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Posterior fusion and implantation of the SOCON-SRI system in the treatment of adult spondylolisthesis

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Surgery for adult patients with lumbar and lumbosacral spondylolisthesis is reserved for those with intractable radiculopathy, claudication, or symptomatic spinal instability. Internal fixation, in which posterior fusion, transpedicular screw fixation, and implantation of titanium devices are performed, has been advocated to improve fusion rates and clinical results. Fourteen consecutive patients with Grade II to III lumbar and lumbosacral spondylolisthesis who underwent posterior decompression, reduction, autologous posterior facet joint arthrodesis, and SOCON-SRI implantation are retrospectively reviewed.

All patients underwent complete preoperative clinical and neuroradiological evaluation. Treatment consisted of posterior decompressive surgery and implantation of the SOCON-SRI system (transpedicular screws, prebent longitudinal rods, and one locking-screw clamps). Distraction of the interbody space and rotation were performed to achieve an optimum spinal realignment. The facet joints were fused by using autologous bone graft. The authors obtained detailed clinical, functional, economic, and neuroradiological follow-up data for up to 14 months (range 8--18 months).

The efficacy of the treatment was evaluated by comparing pre- and postoperative data. Pain was decreased in all cases, neurological dysfunction ameliorated in 50%, and functional and economic status was improved in 78% and 100%, respectively. No cases of fusion failure or instrumentation-related complications occurred. The authors describe their results of treating patients with spondylolisthesis in the light of the rationale for surgery and the more recent pertinent literature.

Key Words * pedicle screw * SOCON-SRI system * spinal fusion * spinal instrumentation * spondylolisthesis

Spondylolisthesis is the anterior subluxation of one vertebral body onto another, usually L-5 onto S-1, and it occasionally affects the upper lumbar spinal segments. Spondylolisthesis can be caused by ligamentous laxity and trauma, and it occurs in people of all ages in up to 5% of the general population.[8-10] Operative management for adults with nontraumatic spondylolisthesis is generally reserved for treating progressive neurological deficits, intractable low-back pain associated with radiculopathy, claudication, or symptomatic spinal instability with the goal of achieving spinal

stabilization, fusion, and resolution of symptoms.[2,20,25] When surgery is performed, fusion is mandatory for isthmic, degenerative, and iatrogenic spondylolisthesis, especially when wide decompressive surgery has been performed, to prevent eventual progression of disc slippage.[2,7,25]

The numerous devices in the treatment of spondylolisthesis described in the literature include systems of screws and rods, sublaminar wires, hooks, and cables. However, fusion rates in patients who have undergone surgery for spondylolisthesis may sometimes be suboptimum. In addition, because some devices are not yet approved by the United States Food and Drug Administration for general use in the lumbar spine, their use may represent a possible source of medicolegal concern for spinal surgeons.

Recently, the use of modern dynamic titanium systems, which are characterized by transpedicular screws with constrained screw/rod connections, seems to be more effective than previously used systems.[3,11,13,19,27] These titanium systems allow for vertebral spatial mobilization, precise reductive maneuvers, and improved spinal fusion and, therefore, result in better clinical outcome for spondylolisthesis. The SOCON-SRI system (Aesculap AG CO., KG, Tuttlingen, Germany) is a titanium internal fixation device consisting of self-locking clamps with transpedicular bone screws that are connected with straight reduction rods, which allows compression and distraction of the lower thoracic and lumbar spine in stabilization and fusion procedures.[19,23,26]

We describe our experience, using carefully defined indications for surgery in the light of the more recent literature, in the treatment of 14 consecutive patients with high-grade symptomatic lumbar and lumbosacral spondylolisthesis who underwent posterior decompressive surgery, facet joint fusion with autologous bone graft, and implantation of SOCON-SRI system.

CLINICAL MATERIAL AND METHODS

Demographic, Clinical, and Selection Data

Between June 1998 and June 1999 at the Neurosurgical Clinic, University of Messina, we treated 14 adult patients from the general population admitted with the diagnosis of lumbar and lumbosacral spondylolisthesis; all 14 patients underwent fusion combined with implantation of the SOCON-SRI system. The mean age of the patients was 56.4 years (range 49--67 years); there were eight women and six men. Spondylolisthesis was classified as isthmic in five and degenerative in nine. Preoperatively no patient was involved in any claims for workers' compensation or litigation following accidents, and 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 11 patients (79%). Deficits consisted of dermatomal sensory loss in eight (57%), diminished or absent reflexes in eight (57%), a positive Lasegùe's sign in six (43%), weakness and motor disturbances in five (36%), and urinary incontinence in three (21%). Four patients were cigarette smokers (Table 1).

Case No.	Age (yrs), Sex	Level	Cause	Preop Data			Postop Data		
				Neurological Status	Economic & Functional Grades	Slippage	Economic & Functional Grades	Slippage	Cigarette Smoker
1	49, M	L5-S1	I	LBP, Lasègue's sign, claudication, hyporeflexia, sensory disturbances	E2, F2	50%	E4, F4	20%	yes
2	53, M	L4-5	I	LBP, Lasègue's sign	E4, F3	30%	E5, F5	15%	no
3	63, F	L3-4	D	LBP, hyporeflexia, sensory disturbances	E3, F4	50%	E4, F4	15%	no
4	55, M	L4-5	D	LBP, paraparesis, sensory disturbances	E2, F3	55%	E3, F4	20%	no
5	52, F	L5-S1	D	LBP, paraparesis, sensory disturbances	E2, F2	55%	E3, F3	20%	yes
6	67, F	L3-4 L4-5	I	LBP, Lasègue's sign, motor & sensory deficits, hyporeflexia, urinary incontinence	E1, F1	65%	E2, F2	25%	no
7	54, M	L5-S1	D	LBP	E4, F3	35%	E5, F5	15%	no
8	50, F	L5-S1	D	LBP, Lasègue's sign, hyporeflexia, sensory disturbances	E3, F3	45%	E4, F3	20%	no
9	54, F	L4-5	I	LBP	E3, F2	40%	E5, F4	15%	yes
10	51, M	L5-S1	D	LBP, Lasègue's sign	E3, F2	45%	E4, F4	15%	yes
11	64, F	L4-5	D	LBP, paraparesis, urinary incontinence	E1, F1	60%	E2, F3	25%	no
12	61, M	L5-S1	D	LBP, claudication	E2, F2	55%	E3, F3	20%	no
13	60, F	L5-S1	I	LBP	E3, F2	45%	E5, F4	20%	no
14	57, F	L4-5 L5-S1	D	LBP, Lasègue's sign, paraparesis, hyporeflexia, urinary incontinence	E1, F1	60%	E2, F3	20%	no

* D = degenerative; I = isthmic; LBP = low-back pain.

Preoperative and postoperative economic (activity) and functional (pain) statuses were assessed and classified according to the grading system proposed by Prolo, et al.,[22] (Table 1).

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

Neuroradiological Studies

The preoperative radiographic evaluation consisted of standard anteroposterior, lateral, oblique, and flexion--extension views (Fig. 1 left). The percentage of slippage was measured, according to the Meyerding's classification for spondylolisthesis.[16] Slippage was classified as Grade II (eight patients) and Grade III (six patients) lumbar or lumbosacral spondylolisthesis. In all patients there was radiographic evidence of spondylolisthesis or translational motion of 3 mm or greater. The study was completed by obtaining computerized tomography studies with bone views and magnetic resonance (MR) imaging studies to detail the extent of neural compression (Fig. 1 right).

Fig. 1. Left: Preoperative lateral x-ray film demonstrating an isthmic L4--5 spondylolisthesis with slippage measured at 54%. Right: Preoperative sagittal T₁-weighted MR image confirming the L4--5 spondylolisthesis associated with disc herniation at the same level, which exerts significant compression on the neural structures.

Operative Technique

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. Following graft harvest, decortication with high-speed drill, and packing of the facet joint, pedicle screws were sized to occupy 70% of pedicle diameter. The pedicles typically accepted 5 to 6 mm screws, which were inserted and advanced, using fluoroscopic guidance, in rostrocaudal orientation to the anterior cortex of the vertebral body, maintaining a trajectory that is parallel to the end plate. To determine both the length of the rod and its contour, should it need to be bent, a malleable tube is 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. Following distraction by means of the longitudinal threaded spindle, spondylolisthesis reduction was performed by operating either the removable lever or the adjusting screw. When reduction was completed, the system was securely fixed using a dedicated torque wrench. At this point, a facet joint fusion procedure was performed. The joint capsules were entered using a sharp rongeur, the cartilage was removed, and the cancellous bony surfaces were exposed. The joints were then packed tightly with autologous cancellous bone graft obtained from the spinous processes.

Postoperative Course and Follow Up

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

spondylolisthesis and to identify the correct placement and stability of the implant system (Fig. 2).

Fig. 2. Postoperative lateral x-ray film revealing the reduction of spondylolisthesis, as well as the correct positioning of the SOCON-SRI system. The slippage has been reduced to 20%.

The mean radiographic follow-up period was 14 months (range 8--18 months), and successful fusion was defined as the presence of bilateral continuous trabecular bone between fixed segments. Postoperative computerized tomography scanning with bone window views and magnetic resonance imaging studies to evaluate the neural decompression were obtained in all patients (Fig. 3).

Fig. 3. Postoperative T₁-weighted MR images (sagittal [left] and coronal view [right]), confirming the spondylolisthesis reduction and demonstrating results of the laminectomy and the resolution of the neural compression.

RESULTS

Table 1 provides a description of the scale proposed by Prolo, et al.,[22] for rating functional and economic status. In Table 2 a summary of demographic, clinical, economic, functional, and radiological pre- and postoperative data is provided for each patient.

TABLE 2 PROLO ECONOMIC AND FUNCTIONAL RATING SCALE	
Grade	Description
economic (activity) status	
1	complete in valid (worse)
2	no gainful occupation (including housework or retirement activities)
3	working/active but not at premorbid level
4	working/active at previous level w/ limitation
5	working/active at previous level w/o restriction
functional (pain) status	
1	total incapacity (worse)
2	moderate-to-severe daily pain (no change)
3	low level of daily pain (improved)
4	occasional or episodic pain
5	no pain

Fourteen SOCON-SRI systems and 60 transpedicular screws were implanted. Fusion was performed at one vertebral level in 12 patients and at two levels in two patients: L5--S1 in eight cases, L4--5 in six, L3--4 in two cases. The average follow-up period was 14 months (range 8--18 months). Fusion was achieved in all cases, as documented at follow-up examinations, with no evidence of motion on flexion--extension radiographs. No major surgery-related complications occurred in our patients, in terms of wound infection, additional neurological dysfunction, dural tears, or vascular injuries due to screw

placement. No patient died, required reoperation, or hardware removal after fusion.

The average measured preoperative slippage was 49% (range 30--65%). Postoperatively, the average slippage was 19% (range 15--25%).

On sensory examination significant improvement was demonstrated in four (50%) of eight patients. Motor disturbances improved in four (80%) of five cases. Reflex responses were not shown to change appreciably after surgery in our patients, 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 the three patients with preoperative urinary incontinence.

The average preoperative economic grade was 2.4 (range 1--4). Postoperatively, the economic grade was 3.6 (range 2--5). Eight patients (57%) returned to their premorbid level of activities of daily living and were considered to have made good outcomes (Grades 4--5). Three patients (21%) although improved, had a reduced level of activity (economic Grade 3). Three cases (21%) did not return to their premorbid level of activity (Grades 1--2). The average change in grade, designated as delta E, in this series was 1.2.

The mean preoperative functional grade was 2.2 (range 1--4). Postoperatively, the functional grade was 3.6 (range 2--5). Eight patients (57%) 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 six patients (43%) who partially improved, but in whom residual leg and low-back pain were still present (Grade 3); these patients did not return to previous work and life style. The average change in function in this series, designated as delta F, was 1.2.

Cigarette smoking did not affect the results obtained in our patients.

DISCUSSION

A retrospective review of 14 adult patients with spondylolisthesis treated with autologous facet joint fusion and implantation of the SOCON-SRI system was performed. A high rate of successful fusion was obtained using this technique, and it was correlated with clinical, economic, and functional amelioration. The efficacy of the surgical procedure, together with the instrumentation implantation, was evaluated by comparing pre- and postoperative clinical data and neuroradiological findings. No instrumentation-related complication occurred. Although we recognize the complexity of the problem, the large number of variables involved in the pathophysiological mechanisms of spondylolisthesis, the different results reported in the literature, the fact that our results are based on a small series of patients, which somehow limits its applicability and suggests caution in drawing definite conclusions, it can be concluded that spondylolisthesis can be successfully treated with posterior fusion and implantation of the SOCON-SRI system.

The curvature of the normal spine provides for balance of the body's weight by maintaining the center of gravity in the sagittal plane over the vertical axis.[2,26] This relationship can be distorted by alteration of the normal spinal curvature or by other changes, resulting in shifting of the center of gravity. The resulting vector generated by posterior elements and axial load forces eliminates shearing forces. In spondylolisthesis there is a failure of the compensatory mechanisms to maintain an adequate posteriorly directed force vector in opposition to the aforementioned shear forces.[8,16] Although spondylolisthesis was recognized as a distinct clinical entity more than two centuries ago[2,16] and it affects more than 5% of the general population,[8,11] it continues to generate considerable controversy regarding its

pathophysiology and management. Medical nonoperative management is indicated as the initial treatment in spondylolisthesis.[2,17,25] In patients with neurological deficits or pain that significantly inhibits lifestyle and in whom nonsurgical management fails to restore comfort and function, consideration of surgical options is warranted. Selection of patients for surgery represents an important aspect of the treatment of spondylolisthesis. In adults, surgical indications include younger age, degree of slippage greater than 25%, movement exceeding 3 mm as demonstrated on flexion--extension x-ray studies, work-related problems, and previous surgery.[9,15,18]

A number of options exist for spinal fusion in patients with spondylolisthesis. Fusion can be performed from an anterior or posterior approach.[1,2,12] With the anterior approach, interbody grafting represents the most commonly used type of fusion, but this approach can prove difficult if the L-5 vertebral body is displaced over the sacrum, because the resulting position of the interspace is then directed inferiorly, away from the surgeon's view.[14] The posterior approach is most commonly used because it provides the necessary exposure for both neural element decompression and fusion. The posterior approach can be performed for posterior (facet joint), posterolateral (intertransverse), and posterior interbody fusion or as a combination of these, with or without placement of graft material. However, the posterior approach alone has been shown to result in high grades of pseudarthrosis formation, as well as an added degree of spinal instability in the early postoperative period.[3,11,12,25]

The use of instrumentation in spinal fusion operations has received increasing attention in the surgical literature, appearing as the treatment of choice because of its association higher fusion rate as well as better clinical results.[2,9] The development of internal fixation systems dates back to the use of the Harrington distraction system in 1951, initially used for the treatment of scoliosis and later for stabilization of fractures, as well as for the treatment of spondylolisthesis.[3--6,24] Numerous devices such as wires, cables, hooks, plates, and screw/rod have been developed for spinal fixation. In lumbar and lumbosacral fixation, actually, screw and rod systems appear to be more effective than hook and rod systems or devices involving sublaminar wires, primarily because of difficulties in attaching to the sacrum and a high complication rate.[2,13] In addition, plate stabilization usually needs the inclusion of healthy adjacent motion segments, and some devices are not yet approved by the United States Food and Drug Administration for general use in the lumbar spine and, most important, may represent a possible source of medicolegal concern for spinal surgeons.

The development of modern titanium devices allows for a complete postoperative neuroradiological assessment for both fusion rates and decompressive procedures. Titanium possesses excellent resistance to corrosion, surpassing that of stainless steel in the human body. Additional bioengineered design features also are used because of titanium's greater notch sensitivity and crack propagation tendencies, as compared with stainless steel.

There is still need for an optimum instrumentation system that can restore the biomechanics of the fused vertebral segments, as well as relieve pain, and enhance resolution of neurological deficit.

The SOCON-SRI system is a dynamic device that allows the manipulation of each instrumented vertebra.[26] In addition, distraction and reduction procedures can be performed to restore the normal neural space. This system consists of transpedicular bone screws, straight and prebent rods, and specially designed clamps that can be tightened by one locking screw. The reduction instrumentation system can be connected directly to the ends of the bone screws, allowing for a wide variety of corrective procedures. It has to be emphasized that, prior to placement of the SOCON-SRI implant, it is mandatory

to perform microsurgical nerve root decompression to avoid iatrogenic lesions from the repositioning of the anteriorly displaced vertebra and to reduce spinal compression. The two roots in the recesses of the affected segment, as well as the entire cauda equina, may be squeezed between the withdrawn vertebral body and degenerated hypertrophic facet joint of the lower vertebra.[21] From a biomechanical point of view, the possibility of restoring the normal relationship between the two vertebral bodies seems to be important to reduce the stress caused by the so-called "shearing forces on the spinal construct." [2]

CONCLUSIONS

Improved intraoperative techniques and postoperative care have reduced operative complications in spondylolisthesis surgery and have permitted spondylolisthesis to be treated in more cases than was previously possible. Our findings, taken together with those of others, regarding both the feasibility and benefit of dedicated dynamic titanium devices for spondylolisthesis, support a recommendation for surgery, when indicated. Posterior facet joint fusion combined with placement of the SOCON-SRI implant is a safe and efficacy surgical option in the treatment of spondylolisthesis, as it prevents progression of neurological deficits, enhances recovery of existing deficits, relieves pain, stabilizes abnormal motion, prevents additional slippage progression, and significantly ameliorates both economic and functional outcomes.

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