

AUGMENTATION OF VENTRAL DEROTATION SPONDYLODESIS ACCORDING TO ZIELKE WITH DOUBLE-ROD INSTRUMENTATION PRELIMINARY REPORT ON TWO-YEAR RESULTS OF THORACOLUMBAR CURVES

H. HALM, U. LILJENQVIST, W. H. M. CASTRO, J. JEROSCH

The advantages of VDS according to Zielke with excellent 3-dimensional correction and shorter fusion levels in comparison to posterior instrumentation techniques are well known. A disadvantage is the necessity of long postoperative immobilization in a body cast or brace due to lack of primary stability. The aim of the VDS double-rod instrumentation is augmentation of the system with the possibility of postoperative treatment without plaster cast or braces.

Following thoracolumbophrenotomy and ligation of the segmental vessels double-hole vertebra clamps are inserted. First VDS screws are placed in the posterior holes of these plates. With a 4-mm threaded compression rod correction is obtained by centripetal compressive forces on the nuts. Next VDS screws for the 5-mm threaded rod are inserted into the anterior holes of the vertebra clamps. The rod is implanted in a slightly compressive manner and augments the system. In a prospective study 8 patients, 4 with idiopathic and 4 with neuromuscular scoliotic deformities, underwent this surgical procedure and now have a follow-up of 2 years. Curves ranged from 45° to 131° Cobb angle. All patients were treated without plaster casts or braces postoperatively, but with only a semielastic vest for 4 to 6 months.

Unusual intra- and postoperative complications have not been noted. Correction of the primary curve averaged 69.4% at follow-up. Tilt of the caudal end vertebra was corrected 75% to an average of 6.3°. Spontaneous partial correction of the upper secondary curve was noted in all cases. Rod fracture of the 5-mm rod without fracture of the 4-mm rod at this level was seen in 1 patient without loss of correction. Solid fusion was achieved at every level in all patients. The sagittal plane was not adversely affected by the instrumentation.

However, larger patient numbers and a longer follow-up are necessary.

Keywords : scoliosis ; VDS ; Zielke ; augmentation.

Mots-clés : scoliose ; rachisynthèse antérieure ; augmentation.

Advantages of ventral derotation spondylodesis (VDS) according to Zielke in comparison to Harrington instrumentation (HI) are the better 3-dimensional correction of the deformity and shorter fusion levels (6, 8, 10, 11, 15, 18). A disadvantage is lack of primary stability, which makes brace treatment necessary for a period of 4 to 8 months (6, 18). With Cotrel-Dubouset instrumentation (CDI) primary stability and good frontal and sagittal plane correction are obtained, but derotational capacities of this implant have led to controversy (5, 9, 12). In order to optimize the advantages of VDS, attempts at augmentation seemed to be justified, especially since newly developed primary stable posterior systems following HI, especially CDI using hooks could not save additional fusion levels in comparison to HI (8, 13).

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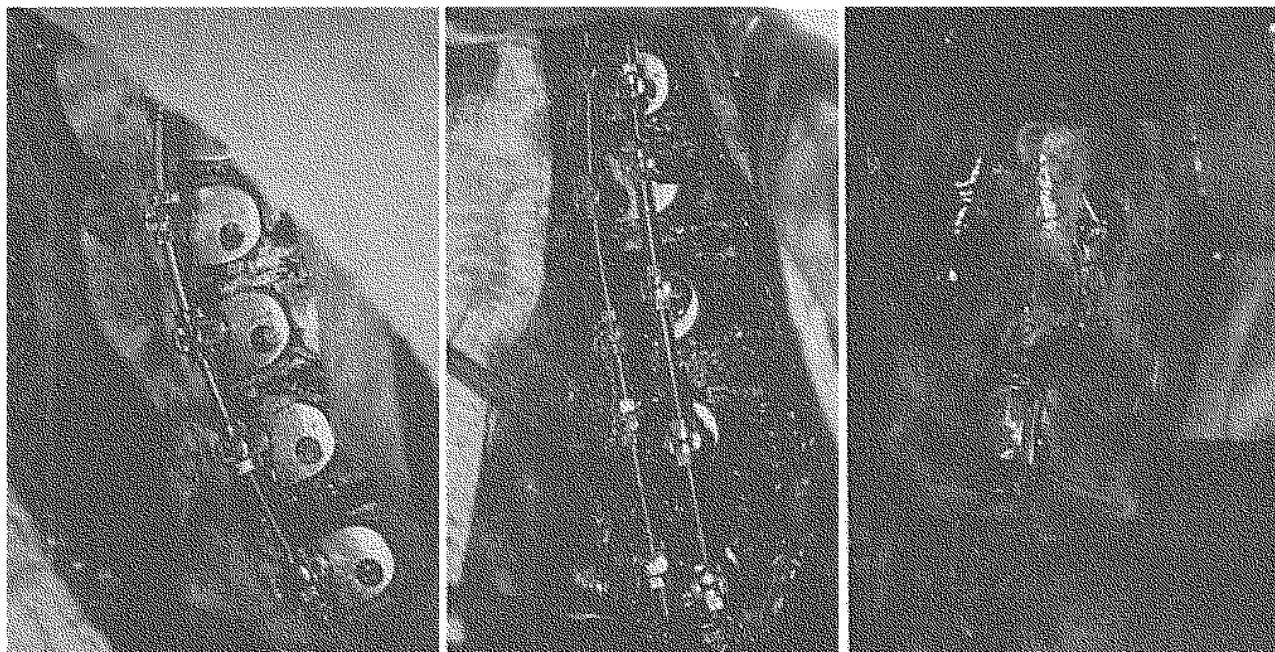


Fig. 1. — Principles of VDS double-rod instrumentation. Insertion of VDS screws into the posterior holes of the double-vertebra plates. Correction is achieved with a 4-mm threaded rod by centripetal compressive forces on the hexagonal nuts. The second anteriorly placed rod augments the system. Pleura finally covers the implant.

MATERIALS AND METHODS

Double-hole vertebra clamps are attached to the lateral part of the vertebral body at the convexity of the curve from end to end vertebra. First VDS screws are placed in the posterior holes of these clamps. Using a 4-mm threaded compression rod, correction is obtained by centripetal compressive force to the hexagonal nuts. The sagittal plane is controlled by correct positioning of these screws in the posterior part of the vertebral body parallel to the posterior longitudinal ligament and solid autologous rib or iliac crest grafts in the intervertebral space. After correction of the curve VDS screws for a 5-mm threaded rod are inserted into the anterior holes of the double-hole plates. The second rod is implanted afterwards and augments the system. Both rods are tightened to the screws with a counter hexagonal nut at each level (7) (fig. 1).

In a prospective clinical trial 8 patients with thoracolumbar scoliosis, 4 with idiopathic and 4 with neuromuscular etiology, ranging from 45 to 135° Cobb angle, underwent VDS double-rod instrumentation (DVDS) and have a sufficient follow-up of at least 2 years. All patients were treated postoperatively without braces or casts, but rather using only a semielastic vest during

the day for a 6-month period. Clinical and radiological data have been obtained pre- and postoperatively. Frontal and lateral standing radiographs were analyzed pre- and postoperatively and at 2-year follow-up. Primary and secondary curves were analyzed in the frontal plane. Curve flexibility was measured on preoperative bending films. For the sagittal plane thoracic kyphosis was measured between T4 and T12, lumbar lordosis between L1 and L5 and the thoracolumbar junction between T10 and L2. If possible the thoracolumbar junction was divided into an upper junction (T10-L2) and a lower junction (T12-L2), but this was impossible for the severe neuromuscular curves. Intra- and postoperative complications were analyzed as well.

RESULTS

Idiopathic thoracolumbar scoliosis

Curves ranged from 45 to 55° Cobb angle with a mean of 50°. Length of the primary curve was 4.75 segments (4 to 5 segments). Length of the fusion was slightly shorter with 4.5 segments (4 to 5 segments), because bending films demon-

strated that in one case instrumentation and fusion could be carried out one segment short of the cranial end vertebra. The primary curves corrected to an average of 21.7° (16 to 28°) on the bending films (56.6% correction). Postoperatively the curves averaged 13° (10 to 14°) and at follow-up after 2 years 15.3° (69.4% correction).

The secondary caudal curve had a mean of 28.3° (16 to 36°) preoperatively, showed an average correction of 81.7% on the bending films, and it measured 13.3° at follow-up. The tilt of the caudal-end vertebra averaged 25° preoperatively and 6.3° at follow-up.

The secondary cranial curve measured 33.1° (20 to 41°) and corrected to a mean of 23.4° on the bending films. Postoperatively the curves showed a spontaneous correction to 22.1° (10 to 33°) and measured 24.9° (9 to 38°) at follow-up (fig. 2).

The sagittal plane was not changed much at the instrumentation site (thoracolumbar junction) and was within physiological ranges of $+10^\circ$ to -10° Cobb angle pre- and postoperatively. In particular no kyphogenic effect due to instrumentation was noted. In one patient kyphosis was increased slightly at the upper thoracolumbar junction between T10 and T12, but this was intentional because of thoracic hypokyphosis above.

Intraoperative blood loss averaged 670 ml (530 to 790 ml) Blood transfusion was not necessary

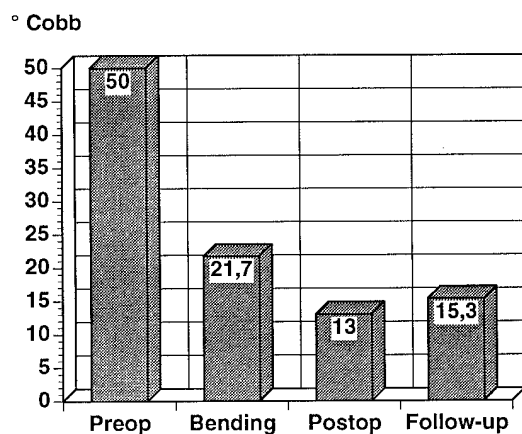


Fig. 2. — Mean angles of the primary curve of the idiopathic scoliosis patients preoperatively, on the bending films, postoperatively and at follow-up.

intra- or postoperatively in any of the 4 cases. Intra- and postoperative complications were not noted (fig. 3).

Neuromuscular thoracolumbar scoliosis

These primary curves were much more severe, measuring 101.6° Cobb angle (53 to 131°) on the average and had a mean length of 6.5 segments. On stress bending films a mean correction to 79.7° was seen. Instrumentation averaged 7 segments. In one of these cases double-rod instrumentation ended 2 segments below the upper fusion level, because these 2 vertebrae were too small to insert more than one screw. But because this was above T11, the cast- and brace-free postoperative regimen was not changed. Postoperatively the primary curves measured 27.3° (73.1% correction) and at follow-up 29.6° (70.9% correction).

The upper secondary curve measured 53° preoperatively and was corrected to 39° on bending films. It showed a spontaneous correction to a mean of 21.6° postoperatively and measured 22.7° at follow-up (fig. 4).

For the sagittal plane, preoperative analysis was impossible in 2 patients because of the severe deformity. In another patient the preoperatively physiological thoracolumbar junction was not changed postoperatively, whereas the third patient had junctional kyphosis of $+30^\circ$ preoperatively, which was corrected to a lordosis of -6° Cobb angle. In this patient, however, lumbar lordosis decreased from -45° preoperatively to -26° at follow-up.

Compared to idiopathic scoliosis patients blood loss was higher in this patient group, averaging 1630 ml (1150 to 2350 ml). Two patients received blood transfusions of 2 units each. Postoperatively a moderate pleural effusion was seen in one patient, but this resolved spontaneously.

In one patient breakage of the 5-mm threaded rod was noted at the most cranial and caudal segment 12 months postoperatively. However, the 4-mm threaded rod was intact and there was solid fusion with no loss of correction. The patient suffered from cerebral palsy with epileptic episodes. No other implant failures have been noted at the 2-year follow-up (fig. 5).

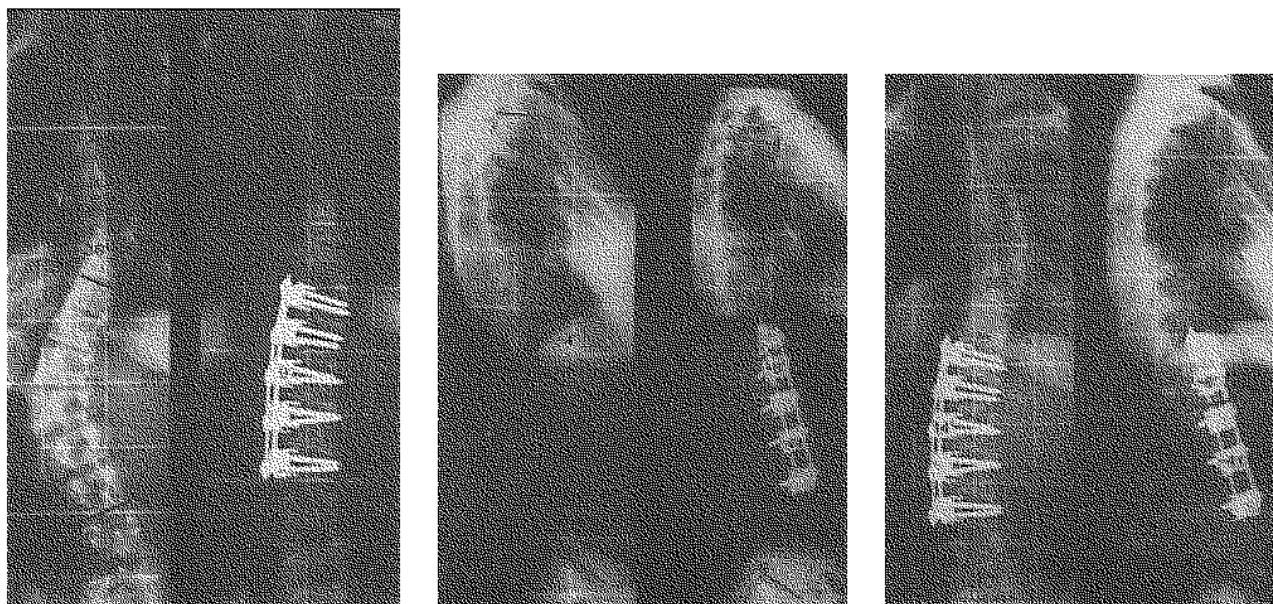


Fig. 3. — A 15-year-old girl with idiopathic thoracolumbar scoliosis of 50° Cobb angle with associated thoracic hypokyphosis. Instrumentation was performed one segment short of the upper-end vertebra and correction was achieved to 9° postoperatively. Spontaneous partial correction took place for the upper compensatory curve to the level of the bending film. At follow-up there was no loss of correction at the instrumentation site or for the secondary curves. Slight gapping (adding on) of the disc spaces L3/4 and T11/12 led to spinal compensation. Physiological sagittal plane.

DISCUSSION

With the evolution of CDI and its primary stable fixation an ever increasing number of scoliotic deformities have been treated from the posterior approach alone. Whereas frontal and

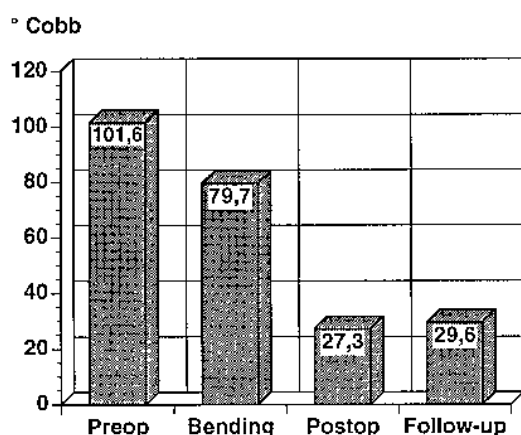


Fig. 4. — Mean angles of the primary curve of the neuro-muscular scoliosis patients preoperatively, on the bending films, postoperatively and at follow-up.

sagittal plane realignment have been reported to be good (2, 5, 9) derotational capacities have been discussed differently. Cotrel *et al.* (5) and Hopf (9) noted good derotational abilities of CDI, but Krismer *et al.* (12) did not find much derotation.

However, single thoracolumbar and lumbar curves have been reported to be the ideal indication for VDS (1, 6, 8, 10, 11, 15, 18). Fusion length in idiopathic scoliosis normally ranges from the opposite end vertebrae, and it is shorter compared to posterior instrumentation systems using hooks. Additionally frontal and rotational plane correction is better due to anterior release by disc resection (17). The influence of VDS on the sagittal plane has been discussed differently in the last years. Whereas some authors found a tendency to produce or increase kyphosis (11, 15, 17), others stated that the influence on this plane is also good (6, 8, 18). Moskowitz *et al.* (14) found a mild kyphogenic effect from the instrumentation, however without significant adverse influence on the sagittal plane. Bridwell (3) noted that placing structural allografts in the anterior concave por-

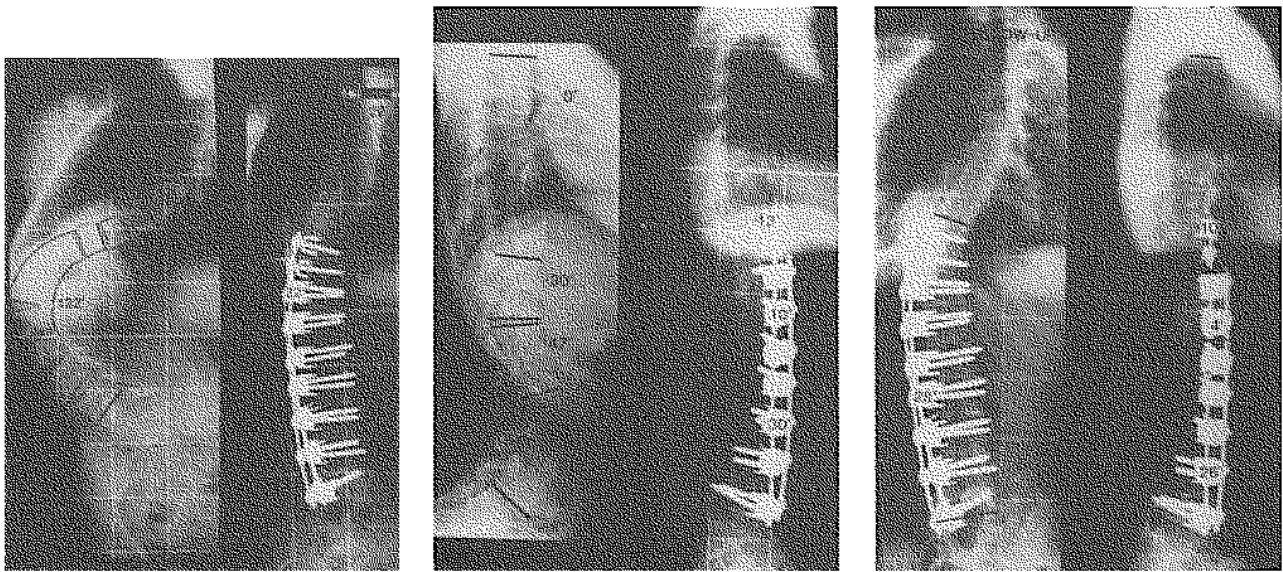


Fig. 5. — A 16-year-old girl with severe thoracolumbar scoliosis and spinal decompensation due to cerebral palsy. Correction was achieved up to 75° on stress bending, as well as good correction of the primary curve postoperatively and at follow-up with spinal compensation. Spontaneous correction occurred for the upper compensatory curve from 60° preoperatively to 22° postoperatively which is stable at follow-up. Therefore there is no indication for inclusion of this curve into the fusion mass.

tions of the disc spaces before closing them down with VDS preserves and in some cases even enhances lumbar lordosis. In our opinion sagittal plane control is possible in patients with rotational thoracolumbar and lumbar kyphosis. Following Zielke's rules and placing the screws in the very posterior part of the vertebral bodies parallel to the posterior longitudinal ligament and using solid autologous rib grafts in the intervertebral spaces almost spontaneously leads to a significant decrease in pathological kyphosis during curve correction. The pathological mechanism and treatment of rotational kyphosis with VDS has been well described by Zielke himself (18).

A disadvantage of VDS is lack of primary stability, which justified the search for augmentation. It is important to point out that the principles of curve correction have not been changed with the method of double-rod instrumentation. Therefore all the advantages of VDS have been maintained, which is demonstrated by the good results of this study in terms of curve correction. The surgical procedure therefore still is a VDS. But the anteriorly placed second 5-mm threaded rod leads to a significant increase in

stiffness. In a preclinical, biomechanical study using an artificial spine model with CAD-CAM designed aluminum alloy vertebrae we analyzed the comparative stiffness of VDS with a 4-mm threaded rod and the DVDS described prior to its clinical use (fig. 6).

In this biomechanical study comparative load-deflection curves of VDS and DVDS were obtained to evaluate the stiffness of both implants under axial compression, flexion, lateral bending and torsion on an electromechanical material-testing apparatus, type Zwick 1445. For measurement of flexion and lateral bending a moment arm of 3 cm and for measurement of torsion a moment arm of 8 cm was used. The stiffness coefficient was defined as the ratio of the load applied to the spine divided by the intervertebral motion produced (N/mm, Nm/ $^\circ$). These multidimensional stability tests provide important information on the stabilizing capabilities of a new implant.

The results of this biomechanical study are shown in fig. 7 and 8. It is clearly shown that DVDS leads to a significant increase in stiffness in all relevant planes. In our opinion these results justified treatment of the patients with only a semi-

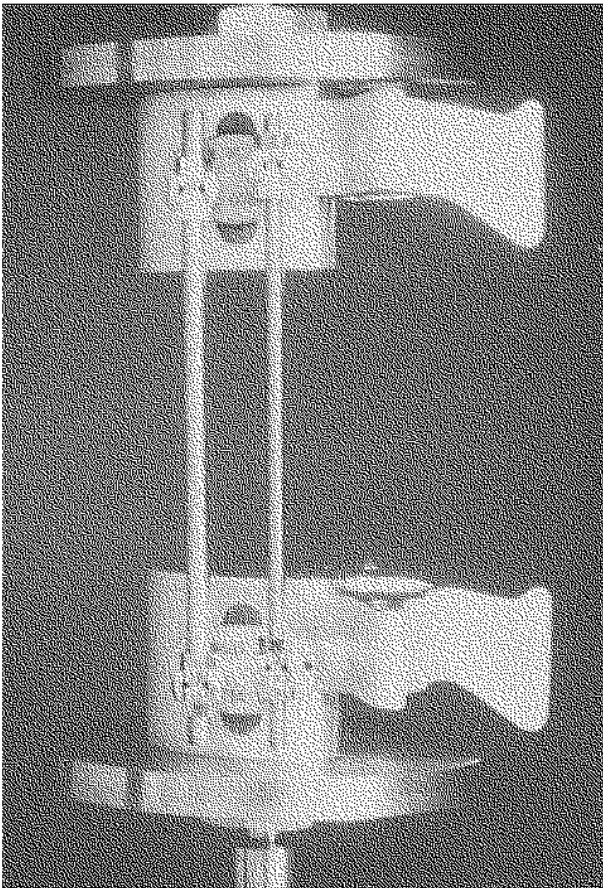
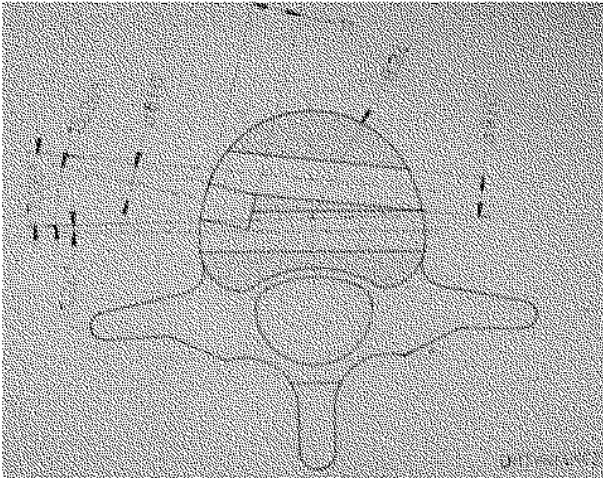


Fig. 6. ... Computer-added design (CAD) of a vertebra model for DVDS. For VDS only one screw hole was used in the posterior part of the vertebrae parallel to the posterior wall. Instrumentation is shown of the computer-added manufacturing (CAM) aluminium alloy vertebrae model with DVDS, which is mounted in axial compression. For VDS instrumentation a single 4-mm threaded rod was used.

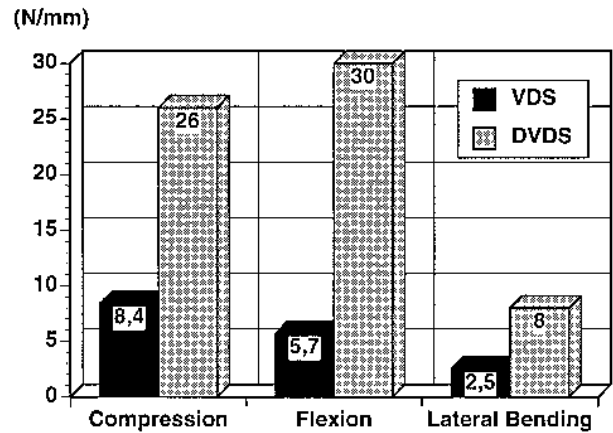


Fig. 7. — Comparative stiffness of VDS and DVDS in compression, flexion and lateral bending.

flexible vest during the day for 6 months instead of using a body cast or orthosis day and night. In one patient we found fractures of the 5-mm threaded rod 12 months postoperatively at the most cranial and caudal levels, leaving the 4-mm rod intact. This patient suffered from cerebral palsy and epileptic episodes, and postoperatively she fell quite often. The rod must have broken some time between 6 and 12 months postoperatively after discontinuation of the vest. There was no loss of correction at the 12-months and 24-months follow-up with solid fusion at these levels. Fractures of threaded rods without loss of correction have been reported earlier in VDS studies, and no loss of correction was seen after consolidation of the intervertebral fusion mass. On the other hand this finding retrospectively justifies the caution of using a vest during the day for 6 months postoperatively, which we still recommend.

However, postoperative management is much easier after DVDS instrumentation for both physician and especially the patient. We do not think that an anterior instrumentation system only using rigid rods is as universal as VDS for thoracolumbar curves, because rod rotation as an adaptation of posterior CDI principles is impossible in severe curves, and in-situ bending is associated with a risk of screw pullout at the bone-metal interface. However, good results have been reported for moderate thoracolumbar and lumbar curves with the TSRH anterior system (14), which has trans-

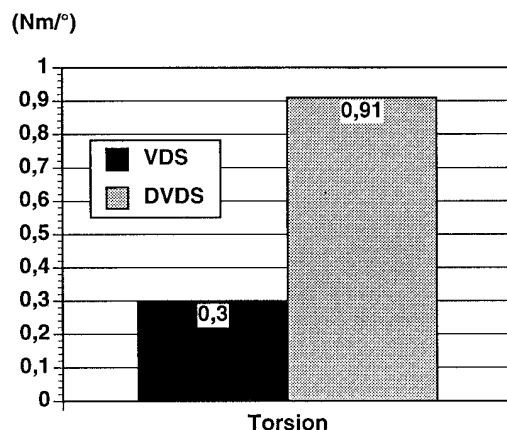


Fig. 8. — Comparative torsional stiffness of VDS and DVDS.

ferred the posterior CDI correcting principles of rod rotation to the anterior part of the spine.

In conclusion, we have found that augmentation of VDS is justified in patients with thoracolumbar and lumbar spinal curvatures, if anterior instrumentation is indicated. This is especially true in patients who have a high risk of skin ulceration due to postoperative plaster cast and brace treatment, especially those suffering from myelodysplasia. However, we would like to point out that this study still represents a preliminary report with a limited number of patients and a follow-up of two years. Larger patient numbers and a longer follow-up are necessary for further conclusions.

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SAMENVATTING

H. HALM, U. LILJENQVIST, W. H. M. CASTRO, J. JEROSCH. *Augmentatie van de VDS volgens Zielke met dubbelstaafimplantatie met een follow-up van twee jaren.*

De voordelen van de VDS (Ventrale Derotatie Spondylodese) volgens Zielke met excellente 3-dimensionele correctie en minder wervelsegmenten die verstijfd dienen

te worden, zijn algemeen bekend. Een nadeel is de noodzakelijke postoperatieve lange immobilisatie in een korset tengevolge van het ontbreken van primaire stabiliteit. Doel van de beschreven VDS-operatie met 2 staven is een augmentatie van het reeds bestaande systeem. Dientengevolge kan postoperatief een korset nabehandeling onnodig worden.

Na het verrichten van een thoracolumbophrenotomie en ligeren van de segmentale vaten worden 2 gatsplaatjes aan het wervellichaam verankerd. De eerste VDS-schroeven worden door de posteriore gaten van deze plaatjes in het wervellichaam geschroefd. Middels een 4 mm compressiestaaf met schroefdraad wordt een correctie d.m.v. de centripetale compressie krachten op de schroeven verkregen. Vervolgens kunnen VDS-schroeven door de anterieure gaten van de plaatjes in het wervellichaam gedraaid worden. Deze schroeven worden met elkaar verbonden door een 5 mm staaf met schroefdraad. De staaf wordt met geringe compressieve krachten geïmplanteerd en augmenteert het systeem. In een prospectieve studie werden 8 patiënten, vier met een idiopatische en vier met een neuromusculaire skoliotische deformiteit, op bovenstaande wijze geopereerd. De follow-up bedroeg twee jaren. De skoliose curve volgens Cobb varieerde van 45° tot 131°. Alle patiënten werden zonder korset gemobiliseerd.

Ernstige intra- en postoperatieve complicaties werden niet gezien. De correctie van de primaire curve bedroeg gemiddeld 69,4%. De tilt van de caudale eindwervel kon om 75%, tot een gemiddelde van 6,3° gecorrigeerd worden. Een spontane partiële correctie van de bovenste secundaire curve werd bij alle patiënten gezien. Een breuk van de 5 mm staaf werd bij 1 patiënt geobserveerd; echter zonder verlies van correctie. Een solide fusie gebeurde in elk segment bij alle patiënten. Het sagittale vlak werd niet beïnvloed door de operatie.

De resultaten van de „dubbelstaaf-VDS” geeft aanleiding tot de voorlopige conclusie, dat de voordelen van de VDS geoptimaliseerd kunnen worden door augmentatie van het systeem, met als gevolg een korsetvrije nabehandeling.

RÉSUMÉ

H. HALM, U. LILJENQVIST, W. H. M. CASTRO, J. JEROSCH. Augmentation de la rachisynthèse antérieure, avec dérotation, selon Zielke, par l'utilisation

d'une double tige. Rapport préliminaire au sujet des résultats à deux ans dans les courbures dorso-lombaires.

Les avantages de la rachisynthèse antérieure, avec dérotation, selon Zielke (VDS) sont généralement reconnus notamment en ce qui concerne la correction dans les trois plans avec un nombre limité de segments vertébraux ankylosés. Un inconvénient de la technique est la relativement longue immobilisation post-opératoire en corset, par suite de l'absence de stabilité primaire. Le but de l'addition de deux tiges longitudinales, à la technique originale de Zielke est d'améliorer la stabilité du système. Cet apport technique permet de se passer d'immobilisation post-opératoire en corset.

Après thoraco-lombo-phrénotomie et ligature des artères segmentaires deux petites plaques à deux trous sont fixées au corps vertébral. Les premières vis de VDS sont introduites dans le corps vertébral, par les trous postérieurs de ces plaques. À l'aide d'une tige de compression de 4 mm, avec pas de vis, on obtient une correction par les forces centripètes exercées sur les vis. Par la suite des vis VDS peuvent être introduites dans les trous antérieurs et réunies par une tige de 5 mm avec pas de vis. La tige est implantée avec une force de compression relativement faible et augmente la stabilité du système. Dans le cadre d'une étude prospective 8 malades, 4 porteurs d'une scoliose idiopathiques et 4 souffrant d'une scoliose neuro-musculaire furent traités selon cette technique. Le recul est de deux ans. La courbure scoliotique, évaluée d'après la technique de Cobb, varia de 45° à 131°. Tous les patients purent être mobilisés sans corset. On ne constata aucune complication pré- ou post-opératoire. La correction de la courbure primaire était en moyenne de 69,4%. La bascule de la vertèbre terminale distale peut être réduite de 75° à 6,3° en moyenne. Une correction partielle de la courbure secondaire supérieure fut observée chez tous les patients. Une fracture de la tige de 5 mm fut notée dans un cas, mais sans perte de correction. Une solide fusion osseuse fut constatée pour chaque segment chez tous les patients. L'intervention n'influença pas les courbures dans le plan sagittal. Les résultats obtenus à l'aide du matériel «double tige-VDS» permettent à l'heure actuelle de conclure que les avantages du VDS peuvent être optimisés par l'addition de 2 tiges, au point de pouvoir se passer d'immobilisation post-opératoire.