Influence of screw type on initial coronal and sagittal radiological correction with hybrid constructs in adolescent idiopathic scoliosis. Correction priorities

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KEYWORDS
Idiopathic scoliosis; Thoracic kyphosis; Posterior fusion; Hybrid construct; Monoaxial screws; Polyaxial screws

Summary

Background: Pedicle screw constructs for spinal instrumentation in patients with adolescent idiopathic scoliosis (AIS) are effective in providing coronal plane correction but can result in loss of kyphosis, which in turn can lead to loss of lordosis. Hybrid constructs have been found superior over pedicle screw constructs in terms of thoracic kyphosis restoration. In this study, our objective was to compare outcomes with monoaxial versus polyaxial screws in an AIS population treated with hybrid constructs.

Hypothesis: Monoaxial screws provide better correction in the coronal plane but result in loss of thoracic kyphosis, whereas thoracic kyphosis is preserved when polyaxial screws are used.

Material and methods: We retrospectively analysed data from 60 patients (mean age, 15 years) with Lenke 1, 2, or 3 AIS treated using a hybrid construct with self-retaining bilaminar hook claws cranially, pedicle screws between the last instrumented vertebra and T11 caudally, and sublaminar universal clamps between the two extremities of the construct. Monoaxial screws were used in the first 30 patients (MS group) and polyaxial screws in the next 30 patients (PS group). Student’s t test was performed to compare the two groups in terms of thoracic Cobb angle correction and T4-T12 kyphosis 3 months after surgery.

Results: No significant preoperative differences were found between the two groups. At last follow-up, the residual Cobb angle was significantly greater in the PS group than in the MS group (20.3° versus 15°) with a percentage of correction of 72.1% in the MS group versus 64.8% in the

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Introduction

The five main goals of surgery for adolescent idiopathic scoliosis (AIS) are to halt curve progression, to correct the deformity by achieving solid fusion, to improve the cosmetic appearance, to improve function, and to minimise the risk of developing degenerative disease in adulthood [1]. In patients with thoracic or thoraco-lumbar curves, the main strategy used to achieve these objectives is posterior spinal fusion and instrumentation.

Although the optimal posterior fusion strategy is still controversial [2,3], the need for achieving an overall satisfactory spinal balance in the sagittal plane and, more specifically, for correcting preoperative hypokyphosis, is more widely recognised [4–8]. Recently introduced techniques relying only on pedicle screws produce very good outcomes in terms of correcting the coronal curve and axial rotation, but may also diminish the thoracic kyphosis [9,10]. One of the consequences of loss of thoracic kyphosis is the development of unfavourable reciprocal interactions in the spinal segments above and below the fused segment. These interactions at the two extremities of the fused segment can result in iatrogenic hypokyphosis with a compensatory decrease in lumbar lordosis caudally [11] and in cervical lordosis cranially [12].

Another treatment option consists in a hybrid construct with pedicle screws at the caudal extremity, hooks at the cranial extremity, and hooks or sublaminar bands for the thoracic segment. Hybrid constructs have been reported to improve thoracic kyphosis while providing coronal correction similar to that obtained with all-screw constructs and having none of the potential risks associated with pedicle screw malposition in the thoracic spine [7,13,14].

The ability of hybrid constructs to restore kyphosis may vary with the type of material used. We hypothesised that monoaxial screws provided better correction in the coronal plane but resulted in loss of thoracic kyphosis, whereas thoracic kyphosis was preserved when polyaxial screws were used. The objective of this study was to evaluate thoracic kyphosis and curve correction in the coronal and sagittal planes after hybrid construct surgery for AIS using monoaxial screws versus polyaxial screws between T11 and the caudal extremity of the construct.

PS group. In the sagittal plane, the thoracic kyphosis was significantly greater in the PS group than in the MS group (26.6° versus 23°).

Discussion: This preliminary study shows that, even within a population managed using hybrid constructs, which are associated with less iatrogenic hypokyphosis, differences exist according to the technique used. The importance of sagittal spinal balance has been abundantly documented in the literature, and sagittal malalignment, particularly due to iatrogenic factors, is associated with poorer clinical outcomes in adults with spinal deformities. Therefore, there is a critical need to determine whether the treatment priority is optimal correction in the coronal plane or in the sagittal plane. We believe that the main focus should be sagittal plane correction, even at the expense of a slight decrease in coronal plane correction. Long-term studies are needed to confirm our preliminary findings.

Level of evidence: IV, retrospective case-series study.
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Material and methods

Study design and inclusion criteria

We conducted a retrospective single-centre study of 60 consecutive adolescents treated by a single surgeon for AIS (Fig. 1). Informed consent was obtained from the parents or legal guardians of each patient before study inclusion.

Inclusion criteria were AIS with a flexible Lenke 1, 2, or 3 curve and a thoracic Cobb angle greater than 45°, absence of neurological disorders or systemic disease before surgery, and normal spinal cord by magnetic resonance imaging (MRI). A baseline neurophysiological recording was obtained preoperatively in all patients to allow intraoperative evoked-potential monitoring. Exclusion criteria were a rigid curve requiring preliminary anterior disectomy, abnormalities by MRI or neurological evaluation, and an inability to obtain a baseline evoked-potential recording.

Figure 1 Preoperative full-spine posterior-anterior and lateral radiographs.
Monoaxial versus polyaxial screws in scoliosis treated with hybrid constructs

grafting was performed routinely using both autologous bone from the spinous processes and a synthetic bone substitute (Biosorb®, SBM, Lourdes, France).

Monoaxial tulip-top screws with the top connecting to the rod (Legacy™, Medtronic, Memphis, TN, USA) were used in the first 30 patients (monoaxial screw, MS group) and polyaxial screws attached to the rod by a lateral connector (PassLP®, Medicrea, Neyron, France) in the next 30 patients (polyaxial screw, PS group). In all 60 patients, titanium rods 5.5 mm in diameter were used.

Preoperative comparison of the two groups

The MS and PS groups were not significantly different for the preoperative values of the Cobb angle (53.6° and 56.7°, respectively), TK angle (19.6° and 17.8°, respectively), or LL angle (43.9° and 42.7°, respectively).

Data collection and radiographic evaluation

For each patient, full-spine posterior-anterior and lateral radiographs (EOS® system, EOS Imaging, Paris, France) were obtained in the standing position before surgery then 3 months after posterior fusion and instrumentation. The thoracic Cobb angle was measured on the posterior-anterior view, whereas T4-T12 kyphosis (TK) and L1-L5 lordosis (LL) angles were measured on the lateral view. All angles were measured manually by an independent observer.

Operative technique

Surgery was performed under general anaesthesia with the patient lying prone on a Jackson table and intraoperative evoked-potential monitoring, as described elsewhere and summarised briefly below [15]. After exposure of the spine via the posterior approach, a hybrid construct was fashioned with pedicle screws caudally (from T11 to the last instrumented vertebra), a self-retaining bilaminal clamp cranially, sublaminar Universal Clamps® (Zimmer, Bordeaux, France) at 3-6 levels in the concavity (after opening of the interlaminar spaces), and 1-2 bands in the convexity. The deformity was then reduced gradually over the involved vertebral levels by using pre-contoured rods and repeatedly applying tension to the Universal Clamps via the dedicated reduction tool permitting the application of postero medial translation forces at the apex of the curve (Fig. 2). Posterior

Table 1 Radiographic variables in the study patients. Asterisks indicate statistically significant differences.

<table>
<thead>
<tr>
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<th>Before surgery</th>
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<th>After surgery</th>
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<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Standard deviation</td>
<td>Mean</td>
<td>Standard deviation</td>
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<tr>
<td>Cobb angle</td>
<td>55.2</td>
<td>10</td>
<td>17.7*</td>
<td>7</td>
<td>&lt; 0.001</td>
<td></td>
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<tr>
<td>Thoracic kyphosis</td>
<td>18.7</td>
<td>8</td>
<td>24.8*</td>
<td>6</td>
<td>&lt; 0.001</td>
<td></td>
</tr>
<tr>
<td>Lumbar lordosis angle</td>
<td>43.3</td>
<td>10</td>
<td>44.1</td>
<td>8</td>
<td>0.418</td>
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</tr>
</tbody>
</table>

Statistical analysis

Student’s t test was performed to compare preoperative variables in the monaxial and polyaxial groups, to evaluate preoperative to postoperative changes in the radiological variables (Cobb angle, TK angle, and LL angle), and to look for differences in these changes between the MS and PS groups. The PS and PS groups were divided into subgroups based on the preoperative TK angle (< 20° or ≥ 20°), which were then compared. In all tests, P values lower than 0.05 were considered significant.

Results

Demographic data and surgical parameters

The 60 adolescents included in our retrospective study were aged 13 to 18 years; 52 were females and eight males. The mean number of sublaminar bands required to reduce the deformity was six (range, 4–9). Intraoperative somatosensory and motor evoked-potential monitoring showed no significant abnormalities. However, one patient experienced transient postoperative L5 radiculopathy, and another had delayed recovery of lower limb mobility upon awakening from the anaesthesia that resolved within a few hours and required no investigations.
Figure 3 Postoperative radiographs: thoracic kyphosis is preserved in this patient with a preoperative thoracic kyphosis angle $>20^\circ$.

Overall radiographic results

The mean preoperative angle values in the overall population were $55.2^\circ \pm 10^\circ$ for the thoracic Cobb angle, $18.7^\circ \pm 8^\circ$ for the TK angle, and $43.3^\circ \pm 10^\circ$ for the LL angle (Table 1).

Three months after posterior fusion, the mean Cobb angle showed a significant 68% decrease ($P<0.001$) (Fig. 3). The mean TK angle was significantly increased, by 33% ($6.1^\circ$, $P<0.001$). No significant difference was found between the preoperative and 3-month postoperative values of the LL angle (mean change, $0.8^\circ$; $P=0.418$).

Comparison of postoperative results in the two groups

Table 2 shows the comparison of the variables measured 3 months postoperatively in the two groups. The decrease in the thoracic Cobb angle was significantly smaller in the PS group than in the MS group ($64.8^\circ \pm 9.1^\circ$ versus $72.1^\circ \pm 7.6^\circ$, $P<0.001$). Restoration of thoracic kyphosis was better in the PS group than in the MS group ($P=0.04$). Finally, no difference was found in LL values between the two groups ($P=0.629$).

Discussion

Spinal deformities in paediatric patients constitute a distinct entity that differs in many ways from spinal deformities in adults. Thus, treatments decisions rest chiefly on the severity of the radiological deformity in patients with AIS and on the degree of pain and disability in adults [16]. Here, our objective was to evaluate differences in correction according to whether monoaxial or polyaxial pedicle screws were used for hybrid constructs in patients with AIS.

<table>
<thead>
<tr>
<th>Table 2</th>
<th>Comparison of radiographic results 3 months after surgery between the groups treated with monoaxial and polyaxial screws. Asterisks indicate significant differences.</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Monoaxial screws</td>
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<tr>
<td></td>
<td>Mean $^\circ$</td>
</tr>
<tr>
<td>Cobb angle</td>
<td>$15.0^*$</td>
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<tr>
<td>Thoracic kyphosis angle</td>
<td>23.0</td>
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<tr>
<td>Lumbar lordosis angle</td>
<td>43.6</td>
</tr>
</tbody>
</table>

In the subgroup with a preoperative TK angle $\geq 20^\circ$, the Cobb angle decrease was also greater in the MS group (mean, $6.7^\circ$; $P=0.027$) and thoracic kyphosis restoration was better in the PS group (mean, $4.8^\circ$; $P=0.041$). In the subgroup with a preoperative TK angle $<20^\circ$, both Cobb angle reduction and thoracic kyphosis restoration versus the preoperative values were significant ($P<0.05$) (Fig. 4), with no difference between the MS and PS groups ($P=0.941$ for the Cobb angle and $P=0.246$ for the TK angle). However, the TK angle increase was greater in the subgroup with preoperative hypokyphosis compared to the subgroup with normal preoperative kyphosis (mean increase, $9^\circ$ in the MS group and $7^\circ$ in the PS group, $P=0.002$ and $P=0.001$, respectively).
Curve correction by the hybrid construct

Recent vast case-series studies show large differences in thoracic kyphosis restoration depending on the posterior instrumentation technique used. In 86 patients with AIS, posterior spinal fusion with hybrid instrumentation including sublaminar cables produced 32% of correction in the coronal plane and a thoracic kyphosis increase of only 2.8° [17]. With thoracic hooks, the increase in thoracic kyphosis was only 0.4° [18]. With screw-only constructs, the results varied with the reduction technique. In 114 patients, screw-only constructs produced 70% of coronal correction but led to a mean 9.9° decrease in thoracic kyphosis when rod derotation was not the main reduction technique [9]. In another study, in 203 patients, there was a mean 5° improvement in thoracic kyphosis and 69% of mean coronal curve correction [10].

Our findings confirm the ability of hybrid constructs including sublaminar bands and clamps to restore thoracic kyphosis in hypokyphotic patients and to maintain thoracic kyphosis in normokyphotic patients. Overall, the TK angle increased by 6.1°. This effect was not obtained at the expense of a noticeable decrease in coronal curve correction compared to other constructs (68% mean decrease). We ascribe this ability to restore thoracic kyphosis while correcting the coronal deformity to application by the dedicated reduction tool of a posteromedial translation force [19] that pulls the spine in contact with the pre-contoured rods, as described with Isola or ST2R screw constructs [20,21], while eliminating all risk of neurological compromise when inserting the screws into the concavity of the curve. Another advantage of this technique is the limited risk of overcorrection in the coronal plane, given the absence of rod derotation manoeuvres as described with screw-only constructs [22,23].

Differences according to the type of pedicle screw used

Overall, correction in the coronal plane was better with monoaxial than with polyaxial screws. On the other hand, the use of polyaxial screws was associated with better thoracic kyphosis restoration. These differences were also present between the MS and PS groups when we confined the analysis to patients having preoperative TK angles ≥20°; it was not found in the analysis of patients with preoperative hypokyphosis, although significant correction of the deformity was obtained in both groups. Previous studies have compared monoaxial and polyaxial screws, but most of them involved screw-only constructs. In a study of 35 patients, the magnitude of coronal correction was comparable and derotation was better with the monoaxial screws [24]. Similarly, in a retrospective study of 100 patients, there was no significant difference in coronal correction but the monoaxial screws were associated with a trend toward greater correction of the clinical hump deformity [25]. In our study, the difference noted in the subgroup of patients with more than 20° of preoperative kyphosis is probably ascribable to greater flexibility of the spine with potentialization of the posterior spinal traction due to the polyaxial screw-top design allowing greater bending of the rods. In contrast, in patients with hyperkyphosis, kyphosis restoration may be limited by the decreased spinal flexibility, which may require preliminary anterior dissection to increase the magnitude of the correction. Another contributor to the difference may be related to the connection between the screw and the rod. Monoaxial screws attach to the rod by the tulip-top and polyaxial screws by a lateral connector that ensures preservation of rod pre-contouring by forcing the rod into the tulip-top to lock the assembly.

Thus, differences in the amount of coronal and sagittal correction occur even within hybrid constructs used to treat AIS. The impact of these differences can be assessed by evaluating the course of the spinal deformities in adulthood. Ageing of the spine is often associated with the gradual development of an anterior imbalance characterised by an increase in the distance separating the vertical line through C7 and the posterolateral corner of S1 (sagittal vertical axis, SVA). This anterior imbalance is related to a combination of increased thoracic kyphosis and decreased lumbar lordosis with compensation by gradual posterior tilting of the pelvis (high pelvic tilt, PT) in an attempt to keep the centre of gravity of the body over the base of support [26]. This spine-pelvis imbalance in the sagittal plane (high PT and increased distance between the vertical line through C7 and the posterolateral corner of S1) correlates strongly with quality-of-life scores in adults [27]. Thus, restoring sagittal balance is among the treatment objectives when correcting spinal deformities [28] (PT < 25°, SVA < 50 mm, and difference between pelvic incidence and LL angle < 10°). These data emphasize the importance of restoring satisfactory sagittal balance in patients with AIS, regardless of the technique used to correct the spinal deformity.

The limitations of our study include the retrospective design and the absence of collection of pelvic parameters and clinical scores. Studies over longer follow-up periods will be needed to assess secondary loss of correction, which may differ between monoaxial and polyaxial screws. The clinical interpretation of our results remains difficult. In one study, hyperkyphosis correlated significantly with clinical score deterioration (SRS-score) [29], but in another study persistent hypokyphosis after fusion for AIS was not associated with any clinical deterioration after 2 years of follow-up [6]. However, although the absence of short-term differences cannot be extrapolated to longer-term outcomes in these adolescents, a crucial point in our opinion is that priority should be given to achieving the best possible correction in the sagittal plane, even at the expense of a slight decrease in coronal correction, in order to create the best possible conditions when these adolescents reach adulthood. Consequently, in our clinical practice, we use a hybrid correction with proximal self-retaining bilaminar hook claws, distal polyaxial screws, and reduction via sublaminar bands in the concavity on a frame.

Disclosure of interest

J-L Jouve is a consultant for Zimmer.
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References