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ORIGINAL ARTICLE

Nerve root decompression without fusion in spondylolytic spondylolisthesis: long-term results of Gill's procedure

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Abstract Nerve root decompression with instrumented fusion is currently most commonly performed in the treatment of patients with spondylolytic spondylolisthesis. The relationship between successful fusion and clinical outcome remains controversial, thereby questioning the necessity of fusion. Nerve root decompression without fusion, i.e. Gill's procedure, might be a less invasive surgical alternative with comparable clinical outcome. The objective of this study is to compare the long-term results of Gills's procedure with data from literature on decompression with fusion, and, moreover, to determine if a future randomised trial is legitimate. We retrospectively reviewed the long-term results of Gill's procedure in patients with grade I or II spondylolytic spondylolisthesis. All patients suffered from leg pain with or without low back pain. No patient had low back pain alone. In 17 patients a bilateral and in 25 patients a unilateral Gill's procedures were performed. The patients were evaluated at three follow-up moments. On moment 1, 38 patients were clinically examined on their last out-patient control (mean follow-up 11 months). On moment 2, 34 patients were interviewed by telephone (mean follow-up 4.4 years). The final long-term follow-up moment 3 (mean follow-up 10.5 years) included a mailed patient-satisfaction questionnaire of 31 patients (response rate 74%). No surgical complication occurred. Ten of the 42 patients were reoperated because of persistent or recurrent radicular pain (mean time interval 2.9 years). Kaplan–Meier analysis showed a disease-free survival rate of 79% at 5 years and 72% at 10 years after the index operation. On the three follow-up moments, the improvement of leg pain was 92, 97 and 88%, respectively. The final long-term follow-up showed 71% good result in terms of patient satisfaction. The Gill's procedure is a less invasive surgical technique in the treatment of patients with leg pain due to low-grade spondylolytic spondylolisthesis. This technique can be considered as an alternative to instrumented fusion in selected cases. Preoperative instability, discectomy at the affected level and neuroforaminal nerve root compression seem to be negative influencing factors, increasing the risk for secondary instrumented surgery. The results of this study justify a randomised trial.

Keywords Spondylolisthesis · Spondylolytic · Isthmic · Nerve root decompression · Fusion · Gill's procedure

Introduction

Spondylolytic spondylolisthesis is an anterior slip of one vertebral body onto another caused by a discontinuity (lysis) of the pars interarticularis of the arch, also called isthmus. As a result of the pseudarthrosis, fibrocartilaginous tissue develops at the isthmic site. Patients may present with low back pain, leg pain or neurogenic claudication due to nerve root compression by the fibrocartilaginous tissue. Treatment of symptomatic spondylolytic spondylolisthesis consists of conservative management or surgery whereby surgery

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yields superior outcome [30]. Several surgical procedures have been described, whereas lumbar fusion with transpedicular fixation is currently the most frequently advocated [1, 2, 10, 13, 18, 25, 26, 36, 37]. However, this procedure implies major surgery and significant comorbidity [15, 29].

A more conservative surgical approach in which nerve root decompression is performed without fusion has been described by Gill et al. [17]. The operation according to Gill consists of removing the loose lamina and excising the fibrocartilaginous tissue in order to decompress the nerve root. When a patient has only one-sided leg pain, a unilateral decompression is performed; we refer to this as hemi-Gill procedure.

The purpose of the present study was to assess the long-term results of patients with low-grade spondylolytic spondylolisthesis treated with a (hemi)-Gill procedure, and, moreover, the possible necessity of a future randomised trial.

Materials and methods

Patient selection

Operation records and diagnosis databases of all patients with symptomatic spondylolytic spondylolisthesis operated in the period between January 1990 and January 1997 were studied retrospectively. The inclusion criteria to perform decompression without fusion were: (1) spondylolytic spondylolisthesis grade I or II according to the Meyerding classification [28]; (2) primary complaint of radicular pain or neurogenic claudication (patients with low back pain only were excluded); and (3) no prior surgical intervention at the affected level. In cases of unilateral symptoms, a hemi-Gill procedure was performed.

The obtained data included patient's history and symptoms, neurological examination and operative findings. The radiological investigations consisted of a standard anteroposterior and lateral X-ray, in addition to flexion–extension studies. In all cases, CT and/or MRI images of the lumbar spine were available. The visual analogue scale (VAS), Roland Disability Index and Likert satisfaction score were obtained at the final study moment.

Study population

A total of 42 patients (28 men and 14 women) with a mean age of 50 years (range 21–87 years) were included (Table 1). The mean duration of symptoms was 13.3 months (range 2–82 months). All patients reported leg pain. Thirty-two patients (76%) suffered from low back pain as well, while no patient had low back pain alone. All but one patient (98%) had neurogenic claudication, four patients (10%) had pareses. The vast majority of spondylolysis was located at the level L5 (74%), followed by L4 (19%) and L3 (7%). According to the Meyerding classification, 34 patients (81%) had grade I spondylolisthesis and 8 patients (19%) grade II. Preoperative flexion–extension radiographic studies showed instability, defined as 3 mm or more anterior–posterior excursion at the affected level, in eight patients (19%).

Surgical procedure

Patients underwent surgery in knee-elbow or Jackknife position under general or spinal anaesthesia. A lumbosacral longitudinal incision was made and subperiosteal dissection of the paravertebral muscles was performed unilaterally or bilaterally, depending on the clinical presentation, to expose the affected lamina. A bilateral approach, Gill's procedure, consisted of removing the loose lamina and excising the fibrocartilaginous tissue at the level of the pars interarticularis defect, i.e. the pseudojoint. Whenever a hemi-Gill operation was performed, the procedure was restricted to one side.

Table 1 Demographics, symptoms, level of spondylolysis and grade of slip presented in number of patients (and percentages). Age and duration of symptoms are presented in years and months, respectively

	N = 42 (%)
Mean age (years)	50 (range 21–87)
Mean duration of symptoms (months)	13 (range 2–82)
Sex	
Male	28 (67)
Female	14 (33)
Symptoms	
Leg pain	42 (100)
Leg pain and low back pain	32 (76)
Neurogenic claudication	41 (98)
Paresis	4 (10)
Level of spondylolysis	
L3	3 (7)
L4	8 (19)
L5	31 (74)
Grade of slip	
Grade I	34 (81)
Grade II	8 (19)
Instability	
L3	3 (7)
L4	0
L5	5 (12)

Usually the nerve root could be found tethered as it passed underneath the pseudojoint but it could also be compressed between the pedicle and slipped disc at the level of the neuroforamen. After the removal of the inferior articular process of the affected vertebra, the nerve root was dissected free on its distal course. In order to decompress the nerve root adequately, when necessary, partial resection of the superior articular process of the underlying vertebra or partial pediculotomy was performed.

Data collection

Patients' evaluation has been done on three different follow-up moments. The last out-patient control was subjected to this study (moment 1). The intermediate follow-up results were submitted by a telephonic interview, including the pain-status, patient satisfaction and work (moment 2). The long-term results were investigated by means of a questionnaire sent by mail (moment 3). This questionnaire included the results of leg pain and low back pain, and the pain intensity marked on a 100 mm VAS from 0 (no pain) to 100 (worst pain imaginable) [5, 20, 46]. Moreover, the long-term patient satisfaction was measured according to the seven-point Likert scale, ranging from 1 to 7 (Table 2). ''Complete recovery of complaints (1)'' and ''almost complete recovery of complaints (2)'' was determined as good result. The functional disability was quantified by the Roland Disability Index, which is composed of 23 questions concerning functional assessment [34]. Of all variables, proportions and their 95% confidence intervals were calculated.

Follow-up

At least one follow-up moment was available in all patients. On moment 1, the last out-patient control, medical charts of 38 patients (response rate 90%) were obtained. Charts of four patients had been destroyed. The mean follow-up from surgery to moment 1 was 11 months (range 0.95–64.7 months). On moment 2, the interview by phone, we studied 34 patients (response rate 81%); six patients were lost from follow-up and two patients had died of unrelated causes. The mean follow-up at moment 2 was 4.4 years (range 0.65–7.1 years). On moment 3, the long-term follow-up by a mailed questionnaire, we studied 31 patients (response rate 74%); five patients were lost from follow-up and six patients had died of unrelated causes. The mean follow-up at moment 3 was 10.5 years (range 6.9–13.5 years). By contacting the general practitioner it was found out that the deceased patients had not undergone a reoperation, but the clinical condition of these patients was not known in detail. To determine the precise long-term reoperation rate, we have retrospectively evaluated the hospital operation records of all 42 included patients.

Table 2 Patient satisfaction according to the seven-point Likert scale, scores 1 and 2 are good result

Likert scale	
1	Complete recovery of complaints
2	Almost complete recovery of complaints
3	Some recovery of complaints
4	Complaints unchanged
5	Some worsening of complaints
6	Serious worsening of complaints
7	Complaints worse than ever

Results

Operative findings

Forty-two patients have been operated, in 17 patients (40%) a Gill's procedure was performed and in 25 patients (60%) a hemi-Gill. In 19 patients (45%) the nerve root was compressed between the pedicle and slipped disc, in 12 patients (29%) underneath the fibrocartilaginous pseudojoint and in 11 patients (26%) it was a combination of compression sites or not known. In order to decompress the nerve root adequately, a partial pediculotomy was performed in 22 patients (52%) and a discectomy at the level of the spondylolisthesis was done in 4 patients (10%) (Table 3). There was neither a nerve root injury nor a dural tear. One postoperative complication was noted (2%). It involved a bladder infection after postoperative catheterisation, which was treated adequately with antibiotics.

Reoperations

Ten of the 42 patients (24%) were reoperated because of recurrent or persistent leg pain. One patient was reoperated twice; first a contralateral hemi-Gill procedure and second a posterior lumbar intercorporal fusion (PLIF) with pedicle screw fixation was performed. One additional patient underwent a contralateral hemi-Gill procedure because of contralateral leg pain, in one patient a bilateral Gill procedure was redone. In seven patients a secondary PLIF with pedicle screw fixation was carried out. The mean time

Table 3 Performed procedure and operative findings according to surgeon's perception

	N = 42 (%)
Hemi-Gill	25 (60)
Gill	17 (40)
Site of nerve root compression	
Neuroforaminal between pedicle and slipped disc	19 (45)
Parapedicular underneath pseudojoint	12 (29)
Both neuroforaminal and parapedicular	3 (7)
Not known	8 (19)
Discectomy at affected level	4 (10)
Partial pediculotomy	22 (52)

interval from primary to secondary surgery was 2.9 years (range 0.4–8.3 years). Kaplan–Meier analysis was performed in order to assess the disease-free (reoperation-free) survival rate of all studied patients, taking into account the patients who had been lost from follow-up (Fig. 1). The disease-free survival rate was 79% at 5 years and 72% at 10 years after the index operation.

We have identified possible influencing factors of recurrent or persistent complaints after Gill's procedure; grade of spondylolisthesis, preoperative instability, discectomy at the affected level, pedicle reduction, partial removal of inferior articular process and neuroforaminal nerve root compression between pedicle and slipped disc (Table 4).

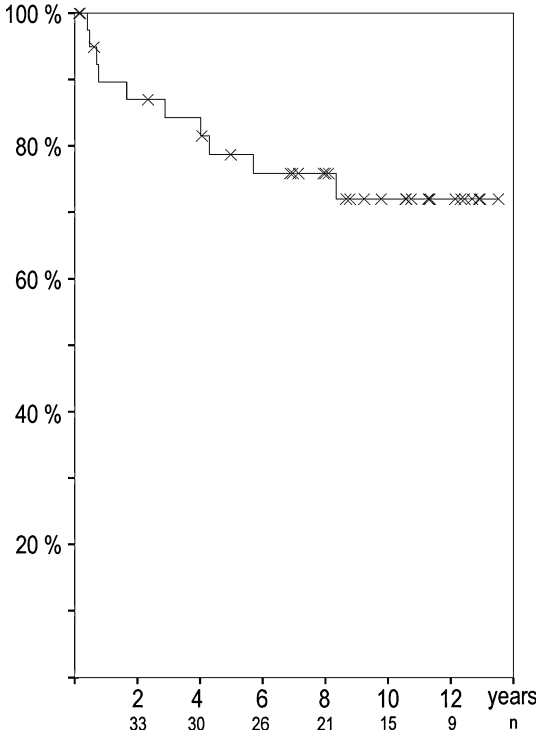

Fig. 1 Kaplan–Meier disease-free survivor curve. Each data point represents the total percentage of patients who entered a given year of follow-up and were expected to remain free of a reoperation

Outcome

The results of leg pain, low back pain, work, VAS and Roland Disability Index are summarised in Table 5. The postoperative improvement of leg pain at the three follow-up moments were 92% (95% CI, 79–98%), 97% (95% CI, 85–100%) and 88% (95% CI, 70–96%), respectively. The improvement of patients who had low back pain was 74% (95% CI, 57–87%), 58% (95% CI, 40–75%) and 84% (95% CI, 66–95%), respectively. Of the 21 patients (50%) who had been working preoperatively, at the last study moment, 11 were active in their old occupation [36% (95% CI, 14–55%)], 5 had to switch to less physical-straining jobs [16% (95% CI, 5–34%)] and 5 received workers compensation [16% (95% CI, 5–34%)]. On moment 3, the VAS of leg pain was 20 (range 0–95), VAS of low back pain 22 (range 0–95), and VAS of leg pain and low back pain 23 (range 0–95). The Roland Disability Index was 7 (range 0–21). The long-term patient satisfaction (including possible secondary surgery) showed that 29% of the patients had complete recovery of complaints, 42% almost complete recovery and 19% some recovery (Fig. 2). This means that 71% of the studied 31 patients had an overall good long-term result with a mean follow-up of 10.5 years.

Discussion

Spondylolytic spondylolisthesis is a condition of the spine in which a discontinuity of the pars interarticularis allows a forward slip of the involved vertebral body [43, 44]. Reactive fibrocartilaginous tissue at the

Table 4 Possible influencing factors of recurrent leg pain after performing (hemi)-Gill's procedure

N = 10	Hemi-Gill (*n* = 2)	Gill (*n* = 1)	PLIF (*n* = 8)
Slip grade I	2	1	7
Slip grade II			1
Preoperative instability			5
Discectomy at affected level	1		2
Partial pediculotomy			4
Partial removal of inferior articular process		1	3
Neuroforaminal nerve root compression			8

N number of patients, *n* number of reoperations

Table 5 Postoperative results of leg pain, low back pain and work at three different follow-up moments

	Moment 1	Moment 2	Moment 3
Mean follow-up	11 months	4.4 years	10.5 years
Patients studied	38	34	31
Lost from follow-up	4	6	5
Died of unrelated causes	0	2	6
Leg pain			
Better	35 [92% (79–98%)]	33 [97% (85–100%)]	27 [88% (70–96%)]
Even	3 [8% (2–21%)]	1 [3% (0–15%)]	2 [6% (0–21%)]
Worse	0 [0% (0–8%)]	0 [0% (0–10%)]	2 [6% (0–21%)]
Low back pain			
Better	28 [74% (57-87%)]	20 [58% (40-75%)]	26 [84% (66-95%)]
Even	9 [23% (11–40%)]	13 [39% (22–56%)]	2 [6% (0–21%)]
Worse	1 [3% (0–14%)]	1 [3% (0–15%)]	3 [10% (2–26%)]
Work			
Old activity		10 [29% (15–48%)]	11 [36% (14–55%)]
Less active		10 [29% (15–48%)]	5 [16% (5–34%)]
Disabled		6 [18% (5–29%)]	5 [16% (5–34%)]
Other		8 [24% (11–41%)]	10 [32% (17–51%)]
VAS leg pain (0–100)			20 (range 0–95)
VAS low back pain (0–100)			22 (range 0–95)
VAS leg pain and low back pain (0–100)			23 (range 0–95)
Roland Disability Index (0–23)			7 (range 0–21)

At the last study moment, the VAS and the Roland Disability Index are documented. Numbers are shown in patients (and percentages with 95% confidence interval). *N* is the total number of patients studied at different follow-up moments

parapedicular trajectory of the root canal can cause nerve root compression. Compression may also occur between the pedicle and slipped disc at the level of the neuroforamen [7, 8, 11, 16, 21]. Patients with spondylolytic spondylolisthesis may present with low back pain, leg pain or neurogenic claudication [31]. In accordance with the most frequent site of spondylolisthesis, which is L5-S1, patients usually present with L5 nerve root radicular pain. Typically, the complaints worsen with physical activity.

Treatment of symptomatic spondylolytic spondylolisthesis consists of conservative and surgical methods, although surgery has been shown to be more effective [30]. Several surgical procedures have been advocated in the treatment of symptomatic spondylolytic spondylolisthesis: direct repair of the isthmic defect, spondylodesis with or without instrumentation, nerve root decompression, or a combination of techniques [1, 4, 6, 9, 10, 12, 13, 16, 17, 19, 23, 25, 26, 37, 40, 41]. Recently, a minimal invasive endoscopic procedure has been described [24, 35].

In 1955, Gill was the first who reported on decompressive surgery without fusion in the treatment of lumbar spondylolytic spondylolisthesis [17]. In Gill's study of 43 patients, he considered 86% satisfactory [16]. In a later study of 75 patients, 83% had a good result at 1 year which dropped to 75% at 5 years or more after surgery [32]. Weiner and McCulloch [42] performed a unilateral nerve root decompression and eight out of nine patients had an excellent or good result.

Which type of surgery is more effective remains controversial, but the objective of any surgical strategy should be nerve root decompression. However, on the basis of patient's history and imaging studies, it may be difficult to determine the exact site of nerve root compression. The nerve root can be compressed either at its parapedicular trajectory by reactive tissue from the pseudojoint, or between the pedicle and slipped disc at the distal root canal or neuroforamen. Entrapment on both locations may occur as well. In the first possibility, entrapment underneath the pseudojoint, nerve root decompression should suffice. Whenever the nerve root is compressed between slipped disc and pedicle at the neuroforamen, instrumented fusion aiming at heightening the vertebral segment is indicated. The long-lasting effect of spondylodesis on the height of the neuroforamen with the associated root decompression is not well documented in the literature. Instrumentation without bony fusion renders the same initial result but secondary material failure is likely to produce relapse of reposition.

Results of instrumented spondylodesis vary and known influencing factors include worker's compensation claims, smoking and the presence of radicular symptoms versus low back pain alone [19, 37]. The relation between successful fusion and clinical outcome remains controversial, thereby questioning the necessity of fusion [19, 33, 37]. A frequently used argument in favour of fusion is the prevention of progressive slippage. However, progression of forward slip is almost exclusively documented in youngsters who

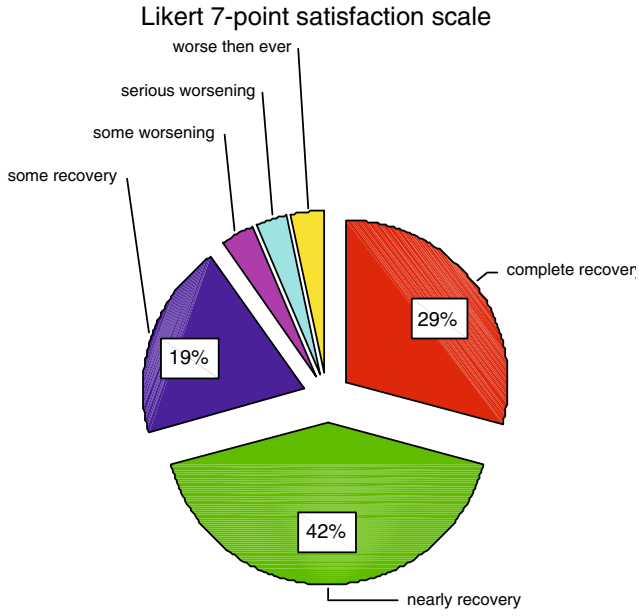

Fig. 2 Likert seven-point satisfaction score; 71% had good result at a mean follow-up of 10.5 years

constitute the minority of the population studied in the literature [3, 14, 38]. Some surgeons advocate nerve root decompression in addition with spinal fusion to prevent postoperative progressive slippage by increased instability as a result of laminectomy [1, 2, 18, 22, 27]. Two studies have shown progressive slippage after Gill's operation but there was no correlation with recurrent symptoms [16, 32].

In this retrospective study, we present the long-term outcome of patients with low-grade spondylolytic spondylolisthesis treated with surgical decompression without fusion. We show that 71% have a good long-term result in terms of patient satisfaction. Our results are comparable with literature data on instrumented and noninstrumented fusion whose follow-up is much shorter (Table 6). However, instrumented spondylodesis constitutes a major operation with considerable blood loss, risk of neurological deficit and wound infection [29, 33, 37, 39, 45]. Recently, Fritzell et al. [15] have shown that the complication rate improves significantly with the extent of instrumented spondylodesis for the treatment of chronic low back pain; 12% complication with noninstrumented posterolateral fusion, 22% with instrumented posterolateral fusion, and 40% with combined anterior and posterior instrumented fusion. Besides the high complication rate, there is inconvenience from postoperative immobilisation in a brace (not applied in all series) and pain from the bone donor site, in case of autologous iliac crest bone graft, is a commonly heard complaint.

In our study, 10 of the 42 patients were reoperated because of persistent or recurrent leg pain and 1 patient was reoperated twice. We will discuss these cases in more detail. Two patients developed contralateral radicular pain which required the completion of Gill's procedure. These are not true recurrences but are rather incidences in the natural course of the nonoperated side. In one patient a Gill's procedure was redone; it appeared that the loose inferior articular process of the affected level had been removed only partially. The result of the second procedure was good. In seven patients a secondary instrumented PLIF was performed, in one patient this procedure was necessary as a third intervention. All of these patients had nerve root compression between the pedicle and slipped disc at the level of the neuroforamen. In accordance with this, one of the reasons to perform a spondylodesis is to heighten the neuroforamen in order to decompress the nerve root. Partial pediculotomy during primary surgery (four patients) was not a technical problem. Five of the eight cases initially had increased segmental excursions on flexion–extension studies. This may imply that primary fusion was indicated, although in the remaining three patients Gill's procedure appeared effective. The degree of spondylolisthesis did not seem to be an influencing factor of outcome since the majority of the reoperated patients had grade I spondylolisthesis. Two out of four patients in whom a discectomy was performed in addition to (hemi)-Gill's procedure needed a secondary instrumented spondylodesis. This may imply that discectomy at the affected level should be prevented, and if nevertheless essential to decompress the nerve root adequately, PLIF should be the primary treatment. During the reexploration of three patients, the initial Gill's procedure was not performed adequately since the inferior articular process of the affected vertebra was only partially removed and consequently the lumbar nerve root was still compromised. Maybe, if the decompressive procedure had been carried out properly in these instances as well, the unsatisfactory outcome might have inflicted only seven (17%) instead of ten patients. Kaplan–Meier analysis predicted a disease-free survival rate of 79% at 5 years and 72% at 10 years after the index operation.

Our study has several important limitations. The main limitation is the loss of follow-up, inherent in a retrospective study. The long-term results concerned 31 of the 42 patients. Six patients had died of unrelated causes. By contacting the general practitioner, we found out that a second surgical intervention had not taken place. Concerning the five patients lost from

Table 6 Literature review of instrumented fusion, noninstrumented fusion and nerve root decompression alone in the treatment of low-grade spondylolytic spondylolisthesis

Author	Type of surgery	Number of patients	Mean follow-up (years)	Good clinical outcome (%)
Hanley et al. [19]	Noninstrumented PLF	50	3.4	60
De Loubresse et al. [9]	Noninstrumented PLF	48	2.7	77
Deguchi et al. [10]	Noninstrumented PLF	83	3.8	71
Kim and Lee [23]	Instrumented PLF	20	2.3	90
	ALIF	20	3.6	85
Moller et al. [31]	Instrumented PLF	37	2	83
	Noninstrumented PLF	40	2	66
Madan and Boeree [26]	Instrumented PLF	21	3.5	86
	Instrumented PLIF + PLF	23	2.4	65
La Rosa et al. [25]	Instrumented PLF	18	2	67
	Instrumented PLIF + PLF	17	2	77
Ekman et al. [12]	Instrumented PLF	37	9	82
	Noninstrumemted PLF	40	9	66
Gill et al. [17]	Gill	43	2.5	86
Osterman et al. [32]	Gill	75	5	75
Weiner and McCulloch [42]	Unilateral decompression	9	2.5	89
Present study	(Hemi)-Gill	42	10.5	71

PLF Posterolateral fusion, *PLIF* posterior lumbar interbody fusion, *ALIF* anterior lumbar interbody fusion

follow-up, we cannot claim beyond any doubt that reoperation has not taken place.

Another limitation concerns the long-term follow-up obtained by telephone interview (moment 2) and a questionnaire sent by mail (moment 3), and not a clinical examination of the patient. However, the main outcome parameters of the present study were alleviation of leg pain and patient satisfaction. These two parameters probably would not have reported different in the setting of an out-patient interview.

At last, we did not perform a routine postoperative dynamic X-ray in order to document possible progression of slip. On the other hand, to our knowledge, there is no correlation between recurrent radicular symptoms and progressive slip [16, 32].

In our surgical strategy, instrumented spondylodesis is not the primary surgical treatment of low-grade symptomatic spondylolytic spondylolisthesis but is only performed as first procedure in case of documented progression of forward slip. Nerve root decompression without fusion is carried out unilaterally or bilaterally, depending on the patient's clinical presentation. Secondary instrumented spondylodesis is performed whenever the Gill or hemi-Gill procedure has failed to relieve the complaints. In order to prevent a rather difficult nerve root dissection in scar tissue when operated later on, secondary surgery is preferably performed within 6 weeks. We believe that the risk of persistent or recurrent symptoms and the possibility of secondary fusion seem justified, since we have prevented the co-morbidity and inconvenience from spondylodesis in the majority of patients. Partly due to the higher complication rate associated with spondylodesis, patients are hospitalised longer, frequently mobilised in a brace and consequently less productive or unemployed for a certain time. Moreover, the cost of instrumentation is high.

The Gill's procedure as primary surgical treatment can be considered as an alternative surgical strategy to instrumented fusion in selected cases. Doing so, the possible complications of instrumented fusion are avoided in the majority of patients. However, one has to realize that secondary surgery may be mandatory in some patients. To minimize the odds of secondary surgery, the identification of selection criteria of when to perform Gill's procedure or primary fusion is warranted. Preoperative instability, discectomy at the affected level and neuroforaminal nerve root compression between pedicle and slipped disc seem to be negative influencing factors increasing the risk for secondary instrumented surgery. The controversy in the treatment of spondylolytic spondylolisthesis justifies a randomised controlled trial comparing instrumented spondylodesis with nerve root decompression alone, regarding clinical outcome as well as cost-effectiveness.

Conclusion

The Gill's procedure is a less invasive surgical treatment for radicular pain related to low-grade spondylolytic

spondylolisthesis. This technique can be considered as an alternative to instrumented fusion in selected cases. Preoperative instability, discectomy at the affected level and neuroforaminal nerve root compression seem to be negative influencing factors increasing the risk for secondary instrumented surgery. In our opinion, this study confirms that clinical results and cost-effectiveness of Gill's procedure need to be investigated in a future randomised controlled trial, comparing nerve root decompression alone with decompression and instrumented fusion.

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