The “Fixatuer Interne” as a Versatile Implant for Spine Surgery

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The “fixateur interne” is a new device for posterior spine surgery. It consists of long Schanz screws which are inserted from a posterior approach through the pedicles into the vertebral bodies, and of connecting threaded longitudinal rods, carrying mobile clamps which can be fixed in every position by nuts. The long leverarms of the Schanz screws facilitate manual reduction. They are removed at the end of operation. As the device is stable against flexion and rotation by itself, it does not act on the four-point bending principle. Thus, the fixation can be restricted to the immediately adjacent vertebrae of a lesion, leaving the rest of the spine mobile. In fracture treatment instrumentation is combined with a direct repair of the anterior loss of bone stock by a transpedicular bone grafting procedure from the same dorsal approach. This report presents and discusses 183 instrumentations in fresh fractures, posttraumatic deformities, degenerative diseases, tumors, and severe spondylolisthesis. The main advantage is the short fixation area and the ease of after treatment. [Key words: “fixateur interne,” posterior spine surgery, pedicle fixation, spinal fracture, spinal deformity]

The common posterior instrumentations for surgery on thoracic and lumbar spine such as Harrington, 1,7,10,22,23,26,27,33,34 Jacobs, 23-35 Luque rods, 21,46,47 or dorsal Roy-Camille plates 48,49 are based on a four-point fixation 49,50; a two-point fixation on both sides of the affected area. On each side they have a mobile link to one vertebra and need a second bony support on the lamina of the next vertebra. This means that generally at least five vertebrae, two above and two below, are included in the fixation. For fracture treatment, Jacobs even recommends a three-above, three-below technique for better stability. 23-35

It is commonly accepted that scoliosis patients with their previously stiff spine tolerate well iatrogenic loss of mobility. However, that principle does not apply to other patients with previously mobile spines. Simultaneous iatrogenic loss of mobility and of lumbar lordosis worsens the impairment. 46,47 Patients without neurologic defects can develop mechanisms of compensation; for paraplegics, however, a stiff thoracolumbar or lumbar spine causes rehabilitation problems. 3

Even restricting the bony fusion to the affected area and removing the implant after consolidation often does not solve the problem because the mobility of the temporarily instrumented part of the spine is not always restored. Extraarticular bridging of an untouched facet joint leads to degeneration of the cartilage. 32,26,37 Therefore a long-range immobilization of intact joints of the thoracolumbar or lumbar spine cannot be the final solution in spine surgery; on the extremities, similar procedures never would be accepted. Furthermore, direct adjustment of the position of one particular vertebra is not possible with any four-point bending system. Shifting of a vertebra or reduction of vertebral fragments can be done only by indirect means and corrective forces can be applied at most in one or two directions. The common posterior instrumentations work excentrically from the center of rotation on the dorsal elements and tend, when distracted, to produce an unwanted kyphotic tilt to the instrumented end vertebrae.

In unstable fractures, 11,31 sometimes stability is not good enough to allow early mobilization of the patient. Slipped hooks and loss of correction are reported complications. 26,43,48

Magerl was the first to introduce 1977 another biomechanical principle when he connected long percutaneous Schanz screws anchored dorsally and transpedicularly into the vertebral bodies with a stable external frame. 51,52 This “fixateur externe” made it possible to leave the four-point fixation and to shorten the instrumented area to three vertebrae. 2 Following Magerl’s ideas and suggestions, a fully implantable and stable spine fixation device was developed at Basle University Orthopaedic Department, which is called “fixateur interne” (FI) instrumentation. 13,14,16

THE IMPLANT

The implant consists of Schanz screws of 5 mm diameter for transpedicular fixation in the vertebrae, and threaded longitudinal rods of 7 mm diameter to connect the Schanz screws (Figure 1). The rods carry clamps which are first mobile in every direction and permit application of forces to produce kyphosis, lordosis, distraction, compression, and rotation. Finally they can be fixed by nuts in the desired configuration. A system of flattened sides on the threaded rods, nonturning washers, grooves and bars secures a firm hold of the position of the Schanz screws relative to each other, including rotational stability (Figure 2). As long as the clamps stay firm, no redislocation will occur.

When testing the FI system, mounted to free polyethylene blocks, with an anterior bending moment up to 70 Nm, no giving way of the clamps occurred. The approximation of the tips of the Schanz screws under load was 2.5 mm with a bending moment of 18.75 Nm; 3.4 mm with 25 Nm; 4.6 mm with 35 Nm; 5.4 mm with 42.5 Nm, and 8.6 mm with 70 Nm. No residual deformation was found after loading and unloading up to 40 Nm of anterior bending moment. With 70 Nm, a plastic deformation of the FI of 0.3 mm remained after unloading.

Further testing was carried out on seven human cadaver spines in
testing machine (Rumul Mikron 654) and submitted to a pure anterior bending moment. Two inductive goniometers (Schaevitz RVDT R 30A) were fixed to the immediately adjacent vertebral bodies and the angulation deformity was measured. Testing included the intact spine, the spine with an experimental combined lesion of the anterior and posterior elements, and the fractured spine after instrumentation with the different fixing devices.

Mean angulation deformation for the FI with an anterior bending moment of 5 Nm was 1°, with 10 Nm 2.9°, with 15 Nm 6.1° and with 20 Nm 6.6°. In two spines with about 12 Nm, there was observed a slow giving away of the cancellous bone around the Schanz screws, leading to elevated angulation (mean age of all specimens, 78 years). For comparison: Harrington distraction rods disengaged\(^\text{54,56,65,68}\) in the same model regularly with 6–10 Nm bending moment. No loosening of a clamp occurred. Figure 3 shows the relation to the other fixing devices in the same experimental set up.

One patient with a severe lumbar fracture with combined anterior and posterior disruption died of pulmonary embolism 17 days after FI instrumentation. His spine was tested in the same way: angulation deformation reached 0.9° with 10 Nm anterior bending moment; 1.1° with 15 Nm; 1.4° with 20 Nm and 2.4° with 47 Nm. No loosening occurred and no residual deformation after unloading was found. After removal of the FI rods the spine was disrupted completely when anterior bending moment reached 9 Nm (Figure 4).

**OPERATIVE TECHNIQUE**

By the usual midline posterior approach, the laminae and facet joints are prepared open and the transverse processes localized. With some experience the points of entry for the Schanz screws dorsally can be found easily. They are located slightly more laterally than those described for dorsal plating by Roy-Camille et al,\(^\text{54,56,65,68}\) Sail- lant,\(^\text{60}\) and Louis and Maresca.\(^\text{60}\) Figure 5 shows the relationship to

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*Fig 1. "Fixateur interne."*
process as far laterally as the lateral border of the upper articular process. In the thoracic spine, the entry point is located immediately below the upper facet joint approximately 3 mm lateral to the middle of the joint near to the base of the transverse process. Therefore, it is recommendable at thoracic levels to remove the transverse process with a bone nibbler.

After localization of the entry points, 2-mm K-wires are inserted parallel to the end plates and convergent 10–15° towards the midline through the pedicles into the vertebral bodies (Figure 6) for a depth of 3 cm (except in S1, which is considerably smaller). After roentgenogram control, the K-wires are replaced by the self-tapping Schanz screws. It is only necessary to open up just the point of entry with a 3.5 mm drill bit for a depth of 5–10 mm. No tapping is done. The Schanz screws are driven manually into the vertebral bodies until their tip lies close to the anterior wall. In an average patient, it is safe to insert the Schanz screws to about 40 mm (in the sacrum, 30 mm). From then on, image intensifier control is mandatory during insertion, as the anterior wall is thin and offers litte resistance. Involuntary perforation cannot be felt.

As the Schanz screws are lying within the closed corticis of the pedicles, they do no harm to the neural structures and achieve firm purchase in the bone. They are connected with the FI rods lying towards the middle in the groove along the spinous processes (Figure 7). Now, forces in every direction can be brought upon the Schanz screws as needed for the individual case. This may be illustrated schematically for a burst fracture (Figure 8): first, the kyphosis is corrected by compressing forcefully the free dorsal ends of the Schanz screws towards each other. In cases where the posterior wall of the vertebral body has been destroyed, first the distraction correction between nut and clamp. By squeezing together the ends, the tips of the Schanz screws are spread apart and thus the desired lordosis is achieved. Then the angle between the Schanz screws is fixed by the lateral nuts and reduction is completed by distraction with the nuts on the threaded rod until the anatomic height of the vertebral body is restored. After tightening the counternuts, the dorsally protruding parts of the Schanz screws are removed; a special bolt cutter cuts them off smoothly and without a sharp edge. The nuts are secured against loosening by compressing their border into the flattening of the threaded rods. Wound closure poses no problems.

Of course, by reversed manners, compressive and kyphosing forces can also be applied. The same is true for rotational corrections. The FI instrumentation yields stability in all directions except parallel lateral dislocation of the instrumented vertebrae, which is normally prevented by the bony dorsal elements. In cases with severe lateral instability cross-linking of the FI rods is recommended.

As soon as consolidation of the fracture and the transpedicular graft is assured, routine implant removal is recommended as at least one mobile disc space is bridged and no posterior fusion is done generally. Tumor cases are of course excepted. Depending on roentgenographic follow-up, implant removal will be possible usually after 9 to 12 months postoperatively, in some cases even earlier.

The different combinations of the possibilities for correction make the FI instrumentation adaptable to both trauma and corrective orthopaedic spine surgery.

**THORACOLUMBAR AND LUMBAR FRACTURES**

In operative treatment of thoracolumbar and lumbar spine fractures, the FI instrumentation offers several advantages.

**Restricted Fixation Area**

The biomechanical principle of the FI, relying on an angle-stable connection of firmly anchored Schanz screws, permits the instrumentation to be restricted just to the vertebrae immediately adjacent to the fracture, avoiding the inclusion of two or three levels above and below; only two motion segments are immobilized (Figure 9), and in pure dislocations even one (Figure 10).

Thus little iatrogenic loss of mobility is ensured. This is important especially for the rehabilitation of paraplegic patients, where independence depends on extensive lumbar spine mobility: 1) to reach the feet, especially if there is not good sitting balance or if hip joint mobility is restricted as in osteoarthrosis or paratrophic ossification; 2) to reach the ground sitting in the wheelchair; 3) to get back into the wheelchair without help after a fall; 4) for standing exercises where hyperlordosis of the lumbar spine is needed (often patients with long stiff areas relate pain when standing); 5) for walking exercises to swing through the splinted lower extremities with the oblique abdominal muscles. Also nonparaplegic patients report a substantial subjective gain of mobility when long rod instrumentations are replaced by the FI (Figure 11).

**Anatomical Reduction**

The second advantage of the FI besides its shortness are the long handles and lever arms of the Schanz screws facilitating the anatomic reduction of the fracture. The continuous threads on the rods instead of the discontinuous ratchet steps of the Harrington distrac-
Angled bone analysis of the instrumented vertebrae (degrees)

**Fig. 4.** The instrumented spine of a 44-year-old male patient with severe fracture-dislocation of L1, who died on the 17th day (embolism), was submitted to an anterior bending moment. The angle of kyphosis between D12 and L2 was measured. The pure elastic deformation was 2.4 degrees under load of 47.5 Nm. After removal of the FI rods complete disruption of the specimen occurred at 9 Nm.

**Independence from Type of Lesion**

FI instrumentation can be applied as well in simple wedge-compression fractures as in incomplete and complete burst fractures, Chance fractures, rotational slice fractures, fracture-dislocations, and pure dislocations. Its biomechanical function makes it independent of intact longitudinal ligaments or of the condition of the posterior elements and of the posterior wall (Figure 13). Even after a previous wide laminectomy (which is only rarely indicated but not uncommonly found in referred patients), the lack of posterior elements does not influence the way of application (Figure 14): the same two-segmental positioning of the Schanz screws is even easier to perform because the remnants of the pedicles can be visualized directly beside the dura. In such cases a posterolateral fusion of the instrumented area is done at the same time. The device is removed after 12 to 15 months in these patients.

**Lack of Iatrogenic Loss of Lumbar Lordosis**
Solid Fixation

The pedicle is the strongest part of a vertebra and, like all transpedicular screws, the Schanz screws get a very firm anchorage. Patients without neurologic impairment can ambulate 3 to 5 days postoperatively; paraplegic patients are allowed to sit in the wheelchair after 1 or 2 weeks. Most patients receive a light-weighted brace of the Jewett-type for 8 weeks; no full plaster or plastic jacket is used. Where the FI instrumentation has a pure tension-band function with dorsal compression (chance fractures, pure luxations, "fracture-dislocation en carrier d’orange"), no external support at all may be used.

Special Considerations

Because of the high bending forces acting on the short part of the Schanz screws outside the pedicle in reduced wedge-compression or burst fractures, attention has to be paid to the loss of bone stock anteriorly to avoid fatigue fractures of the Schanz screws. Therefore, a direct anterior repair simultaneously with the FI instrumentation from the same posterior approach is strongly recommended. One or both pedicles of the fractured vertebra are opened up with a 6-mm drill bit, as Daniaux has described (Figure 16). Through this canal, the defect in the vertebral body can be filled with small pieces of autologous cancellous bone using a funnel and a slightly curved impactor (Figure 17). The funnel must reach the vertebral body itself to protect the canal from intrusion of bone graft particles through potential lesions of the pedicle. Another way of access to all distraction rods even if they are square-ended and bent into lordosis, is avoided (Figure 15).

Easy Removal

In case of complications or implant removal after fracture healing, the posterior approach makes reinterventions easy in contrast to anterior procedures. The implant is removed by unscrewing the Schanz screws grasped on their overstanding part with a special
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