L5–S1 SPONDYLOLISTHESIS: WHAT HAS CHANGED IN 20 YEARS? A REVIEW OF KEY ISSUES IN COMPARISON WITH PERSONAL EXPERIENCE

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The very first issue of the Russian Journal of Spine Surgery (2004;(1):39–46) published an article entitled "Surgical Treatment for L5 Spondylolisthesis with Transpedicular Fixators". Twenty years later, the authors analyzed changes in approaches to surgical treatment of spondylolisthesis, taking into account the experience in surgical treatment of this pathology gained at the N.N. Priorov National Medical Research Center of Traumatology and Orthopaedics. The issues of classification, fixation methods, reduction, changes in sagittal balance, the possibility of using additive technologies and possible complications of surgical treatment are considered.

In conclusion, it is noted that the development of surgical treatment methods, the study of biomechanical features, the introduction of additive technologies and much more enable improving the outcomes of spondylolisthesis treatment.

Key Words: L5–S1 spondylolisthesis; surgical treatment of spondylolisthesis; transpedicular fixation.

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Two decades ago, the authors from the N.N. Priorov National Medical Research Center of Traumatology and Orthopaedics published an article on surgical treatment of L5 spondylolisthesis using transpedicular fixation in the Russian Journal of Spine Surgery. In the meantime, our own experience in surgical treatment of spondylolisthesis has been accumulated, and research activities have been performed, as well as data from numerous academic papers that have been reviewed. In the proposed article, we would like to look back and evaluate the progress, the knowledge and experience gained, and consider how approaches to the treatment of spondylolisthesis have changed.

Reading again the article of 2004, we would like to highlight several aspects. These include classification, fixation techniques, reduction, changes in sagittal balance, the use of additive techniques, and possible complications of surgery.

More on the issue of spondylolisthesis classifications

The Marchetti – Bartolozzi etiological classification remains relevant and provides the possibility to divide spondylolisthesis into two main types. Yet, to this day, articles and scientific reports still use elements of the Wiltse et al. classification that sometimes leads to confusion between etiological and morphological criteria.

Definitely, the main commonly accepted classification of the severity of dislocation has been and remains the well-known Meyerding Spondylolisthesis Grading. Nevertheless, the fact that deformity in spondylolisthesis is not limited to an anteroposterior dislocation has been obvious to many researchers. I.M. Mitbreit and V.E. Belenky stated that the slip angle of the overhanging vertebra, rather than the linear magnitude of the dislocation, is of greater significance, and a grading of dislocation degrees was proposed on this basis. Dubousset recommended measuring the lumbosacral angle, the so-termed Dub-LSA (Dubousset lumbosacral angle), and stated that its correction to at least 100° allows to avoid unsuccessful surgical treatment [2]. The more recent papers have confirmed the importance of correction of lumbosacral kyphosis and the correlation of its magnitude with quality of life [3].

The new information, gained from the study of sagittal balance parameters, has provided a better understanding of biomechanical disorders and compensatory mechanisms in spondylolisthesis. Based on this, the SDSG (Spinal Deformity Study Group) classification was proposed [4]. Depending on the severity, two types of spondylolisthesis are distinguished: low grade (I–II) and high grade. The SDSG classification, depending on the radiological parameters and features, compensation or decompensation of the sagittal balance, provides an opportunity to determine the surgical strategy: in situ fixation or reduction of the L5 vertebra with restoration of the spinopelvic relationship.

Radiological parameters for the evaluation of spondylolisthesis

As noted above, the deformity in spondylolisthesis is based on two components: translational and angular. The translational component is expressed in grades (the Meyerding classification [5]) or in percent, as described in Boxall et al. [6]. The angular component consists of measuring dislocation angles and is expressed in degrees, as described in the classic monograph by I.M. Mitbreit [7]. In studies of the end of the last century and the beginning of this century, such radiological parameters as lumbar lordosis, sacral slope, L5 tilt angle, sagittal rotation angle, Mitbreit – Belenky angle, and many others were used to evaluate the spinopelvic relationship. The data given in our article shows a reliable improvement in the parameters characterizing the angular component of lumbosacral deformity – sagittal rotation angle, Mitbreit dislocation angle, etc.

The gaining of information on the parameters and relationships describing the sagittal balance of the spine in particular and the trunk in general, as well as the introduction of the postural full-height radiological examination, has provided new instruments for a more complete evaluation of changes in spondylolisthesis. A number of parameters have been introduced: Pelvic Incidence (PI), Pelvic Tilt (PT), and Sacral Slope (SS), that describe the morphology and position of the pelvis in space. The load distribution in the lumbosacral spine also depends on these parameters [8]. PI is a static (anatomical) parameter, the value of which is individual and constant for each person, unlike SS and PT, which, in turn, reflect compensatory changes [9].

A particular area of interest is the results of studies [10–13] demonstrating that sagittal pelvic parameters differ between healthy individuals and patients with spondylolisthesis, with the degree of abnormalities correlating directly with the severity of spondylolisthesis.

During the studies of sagittal balance in patients with spondylolisthesis, we concluded that the key point of surgical treatment of this group of patients is to resolve the angle of local lumbosacral kyphosis; in turn, the parameters of sagittal balance may be not fully restored [14].

Techniques of posterior fixation in spondylolisthesis

The title of the article itself reflected the use of transpedicular fixation at the time, emphasizing the importance of the technique and its novelty. Professor Stepan Timofeevich Vetrile was the first to perform the surgery using the transpedicular fixation for spondylolisthesis in our country at the N.N. Priorov National Medical Research Center of Traumatology and Orthopaedics in 1992. The instrumentation system developed by Arthur D. Steffe [15], consisting of pedicle screws and plates fixed to the screws with nuts, was used. In the early 2000s, this technique, although already used in specialized units of leading traumatology and orthopaedic as well as neurosurgical centers, was not widespread. Undoubtedly, transpedicular fixation is the main technique in the surgical treatment of spondylolisthesis for correction of abnormal relationships and stabilization. Previously, in order to reduce the dislocated vertebra and stabilize it, a rather extended fixation (two- and three-segment fixation) was performed considering that less than a third of the patients analyzed in this article had I–II-degree dislocation. Certainly, the gained experience with screw placement, intraoperative imaging options, and available technical devices for correction of vertebral relationships, and rod fixation now allow to perform less extensive fixation in most cases and are often limited to a single segment. However, the criteria for selecting fixation levels proposed by Lamartina et al. [16] in 2009 and based on the calculation of the "stable area," provide to choose an optimal extent of fixation and prevent possible dislocation of the superjacent vertebra.

L5–S1 anterior support column stabilization techniques

It is unquestionable that stabilization of the anterior support column is crucial for successful outcomes in the treatment of spondylolisthesis with lumbosacral spine fixation. Numerous articles confirm this, and our experience, represented in the article of 2004, has shown that in the absence of interbody fixation there is a high percentage of fractures of the instrumentation (23.3 % in the study group). Simultaneous surgeries with TLIF or PLIF with sufficient reduction and preserved anatomical shape of the vertebral end plates is the procedure of choice. Nevertheless, in cases of a high degree of both dysplastic and secondary deformities of the adjacent vertebral end plates of the L5 and S1, the so-termed dome shape of S1, and incomplete reduction of dislocation in high-grade spondylolisthesis, it is difficult or even impossible to achieve a full-fledged interbody bone block with cages from the posterior approach. In such cases, interbody fixation from the anterior approach is most often the procedure of choice. Most of the patients studied in this article underwent an anterior extraperitoneal fusion with a cortical allograft. This technique has been widely used by us; it provided primary stable fixation and a good outcome in the long term (Fig. 1). The introduction of mesh implants, along with the limited availability of the necessary cortical allografts, has led to the use of 12 mm cervical mesh cages filled with bone chips to perform interbody fixation. For the same purpose, customized extended cages with threads have been developed and successfully used (Fig. 2). The technique of using the so-termed Dotsenko mega-cage for L5–S1 fusion is effective; its benefit is the possibility of using in revision surgeries after PLIF/TLIF-type failed fusion and, when necessary, to perform anterior decompression of neural structures at the L5–S1 level [17].

Reduction

The elimination of linear, anteroposterior dislocation is understood under the term "reduction", when evaluating the surgical outcomes of spondylolisthesis. As noted above, the key point is the correction of the angular relationship of the lumbosacral spine. Nonetheless, the issue of reduction always arises

when discussing spondylolisthesis. Systematic reviews and meta-analyses performed and published in articles of the highest level of evidence agree that reduction and in situ fixation for spondylolisthesis are equally valid and have no significant differences in clinical outcomes. A higher level of co-ossification and, accordingly, a lower incidence of pseudarthrosis are registered when performing reduction [18–22]. However, it should be noted that a number of papers indicate that neurological complications are more common when reduction is performed [23, 24].

The most difficult for treatment is the extreme degree of dislocation – spondyloptosis. One of the most radical techniques is the Gaines procedure: vertebrectomy of the L5 vertebra located in front of the sacrum and fixation of the L4 vertebra on the S1. In one case, we successfully applied this technique, modifying it with additional fixation of L4–S1 with cages with excellent long-term outcomes, but we should not recommend widespread use, given the complexity and high risk of neurological and other complications. The author points out a high risk of neurological complications in the analysis of 30 cases of treatment [25]. In spondyloptosis, it is essential to correct L5–S1 kyphosis, to control visually and neurophysiologically the condition of the roots and the dural sac during correction, and to perform an adequate L5–S1 fusion either from the anterior approach (Fig. 1) or from the posterior approach in a trans-sacral technique, as described in our paper, or with more often preferred Bohlman technique with the use of a mesh cage. Trans-sacral fixation with long screws is also effective [26, 27]. A case of successful use of external fixation instrumentation for gradual elimination of deformity in spondyloptosis followed by transpedicular fixation and anterior fusion has been described [28].

Caudal extension of fixation with spinopelvic fixation and placement of screws in the iliac bones is also becoming more frequently used to increase the stability of fixation [29].

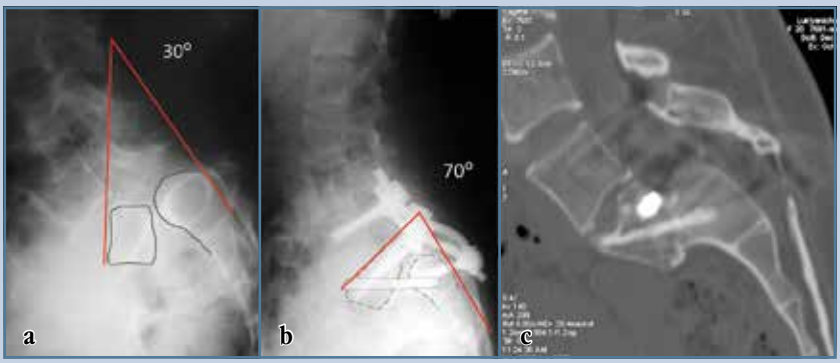

Fig. 1
A 12-year-old patient underwent two-stage surgical treatment for spondyloptosis of the L5 vertebra, i.e. transpedicular fixation of the L4–L5–S1 and anterior extraperitoneal fusion of the L5–S1 with a cortical allograft: **a** – radiological image in lateral view, lumbosacral kyphosis; **b** – correction of lumbosacral kyphosis; **c** – CT scan 15 years after surgery – complete fusion of the L5–S1

Additive technologies

The first application of additive technologies in spine surgery in our country was associated with the treatment of spondylolisthesis. V.V. Dotsenko et al. [30] in 2004 described the use of stereolithographic full-size models in planning surgical treatment of spondylolisthesis and the making of customized instrumentation for anterior stabilization of the lumbosacral spine. After anterior decompression at the L5–S1 level, in situ fixation with a customized plate was performed from the extraperitoneal mini-approach proposed by the authors. We used this technique in several cases and after partial reduction from the posterior approach for fixation of the anterior support column [31].

The extensive development and availability in the last decade of computer simulation and additive technologies for the making of full-size spine models and customized implants has also found its application in the surgery for spondylolisthesis. The N.N. Priorov National Medical Research Center of Traumatology and Orthopaedics has developed a technique and a customized design for surgical treatment of patients with spondylolysis [32]. An customized instrumentation, contouring of the L5 vertebral arch with sublaminar fixation and covering the base of the spinous process, provides indirect restoration of the arch integrity in spondylolysis in combination with transpedicular fixation. The possibility of preoperative planning provides the opportunity to make the instrumentation in such a way that when fixing it to the screws, reduction of the anterior part of the vertebral body is achieved in spondylolisthesis of grade I–II. The first application of this technique in 29 patients with spondylolysis, 22 of whom also had grade I–II spondylolisthesis, showed its efficacy [33]. The obvious advantage is the preservation of movement in the L5–S1 segment.

Neurological complications

In our article of 2004, it was noted in the study group that 2 (6.7 %) patients developed paresis of the extensor muscles of the foot and toes after surgery that decreased satisfaction with the surgical outcome. Fu et al. [23] analyzed a group of 605 children and adolescents operated on for spondylolisthesis and noted the onset of neurological deficit after surgery in 5 %.

Kasliwal et al. [24], analyzing the treatment outcomes of 165 patients, adults and children, noted the onset of neuro-

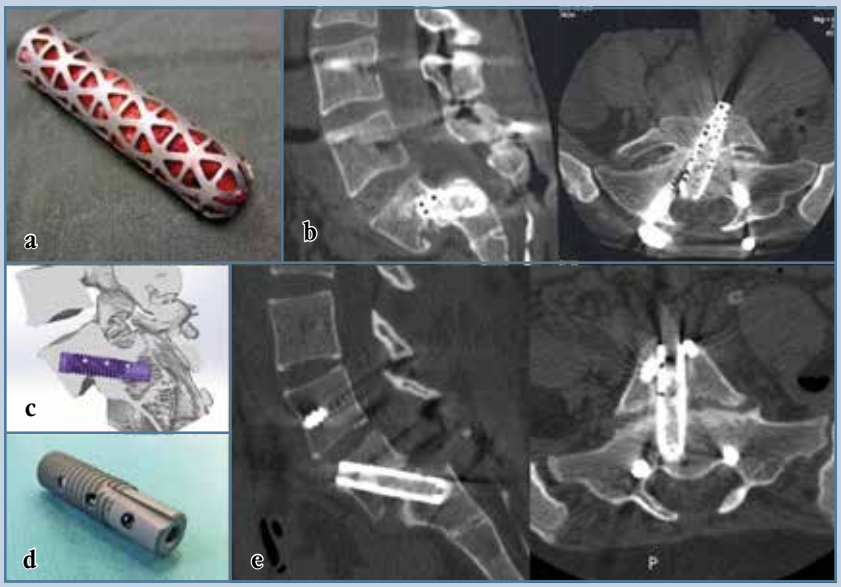

Fig. 2
Variants of performing anterior interbody fusion of the L5–S1: **a** – 12 mm mesh cage filled with autografts; **b** – CT of the L5–S1 interbody bone block with a mesh cage; **c** – planning of a surgery using a special extended threaded cage; **d** – appearance of the threaded cage; **e** – CT of the patient after performing anterior fusion of the L5–S1 with a special cage

logical complications in 11.5 % of cases, and the use of intraoperative neurophysiological monitoring (IONM) did not always make it possible to avoid these complications. In reduction and correction of angular relationships, especially in large grades of spondylolisthesis, in our opinion, direct visualization of the roots is crucial to ensure their compression and tension are not present. Nonetheless, the use of IONM during vertebroplasty is undoubtedly valuable, and the development of new IONM techniques will prevent neurological complications to a greater extent [34].

Conclusion

The development of surgical techniques, new aspects of etiopathogenesis and biomechanical features, introduction of additive technologies and so on can improve the outcomes of spondylolisthesis treatment. Original studies performed with a high degree of evidence, analysis of the international literature, and exchange of experience are significant in this way.

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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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