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ORIGINAL PAPER

Operative management of high-grade dysplastic L5 spondylolisthesis with the use of external transpedicular fixation: advantages and drawbacks

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Abstract
Purpose The aim of our study was to analyze clinical and radiographic outcomes of operative management of L5 high-grade dysplastic spondylolisthesis with the apparatus for external transpedicular fixation (AETF), and to compare the results of its use for reduction and spondylodesis.
Methods There were 13 patients with L5 dysplastic spondylolisthesis of grade 4 (Meyerding grading) and having a mean age of 25.0 ± 3.6 years. The management included two stages: gradual reduction with the AETF, followed by either isolated anterior spondylodesis with the same AETF (group 1, $n = 8$), or by spondylodesis using a combined method (internal transpedicular instrumentation and posterior lumbar interbody fusion [PLIF]) (group 2, $n = 5$). Clinical evaluation included pain (VAS scale) and functional status (Oswestry questionnaire [ODI]). Reduction and fusion completeness were assessed radiographically after treatment and at a mean follow-up of 2.1 ± 0.4 years.
Results Initial slippage was reduced by 51.6 % with AETF and was of grade 1 or 2. Reduction made up 31.1 % at follow-ups (grade 2 or 3). Pain decreased by 57.6 % ($p < 0.01$). The functional status improved. ODI decreased by 37.7 % ($p < 0.01$) after treatment and by 41.7 % ($p < 0.01$) at follow-ups. Fusion at the level of the involved segment was poor in group 1. All the cases fused in group 2.
Conclusions The use of AETF for L5 high-grade dysplastic spondylolisthesis provides gradual controlled reduction of the slipped vertebra, decompression of cauda equine roots, and recovery of the local sagittal spinal column balance. It creates conditions for achieving stability of lumbosacral segments with combined spondylodesis (internal transpedicular instrumentation and PLIF). AETF is not suitable for spondylodesis due to a high rate of pseudarthrosis.

Keywords High-grade dysplastic spondylolisthesis · Reduction · Apparatus for transpedicular external fixation · Spondylodesis · Pseudarthrosis

Introduction

Management of high-grade dysplastic spondylolisthesis continues to be discussed [1–5]. The main topic of the discussion is the choice of an optimal operative technique: “in situ” fusion or deformity reduction and fusion [5–7]. The technique of “in situ” fusion is the most common method of treatment and is supported by many authors [8, 9]. However, it has a potential risk of nonunion and displacement progression that results in the extension of spondylodesis to provide spinal stability [10]. The other approach that includes reduction of the slipped vertebra and fusion has been mostly used in patients with high-grade spondylolisthesis [5, 11, 12].

Various means and methods of reduction and fusion were proposed in the past that include the Harrington rod distraction [11], cast reduction [12], Cotrel-Dubousset instrumentation, and pedicle screw instrumentation [13–16]. Partial reduction and transsacral titanium cage [17], transsacral rod fixation [3], sacral dome resection for one-stage reduction and fusion [2] are among the current techniques that have been discussed.

Our study was aimed at a retrospective analysis of the outcomes in the management of L5 high-grade dysplastic spondylolisthesis that included gradual reduction with the

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apparatus for external transpedicular fixation (AETF) that was followed by either isolated anterior spondylodesis with the same AETF, or combined spondylodesis for interbody fusion using internal instrumentation and posterior lumbar interbody fusion (PLIF).

Materials and methods

This study was a retrospective analysis of treatment outcomes in 13 patients that had complicated high-grade dysplastic spondylolisthesis (grade 4 according to H.W. Meyerding) of the L5 vertebra (L5-S1 segment) [18]. There were seven females and six males, aged from 15 to 60 years (mean, 25.0 ± 3.6 years). Mean L5 slippage was 3.02 ± 0.1 cm (range, 2.8-3.5 cm).

The functional radiographic examination revealed pathological instability at the level of spondylolisthesis in all the patients. Five patients had chronic low-back pain and pain in the lower limbs; six had radicular pain that was resistant to conservative treatment. Mild lower paraparesis was revealed in two patients. Pain was assessed using the visual analog scale (VAS, 10 points), and the functional status was studied with Oswestry questionnaire (ODI scale) (Table 1) [19].

The patients were operated on between 2001 and 2011. The indication for surgery was relief of low-back and radicular pain. Gradual reduction was performed with the apparatus for external transpedicular fixation (AETF) (EP0418387A4, JPH03505049) available on the market (Fig. 1). Following reduction, eight patients underwent the operation of isolated anterior spondylodesis of L5-S1 with the use of the same AETF (group 1), and in five cases (group 2) the fusion method was a combined spondylodesis (internal transpedicular instrumentation and PLIF).

The operative techniques and management utilized for the two stages were as follows:

Stage 1: placement of AETF and reduction

The intervention ran under endotracheal narcosis and image intensifier control with the patient in the prone position. The AETF placement started with the introduction of screws into the slipped vertebra transpedicularly and into two or three vertebrae lying above it (Fig. 2). Two pairs of screws were inserted into the iliac wings. The screws were inserted in a closed way through small skin incisions in the projection of pedicles and illiac wings. The screws were attached to plates in couples. The plates were connected to support units with threaded rods that provided correction. Reduction of the slipped vertebra was measured in centimeters. Acute correction up to 1 cm was realized with AETF.

Gradual reduction in the postoperative period ran under radiographic control (lateral spondylograms). Maximum possible correction was obtained in order to improve the anatomical and biomechanical relationship in the involved segment for further spondylodesis. Mean reduction rate was 1.0-1.5 mm a day and continued 14.4 ± 2.5 days on average (range, 7-21 days). Reduction was discontinued if pain and transient neurologic disorders appeared.

Stage 2

Isolated anterior spondylodesis with AETF

Laminectomy at one or two levels in the slipped vertebra and the above lying vertebra as well as discotomy in L5-S1 segment were performed upon completion of reduction with the AETF in group 1. In order to obtain anterior interbody fusion, the AETF was in place for 60 or 70 days (Fig. 3).

Table 1 Clinical outcomes

Parameter	Study point		
	Before operation	Immediately after treatment	Follow-up
VAS (points), M ± m, $n = 13$	7.6 ± 0.3 (range, 6-9)	4.6 ± 0.3* (range, 3-6)	3.3 ± 0.2* (range, 2-4)
ODI (%), M ± m, $n = 13$	54.9 ± 2.3 (range, 42-72)	34.0 ± 0.9* (range, 28-40)	32.0 ± 0.9* (range, 26-36)
Neurologic status (n)			
1. Lower mild paraparesis	2	Absent	Absent
2. Radicular syndrome	6	Absent	Absent
3. Chronic pain	5	2	2
4. Intermittent pain	–	1	1

* Significant difference compared with preoperative value, $p < 0.01$

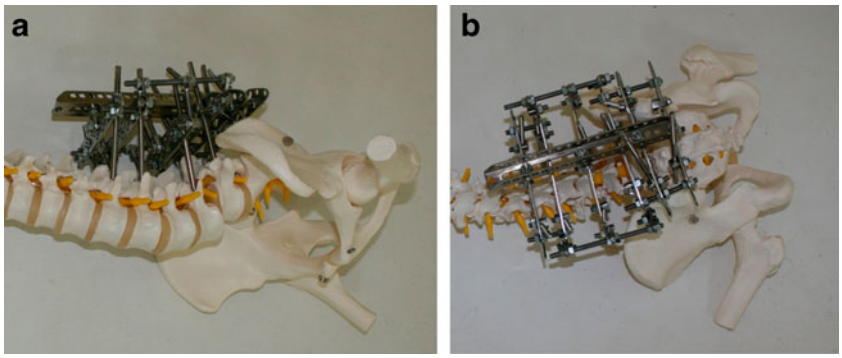

Fig. 1 Lateral (**a**) and upper (**b**) views of the AETF mounted on a dry bone model

Combined anterior-posterior spondylodesis using internal instrumentation and PLIF

Upon completion of gradual reduction in group 2, the AETF was dismounted under intubation anesthesia while the patient was in the prone position. The reduction was retained with the AETF temporary screws, left at the extreme levels. Transpedicular screws of the internal instrumentation system were introduced into the canals of AETF crews of the bodies of L4, L5, and S1 on both sides from the middle posterior approach. L5 laminectomy was performed, and L5-S1 PLIF cages were introduced for achieving anterior spondylodesis (Fig. 4).

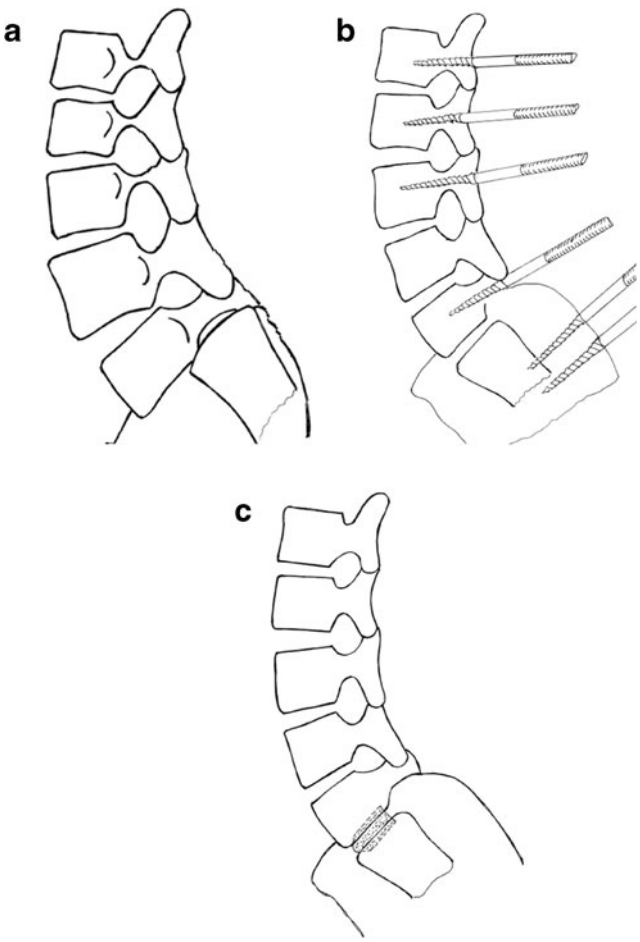

Fig. 2 Diagrams of the segments before treatment (**a**), during reduction (**b**), and upon spondylodesis completion (**c**)

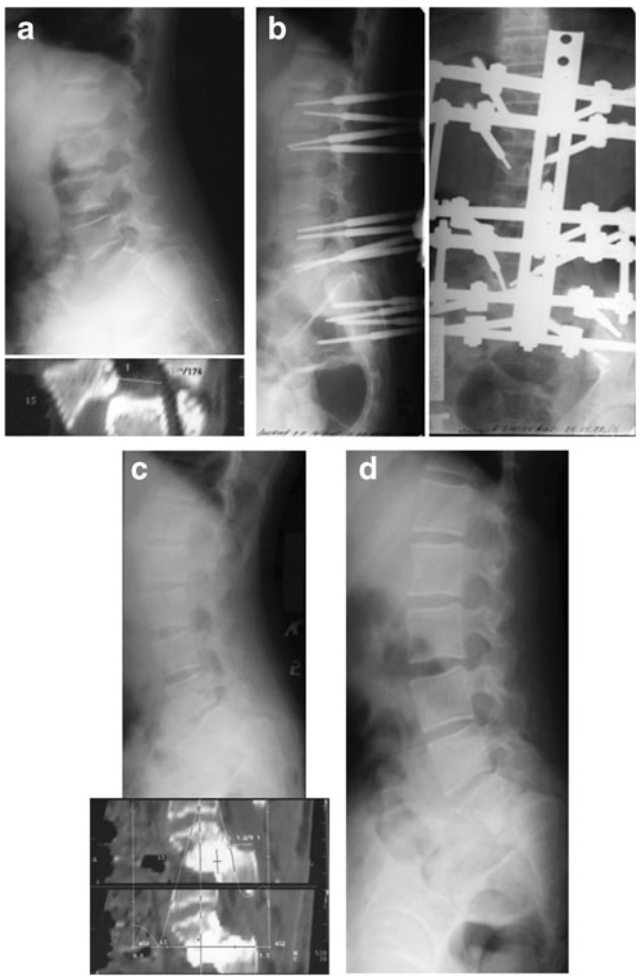

Fig. 3 Dysplastic L5 antelisthesis of grade 4 in a male patient (**a**) was treated in two stages: closed placement of the AETF, acute reduction of 1 cm, gradual reduction for 15 days (**b**); stage 2: L5 laminectomy, partial L4 laminectomy, L5-S1 discotomy, anterior L5-S1 spondylodesis using an autologous graft (**c**) and the AETF (**c**); 3-year outcome (**d**)

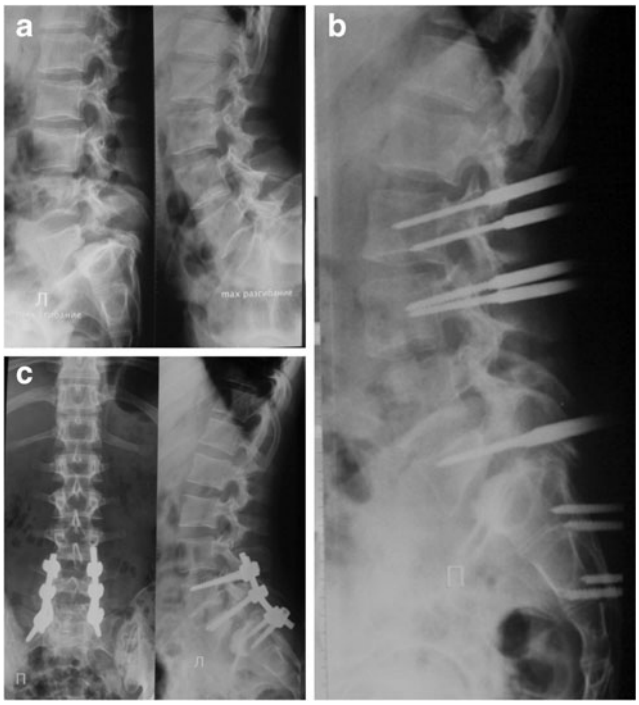

Fig. 4 Spondylograms of a male patient with high-grade dysplastic L5 antelisthesis of grade 4 before the operation (**a**); after gradual reduction during 13 days with the external fixator (**b**); after completion of spondylodesis (**c**) with a combined method (posterior transpedicular instrumentation and PLIF)

Analysis

Clinical and radiographic analysis of the deformity correction was conducted in all the patients immediately after reduction, treatment completion, and at follow-ups (mean, 2.1 ± 0.4 years).

Microsoft EXCEL-2010 was used for statistical analysis. Mean values, odds and significance level were calculated. Student's *t*-test was used for significance of difference between the means. The non-parametric Mann-Whitney test and Wilcoxon test were the additional methods for independent and conjugate variance (for small samples) with the significance level of 0.05.

Results

Reduction

It was possible to reduce the slippage with the AETF down to 1.46 ± 0.22 cm on average (Fig. 5). The correction made 51.6 %. Spondylolisthesis degree decreased to grades 1 or 2 in all the patients. It was enough for recovery of anatomical and biomechanical relations at the level of the involved segment and for creation of optimal conditions for further fusion.

At follow-ups, the loss of correction was 0.62 cm (42.5 %, $p < 0.05$). Mean slippage value was 2.08 ± 0.22 cm at long-term follow-ups. Correction made up 31.1 % from the initial values, and spondylolisthesis grades were 2 or 3. Progression of slippage in six out of eight patients with isolated anterior spondylodesis was due to incomplete fusion.

Clinical results

We revealed the improvement of neurological disorders in all the patients (Table 1).

Pain decreased by 57.6 % ($p < 0.01$) at the follow-ups. ODI was lower by 37.7 % ($p < 0.01$) immediately after treatment, and by 41.7 % ($p < 0.01$) at follow-ups.

Operation time and blood loss

At stage 1, the operation time was 62.5 minutes (range, 40–85 min) with a mean blood loss of 50.1 ± 3.4 ml (range, 40–60 ml).

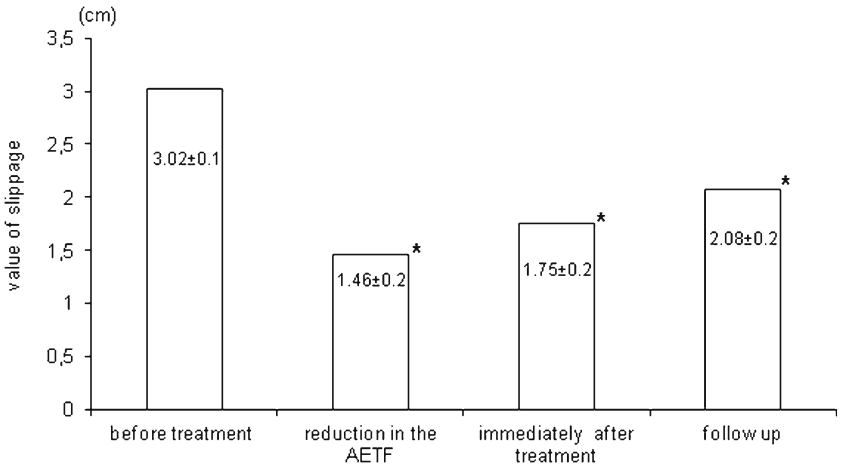

Fig. 5 Slippage values (M ± m, $n = 13$) in the periods studied. *AETF* apparatus for external transpedicular fixation
*Significant difference compared with pre-operative value ($p < 0.05$)

At stage 2, the operation continued 170 minute (range, 100-200 min) with a mean blood loss of 400.5 ± 8.6 ml (range, 300–500 ml).

Complications

There was a disorder of pelvic organs functioning in one case (7.7 %). Mild spastic paraparesis was observed in two cases (15.4 %) after acute reduction. Therefore, the AETF efforts were decreased and the medication therapy administered. It resulted in cessation of neurologic manifestations in all these cases. There were no residual neurologic complications at follow-ups.

Pseudarthrosis was revealed in six patients of group 1 at long-term follow-ups. Additional interventions with the use of internal transpedicular instrumentation and PLIF were performed in two cases. Four patients rejected re-operations.

Discussion

High-grade dysplastic spondylolisthesis is a challenging problem. Indications for operative treatment are progression of slippage, high-grade spondylolisthesis accompanied by lumbosacral kyphotic deformities with the sagittal imbalance of the spine, compression of nerve roots, low-back and radicular pain that does not respond to conservative treatment [7]. The main objectives of treatment are the recovery of the spine balance, stability in lumbosacral segments, and decompression of the cauda equina roots to relieve pain [2, 6, 20].

Management of high-grade dysplastic spondylolisthesis continues to be discussed [1–5]. There is no common point of view on the choice of the optimal surgical technique of treatment: “in situ” fusion or deformity reduction and fusion [5–7]. Most authors defend the methods of “in situ” fusion without reduction for spondylolisthesis of grades 3 or 4 in adults and children and describe good function and pain relief in the long term [8–10, 21].

However, there is an opinion that the “in situ” spondylodesis contradicts the principle of physiological balance for both low-grade (grades 1–2) and high-grade (grades 3–4) spondylolisthesis as far as there are long-term negative impacts on the adjacent intact segments [22, 23]. Significant residual lumbosacral kyphosis results in sagittal spine imbalance and compensatory changes such as lumbar hyperlordosis to balance the pelvic line [7]. The patients walk with their femurs and knees flexed due to the pain and fatigue that occur. Thus, the conditions for degenerative changes are created that develop caudally to the spondylodesis level. It is considered that this technique is associated with high rates of pseudarthrosis (up to 50 %) and progression of slippage [5, 24]. It results in the necessity to extend spondylodesis for providing stability [10, 25].

Reduction of the slipped vertebra may improve both patient’s condition and the outcome of treatment. Reduction in a high-grade spondylolisthesis decreases the angles of lumbosacral kyphosis, provides decompression of neural structures, restores the spine sagittal balance, improves the ability of the patient to stand, and allows for a spontaneous correction of the thoracic hypokyphosis and lumbar hyperlordosis [26, 27]. Moreover, the decrease in the slippage creates better biomechanical conditions for spondylodesis [20], provides a faster bone union and prevents progression of the deformity [7].

Despite the factors mentioned above, the role of reduction remains disputable due to complications. The main arguments against reduction are an increased volume and time of surgical intervention, as well as a greater risk of possible neurologic disorders (up to 31-41 %) and subsequent loss of reduction [3, 13, 14, 24, 28, 29].

However, the study that compared the available literature on “in situ” fusion versus deformity reduction and fusion for high-grade spondylolisthesis (101 cases of “in situ” fusion, 165 cases of deformity reduction and fusion) found that the reduction improved the biomechanics of the spine, reduced the angles of lumbosacral kyphosis, and decreased the degree of slippage [5]. The rate of neurologic deficit did not differ significantly from the rates of “in situ” spondylodesis. Moreover, the rate of pseudarthrosis was lower.

Several studies reported on the clinical use of external fixation for high-grade spondylolisthesis [30–32]. External transpedicular fixation features several advantages, such as the possibility of gradual controlled reduction aimed at spinal canal content decompression and restoration of anatomical and biomechanical relations of the segment. It also creates better conditions for producing spondylodesis [20, 32]. Margel’s apparatus of external fixation was used for gradual reduction in combination with “circumferential fusion” for recovery of the sagittal balance and esthetic compensation in patients with high-grade spondylolisthesis [32].

The AETF used in our series was developed for treating spinal deformities or injuries, and is available on the market. Biomechanical features of the AETF provide correction in all the three planes. Fixation rigidity of specific vertebras is enough for their sufficient stability under all types of loading [33]. Our patients were mobile on the 2nd day after the operation.

It was concluded that this apparatus could be successfully used for spondyloptosis despite the long fixation period [31]. In our series, the AETF was used for reduction of the slipped vertebra in both groups. Partial acute reduction was realized intraoperatively, and was followed by gradual reduction postoperatively under radiographic checking and control of neurologic events. The advantage of gradual reduction is the possibility to check the appearance of neurologic events that may complicate the process. Reduction manipulations can be ceased or decreased

when pain increases, or transient motor or sensation changes appear. In group 1, it was applied by us for reduction and fixation of the slipped vertebra. Upon completion of reduction, the AETF was put into the fixation mode until bone union between the vertebrae was achieved [30].

Up to the moment, the amounts of reduction in operative management of spondylolisthesis have been still discussed. Several authors showed severe neurologic complications after complete intra-operative reduction. The reported rates range from 6 up to 100 % [34]. Acute reduction of the slipped vertebra may result in acute pain in the area of operation and in the lower limbs, as well as in neurologic disorders [35–37]. Correlation between the frequency of such complications and the amount of intra-operative reduction was observed. The rate of neurologic complications by complete acute reduction in high-grade spondylolisthesis and spondyloptosis may rise to 50 % [34]. It is about 20 % if half of the anteroposterior amount is reduced [35, 36].

In our patients, acute reduction did not exceed 1 cm (24 % from the initial slippage). However, neurologic complications were diagnosed in three patients (23 %). The external fixation allowed us to decrease the AETF efforts applied. Along with medication therapy, this measure could relieve neurologic events in all the cases. Residual neurologic complications were not noted in the follow-up period.

The loss of reduction was not statistically different between our groups (43.0 versus 42.5 %, $p > 0.05$). However, the rate of pseudarthrosis, which is the most common complication [38], was significantly higher in group 1.

Thus, the main advantages of the AETF are efficient gradual reduction and the possibility to control neurologic manifestations that complicate the process. Pain and its progression, transient motor and sensatory changes may be resolved by the decrease in the reduction rate or by its cessation. Combined spondylodesis is a better method for anterior interbody fusion than the isolated anterior spondylodesis with AETF.

Conclusion

The use of AETF for L5 high-grade dysplastic spondylolisthesis provides gradual controlled reduction of the slipped vertebra, decompression of cauda equine roots, and recovery of the local sagittal spinal column balance. It creates conditions for achieving stability of lumbosacral segments with combined spondylodesis (internal transpedicular instrumentation and PLIF) that follows. However, the use of AETF is not suitable for spondylodesis due to a high rate of pseudarthrosis. Other methods should be used instead.

Compliance with ethical standards Informed consent statements were given by all the parents. The study was approved by the ethics committee of our institution and was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki.

Conflicts of interest None.

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