Changes in the loads on an internal spinal fixator after iliac-crest autograft

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Spines are often stabilised posteriorly by internal fixation and anteriorly by a bone graft. The effect of an autologous bone graft from the iliac crest on implant loads is unknown. We used an internal spinal fixation device with telemetry to measure implant loads for several body positions and activities in nine patients before and after anterior interbody fusion. With the body upright, implant loads were often higher after than before fusion using a bone graft. Distraction of the bridged region led to high implant loads in patients with a fractured vertebra and to marked changes in load in those with degenerative instability. Leaving the lower of the bridged intervertebral discs intact led to only small changes in fixator load after anterior interbody fusion. A bone graft alone does not guarantee a reduction of implant loads.

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We have compared the fixator loads before and after anterior interbody fusion in several body positions and activities including standing, walking and lying supine.

Patients and Methods

We implanted modified internal spinal fixators into nine patients (Table I) and in a second session performed anterior interbody fusion (AIF) using one or two bone grafts from the iliac crest. Bisegmental fixators were used in all cases. There were six patients with a compression fracture of a vertebral body and three with a degenerative instability. The L4 vertebra was bridged three times, the L1 and L3 twice each and the T11 and T12 once each. The bridged region was distracted during implantation in four patients, distracted with increased lordosis in two, and compressed in one, while in two only the lordosis was increased. Four patients (cases 3, 5, 8 and 9) had only the upper bridged disc removed while the lower one was left intact. In one patient (case 7) a Zielke fixator was additionally implanted ventrally during AIF. The surgical procedure was explained to the patients beforehand, and they gave their written consent to implantation of instrumented internal fixation devices and subsequent measurements.

Instrumented fixator. We modified the bisegmental internal spinal fixator described by Dick in order to measure the loads acting on it. A measuring cartridge containing six load sensors, a telemetric unit and a coil for the inductive power supply was integrated into the longitudinal rod (Fig. 1). This modified implant allowed measurement of three force components and three moments acting on the fixator. We used a flat coil and a small antenna placed on the patient’s back to activate the paired spinal implants. The patient was videotaped during measurements, and the load-dependent signals of both fixators were stored on videotape together with the images. The implant loads were calculated from the telemetric signals and shown online on a computer monitor during the measurements. The instrumented implant, the telemetry system, the external equipment, and the accuracy of the device have been described in detail elsewhere.

Measurements. Initial measurements were made soon after implantation of the fixators and were then repeated about two weeks after the second operation. The loads
were measured once or twice a week during hospitalisation and then about once a month until removal of the implant. We compared implant loads measured a few days before AIF and up to 130 days thereafter when lying supine, standing and walking. Previous measurements\(^5\) had shown that the axial force and the bending moment (\(M_{b,sag}\) (flexion bending moment)) in the sagittal plane are the most important load components and these were chosen for comparison. A negative axial force component was evoked by compres-

### Results

Figure 2 shows loads measured before and after AIF in the left and right fixator of the nine patients when walking and lying in a supine position. Medians are given for the axial compression force and flexion bending moment measured in the sagittal plane of each fixator during several sessions. For walking, ten of the 18 fixators had a higher flexion bending moment and 11 a higher axial compression force after than before AIF. Similar results were found for standing. The maximum values and the changes in load were much smaller when lying supine than when walking or standing. There was no recognisable trend concerning an increase or decrease in fixator loads within the time periods chosen. In most cases implant loads changed only slightly between the second operation and removal of the implant.

Table II shows the maximum bending moments measured in the left and right fixator of the nine patients before AIF and the changes due to AIF. Bending moments were divided into several groups. When lying supine they were low before AIF in all cases. Compression of the bridged region (case 2) led to low bending moments in flexion on the fixators and small load changes after AIF. Increasing lordosis alone (cases 8 and 9) gave medium bending moments in the implants. Distracting the bridged region caused low to medium flexion bending moments in the fixators for the patients with degenerative instability (cases 1, 4 and 6) and high implant loads for those with a
fractured vertebral body (cases 3, 5 and 7). The increase in the load caused by inserting bone grafts was often very high in the patients with degenerative instability. Anterior placement of an additional Zielke fixator (case 7) significantly reduced fixator loads for standing and walking.

The level of the bridged vertebra had no obvious influence on the average flexion bending moment measured in the fixators (Fig. 3). In four of the nine patients, the lower of the two bridged intervertebral discs was kept intact. Figure 4 compares the two groups for flexion bending.

Table II. Maximum flexion bending moments in the fixators (left; right) before anterior interbody fusion (AIF) and changes in bending moments due to AIF

<table>
<thead>
<tr>
<th>Case</th>
<th>Indication</th>
<th>Number of bone grafts</th>
<th>Distraction</th>
<th>Compression</th>
<th>Lordosis increased</th>
<th>Maximum bending moment before AIF, supine position*</th>
<th>Maximum bending moment before AIF, walking*</th>
<th>Changes in bending moment due to AIF, supine position†</th>
<th>Changes in bending moment due to AIF, walking†</th>
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<tbody>
<tr>
<td>1</td>
<td>Degenerative instability</td>
<td>2</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
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<td>L; L</td>
<td>++; +</td>
<td>0; -</td>
</tr>
<tr>
<td>2</td>
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<td>1 (large)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>VL; L</td>
<td>VL; M</td>
<td>++; ++</td>
<td>++; +</td>
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<td>Yes</td>
<td>No</td>
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<td>M; H</td>
<td>++; ++</td>
<td>++; +</td>
</tr>
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<td>Degenerative instability</td>
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<td>Yes</td>
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<td>H; H</td>
<td>++; ++</td>
<td>++; +</td>
</tr>
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<td>2</td>
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<td>Yes</td>
<td>No</td>
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<td>L; L</td>
<td>++; ++</td>
<td>++; +</td>
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<tr>
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<td>Yes</td>
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<td>No</td>
<td>VL; L</td>
<td>L; L</td>
<td>++; ++</td>
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<td>Fracture</td>
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<td>++; ++</td>
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<td>9</td>
<td>Fracture</td>
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<td>Yes</td>
<td>No</td>
<td>VL; L</td>
<td>M; M</td>
<td>++; ++</td>
<td>++; +</td>
</tr>
</tbody>
</table>

* VL, very low (< 1 Nm); L, low (1 to 3 Nm); M, medium (3 to 5 Nm); H, high (5 to 7 Nm); VH, very high (>7 Nm)
† ---, < -4 Nm; -, -2 to -4 Nm; -, -0.3 to -2Nm; 0, -0.3 to 0.3 Nm; +, 0.3 to 2 Nm; ++, 2 to 4 Nm; ++++, >4 Nm
moments before and after AIF. When one disc was left in place, the flexion moments were mostly relatively high before AIF, and the load changes were small. The range of loads measured after AIF and the load changes due to this procedure were much greater after both discs had been removed.

Discussion

Fixator loads are normally altered by AIF. The flexion bending moment and axial compression force on the implants are increased by AIF in some cases, and decreased in others. Distraction of the bridged region led to high fixator loads or a considerable increase in these loads because of AIF. Harms and Stoltze normally begin the operation with ventral release and restoration of the pressure loading of the ventral column followed by dorsal tension-band instrumentation. This prevents high implant loads by minimising deformation in the bridged region. It also allows the use of relatively thin implant rods without a risk of breakage.

AIF led to a high increase in load in patients with degenerative instability who required distraction of the bridged region during implantation. The intervertebral space was opened during the second intervention by lowering the foot end of the operating table and inserting two bone grafts very precisely with a hammer in all three cases. After AIF, the load transfer in the posterior part of the spine was probably reduced by distraction. One of the three patients with degenerative instability (case 1) developed pseudarthrosis, and another (case 4) had a broken pedicle screw 11 weeks after AIF. The use of two bone grafts may have reduced the stability of the bridged vertebra and
contributed towards the large increase in load in these cases.

One patient (case 7) had an additional fixator implanted anteriorly since the spinal curvature could not be re-established during implantation of the dorsal fixators. The use of the anterior fixator led to a marked decrease in loads during standing and walking.

In cases in which AIF greatly increased the implant loads for standing and walking, relatively low loads were found when lying supine. This indicates that the bridged region was less stiff in these patients after than before AIF. Stiffness of the bridged region was reduced by AIF in patients with degenerative instability but increased in those with a fractured vertebra and high pre-AIF implant loads owing to distraction of the bridged region during implantation of the fixators. When one of the bridged intervertebral discs was kept intact in the patients with a fractured vertebral body, the loads before AIF were mostly relatively high. The load changes owing to AIF were frequently relatively low in these cases. The bending moment was smaller after AIF in four of the eight fixators. Load changes (e.g. during walking) in the intact bridged disc are lower than normal.

Three patients wore a Boston overlap brace during some of the measuring sessions but it has been shown that a brace has only a negligible effect on implant loads. The authors appreciate the friendly cooperation of their patients. We thank Dr. Weirowski for editorial assistance. The work was supported by the German Research Society (Ro 581/7-2).

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References