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ORIGINAL ARTICLE

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Comparative analysis of pedicle screw and hook instrumentation in posterior correction and fusion of idiopathic thoracic scoliosis

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Abstract Posterior correction and fusion with segmental hook instrumentation represent the gold standard in the surgical treatment of progressive idiopathic thoracic scoliosis. However, there is a debate over whether pedicle screws are safe in scoliosis surgery and whether their usage might enable a better curve correction and a shorter fusion length. The details of curve correction, fusion length and complication rate of 99 patients with idiopathic thoracic scoliosis treated with either hook or pedicle screw instrumentation were analyzed. Forty-nine patients had been operated with the Cotrel-Dubousset system using hooks exclusively ("hook group"). Fifty patients had been operated with either a combination of pedicle screws in the lumbar and lower thoracic and hooks in the upper thoracic spine or exclusive pedicle screw instrumentation using the Münster Posterior Double Rod System ("screw group"). The preoperative Cobb angle averaged 61.3° (range 40°–84°) in the hook group and 62.5° (range 43°–94°) in the screw group. Average primary curve correction was 51.7% in the hook group and 55.8% in the screw group ($P>0.05$). However, at follow-up (2–12 years later) primary curve correction was significantly greater ($P=0.001$) in the screw group (at 50.1%) compared to the hook group (at 41.1%). Secondary lumbar curve correction was significantly greater ($P=0.04$) in the screw group (54.9%) compared to the hook group (46.9%). Correction of the apical vertebral rotation according to Perdriolle was minimal in both groups. Apical vertebral translation was corrected by 42.0% in the hook group and 55.6% in the screw group ($P=0.008$). Correction of the tilt of the lowest instrumented vertebra averaged 48.1% in the hook group and 66.2% in the screw group ($P=0.0004$). There were no differences concerning correction of the sagittal plane deformity between the two groups. Fusion length was, on average, 0.6 segments shorter in the screw group compared to the hook group ($P=0.03$). With pedicle screws, the lowest instrumented vertebra was usually one below the lower end vertebra, whereas in the hook group it was between one and two vertebrae below the lower end vertebra. Both operative time and intraoperative blood loss were significantly higher in the hook group ($P<0.0001$). One pedicle screw at T5 was exchanged due to the direct proximity to the aorta. There were no neurologic complications related to pedicle screw instrumentation. Pedicle screw instrumentation alone or in combination with proximal hook instrumentation offers a significantly better primary and secondary curve correction in idiopathic thoracic scoliosis and enables a significantly shorter fusion length.

Keywords Scoliosis · Pedicle screw · Hook instrumentation · Posterior fusion

Introduction

Posterior correction and fusion represent the gold standard of surgical treatment in progressive idiopathic thoracic scoliosis [9, 13, 19, 22, 29, 39]. Since the introduction of Cotrel-Dubousset Instrumentation (CDI) in 1984, the correction technique has changed from the former Harrington technique of predominantly concave distraction to one of segmental translation. This is achieved either by the rod rotation maneuver or by segmental approximation, mainly via the concave rod [12, 22, 29, 39]. The original instrumentation technique consisted of multiple hooks connected to bilateral solid rods. Pedicle screw instrumentation for lumbar curves has gained in popularity since several studies have demonstrated a better curve correction and a shorter fusion length using pedicle screws instead of hooks [4, 17, 18, 30]. However, the role of pedicle screw instrumentation in thoracic curves is still a matter of debate. Some authors report better correction results and a shorter fusion length even in thoracic curves [14, 25, 36, 37, 38], while others question the benefits of pedicle screw fixation in thoracic curves due to the different vertebral morphology in scoliosis, the potential risks and the questionable benefits [3, 26, 28, 31, 35].

The aim of this study was to compare pedicle screw versus hook instrumentation in idiopathic thoracic scoliosis with respect to curve correction, fusion length and complications.

Materials and methods

The hook group consisted originally of 58 patients with idiopathic thoracic scoliosis, who were operated at our institution between 1986 and 1992 using CD instrumentation with hooks. Nine patients had to be excluded from this retrospective evaluation since the postoperative follow-up was less than 24 months. Seven patients either had incomplete notes or were impossible to contact due to missing addresses. Two patients were not willing to attend the follow-up investigation since they were free from any complaints. Thus, 49 patients were available for further evaluation, of whom 35 were female and 14 were male. According to the King classification [21], there were 16 type II, 26 type III, 6 type IV and 1 type V curves. The average age at surgery was 17.3 years (range 10–32 years). The follow-up averaged 83 months (range 24–144 months).

The screw group included all patients with idiopathic thoracic scoliosis who were surgically treated with the Münster Posterior Double Rod System (MPDS, Schäfer micomed, Schorndorf, Germany) at our institution between 1993 and 1997. Out of these 52 patients, 50 were prospectively studied, with a minimum follow-up of 24 months. Two patients were lost to follow-up. Eighteen patients were exclusively instrumented with pedicle screws, 32 patients were surgically treated with a combination of hooks in the upper thoracic and pedicle screws in the lower thoracic and lumbar spine. Forty-three patients were female, seven were male. There were 18 King type II, 12 type III, 7 type IV and 13 type V curves. Average age at surgery was 16.3 years (range 10–26 years). Follow-up averaged 38 months (range 24–72 months).

Data collection was carried out retrospectively in the hook group and prospectively in the screw group by two independent observers not involved in the surgical treatment. Intra- and postoperative complications as well as operative time and intraoperative blood loss were registered. Radiographic analysis included Cobb angle measurements [10] of the primary thoracic and secondary lumbar curves on the preoperative, postoperative and the follow-up radiographs. The curve flexibility was determined on the preoperative bending films. Additionally, in case of loss of correction of more than 5° in the hook group, the radiographs at 24 months follow-up were analyzed. Other parameters measured in the frontal plane were: tilt angle of the lowest instrumented vertebra (LIV), apical vertebral rotation (AVR) according to Perdriolle [32] and translation of the apical vertebra (AVT). AVT was measured as the distance of the center of the apical vertebral body from the line drawn between the spinous processes of C7 and S1. Spinal balance in the frontal plane was measured as the distance between the plumb line dropped from C7 and the central sacral line. Shoulder balance was determined by comparing the intersections of the first or second rib with the clavicles. On the lateral radiographs, thoracic kyphosis was measured from T4 to T12, the thoracolumbar junction from T10 to L2 and the lumbar lordosis from L1 to L5. Normal values were regarded as between 25° and 40° for the thoracic kyphosis, between –10° and 10° for the thoracolumbar junction and between –35° and –55° for the lumbar lordosis [7, 8]. Sagittal balance was determined as the distance between a plumb line dropped from the center of the intervertebral space C7/T1 and the intervertebral space L5/S1.

Statistical analysis was carried out with Microsoft Excel 97 (Richmond, Wash., USA) and StatView 5.0 (SAS Institute Inc., Cary, N.C., USA), applying the Mann-Whitney U-test with a level of significance of 5% ($P<0.05$).

Results

Preoperative Cobb angle and the flexibility of the primary curves were comparable in the hook and the screw group without significant differences ($P>0.05$, Table 1, Table 2). Initial primary curve correction averaged 51.7% in the hook group and 55.8% in the screw group ($P>0.05$). However, due to the significantly higher loss of correction in

Table 1 Correction of the primary thoracic and secondary lumbar curve in the hook group

	Preop. curve	Bending	Correction	Postop. curve	Correction	Follow-up curve	Correction	Loss of correction
Primary curve	61.3° (40°–84°)	37.9° (17°–76°)	38.2%	29.6° (8°–52°)	51.7%	36.1° (10°–67°)	41.1%	6.5°
Secondary curve	37.1° (12°–74°)	12.1° (0°–43°)	67.4%	16.5° (2°–37°)	55.5%	19.7° (4°–38°)	46.9%	3.2°

Table 2 Correction of the primary thoracic and secondary lumbar curve in the screw group

	Preop. curve	Bending	Correction	Postop. curve	Correction	Follow-up curve	Correction	Loss of correction
Primary curve	62.5° (43°–94°)	40.7° (17°–70°)	34.9%	27.6° (14°–52°)	55.8%	31.2° (16°–58°)	50.1%	3.6°
Secondary curve	39.7° (20°–72°)	16.5° (–6° to 52°)	58.4%	16.2° (0°–38°)	59.2%	17.9° (2°–38°)	54.9%	1.7°

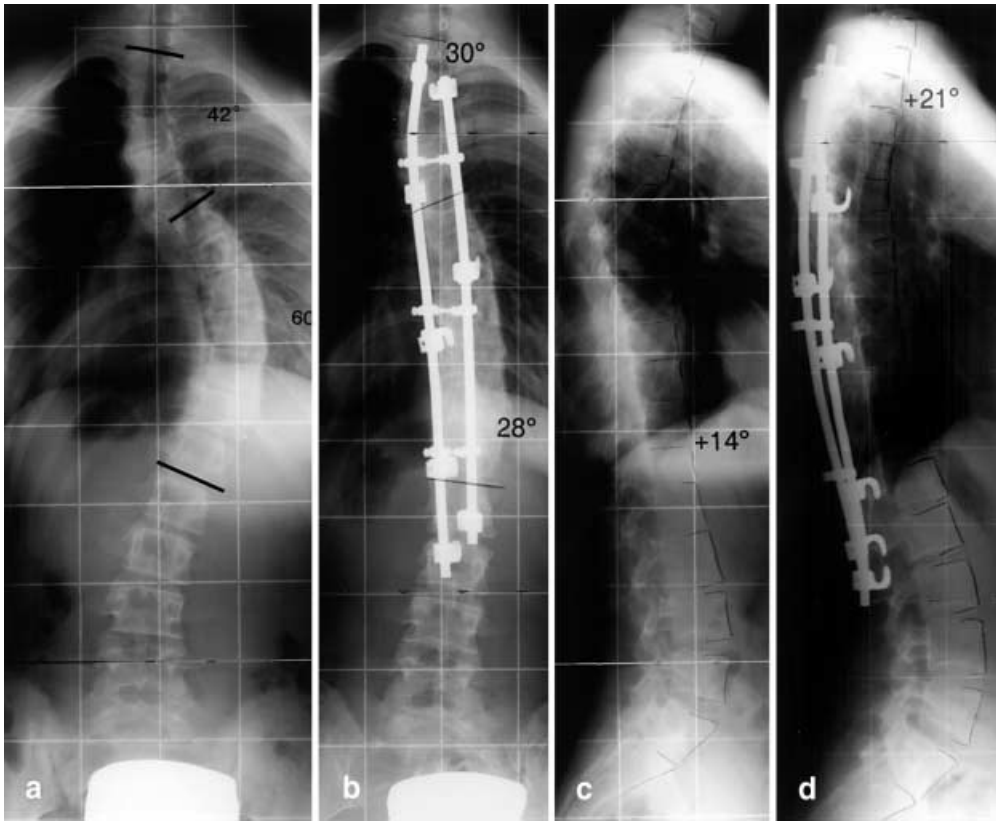

Fig. 1A–D A 14-year-old girl with a right thoracic King type V curve with a secondary rigid upper left thoracic curve (24% flexibility on preoperative bending films). T12 is the distal end vertebra (only 11 ribs). Radiographs taken 72 months after posterior correction and fusion with Cotrel-Dubousset (CD) instrumentation from T2 to L1 show a satisfactory correction of both curves

the hook group, curve correction after 2 years as well as at the latest follow-up was significantly greater in the screw group (P=0.001, Fig. 1, Fig. 2, Fig. 3, Fig. 4).

Preoperative Cobb angles of the secondary lumbar curves were comparable in the two groups (Table 1, Table 2). However, despite a significantly greater curve flexibility in the hook group, the final curve correction was significantly greater in the screw group (P=0.04). At follow-up, the lumbar curve correction in the screw group corresponded to the correction on the preoperative bending films; whereas in the hook group, lumbar curve correction was 47% compared to 67% on the bending films.

The high left thoracic curve in the 13 King type V curves (screw group) was corrected by 40.3% on average, from 47.4° (range 26°–62°) to 28.3° (range 14°–48°). At the latest follow-up, the average Cobb angle was 31.9° (range 12°–46°). In three patients, the upper thoracic curve was not included in the fusion, leading to a left-sided shoulder elevation.

Fusion length was on average 0.6 segments shorter in the screw group compared to the hook group (P=0.03). With pedicle screws, the lowest instrumented vertebra was usually one below the lower end vertebra, and in the hook group it was usually between one and two vertebrae below the lower end vertebra for the King type III–V curves. In King type II curves, however, fusion extended to L3 or L4 in 12 out of 16 patients in the hook group and in 14 out of 18 patients in the screw group, due to the structural appearance of the lumbar curves (average preoperative Cobb angle of the lumbar curves was 47.9° in the hook group and 55.7° in the screw group, Fig. 4).

The correction of both translation of the apical vertebra (AVT) and tilt of the lowest instrumented vertebra (LIV) was significantly greater in screw group than in the hook

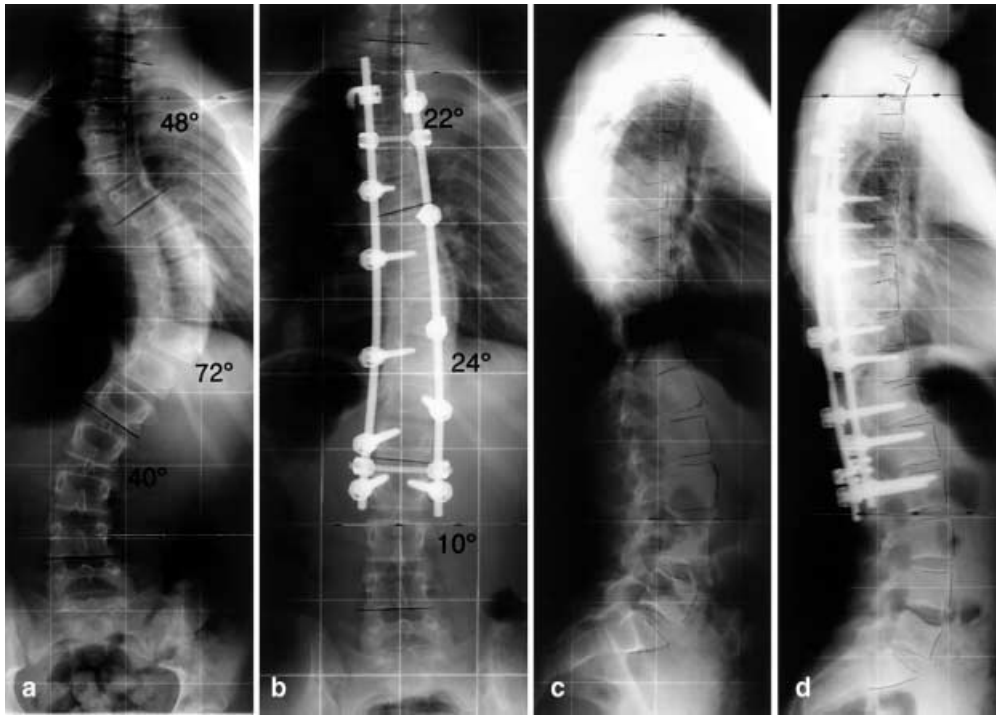

Fig. 2A–D A 12-year-old girl with a double thoracic King type V curve. Radiographs taken 52 months after posterior correction and fusion from T3 to L2, using the Münster Posterior Double Rod (MPD) system with predominantly pedicle screws, show good correction of the frontal and sagittal planes with balanced shoulders

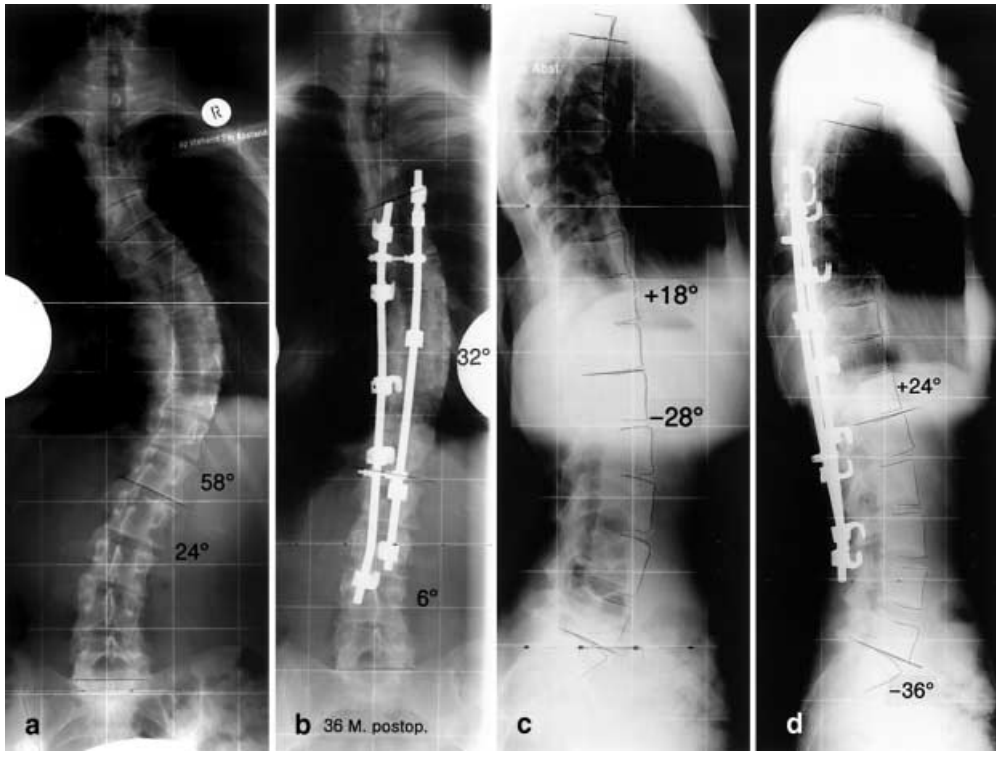

Fig. 3A–D A 16-year-old girl with an idiopathic right thoracic scoliosis King type IV curve of 58°. Radiographs taken 36 months after posterior correction and fusion with CD instrumentation from T6 to L3 show good correction in the frontal and sagittal planes. On preoperative bending films, the L2/L3 disc space opened to both sides; therefore, using pedicle screws, a fusion to L2 may have been sufficient

group (AVT P=0.008, LIV P=0.0004, Table 3). Shoulder imbalance was corrected from 1.1 cm (range 0–4.0 cm) to 0.9 cm (range 0–3.2 cm) in the hook group, and from 1.0 cm (range 0–2.5 cm) to 0.6 cm (range 0–2.0 cm) in the screw group. Frontal imbalance was reduced from 1.1 cm (range 0–3.8 cm) to 0.8 cm (range 0–2.5 cm) in the hook group, and from 1.5 cm (range 0–4.0 cm) to 0.7 cm (range 0–2.0 cm) in the screw group. Apical vertebral rotation av-

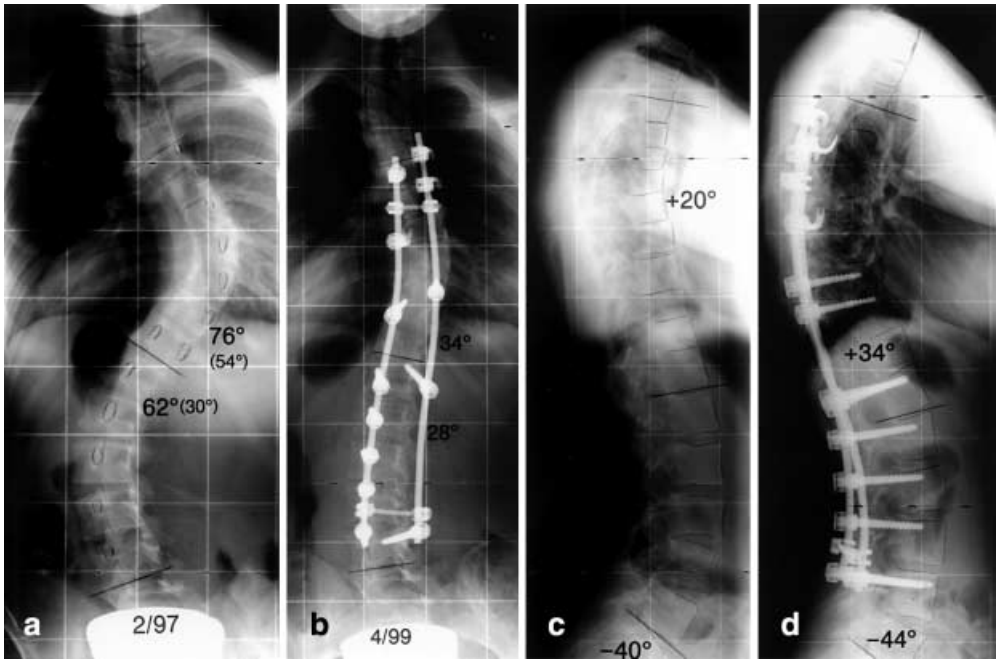

Fig. 4A–D A 15-year-old girl with idiopathic right thoracic scoliosis King type IIb curve, with a structural lumbar secondary curve and significant rotation. Posterior correction and fusion of both curves using the MPD system from T5 to L4 was performed. Radiographs taken 26 months postoperatively show good correction of the frontal and sagittal planes with a balanced spine

Table 3 Correction of the apical vertebral translation (AVT) and the tilt of the lowest instrumented vertebra (LIV) in the two groups

	Preop.	Postop.	Correction	Follow-up	Correction	Loss of correction
Hook group						
AVT	5.0 cm (1.5–8.5 cm)	2.3 cm (0–6.5 cm)	54.0%	2.9 cm (0–6.9 cm)	42.0%	0.6 cm
Tilt LIV	18.1° (0°–38°)	7.3° (0°–24°)	59.7%	9.4° (0°–28°)	48.1%	2.1°
Screw group						
AVT	4.5 cm (2.8–7.5 cm)	1.6 cm (0–3.7 cm)	64.4%	2.0 cm (0.3–4.0 cm)	55.6%	0.4 cm
Tilt LIV	20.7° (6°–34°)	6.3° (0°–16°)	69.6%	7.0° (0°–18°)	66.2%	0.7°

eraged 23.8° (range 5°–45°) preoperatively and 22.5° (range 5°–45°) at follow-up in the hook group and 26.9° (range 15°–45°) preoperatively and 23.3° (range 10°–35°) at follow-up in the screw group.

The parameters in the sagittal plane are listed in Table 4. In the hook group, the thoracic kyphosis was corrected from 22.3° preoperatively to 30.1° at follow-up, and the thoracolumbar junction was corrected from 9.0° to 5.9°. In cases of a preoperative thoracic hypokyphosis of less than 25°, this was corrected from 8.1° (range –14° to 24°) to 19.2° (range 0°–38°) at follow-up. A preoperative pathological thoracolumbar junction in 18 patients in the hook group was corrected to normal values in 14 patients. In the screw group, preoperative thoracic hypokyphosis was corrected from 9.3° (range –8° to 22°) to 18.2° (range 12°–36°) at follow-up. A preoperative pathological thoracolumbar junction in 12 patients in the screw group was corrected to normal values in 8 patients. Sagittal trunk shift measured 1.9 cm (range –4.0 to 6.0 cm) preoperatively, and remained unchanged during follow-up (on average 1.8 cm, range –3.0° to 5.5 cm) in the hook group. In the screw group, preoperative sagittal trunk shift was 1.9 cm (range –3.0° to 5.0 cm) on average, and was changed to 1.1 cm (range –3.0 to 5.0 cm) at follow-up.

The average operative time was 330 min (range 175–510 min) in the hook group and 210 min (range 150–300 min) in the screw group ($P<0.0001$). Intraoperative blood loss was 4196 ml (range 1000–9000 ml) in the hook group and 1241 ml (range 200–6000 ml) in the screw group ($P<0.0001$). The intra- and postoperative complications are listed in Table 5. In the hook group there was one patient with an early deep infection. The implants were removed after 2 weeks and reinstrumented after a further 2 weeks. The further course was uneventful. In the case of

Table 4 Correction of the sagittal plane in the two groups (*TLJ* thoracolumbar junction)

	Preop.	Postop.	Follow-up
Hook group			
Thoracic kyphosi	22.3° (–14 to 66°)	26.2° (–2 to 62°)	30.1° (0 to 70°)
TLJ	9.0° (–14° to 22°)	6.4° (–12° to 15°)	5.9° (–12° to 15°)
Lumbar lordosis	–45.2° (–15° to 76°)	–45.7° (–15° to 74°)	–46.8° (–22° to 88°)
Screw group			
Thoracic kyphosis	29.6° (–8° to 72°)	27.6° (10° to 54°)	31.0° (12° to 58°)
TLJ	7.1° (–30° to 22°)	6.7° (–22° to 14°)	6.4° (–20° to 12°)
Lumbar lordosis	–46.0° (–10° to 90°)	–44.6° (–18° to 76°)	–47.8° (22° to 78°)

Table 5 Intra- and postoperative complications in the two groups

Hook group
5x intraoperative hook pull-out
1x high intraoperative blood loss of 9000 ml (platelet dysfunction)
1x respiratory insufficiency with prolonged postoperative ventilation
3x superficial wound infection requiring surgical revision
1x deep infection requiring implant removal after 2 weeks
2x postoperative hook dislocation requiring surgical revision
Screw group
6x intraoperative hook pull-out
1x high intraoperative blood loss of 6000 ml (prolonged wake-up test, osteoporosis)
1x incomplete paraparesis 6 h after posterior correction and fusion, immediate surgical revision with restitutio ad integrum
1x pedicle screw exchange due to direct proximity to thoracic aorta at T5
1x respiratory insufficiency with prolonged postoperative ventilation
1x deep infection 36 months postoperative, requiring surgical revision

postoperative incomplete paraparesis 6 h after posterior correction with a combination of pedicle screws and hooks, immediate surgical revision showed correctly placed pedicle screws, which were left in place. The correction was released and an in-situ fusion was performed. Intraoperative wake-up test during the first operation was normal. Within the first 3 postoperative months all neurological symptoms resolved. In the case of deep infection, all implants were removed; there was no evidence of pseudarthrosis. The infection healed with an uneventful further course.

Discussion

The aim of this study was to compare standard segmental hook instrumentation and pedicle screw instrumentation in posterior correction and fusion of idiopathic thoracic scoliosis. Forty-nine patients treated with CD instrumentation using hooks only were compared with 50 patients treated with the Münster Posterior Double Rod System, using either exclusively pedicle screws or a combination of hooks in the upper thoracic spine and pedicle screws in the lower thoracic and the lumbar spine.

With hooks, the initial correction of the primary curve was 51.7%. Loss of correction was 6.5°, leaving a final correction of 41.1%, which is comparable to the flexibility on the preoperative bending films. Lenke et al. [23] reviewed their patients 5–10 years after CD instrumentation and found 6° loss of correction after an initial correction of 57%, leaving a final correction of 45%. Other authors report on similar correction results after multisegmental hook instrumentation, with final curve corrections of between 39 and 61% after a minimum of 2 years follow-up [20, 24, 33, 34, 36].

In the screw group the initial primary curve correction was 56%, with an average loss of correction of 3.6°, leaving a 50.1% final correction, which exceeds the flexibility on the preoperative bending films by 15%. The final curve correction was significantly greater in the screw group compared to the hook group. Suk et al. [36, 37] analyzed their results with hook and pedicle screw instrumentation in idiopathic thoracic scoliosis, and found significantly greater correction results with screws compared to hook instrumentation. Delorme et al. [14] confirmed these observations. Further studies on posterior correction and fusion of thoracic idiopathic scoliosis with a combination of pedicle screw and hook instrumentation report an average curve correction of between 52 and 63% [2, 9, 29].

The correction of the secondary lumbar curve was 47% in the hook group, which was considerably below the flexibility on the preoperative bending films (67%). In the screw group, secondary curve correction was significantly greater and was comparable to the flexibility on the preoperative bending films (55%). Correction of the lumbar curve in thoracic scoliosis depends heavily on the degree of the primary curve correction, which is demonstrated by these data and confirmed by other authors [24, 36].

Correction of the apical vertebral translation was significantly greater in the screw group compared to the hook group (56% vs 42%). Arlet et al. [2] reported a correction of 70% using segmental concave instrumentation with modified pedicle hooks. The amount of correction of the apical translation depends on the number of segmentally placed anchors on the concavity [36] and on the pull-out strength of the fixation device. Cadaver studies have shown that pedicle screws offer significantly greater resistance to tensile forces compared to hooks [6, 27]. Therefore, segmentally placed pedicle screws or modified pedicle hooks with greater pull-out strengths than regular hooks enable a greater correction of the apical vertebral translation.

The correction of the lowest instrumented vertebra (LIV) was significantly greater in the screw group than in the hook group (66% vs 48%). This observation is confirmed by other studies comparing hook and screw instrumentation in lumbar curves. Barr et al. [4] report a correction of the LIV of 62% in the screw group and 11% in the hook group. Hamill et al. [18] found a correction of the LIV of 82% in the screw group and 50% in the hook group. Pedicle screw instrumentation offers a better horizontalization of the LIV for two reasons: first, the more lateral position of the pedicle screw compared to a laminar hook provides a considerably better leverage [17]; second, the tangential fixation strength of pedicle screws is significantly greater than that of hooks [27].

Saving distal motion segments is of paramount importance in scoliosis surgery, to prevent degenerative alterations at the adjacent levels [1, 9, 11, 15]. With pedicle screws, fusion length was significantly shorter compared to the hook group. Pedicle screws allow a distally shorter fusion length, as already demonstrated by other authors [17, 36].

The sagittal profile was successfully controlled in both groups. Significant differences between hook and pedicle screw instrumentation, as reported by Suk et al. [38], were not found in this study. Numerous authors have demonstrated that both hook and pedicle screw instrumentation enable a good correction even of the sagittal plane deformity in idiopathic scoliosis [8, 16, 23, 30].

There were no implant-related neurological complications in this series. However, with both pedicle screws and hooks, spinal cord compression can occur [5, 31]. Morphometric studies have shown that, in idiopathic thoracic scoliosis, the concave pedicles are significantly smaller than the convex ones. Furthermore, the spinal cord is shifted to the concavity with less epidural space [26, 28]. Therefore, pedicle screw placement, especially on the concavity of scoliotic curves, has to be done with maximum caution.

Conclusion

The present study of 99 patients with idiopathic thoracic scoliosis demonstrates that pedicle screw instrumentation alone or in combination with proximal hook instrumentation offers a significantly better primary and secondary curve correction at follow-up with a significantly shorter fusion length compared to exclusive hook instrumentation.

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