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The Internal Skeletal Fixation System

A New Treatment of Thoracolumbar Fractures and Other Spinal Disorders

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A new internal skeletal fixation system (ISFS) for stabilizing thoracolumbar fractures and other spinal disorders was developed by Dick in Switzerland. The ISFS is a modification of the Magerl external skeletal fixation system of the spine. The Dick modification consists of a threaded rod connected by clamps to Schanz screws and is located in the vertebral pedicles on both sides of the spine. Due to a stable angle between the rod and Schanz screw, a one-point fixation above and below the diseased vertebra is sufficient. The ISFS provides a short fixation and promotes fusion. Control of lordosis, kyphosis, and rotation of the spine is possible with threaded rod distraction and compression and through manipulation of the Schanz screws held by movable clamps. The advantage of the ISFS is the ability to achieve reduction and fixation with the same instrumentation. ISFS has been used in more than 90 patients and proven most adequate for thoracolumbar fractures and other localized spinal disorders. The Harrington system and its modifications are no longer in use for these problems.

During the past two decades, the development of spinal surgery has been influenced principally by new instrumentation for such spinal problems as scoliosis, trauma, tumor reconstruction, and degenerative diseases.[3,8,11–14,16,19,21–24,26–28,30] In North America scoliosis surgery was the major stimulus for development of the classical Harrington instrumentation, but in Europe trauma surgery specifically initiated new developments in spinal instrumentation.[8,9,24–26] In many European centers, the standard treatment of thoracolumbar spine fractures employed Harrington instrumentation,[18] which has been widely used until the present.[2] However, the Harrington system and its modifications were made for correction of scoliosis, in which long fixation and fusion are mandatory. It was not made for single or bisegmental injuries to the spine.

The goals of treatment of any spinal injury include: (1) effective decompression of the spinal canal, if necessary, achieved mostly with adequate reduction; (2) healing of the spine without deformity, limitation of motion, instability, or pain; and (3) early mobilization and simplified nursing care. In general, surgical treatment of spinal trauma is advantageous only if these goals can be achieved more easily and more quickly than with nonsurgical treatment and if complications are minimal.

The Harrington distraction system has some disadvantages. Many healthy segments of the spine are included in the fixation (and fusion), resulting in functional deficits to the lumbar spine. Furthermore, instrumentation failure and loss of correction have been problems.[2,4,7,10,15,17,29] New instrumenta-

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tions, both posterior and anterior, have not been essentially different. The Luque sublaminar wiring system also requires long fixation, and the amount of reduction and correction is minimal because distraction is not possible.[23] The combination of Harrington distraction rods and sublaminar wiring later became very valuable in spinal trauma management,[16] but the problem of long fixation remained. Plate fixation of the spine, proven by French investigators to be most effective,[20,26] is very rigid; the anchorage of screws in the pedicles has introduced a new approach to spinal fixation. Usually, however, the plates also require fixation of two vertebrae above and two below the injured vertebra, and additional instrumentation is needed for fracture reduction.

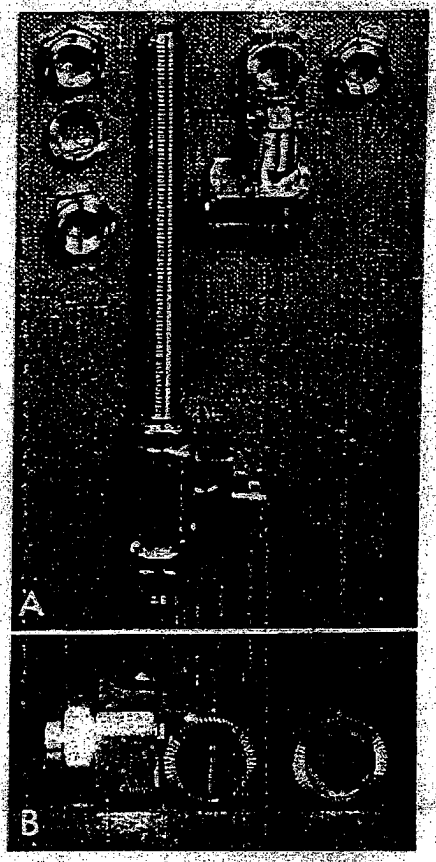
Under emergency conditions, an anterior approach to the injured thoracolumbar spine is demanding, but an ideal anterior instrumentation for fracture treatment that would provide enough stability and fixation to prevent deformity, even in osteoporotic bone is not yet available.[12,21,22]

Magerl initiated a new dimension in spinal instrumentation with the external skeletal fixation system (ESFS). He intended to develop a system that would require only short fixation and fusion of the injured vertebra. It should also give optimal stability and allow immediate mobilization of the patient.[24] This gave rise to further developments, and at the end of 1982 Dick[8] and coworkers[9] designed the internal skeletal fixation system (ISFS), which eliminated some of the minor disadvantages of the ESFS. The ISFS can be used internally, requires only a short length of the spine for fixation, allows reduction and fixation with the same instrumentation, and is so stable that mobilization can be started in the early postoperative days without significant external support. Magerl and Dick based their systems on the experience of French orthopedic surgeons with plate fixation, who showed that screws could be anchored securely through the pedicles into the vertebral body.[20,26] Firmly anchored screws provide sufficient stability with a connecting rod system that is put under distractive or compressive stress.

The ISFS is a short segmental fixation system designed for the treatment of spinal trauma. It has turned out to be useful as well for the treatment of other spinal disorders.

THE INTERNAL SKELETAL FIXATION SYSTEM (ISFS)

The standard internal skeletal fixation system consists of a threaded square-ended steel rod, 10 cm long and 7 mm in diameter. This rod is flattened on two opposing sides to prevent loosening of the nuts when their soft collars are crimped against the flattened part of the rod (Fig. 1A). In addition, a serrated washer with the same square shape as the rod is put over it and holds the clamp in the desired rotation as soon as the nuts are tightened with wrenches (Fig. 1B). The rotation of this ring can be changed in 6° increments. Schanz screws are connected to the threaded rods with clamps. The Schanz screws are held at a fixed angle and rotation by the clamp on the rod (Figs. 2A and 2B). As long as the clamp hinges remain secure, no loss of reduction will occur. The self-tapping Schanz screws are 5 mm in diameter. The long shaft of the Schanz screw can be used as a lever arm to facilitate reduction maneuvers. At the end of the operation, the excess length of each Schanz screw is removed with a Harrington cutter. This system allows correction in all planes of motion. Through the threaded rod, distraction, compression, rotation, and neutral fixation are possible. In contrast to the Harrington rod, distraction results not in a tendency toward kyphosis,[27] but in parallel distraction or compression due to the fixed angle between the threaded rod and the Schanz screw in its clamp. An important advantage of this system is that it can be restricted to the vertebrae above and below the injured vertebra, regardless of complete dislocation with fractured posterior elements and/or torn ligaments. The system



FIGS. 1A AND 1B. Instruments and implants of the internal skeletal fixation system (ISFS). (A) Threaded rod with a completely mounted, hinged clamp at the bottom. A disassembled hinged clamp at the top right and two nuts and the serrated washer at the top left (nuts identified by arrows). (B) The serrated end of the hinged clamp and a serrated washer.

itself is stable; therefore, one-point fixation is appropriate in the pedicles one vertebra above and below the injury. In contrast, systems such as Harrington instrumentation require at least two-point fixation above and below the injured vertebra. One point is the hook, which is a mobile link to the lamina of the vertebra, two above or below, and the other point is the bony support of the lamina, one above or below the injured vertebra. The classical spinal plate systems, also anchored in the pedicles, need two-point fixation above and also below, because the screw-plate interface is not stable. The long lever arms of the Schanz screws are another advantage of the ISFS. Especially in fracture treatment, but also in spinal deformities, the Schanz screws permit reduction and adjustment of a single vertebra in any desired direction, first by hand and then by the connecting rods (Fig. 3).

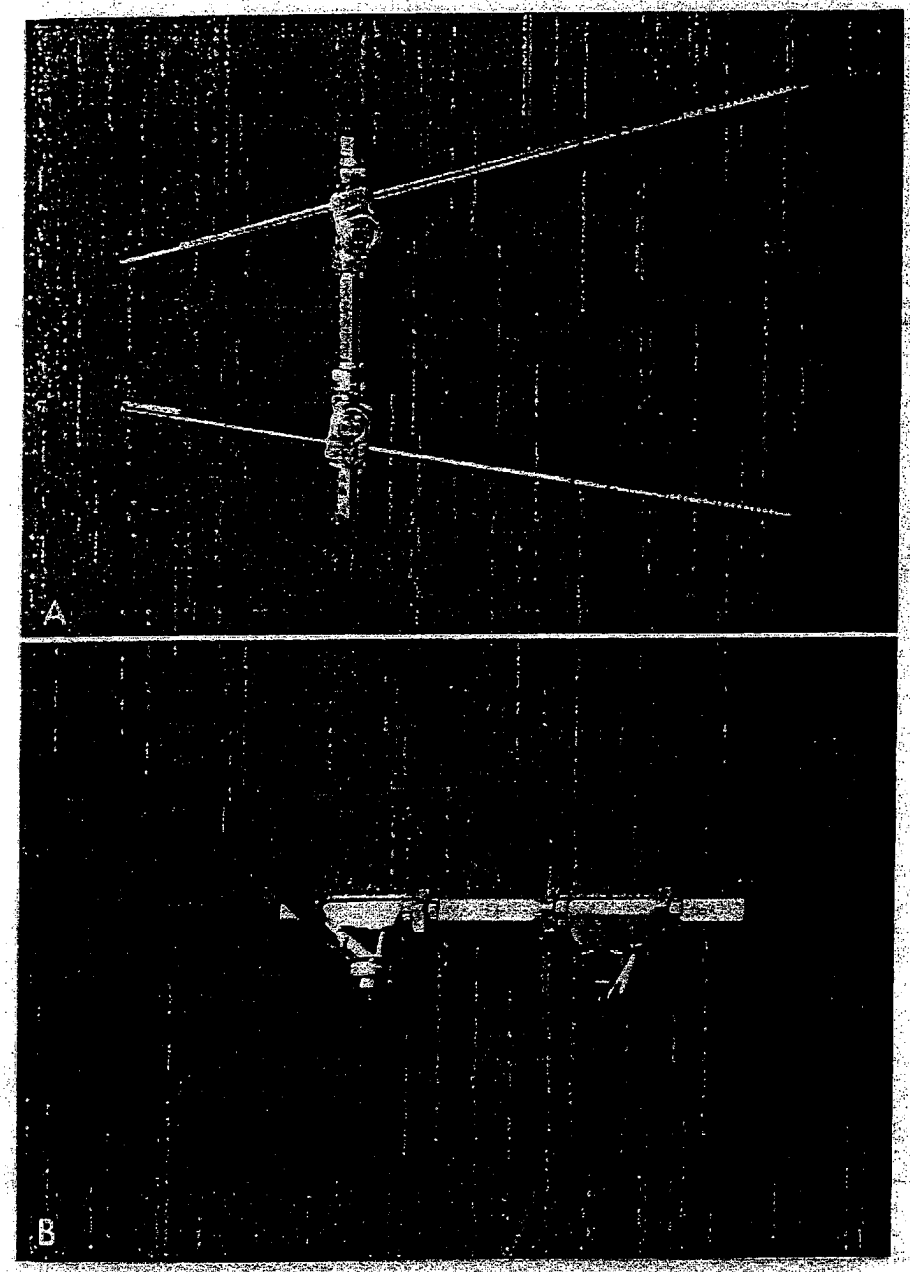
Biomechanical testing of the systems with cadaver spines has been done by Dick[8] on a universal testing machine. He showed that the range of elasticity of the device reached 40 newtons (N) with an anterior bending moment. From 40 to 70 N, a small deformation occurred without loosening of the hinges. Human cadaver spines with experimental anterior and posterior lesions were then loaded by a simple anterior bending moment. The ISFS showed better stability than classical Harrington rods or the locking hook system of Jacobs and Casey.[19] Those systems ended with hooks pulling out of laminae at 6–10 N and 19–35 N, respectively. Loosening of the screws or disengagement of the hinges did not occur in bending moments up to 70 N, which are much higher values than recorded *in vivo*.

SURGICAL TECHNIQUE

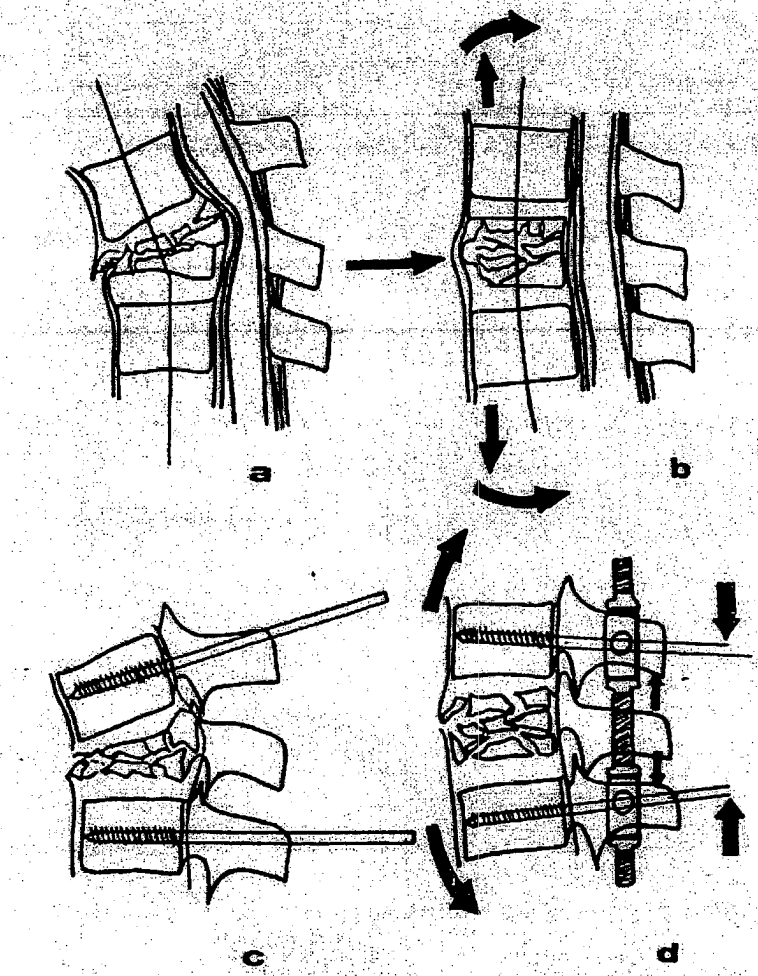
A standard posterior approach is used. The paravertebral muscles are subperiosteally stripped as far laterally as the base of the transverse processes. The anatomic landmarks of the projection of the pedicles onto the posterior elements are established (Fig. 4A). Kirschner wires are drilled into the pedicles of the vertebra above and below the injured vertebra, parallel to the endplates and convergent 10°–15° toward the midline (Fig. 4B). Their position is checked using the image intensifier in two planes. If correctly



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FIGS. 2A AND 2B. The internal skeletal fixation system assembled. (A) Configuration demonstrating a lordotic position of the Schanz screws in the hinged clamps (kyphotic correction is also possible). (B) Rotation of the clamps around the axis of the rod. Rotation is secured by the serrated washers.



FIGS. 3A–3D. Principles of reduction of a burst compression fracture. (A) and (B) Lordosis and distraction open the wedge and distraction reduces the posterior wall of the vertebral body through ligamentotaxis. (C) and (D) Instrumented spinal segments use the same principles of reduction by means of the Schanz screws in the pedicles and distractions with the threaded rods.

placed, the Kirschner wires are replaced by the self-tapping Schanz screws. The tips of the screws should end up close to the anterior wall of the vertebral body. The Schanz screws are then connected to the threaded rods. The connecting hinged clamps are at first allowed to move in all directions to obtain kyphosis, lordosis, rotation, distraction, and compression. At the end of the operation, they are secured with nuts in their definitive position. In all previous cases, a posterolateral fusion was performed after im-

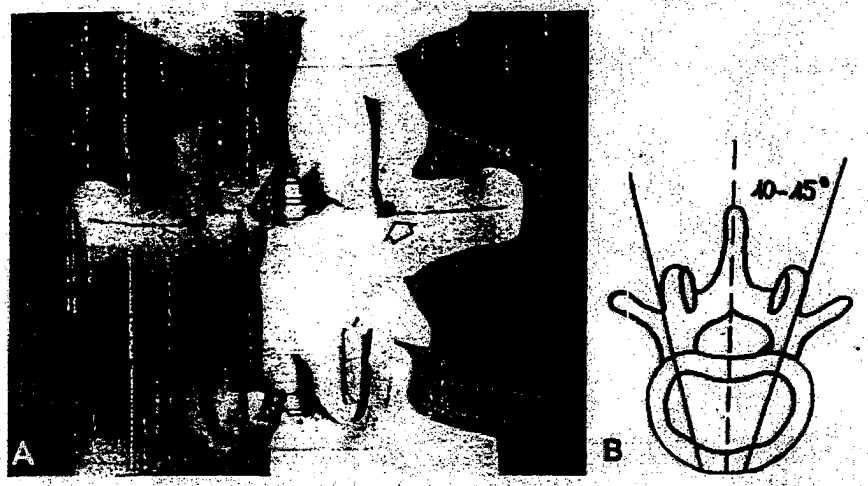


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FIGS. 4A AND 4B. (A) The posterior landmarks for the pedicles are slightly lateral to the intersection of a line through the transverse process of the vertebra and a line through the facet joints demonstrated in a vertebral model. (B) The Schanz screws are inserted to converge toward the midline at an angle of about 10°–15°.

plantation of the ISFS. In severely compressed and destroyed vertebral bodies, transpedicular cancellous bone grafting was used, as described by Daniaux.[5]

INDICATIONS

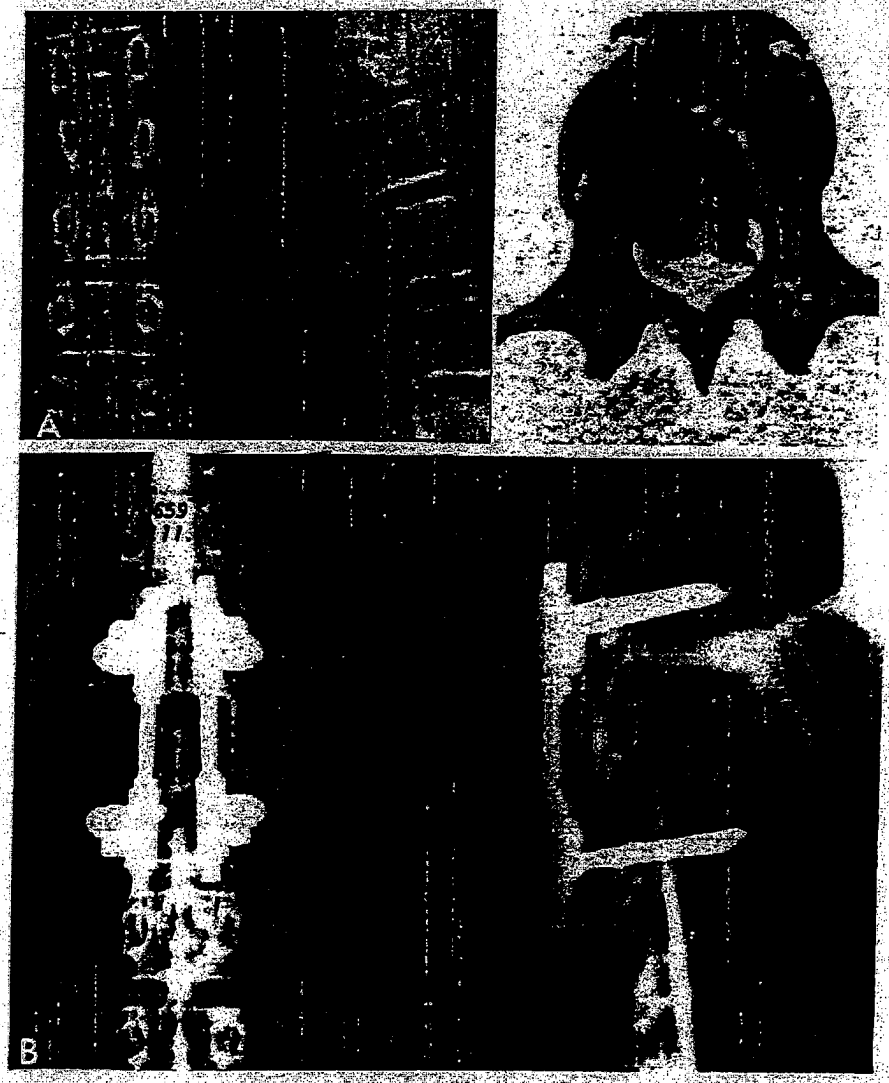
THORACOLUMBAR FRACTURES AND FRACTURE DISLOCATIONS

The ISFS can be applied to almost any type of fracture of the thoracolumbar spine, from T8 to S1. The most frequent fracture type that needs surgical treatment is the burst fracture, Denis Types A–E.[6] The kyphotic deformity is reduced by the powerful lever arm of the Schanz screws, which are pushed together to create lordosis (Fig. 3C). Distraction is then applied (Fig. 3D), which in most cases leads through ligamentotaxis to a reduction of the destroyed posterior vertebral body wall, restoring the original height of the injured vertebra (Figs. 5A and 5B). This procedure is always followed on an intraoperative myelogram. The ISFS can be used even after laminectomy, because the position of the Schanz screws in the pedicle is not compromised.

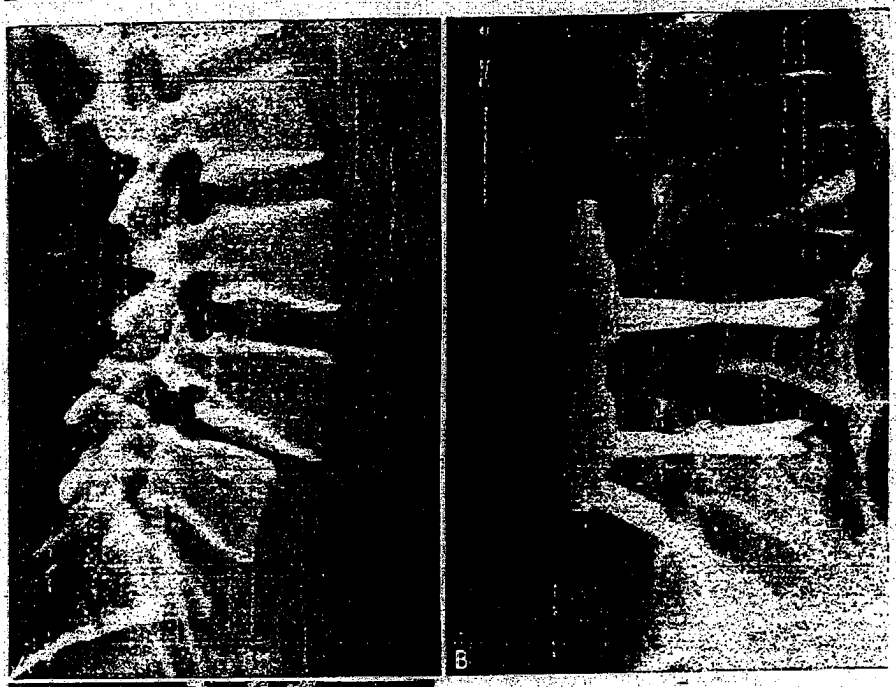
In the first 30 injured patients, who were followed for at least six months, the average local kyphosis was improved from 15.8° to 3.5°, and the spinal canal diameter from 55% narrowing on average to less than 10% in all but one case (preoperative range, 10%–100%). One patient, who was treated several weeks after injury, needed an additional anterior decompression one week after a posterior approach and fixation because of incomplete reduction and an incomplete paraplegia. He recovered almost completely.

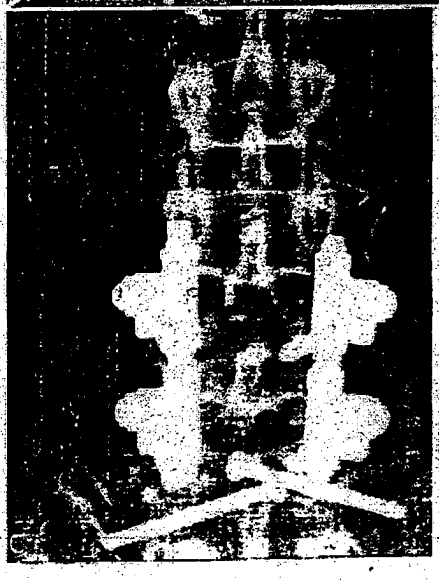
The neurologic recovery in the 14 patients with preoperative neurologic deficits was at least one Frankel grade. No neurologic complications, infections, or other major complications occurred from insertion of the Schanz screws. The average hospitalization time was 17 days (range, seven to 35 days).

Two complications occurred due to instrumentation failure. Both were early cases in this series and were caused by inadequate

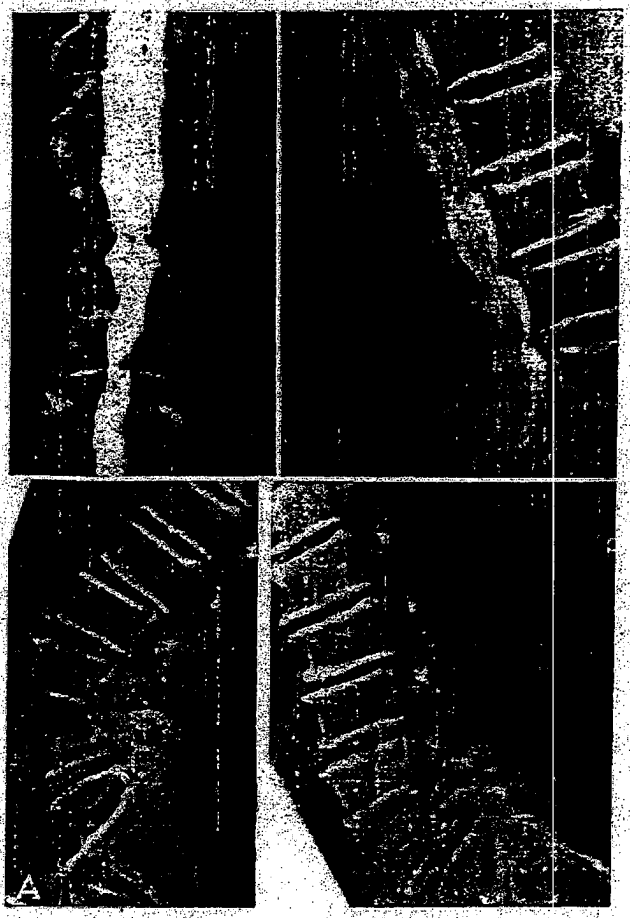


FIGS. 5A AND 5B. A 25-year-old woman with an L1 burst fracture (arrows) and protrusion of a wall fragment into the spinal canal. (A) Preoperative roentgenograms (left) and CT scan (right). The spinal canal diameter is narrowed by more than 58%. The patient had bladder paralysis and perianal hypoesthesia. (B) The postoperative roentgenogram and myelogram show complete restitution of the posterior wall of L1 (arrows). Three months after operation, the patient has recovered completely from the neurologic deficit and returned to work.





FIGS. 6A–6C. A 39-year-old patient with an unstable spondylolisthesis L4–5 and left L5 radiculopathy. (A) Preoperative roentgenogram showing spondylolisthesis L4–5 Grade 2 and spondylolysis. (B) Postoperative lateral roentgenogram with partial reduction and significant distraction of the L4–5 segment. The root symptoms have disappeared. (C) Postoperative AP view. The segment L5–S1 has been stabilized and fused with translaminar screws and a posterolateral fusion.



FIGS. 7A AND 7B. A 58-year-old man with classical symptoms of neurogenic claudication due to spinal stenosis. The patient had had two laminectomies without relief of symptoms. (A) AP (top left) and lateral (top right) myelograms, showing significant stenosis over at least three segments. Maximal reclination (bottom left) and maximal inclination (bottom right) in functional roentgenograms showing unstable L3-4 and L4-5 segments. (B) A P (left) and lateral (right) postoperative roentgenograms after stabilization of this severely degenerative lumbar spine with a rod plate modification to the sacrum. The patient is now able to walk several miles without significant pain.



tightening of the nuts on the clamps with the standard wrench. As a result, the Schanz screws slipped out of the hinged clamp. A secondary kyphosis occurred in both patients, but in one without clinical consequence. In the second patient, however, paresthesias and bladder paresis occurred, requiring a second operation. A dual approach in the lateral position was used: a posterior approach to replace the failed ISFS, and an anterior retroperitoneal approach to decompress the spinal canal and replace the fractured L2 with an autogeneic iliac bone graft. The patient had complete neurologic recovery within four weeks.

SPONDYLOLISTHESIS

After early experience with the ISFS system in injured patients, the authors used it more frequently for the treatment of Grade 1 to 3 adult spondylolisthesis at either the L5–S1 or L4–5 level (15 patients). Two essential goals in the treatment of this disorder are achieved: (1) stable fixation in an unsta-

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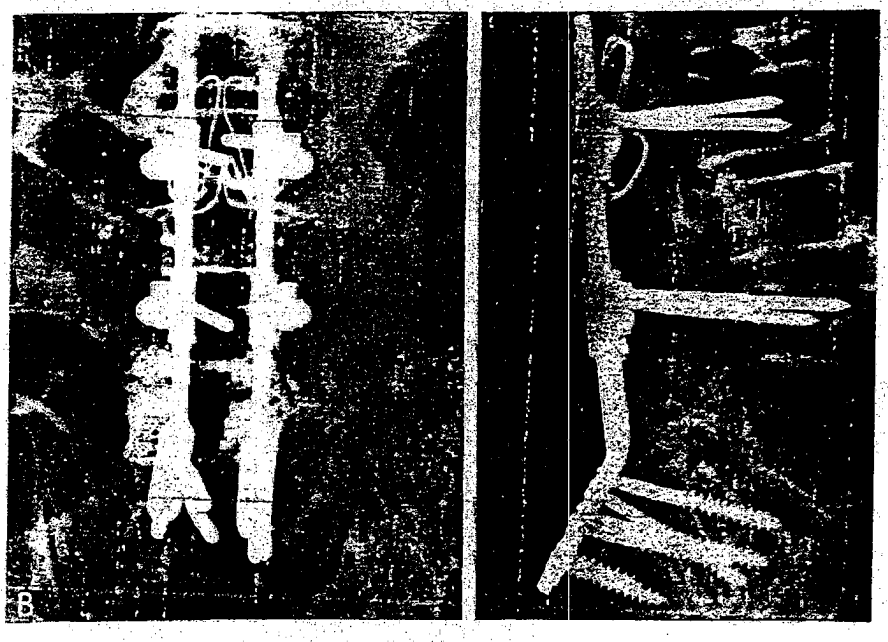


FIG. 7 (*Continued*).

ble painful lesion; and (2) vertebral reduction with resultant nerve root decompression.

Frequently, L4–S1 is spanned with the fixation system. Through distraction and manipulation of the Schanz screws, partial reduction can be achieved. Nerve root irritation is alleviated to a great extent without opening the spinal canal (Fig. 6). A posterolateral fusion is always added, either from L4 to S1 or, occasionally, L5 to S1. Whether this procedure will result in fewer nonunions and in overall better results than fusion alone or an anterior approach and fusion—as has been suggested[28]—has yet to be shown through long-term follow-up study. With the ISFS it is possible to mobilize patients immediately after surgery. The patients' average hospital stay in this series has been 12 days.

OTHER SPINAL DISORDERS

The ISFS was applied to other spinal disorders, such as vertebral body tumors, spondylitis, spondylosis, spinal stenosis, and even neglected adult lumbar scoliosis. For sacral fixation, the ISFS was modified by adding a sacral plate to the threaded rod of the standard ISFS[1] (Fig. 7).

Results of treatment of spinal stenosis associated with degenerative disease of the lumbar spine have been gratifying when the ISFS was used over several segments. The main advantages have been its use when laminectomy has been performed and rigid fixation of unstable segments was needed. Postoperative pain and neurogenic claudication have decreased significantly. The nine patients with significant neurogenic claudication (limited walking distance of about 100 m) improved to the extent that each was able to walk up to several miles at a time without any problems.

In tumor surgery, the surgeon can employ stable fixation from a posterior approach while doing a complete vertebrectomy



FIGS. 9A AND 9B. A 57-year-old woman with a 26-year history of low back pain caused by neglected adult lumbar scoliosis. Increasing symptoms of spinal stenosis and left L4-5 radiculopathy. (A) Left convex lumbar scoliosis with a Cobb angle of 42° and significant lateral translation of L2 and L3 (left) as well as lumbar kyphosis (right). (B) Posterior derotation, distraction, and fixation with the ISFS from L1 to S1. After operation, the scoliosis measured 14° (left). Restoration of a lordosis (right).

through a retroperitoneal approach. Four patients in whom a complete corpectomy was performed were mobilized within the first postoperative week with a light three-point brace (Fig. 8). Because the fixation system is positioned posterior to the resected vertebra, postoperative irradiation is simplified.

CASE REPORT

A 57-year-old woman with neglected adult lumbar scoliosis of 42° had had low back pain for more than 26 years and developed symptoms of spinal stenosis with root involvement of L4 and L5 on the left side. She was treated with an ISFS from L1 to S1 with pedicular fixation to L1, L2, L4, L5, and S1. With the Association for the Study of Internal Fixation (ASIF) femoral distractor applied to the Schanz screws on the concave side of the curve, it was possible to derotate and distract the lumbar spine from the posterior after having resected the facet joints. A correction to 14° was achieved. It was also possible to change the lumbar kyphosis to slight lordosis. Then the ISFS was applied as a compression system on the convex side, and as a distraction system on the concave side. No neurologic complication ensued from this procedure (Fig. 9), and the patient was walking on the fourth postoperative day with a Boston-type brace.

This case demonstrates that a derotation with the ISFS was possible to a certain extent through the very firm anchorage of the Schanz screws in the strong pedicles, allowing a multidirectional rotational control of the vertebral body. The authors have since operated on another six patients with adult neglected lumbar scoliosis, using the same technique. The preliminary results are promising.