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LUMBAR SPONDYLOLYSIS: TACTICAL APPROACHES, INDICATIONS AND TYPES OF SURGICAL INTERVENTIONS, TREATMENT RESULTS. A SYSTEMATIC REVIEW

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Objective. To analyze the literature data on treatment tactics for patients with spondylolysis of the lumbar vertebrae, and to determine indications for surgical treatment, types of surgical interventions, criteria for assessing treatment results, complications and rehabilitation after treatment.

Material and Methods. Full text articles were selected from the Pubmed, EMBASE, eLibrary, Google and Yandex databases. The type of articles was a systematic review and meta-analysis, and the search period was 10 years. The literature search was carried out by three researchers. The study was conducted in accordance with the international PRISMA guidelines for writing systematic reviews and meta-analyses. The levels of evidence reliability and gradation of strength of recommendations were assessed according to the ASCO protocol.

Results. A total of 6812 articles on the topic under consideration were found, of them 4922 articles with full text, 2155 over the past 10 years, 115 systematic reviews and meta-analyses. Fourteen articles met the inclusion criteria.

Conclusion. Indications for surgical treatment of spondylolysis are the failure of conservative treatment for 6 months, worsening of clinical symptoms, and development of spondylolisthesis. The goal of the surgery is bone fusion formation at the level of the defect, restoration of spinal stability and preservation of mobility of the corresponding segment. Surgical treatment methods for spondylolysis using transpedicular screws and a beam (Gillet) showed a higher fusion result than the Scott and Morscher methods. Minimally invasive methods (Buck method and its modifications) provide better functional results. The highest complication rate is observed in surgical interventions using the Scott method (wire rupture, transverse process fracture, lack of fusion) and those using the Morscher method (superficial infection, instability of implants and persistent back pain). The choice of surgical method should be based on the surgeon's preferences and experience.

Key Words: spondylolysis of the lumbar vertebrae; lumbar spondylolysis.

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Spondylolysis is defined as a pars interarticularis defect between the superior and inferior articular processes and was first described in the mid-1800s by Kilian, Neugebauer, and Lambl. Its incidence differs according to ethnicity, gender, age, fitness level, occupation, and certain medical conditions.

Currently, the cause of arch defects has not been fully determined. It is suggested that genetically driven dysplasia of pars interarticularis may predispose to stress fractures. The incidence of spondylolysis tends to increase with age until adulthood and remains relatively constant after the second decade of life [1].

The course of spondylolysis can be asymptomatic or with clinical manifestations in the form of pain in the lumbar spine aggravated by physical activity [2].

Treatment of spondylolysis can be conservative (load limitation, analgesia, physiotherapy, corsets, nerve root blocks), and surgical in the absence of effect [1, 3]. The surgical treatment options are segmental spinal fusion or osteoplastic surgery to form a fusion at the level of the defect. The aim of reconstructive surgeries is to restore the stability of the spine and preserve the mobility of the corresponding segment; various surgical techniques are used: fixation with screws, hooks, wires, or a combination of them [1].

In a preliminary literature search, no meta-analyses or randomized controlled trials of the outcomes of conservative and surgical treatment of patients with spondylolysis in different age groups were found. The lack of defined indications for surgical treatment, choice of treatment technique, evaluation of its efficacy, and approaches to rehabilitation determined the focus of the systematic review.

The objective is to analyze the literature data on treatment tactics for patients with spondylolysis of the lumbar vertebrae and to determine indications for surgical treatment, types of surgical interventions, criteria for assessing treatment outcomes, complications, and rehabilitation after treatment.

Material and Methods

Strategy for literature search and selection

We searched for studies in Pubmed, EMBASE, eLibrary, Google and Yandex

databases assessing the prevalence, diagnosis, indications, and types of surgical restoration of the integrity of the pars interarticularis of the vertebral arch in spondylolysis, as well as rehabilitation, outcomes, complications, and causes of unsatisfactory treatment outcomes. Three researchers performed the literature search. The study was performed in accordance with the PRISMA international protocol (Table 1).

Inclusion criteria: full-text articles in English and Russian, available in free access, systematic reviews and meta-analyses of the outcomes of conservative and surgical treatment of patients of any age with spondylolysis using osteoplastic reconstruction of the lumbar vertebral arch defect.

Exclusion criteria: systematic reviews and meta-analyses on the diagnosis of spondylolysis, surgical treatment using fusion, treatment of spondylolisthesis associated with spondylolysis, patients with comorbidities (spinal canal stenosis, intervertebral disc degeneration, and radiculopathy), abstracts, and articles not available in full-text version.

A literature search using the keyword "spondylolysis" was performed as part of the PRISMA protocol at the first phase. The depth of the search was 10 years. At the second phase, we excluded papers that did not meet the study criteria. At the third phase, we evaluated the full texts of the selected articles for compliance with the inclusion criteria and the reference lists for the presence of relevant studies (Table 1, Fig. 1).

In order to analyze the papers, the main research questions were formulated:

1) the incidence of spondylolysis;

2) conservative treatment strategy and evaluation of the outcomes;

3) indications for surgical treatment;

4) types of surgical treatment and their efficiency; evaluation criteria for outcomes;

5) complications and reasons for unsatisfactory outcomes;

6) rehabilitation after surgical treatment.

Results and Discussion

A total of 6,812 articles were found in the databases by keywords: full-text articles – 4,922; articles for the last 10 years – 2,155; systematic reviews and meta-analyses – 115. 14 articles met the inclusion criteria (Table 2).

Spondylolysis incidence

The incidence of spondylolysis in children under 6 is 4.4 % and increases to 6.0–11.5 % in adults [1–3]. Spondylolisthesis is less common, and its incidence is 3.1 % [8].

In adolescents who participate in sports involving repetitive hyperextension and rotation of the lumbar spine, the incidence of spondylolysis is 15.0 % [1].

Engagement in sports is associated with a higher risk of spondylolysis. Repetitive axial loads and hyperextension of the lumbar spine in weightlifting, cricket, soccer, and gymnastics result in stress fractures. The predisposing sports are cricket 55.0 %, baseball 59.7 %, swimming 57.5 % [9], wrestling 30.0–35.0 %, gymnastics 11.0–30.0 %, American football 20.0 %, and throwing 26.6 % [4].

Spondylolysis represents 8.8 to 47.0 % of symptomatic low back pain in young athletes and approximately 6 % in the general population [4].

Up to 93 % of adult patients with spondylolysis are young adults aged 18-35 years, with a male predominance (4.4 : 1.0). The defect is primarily bilateral (96.4 %). The pathology is most often localized at L5 (68.5 %), followed by L4 (15.9 %); multilevel localization is found in 13.7 % of cases. Approximately 75.0 % of spondylolysis cases progress to spondylolisthesis; meanwhile, 60.0 % of spondylolisthesis cases are low grade (Meyerding grade I/II) [7].

Conservative treatment strategy, outcome assessment, and rehabilitation

The main techniques and approaches to conservative treatment are described for young athletes due to the injury-related pattern of spondylolysis.

Conservative treatment includes load limitation (temporary elimination of sports activities requiring flexion-extension and rotation of the trunk), corset treatment, medication (non-steroidal anti-inflammatory drugs, analgesics, and steroid/local anesthetic injections), specially designed complexes of therapeutic exercises to strengthen the trunk muscles, and physical therapy. Conservative treatment is efficient at early diagnosis [13], and its duration varies from 3 to 72 months [7]. The effectiveness of conservative treatment (abatement of symptoms) is approximately 85 % [1–3].

There are no clear recommendations on the types of corsets and timing of resumption of sports activities in the analyzed studies.

A systematic review and meta-analysis of randomized trials by Lin et al. [8] demonstrate the effectiveness of exercises to strengthen the lumbar muscles in improving the functional status of patients, but not to reduce the intensity and pattern of pain syndrome. As noted by the authors, the relationship between spondylolisthesis and low back pain is still unproven, like the concept of the relationship between lumbar instability and pain syndrome [8].

Indications for surgical treatment

Indications for surgical treatment are defined when the pain syndrome persists under conservative treatment, the onset of new neurological symptoms, and, depending on the age of the patient, determining the condition of the spinal motion segment.

According to the data from the literature, approximately 9–15 % of patients fail to benefit from conservative treatment or spondylolysis progresses to spondylolisthesis [2].

The main determinant of surgical outcomes is patient selection. The ideal candidate for surgical treatment is a young person, with or without mild degenerative changes of the intervertebral disc, with or without low-grade spondylolisthesis [9].

The indications for surgical treatment in both adolescents and adults are as follows: ineffectiveness of conservative treatment within 6 months, aggravation of clinical symptoms, and formation of spondylolisthesis [1, 6, 7, 13].

However, for adult patients, the indications are primarily guided by degen-

erative changes of the intervertebral disc at the level of displacement [9]. According to Kumar et al. [7], reparative surgery of a vertebral arch defect is indicated at the age between 18 and 45 years, in case of moderate degenerative changes of the disc or facet joints or without them, a positive diagnostic test for infiltrative block, and normal preoperative discography.

Types of surgical treatment and their effectiveness, criteria for evaluation of outcomes

The main surgical approach to treat patients, especially young ones, is reconstructive surgery to form a fusion in the area of spondylolysis. The purpose of the surgery is to create a bone block at the level of the defect, restore the integrity of the middle column, and preserve the mobility of the corresponding segment. Many surgical techniques have been reported (Fig. 2), some of the main ones being screw fixation of the arch defect (Buck technique), wire fixation behind the transverse and spinous processes (Scott technique), a combination of screw and hook fixation (Morcher technique), and transpedicular fixation with a curved transverse beam (Gillet technique) [1, 9].

Modifications of the Back technique are the Brennan and Wilson techniques (percutaneous screw placement under O-arm 3D navigation). Variants of the Scott technique: a combination of wire, lavsan band, and screws (Salib, Pettine, Songer, Rovin). An improvement of the Morcher technique (Kakiuchi, TSRH) involves more rigid fixation. Variants of the transpedicular fixation technique (Gillet and Petit) involve both a curved transverse beam and the additional use of a polyester band.

A comparative analysis of the surgical outcomes (bone block formation, functional outcome, and complication rate) based on the analyzed papers is given in Table 3.

Opinions on the use of radiography or CT for outcome evaluation are controversial. According to Kumar et al. [7], studies evaluating bone block formation have reported only general measures, with no separate reports based on radio-

Table 1
Inclusion/exclusion criteria and selection of publications in accordance with PRISMA principles

PRISMA criteria	Inclusions	Exclusions
Participants	Patients who underwent conservative and reconstructive surgical treatment for spondylolysis	Patients for whom spinal fusion was the treatment of choice
Intervention	Surgical treatment of spondylolysis using the Buck, Morcher, Scott, Gillet techniques and their modifications	Surgical treatment with spinal fusion
Comparison	Study groups in the selected articles	
Outcome	Prevalence, indications and types of surgical restoration of the integrity of the pars interarticularis of the vertebral arch in spondylolysis and rehabilitation, outcomes and complications, causes of unsatisfactory treatment outcomes	
Study design	Systematic review	Randomized and non-randomized, retrospective, prospective trials. Clinical cases, clinical case series
Publications	In Russian, English, full text	In any other languages, without access to the full text

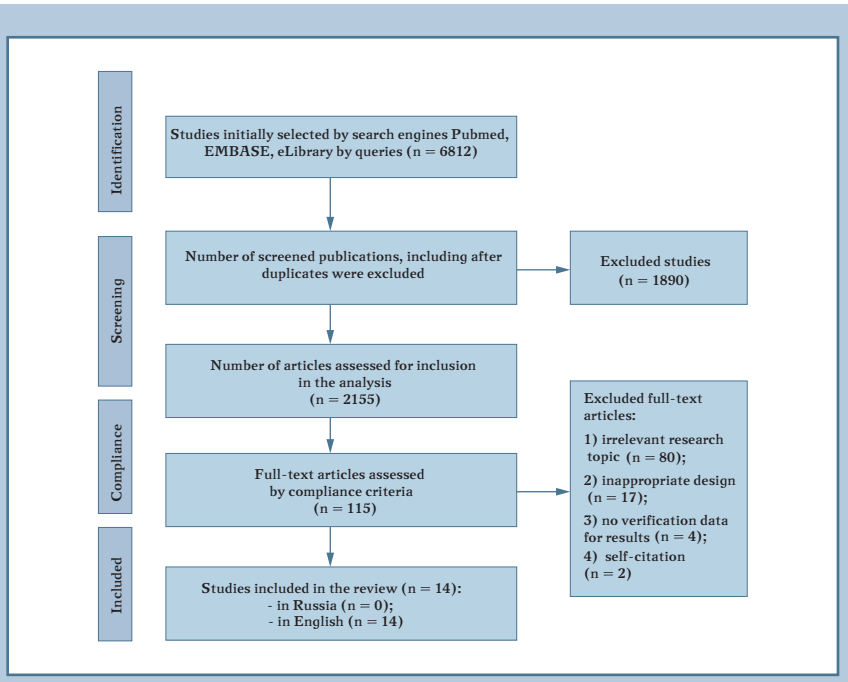

Fig. 1
Schematic algorithm for selecting thematic publications in accordance with the PRISMA criteria

Table 2
The articles that have met the selection criteria and were included in the review

Authors	Year of publication	Study design	Number of included articles	Search strategy	Research direction	Analyzed treatment techniques
Berjano et al. [1]	2020	Systematic review	21	PRISMA	Assessment of surgical treatment techniques	Buck, Scott, Morcher techniques, pedicle screws with beam
Bouras et al. [4]	2015	Systematic review	27	Medline	Origin, incidence, diagnosis, assessment of surgical treatment techniques	Buck, Morscher, Scott techniques, minimally invasive Buck technique
Grazina et al. [5]	2019	Systematic review	14	PRISMA	Functional status and return to sports after surgical and conservative treatment of athletes	Conservative treatment, Buck, Scott techniques, osteoplastic spinal fusion
Kolcun et al. [6]	2017	Systematic review	16	PRISMA	Assessment of surgical treatment techniques	Buck, Scott, Gillet techniques,
Kumar et al. [7]	2021	Systematic review	47	PRISMA	Assessment of surgical treatment techniques in adults	Buck, Scott, Morcher techniques, pedicle screws with beam
Lin et al. [8]	2024	Systematic review and meta-analysis of randomized controlled trials	5	PRISMA	Assessment of conservative treatment techniques	Back muscle strengthening complexes
Mohammed et al. [9]	2018	Meta-analysis	46	PRISMA	Assessment of surgical treatment techniques	Buck, Scott, Morcher techniques, pedicle screws with beam
Muthiah et al. [2]	2022	Systematic review	14	PRISMA	Assessment of surgical treatment techniques in adults	Buck technique and its modifications
Overley et al. [10]	2021	Meta-analysis	11	PRISMA	Functional status and return to sports after surgical and conservative treatment of athletes	Conservative treatment, Buck, Scott techniques
Scheepers et al. [11]	2015	Systematic review	5	PRISMA	Assessment of surgical versus conservative treatment of unilateral spondylolysis	Buck, Morcher techniques, segmental needle
Sellyn et al. [12]	2019	Systematic review	33	PRISMA	Assessment of surgical treatment techniques	Buck, Morscher, Scott techniques
Tsai et al. [13]	2022	Systematic review	40	PRISMA	Assessment of surgical treatment techniques	Buck, Scott, Morcher techniques, pedicle screws with beam
Tanveer et al. [14]	2021	Systematic review	12	PRISMA	Assessment of surgical treatment techniques	Buck, Morscher, Gillet techniques
Westacott and Cooke [3]	2014	Systematic review	9	Medline	Assessment of surgical treatment techniques in adolescents	Conservative treatment, Buck, Scott techniques

logical or CT imaging. Fusion formation was assessed by radiography in most studies; CT was used selectively and more often in uncertain cases [7].

Various scales are used to evaluate functional outcomes: VAS, Oswestry Disability Index (with a score of less than 20 points), and Henderson, Odom, and MacNab scales. It should be emphasized that the ODI is not validated for adolescent spondylolysis and cannot be applied to children and adolescents according to a number of used indicators. The SRS questionnaire is recognized as a more appropriate tool for evaluating the functional status of adolescents because it does not, for example, contain questions about sexual function [3].

The systematic reviews by Mohammed et al. [9] and Tsai et al. [13] are of interest since they provide an analysis of outcomes of the main surgical techniques using integrated indices.

According to Mohammed et al. [9], the pedicle screw technique is the best choice with the highest rate of bone block formation and a low complication rate, followed by surgery using the Buck technique. Surgeries using the Morcher technique and the Scott technique have shown high level of complications and low rates of fusion.

While analyzing the functional status of patients, the authors use a unified rate including pain relief and return to work, the postoperative Oswestry Disability Index (less than 20 points), and excellent/good outcomes according to the Henderson, Odom, and Macnab criteria. Patients who experienced persistent pain and/or were unable to return to work due to pain were categorized as negative outcomes [9].

Through a systematic review and meta-analysis by Tsai et al. [13], the outcomes of surgical treatment were analyzed based on the sensitivity assessment of available data. The rate of bone fusion with transpedicular fixation was 95 %, with the Buck technique – 93 %, with the Scott technique – 85 %, and with the Morcher technique – 63 %. Positive functional outcome was higher with the Morcher technique (91 %), followed by the Buck technique (85 %), then transpedicular fixation (84 %), and lowest with the Scott technique (80 %). The complication rate was highest in the Scott treatment group (12 %) and in the Morcher treatment group (12 %).

Data on the physical activity of patients after treatment are reported only in the study by Kumar et al. [7]. Patients treated with the techniques of Buck, Scott, Morcher, and pedicle screws returned to regular physical activity/sports in 90, 91, 87, and 100 % of cases, respectively.

Rehabilitation after surgical treatment

The total duration between recovery and return to activity/sports is on mean 3 to 12 months [7, 9]. A return to the previous level of activity was recommended after 6 months for non-combative sports and after 1 year for combative sports. Nevertheless, some experts recommend never returning to combative sports (football, hockey, etc.) after spine surgery because of the high risk of reinjury [12].

In preparation for future return to the same level of play, rehabilitation of athletes consists of lower-intensity exercise for 1–6 months after surgery using CT or radiological monitoring of the fusion area [5, 12].

The specific feature of screw fixation using the Scott technique requires load limitation and wearing a postoperative brace for 3 months [1].

Early return to sports, intensive training and exercise after surgery, and termination of wearing a lumbar corset may promote implant failure and lack of recovery [9].

Complications and causes of unsatisfactory outcomes

The overall complication rate was 11.9 %; the most common complication was implant instability – 3.4 % [7].

The comparative analysis of surgical complications according to the data of the reviewed articles is given in Table 4.

According to Mohammed et al. [9], the lowest complication rates were reported for pedicle screws and the Buck technique, the highest one for the Morcher technique. The incidence of superficial wound infections was the highest

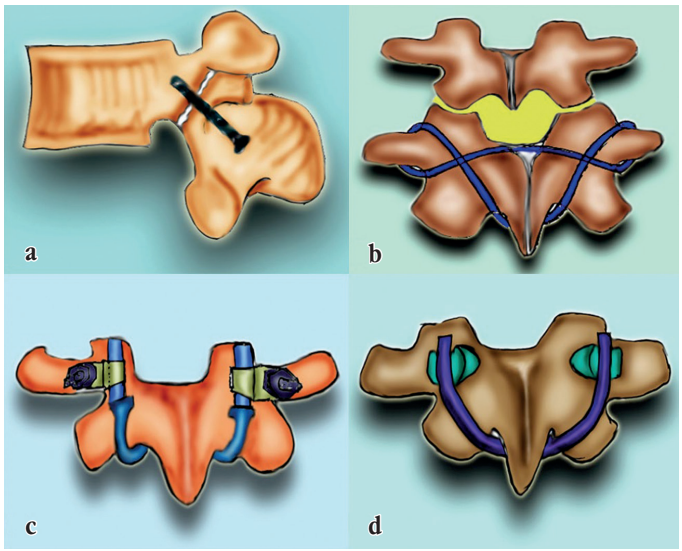

Fig. 2
Images of the main surgical techniques of arch defect reconstructive surgery [9]: **a** – Buck technique; **b** – Scott technique; **c** – Morcher technique; **d** – pedicle screw with U-shaped rod

Table 3
Comparative analysis of surgical treatment outcomes (according to literature data)

Used technique	Bone block formation	Good functional outcome	ODI: initial outcome	ODI: final outcome	VAS: initial outcome	VAS: final outcome	Complication rate
Buck technique	97.00 % [2] 93.00 % [13] 83.53 % [9] 86.00 % [7]	94.00 % [2] 91.00 % [13] 84.30 % [9] 88.00 % [1] 90.00 % [7]	55.5 ± 16.3 [14]	10.6 ± 6.9 [14]	5.5 ± 1.3 [14]	0.7 ± 1.2 [14]	1.00 % [13] 13.41 % [9] 40.00 % [1] 11.60 % [7]
Transpe dicular fixation	95.00 % [13] 90.21 % [9] 79.00 % [7]	84.00 % [13] 80.10 % [9] 80.00 % [1] 70.00–100.00 % [7]	43.5 ± 21.0 [14]	20.9 ± 22.1 [14]	8.0 ± 1.0 [14]	3.1 ± 2.9 [14]	0.00 % [13] 12.80 % [9] 30.00 % [1] 12.00 % [7]
Scott technique	85.00 % [13] 81.57 % [9] 92.00 % [7]	80.00 % [13]) 82.90 % [9] 91.00 % [7]	–	–	–	–	12.00 % [13] 22.35 % [9] 14.00 % [1] 14.30 % [7]
Morcher technique	63.00 % [13] 77.72 % [9] 90.00 % [7]	91.00 % [13] 80.30 % [9] 87.00 % [7]	41.2 ± 5.8 [14]	9.5 ± 2.6 [14]	5.8 ± 0.7 [14]	0.4 ± 0.5 [14]	12.00 % [13] 27.42 % [9] 44.00 % [1] 15.90 % [7]

in patients who underwent the Morcher technique [13].

Some types of complications are unique to the type of surgery used. Wire breakage and transverse process fractures are typical complications of Scott surgery resulting in non-union of the defect [9].

Some types of complications are unique to the type of surgery used. Wire rapture and transverse process fractures are typical complications of Scott surgery resulting in non-union of the defect [9]. According to Tsai et al. [13], the complication rate was the highest when using the Scott technique (wire rapture) and the Morcher technique (superficial infection, implant instability, and persistent back pain). The level of implant instability was similar when using the Scott and Morcher techniques [13].

A review by Kumar et al. [7] identified factors that delay fusion: elderly age, intervertebral disc degeneration, spondylolisthesis, multilevel defects, open surgery with extensive muscle dissection, early return to sports, high level of physical activity or cessation of lumbar corset use, and pseudarthrosis [7].

Conclusion

Spondylolysis is most frequently diagnosed in young athletes with lumbar pain and is associated with hyperextension and rotation of the trunk. Dysplasia of the pars interarticularis of the vertebral arch predisposes to injury and stress fractures.

The choice of treatment and indications for use of certain surgical technique remain unclear because of the wide range of surgical techniques.

Indications for surgical treatment of spondylolysis are ineffectiveness of conservative treatment within 6 months, aggravation of clinical symptoms, and formation of spondylolisthesis. This approach is founded on the probability of successful conservative treatment at early diagnosis of spondylolysis [13]. The efficiency of conservative treatment (abatement of symptoms) is approximately 85 % [1–3].

The main approach in the surgical treatment of patients, especially young ones, is reconstructive surgery to form a fusion in the area of spondylolysis. These techniques are indicated for minimal degenerative disc changes and are aimed at restoring anatomical integrity and, consequently, segmental relations and motion in the lumbar segment.

The choice of technique should be guided by the surgeon's preference and experience; nonetheless, surgical treatment strategies for spondylolysis based on pedicle screws and beams (Gillet) have shown better fusion of the defect and fewer complications than the Scott and Morcher techniques.

Minimally invasive techniques (Buck technique and its modifications) provide better functional outcomes that is most likely associated with minimal injury to the back muscles.

The highest rate of complications was found in the Scott technique (wire rapture, transverse process fracture, lack of fusion) and the Morcher technique (superficial infection, implant instability, and persistent back pain).

Therefore, it can be stated that the pedicle screw-based technique with a transverse beam provides a more rigid fixation of the arch with the inferior articular processes forming a more sta-

Table 4
Comparative analysis of surgical treatment complications (according to literature data)

Type of complication	Buck technique	Transpedicular fixation	Scott technique	Morcher technique
Superficial infection	0.0 % [13] 0.8 % [7]	1.0 % [13] 2.4 % [7]	1.0 % [13] 0.0 % [7]	4.0 % [13] 1.4 % [7]
Dura mater injury	1.0 % [13]	0.0 % [13]	0.0 % [13]	1.0 % [13]
Radicular syndrome	1.0 % [13] 0.9 % [7]	1.0 % [13] 7.1 % [7]	2.0 % [13]	1.0 % [13]
Wire rapture	0.0 % [13]	0.0 % [13]	9.0 % [13] 12.2 % [7]	0.0 % [13]
Implant instability	1.0 % [13] 4.0 % [7]	0.0 % [13]	1.0 % [13] 2.0 % [7]	5.0 % [13] 4.3 % [7]
Periodic back pain	1.0 % [13]	0.0 % [13]	0.0 % [13]	10.0 % [13]
Revision surgery	3.0 % [13]	1.0 % [13]	2.0 % [13]	1.0 % [13] 8.7 % [7]

ble structure by creating a single biomechanical closed system.

Despite an adequate number of good outcomes of reconstructive surgeries, there is a question about the reasons for ineffectiveness and persistent back pain after surgical treatment. It is possible that the response is associated with localized segmental relationships and high pelvic tilt, suggesting the formation of a higher load on the surgical site under these conditions. We expect future research will be dedicated to studying these questions.

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

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