Acta Orthop. Belg., 2016, **82**, 730-736

ORIGINAL STUDY

Fusion-segment of high-grade Lumbar Spondylolisthesis: 2-year follow-up

Xiaolong Li, Lian Xu, Qingquan Kong

Department of Orthopedics, West China Hospital of Sichuan University, Chengdu, China

The clinical efficacy of reduction and fusion surgery and the suitable range of fusion-segment were evaluated in 12 pediatric patients treated for high-grade spondylolisthesis. Pre/post-operative clinical and radiological assessments were analyzed. A transient L5 nerve root paralysis was observed in one patient with L5 spondylolisthesis. No degenerative spondylolisthesis or adjacent segmental instability occurred above the fusion segments. In conclusion, we suggest that, in case of spondylolisthesis without severe structural scoliosis deformity or only associated with lumbosacral deformity, the posterior ligament complex should be protected in case of adjacent segmental instability and spondylolisthesis. If the spondylolisthesis is complicated with severe structural scoliosis deformity (Cobb ≥ 70°), in principle, the treatment should be performed according to the characteristics of the two diseases respectively.

Keywords : high-grade lumbar spondylolisthesis ; reduction and fusion ; posterior approach ; fusion-segment.

INTRODUCTION

Among pediatric patients, surgical intervention is generally indicated for severe spondylolisthesis. The primary goals of surgical treatment are neurological decompression and stability reconstruction. The investigators have recommended fusion in situ or deformity reduction and fusion *(10-11,24)*. Although satisfactory clinical outcome has been reported after in situ fusion *(11,14,19)*, this procedure was also probably associated with higher rates of pseudarthrosis, subsequent slip progression and necessitates extended fusion to a higher normal disc level in terms of stability *(1,5)*. In order to reduce the postoperative complications, other investigators recommended reduction and fusion *(20-21)*. Reduction of the spondylolisthesis could enhance fusion rate. Moreover, reduction and fusion could also restore the segmental lordosis, improve lumbosacral alignment and therefore improve the sagittal profile of the spine *(8-9,15)*.

■ Xiaolong Li
■ Lian Xu
■ Qingquan Kong
Department of Orthopedics, West China Hospital of Sichuan University, Chengdu, China
Correspondence : Qingquan Kong. Department of Orthopaedics, West China Hospital of Sichuan University, No. 37 Guoxue Lane, Wainan Street, Wuhou District, Chengdu, Sichuan, China, 610041.
E-mail : kqqspine@163.com

No benefits or funds were received in support of this study.
The authors report no conflict of interests.

However, adjacent segment disease (ASD) and slip progression occurred after reduction and fusion for some pediatric patients with severe lumbar spondylolisthesis. As previously reported, the fusion-segment could be regarded as one of the most important risk factors *(16-18)*. Most authors believed that mono-segmental fusion could reduce the incidence of ASD more effectively compared with multi-segmental fusion. Therefore, it's very important to find the most appropriate extension of fusion for patients with high-grade spondylolisthesis, in order to reduce the incidence of such complications. Based on the study mentioned above, we summarized our experience in pediatric patients with high-grade lumbar spondylolisthesis by reduction and fusion through posterior approach.

METHODS

Inclusion and exclusion criteria

Inclusion criteria are: (1) Meyerding grade ≥ III; (2) the surgical procedures include posterior pedicle screws fixation, lamina/facet and disc resection and decompression, slip reduction, intervertebral and posterolateral lumbar fusion; (3) a minimum of 2-years follow-up; (4) preoperative, postoperative and follow-up imaging data including whole-spine standing anteroposterior (AP) and lateral radiographs, lumbar dynamic radiographs and 3D CT reconstruction of surgical fixation and fusion segments.

Exclusion criteria were: (1) age ≥ 18 years old; (2) patients with high-grade lumbar spondylolisthesis treated with in situ fusion by posterior approach.

There were 2 males and 10 females with an average age of 11.3 years old (range, 7-15). The course of the disease was between 5 months and 6.3 years, with an average of 2.4 years. The clinical manifestations included low back pain, aggravated when standing and after walking, combined with pain in bilateral lower limbs in 8 cases and unilateral pain in 4 cases; intermittent claudication in 9 cases. Preoperative examination showed weakened plantar flexion strength in 3 cases, weakened dorsal extensor strength in 5 cases and symptoms of cauda equina damage in one case. Frankel grade showed D grade in 8 cases and E grade in 4 cases. Preoperative mean VAS of low back pain and leg pain was 6.58 (± 1.00) and 7.17 (± 1.12) respectively. The mean ODI was 57.68 (± 10.00) %.

Clinical classifications were: (1) according to the level of spondylolisthesis: 10 patients at L5, 2 patients at both L4 and L5 while only L5 was classified as severe spondylolisthesis; (2) according to Meyerding classification: 7 cases of grade III, and 5 cases of grade IV; (3) according to Marchetti-Bartolozzi classification: all cases were developmental spondylolisthesis, among which 9 cases were classified as high-dysplastic type, while 3 cases were classified as low-dysplastic type; (4) according to Spinal Deformity Study Group (SDSG) classification: 7 cases of type 4, 4 cases of type 5, 1 case of type 6.

Preoperative radiographic assessments were: mean vertebral slip percentage (SP) measured by Taillard's method was 70.08 (± 12.38) %; mean SDSG lumbosacral angle (L5S1 angle of kyphosis) was 20.50 (± 6.04) °; pelvic incidence (PI) of all patients were greater than 60 °, with an average of 67.17 (± 3.97) °. 2 cases had combined scoliosis deformity. All 12 cases were followed up for 24 to 48 months with an average of 35 (± 8) months.

Surgical technique

(1) Nerve root decompression: the efferent and descending nerve roots, with vertebral facet as the center, were decompressed bilaterally;

(2) Intervertebral loosening: after bilateral resection of facet joints and intervertebral disc tissue of target segment, a Cobb detacher or an osteotome with proper width was inserted into the intervertebral space to pry and loosen the intervertebral space, using the posterosuperior angle of the lower vertebral as a fulcrum;

(3) Slip reduction: the slipped vertebrae was reduced and fixed with two-dimensional Schanz screws, using a cantilever pulling technique. In principle, the spondylolisthesis should be reduced within Meyerding grade II. A sufficient loosening of the intervertebral space was indicated before slip reduction. For spondylolisthesis of high-dysplastic type, it is necessary to resect the superior margin

of the dome-shaped S1 vertebral body in order to reduce not only the slip but also kyphosis;

(4) Bone graft fusion: This method was a combined application of intervertebral and posterolateral fusion. To avoid the L5 nerve root palsy, spinal shortening is recommended for this procedure.

The spinal fusion range was comprehensively determined according to the concept of "unstable zone" *(9)* and characteristics of spinal deformity. In this group, 3 cases underwent bi-segmental fixation at L4-S1, and 9 cases underwent mono-segmental fixation at L5-S1. After fixation, intervertebral and posterolateral fusion were performed on the corresponding segments. Intraoperative screws implantation was performed using two-dimensional navigation in 3 cases, while others were performed with manual implantation.

Postoperative outcome evaluation

The operation time, blood loss and postoperative complications were recorded. The nerve function of patients was evaluated by using the Frankel grading system. The visual analogue scale (VAS) for leg pain and back pain was used. Preoperative and postoperative lower limb function and daily activity state was assessed by Oswestry Disability Index (ODI). Radiological assessments included a whole-spine standing lateral radiograph, a 3D CT reconstruction, PI and lumbosacral angle (LSA). In plain radiographs, the degree of anterior displacement was evaluated by Meyerding's method *(7)* and Taillard's method *(22)*.

Statistical analysis

Results were analyzed by ANOVA and Student's t-test, with significance at $P< 0.05$, using SPSS software (version 17.0, IBM Inc., Chicago).

RESULTS

The operation time was 140-225 mins with an average of 181 ± 26 mins. The blood loss was 300-550 mL with an average of 391 ± 77 mL. The success rate of screws implantation was 100%. One patient developed cerebrospinal fluid leakage. The dura mater was closed by a fine continuous suture, and drainage was continued for 5 days with satisfactory results. 2 patients developed urinary tract infection and were treated with antibiotics until the body temperature and white blood cells level had been normal for 3 days. No postoperative superficial or deep wound infection was observed. A transient L5 nerve root paralysis was observed in one patient with L5 spondylolisthesis (Meyerding grade III°, high-dysplastic, SDSG type 6). But the symptoms resolved spontaneously at 4 weeks after postoperation (Figure 1). The nerve function of each-case was classified as Frankel grade E at 12 months follow up. The average VAS scores of leg pain and low back pain in all cases were 1.08 (± 0.67) and 1.33 (± 0.89). The average ODI was 20.84 (± 5.21) %. In addition, the VAS score and ODI of low back pain at 12 months follow up were significantly lower compared with that at 4 weeks after operation, and the difference was statistically significant (Table I.).

The average PI was 53.75 (± 5.46)°. The average percentage of vertebral slip measured by Taillard method was 14.83 (± 7.58) %. The average LSA was -5.58 (± 2.88) °. All the parameters above were statistically different compared with the preoperative parameters ($P < 0.05$). Visible growth of mature bone bridge was found and no broken screw or rod was observed in the 3D CT of 11 cases at 12 months follow up. During the follow-up period, no patient had degenerative spondylolisthesis or adjacent segmental instability above the fusion segments. One patient had scoliosis deformity and was completely corrected at 12 months follow up (Figure 2). 11 patients (91.7 %) showed favorable results.

DISCUSSION

As previously reported *(7,13)*, high-grade lumbar spondylolisthesis (Meyerding grade ≥ III) often come forth with different degrees of spinal deformity. The deformity mainly included a lumbosacral angle with kyphosis deformity (SDSG type 5) and spinal sagittal imbalance (SDSG type 6). The former was mainly due to the change of lumbosacral muscle force along with the continuous progression of lumbar spondylolisthesis, while the latter was also known as idiopathic scoliosis.

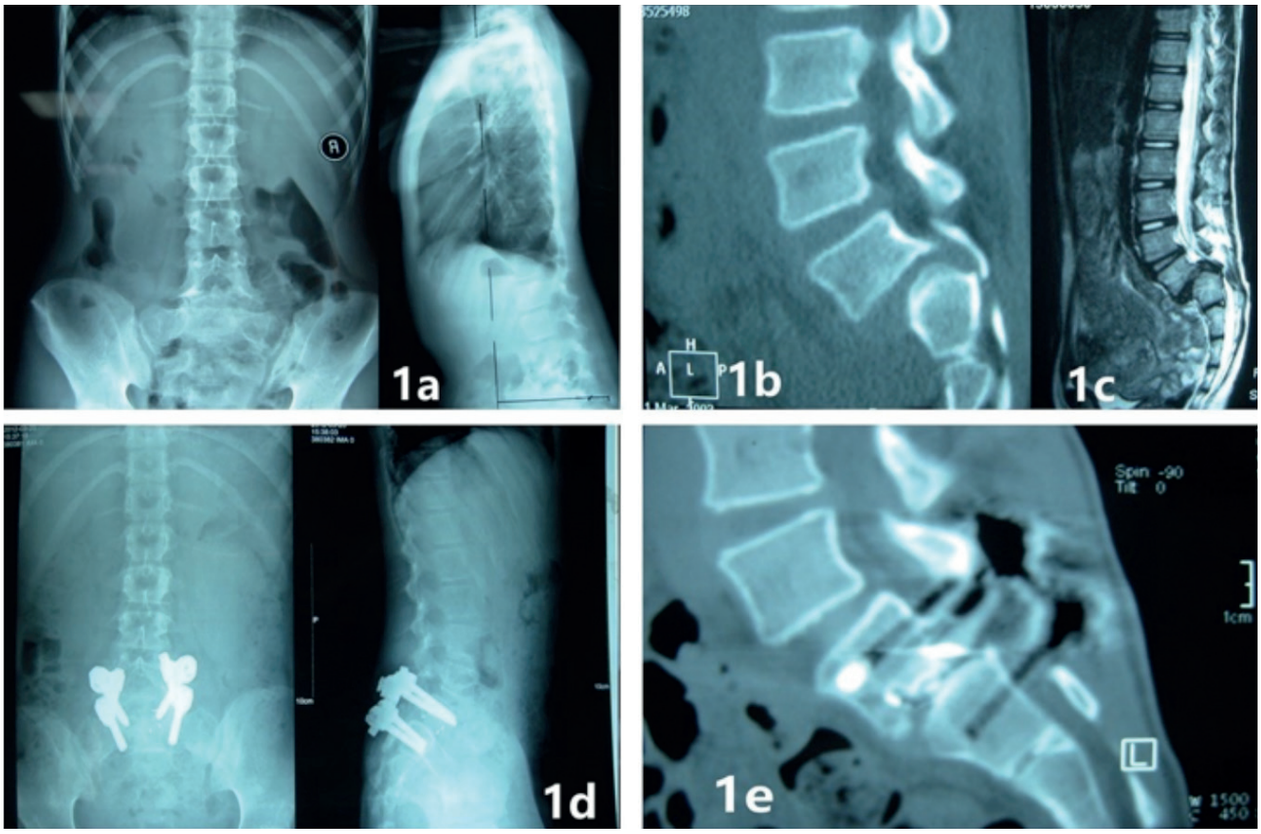

Fig. 1. — A 8 year-old girl with L5 spondylolisthesis (Meyerding III°, high-dysplastic, SDSG 6) underwent the reduction of L5, spinal canal decompression and L5-S1 fixation and fusion by posterior approach. Preoperative AP/lateral X-ray (1a); Preoperative CT 3D reconstruction (1b) and MRI (1c) showed high-grade spondylolisthesis ; X-ray (1d) and CT 3D reconstruction (1e) at 12M FU showed good reduction and correction.

Most investigators believed that it was very important to correct LSA for patients with sagittal plane deformity or loss of balance for high-grade lumbar spondylolisthesis *(1,10,16)*. The sagittal plane deformity and loss of balance would then be spontaneously corrected after the correction of LSA. For pediatric patients with high-grade (SDSG type 5, 6) lumbar spondylolisthesis, to correct LSA deems important *(4,6)*.

In recent years, many researchers have investigated adjacent segmental instability and spondylolisthesis on pediatric patients with high-grade lumbar spondylolisthesis. These patients underwent reduction and fusion, and the occurrence rate was 5-43% *(2,24)*. Most investigators believed that multiple factors contributed to this postoperative complication, while the effects of fusion-segment and secondary injury of spinal posterior ligament complex were two important factors. The concept of the 'lumbosacral unstable zone' was proposed by Lamartina to explain an adjacent L4 segmental instability after spinal fusion on L5-S1 segments in pediatric patients with high-grade lumbar spondylolisthesis *(9-10)*. He also proposed that all the vertebras located in the unstable zone should be fixed and fused, except for cases with complete reduction, LSA correction, pelvic inversion correction and sagittal spinal alignment recovery. In fact, the main idea of this concept was to fix the upper vertebra with proper PI angle. If the PI were greater than 60 °, the incidence of adjacent segmental instability or even slipping would be sig-

Table I. — Radiographic and clinical improvement after surgical correction (Mean ±SD)

	PI(°)	SP(%)	LSA (°)		VAS	ODI(%)
			LBP	LP		
Preop.	67.67±3.94	71.50±6.47	18.06±2.41	6.58±1.00	7.17±1.12	48.52±8.76
4W Postop.	52.92±5.50*	13.92±4.23*	-6.63±2.08*	3.75±1.22*	1.25±0.75*	22.12±5.76*
12M FU	53.67±5.48*	14.67±4.52*	-6.61±1.29*	1.33±0.89*#	1.08±0.67*	13.84±4.59*#
Statistic	*F=32.763*	*F=489.545*	*F=620.031*	*F=76.309*	*F=191.466*	*F=90.153*
	P=0.000	*P=0.000*	*P=0.000*	*P=0.000*	*P=0.000*	*P=0.000*

W: week(s); M: month(s); FU: follow-up; SP, slip percentage; LSA, Lumbosacral angle; ODI, oswestry disability index; VAS, visual analog scale. LBP, low back pain; LP, leg pain. *Versus preop. $P < 0.05$; # 12M FU versus 4 W postop. $P < 0.05$

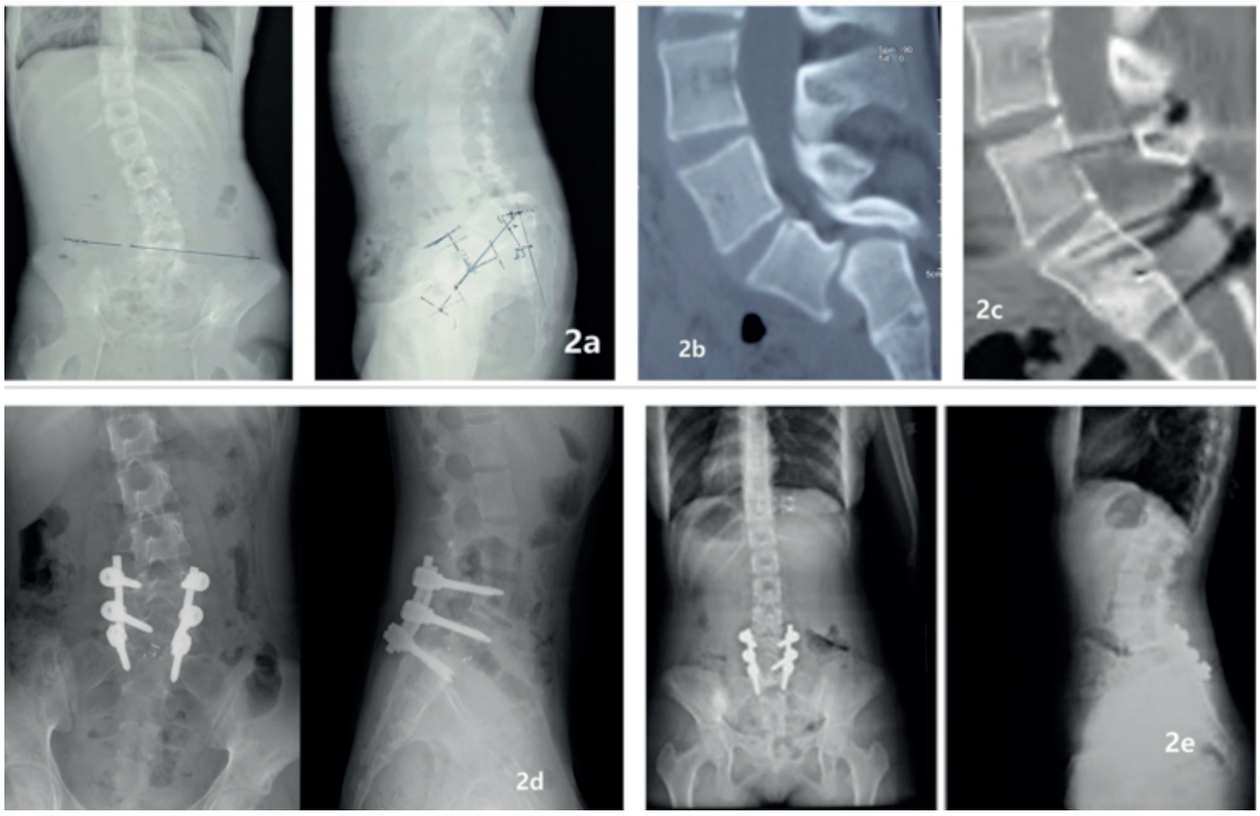

Fig. 2. —A 12 year-old girl with L5 spondylolisthesis (Meyerding IV°, high-dysplastic, SDSG 5) and scoliosis underwent reduction of L5, L5-S1 spinal canal decompression and L4-S1 fixation by posterior approach. Preoperative AP/lateral X-ray (2a); Preoperative CT 3D reconstruction (2b) showed spondylolisthesis (Meyerding IV°) and scoliosis; AP/lateral X-ray (2d) at 6M FU, showed spondylolisthesis was reduced to Meyerding 0° but scoliosis had no correction; X-ray (2e) and CT 3D reconstruction (2c) at 12M FU showed good reduction and correction, as well as solid bony fusion.

nificantly increased. Holdsworth first introduced the notion of posterior ligament complex (PLC), the second factor responsible of postoperative adjacent instability *(12)*. PLC is the main component of the posterior column, which includes supraspinal ligament, interspinal ligament, ligament flavum and bilateral facet joint capsule. The results of Panjabi et al showed that the supraspinal ligament, interspinal ligament and ligament flavum play important roles in maintaining the stability of spinal flexion, and the

PLC was defined as "endogenous ligament stabilizing system" *(19)*. Asano et al also demonstrated that the supraspinal ligament and interspinal ligament showed significant effect on the tension load and strength coefficients, and played an important role in maintaining the stability of PLC *(3)*. However, for patients with high-grade lumbar spondylolisthesis, fusion surgery may cause various degrees of direct or indirect damages on PLC, which affects the stability of the whole spine and accelerates the adjacent segments degeneration and even leads to adjacent segmental instability or slipping. Therefore, no matter which technique is used in the vertebral fusion treatment with high-grade lumbar spondylolisthesis, PLC must be protected carefully to minimize the damage during the surgery.

In our series, PI in all patients was greater than 60°. Among them, two cases associated scoliosis deformity (one classified as nonstructural scoliosis, and the other as structural scoliosis) with a double segmental slippage (L4-5). Three cases underwent bisegmental fixation and fusion at L4-S1, and 9 cases underwent single segmental fixation and fusion at L5-S1. At final follow-up, the clinical efficacy was very great. And at 12 months follow up, visible growth of mature bone bridge was found and no broken screw or rod was observed in 3D CT of 11 cases. During the follow-up period, no patient had degenerative spondylolisthesis or adjacent segmental instability above the fusion segments.

Although above-mentioned treatments showed a satisfactory clinical efficacy in the follow-up of 2-year, some limitations appear: a) limited number of cases, b) absence of control group, c) no blind revision.

CONCLUSION

In conclusion, we suggest that, in case of spondylolisthesis without severe structural scoliosis deformity or only associated with lumbosacral deformity, the posterior ligament complex should be protected in case of adjacent segmental instability and spondylolisthesis. If the spondylolisthesis is complicated with severe structural scoliosis deformity (Cobb ≥ 70°), in principle, the treatment should be performed according to the characteristics of the two diseases respectively.

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