Hybrid instrumentation for correction of adolescent idiopathic scoliosis

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INTRODUCTION

Adolescent idiopathic scoliosis is a complex 3-dimensional musculoskeletal disorder characterized by lateral spine curvature in the coronal plane, thoracic hypo-kyphosis in the sagittal plane and vertebral rotation in the transverse plane. Epidemiologic studies show that 2 to 3% of the adolescent population is affected. However, less than 10% of these patients require treatment (19). Over the past years, surgery has mainly focused on correcting the coronal curve, but nowadays the aims of posterior fusion and instrumentation are to achieve a stable, well-balanced spine in the coronal as well as in the sagittal planes, prevent curve progression and also achieve solid fusion, whilst keeping the fusion as short as possible (30).

Without doubt, over the last few years the use of pedicle screws has gained in popularity, due to its perceived superior ability of curve correction in the coronal plane (25). However, clinical concern has...
focused on the safe application of these screws (7), especially at the thoracic level, mainly because the morphology of scoliotic thoracic vertebrae differs from that of the vertebrae in normal spines. Furthermore, although pedicle screws are highly effective, they have been associated with a potential decrease of the thoracic kyphosis (29). In sharp contrast, hybrid instrumentation is safer at the thoracic level, and leads to a satisfactory correction, not only in the coronal plane, but also in the sagittal plane (20). The purpose of this retrospective study was to report the outcome of surgical correction achieved by hybrid instrumentation in a single institution.

MATERIALS AND METHODS

Forty-three consecutive patients (14 males and 29 females), in whom a hybrid construct was used between 2000 and 2008, were retrospectively reviewed. The mean age of the patients at the time of surgery was 14.4 years (range: 10.2-18.1 years), and the minimum follow-up was 2 years (mean: 3.4 years; range: 2-9 years). The curves were evaluated according to the Lenke (16) classification system. There were no patients who had undergone previous spine surgery.

Standard 36-inch posteroanterior and lateral radiographs of the entire spine, taken with the patient standing, were used to measure coronal and sagittal parameters. The curves were measured using the Cobb technique. Radiographic analysis of the coronal plane included the major curve Cobb angle, translation of the apical vertebra as the distance in millimeters from the central sacral line to the mid-point of the apical body, and coronal balance as the distance between the C7 plumb-line and the center sacral vertical line. Spinal imbalance was recorded when the horizontal distance of the C7 spinous process from the center sacral line exceeded 2 cm. The minus (-) sign was used to express the translation or imbalance to the right and the plus (+) sign to the left. Sagittal plane parameters included: thoracic kyphosis measured from the superior endplate of T3 to the inferior endplate of T12, thoracolumbar junctional kyphosis measured from T10 to L2, and lumbar lordosis measured from the upper endplate of L1 to the upper endplate of S1. Positive values were used to indicate kyphosis and negative values to indicate lordosis. Patients were considered to have postoperative distal junctional kyphosis when the T10-L2 angle was greater than 10°. Normal values for thoracic kyphosis were 10°-40°. Overall, sagittal spinal balance was assessed as the distance between the C7 plumb-line and the anterior corner of the sacrum on an upright long lateral radiograph of the spine. Positive values indicated that the plumb-line was in front of the sacrum whereas negative values meant the opposite. Patients in whom C7 was within +2 cm or -2 cm from the anterior sacral corner were considered balanced in the sagittal plane.

The percentage correction was calculated using the following formula as described by Mielke et al (23):

% correction = [(preoperative value – follow-up value) / preoperative value] × 100. Measurements were performed before surgery, as well as immediately after surgery, one year postoperatively and at the last follow-up. All measurements were performed by a single observer.

Radiographic analysis also included the rigidity of the curves, based on preoperative left and right bending radiographs compared with the standing posteroanterior radiograph. Prior to all surgical procedures, intramedullary abnormalities or other causes of scoliosis were ruled out by MRI.

In addition, all patients had pulmonary function tests before surgery.

All patients underwent posterior spinal arthrodesis by means of hybrid instrumentation (hooks and wires proximally, pedicle screws distally) (Fig. 1) after a standard posterior midline incision. Thoracic exposure of the posterior elements of the thoracic spine was made to the tip of the transverse processes bilaterally. The number of vertebral segments to be fused was based on the curve type. Laminal, transverse process and pedicle hooks as well as wires were placed proximally while pedicle screws were inserted into the distal vertebrae. The uppermost hooks were always placed in a claw pattern. The pedicle screws were placed using a free hand technique. The correction was achieved using various techniques: derotation of the rod, cantilever reduction, translation and in situ rod bending. Finally, apical compression in the convexity and distraction in the concavity were carried out, in order to achieve additional correction in both planes, on the one hand, and on the other hand to restore the coronal balance. Arthrodesis included decortication of the laminae, cleaning of the facet joints and application of autografts and allografts. From 2002 on, the patients were constantly monitored via somatosensory and motor-evoked potentials. Autotransfusion was used. All patients were allowed to return to school within the first month postoperatively. They were also given an exercise protocol for a six month period till they returned to their preoperative daily activities.
Statistical analysis

The SPSS was used (ver. 13.0K, SPSS Inc., Chicago, IL). The Repeated Measures ANOVA was applied, and all measurements were compared with a paired t-test, using Bonferroni’s correction, in order to correct the probability at which the test was accepted. A p value < 0.05 was considered to be significant.

RESULTS

The most frequent curve type was Lenke type 1 (32 patients, 74.41%), followed by Lenke type 3 (4 patients, 9.3%). There were also 2 patients with Lenke type 2 (4.65%), one with type 4 (2.32%), 3 with type 5 (6.97%) and one with type 6 (2.32%).

As to kyphosis, 29 patients were normokyphotic (T3-T12, 10° to 40°), 8 hyperkyphotic (T3-T12, > 40°) and 6 hypokyphotic (T3-T12, < 10°).

The average number of levels fused was 14 (range: 6-15). The distal fusion level was T11 in 2 patients, T12 in 2, L1 in 9, L2 in 11, L3 in 8, L4 in 4 and L5 in 6. The average operating time was 270 ± 40 minutes and the mean intraoperative blood loss 930 ± 103 ml.

Coronal plane: the main coronal curve was 60.85° ± 21.1° (Table I), with a mean flexibility of 47.5%. The immediate postoperative Cobb angle was 24.21° ± 12.3° (Fig. 1a). This reduction of the Cobb angle averaged 60.2% and was statistically significant (p < 0.0001). The mean Cobb angle was 28.25° ± 10.5° at the 1-year follow-up (p < 0.0001), and 28.44° ± 11.9° at the final follow-up, still demonstrating a 53.3% correction (p < 0.0001). There was a loss of correction of 4.23° ± 0.4° between the early postoperative correction and the final follow-up. The mean coronal balance was -0.09 ± 19.9 mm preoperatively (range, -45 mm to 40 mm) with a postoperative mean value of 4.60 ± 15.6 mm (range, -30 mm to +33 mm) and of 4.44 ± 12.9 mm at final follow-up: all these corrections were not significant. The mean translation of the apical vertebra was corrected from -19.13 ± 49.9 mm (range, -140 to +81) preoperatively, to -5.07 ± 26 mm at the immediate postoperative evaluation (73% improvement, p < 0.04). At the last follow-up the mean translation of the apical vertebrae was -9.42 ± 28.9 mm (p < 0.021).

Sagittal plane: the mean preoperative thoracic kyphosis (Table II) was 24° ± 13° and it was corrected to 33.4° ± 7.5° immediately after surgery (Fig. 1b). This corresponded to a mean kyphosis correction of 39.2%. At 1-year follow-up, the mean kyphosis was 31.5° ± 7.2°. The final value was 30.7° ± 7.1°. None of these corrections was significant, but the kyphosis was improved. Changes in lumbar lordosis and sagittal balance were not significant. As to the thoracolumbar junction, patients were slightly kyphotic at the T10-L2 level with a mean of 4.86° ± 12.3°, which improved to -2.6° ± 7.51° postoperatively and remained within the same range at the last follow-up (-2.5° ± 6.1°). None of the patients developed proximal junction kyphosis during the follow-up.

The present study demonstrates that hybrid instrumentation satisfactorily corrects the curvature and that the correction is maintained in the long term.

COMPLICATIONS

No intraoperative complications were seen. Postoperative complications were noted in 4 patients (9.3%). Two of these had an infection, respectively after 10 days and after 2.5 years. Implant removal was necessary in the second case. Two other
patients needed extension of the fusion area, because of curve progression. Importantly, there were no neurologic complications or implant failures such as implant breakage or dislodgement. No pseudarthrosis was noted.

**DISCUSSION**

Some authors, such as King (13), feel that a good result can be obtained, independently of the implant system used, if certain guidelines are followed, for example about the correct fusion level. Nevertheless, the question which instrumentation system is most efficacious remains controversial (20).

**From multi-hook constructs to hybrid constructs (hooks or wires proximally and screws distally) to screw-only constructs**

A major advance, after the Harrington rod, was the Cotrel-Dubousset instrumentation, a dual-rod multi-hook system, which allowed a 48% correction and immediate mobilization of the patient (17). However in 1996, Hamill et al (8) compared lumbar hooks with lumbar pedicle screws and found that the latter were significantly more efficient. It is without doubt that lumbar pedicle screws offer greater lumbar curve correction and better maintenance of correction than hook constructs (1). This pleaded for a hybrid construct: thoracic hooks plus lumbar pedicle screws. Moreover, adding sublaminar wires to the thoracic hooks not only allowed for apical vertebra translation to a pre-contoured rod, but also increased the chest volume (32). Sublaminar wiring was further elaborated using the Universal Clamp posteromedial translation technique (22).

The hybrid construct was however challenged by the dual-rod pedicle screw-only construct. Suk et al (27) were among the first protagonists. Lehman et al (15) noted corrections from 50% to 68%, as a function of the scoliosis type, but admitted that the sagittal thoracic alignment decreased. Corrections of 62%, 66%, 68% and 76% have been obtained by other authors (1,11,14,24).

**Table I. — Measurements in the frontal plane**

<table>
<thead>
<tr>
<th></th>
<th>Preop. value (mean ± SD)</th>
<th>Postop. value (mean ± SD)</th>
<th>At 1 year (mean ± SD)</th>
<th>At final F.O. (mean ± SD)</th>
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<tbody>
<tr>
<td>Cobb (°)</td>
<td>60.85 ± 21.1</td>
<td>24.21 ± 12.3</td>
<td>28.25 ± 10.5</td>
<td>28.44 ± 11.9</td>
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<tr>
<td></td>
<td>p &lt; 0.0001</td>
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<td>Balance (mm)</td>
<td>-0.09 ± 19.9</td>
<td>4.6 ± 15.6</td>
<td>2.41 ± 14.5</td>
<td>4.44 ± 12.9</td>
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<tr>
<td>Apical translation (mm)</td>
<td>-19.13 ± 49.9</td>
<td>-5.07 ± 26</td>
<td>-7.42 ± 27.8</td>
<td>-9.42 ± 28.9</td>
</tr>
<tr>
<td></td>
<td>p &lt; 0.04</td>
<td>p &lt; 0.04</td>
<td>p &lt; 0.021</td>
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The symbol minus (-) means a shift to the right.

**Table II. — Measurements in the sagittal plane**

<table>
<thead>
<tr>
<th></th>
<th>Preop. value (mean ± SD)</th>
<th>Postop. value (mean ± SD)</th>
<th>At 1 year (mean ± SD)</th>
<th>At final F.O. (mean ± SD)</th>
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<tbody>
<tr>
<td>Kyphosis (°)</td>
<td>24 ± 13</td>
<td>33.4 ± 7.5</td>
<td>31.5 ± 7.2</td>
<td>30.7 ± 7.1</td>
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<td>Lordosis (°)</td>
<td>-47.47 ± -18.33</td>
<td>-39.51 ± -18.47</td>
<td>-41.66 ± -17.6</td>
<td>-37.35 ± -27.63</td>
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<tr>
<td>T10-L2 (°)</td>
<td>4.86 ± 12.32</td>
<td>-2.60 ± 7.51</td>
<td>1.00 ± 16</td>
<td>-2.50 ± 6.12</td>
</tr>
<tr>
<td>Sag. balance (mm)</td>
<td>-15.48 ± 45.47</td>
<td>-11.19 ± 39.34</td>
<td>-11.19 ± 39.3</td>
<td>-16.57 ± 37.75</td>
</tr>
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Hybrid or screw-only?

Kim et al.(11,12) compared both techniques and demonstrated significantly better major curve correction and pulmonary function in the all-screw patients. But sagittal balance, lowest instrumented vertebra, operative time and SRS-24 scores were not significantly different. Lowenstein et al.(20) came to comparable conclusions, but noted that the all-screw group demonstrated a significant decrease in kyphosis from 29.65° to 19.35°, a decrease which was not significant in the hybrid group (26.23° to 22.42°). The current study showed that hybrid instrumentation satisfactorily increased thoracic kyphosis T3T12, and that this correction was maintained. Other studies came to the same conclusion (20,26,29). Pedicle screws at the thoracic level may decrease the thoracic kyphosis (29).

So far, the all-screw construct seemed to be superior, exception made for the kyphosis. However, the aforementioned studies did not take into consideration the preoperative flexibility of the curve. Vora et al.(29) compared the correction of Lenke type 1 scoliosis, taking into account the flexibility of the curve preoperatively. They used the Cincinnati Correction Index (CCI), which was expressed as the ratio: postoperative correction (%) / preoperative flexibility (%). Pedicle screw fixation did not give a better correction and had a lordosing effect on the thoracic spine, so that there was no significant benefit in using an expensive pedicle screw system.

Safety is an other variable which pleads in favor of hybrid constructs. Di Silvestre et al.(7) drew the attention to the troublesome application of pedicle screws, especially in the thoracic spine, because the morphometry in scoliotic thoracic vertebrae differs from that of vertebrae in normal spines. Overall, the risks include neurologic injury, major vessel injury, violation of the pleura and increased radiation exposure during screw placement (6,9,10). Cadaver studies have reported frequent pedicle wall violations, between 12.5% and 43%, after thoracic pedicle screw insertion (2,6,18,28).

Pullout strength is one more variable which pleads for hybrid constructs. An experimental study, using vertebrae from human cadavers, demonstrated that the claw hook pattern in the thoracic spine exhibits a greater pullout strength than the pedicle screw construct (5): claws had an average pullout strength of 577 N and screws of 309 N. This is a strong advantage when the surgeon must deal with osteoporotic bone.

Limited cost is another advantage of hybrid constructs. The average cost of a hybrid construct is significantly lower than that of an all-screw construct. Kim et al.(11) reported a cost of 5.816 USD for 11.8 fixation points in their hook group versus 11.508 USD for 17.1 fixation points in their screw group (p < 0.001). This is probably why Winter et al.(31) recently challenged the extreme attention given to the percent of coronal curve correction, wondering whether a few more degrees of correction are enough to justify a construct that costs twice as much as a simple hook system and that increases the risk of damage to the spinal cord or major vessels.

In the present study, no functional score was used to evaluate patient outcomes and this is a weakness of the study.

REFERENCES