EFFICIENCY OF VARIOUS OPTIONS FOR SURGICAL TREATMENT AND PREVENTION OF PROXIMAL JUNCTIONAL KYPHOSIS IN PATIENTS WITH LUMBAR SPINE DEFORMITIES AND CONCOMITANT OSTEOPOROSIS

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Objective. To conduct a comparative analysis of the effectiveness of various options for the prevention of proximal junctional kyphosis (PJK) in the surgical treatment of adult patients with deformities of the lumbar spine, including taking into account the degree of correction of the lumbar lordosis.

Material and Methods. The results of instrumental fixation of the spine performed in 140 adult patients with severe frontal spinal deformity and/or sagittal imbalance corresponding to types III and IV according to Berjano and Lamartina were studied. The patients were divided into 4 clinical groups depending on the methods of surgical treatment: in 36 cases, correction of lumbar lordosis of no more than 30° was performed without the use of PJK prevention methods (Group I); in 24 — the same correction was supplemented with laminar fixation of the vertebra above the fusion zone (Group II); 20 patients underwent complete restoration of the sagittal and frontal balance with prophylactic vertebroplasty of the superjacent vertebra above the zone of instrumental fixation (Group III); and in 60 — the same intervention was performed without the use of the PJK prevention methods (Group IV).

Results. Statistically significant differences in lumbar lordosis, difference in the pelvic angle and lumbar lordosis, and displacement of the sagittal vertical axis were found between the pairs of groups I and II, and III and IV. Postoperative values of the index of the proximal junctional angle (PJA) in patients of Group II differed significantly from the corresponding indicators of other groups. A statistically significant increase in the PJA after surgery was found in patients of groups III and IV. There was a statistically significant decrease in PJK cases in Group II in comparison with other groups ($p = 0.001$), as well as more pronounced trend to decrease in pain intensity and ODI score. Laminar fixation of the superjacent vertebra leads to a decrease in local kyphosis over the area of instrumental fixation and reduces the load on the ventral parts of the vertebra. Prophylactic vertebroplasty (Group III) provides better results compared to a comparable cohort (Group IV).

Conclusion. Partial correction of lumbar lordosis (no more than 30°) and preventive laminar fixation of the superjacent vertebra showed significantly better clinical results (by more than 50 %; $p = 0.001$) compared with the other three clinical groups in terms of reducing the level of pain and improving the quality of life, as well as of decrease in number of cases of PJK development — by 16—28 % ($p = 0.001$).

Key Words: adult spine deformities, prevention methods, proximal junctional kyphosis, laminar fixation, vertebroplasty, osteoporosis, lumbar lordosis, sagittal balance.

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Spinal deformities in middle-aged and elderly patients are a common pathology. It significantly worsens the quality of life and causes serious socio-economic loss [1, 2]. Their frequency can reach 68 %. There is a trend of stable growth because of the increased longevity of the population. Meanwhile, the extent of degenerative scoliosis progression ranges from 1 to 6 % per year. On average it is 3 % [3, 4].

Treatment of patients with degenerative spinal diseases in combination with deformities is a major concern and may be variable. According to Berjano and Lamartina's classification [5], the use of selective interventions is acceptable for deformity of I and II types. In this case, short–segment fixation is used. It is reasonable to perform correction by applying extended fixation systems for deformity of III and IV types. Nevertheless, this type of intervention is associated with a high frequency of adverse outcomes and postoperative complications. The most common complication is proximal junctional kyphosis [6].

According to the literature data, more than 15 risk factors signify in the development of proximal junctional kyphosis [7–9]. Previous analysis showed that three risk factors significantly affect the development of proximal junctional kyphosis. They are the correction extent of lumbar lordosis (the correction volume is more than 30°), the presence of osteoporosis and the value of proximal junctional angle [10].

The levels located cranial to the proximal fixation point mainly are exposed to a greater risk of proximal junctional kyphosis [9, 11, 12]. This is confirmed by clinical and experimental studies. Meanwhile, the key reason for the onset of proximal junctional kyphosis is bone injuries in the transitional zone. They may be presented in the form of fractures of the superjacent vertebra, the vertebra of the proximal fixation point, or a combination of them. Proximal junctional kyphosis occurs statistically earlier due to these types of fractures than with a degenerative development mechanism [13].

Previously obtained clinical and experimental and analytical data formed the basis of this study to assess the effectiveness of various variations of surgical interventions, as well as methods for the prevention of proximal junctional kyphosis.

The objective is to conduct a comparative analysis of the effectiveness of various options of the surgical treatment of adult patients with deformities of the lumbar spine, including taking into account the degree of correction of the lumbar lordosis and of the measures for the prevention of proximal junctional kyphosis (PJK).

Material and Methods

Study design: a prospective multicenter non-randomized study of case series (n > 100).

The results of instrumental fixation of the spine performed in 2010–2015 in 140 adult patients with lumbar spine deformities were analyzed. Indications for surgery were determined based on the presence of severe frontal spinal deformity and/or sagittal imbalance corresponding to types III and IV (Berjano and Lamartina) [5].

Entry criteria:

– age of 52–66 y.o.;

– deformities of the lumbar spine associated with the degenerative process and/or systemic osteoporosis;

– comorbid osteoporosis (T-criterion less than -2.5 SD).

Exclusion criteria:

– the offset of the sagittal vertical axis (SVA) anteriorly is more than 15 cm;

– the frontal imbalance is more than 5 cm;

– the preoperative proximal junctional angle exceeding 10°.

Patients

The patients were divided into 4 clinical groups depending on the methods of surgical treatment.

Group I: in 36 cases, correction of lumbar lordosis of no more than 30° was performed without the use of PJK prevention methods.

Group II: 24 patients underwent correction of lumbar lordosis; its volume was no more than 30° and laminar fixation of the vertebra above the spinal fusion zone.

Group III: 20 patients underwent a complete restoration of the sagittal and frontal balance with prophylactic vertebroplasty of the vertebra above the zone of instrumental fixation.

Group IV: 60 patients were treated with the same complete restoration of sagittal and frontal balances without the use of PJK prevention methods.

Methods

As a basis, we took the calculated indicators of Kim et al. [14] on the optimal sagittal profile (20° < PI + TK - LL < 45°) and Makhni et al. [15], with the determination of optimal (0–3 cm) and suboptimal (3–8 cm) SVA values. This was done in accordance with the data on the need to correct the sagittal imbalance, which causes the intensity of the pain and a decrease in the quality of life.

Therefore, the study proposed a comparison of methods for restoring a suboptimal and optimal sagittal profile, accounting for various corrections of the lumbar lordosis magnitude. Measures aimed at preventing the development of proximal junctional kyphosis have also been considered.

For an objective evaluation of the patient's condition, neurological and clinical examinations were used. The intensity of the pain and the quality of life were estimated by VAS and the Oswestry Index (ODI). CT, DXA, MRI, and TRGs were used to visualize the pathological substrate.

From a technical point of view, surgical treatment was performed via a posterior approach according to a standard open method.

Statistical analysis

Calculations were conducted under the analysis of teleroentgenograms in Surgimap version 2.2.9.9.9.

The surgical outcomes were evaluated based on X-ray examination data and questionnaires before the surgery, immediately after it, and in the long-term period (after 3, 6, 12 and 24 months).

Numerical data is given in the form of the mean ± standard deviation. The obtained clinical outcomes were processed using IBM SPSS 16 software.

The hypothesis of the normality of the magnitude distribution was verified using the Kolmogorov-Smirnov criterion. The nonparametric statistical test (Kruskal – Wallis and Mann – Whitney) was used to evaluate the significance of differences in sample populations; the level of statistical significance $p < 0.05$ was accepted as the lower confidence level.

Results

The mean age of the patients was 59.8 ± 5.2. Women predominated among the studied patients – 113 (80.7 %). There were 27 (19.3 %) men. According to the Aebi classification, 106 (75.7 %) patients had lumbar spine deformity of type I. Thirty four (24.3 %) patients had a deformity of type IIIb. As stated earlier, indications for instrumental fixation were defined only in deformity of types III and IV according to Berjano and Lamartina [5]. Type III was observed in 89 (63.6 %) patients, IV – in 51 (36.4 %) patients.

A preoperative study of the initial data on the occurrence and severity of osteoporosis and the presence of primary low-energy fractures showed comparability of the information in all groups. Additionally, the spinopelvic ratios were also comparable: pelvic index (PI), pelvic tilt (PT), lumbar lordosis (LL), thoracic kyphosis (TK), PI-LL, the sagittal vertical axis (SVA), proximal junctional angle (PJA), PI + TK - LL. Therefore, the absence of significant differences in four groups of patients at the preoperative stage was statistically confirmed. In this regard, the groups were considered as being comparable (Table 1).

The main surgical option for correcting the global sagittal imbalance is to correct the depth of lumbar lordosis and bring it into line with theoretical values under individual PI data.

In groups I and II, a strategy of partial recovery of lumbar lordosis (correction volume no more than 30°) was used to achieve suboptimal indicators of global sagittal balance according to the characteristics of the SVA location after surgery. In groups III and IV, a complete recovery of the global sagittal balance was performed with the achievement of its optimal parameters. It was done due to a deep correction of the lumbar lordosis (the volume of correction was more than 30°). All spinopelvic relationships were brought to their optimal values as well. One of the two groups of each surgical correction type was the studied prevention method of proximal junctional kyphosis (Group II - laminar tape fixation, Group III – preventive vertebroplasty). Postoperative radiological outcomes are given in Table 2.

Thus, after surgical treatment, statistically significant differences were found between the groups. There was a complete recovery of the sagittal profile (III and IV) to its optimal values and the groups with balance recovery to suboptimal values due to the correction of lumbar lordosis of no more than 30° (I and II) in the parameters of lumbar lordosis (LL), the difference in pelvic angle, and lumbar lordosis (PI-LL), and the displacement of SVA. Additionally, the postoperative values of PJA index in Group II significantly differed from the corresponding values in patients of the other groups. There was also a statistically significant increase in PJA after surgery in patients of groups III and IV.

During the preoperative stage, the analysis of pain intensity in the back and lower extremities showed no significant differences in this parameter in patients of the studied groups ($p = 0.877$; $p = 0.827$). The assessment of the dynamics of back pain in the postoperative period revealed no statistically significant differences between the groups in the first 6 months after surgery ($p = 0.988$; $p = 0.922$). There was a significant difference after 12 and 24 months ($p = 0.001$; $p = 0.001$). The groups with significant differences were further analyzed in pairs. This analysis revealed a significant decrease in the intensity of pain in Group II compared with patients of the other groups 12 and 24 months after surgery. Trend estimation of the intensity of pain in each group showed its significant decrease since the 6th month after surgery in all groups ($p = 0.021$; $p = 0.011$; $p = 0.004$; $p = 0.001$). Meanwhile, a significant decrease in the back pain level was found in Group II during the entire follow-up ($p = 0.011$; $p = 0.001$).

The analysis of pain intensity in the lower extremities showed a statistically significant difference between pre- and postoperative values in all groups since the 3rd month after surgery ($p = 0.001$; $p = 0.016$; $p = 0.001$; $p = 0.001$). Evaluation of this pain in the further postoperative period did not show statistically significant dynamics in any group ($p = 0.954$; $p = 0.146$; $p = 0.331$; $p = 0.844$). This trend may indicate the effectiveness of the decompression treatment stage in all groups of patients.

There were no significant differences in preoperative ODI values between the study groups ($p = 0.532$). Positive dynamics in the form of a reduction in ODI during the postoperative period was noted in all groups ($p = 0.001$). However, the most pronounced trend of improving the quality of life was in Group II. This is statistically verified by pairwise comparison of groups using the Mann – Whitney U test.

Over two years of follow-up, 86 (61.0 %) cases of complications were found in patients. There were 11 (12.8 %) cases of surgical site infection, 9 (10.4 %) cases of neurological deficits, and 13 (15.11 %) cases of liquorrhea. They were classified as early complications (within a month). In the long-term period, 32 (37.2 %) cases of proximal junctional kyphosis and 21 (24.4 %) cases of surgical hardware instability (osteolysis around screws, migration, fracture) were found. All cases of proximal junctional kyphosis were analyzed according to the development mechanism. The outcomes are given in Table 3.

In 29 (91 %) cases, the development of proximal junctional kyphosis was associated with vertebral fractures. The highest incidence of proximal junctional kyphosis was found in patients of Group IV ($n = 19$). This indicator significantly differed from tht in Group I ($n = 8$), II ($n = 1$) and in Group III ($n = 4$); $p < 0.05$. Similarly, significant differences in the incidence of this complication were found between Group II ($n = 1$) and the rest of the prospective study groups ($p = 0.001$). An analysis of the causes of proximal junctional kyphosis has shown that the occurrence of complications in most cases was associated with a superjacent vertebra fracture ($n = 17$): in Group I – 5 cases, in Group IV – 12 cases. It should be mentioned that no fractures of the superjacent vertebra were found in groups II and III. A vertebral fracture of the proximal fixation point was the cause of proximal junctional kyphosis in 7 (22 %) cases. Meanwhile, there were no significant differences between the study groups ($p = 0.454$). It is worth noting that in these 7 cases, the proximal fixation point vertebra was not augmented with bone cement.

Operative exploration was required in 30 (94 %) cases with the development of proximal junctional kyphosis. Two (6 %) patients were excluded due to the formation of proximal junctional kyphosis associated with degenerative changes in the superjacent intervertebral cartilage. They underwent complex conservative treatment with a favorable effect.

Thus, summarizing the nature and frequency of complications occurring in prospective groups, we can say that proximal junctional kyphosis in patients with osteoporosis develops with a high frequency (23 %). In this case, the restoration of the optimal sagittal profile of the spine has no effect. Apparently, the crucial role in the development of this complication belongs to the value of PJA. It increases in a compensatory manner due to a significant change in the lumbar lordosis magnitude. For example, in groups III and IV, this indicator was 12.9° ± 1.4° and 13.8° ± 1.9° with its initial values of 3.5° ± 1.9° and 4.0° ± 1.7°, respectively.

The reduction of local kyphosis proximal to the installed surgical hardware is facilitated by the magnitude of lumbar lordosis correction of no more than 30° and by the use of laminar fixation systems in the junctional region.

Discussion

Surgical treatment of patients with deformities of the lumbar spine is a complicated issue. Selective procedures may be effective in cases characterized only by local neurological symptoms or by confirmed mono-/bisegmental problem. Surgical repair is indicated for a multi-level process. It involves extensive decompression, fixation, and correction of deformity in the affected spine. Correction of sagittal imbalance is done to relieve pain and improve the quality of life. Nevertheless, these interventions are associated with a certain number of complications both in the early and late postoperative periods.

Based on literary data concerning the high incidence of proximal junctional kyphosis and our practical experience concerning this complication in various groups of patients (including in the absence of deformities), we came to understanding that the main task of the surgeon is to reduce the likelihood of a conflict on the frontier with surgical hardware. Due to modern knowledge regarding the multifactorial nature of proximal junctional kyphosis, the surgeon is capable to consider risk factors,

Table 1

Preoperative data of patients in the study groups

Risk factors	Group I (n = 36)	Group II (n = 24)	Group III (n = 20)	Group IV (n = 60)	p-value (H-test)
Osteoporosis (T-criterion)	-2.8 ± 0.6	-2.9 ± 0.4	-2.8 ± 0.3	-3.1 ± 0.6	0.233
Low-energy fracture, n (%)	11 (31)	8 (33)	6 (30)	16 (27)	0.576
Established osteoporosis, n (%)	14 (39)	11 (46)	12 (60)	25 (42)	0.124
PI, deg.	56.9 ± 4.9	57.6 ± 4.1	57.8 ± 4.1	57.6 ± 3.5	0.963
PT, deg.	23.4 ± 3.9	22.5 ± 3.8	23.5 ± 4.0	23.4 ± 4.1	0.743
LL, deg.	21.8 ± 4.4	21.0 ± 4.0	21.1 ± 3.5	20.5 ± 2.8	0.718
TK, deg.	31.5 ± 4.4	30.2 ± 4.4	33.1 ± 4.6	30.4 ± 4.4	0.084
PI-LL, deg.	35.1 ± 6.2	36.6 ± 5.9	36.7 ± 5.1	37.1 ± 4.3	0.532
SVA, mm	106.7 ± 29.8	105.0 ± 27.4	98.5 ± 25.6	97.2 ± 22.9	0.357
PJA, deg.	4.4 ± 2.0	4.5 ± 1.8	3.5 ± 1.9	4.0 ± 1.7	0.191
PI+TK - LL, deg.	66.6 ± 4.4	66.8 ± 6.4	69.8 ± 3.4	67.5 ± 4.2	0.085

Table 2

Postoperative data of patients in the study groups

Risk factors	Partial correction		Total correction		p-value (H-test)
	Group I (n = 36)	Group II (n = 24)	Group III (n = 20)	Group IV (n = 60)	
PI, deg.	56.9 ± 4.9	57.6 ± 4.1	57.8 ± 4.1	57.6 ± 3.5	0.963
PT, deg.					
before surgery	23.4 ± 3.9	22.5 ± 3.8	23.5 ± 4.0	23.4 ± 4.1	0.743
after surgery	19.0 ± 2.7	18.8 ± 2.6	18.9 ± 2.7	19.1 ± 2.8	0.990
changes	4.4 ± 3.0	3.7 ± 5.1	4.5 ± 5.6	4.3 ± 4.9	0.968
LL, deg.					
before surgery	21.8 ± 4.4	21.0 ± 4.0	21.1 ± 3.5	20.5 ± 2.8	0.718
after surgery	46.7 ± 4.4	44.9 ± 4.0	56.4 ± 5.9	54.1 ± 4.8	0.001
changes	24.9 ± 2.5	23.9 ± 2.6	35.3 ± 3.9	33.6 ± 4.2	0.001
TK, deg.	31.5 ± 4.4	30.2 ± 4.4	33.1 ± 4.6	30.4 ± 4.4	0.084
PI-LL, deg.					
before surgery	35.1 ± 6.2	36.6 ± 5.9	36.7 ± 5.1	37.1 ± 4.3	0.532
after surgery	10.2 ± 6.6	12.7 ± 6.3	1.4 ± 5.9	3.5 ± 6.1	0.001
changes	24.9 ± 2.5	23.9 ± 2.6	35.3 ± 3.9	33.6 ± 4.2	0.001
SVA, mm					
before surgery	106.7 ± 29.8	105.0 ± 27.4	98.5 ± 25.6	97.2 ± 22.9	0.357
after surgery	60.6 ± 11.9	60.4 ± 11.6	23.5 ± 5.9	18.0 ± 6.1	0.001
changes	46.1 ± 21.3	44.6 ± 19.1	75.0 ± 24.0	79.2 ± 22.1	0.004
PJA, deg.					
before surgery	4.4 ± 2.0	4.5 ± 1.8	3.5 ± 1.9	4.0 ± 1.7	0.191
after surgery	7.3 ± 2.1	2.5 ± 1.3	12.9 ± 1.4	13.8 ± 1.9	0.001
changes	2.9 ± 0.2	-2.0 ± 1.2	9.4 ± 1.4	9.8 ± 0.6	0.001
PI + TK - LL, deg.					
before surgery	66.6 ± 4.4	66.8 ± 6.4	69.8 ± 3.4	67.5 ± 4.2	0.085
after surgery	41.7 ± 4.2	42.9 ± 6.2	34.5 ± 3.2	33.9 ± 4.1	0.001

use prevention methods and flawlessly follow the surgical technique.

The most relevant risk factor for the development of proximal junctional kyphosis associated with the patient is osteoporosis. It increases the risk of developing the complication by 3.5 times [9, 10]. This factor is of great importance both in the area of the proximal fixation point vertebra and in the area of the superjacent vertebra. The study has shown that disregard for the augmentation of the proximal fixation point vertebra causes the proximal junctional kyphosis to develop due to its fracture.

Another key factor in the development of proximal junctional kyphosis is PJA. Its effect on the occurrence of proximal junctional kyphosis is not well described in the Russian literature. Meanwhile, this indicator is considered to be extremely relevant in world literature [16]. According to the data collected during our previous studies, PJA of more than 10° increases the risk of proximal junctional kyphosis by 2.5 times. The study demonstrated the vulnerability of the proximal junctional zone to the development of proximal junctional kyphosis in the case of high PJA values.

The last statistically significant risk factor for the occurrence of proximal junctional kyphosis, which belongs to the category associated with surgery, is the depth of lumbar lordosis correction. If the correction magnitude is no more than 30° from the baseline, in the case of gross sagittal deformity, it is possible to achieve suboptimal indicators of the global sagittal balance. In this case, the transverse stress forces in the proximal junctional zone are not critical. They cause an uncontrolled increase in PJA to a lesser extent. On the contrary, total submission to the principles of restoring ideal parameters under the created mathematical model contributes to excessive overstrain in the proximal instrumentation zone. In conditions of extended fixation, hyperlordosis combined with pronounced rigidity of the thoracic spine associated with degenerative changes makes preconditions for vertebrae destruction in the junctional zone pursuant to hammer and anvil principle [17, 18].

Novadays, there are two methods of protecting junctional vertebrae and preventing proximal junctional kyphosis: the creation of hybrid semi-rigid stabilization at the level of proximal fixation points and preventive vertebroplasty.

Recent studies have shown that ensuring a smooth transition between the rigid and mobile segments and the spine using semi-rigid fixation of the superjacent vertebra can potentially decrease the frequency of proximal junctional kyphosis [19]. Such hybrid designs include hooks, Mersilene and laminar tapes [20].

The data in our study showed the effectiveness and safety of laminar fixation of the superjacent vertebra as a prevention method of proximal junctional kyphosis.

Viswanathan et al. came to the same conclusions in their work [21]. They analyzed the treatment outcomes of 40 patients after thoracolumbar fusion.

A large number of clinical and experimental studies have been devoted to the investigation of the effectiveness of vertebroplasty in preventing proximal junctional kyphosis. The quintessence of these papers is the effectiveness of the method under consideration in terms of preventing the occurrence of proximal junctional kyphosis [22]. The study shows the absence of fractures of the superjacent vertebra above the zone of extended instrumentation. The idea of this technique is to strengthen the superjacent vertebra to resist vertical loads. Meanwhile, the vertebra itself remains free from fixation and balances above the surgical hardware due to two free spinal motion segments. However, the disadvantage of this technique is the increased load on these spinal motion segments. This results in faster degenerative changes and switching of the load to the superjacent vertebra (superjacent vertebra + 1).

The most reasonable situation in which preventive vertebroplasty can be used is a complete correction of the lumbar-pelvic relationship with maximum recovery of lumbar lordosis (more than 30°). This is required when the use of laminar tapes is associated with the risk of their incompetence.

There was a statistically significant decrease in PJK cases in the Group II in comparison with other groups ($p = 0.001$), as well as a more pronounced trend to decrease in pain intensity and

Table 3

Development of proximal junctional kyphosis in the postoperative period in patients of prospective groups

Proximal junctional kyphosis	Group I (n = 36)	Group II (n = 24)	Group III (n = 20)	Group IV (n = 60)	p-value (H-test)*
Degenerative	–	–	1	2	–
Fracture of SPV	5	–	–	12	0.001
Fracture of SPV + 1	–	–	2	–	–
Fracture of PFPV	2	1	1	3	0.454
Fracture of PFPV + SPV	1	–	–	2	–
Total	8 (22 %)	1 (4 %)	4 (20 %)	19 (32 %)	0.001

* Based on Kruskall – Wallis test; SPV – Superjacent vertebra; SPV + 1 – the vertebra cranial to the superjacent vertebra; PFPV – Proximal fixation point vertebra.

ODI score. Laminar fixation of the superjacent vertebra leads to a decrease in local kyphosis over the area of instrumental fixation and reduces the load on the anterior parts of the vertebra. It shifts the vertical axis posteriorly and eliminates excessive mobility in this segment during constant variable axial loads. In its turn, the use of prophylactic vertebroplasty (Group III) provides better results compared to a matched cohort (Group IV).

Despite the complete restoration of the sagittal profile in all cases, the highest incidence of proximal junctional kyphosis (n = 19) was found in patients of Group IV. The occurrence of a stress-deforming condition at the upper boundary of the fixation zone is due to the complex influence of such risk factors on the development of proximal junctional kyphosis. They are osteoporosis, lumbar lordosis correction of more than 30°, and an increase in PJA, as well as the lack of prevention methods. All of the above combined with the presence of rigidity of the thoracic spine, cause the most unfavorable conditions for the balanced functioning of the stabilized spine.

Conclusion

Partial correction of lumbar lordosis (no more than 30°) and preventive laminar fixation of the superjacent vertebra showed significantly better clinical results (by more than 50 %; p = 0.001) compared with the other three clinical groups in terms of reducing the level of pain and improving the quality of life, as well as of decrease in the number of cases of PJK development – by 16–28 % (p = 0.001). When the spinopelvic parameters are fully corrected to optimal values and the lumbar lordosis is reconstructed at more than 30°, it is advisable to perform vertebroplasty of the vertebra superlying the instrumental fixation zone. It will significantly downgrade the risk of proximal junctional kyphosis. Additional studies are required to assess the effectiveness of the combination of laminar fixation and vertebroplasty to prevent proximal junctional kyphosis.

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