TREATMENT OF PATIENTS WITH POSTTRAUMATIC DEFORMITIES OF THE THORACOLUMBAR SPINE USING SCHWAB 5 OSTEOTOMY THROUGH COMBINED AND POSTERIOR APPROACHES

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Objective. To analyze the results of surgical treatment of patients with rigid posttraumatic deformities of the thoracolumbar spine operated on using Schwab 5 osteotomy through combined and posterior approaches.
Material and Methods. A retrospective cohort study was conducted. Study group included 60 patients (m/f = 25/35). Median age was 48 (26–58) years, median time since injury was 11 (9–14) months, and minimum follow-up period was 2 years. A two-stage intervention with resection of the vertebral body, correction of the deformity, and placement of an interbody implant through the anterior approach followed by final fixation through the posterior approach (VCR_{a+p} group) was performed in 29 cases. Vertebral body resection through the posterior approach with correction of the deformity, installation of an interbody implant, and rigid transpedicular fixation (VCR_p group) was performed in 31 cases. In all patients, the magnitude of correction was assessed, as well as the following parameters: frontal balance, sagittal balance, thoracic kyphosis, lumbar lordosis, pelvic incidence, sacral slope and pelvic tilt. The results of treatment were evaluated in dynamics by the level of pain syndrome (VAS) and quality of life (ODI), as well as based on the analysis of postoperative complications.
Results. The groups were comparable in terms of gender, age, magnitude of the kyphotic component of the deformity, level of pain syndrome and degree of initial neurological deficit ($p > 0.05$). Correction of the deformity kyphotic component was significantly better in patients in the VCR_p group compared to those in the VCR_{a+p} group ($p = 0.036$). Both groups showed a significant decrease in the level of pain syndrome 3 months after surgery. However, further follow-up showed a tendency for back pain to increase on average one year after surgery in the VCR_{a+p} group. A total of 67 complications were revealed in 40 (66.7 %) patients. Herewith, in the early postoperative period there were 55 complications in 31 patients, and in the late period there were 12 complications in 9 patients. Analysis of early complications showed a higher incidence of anemia ($p = 0.002$) and liquorrhea ($p = 0.017$) in the VCR_p group compared to those in the VCR_{a+p} group. The incidence of long-term complications did not differ significantly between groups ($p = 0.866$). An increase in back pain in the long-term period was observed in 12 (41.4 %) patients of the VCR_{a+p} group and in 4 (12.9 %) patients of the VCR_p group. Analysis of risk factors for this condition showed a tendency for back pain to increase in the long-term period in patients with residual local deformity against the background of low pelvic index values.
Conclusion. Correction of the kyphotic component of deformity was significantly better in patients of the VCR_p group, which was accompanied by greater surgical trauma and incidence of early postoperative complications. The tendency of patients' quality of life to deteriorate in the long-term follow-up period seems to be related to the occurrence of pain syndrome in the lumbar spine in patients with residual kyphotic deformity against the background of initially low compensatory capabilities.
Key Words: post-traumatic deformity, surgical correction, long-term results.
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Surgical treatment of posttraumatic spinal deformities is currently one of the most discussed issues in the professional literature [1–3]. Meanwhile, the main concept of surgical treatment is to correct local deformity as much as possible with the restoration of normal interrelations of the spinal motion segments [4, 5]. In cases of rigid deformity, especially in the presence of an anterior bone block, surgical correction is a highly traumatic, prolonged and often multi-stage surgery with certain difficulties in preoperative planning and a significant complication rate in the postoperative period [6–9]. Surgical techniques used to correct the described deformities include Schwab grade 3, 4 and 5 osteotomies. Meanwhile, the elimination of local kyphosis of more than 30°, according to most authors, is possible using a three-column osteotomy (Schwab 5, Vertebral Column Resection, VCR). Widely used alternative techniques based on shortening osteotomies (Pedicle Substraction Osteotomy, Bone Disc Bone Osteotomy) and their modifications are, according to the literature [1, 10–12], less traumatic. However, they have limited surgical correction options and controversial long-term treatment outcomes.

Nevertheless, Schwab grade 5 osteotomies performed through the combined (anterior and posterior) approach (VCR anterior + posterior; VCR_{a+p}) and simultaneous posterior approach (VCR posterior; VCR_p) have different injury rates, despite the same aim of surgical treatment. Moreover, the choice of a particular treatment option is often based on the personal preferences of a surgeon.

The objective is to analyze the results of surgical treatment of patients with rigid post-traumatic deformities of the thoracolumbar spine operated on using the VCR_{a+p} and VCR_p techniques.

Material and Methods

The retrospective cohort study included an assessment of outcomes in 60 patients operated on in 2012–2020.

Inclusion criteria: post-traumatic deformity of the thoracolumbar spine with a consolidated fracture at the level of T11–L2 vertebrae; an anterior bone block confirmed by CT; a magnitude of the local kyphosis is in the range of 30–90° according to Cobb.

Exclusion criteria: neurological deficit of grades A–C according to the ASIA Impairment Scale; rheumatological comorbidity (rheumatoid arthritis or systemic lupus erythematosus); diabetes mellitus; severe osteoporosis (T-score of more than -2.5); the lack of a complete radiographic examination before and after surgery. In addition, the exclusion criterion was the presence of a pronounced anterior bone block at the injury level (according to CT findings).

The minimum follow-up period for patients after surgery was 2 years. The study included 35 (58.3 %) women and 25 (41.7 %) men. The median age of the patients was 48 (26–58) years and the median time since the injury was 11 (9–14) months.

The patients underwent two types of surgeries:

1) vertebral body resection through the posterior approach (VCR_p) with deformity correction, placement of an interbody implant and rigid transpedicular fixation;

2) a two-stage intervention (VCR_{a+p}) with vertebral body resection, correction of the deformity and placement of an interbody implant through the anterior approach followed by final fixation through the posterior approach.

Global spinal balance and the main spino-pelvic ratios were assessed in all patients. This analysis was performed based on the study the radiographs of full-length standing up and lateral position (teleroentgenograms) in anterior and lateral views, follow-up control of its results were considered after surgery. Global spinal balance was assessed by the dislocation of the T1 vertebra relative to the central sacral vertical line (CSVL) in the frontal plane and by the sagittal vertical axis (SVA) in the sagittal plane. The assessed spino-pelvic parameters included thoracic kyphosis (TK), lumbar lordosis (LL), pelvic incidence (PI), sacral slope (SS) and pelvic tilt (PT). Meanwhile, the measurement of thoracic kyphosis and lumbar lordosis was performed up to the level of post-traumatic deformity.

The assessment of the surgical outcomes was performed based on the changes in the indicators of pain syndrome (according to VAS), quality of life (according to ODI) and the analysis of complications of the early and long-term postoperative periods. The follow-up examinations with filling out the appropriate assessment questionnaires were performed 3, 6, 12, 18 and 24 months after surgery.

Statistical analysis was performed using specialized IBM SPSS Statistics 23 software. The normality of the distribution of numerical data was assessed using the Shapiro-Wilk test and the Kolmogorov-Smirnov test. Meanwhile, the main volume of data did not correspond to the normal distribution; its description is given in the following format: median (1st–3rd quartiles). Intergroup comparisons of continuous independent variables were analyzed using the Mann – Whitney U test. The comparison of binary and categorical data was performed using Pearson's chi-squared test and Fisher's exact test. Data in dependent samples were compared according to the Wilcoxon signed-rank test. The statistical significance of the factors affecting the development of postoperative complications was assessed using binary logistic regression. The differences between the values were considered statistically significant at the level of $p < 0.05$, which is accepted in biomedical research.

Results

The distribution of patients by gender, age, fracture localization and the magnitude of the kyphotic deformity was studied to determine the comparability of the groups. Moreover, the mean PI values in patients of both groups were reviewed (Table 1).

According to the results of the analysis of preoperative indicators, there were no statistically significant differences in the distribution of patients by gender, age, the magnitude of the kyphotic deformity, pelvic index, the level of pain syndrome or the grade of the initial neurological deficit. Nevertheless, a certain tendency was revealed in the VCR_{a+p} group of patients with deformity as a result of fracture of the lumbar vertebrae (L1 and L2), while in the VCR_p group, in most patients deformity was formed after fracture of the thoracic vertebrae (T11 and T12). This tendency seems to be related to the willingness of surgeons to avoid the risks of damaging the nerve roots of the lumbar spine during the removal of the vertebral body and the placement of an interbody implant. Despite the fact that this tendency has not been statistically validated, the corresponding feature of the distribution of patients reduces the reliability of the assessment of postoperative neurological complications. Regarding possible mistakes in data interpretation, the analysis of the changes in the neurological status of patients after treatment was not performed in this study. There were no statistically significant differences between the mean preoperative values of the spino-pelvic parameters in both groups.

Therefore, there were no statistically significant differences in the distribution of patients by gender, age, radiographic and main clinical and neurological parameters. This made it possible to objectively assess the results of treatment in a comparative manner.

The surgical outcomes were assessed in the early and long-term postoperative periods. The main indicators of surgery and the early postoperative period are given in Table 2.

Significant differences in the volume of intraoperative and drainage blood loss were found in the study groups. The duration of surgery in the groups did not significantly differ. Nevertheless, the revealed tendency of longer duration in the VCR_p group requires further follow-up and analysis.

The change in the mean values of the main radiographic parameters after surgery had enabled us to assess the possibilities of surgical correction depending on the surgical approach, the degree of restoration of global balance and changes in the parameters of compensatory mechanisms (Table 3).

Consideration of the assessment of radiographic parameters after surgery in patients of both groups made it possible to reach normal values of global spinal balance according to CSVL and SVA. Correction of the kyphotic component of the deformity was considerably better in patients of the VCR_p group compared with patients of the VC_{Ra+p} group (p = 0.036). Additionally, both groups showed a statistically significant increase in thoracic kyphosis and a decrease in lumbar lordosis suggesting a decrease in the severity of the involved compensatory mechanisms. Also, the SS and PT indicators significantly changed in both groups as a result of pelvic anteversion after deformity correction.

An assessment of clinical signs showed a significant decrease in the back pain intensity 3 months after surgery in both groups. The analysis of long-term outcomes revealed significant differences in the groups at the stage of control examinations 1.5 years after surgery. Meanwhile, there was a tendency of worsening back pain syndrome in the VCR_{a+p} group on average a year after surgery (Fig. 1).

Patients in both groups showed a significant improvement in their ODI-measured quality of life outcomes after surgery. Nevertheless, a moderate negative tendency was observed in the VCR_{a+p} group one year after surgery (Fig. 2).

A total of 67 complications were found in 40 (66.7 %) patients. Out of them, 55 complications were detected in 31 patients in the early postoperative period, and 12 complications were detected in 9 patients in the late period (Table 4).

A comparative analysis of complications of the early postoperative period showed a higher incidence rate of anemia and liquorrhea in patients in the VCR_p group. As for other cases, the incidence rate of early complications did not considerably differ in both groups. Repeated surgery in the early postoperative period was necessary in all cases of deep-infected surgical sites (n = 4).

Generally, complications of the early postoperative period were considerably more common in patients in the VCR_p group (p = 0.016).

In the long-term period, the following complications were detected in patients of both groups: instability of the metal instrumentation; the formation of pseudoarthrosis and the adjacent segments pathology that included the development of pronounced degenerative changes at the level of the superjacent or subjacent spinal motion segment; the occurrence of clinically significant kyphosis in these regions; and fractures of the vertebrae adjacent to the fixation zone. We identified degenerative changes in adjacent segments as complications if their progression was by more than two degrees according to the Pfirrmann classification (compared with preoperative values). A clinically significant kyphosis in adjacent segments was diagnosed if the proximal or distal junctional angle increased by more than 10° in comparison to postoperative indicators with concurrent local pain syndrome. Repeated surgery in the long-term period was required in cases of instability of the metal instrumentation and in cases of formation of pseudoarthrosis (n = 4).

The incidence rate of long-term complications did not significantly differ in patients of both groups (p = 0.866).

Moreover, considering the revealed negative tendency of pain syndrome in the long-term postoperative period and its considerable effect on the quality of life of patients, an analysis was conducted aimed at determining risk factors for the development of pain syndrome in the lumbar spine. This condition was noted in 16 (26.7 %) patients in the entire cohort of follow-up. Meanwhile, 12 (41.4 %) patients with the corresponding symptoms were identified in the VCR_{a+p} group and 4 (12.9 %) patients in the VCR_p group.

The logistic regression study of the risk factors for the development of pain syndrome revealed that the residual local deformity and pelvic index value had a significant impact on the long-term increase in pain syndrome (Table 5).

An increase in residual kyphosis by 1° enhances the risk of pain syndrome development in the long-term period by 1.35 times (or by 35 %; p = 0.013; OR: 1.354; 9 5% CI: 1.066–1.720), while an increase in the pelvic index by 1° reduces the risk of developing this pathology by 1.2 times (1/0.834) or by 20 % (p = 0.018; OR: 0.834; 95 % CI: 0.718–0.969).

Clinical case 1. Patient G., female, 56 years old, suffered the complications of a spinal cord injury and a rigid posttraumatic deformity of the thoracolumbar spine due to a consolidated fracture of the L2 vertebra.

Table. 1

Characteristics of patients in the study groups

Parameters	Total (n = 60)	VCR_{a+p} (n = 29)	VCR_p (n = 31)	p
Gender, n				
male	25	13	12	0.631*
female	35	16	19	
Age, years	48 (26–58)	39 (26–56)	50 (29–61)	0.358**
Fracture localization, n (%)				
T11	7 (11.7)	2 (6.9)	5 (16.1)	0.078*
T12	24 (40.0)	8 (27.6)	16 (51.6)	
L1	22 (36.6)	14 (48.3)	8 (25.8)	
L2	7 (11.7)	5 (17.2)	2 (6.5)	
Local kyphosis, degrees	48 (42–58)	47 (41–56)	49 (43–65)	0.121**
Pelvic incidence, degrees	55 (47–60)	51 (47–60)	59 (50–60)	0.088**
Pain syndrome according to the VAS, points	6 (5–7)	6 (5–7)	6 (5–6)	0.619**
*Neurological deficit according to the ASIA, points****	5 (4–5)	5 (4–5)	5 (4–5)	0.634**

* The Pearson's chi-squared test; ** according to the Mann — Whitney test;

*** degree of neurological deficit according to the ASIA scale, where A — 1 point, E — 5 points.

The back pain intensity, according to the VAS, was 7 points. The magnitude of the local kyphotic deformity was 51.8°. There was a pronounced impairment of sagittal balance (SVA = 160.6 mm) associated with the compensatory mechanisms involved (decrease in TK, increase in LL, pelvic retroversion and flexion in the hip joints; Fig. 3a).

The T12–L1–L3–L4 transpedicular fixation with bone cement-augmented screws, Schwab grade 5 osteotomy, deformity correction and placement of an interbody cage with an autogenous bone graft at the L1–L3 level were performed through the posterior approach during one stage surgery. The surgery duration was 260 minutes; intraoperative blood loss was 1,200 ml. There were no significant complications in the early and long-term postoperative periods.

The outcomes of the postoperative examination showed the achievement of sagittal profile correction (SVA 45.2 mm) and decrease in the degree of the compensatory mechanisms in the form of the thoracic kyphosis (TK 37.2°) and the lumbar lordosis (LL -23.9°). The residual deformity in the sagittal plane was 3.1° (Fig. 3b).

The intensity of back pain was 2 points 12 months after surgery. There were signs of bone block formation at the L1–L3 level on the control CT scan (Fig. 4).

Clinical case 2. Patient M., female, 68 years old, suffered the consequences of a spinal cord injury and a rigid posttraumatic deformity of the thoracolumbar spine associated with a consolidated T12 vertebral fracture.

The back pain intensity, according to the VAS, was 8 points. The magnitude of the local kyphotic deformity was 36.3°. There was also a moderate impairment of sagittal balance (SVA 48.3 mm) associated with the compensatory mechanisms involved (decrease in TK, increase in LL, pelvic retroversion and flexion in the hip joints; Fig. 5a).

Two-stage surgery was performed in one surgical session. The T12 vertebral body resection, deformity correction, and placement of an interbody cage with an autogenous bone graft at the T11–L1 level were performed through the anterior approach at the first stage. The transpedicular fixation of T10–T11–L1–L2 was performed through the posterior approach at the second stage.

The surgery duration was 240 minutes; intraoperative blood loss was

Table 2

Comparative analysis of the main indicators of surgical intervention and the early postoperative period in the study groups

Parameters	Groups		p*
	VCR_{a+p} (n = 29)	VCR_p (n = 31)	
Surgery duration, min	244.0 ± 40.0	303.0 ± 50.1	0.064
Intraoperative blood loss volume, ml	424 ± 120	1356 ± 100	0.001
Drainage blood loss volume, ml	114 ± 60	258 ± 80	0.001
Hospital stay after surgery, days	17.0 ± 6.1	19.0 ± 5.8	0.126

* According to the Mann — Whitney test.

Table 3

Comparative analysis of changes in the main radiographic parameters in the study groups

Parameters	Groups		p*
	VCR_{a+p} (n = 29)	VCR_p (n = 31)	
CSVL, мм			
before surgery	12 (8–19)	13 (8–18)	0.959
after surgery	4 (3–5)	3 (1–5)	0.346
p**	<0.001	<0.001	–
SVA, мм			
before surgery	42 (35–55)	50 (40–57)	0.252
after surgery	6 (4–8)	6 (3–7)	0.276
p**	<0.001	<0.001	–
TK, degrees			
before surgery	16 (14–18)	17 (14–22)	0.499
after surgery	28 (26–30)	27 (25–30)	0.237
p**	<0.001	<0.001	–
LL, degrees			
before surgery	68 (62–71)	67 (63–72)	0.772
after surgery	48 (43–52)	50 (46–54)	0.098
p**	<0.001	0.001	–
SS, degrees			
before surgery	25 (22–28)	28 (23–33)	0.197
after surgery	40 (33–47)	46 (36–50)	0.094
p**	<0.001	<0.001	–
PT, degrees			
before surgery	26 (23–29)	28 (26–30)	0.070
after surgery	11 (8–15)	10 (8–14)	0.870
p**	<0.001	<0.001	–
Local kyphosis, degrees			
before surgery	47 (41–56)	49 (43–65)	0.121
after surgery	10 (6–11)	7 (5–10)	0.036
p**	<0.001	<0.001	–

*According to the Mann – Whitney test; ** according to the Wilcoxon test.

500 ml. There were no significant complications in the early postoperative period.

According to the postoperative radiographic examination, the residual deformity in the sagittal plane was 11.8°. Additionally, the sagittal profile was corrected (SVA 48.3 mm), and the degree of compensatory mechanisms (an increased thoracic kyphosis (TK 37.2°) and a decreased lumbar lordosis (LL -40.8°)) was lessened (Fig. 5b).

The back pain intensity was 3 points six months after surgery and 5 points after 12 months. There were signs of progression of degenerative changes in L2–L5 on the control MRI scan (Fig. 6).

Discussion

The generally recognized surgical technique for the treatment of patients with posttraumatic deformities of the thoracolumbar spine today is a two-stage surgical procedure. The first stage in this technique is anterior release from an anterolateral approach with resection of the bone block, the body of the deformed vertebra and adjacent intervertebral discs, nerve decompression, reconstruction of the spinal canal, and prosthetic repair of the vertebral body with the restoration of the planned ratios of the spinal motion segment. The final stage is posterior stabilization by transpedicular fixation systems that can be performed using minimally invasive percutaneous systems or, if necessary, supplemented by posterior release at the level of local deformity. The limitation of this surgical technique, in addition to the technical features of the anterior approach, is considered to be the incomplete manageability of the correction due to its fulfilment mainly by means of the anterior support column and insufficient mobility of the posterior elements. Moreover, the typical position of the patient does not allow to take advantage of the options of orthopedic table for deformity correction as well as perform the radiographic control [6, 10, 18]. A specific complication of the technique is the dislocation of the interbody implant in the absence of posterior stabilization, which often results in the need for additional surgery to correct its position [1, 7–9, 19].

Surgical treatment with vertebral body resection through the posterior approach provides maximum possibilities for the correction of rigid deformity with the most accurate correspondence of the restoration degree of the ratios of the spinal motion segment to preoperative planning. In this case, correction is achieved not only by distraction of the anterior support column but also by means of the repositioning instrumentation of transpedicular systems and the orthopedic table itself [9, 20–22]. From a technical point of view, the most complicated stages are complete anterior release and the placement of an interbody implant of considerable size through the posterior approach. Nevertheless, this technique, despite the single stage of surgery, refers to a highly traumatic surgical treatment associated with a significant blood loss volume and a high incidence rate of complications [1, 2, 21, 23].

Kyphotic deformity correction can be achieved by pedicle subtraction osteotomy (PSO) [10, 11, 24, 25]. This technique involves performing a wedge osteotomy at the local deformity level through the posterior approach. The limitations include a reduced degree of correction because of the posterior support column's shortness and the risk of neuro-

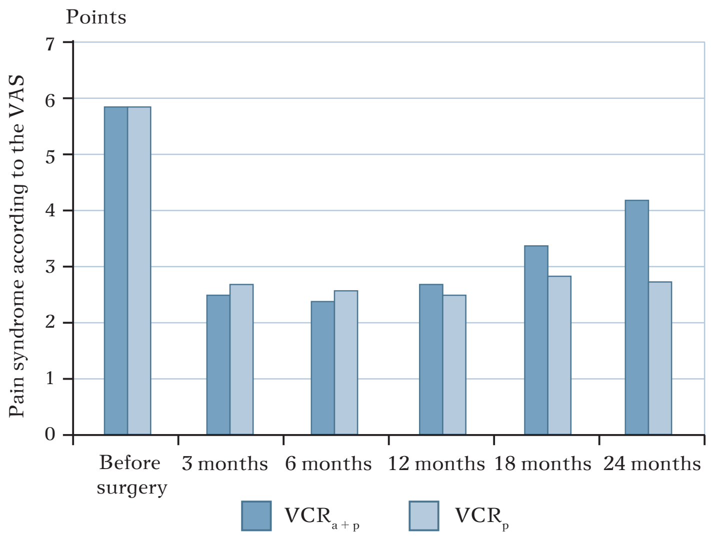

Fig. 1
Dynamics of pain syndrome in the back after surgical treatment in the study groups according to the VAS

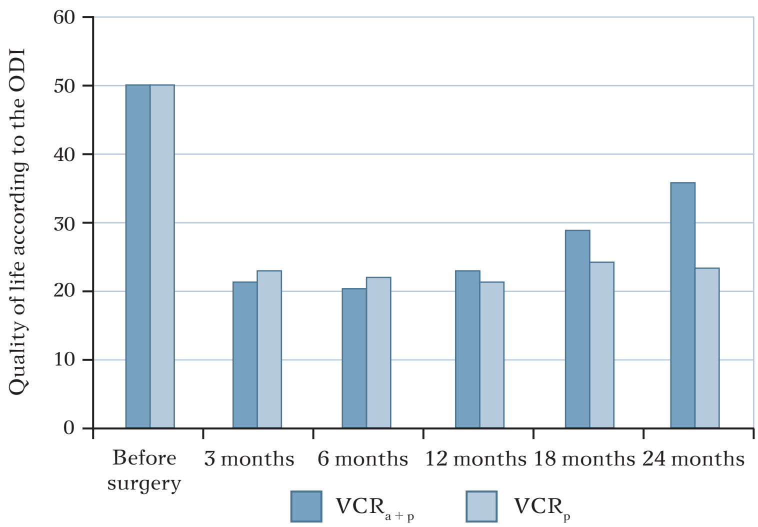

Fig. 2
Dynamics of quality of life after surgical treatment in study groups according to the ODI

logical complications associated with the corrugation of the dural sac content at this level. It is often impossible to define an acceptable extent of correction at the stage of preoperative planning, as this requires intraoperative monitoring of the condition of nervous structures. Moreover, the technique is one of the least traumatic options for correcting rigid post-traumatic deformities [11, 23, 26, 27].

According to our data, the patients in the VCR_p group had considerably higher mean values of the volume of intraoperative and drainage blood loss than the patients in the VCR_{a+p} group. This fact indicates a higher injury rate of this surgical option.

The degree of kyphotic deformity correction was considerably higher during surgical treatment using the VCR_p technique ($p = 0.036$). Nevertheless, there were no impairments in global spinal balance in patients in both groups. These outcomes may be the result of high compensatory capabilities in patients of predominantly young age. On the contrary, the constant functioning of compensatory mechanisms causes overload of the lumbar spine first of all, and it can contribute to the early development of degenerative pathology and clinically manifest itself as an increased pain syndrome [14–17].

The complication rate, according to the study, differed between the groups in the early follow-up period. Such complications predominated in patients in the VCRp group ($p = 0.016$) that may be a consequence of the higher injury rate of this approach. The late complication rate among the patients in the studied groups did not significantly differ ($p = 0.866$).

The assessment of clinical outcomes showed the efficiency of the described surgical techniques. Nevertheless, there was a tendency towards a decrease in efficiency in patients of both groups in the long-term follow-up period. Despite the relatively low complication rate of the long-term period after the posttraumatic deformity correction, there was a considerable number of unsatisfactory treatment outcomes and a reduced quality of life for the entire cohort of patients. These outcomes were due to the development of a pronounced pain syndrome in the lumbar spine in 16 (26.7 %) patients. According to the analysis of risk factors, there was no statistically significant dependence of pain

Table 4

Postoperative complications in patients of the study groups, n (%)

Complications	Groups		p*
	VCR_{a+p} (n = 29)	VCR_p (n = 31)	
Early postoperative period			
Anemia	4 (13.8)	16 (51.6)	0.002
Deep wound infection	1 (3.5)	3 (9.7)	0.332
Liquororrhea	1 (3.5)	8 (25.8)	0.017
Hemothorax	5 (17.2)	7 (22.6)	0.424
Pulmonary artery thromboembolia (PATE)	2 (6.9)	2 (6.5)	0.668
Pneumonia	3 (10.4)	3 (9.7)	0.632
Total (early period)	16 (29.1)	39 (70.9)	0.016**
Late postoperative period			
Instability of metal instrumentation	1 (3.5)	2 (6.5)	0.525
Pathology of adjacent segments, including:	3 (10.4)	3 (9.7)	0.632
degenerative changes	2 (6.9)	1 (3.2)	0.475
kyphosis	1 (3.5)	1 (3.2)	0.737
vertebral fractures	0 (0.0)	1 (3.2)	0.517
Pseudoarthrosis	1 (3.5)	2 (6.5)	0.525
Total (late period)	5 (17.2)	7 (22.6)	0.866**
Pain syndrome in the lumbar spine	12 (41.4)	4 (12.9)	0.013

* According to the Fisher's exact test; ** according to the Pearson's chi-squared test.

Table 5

Logistic regression analysis of risk factors for the development of pain syndrome in the long-term period

Risk factors	B	Significance	Odds ratio (Exp (B)) (95 % Confidence interval)
Residual kyphosis	0.303	0.013	1.354 (1.066–1.720)
SVA	0.069	0.567	1.071 (0.847–1.355)
CSVL	0.001	0.997	1.001 (0.701–1.429)
PI	-0.181	0.018	0.834 (0.718–0.969)
LL	-0.027	0.694	0.974 (0.852–1.112)
TK	-0.188	0.083	0.829 (0.671–1.025)
Late complications	-0.977	0.375	0.377 (0.043–3.260)

syndrome in the long-term period on impairment of global spinal balance or complications of the long-term period. The tendency of the direct influence of residual kyphotic deformity on the risk of developing pain syndrome in the long-term follow-up period and the reverse effect of the pelvic index were identified. These outcomes are probably the result of increased load on the lumbar spine due to the presence of a minor local kyphotic deformity with low compensatory capabilities. Further study with a larger patient cohort and longer follow-up periods is required to determine the threshold values of the specified indicators at which a statistically significant effect on the risk of the development of pain syndrome over the long-term follow-up will be identified.

Conclusion

According to our data, correction of the kyphotic component of the deformity was significantly better in patients in the VCRp group that was associated with higher injury and complication rates in the early postoperative period. The tendency of deterioration in quality of life in the long-term follow-up period appears to be associated with the of pain syndrome in the lumbar spine in patients with residual kyphotic deformity and the background of low compensatory capabilities.

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

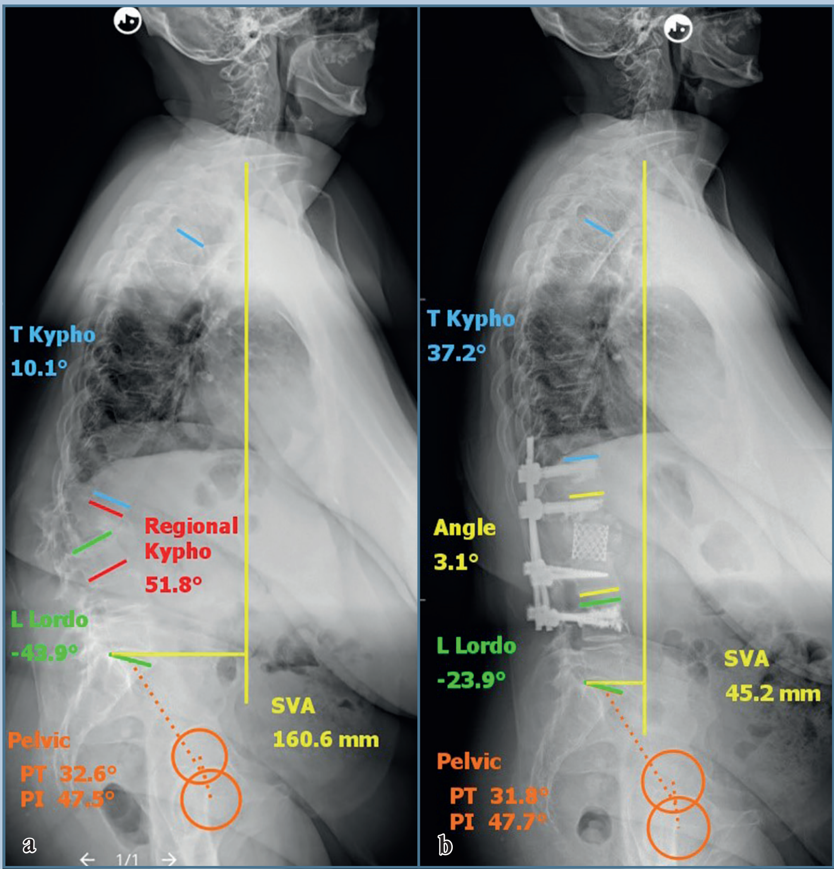

Fig. 3
Teleroentgenograms of patient G., female, 56 years old: **a** – before surgery in the lateral view; a local kyphotic deformity of 51.8° and an impairment of the sagittal balance (SVA 160.6 mm) are determined; **b** – after surgery in the lateral view; a residual local kyphotic deformity of 3.1° and a decrease in the severity of compensatory mechanisms are determined

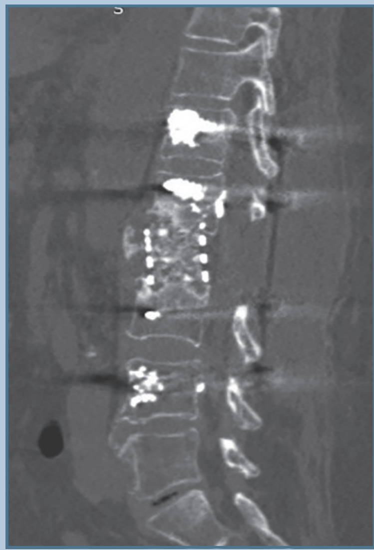

Fig. 4
CT scan of patient G., female, 56 years old, 12 months after surgery: signs of bone block at the L1–L3

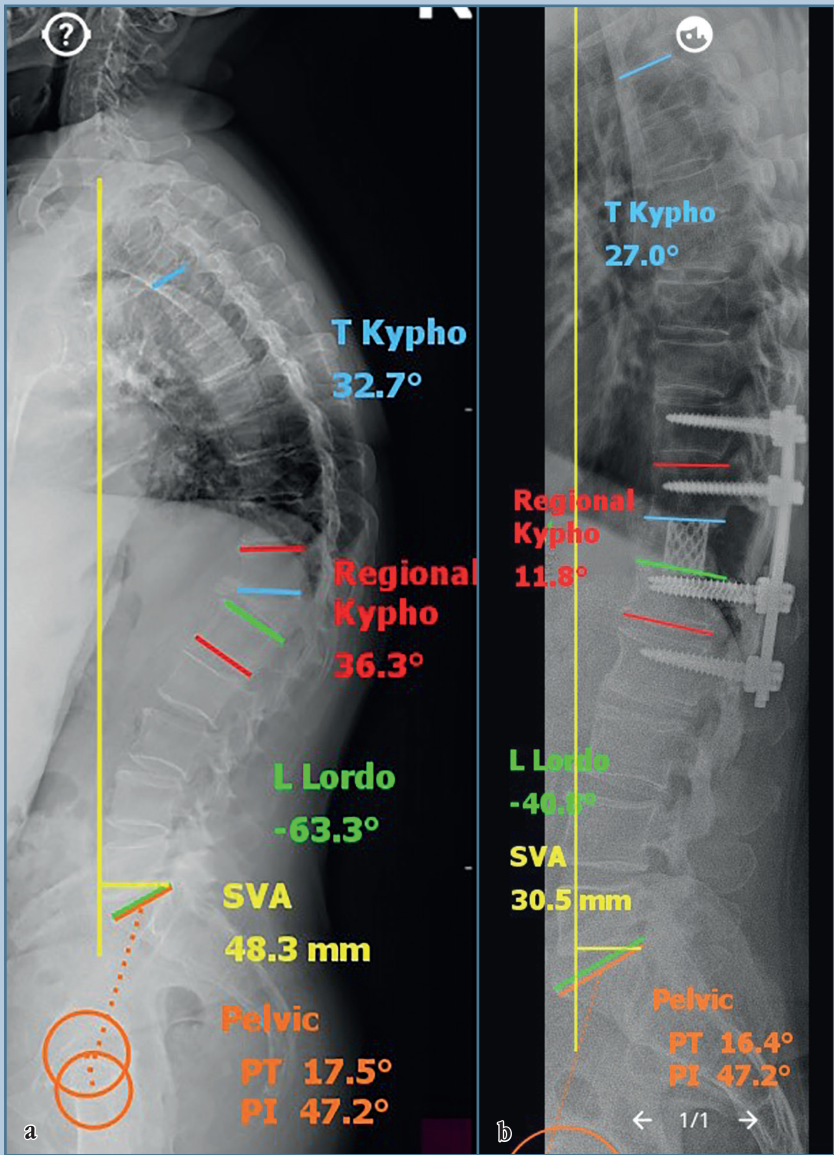

Fig. 5
Teleroentgenograms of patient M., female, 68 years old: **a** – before surgery in the lateral view; a local kyphotic deformity of 36.3° and moderate impairment of the sagittal balance (SVA 48.3 mm) are determined; **b** – after surgery in the lateral view; a residual local kyphotic deformity of 11.8° and a decrease in the severity of compensatory mechanisms are determined

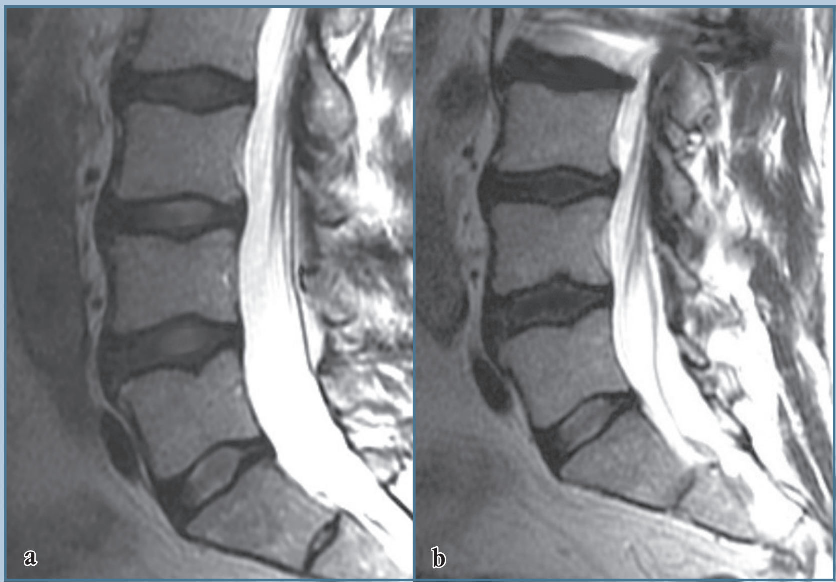

Fig. 6
MRI scan of patient M., female, 68 years old: **a** – sagittal section before surgery, L2–L3–L4 initial degenerative changes of Pfirrmann 3–4 degrees are determined; **b** – sagittal section after surgery, the progression of L2–L3–L4–L5 segments degenerative changes of Pfirrmann 5–6 degrees is determined

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