Spondylolisthesis is the anterior subluxation of one VB onto another. In spondylolisthesis because there is a failure of the compensatory mechanisms to maintain an adequate posteriorly directed force vector, the shear forces that exist in the intervertebral disc cause anterior VB slip.

This failure can be caused by ligamentous laxity, a defect in the pars interarticularis, previous surgery, or trauma, and it occurs in people of all ages in up to 5% of the general population.12–14

Spondylolisthesis is usually associated with a number of angular changes in the sagittal plane that cause additional stress to the lumbar spine to maintain the body’s balance. The normal curvature of the spine actually provides for balance of the body’s weight by maintaining the center of gravity over the vertical axis. Modern analysis of the biomechanical distribution of forces on the spine has improved our knowledge in the pathogenesis of spondylolisthesis, as well as spurred the advancement of instrumentation systems and the concept of segmental fixation.

It is widely accepted that in lumbar fusion the prime focus is the pedicle; the use of modern systems characterized by transpedicular screws with constrained screw/rod connections seems to be more effective than previously used systems.3,10,23,30,37–39 Some of these devices can be considered “dynamic,” because they allow for vertebral spatial mobilization by precise reductive maneuvers, resulting in a better correction of the spinal balance and, consequently, in a higher fusion rate.

Pedicle/screw constructs may be used in posterior (intertransverse and/or facet joints) or interbody fusion. The pertinent literature does not address, definitively, the advantage of one technique over the other.

We retrospectively reviewed 30 consecutive patients who underwent posterior lumbar fixation and posterior facet joint or posterior interbody fusion for Meyerding Grade II/III spondylolisthesis were assessed: 1) to address the suitability of a dynamic stabilization; and 2) to investigate whether there are differences in terms of clinical and functional results and biomechanical properties between these two types of arthrodesis.

Methods. Between June 1998 and April 2000, 16 patients underwent posterior interfacet fusion and implantation of the SOCON-SRI system. In 14 patients posterior lumbar interbody fusion (PLIF) and placement of the same system were performed. Clinical, economic, functional, and radiographic data were recorded pre- and postoperatively.

The average changes in the Prolo Scale economic and functional scores were 1.25 and 1.62, respectively, in patients who underwent posterior fusion; the average measured preoperative vertebral slippage was 47.8% (range 30–65%), and postoperatively it was 18.5% (range 15–25%). In patients in whom PLIF was performed, the average changes in economic and functional score were 1.21 and 1.36, respectively, and the average preoperative vertebral slippage was 43.5% (range 30–55%) compared with 20% (range 15–25%) postoperatively.

Conclusions. The use of a segmental pedicle screw fixation with the SOCON-SRI system successfully combines the goal of solid fusion with the requirements of nerve root decompression. When the two fusion techniques were compared, an overall superior reliability and resistance of the systems was associated with the PLIF procedure (p = 0.04) but clinical outcomes did not differ greatly (p > 0.05).

**KEY WORDS** • spondylolisthesis • spinal fusion • lumbar spine • decompression
CLINICAL MATERIAL AND METHODS

Demographic, Clinical, and Selection Data

Between June 1998 and April 2000 at our clinic, we treated 30 adult patients from the general population who were admitted with the diagnosis of lumbar and lumbosacral spondylolisthesis; all 30 patients underwent one of two types of fusion combined exclusively with implantation of the SOCON-SRI system. In 16 cases posterior interfacet fusion was performed, and in 14 patients PLIF was performed. The population consisted of 14 men and 16 women, and the mean age was 57.1 years (range 49–67 years). Spondylolisthesis was classified as isthmic in 15 and degenerative in 15. Preoperatively no patient was involved in any claims for workers’ compensation or litigation following accidents, and no cases of spondylolisthesis were related to previous lumbar surgery. Symptoms consisted of back, buttock, and posterior thigh claudication pain or lumbosacral radiculopathy in all patients. Examination revealed neurological deficits that correlated with radiographically demonstrated pathological processes in 25 patients (83.3%). Deficits consisted of dermatomal sensory loss in 17 (56.7%), diminished or absent reflexes in 18 (60%), a positive Lasègue sign in 15 (50%), weakness and motor disturbances in 13 (43.3%), and urinary incontinence in four (13.3%). Eight patients were cigarette smokers.

Preoperative and postoperative economic (activity) and functional (pain) statuses were assessed and classified according to the grading system proposed by Prolo, et al., (Table 1).27

In those patients selected for surgery, conservative medical treatment, including bedrest, antiinflammatory medication, physiotherapy, and external bracing, had failed to resolve symptoms.

Preoperative Neuroradiological Studies

The preoperative radiographic evaluation consisted of standard anteroposterior, lateral, oblique, and flexion–extension studies (Fig. 1). The percentage of VB slippage was measured according to the Meyerding classification system for spondylolisthesis.3 Subluxation was classified as Grade II (17 patients) and Grade III (13 patients) lum-}

TABLE 1
Summary of the modified Prolo Functional Economic Rating Scale

<table>
<thead>
<tr>
<th>Status</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>economic (activity) grade</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>complete invalid (worse)</td>
</tr>
<tr>
<td>2</td>
<td>no gainful occupation (including housework or retirement activities)</td>
</tr>
<tr>
<td>3</td>
<td>working/active but not at premorbid level</td>
</tr>
<tr>
<td>4</td>
<td>working/active at previous level w/ limitation</td>
</tr>
<tr>
<td>5</td>
<td>working/active at previous level w/o limitation</td>
</tr>
<tr>
<td>functional (pain) grade</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>total incapacity (worse)</td>
</tr>
<tr>
<td>2</td>
<td>moderate-to-severe daily pain (no change)</td>
</tr>
<tr>
<td>3</td>
<td>low level of daily pain (improved)</td>
</tr>
<tr>
<td>4</td>
<td>occasional or episodic pain</td>
</tr>
<tr>
<td>5</td>
<td>no pain</td>
</tr>
</tbody>
</table>

bar or lumbosacral spondylolisthesis, and the maximum percentage of subluxation was 65%. The study was completed by obtaining bone-view computerized tomography studies and MR imaging studies to detail the extent of neural compression.

Operative Technique

All patients underwent internal fusion combined with implantation of the SOCON-SRI system. The decompressive procedure consisted of removal of the spinous process, bilateral laminectomy, partial bilateral facetectomy, and foraminotomy. The disc spaces were carefully assessed for herniated disc material or prominent bulges, and when necessary, the discs were removed. Pedicle screws were sized to occupy 70% of pedicle diameter; the pedicles typically accepted 5- to 6-mm screws, which were inserted and advanced under fluoroscopic guidance in rostrocaudal orientation to the anterior cortex of the VB, maintaining a trajectory that is parallel to the end plate. To determine both the required length of the rod and its contour, should it need to be bent, a malleable tube was used as a template for the rod. The rods were bent to match the template and attached to the pedicle screws with the use of one-locking clamps. The transpedicular bone screws have an attachment for the adaptation of reduction levers. After distraction had been achieved using the longitudinal threaded spindle, the subluxation was reduced by operating the removable lever or the adjusting screw. When reduction was completed, the system was securely fixed using a dedicated torque wrench.

Fusion Site Preparation

A facet joint fusion procedure was performed in 16 patients. A high-speed drill was used to decorticlate bone surface at the fusion site. The joint capsules were entered using a sharp rongeur, the cartilage was removed, and the cancellous bone surfaces were exposed. The joints were then packed tightly with autologous cancellous bone graft.
In 14 patients a PLIF was performed using the Prospace PLIF system (Aesculap AG & CO. KG), which is a solid titanium block characterized by a cuboidal shape (7-mm width, 7-mm height, 22-mm length) and a porous pure titanium coating facilitating bone ongrowth. After the durotomomy, the dural sac was mobilized disc removal and preparation of endplates were performed in a three-step procedure of reaming, rasping, and broaching in which dedicated instruments were used. The cortical bone was roughened and only partially removed. Autologous cancellous bone was packed into the grooves in the side of the implant medially and laterally (Video Clip).

All patients underwent internal fusion combined with implantation of the SOCON-SRI system. The decompressive procedure consisted of spinous process removal, bilateral laminectomy, partial bilateral facetectomy, and foraminotomy. The disc spaces were carefully checked for herniated disc material or prominent bulges, and when necessary, the discs were removed. Pedicle screws were sized to occupy 70% of pedicle diameter, and the pedicles typically accepted 5- to 6-mm screws, which were inserted and advanced under fluoroscopic guidance, in a rostrocaudal orientation to the anterior cortex of the VB; thus a trajectory parallel to the endplate was maintained. The rods were bent and attached to the pedicle screws with the use of one-locking clamps. The transpedicular bone screws have an attachment for the adaptation of reduction levers. Following distraction by means of the longitudinal threaded spindle, the subluxation reduction was performed by operating either the removable lever or by the adjusting screw. When reduction was completed, the system was securely fixed using a dedicated torque wrench.

In 14 patients a PLIF was performed using the Prospace PLIF system, which is a solid titanium block characterized by a cuboidal shape (7-mm width, 7-mm height, 22-mm length) and a porous pure titanium coating facilitating bone ongrowth. After durotomomy, the disc was removed and the endplates prepared in a three-step procedure of reaming, rasping, and broaching in which dedicated instruments were used. The cortical bone was roughened and only partially removed. Then titanium fusion block pairs were inserted and advanced.

### Postoperative Course and Follow-Up Evaluation

All patients were mobilized within 3 days postoperatively, and a semirigid lumbosacral brace dressing was prescribed for the following 5 months. Rehabilitative therapy was initiated within the 1st week after surgery. All patients underwent serial clinical follow-up evaluations for periods ranging from 2 to 18 months. Radiographs were obtained postoperatively and at regular follow-up intervals to evaluate the reduction of spondylolisthesis and to identify the correct placement and stability of the implant system (Fig. 2).

The mean radiographic follow-up period was 14 months (range 9–18 months). Successful fusion was defined as: 1) absence of motion on flexion–extension radiographs; 2) absence of halo around the implant; and 3) presence of bilateral continuous trabecular bone between the fused segments. Postoperative bone-window computed tomography or MR imaging studies were obtained in all patients to evaluate the results of neural decompression.

### Statistical Data Analysis

Statistical data analysis was accomplished using the chi-square test and the Student t test for continuous data (slippage percentage and nonunion and hardware failure rates). The Mann–Whitney u test was used to compare categorical data (economic and functional outcome). A p value of 0.05 was used to define statistical significance.

### RESULTS

Table 1 provides a summary of the grading system used in the Prolo Functional Economic Rating Scale. A summary of salient demographic, economic, functional, and radiological pre- and postoperative data is provided in Table 2 for each patient who underwent posterior fusion and in Table 3 for those who underwent PLIF.

Thirty SOCON-SRI systems and 124 transthecal screws were implanted. Fusion was performed at one vertebral level in 28 patients and at two levels in two patients: at L5–S1 in 17 cases, L4–5 in 13, and L3–4 in two cases. The average follow-up period was 14 months (range 9–18 months). Radiographic evidence of bone fusion, defined as the presence of bilateral trabecular bone between fused segments, was achieved in all cases but two; the absence of motion on flexion–extension radiographs was, however, evident in all patients. No major surgery-related complications occurred, in terms of wound infection, additional neurological dysfunction, or screw placement–related vascular injuries due to screw placement. No patient died or required reoperation or hardware removal after fusion. Cigarette smoking did not affect the results obtained in our patients (p > 0.05).

### Posterior Fusion Subgroup

In the subgroup of 16 patients in whom posterior interfacet fusion was performed, the average preoperative ver-
tebral slippage was 47.8% (range 30–65%). Postoperatively, the average slippage was 18.5% (range 15–25%). On sensory examination significant improvement was demonstrated in six (66.7%) of nine patients who presented with sensory deficits. Motor disturbances improved in six (85.7%) of seven cases. Reflex responses were not shown to change appreciably after surgery, presumably because of both the long-lasting clinical symptoms and the limited duration of the follow-up period. Significant amelioration of function was seen in three patients with preoperative urinary incontinence.

The average preoperative Prolo economic grade was 2.5 (range 1–4); postoperatively, the economic grade was 3.75 (range 2–5). Ten patients (62.5%) returned to their premorbid level of activities of daily living and were considered to have made good outcomes (Prolo Grades 4–5), Three patients (18.7%), although improved, experienced a reduced level of activity (Prolo economic Grade 3). Three patients (18.8%) did not return to their premorbid level of activity (Prolo Grades 1–2). The average change in grade, designated as delta E, in this subgroup was 1.25.

The mean preoperative Prolo functional grade was 2.2 (range 1–4); postoperatively, the functional grade was 3.75 (range 2–5). Nine patients (56.3%) reported a significant functional amelioration, with absent or occasional leg and back pain, and were considered to have achieved good outcome (Prolo Grades 4–5). Fair functional outcome was observed in five patients (31.3%) who partially improved, but in whom residual leg and low-back pain were still present (Prolo Grade 3). The average change in function in this subgroup, designated as delta F, was 1.62.

In one case, we documented hardware failure represent-
Posterior or interbody fusion in spondylolisthesis

ed by detachment of the rods from the screws; in another case the failure of the system was demonstrated by loss of the reduced angle of slippage and partial collapse of the disc space. In two cases a nonunion of the facets was documented. Intraoperative dural leakage was observed in one case.

**Posterior Lumbar Interbody Fusion Subgroup**

In patients in whom PLIF was performed, the average preoperative vertebral slippage was 43.5% (range 30–55%); postoperatively, the average slippage was 20% (range 15–25%). On sensory examination significant improvement was demonstrated in five (62.5%) of eight patients who presented with sensory deficit. Motor disturbances improved in five (83.3%) of six cases. Significant amelioration of function was seen in one patient with preoperative urinary incontinence.

The average preoperative Prolo economic grade was 2.7 (range 1–4). Postoperatively, the economic grade was 3.9 (range 2–5). Eleven patients (78.6%) returned to their premorbid level of activities of daily living and were considered to have made good outcomes (Grades 4–5). One patient (7.1%) although improved, experienced a reduced level of activity (Prolo economic Grade 3). Two patients (14.3%) did not return to their premorbid level of activity (Grades 1–2). The average change in grade, designated as delta E, in this subgroup was 1.21.

The mean preoperative Prolo functional grade was 2.7 (range 1–4); postoperatively, it was 4 (range 2–5). Nine patients (64.3%) reported a significant functional amelioration, with absent or occasional leg and back pain, and were considered to have made good outcome (Grade 4–5). Fair functional outcome was observed in five patients (35.7%) who improved partially, but in whom residual leg and low-back pain were still present (Grade 3). The average change in function in this subgroup, designated as delta F, was 1.36.

Neither fusion failure nor hardware breakage was demonstrated during radiographic follow-up studies. In two cases an intraoperative dural leakage was recorded.

**Differences Between the Two Subgroups of Patients**

No statistical differences were demonstrated in terms of economic or functional outcome between the two subgroups (p > 0.05); no significant difference was shown concerning reduction of subluxation between subgroups (p > 0.05).

The presence of failed fusion in two cases in the posterior fusion subgroup turned out not to be statistically significant (p = 0.16). On the other hand, if considered together, the rates of hardware failure and bone nonunion reached a level of statistical significance (p = 0.04).

**DISCUSSION**

Spondylolisthesis is a condition characterized by a failure of the three-column support in which there is severe, complex instability that requires reconstruction of the altered supporting structures. The segmental use of posterior lumbar pedicle screw devices is currently the standard for this reconstructive surgery; the widespread dissemination of these screws began this era of segmental spinal fixation.1,3,10,22,39

Biomechanically, pedicle screw systems allow three-column stabilization in which grip force is stronger than in other posterior fixation systems; do not require intact posterior elements; preserve adjacent normal motion segments; prevent deformity progression; and reduce mechanical pain syndromes, thereby encouraging immediate ambulation.1,3,10,23,30,37–39 Fusion of the posterior elements of the lumbar spine combined with placement of instrumentation represents a valid solution for spinal instability and may result in a solid fusion in up to 95% of cases.9,10,24,30 A number of authors have argued, however, that in cases of anterior column failure a strong anterior support is required, especially when only one or two vertebral segments are being bridged, and furthermore, that interbody fusion may improve the rate of arthrodesis and endurance of the posterior construct.2,22

The failure of a posterior arthrodesis may be caused mainly by lack of bone bases—with only transverse processes and the lateral aspect of facet joints remaining for graft placement and the large gap between the fusion bases resulting from anterior vertebral displacement and by an incompetence of the disc support.15,29,32,38

Theoretically, because a reversal of the aforementioned factors might improve the outcome, a reduction of the subluxation was attempted, and in a subgroup of patients an anterior support was provided via a PLIF procedure.

**The Role of Curvature Remodelling**

Correction of lumbar curvature may improve the fusion rate by means of a mechanical effect, reducing the shearing forces that cause anterior slippage.2,17 At the same time, it restores intervertebral disc height and the foraminal area and may enhance fusion by narrowing the gap between the fusion bases and reducing the bending moment over the graft.18,31,32 Reduction may be achieved by many methods, including instrumental reduction, leverage, and casting. We used the SOCON-SRI, a pedicle screw/rod system, that allows manipulation of each instrumented vertebra by means of dedicated longitudinal threaded spindles for distraction and levers for reductive maneuvers.20,36

It must be emphasized that these procedures should be preceded by a microsurgical nerve root decompression to avoid iatrogenic lesions from the repositioning of the anteriorly displaced vertebra, with nerve roots squeezing between the withdrawn VB and the degenerated hypertrophic facet joint of the lower vertebra (Fig. 3).

**The Role of the Anterior Support**

On a pure biomechanical level, the advantage of anterior support in complex segmental instabilities involving the anterior and the posterior spine, such as in spondylolisthesis, rests on the concept of axial “load sharing” on the spinal segment.11,16 The physiological axial load is 80% through the anterior column and 20% through the posterior elements. In fused segments, the absence of anterior support makes the whole axial load pass through the system, reducing, as a result, its endurance. Additionally it must be remembered that the transpedicular systems work through posteriorly attached screws with a large lever arm, and thus flexion movements may result in placing extreme stress on the screw. Interbody fusion devices, on
a reduced propensity for osteoinduction. The metal is sive; furthermore, when sterilized in ethylene oxide, it has Banked bone may become brittle and porous and is expen-
tical bone but are often slow to integrate into the fusions. tricortical grafts have support columns of cortical 
fusions, although it has inadequate initial mechanical 
tologous cancellous bone is the favored material for most 
cortical contact zone; it is coated with highly porous pure titanium (Plasmapore; Aesculap AG & CO KG) and dem-
sion.4,19,28

Another advantage is represented by the wide vertebral bone bed surrounding the graft, which provides a consistent, nourishing circulation with essentially no influence by such agents as vasoactive drugs or nicotine.

Posterior lumbar interbody fusion was pioneered by Cloward. It can be performed using several systems: autologous cancellous bone is the favored material for most fusions, although it has inadequate initial mechanical strength; tricortical grafts have support columns of cortical bone but are often slow to integrate into the fusions. Banked bone may become brittle and porous and is expensive; furthermore, when sterilized in ethylene oxide, it has a reduced propensity for osteoinduction. The metal cages, introduced by Ray and Brantigan independently in 1989, in which an autologous bone graft is used, resolved these drawbacks and allowed for an immediate mechanical resistance and the possibility of a long-term bone fusion.

We used the Prospace PLIF system, a solid titanium device with a cuboidal shape that provides a maximum cortical contact zone; it is coated with highly porous pure titanium (Plasmapore; Aesculap AG & CO KG) and demonstrated an enhancement in bone formation along the block perimeter. The cuboidal shape and the not completely removed endplates provide resistance to uncontrolled bone subsidence, and an inclination of the contour of 4° aids correction of the lumbar curvature.

Despite the advantages of interbody devices, graft collapse, slippage, displacement, or extrusion may occur in 3–10% of cases when PLIF is the only fusion procedure undertaken. Furthermore, investigators of recent biomechanical studies have demonstrated the superior stability offered by screw/rod systems and suggested that interbody fusion hardware should not be used as a stand-alone device to treat lumbar spondylolisthesis.

Analysis of Results

Because the study is based on a relatively limited number of patients, the applicability of the results is limited. Compared with others, however, our study is based on a group of patients with spondylolisthesis in whom homogeneous preoperative clinical and radiological variables were demonstrated, and all patients were treated using a modern pedicle screw system.

The radiological and clinical results demonstrated in this study agree with those reported by a number of authors and support the view that a rigid segmental fixation combined with interbody fusion is the treatment of choice for segmental lumbar instabilities. In fact, a solid fusion was achieved in all patients, and there were no graft-related complications or serious neurological complication in the PLIF subgroup.

Although we did not record differences in terms of pure fusion rate, when the rates of fusion failures, hardware breakage, and loss of distraction/reduction are taken together as a result of a mechanical impairment, our findings confirm a superior reliability of the system when it is combined with a PLIF procedure.

Clinically, in the PLIF subgroup good economic and functional outcome was obtained in 78.6% and 64.3%, respectively, whereas in the posterior fusion subgroup these same results were found in 62.5% and 56.2% of the cases, respectively.

Despite this difference in raw data, changes in functional and economic scores did not show a wide gap between the two groups (p > 0.05). In other words, similar results were achieved in the two subgroups independent of the mechanical properties of the two systems. This lack of differences can be explained by the fact that variables other than solid bone fusion markedly influenced clinical outcome. For example, the decompressive procedure that preceded the implantation, the effect on the mechanical pain, and the restoration of the neural space created by the system could have played a role in both groups and positively influenced results.

Of note, a complete correlation between good outcome (70% economic, 60% functional) and fusion rate (93%) was not recorded in our series nor in most others, confirming that there are factors (such as age or secondary gain provided by previous surgery) other than preoperative symptoms or radiographic fusion that may influence results in a study of clinical outcome.

CONCLUSIONS

Despite the large number of variable involved in a definition of “good results” and all the complex conditions characterized by spinal segmental instability, it can be concluded that the use of a segmental pedicle screw fixation in which the SOCON-SRI system is successfully used achieves the goals of solid fusion and nerve root decompression. Overall superior reliability and resistance of the systems was achieved when using the PLIF procedure compared with posterior interfacet fusion, but there was no appreciable difference in terms of clinical outcome between the two subgroups.
Posterior or interbody fusion in spondylolisthesis

References


Manuscript received February 20, 2001. Accepted in final form March 20, 2001. Address reprint requests to: Giovanni La Rosa, M.D., Neurosurgical Clinic, Policlinico Universitario, Via Consolata Valeria, 1, 98122 Messina, Italy. email: gnntco@tin.it.