Repair of spondylolylosis using compression with a modular link and screws

We describe the results of a prospective case series of patients with spondylolylosis, evaluating a technique of direct stabilisation of the pars interarticularis with a construct that consists of a pair of pedicle screws connected by a U-shaped modular link passing beneath the spinous process. Tightening the link to the screws compresses bone graft in the defect in the pars, providing rigid intrasegmental fixation. We have carried out this procedure on 20 patients aged between nine and 21 years with a defect of the pars at L5, confirmed on CT. The mean age of the patients was 13.9 years (9 to 21). They had a grade I or less spondylolylosis and no evidence of intervertebral degeneration on MRI. The mean follow-up was four years (2.3 to 7.3). The patients were assessed by the Oswestry Disability Index (ODI) and a visual analogue scale (VAS). At the latest follow-up, 18 patients had an excellent clinical outcome, with a significant ($p < 0.001$) improvement in their ODI and VAS scores. The mean ODI score at final follow-up was 8%. Assessment of the defect by CT showed a rate of union of 80%. There were no complications involving the internal fixation.

The strength of the construct removes the need for post-operative immobilisation.

A spondylolylosis is a defect of the pars interarticularis. Usually there is a complete break in the pars on one or both sides of the neural arch. The condition is often asymptomatic, but may be the cause of pain in the back. Free nerve endings with nociceptive function have been identified in the area of the lysis by Schneiderman et al.¹ Neuropetides which mediate in the sensation of pain have been described at the site of the defect by Eisenstein et al.²

The surgical management of symptomatic spondylolylosis or isthmic spondylolisthesis was first described by Albee,³ Hibbs,⁴ and Bosworth et al.⁵ using posterior fusion to stabilise the defect by eliminating the movement segment. Cleveland, Bosworth and Thompson⁶ and Watkins⁷ described the technique of posterolateral fusion.

Kimura⁸ was the first to describe the direct repair of the pars defect using an isolated bone graft without instrumentation. Patients who underwent this procedure had to remain recumbent for a number of weeks, followed by external immobilisation in a cast for up to six months. Buck⁹ first described the technique of direct repair by filling the gap in the defect with iliac cancellous autograft and placing screws directly through the defect itself.

A number of techniques have since been described for direct repair of the defect, but have been associated with complications such as loosening and breakage of the internal fixation, technical difficulty, extensive muscle and tissue dissection, and variable rates of consolidation of the defect.

We describe a prospective case series evaluating a technique of direct repair of the pars stabilised with a construct consisting of a pair of pedicle screws connected by a U-shaped modular link passing beneath the spinous process. Tightening the link to the screws compresses the bone graft in the defect, providing rigid intrasegmental fixation. This technique was first described by the senior author (HHN).

Patients and Methods

Patients were selected who had chronic disabling pain located in the lower back without sciatica, which had been resistant to conservative treatment for at least 12 months, including modification of activity and a trial of bracing and physiotherapy. All had defects in the pars at L5 on CT scans. Other inclusion criteria were the absence of adjacent degenerative disc disease confirmed by normal T2-weighted MRI, and no more than a grade I spondylolylosis.¹⁰

Of the 20 patients in this series, 12 were male and eight were female, and nine had grade I spondylolylosis. There was one...
The patient was male. The mean age of the patients was 13.9 years (9 to 21). None had a motor or sensory deficit. Bony union of the pars was assessed by plain lateral radiographs and CT scans in all patients. The clinical outcome was evaluated using the Oswestry Disability Index (ODI),11 and a visual analogue scale (VAS)12 with 0 representing no pain and 10 maximum pain, both pre-operatively and at follow-up. Complications were also recorded.

Statistical analysis used the paired t-test and the Wilcoxon’s signed-ranks test. Significance was set at p < 0.05. Surgical technique. The patient is positioned prone. A midline incision is made and the paraspinal musculature elevated laterally to expose the lamina, the pars and the base of the transverse process. Care is taken not to injure the capsule of the facet joint. The defect in the pars is exposed and the fibrocartilaginous element curetted. A burr is used to decorticate the defect and the corresponding lamina and transverse process. Anatomical landmarks and fluoroscopy are then used to determine the starting point for the pedicle screw. A starting hole is burred and a pedicle finder used to enter the pedicle. The walls and floor are assessed with a ball-tipped probe, and the hole is tapped and prepared for a 5 mm pedicle screw. Bone graft is harvested from the iliac crest, placed in the defect and impacted before insertion of the screw. After placement of the screw, a rod is contoured in a U-shape, placed just caudal to the spinous process, deep to the interspinous ligament of the affected level, and attached to each pedicle screw (Figs 1 and 2). When tightened to the screws, the rod compresses the defects. It is firmly fixed against the spinous process and the laminae, which promotes compression of the graft in the defect and stabilises the posterior arch.

Finally, fluoroscopic imaging (Fig. 3) confirms correct placement of the screw and link. Post-operative instructions include the administration of intravenous antibiotics until the wound is dry. The patient is mobilised without a brace.

Results
The mean follow-up was four years (2.3 to 7.3). None of the patients was lost to follow-up. The mean in-patient stay was three days (2 to 5). Post-operative complications
included one superficial wound haematoma which did not require evacuation, and two superficial wound infections which responded to antibiotic treatment.

Bony union of the defect (Figs 4 and 5) occurred in 16 of the 20 patients. Three of the four patients with nonunion had a grade I spondylolisthesis. At the latest follow-up, 18 of the 20 patients had a significant ($p < 0.001$) improvement in their ODI (Table I) and in their VAS scores compared with the pre-operative levels. The mean ODI improved from 54% (42 to 78) pre-operatively, denoting severe disability, to 8% (0 to 42), indicating minimal disability. The mean VAS improved from 8.1 (6.5 to 10) pre-operatively to 1.6 (0 to 8.2) after operation. The mean ODI and VAS of the 16 patients with union of the defect was 3% and 0.4 respectively, at final follow-up.

The two patients who did not have a significant improvement in outcome had no evidence of union of the pars defect on the CT scan. The other two patients with nonunion were asymptomatic. Of the two patients who developed a symptomatic nonunion, one was classified as having severe disability at follow-up. He was a smoker, and was offered a further grafting procedure. The second patient was classified as having moderate disability, was a non-smoker, and had grade I spondylolisthesis. This patient had some subjective improvement and wanted no further intervention.

Discussion

The aetiology of spondylolysis remains unknown, but current opinion is that there is an element of weakness which is genetically determined, or a degree of dysplasia at the pars interarticularis which renders it susceptible to the stresses of normal activity, resulting in a stress fracture.

Lateral radiographs showing a) the pars defect at L5 pre-operatively and b) union of the pars defect at six months post-operatively.

Lateral CT scans showing a) the pars defect at L5 pre-operatively and b) union of the pars defect at six months post-operatively.
A minority of those affected need treatment and only a few require surgery. Most patients considered for surgical treatment have had the time for adjacent disc disease to develop, or have a spondylolisthesis. Lumbosacral fusion is the most common operation performed in these cases. For a grade I or less spondylolisthesis, a direct repair of the pars defect may be considered. This has the advantage of preserving adjacent movement segments and dealing directly with the anatomical defect responsible for any listhesis.

Buck\(^3\) initially carried out his technique of direct repair in 16 patients. None developed nonunion, which was assessed radiologically, but three patients had a poor outcome. He suggested that this technique should only be used in cases where the gap in the neural arch was < 3 mm to 4 mm. In 1979\(^4\) he described a larger series of 75 patients, 88% of whom had a satisfactory result. The accurate placement of the screw in this technique was found to be difficult, with a lengthy learning curve, and complications of this procedure most commonly arose secondary to screw loosening or misplacement.\(^14\)

The Scott technique\(^5\) involved stabilisation of the loose posterior arch by cerclage wiring of the transverse process to the spine. This technique requires greater surgical exposure, with extensive stripping of the muscle in order to expose the transverse process completely. Placement of the wires under the transverse processes is difficult and can lead to substantial bleeding. There is also a risk of injuries to the nerve root. Several cases of wire breakage have been reported.\(^16\) Salib and Pettine\(^7\) described a modification of this technique that consisted of a tension band wire around the posterior process, with a screw in the pedicle. The proposed advantages were that there was no need to pass the wire around the transverse process, with its associated risk of injury to the nerve root, and the better anchorage of the wire using the pedicle screw. The strength and linkage of wires and the diversion of the compression force away from the graft mass are disadvantages. Songer and Rovin\(^8\) described a small series in which the cerclage wire was replaced by a cable passing underneath the lamina, fixed on a pair of pedicle screws, in a technique that requires specific instrumentation.

In 1984, Morscher, Gerber and Fasel\(^9\) described a new repair technique that used a laminar hook positioned in the defect and a compressive force placed upon it with a spring held against a screw within the articular process. The proposed advantages of this technique were that the fixation did not depend on the shape of the defect; it allowed for maximal grafting of the defect; and it would exert a compressive force across the lamina. Numerous problems have been encountered with this technique, including difficulty in screw placement, screw loosening\(^20\) and breakage,\(^21\) and a high rate of failure. Tokuhashi and Matsuzaki\(^22\) described a modified technique that stabilised bone grafted to the pars defect with a pedicular screw, a hook and a rod used in combination. They described significant relief of symptoms in six patients over a limited period of follow-up.

Kakiuichi\(^23\) used a variable-angle pedicle screw, a rod and a laminar hook with bone graft placed across the defect. The proposed advantage was fixation which was more rigid. He reported resolution of symptoms in 13 of 16 patients and bony union in all at a mean follow-up of 25 months.

Gillet and Petit\(^24\) described direct repair by placing screws on the pedicles of the involved vertebra and fixing the loose posterior arch with a solid rod bent into a V-shape, taking purchase on the spinous process and laminae. They achieved excellent results in six of ten patients, with no complications.

In our series of 20 patients we achieved an excellent clinical outcome in 18, with a mean follow-up of four years. Union of the pars defect was achieved in 16 patients (80%). Contradictory opinions have been reported as to the effect of nonunion on outcome. According to Nicol and Scott,\(^25\) Debnath et al,\(^26\) Wu, Lee and Chen\(^27\) and Dai et al,\(^28\) patients with a pseudarthrosis have a poor or fair outcome. However, Hefi, Seelig and Morsch,\(^29\) Johnson and Thompson\(^30\) and Pellisé et al\(^31\) could not prove this relationship. In our series, of the four patients with a nonunion,\(^32\) two had a poor and two an excellent outcome.

The treatment of defects of the pars that appear cold on a bone scan is associated with a higher rate of nonunion.\(^32\) Although the patients in our study did not have a preoperative bone scan, this may be a useful investigation to identify the rate of nonunion in those patients who have a cold lesion. Biomechanical studies may also be useful to further evaluate the distribution of compressive forces across the pars defect in our construct. Most studies\(^9,16,18,19,23\) on spondylolysis have used plain radiographs for the assessment of union, with its associated limited sensitivity.\(^33\) In our study we used CT imaging, which is more sensitive and specific when used to assess union.\(^33\) This may give an impression of a higher rate of pseudarthrosis in our study as compared with other studies which have used radiographs to assess union.

Some authors\(^30,34,35\) consider that a slight degree of spondylolisthesis does not affect the outcome of patients undergoing direct repair of the pars. Others\(^16,17\) carry out direct repair of the pars in patients with a spondylolisthesis of up to 25%. Jeanneret\(^38\) found no difference in outcome.

### Table I. Post-operative clinical assessment using the Oswestry Disability Index\(^1\)

<table>
<thead>
<tr>
<th>Score (%)</th>
<th>Number of patients</th>
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<tbody>
<tr>
<td>Excellent (minimal disability)</td>
<td>0 to 20</td>
</tr>
<tr>
<td>Good (moderate disability)</td>
<td>21 to 40</td>
</tr>
<tr>
<td>Fair (severe disability)</td>
<td>41 to 60</td>
</tr>
<tr>
<td>Poor (complete disability)</td>
<td>61 to 80</td>
</tr>
<tr>
<td>Very poor (bedbound)</td>
<td>81 to 100</td>
</tr>
</tbody>
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between patients with a spondylolisthesis of between 0% and 25%. In our series, nine of the 20 patients had grade I spondylolisthesis, three of whom developed a nonunion of the defect.

Our patients were aged between nine and 21 years, with no evidence of adjacent level disc disease on MRI, and spondylolisthesis not greater than grade I. Numerous authors have found that patients in the age range 20 to 30 years have worse results than younger patients.38-40 The primary reason for this failure is thought to be associated with the appearance of degenerative disc disease.

Our technique uses readily available instrumentation to provide a strong construct. The bone graft in the pars defect is our technique uses readily available instrumentation to provide a strong construct. The bone graft in the pars defect is

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