ANTERIOR SPINAL FUSION THROUGH A MINIMALLY INVASIVE RETROPERITONEAL APPROACH IN THE TREATMENT OF PATIENTS WITH PSEUDOARTHROSIS AFTER DECOMPRESSION AND STABILIZATION SURGERIES FOR DEGENERATIVE-DYSTROPHIC DISEASES OF THE LUMBAR SPINE

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Objective. To analyze the clinical efficacy of anterior fusion through a minimally invasive retroperitoneal approach in the treatment of patients with pseudoarthrosis after decompression and stabilization surgery for degenerative spinal stenosis.

Material and Methods. Twenty six patients with previously performed decompression and stabilization surgeries for degenerative spinal canal stenosis underwent repeated surgical interventions using anterior/anterolateral fusion due to clinical and radiographic signs of pseudoarthrosis resistant to complex conservative therapy for at least 12 weeks. The outcomes of surgical treatment were analyzed based on the assessment of clinical and radiological characteristics before and after surgery.

Results. At a follow-up examination 12 months after surgery, leg pain aggravated after exercise bothered 5 patients (19.2 %). According to CT data, 16 (61.5 %) patients had signs of the formation of grade 1 interbody bone block. In 2 (7.7 %) patients, instability of the fixation system developed and there were no signs of union, which required repeated surgical interventions.

Conclusion. Anterior interbody fusion in the treatment of patients with pseudoarthrosis allows safe removal of the preinstalled interbody implant and creation of optimal conditions for the formation of interbody fusion. Despite clinical improvement, significant functional disorders persist in most patients.

Key Words: pseudoarthrosis, spinal stenosis, anterior interbody fusion.

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Transpedicular fixation in conjunction with interbody fusion is a widely approved surgical approach for patients with unstable spondylolisthesis, recurrent intervertebral disc herniation, or spinal stenosis with signs of instability. The frequency of repeated surgeries after these procedures ranges from 5 to 23 % with follow-up periods of up to 10 years. Simultaneously, pseudoarthrosis develops with a frequency of 3–9 % of cases and is one of the main reasons for repeated surgical procedures [1–3].

It should also be considered that the factors surgeons face to when planning repeated surgeries are extremely varied. The peculiarities of the primary surgery, physical status, the condition and position of the installed implants, and other factors may all have an impact on surgical approaches. One of the key challenges of a surgeon when performing procedures for pseudoarthrosis is to generate optimal conditions for the formation of a solid bone block. Despite a sufficiently large number of papers dedicated to the treatment of patients with pseudoarthrosis, the criteria defining the choice of surgical approach and the required volume of surgery have not been determined. Meanwhile, the use of the posterior approach for the removal and re-installation of the interbody implant has significant technical limitations. This is due to considerable cicatricial changes in the area of the migrated cage, making any manipulation in this area extremely hazardous owing to the high probability of nerve injury or dura mater rupture. In this regard, anterior and anterolateral approaches are often a saving alternative for repeated surgeries. Furthermore, anterior surgeries make it possible to prepare adjacent vertebral end plates and the insertion of large-sized lordotic cages, according to researchers [4–10].

The objective is to analyze the clinical efficacy of anterior fusion through a minimally invasive retroperitoneal approach in the treatment of patients with pseudoarthrosis after decompression and stabilization surgery for degenerative spinal stenosis.

Design: the study is retrospective and monocentric.

Material and Methods

A retrospective analysis of medical records and neuroimaging study results of patients who, from July 2015 to January 2018, were treated in the Neurosurgical Unit of the National Medical and Surgical Centre named after N.I. Pirogov with pseudoarthrosis at the lumbar level after fixation for degenerative diseases of the lumbar spine was performed. The follow-up period ranged from 3 to 7 years. All patients had clinical manifestations of pseudoarthrosis resistant to complex conservative therapy for at least 12 weeks. An anterior or anterolateral approach to the anterior parts of the spine was used during the surgery.

The inclusion criteria were: diagnosed pseudoarthrosis resistant to complex conservative therapy for 12 weeks; anterior or anterolateral approach used during surgery; availability of a complete study files; questionnaires according to VAS and Oswestry before surgery and 12 months after it.

Exclusion criteria: manifestations of adjacent segment disease, pathologies of the cervical or thoracic spine and spinal cord.

Patients

The study group included 26 patients: 14 (53.8 %) men and 12 (46.7 %) women. The mean age of patients was 61.30 ± 8.35 years old. Primary surgeries were performed in various medical institutions: 16 (61.5 %) for spinal canal stenosis; 5 (19.2 %) for degenerative spondylolisthesis; and 5 (19.2 %) for herniated intervertebral discs.

The period between the primary and repeated surgeries ranged from 12 to 56 months (means 18.8 ± 4.7 months). False joints formed at the level between the L5 and S1 vertebrae in 13 (50.0 %) patients, at the L4–L5 level in 7 (26.9 %), at the L3–L4 level in 3 (11.5 %), and at the L2–L3 level in 3 (11.5 %).

During the primary surgery, fixation was performed on one level in 11 (42.3 %) patients, on two levels in 9 (34.6 %), and on three levels in 6 (23.1 %).

The most frequent clinical manifestations in patients with pseudoarthrosis upon admission to the hospital were vertebrogenic pain syndrome and radiculopathy of various degrees of severity; less often, weakness in the legs and pelvic organ dysfunction (Table 1).

During admission to the hospital and 12 months after surgery, the pain intensity was evaluated according to the VAS (separately in the legs and lumbar spine) and the degree of impairment (according to the Oswestry questionnaire).

Techniques

All patients underwent lumbar spine X-rays prior to admission to treatment. The number and level of fixed spinal segments, the position of implants (signs of dislocation of interbody cages and pedicle screws), the height of intervertebral spaces at the affected levels, and interbody angles were defined. According to CT findings, bone trabeculations in the interbody space and inside the implant, the size of the pedicle screws and the accuracy of their insertion, the diameter of vertebral pedicles and the integrity of their walls, the presence and magnitude of the region of deossification around the pedicle screws and interbody cages, and the direction of dislocation of the interbody implants were assessed.

Twenty two (84.6 %) patients had signs of instability of the instrumentation system. Two groups of patients were distinguished when measuring the region of deossification in the pedicle in the area of insertions of pedicle screws. The first group consisted of 4 patients with a deossification of up to 1 mm (11.5 %); the second group consisted of 11 patients with a deossification of more than 1 mm (42.3 %). A separate group included 7 (26.9 %) patients with a fracture of the instrumentation.

During the evaluation of the position of the interbody implants, the anterior and posterior directions of dislocation of the interbody cage as well as its subsidence (dislocation into the body of the subjacent vertebra) were determined.

According to CT findings, dislocation in various directions was found in 18 out of 31 previously inserted interbody cages. Meanwhile, cage subsidence occurs most frequently – 11 (35.5 %) of cases; migration posteriorly was found in 5 (16.1 %) cases; and migration anteriorly in 2 (6.5 %) cases.

During the measurement of the height of the cages inserted during the primary surgery, it was found that in 22 (71.0 %) cases the height ranged from 10 to 12 mm. Cages with a height of more than 12 mm were implanted in only 5 (16.1 %) patients. Meanwhile, when evaluating the height of the formed interbody space, it was found that the maximum height in the anterior parts reached 19 mm and it's mean value was 14.9 ± 2.3 mm (from 9 to 19 mm). In the posterior parts, the mean height of the interbody space was 8.2 ± 2.4 mm (from 4 to 12 mm). The mean angle of the interbody disc was 15.4° ± 3.1° (from 4 to 19°). These data were used in the planning of surgery and the selection of implants.

During the evaluation of the state of transpedicular system, it was determined that screws with a diameter of 6.0 and 6.5 mm were used in patients more frequently (82.2 % of cases). The mean pedicle width was 7.4 ± 1.9 mm (from 5.8 to 9.2 mm). This parameter was used to identify the possibility of preserving the transpedicular fixation and the selection of implants.

Four patients had a significant (more than 4 mm) malposition of pedicle screws. The size of the screws and the vertebral arches were assessed to study the possibility of using anchoring elements of a larger diameter.

During the evaluation of the treatment given, the intraoperative blood loss, the surgery duration, the number of surgical complications, and the length of hospital stay were considered. The quality of the formed bone block was evaluated according to CT findings 12 months after surgery. Signs of consolidation were determined in accordance with the classification of Tan et al. [11], distinguishing 4 grades of fusion: grade 1 is the complete fusion of an implant and stabilization of the segment, and grade 4 is the

complete instability of an implant and the vertebral segment.

Surgical approach. Surgeries on the anterior spine were performed through a minimally invasive paramedian retroperitoneal approach. The anterior longitudinal ligament and the anterior part of the fibrous ring were excised. The interbody cage inserted at the previous surgery was removed. Adjacent vertebral end plates were skeletonized, and decompression of nerve structures in the spinal canal and foraminal recesses was performed if required. Lordotic cages filled with synthetic β-tricalcium phosphate composite were inserted on the background of maximum distraction of the anterior spine.

An anterior surgery was followed by a posterior spine procedure in 19 (73.1 %) patients. Both stages of the surgery were performed in a single surgical session, first on the anterior and then on the posterior spine. A surgery on the posterior spine was used when it was necessary to reinstall or remove the pre-installed pedicle screws and restore the stability of the fixing system. Pedicle screws were inserted along an alternative trajectory in 7 patients with a fracture of instrumentation. Nine patients with a region of deossification in the pedicle of more than 1 mm had the screws re-installed with a change in trajectory; if there were no defects in the pedicle, augmentation with bone cement was performed. In one patient from this group, due to a violation of the integrity of the lower wall of the pedicle, fixation was performed with laminar hooks in the compression mode. In only one case, due to the significant destruction of the pedicle, the absence of a vertebral arch, and the extremely high risk of extravertebral leakage of bone cement, the pedicle screws were removed and the posterior fixation was not performed. The screws were replaced with ones with a longer length and diameter in two patients with a region of deossification in the insertion area of fixing elements of less than 1 mm. In two patients in this group, the transpedicular system was not corrected; instead, the vertebral bodies were augmented with bone cement after the lordotic cage was inserted.

Statistical analysis

Statistical data processing was performed in Jamovi software version 2.2.5. The value $p < 0.05$ was assumed to be the level of statistical significance. We relied on the Shapiro-Wilk test as well as the graphical representation of the data to define the normality of the distribution of quantitative indicators. The mean value was used and the standard deviation was indicated to introduce quantities with a normal distribution; the median and interquartile range were designated for quantities with an abnormal distribution. The Kruskal – Wallis one-way analysis of variance was used during the comparison of indicators with an abnormal distribution in three independent groups. The paired Student's t-test was used to compare normally distributed quantitative indicators in groups of patients before and after surgery; the Wilcoxon signed-rank test was used for abnormally distributed values; and Spearman's rank correlation coefficient was used to identify correlations.

Results

During a follow-up examination 12 months after surgery, lumbar spine pain of varying severity was noted in 19 (73.1 %) patients. Meanwhile, the pain median decreased significantly and amounted to 3 (2.0) points according to the VAS. Leg pain aggravated after exercise bothered 5 (19.2 %) patients. Nevertheless, a significant positive trend was noted in comparison with the preoperative level (Table 2).

In evaluating the grade of impaired activity 12 months after surgery, it was found that the majority of patients retained sufficiently pronounced disorders. For example, the mean value of the Oswestry index reached 23.8 ± 9.9. Despite a significant reduction in this indicator in comparison with the preoperative level, most patients remarked that lumbar spine pain limited their activity.

A statistical analysis was done to find out the dependence of pain intensity and the grade of impairment in the postoperative period on the level of pseudoarthrosis, the number of treated spinal motion segments, the magnitude of total lumbar and local lordosis, and the presence of obesity in patients. The generated correlation matrix failed to discover the dependence of pain intensity and the value of the Oswestry index on the magnitude of overall lumbar (rho = 0.035; p = 0.867) and local lordosis (rho = 0.002; p = 0.991). Moreover, a significant decrease in impaired quality of life according to the Oswestry score in the postoperative period was found in patients with higher values in the preoperative period (rho = 0.638; $p < 0.001$).

The number of surgically treated levels also did not influence on the value according to the Oswestry score significantly, neither before surgery (p = 0.711) nor after it (p = 0.693). In the group of patients with obesity, the ODI median before surgery was 50.0 (20.0), in the group without obesity – 49.0 (24.0); and after surgery it was 23.0 (13.0) and 22.0 (15.0), respectively. The identified changes are minimal and statistically insignificant (p = 0.911 and p = 0.717).

According to CT findings 12 months after surgery, 16 (61.5 %) patients had signs of formation of grade 1 interbody bone block. Two (7.7 %) patients had instability of the fixation system, and

Table 1

Main clinical manifestations in patients with pseudoarthrosis before surgery

Indicator	Patients, n (%)
Pain in the lumbar spine	26 (100.0)
Pain in the legs	23 (88.5)
Sensitivity disorders	22 (84.6)
Paresis	12 (46.2)
Pelvic organ dysfunction	2 (7.7)

there were no signs of fusion, which required repeated surgery (Fig. 1).

The mean surgery duration was 171 ± 107 minutes, and the mean blood loss was 200 (288) ml. Blood transfusions in the perioperative period were done in 2 (7.7 %) patients. The median of inpatient treatment duration was 5 (2.75) days.

Dura mater injury during surgery was recorded in 2 (7.7 %) patients. In both cases, this occurred when the posteriorly dislocated interbody cage was removed. Cerebrospinal fluid stasis was achieved by layering a fat autograft, a hemostatic local administration preparation including fibrinogen and thrombin in the form of a dry coating on the surface of a collagen sponge, and an adhesive biocomposite. After sealing the dura mater, there was no external liquorrhea and isolated accumulation of cerebrospinal fluid in the postoperative period.

An infectious complication developed in the area of the postoperative wound in the posterior parts in one (3.8 %) patient, necessitating repeated surgery, which comprised debridement of the suppurative focus followed by VAC drainage. Secondary sutures were imposed after the debridement of the wound.

Clinical case study. Patient I., male, 59 years old, underwent transforaminal interbody fusion and transpedicular fixation for grade 1 degenerative spondylolisthesis of the L5 vertebra 14 months before admission to the unit. 10 months after surgery, pain appeared in the lumbar spine (VAS: 7 points) and in the left leg (VAS: 6 points). During CT, pseudoarthrosis was diagnosed at the L5–S1 level and instability of the instrumentation was noted (Fig. 2).

An anterior interbody fusion was made with a lordotic cage; unstable fixation elements and pedicle screws were removed from the L4 vertebra. In S1, the screws were inserted along an alternative path. The surgery duration was 250 minutes; there were no perioperative complications. The patient was discharged from the hospital on the fourth day. In 12 months after surgery, the pain severity in the lumbar spine and left leg was 1 point according to VAS. The formation of a bone block at the level of L5–S1 (grade 2) was observed during the control CT; the position of the instrumentation was stable (Fig. 3).

Discussion

The primary challenge a surgeon face when performing procedures for pseudoarthrosis is to create optimal conditions for the formation of a solid bone block. In this respect, a wide range of circumstances, including both objective features of prior treatments and anatomical changes, as well as the personal preferences of surgeons, impacts the selection of surgical techniques.

Thus, according to a number of authors [2, 3, 5, 6, 12], the increase in the number of fixed segments and the expansion of the fusion area remain the gold standard of surgical treatment for pseudoarthrosis. Meanwhile, it is proposed to increase the diameter of the screws with a possible change in the vector of their insertion or the introduction of bone cement as a posterior fixation technique. It is suggested to use anterior interbody fusion as an alternative to posterior fixation. The advantages of this technique include direct visualization and a wide approach to the anterior spine. That makes it quite easy to perform a discectomy, skeletonize the end plates, install a large cage with a different angle for indirect decompression of nerve structures and correction of lumbar lordosis, and also promote greater stability. A number of researchers [6, 10, 13] consider that surgeries through the anterior approach allow to reduce the risk of intraoperative complications, such as impaired wound healing, dura mater injuries and neurological disorders. It is connected with the absence of the need to perform procedures through the posterior approach in conditions of altered anatomical landmarks and scar tissues [14]. In our study, dura mater injury during surgery occurred in 2 (7.7 %) patients and was associated with the removal of an interbody cage that migrated into the spinal canal.

Significant factors influencing the surgery volume are the direction and degree of dislocation of the interbody cage, as well as the size of the resulting interbody space. Subsidence of the interbody cage with disruption of the integrity of the upper end plate of the subjacent vertebra was found in 68.8 % of cases in our group of patients. This dislocation significantly increased the height of the formed interbody space, which in the anterior and middle parts reached 19 mm, mean 14.9 mm. At the same time, in the posterior parts, the height of the interbody space in most cases was significantly lower, mean 8.2 mm. The obtained data show that the interbody space generated during the subsidence of the interbody implant greatly hinders the re-insertion of a cage of suitable size from the posterior approach.

We turned to additional posterior spine fixation if further use of pedicle screws for secure fixation was possible. The dimensions of the vertebral pedicle as assessed by CT data, the diameter and length of the pre-inserted pedicle screws, the region of deossification around the fixing components, and the presence of defects in the pedicle walls were the cri-

Table 2
Dynamics of the main clinical manifestations in patients with pseudoarthrosis before and after surgery

Indicators	Before surgery	12 months after	p
Intensity of pain in the lumbar spine according to VAS, points	6 (1.75)	3 (2.00)	<0.001*
The intensity of pain in the legs according to VAS, points	6 (1.00)	0 (0.00)	<0.001*
Oswestry Index	47.8 ± 15.4	23.8 ± 9.9	<0.001**

* Wilcoxon test; ** Paired Student's t-test.

teria for this. The region of deossification in the area of the inserted pedicle screws exceeded 1 mm in 11 (42.3 %) patients, and thus the size of the canal inside the vertebral pedicle exceeded 8 mm, preventing the use of bigger diameter screws. Defects of the inner or lower walls of the vertebral pedicle were detected in 9 (34.0 %) patients, which, in our opinion, significantly increases the chance of bone cement release when using it. In such cases, bone cement was administered into these vertebrae only from one side. Seven patients had fractures of the inserted pedicle screws (11 screws in total). The most common (8 screws) is the failure of the screws inserted into the S1 vertebra. In these cases, according to CT data, an alternative point of insertion and the path of insertion of an additional screw were planned in case it was impossible to remove the distal fragment of the screw.

While evaluating the treatment outcomes, most authors analyze the bone block formation. According to various studies [1, 9, 15], the frequency of bone block formation after repeated surgeries ranges from 32 to 100 %. The big difference in outcomes is due to the fact that all the research studies were conducted as a retrospective analysis of a small number of patients. In our study, one patient had not any sign of fusion after 12 months. Two more patients showed signs of fusion in only one end plate. Meanwhile, there were no signs of deossification in the area of the inserted pedicle screws. In our study, despite the good radiological outcome received in 21 (80.7 %) cases, most patients suffered lumbar spine pain of various degree of severity a year after surgery, and a number of them had pain and impaired sensitivity in the legs. In 22 (84.6 %) patients, a reduction in the Oswestry index by more than 20 units was observed after a year as a result of surgical treatment, but the degree of disability remained quite significant and averaged 23.8 ± 9.9. Other authors have obtained similar outcomes in their research. Therefore, Albert et al. [13] have proved that with a sufficiently low frequency (10 %) of false joints after repeated surgeries, 21 % of patients have

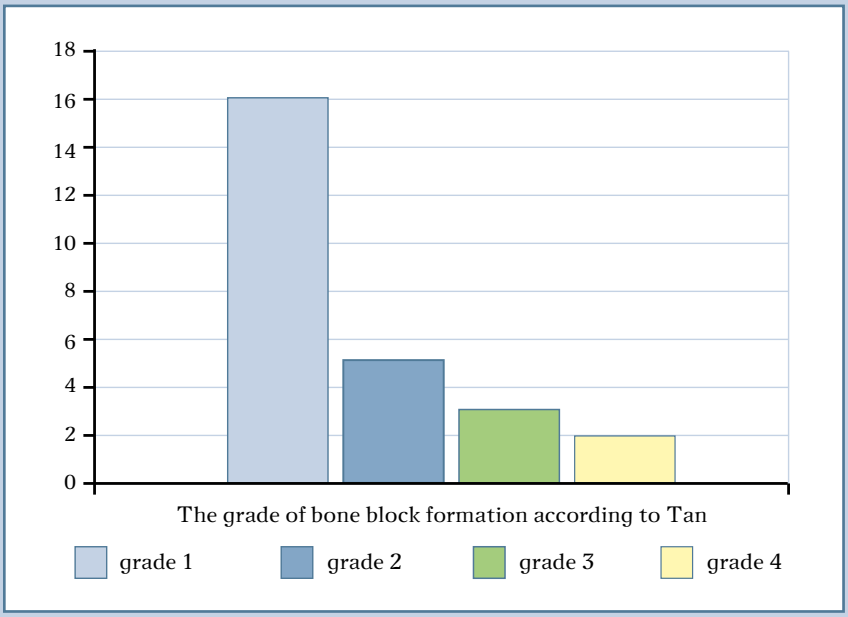

Fig. 1
Signs of consolidation according to the classification of Tan et al. [11] 12 months after repeated surgery

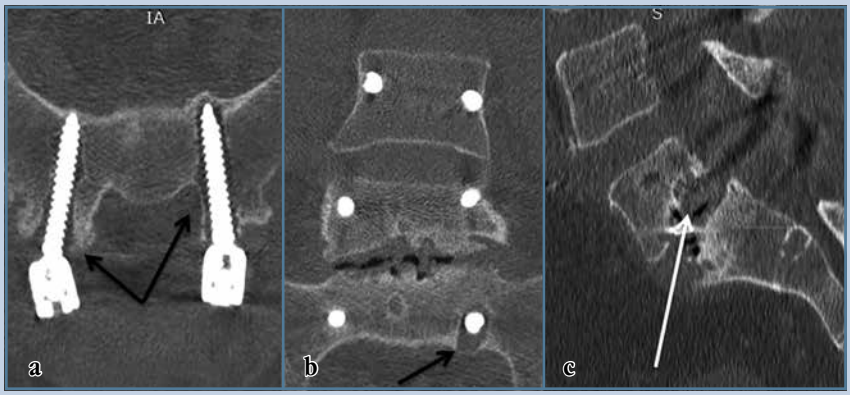

Fig. 2
Preoperative CT scan of the lumbar spine of patient I., male, 59 years old, in axial **(a)**, frontal **(b)**, sagittal **(c)** views: areas of deossifacation along the boundaries of transpedicular fixators in the S1 vertebral body (black arrows), the absence of a bone block and the presence of areas of enlightenment around the interbody implant (white arrow)

a poor clinical outcome despite good radiological findings after a combined (anterior and posterior) approach. Additionally, according to Cassinelli et al. [16], there is no significant difference between the pre- and postoperative Oswestry Disability Index scores, despite the 94 % frequency of complete bone block formation. In this study, the authors considered a cohort of patients with posterior interbody fusion without fixation who showed pseudoarthrosis. During the surgery, interbody fusion was supplemented with transpedicular fixation and posteri-

or fusion with autograft [16]. These outcomes suggest that a false joint after decompression and stabilization surgeries is just one of the challenges that cause the development of vertebrogenic pain syndrome and an impaired quality of life. Possible reasons of persistent pain may be the progression of the degenerative process, disruption of sagittal balance, or the development of neuropathic pain syndrome. The identification of these reasons and the subsequent improvement of the outcomes of surgical treatment will be the aim of further research.

Study limitations. This study has several limitations. The small number of patients does not allow an adequate statistical analysis and identification of the true number of complications. We evaluated only a small number of local risk factors for the development of pseudoarthrosis without considering factors such as diabetes mellitus, smoking and osteoporosis that impact on the bone block formation. It was impossible to assess the criteria of sagittal balance before the primary surgery; not all patients underwent postural radiography before surgery for pseudoarthrosis.

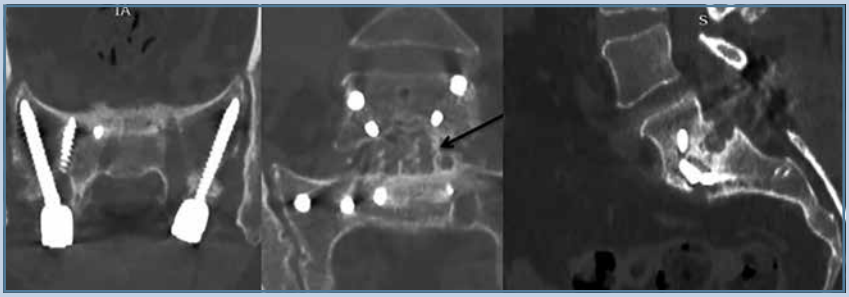

Fig. 3
Control CT scan of patient I., male, 59 years old, 12 months after surgery: the formation of bone bridges between the L5 and S1 vertebral bodies is noted (black arrow)

Conclusion

Due to the thorough preparation of the vertebral end plates and the use of implants of suitable size, anterior fusion from a minimally invasive retroperitoneal approach in the treatment of patients with pseudoarthrosis ensures optimum circumstances for interbody fusion. The use of anterior approaches allows for the safe removal of a pre-inserted interbody implant as well as direct and indirect nerve decompression. Nevertheless, despite the clinical improvement, significant functional disorders persisted in the majority of patients.

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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