International Orthopaedics (SICOT) (2008) 32:663–669
DOI 10.1007/s00264-007-0367-0

ORIGINAL PAPER

In situ instrumented posterolateral fusion without decompression in symptomatic low-grade isthmic spondylolisthesis in adults

Mohammed Farooq Butt · Shabir Ahmed Dhar · Imtiyaz Hakeem · Munir Farooq · Manzoor Ahmed Halwai · Mohammad Ramzan Mir · Khursheed Ahmed Kangu

Received: 9 February 2007 / Revised: 20 March 2007 / Accepted: 20 March 2007 / Published online: 11 May 2007

Abstract Forty patients with an average age of 26.5 years were treated for symptomatic low-grade isthmic spondylolisthesis with in situ instrumented posterolateral fusion. All patients had failed previous conservative treatment. Average follow-up was 42.2 months (range: 30–62 months). Low-back pain resolved in 70% of the patients, whereas 65% of those with radicular pain reported complete resolution of the symptoms. At the final follow-up 82.5% of the patients had improvement in their function. Solid fusion was achieved in 70% of the patients. It was uncertain in 10% and a fusion failure was seen in 20%. The anterior slippage as measured by the Taillard method was 31.55% and an average 35% correction was seen after surgery. However, an average 10% loss of correction was seen at the final evaluation. The clinical results were evaluated by Kim and Kim criteria. Satisfactory results were obtained in 65% of patients and this was closely associated with the rate of successful fusion. The results suggest that clinical outcome is closely related to the attainment of solid fusion and decompression or removal of the loose laminar fragment seems unnecessary in patients without major neurological symptoms.

Résumé Quarante patients dont la moyenne d'âge était de 26.5 ans ont été traités pour un spondylolisthesis symptomatique de bas grade avec une arthrodèse postérolatérale instrumentatée en place. Tous les patients avaient eu avant l'intervention un traitement orthopédique conservateur qui avait échoué. Le suivi moyen était de 42.2 mois (entre 30 à 62 mois). Le problème des lombalgies a été résolu chez 70% des patients, 65% d'entre eux présentant des douleurs radiculaires ont vue celles-ci disparaître. Au suivi final, 82.5% des patients ont été améliorés sur le plan fonctionnel. Une greffe solide a été obtenue chez 70% des patients. Un échec de la greffe a été constatée chez 20% des patients et dans 10% d'entre eux il a été difficile d'affirmer la solidité. Le glissement antérieur a été mesuré selon la technique de Taillard, il était de 31.55% avec une moyenne de correction de 35% après l'intervention. Cependant, il faut constater une perte de correction de 10% à l'évaluation finale. Le résultat clinique a été évalué selon les critères de Kim et Kim, avec des résultats satisfaisants chez les 2/3 des patients, ces bons résultats étant toujours associés à une bonne greffe. Ceci nous incite à penser que ce traitement sans décompression et sans ablation de l'arc postérieur peut entraîner un bon résultat et que ces gestes ne sont pas indispensables chez ces patients.

M. F. Butt (✉) · S. A. Dhar · I. Hakeem · M. Farooq · M. A. Halwai · M. R. Mir · K. A. Kangu
Government Hospital for Bone and Joint Surgery, Barzallah, Srinagar, Kashmir 190005, India
e-mail: mfbutt72@yahoo.co.in

Introduction

Isthmic spondylolisthesis is the most common spondylolytic disorders. It is one of the most common causes of low back pain and sciatica in adolescents and adults. In most cases symptoms are mild and respond to non-surgical options like activity modification, bracing, physical therapy, and intervention in the form of medications and injections and use of muscle relaxants and narcotics may be appropriate for managing initial acute pain [19].

Several possible sources of pain in isthmic spondylolisthesis include instability at the defect causing lumbar strain

and osteoarthritis, foraminal entrapment of a nerve root (chronic root traction, irritation and compression), disc herniation or disc degeneration at, above or below the slip, and hyperlordosis [9]. The pars non-union itself may be a source of pain. Also the late progression of slip in adults may turn an asymptomatic lesion into a symptomatic one.

The purpose of surgical treatment is to reduce low-back pain and radiating pain, to relieve the neurological symptoms, and to improve the posture and gait by eliminating the instability of the lumbosacral region [12]. A multitude of surgical procedures exists for operative treatment of this condition. The traditional surgical management of symptomatic spondylosis or isthmic lysthesis with minimum displacement has been posterior fusion, posterolateral fusion, decompression of loose laminar piece or a combination of these. Surgical procedures have also been described to fuse only the pars defect, but have mostly been recommended for patients below the age of 30 years.

Recently, anterior [12] or posterior [14] lumbar interbody fusion, instrumented reduction and repair of the defect [16] and muscle pedicle bone grafting for fusion of lumbosacral lysthesis have been described [1]. The advantages of decompression, as has been mentioned in some studies, in instrumented fusion has remained inconclusive [2] as has been the role of instrumentation to support the posterolateral fusion [4].

The purpose of this study was to evaluate the efficacy of in situ instrumented posterolateral fusion without decompression in adults with low-grade isthmic spondylolisthesis in whom a fair trial of non-surgical options failed to yield a desirable outcome.

Materials and methods

The clinical data of 40 consecutive adult patients who had undergone operation for isthmic spondylolisthesis from April 2001 through September 2003 were reviewed. All patients had completed 2 years of follow-up. Plain radiographs, magnetic resonance imaging (MRI) and clinical records were reviewed. In plain radiographs, the degree of anterior displacement was evaluated by Meyerding's method and Taillard's [23] method.

Patients were considered for surgery only after a failure of non-surgical options that included non-steroidal anti-inflammatory drugs, weight reduction, activity modification, muscle relaxants, narcotics, bracing and, in some cases, plaster of Paris jackets. The hemi-Bermuda cast was not used in the segregation and treatment of patients preoperatively. The patients with degenerative disease, failed previous surgery, MRI documented desiccated disc or nerve root compression were excluded from the study. Patients with radiculopathy and documented neurological deficit were also excluded. Preoperative evaluation involved complete clinical, neurological, functional, radiographic and MRI evaluation. Patients were evaluated for pain and functional status by using the pain and function scale of Steffee et al. [22]. The average preoperative pain scale was 2 (range 1–3) and the average function score was 2.4 (2 to 3). Patients were said to have radicular pain if their extremity pain followed a dermatomal distribution. Patients with diminished reflexes, motor and sensory deficit and muscle wasting were said to have radiculopathy. In most cases pain was low lumbar, with or without radiation into one or both extremities. Most patients had limitations of lumbar movement. A palpable defect was elicited in most cases, but a mobile posterior element could only be palpated in a few patients.

Anteroposterior and standing lateral radiographs were obtained. The degree of anterior displacement was evaluated by Meyerding's method and Taillard's method. MRI was done to exclude disc disease or nerve root compression that would necessitate discectomy or decompression.

Operative procedure

Patients were operated upon in prone position on foam rubber cushions. A standard midline incision was made and subperiosteal dissection was extended up to the tips of transverse processes. Decortication of outer cortices of lamina, transverse processes and facet joints was used order to prepare a bed for fusion. Bone graft was harvested from either of the posterior iliac crests using the lower part of the same incision, and placed bilaterally on the previously prepared bed after the insertion of pedicle screws (Steffee VSP). The pedicle entry point was identified by Roy-Camille's technique. An awl was used to ream a canal into the pedicle and also to feel for any violation of its walls. The subsequent steps of tapping the posterior portion of the pedicle and placement of 5.5-mm-diameter 40–42-mm-length screws followed. Plates of adequate length were contoured to the lumbar curvature and secured on the screws by umbrella and locking nuts. Closure was done in layers over a sub-facial suction drain. Perioperative transfusion of cross-matched donor blood was performed in all cases. Parentral antibiotics were administered for 5 days. Patients were mobilised in most instances within 3 days. And patients were discharged on the 5th postoperative day. Postoperatively patients were encouraged to ambulate early with the help of a semi-rigid lumbosacral corset and were followed at regular intervals to note clinical (pain, function) and radiological parameters (fusion, loss of reduction, implant failures).

Patients were followed up every 3 months until 1 year after the operation, then every 6 months thereafter. At each

visit clinical symptoms were recorded, physical examination was conducted, and radiographic assessment was made. The criteria for fusion were based on the radiological evidence of trabecular crossings and a fusion grade was assigned as per the Anatomic Grade of Massachusetts General Hospital Anatomic, Economic and Function rating system [5] (Table 2).

The correction rate of anterior displacement was measured by Taillard's method. The clinical results were evaluated by using the criteria of Kim and Kim [11].

Results

A total of 160 pedicle screws were inserted. One level instrumentation was performed in all 40 patients. The operated segments included L5-S1 in 28 and L4-L5 in 12 patients.

The data on patients and variables is presented in Table 1.

The average age of the patients was 26.5 years (range, 17–37 years). The study included 7 men and 33 women. The follow-up averaged 42.2 months (range 30–62 months).

The main symptom was low-back pain with radiating pain to the lower extremities. Nine patients had associated spina-bifida occulta. There was no difference in the clinical symptoms and physical findings between the males and females. Whereas all females were non-smokers, three men smokers stopped smoking at least 6 months before being considered for surgery.

The pars interarticularis defect was at L4 in 12 patients and L5 in 28 patients.

The degree of anterior displacement measured by Meyerding's method was grade I in 10 (25%) patients and grade II in 30 patients. The degree of anterior displacement by Taillard's method averaged 31.55% (range, 16–48%). Although no separate effort was made to reduce the spine during the operation, an average 35% (range, 15–50%) improvement in anterior displacement was seen in the postoperative radiographs. However, an average loss of reduction of 10% (range, 1–15%) was seen at the final follow-up.

The average postoperative pain score in our patients improved to 4.2 (range 35). The majority of the patients (60%) had a preoperative pain score of 1 (18%) or 2 (42%), i.e., severe and constant or moderate constant pain with severe intervals. All of these patients moved to a better grade, i.e., three grade improvement in 32% and two grade improvement in 12%. Only three patients did not show any improvement in their pain scale. Low-back pain resolved in 70% of the patients, whereas 65% of those with radicular pain reported complete resolution of the symptoms.

An overall improvement in function was seen as well. The average postoperative function score improved from a preoperative of 2.4 to 4. Twenty-three patients had near normal daily activity and the other 17 presented with significant limitation of daily activity before surgery. Most (82.5%) of the patients had improved when assessed at the final follow-up.

Table 1 Fusion component of Massachusetts General Hospital Anatomic, Economic and Functional (AEF) rating system

A0-	Pseudarthrosis
A1-	Unilateral pseudarthrosis
A2-	Insufficient unilateral fusion mass
A3-	Contiguous fusion mass without hypertrophy
A4-	Solid fusion with hypertrophy

The fusion of the grafted bone was evaluated by the crossing of bony trabeculae detected on plain radiographs. Using the anatomical grade in fusion assessment an acceptable fusion (A3, A4) was achieved in 70% of patients. It was indeterminate (A2) in four (10%) and a failure of fusion was seen in eight (20%) cases (i.e., A1, A0).

As per Kim and Kim criteria, clinical results were excellent in 8 (20%), good in 18 (45%), fair in 5 (12.5%) and poor in 9 (22.5%) patients. Therefore, satisfactory results were obtained in 65% of the patients.

Twenty complications occurred in 17 patients and are depicted in Table 3. Transient L5 paraesthesia in one patient recovered in early follow-up. The weakness of EHL in another, however, did not recover at all, though the postoperative CT scan revealed no pedicle violation. Deep infection was treated by appropriate antibiotics after culture sensitivity. Graft site pain did not recover fully in one of the three patients with this complication. Though 11 pedicle screw-related complications were seen in nine patients, none of these resulted in significant morbidity. There was 3.1% incidence of screw breakage, 1.8% screw bending and 0.6% incidence of screw loosening. Malplacement occurred in 1.2% of the 160 screws. Cases with screw breakage and bending had correspondingly lower grades of fusion progression (Table 3).

Discussion

Posterolateral fusion has long been considered the gold standard technique for surgical treatment of adult spondylolisthesis [6] and is preferred by many in the treatment of low-grade symptomatic lesions. Currently, instrumented PLIF or ALIF or 360° circumferential fusions are probably the only alternatives that might yield better outcome than posterolateral fusion [24]. The clinical studies, however, have revealed no significant difference in outcome between anterior lumbar interbody fusion (ALIF) and posterior lumbar interbody fusion (PLIF) with transpedicular fixation for the treatment of isthmic

Table 2 A master chart on patient variables, evaluation and outcome

Serial no.	MRD no.	Age (years)	Sex	Date of surgery	Follow-up (months)	Level	Grade	Anterior displacement pre op	Anterior displacement post op	Pain score pre op	Pain score post op	Fxn Score pre op	Fxn score post op	Fusion grade	Clinical Outcome	Complications
1	011	27	F	0.4./2001	62	L4	II	36	24	2	5	3	5	4	E	
2	1100	29	F	0.5/2001	61	L4	II	46	36	2	4	3	4	0	P	Screw breakage
3	9781	29	F	0.12/01	54	L4	II	27	14	1	5	2	5	3	E	
4	12551	19	F	0.3./2002	51	L5	I	16	10	2	4	3	4	3	G	Screw loosening
5	12341	25	F	0.4.2002	50	L5	II	36	26	3	4	3	4	3	G	DWI
6	504	19	F	4/2002	50	L5	II	40	26	3	5	3	5	4	E	
7	826	32	F	4/2002	50	L5	II	29	18	2	5	3	5	3	G	SWI
8	838	34	M	5/2002	49	L4	II	43	30	3	4	2	4	3	G	
9	1236	32	F	5/2002	49	L5	II	36	22	2	5	3	5	3	E	GSP
10	10829	26	F	5/2002	49	L5	I	20	10	2	3	2	3	1	P	Screw breakage
11	1843	20	F	6/2002	48	L5	II	36	26	3	4	3	4	3	G	
12	3017	31	F	6/2002	48	L5	I	24	14	2	5	3	5	4	E	
13	4803	25	F	8/2002	46	L5	II	44	30	2	4	2	4	3	G	
14	4960	25	M	8/2002	46	L4	II	42	30	1	4	2	4	3	G	SWI
15	4977	21	F	8/2002	46	L5	II	30	16	3	4	3	4	3	G	
16	5499	33	F	8/2002	46	L4	II	28	20	2	3	2	3	1	P	Screw misplacement
17	10485	23	F	1/2003	42	L5	II	37	24	2	3	3	4	3	P	
18	11793	18	F	2/2003	40	L4	II	33	20	3	4	2	3	0	P	
19	11543	30	F	3/2003	39	L5	II	37	24	2	3	3	4	3	G	
20	12172	32	F	3/2003	39	L4	I	21	10	2	4	2	4	3	F	GSP
21	12235	28	F	4/2003	38	L5	II	46	36	1	4	2	3	2	P	L5 Parasthesia
22	240	30	F	4/2003	38	L5	I	21	10	3	3	2	4	3	G	
23	194	18	F	4/2003	38	L5	II	48	34	2	4	3	4	3	E	Post.op EHL weakness
24	1141	27	F	5/2003	37	L4	II	32	20	2	4	2	4	3	G	
25	1245	27	F	5/2003	37	L5	II	29	20	3	4	2	3	0	P	Screw breakage
26	1452	25	F	5/2003	37	L5	II	30	20	2	3	3	4	3	F	
27	3185	26	M	7/2003	35	L5	II	32	22	1	4	2	4	2	G	DWI
28	3880	33	M	8/2003	34	L5	I	21	10	1	4	2	4	3	F	
29	4846	20	F	8/2003	34	L5	I	20	12	2	4	2	5	3	G	
30	5459	17	F	8/2003	33	L4	I	24	14	3	5	2	4	4	E	
31	7025	34	M	9/2003	32	L4	II	29	15	2	4	3	4	3	F	Screw bending
32	9158	20	F	11/2002	30	L5	II	30	16	2	4	2	4	3	G	
33	6901	32	F	10/2002	44	L5	II	32	21	1	4	2	4	1	F	
34	9620	20	F	12/2002	42	L4	II	34	22	2	4	2	4	3	G	
35	11457	35	F	3/2003	39	L5	II	39	24	3	4	2	4	2	G	
36	9806	29	F	12/2002	42	L5	I	20	12	1	4	2	3	0	P	Screw breakage

37	1041	22	F	5/2002	49		L5	II	32		21		2		3		3		5		3		E	
38	1001-s	22	F	5/2002	49		L5	II	30		20		2		5		3		3		0		P	Screw bending
39	6801-b	37	M	12/2002	42		L5	II	34		24		1		3		2		4		2		G	Screw misplacement
40	11457-b	30	M	3/2003	39		L5	I	18		10		1		4		2		4		3		G	

E-excellent, P-poor, G-good, F-fair, DWI-deep wound infection, SWI, superficial wound infection
GSP-graft site pain, M-male, F-female, MRD-medical record department

spondylolisthesis in adults [12]. Similarly, posterolateral fusion has been reported to produce better clinical outcome in low grade isthmic spondylolisthesis (LGIS) as compared to PLIF [14]; the latter has been reported to be useful in high grade spondylolisthesis requiring reduction [6].

Whereas posterolateral fusion has yielded satisfactory outcome in many clinical trials, resection of pseudoarthrosis and decompressing the root canal in an instrumented posterolateral fusion (PLF) for low-grade isthmic spondylolisthesis (LGIS) is claimed to improve outcome [16]. Ricciardi et al. [20] also reported a high rate of fusion, satisfactory clinical results and high return to work in instrumented PLF in combination with Gill's procedure and L5 nerve root decompression in symptomatic lumbosacral isthmic spondylolisthesis. The benefit of removal of loose fragment and decompression has been of no significance in comparative studies. Noorie et al. [18] compared the results of spinal decompression, stabilisation and fusion in 19 patients with 26 others who received stabilisation and fusion alone. They found no significant difference in the outcome between the two groups. Similarly another study revealed that decompression in addition to fusion in adults with LGIS and radicular pain does not improve the functional outcome [2]. We did not decompress the nerve canal or remove the loose fragment, and our clinical results are comparable with other studies. We concur with Carragee [3] in that addition of decompression to PLF performed with or without instrumentation for LGIS in patients who do not have a serious neurological deficit does not appear to improve the results and may significantly increase the rate of pseudarthrosis and unsatisfactory results. We also agree with Wiltse [25], in that the typical nerve root compression in isthmic spondylolisthesis is the result of an irritation or compression effect caused by the mobility of the fibro-cartilaginous mass at the pars interarticularis defect. We believe that the initial relief in the symptoms may be due to the stabilisation effect of the internal fixation device, and permanent relief can be related to attainment of satisfactory fusion, and resorption of the ostocartilaginous mass may also contribute to the clinical improvement.

A fusion rate of 68–100% has been reported with posterolateral fusion in low grade isthmic spondylolisthesis. Accurate determination of fusion or pseudoarthrosis, however, has been an unresolved problem throughout the history of spinal surgery [22], and in fact exploratory re-operation for fusion failure was recommended to repair pseudoarthrosis. Difficulty of assessing solid fusion in the presence of fixation is acknowledged [20]; in addition the overlying shadows of plates add to the fusion uncertainty in the studies using VSP instrumentation [22]. We used radiographic criteria for fusion assessment and our fusion rate

Table 3 Complications that were seen in some of the patients

Complications	No.	No. of patients
Neurological	2	2
Superficial wound infection	3	2
Deep wound infection	2	2
Graft site pain	2	2
Screw breakage	5	4
Screw bending	3	2
Screw misplacement	2	2
Screw loosening	1	1

was 70%. Adding pedicle screw fixation to fusion has been reported to increase the rate of arthrodesis for low grade isthmic spondylolisthesis [20], and also to improve clinical outcome [13]. But McGuire and Amundson [15] found no advantage in using instrumentation. Kim et al. [10] also noted no additional benefits from instrumentation. In fact the fusion rate in their instrumented patient was lower than those in the uninstrumented group. There is disagreement in the literature as to whether fusion correlates with clinical outcome in the treatment of lumbar spinal disorders [21]. A direct relationship between failure to achieve arthrodesis and unsatisfactory pain outcome was reported in a prospective study [15]. Some other studies have also reported a direct relationship between failure to achieve a satisfactory arthrodesis and an unsatisfactory outcome [7]. On the other hand Schnee et al.[21] reported good clinical results in only 60% of cases, though a 90% fusion rate had been achieved. They concluded that factors other than preoperative symptoms and radiographic fusion significantly influenced results.

Objective assessment of clinical status in non-traumatic lumbar disorders remains elusive [22]. Numerous studies have provided subjective description of criteria for excellent, good, fair and poor results. Similarly various pain scores, visual analogues, pain and disability questionnaires are described. We used Kim and Kim criteria for final assessment of results because we found it to be simple and it had been used in a study comparing results of posterolateral fusion and posterior lumbar interbody fusion; our results showed a 68% satisfactory outcome and it is comparable to the 60–98% reported in the literature [8]. A strict comparison of results is, however, difficult because of differences in surgical procedures, types of bone grafts, choice of instrumentation, postoperative immobilisation, rehabilitation and smoking. The results of our study showed a close relation between satisfactory clinical outcome (68%) and solid fusion (70%).

Reduction of spondylolisthesis is not required in most cases of low-grade isthmic spondylolisthesis to effect a better outcome [24]; in fact short segment posterior stabilisation (in situ fusion and fixation) is associated with a measurable reduction when used as the sole treatment [17]. Kim et al. [12] reported an overall correction of 35% in anterior displacement without any attempt at reduction. In our study, an average correction of anterior displacement of 35% was seen in the early postoperative period, though no separate attempt to reduce the slip was made. An average loss of correction of 10% was noted subsequently.

We conclude that the results in symptomatic low-grade isthmic spondylolisthesis in adults, with low back and radicular pain and without major neurological deficit, of in situ instrumented posterolateral fusion without decompression yield a satisfactory outcome in the majority of cases. Fusion is achieved in a large number of subjects and is closely related to the satisfactory outcome. There was however a significant number of patients with instrument failure that was found in association with fusion failure. There were other minor complications as well.

References

1. Adam FF (2001) Modified sacrospinalis muscle pedicle bone graft for fusion of isthmic spondylolisthesis. Int Orthop 26 (5):326–330
2. Adam FF (2003) Surgical management of isthmic spondylolisthesis with radicular pain. Int Orthop 27(5):311–314
3. Carragee EJ (1997) Single level posterolateral arthrodesis, with or without posterior decompression, for treatment of isthmic spondylolisthesis in adults. J Bone Joint Surg 79A(8):1175–1180
4. Christensen FB, Hansen ES, Laursen M et al (2002) Long term functional outcome of pedicle screw instrumentation as a support for posterolateral spinal fusion. Spine 27:1269–1277
5. Dawson EG, Lotysch M, Urist MR (1981) Itertransverse process lumbar arthrodesis with autogenous bone graft. Clin Orthop 154:90–96
6. Dehoux E, Fourati E, Madi K et al (2004) Posterolateral versus interbody fusion in isthmic spondylolisthesis. Functional results in 52 cases with a minimum follow up of 6 years. Acta Orthop Belg 70(6):578–582
7. El Masry MA, El Assuity WI, El Hawary YK et al (2005) Instrumented insitu posterolateral fusion for low grade isthmic spondylolisthesis in adults. Acta Orthop Belg 71(1):83–87
8. Jacobs WC, Vreeling A, De Kleuver M (2006) Fusion for low - grade adult isthmic spondylolisthesis: a systemic review of the literature. Eur Spine J 15(4):391–402
9. Kaneda K, Satoh S, Nohara Y, Oguma T (1985) Distraction rod instrumentation with posterolateral fusion in isthmic spondylolisthesis. Spine 10:383–389
10. Kim SS, Denis F, Loustein JE et al (1990) Factors affecting fusion rate in adult spondylolisthesis. Spine 15:979–984
11. Kim NH, Kim DJ (1991) Anterior interbody fusion for spondylolisthesis. Orthopaedics 14:1069–1076
12. Kim NH, Lee JW (1999) Anterior interbody fusion versus posterolateral fusion with transpedicular fixation of isthmic spondylolisthesis in adults. Spine 24:812–817
13. Kwon BK, Bilibrand AS, Malloy K et al (2005) A critical analysis of the literature regarding surgical approach and outcome for adult low-grade isthmic spondylolisthesis. J Spinal Disord Tech 18:530–540

14. Madan S, Boeree NR (2002) Outcome of posterior lumbar interbody fusion verses posterolateral fusion for spondylolytic spondylolisthesis. Spine 27:1536–1537
15. McGuire RA, Amundson GM (1993) The use of primary internal fixation in spondylolisthesis. Spine 18:1662–1672
16. Morelos O, Pozzo AO (2004) Selective instrumentation, reduction and repair in low grade isthmic spondylolisthesis. Int Orthop 28 (3):180–182
17. Naderi S, Manisali M, Acar F et al (2003) Factors affecting reduction in low grade instrumented spondylolisthesis. J Neurosurg 99:151–156
18. Nooraie H, Ensafdaran A, Arasteh MM (1999) Surgical management of low-grade sponlylisthesis with C-D instrumentation in adult patients. Arch Orthop Trauma Surg 119:337–339
19. O'Brien MF (2003) Low grade isthmic lytic spondylolisthesis in adults. Instr Course Lect 52:511–524
20. Ricciardi JE, Pflueger PC, Isaza JE (1995) Transpedicular fixation for the treatment of isthmic spondylolisthesis in adults. Spine 20:1917–1922
21. Schnee CL, Frcese A, Ansell LV (1997) Outcome analysis for adults with spondylolisthesis treated with posterolateral fusion and transpedicular screw fixation. J Neurosurg 86:56–63
22. Steffee AD, Brantigan JW (1993) The variable screw placement spinal fixation system. Spine 18:1160–1172
23. Taillard W (1954) Le Spondylolisthesis Chez l'enfant et l'adolescent. Acta Orthop Scand 24:115–144
24. Wenger M, Sapio N, Markwalder TM (2005) Long-term outcome in 132 consecutive patients after posterior internal fixation and fusion for Grade I and II isthemic spondylolisthesis. J Neurosurg Spine 2:289–297
25. Wiltse LL, Jackson DW (1976) Treatment of spondylosis and spondylolisthesis in children. Clin Orhop 117:92