme; **b** – radiological control

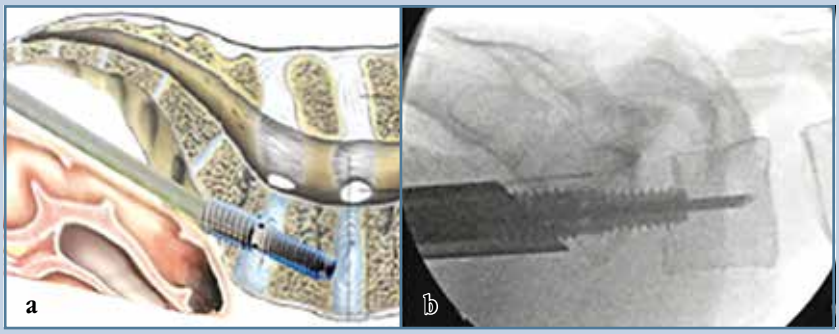

Fig. 3
Installation of the implant into the formed channel: **a** – approach scheme; **b** – radiological control

Discussion

He et al. [19] conducted a biomechanical examination of patients with spondylolysis or unilateral direct decompression after presacral axial fusion; appropriate models were created. The Von Mises Stress Distribution or the stress distribution experienced by the bone components and the axial screw was assessed. Result: presacral axial fusion satisfies the basic need to ensure sufficient stress resistance for normal activity of the body. For patients with

spondylolysis or requiring unilateral direct decompression, the effect that was exercised on load transfer after axial decompression did not matter.

Zeilstra et al. [20] analyzed 6 years of work on the use of presacral axial fusion. 131 surgeries were performed in patients with osteochondrosis. During this period, there were no cases of intraoperative complications, including injuries to blood vessels, the nervous system, pelvic organs, or the intestines. The severity of back and leg pain decreased by 51 and 42 %, respectively ($p < 0.001$). Clinical success, defined as an improvement of 30 %, was 67 % for the severity of back pain, 65 % for the severity of leg pain, and 71 % for back function. The employment rate rose from 47 % before surgery to 64 % at the final follow-up ($p < 0.001$). Patients' satisfaction with presacral axial fusion was 83 %.

Nowadays, the view on the existing surgical techniques for the considered pathology remains ambiguous and requires further study and analysis. In our opinion, the most relevant surgical techniques remain transpedicular stabilization with TLIF and presacral axial fusion.

These are the advantages of L5–S1 presacral axial fusion:

1) excludes injury of fascia and paraspinal muscles; reduces the possibility of nerve root injury; eliminates the need for resection of vertebral bodies, the fibrous ring of the intervertebral disc, ligaments, and joints;

2) allows reliable fixation of the L5–S1 segment;

3) reduces the surgery duration;

4) reduces the postoperative rehabilitation period.

Disadvantages of L5–S1 anterior axial fusion: it does not enable a full decompression of nerve structures with pronounced compression of the dural sac and spinal roots; it is impossible to relieve the facet joints with pronounced spondyloarthrosis; it is impossible to perform reduction of the L5 spondylolisthesis.

These are the advantages of the L5–S1 transcutaneous fixation combined with TLIF: it enables reduction of the L5 spondylolisthesis; reliably fixes the spinal motion segment; is relatively ease in installation; and provides a possibility of wide decompression of the dural sac and spinal roots. Disadvantages: the need to handle the paraspinal musculature, nerve structures, and a rather high injury rate.

Table 4

Distribution of patients according to the outcomes of treatment according to the MacNab scale, n (%)

Group	Outcome			
	excellent	good	satisfactory	unsatisfactory
Study	4 (16.00)	18 (72.00)	3 (12.00)	0 (0.00)
Control	5 (10.86)	37 (80.43)	4 (8.69)	0 (0.00)

Table 5

Assessment of the general condition of patients according to ODI (M ± m)

Period	Study group	Control group
Before surgery	50.7 ± 12.4	48.2 ± 14.2
7 days after	30.2 ± 6.5	45.3 ± 9.6
14 days after	32.3 ± 8.1	30.2 ± 5.2
1 month after	8.1 ± 4.4	6.3 ± 2.2
6 months after	4.0 ± 2.1	6.2 ± 4.1
1 year after	4.3 ± 1.8	2.1 ± 1.9
5 years after	2.2 ± 2.0	2.8 ± 1.8

$p < 0.05$.

Table 6

Dynamics of pain syndrome according to VAS before and after surgical treatment, points

Period	Study group	Control group
Before surgery	5.4 ± 3.0	5.8 ± 3.1
7 days after	1.5 ± 0.5	4.0 ± 1.0
14 days after	2.0 ± 1.0	2.5 ± 0.5
1 month after	1.0 ± 0.7	2.0 ± 1.0
6 months after	1.0 ± 1.0	0.6 ± 0.4
1 year after	0.5 ± 0.5	0.5 ± 0.3
5 years after	0.5 ± 0.5	0.5 ± 0.5

$p < 0.05$.

Conclusion

Analyzing the surgical outcomes of patients with grade I and II isthmic spondylolisthesis according to Meyerding (the L5 dislocation degree relative to S1 is up to 37 %) without sagittal balance disorder and without radiculopathy with the use of transpedicular fixation with TLIF interbody fusion and with the use of anterosacral axial fusion, it can be concluded that the results are comparable. According to ODI and VAS, there is a statistically significant advantage to anterosacral axial fusion in the early postoperative period (2 weeks after surgery). There was a decrease in the length of hospital stay and early rehabilitation by 1.5 times ($p < 0.05$) in the study group of patients. Subsequently, there was no statistically significant difference between the two groups. Thus, anterosacral axial fusion may be the method of choice in the surgical

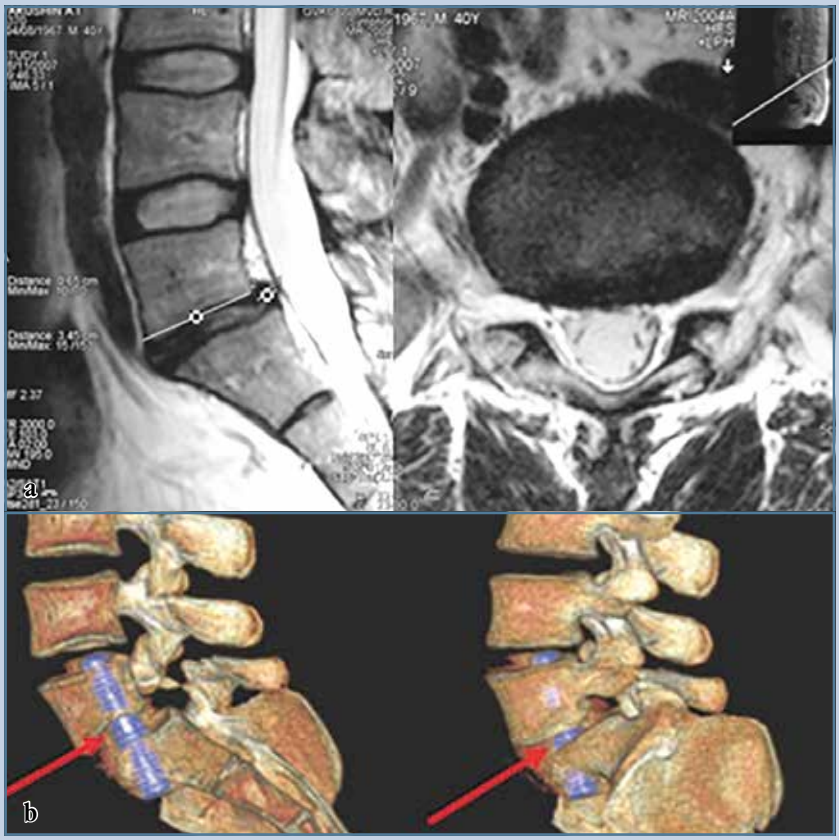

Fig. 4
MRI and CT of the lumbosacral spine of patient L., male, 27 years old, with grade I spondylolisthesis of the L5 vertebra: **a** – before surgery in the sagittal and axial projections; **b** – sagittal slices of 3D reconstruction after fusion of L5–S1 vertebrae

treatment of grade I and II isthmic spondylolisthesis not complicated by radiculopathy and sagittal imbalance.

The study had no sponsors.
The authors declare that they have no conflict of interest.
The study was approved by the local ethical committee of the institution.
All authors contributed significantly to the research and preparation of the article, read and approved the final version before publication.

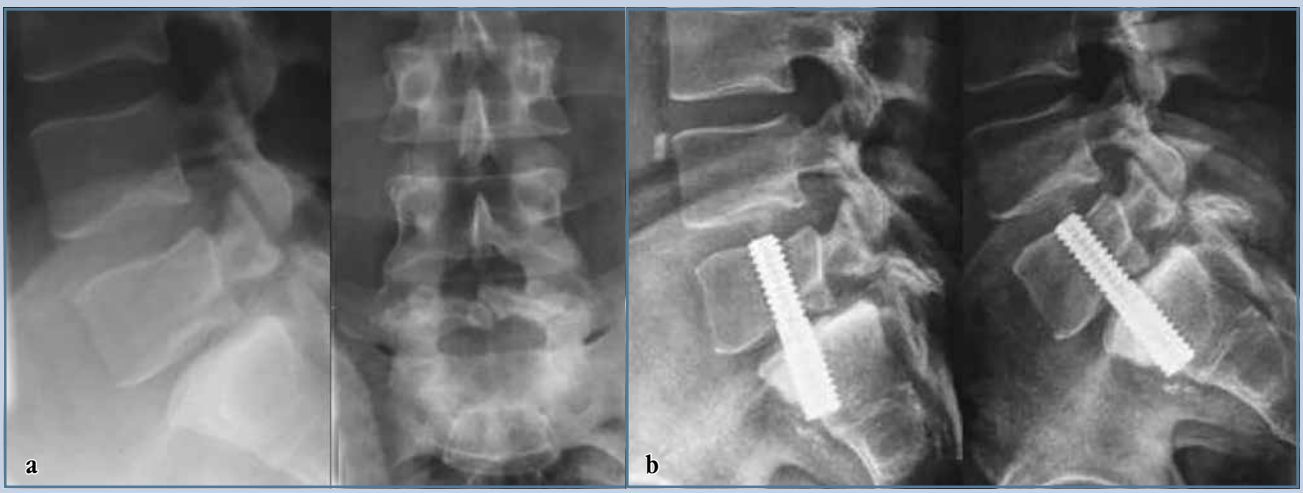

Fig. 5
Plain and stress radiographs of the lumbosacral spine of patient O., female, 45 years old: **a** – before surgery in frontal and lateral projections; **b** – after surgery (flexion and extension)

Fig. 6
Plain radiographs in frontal and lateral projections of patient Ch., female, 40 years old

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