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Original article

Adolescent idiopathic scoliosis correction achieved by posteromedial translation using polyester bands: A comparative study of subtransverse process versus sublaminar fixation

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ABSTRACT

Purpose: Sublaminar polyester bands have been used in hybrid construct to achieve correction of adolescent idiopathic scoliosis since 2003. Despite the reported safety of the bands, some surgeons remain reluctant at the idea of approaching the canal because of the potential neurological complications reported with the Luque wiring. Sub transverse bands might be an alternative. The present study is the first to compare sublaminar polyester band fixation to fixation of polyester bands around the transverse processes in hybrid constructs used to treat AIS.
Methods: Two cohorts of consecutive patients treated for thoracic AIS were retrospectively reviewed, with a minimum 2-year follow-up. Posteromedial translation was used for main curve correction in all cases. Sublaminar polyester bands were used in group 1 (20 patients). In group 2 (20 patients), the same implant was used, but the bands were passed around the transverse process instead of the lamina. Radiographic analysis included frontal Cobb angle measurements for each curve, thoracic kyphosis and rotation of the apical vertebra (RVA).
Results: Mean operative time was similar in groups 1 and 2 (235 ± 35 and 240 ± 30 minutes, respectively). Mean frontal correction achieved for the main curve was similar in both groups, $62.5 \pm 17.4\%$ in group 1 and $54.1 \pm 19.4\%$ in group 2. Sagittal correction was similar, with a final mean thoracic kyphosis of $30.9^\circ \pm 9.7^\circ$ and $27.8^\circ \pm 6.8^\circ$ in group 1 and 2, respectively. Correction of RVA was similar in both groups postoperatively, 65.8% (±29.1) and 54.4% (±42.7) in group 1 and 2 respectively. No transverse process or lamina fracture was observed during insertion of the bands or curve correction in any of the groups.
Conclusion: This study confirms that anchorage of Universal clamps (UCs) around transverse processes is a safe and efficacious technique in both the frontal and sagittal planes, providing a useful alternative for the correction of moderate AIS. UCs attached to transverse processes can achieve correction of moderate AIS similar to that obtained with sublaminar UCs while further reducing risks of vertebral canal complications.
Level of evidence: Level IV.

1. Introduction

Scoliosis surgery should result in a zone of balanced fusion centered over the pelvis in both the frontal and sagittal planes, and restore trunk height while preserving maximum adjacent mobility.

At present, two of the most widely used surgical techniques for the correction of adolescent idiopathic scoliosis (AIS) are cantilever reduction (CR) with total pedicle screw instrumentation, which also permit direct vertebral derotation, and posteromedial translation (PMT), achieved with hybrid constructs. According to some authors, pedicle screw instrumentation offers a greater potential for curve correction in the coronal plane[1–4]. As pointed out by Winter [5], however, maintaining or restoring physiological thoracic kyphosis is essential to avoid junctional complications at both extremities of the instrumented spine. Posteromedial translation using hybrid constructs more effectively corrects hypokyphosis than CR with

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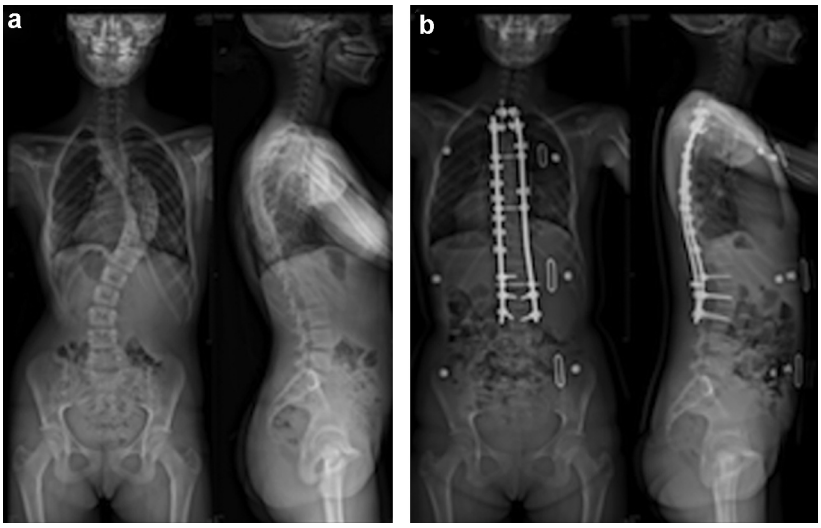

Fig. 1. Preoperative (a) and postoperative (b) anteroposterior and lateral standing radiographs of a 16-year-old girl with AIS operated with a hybrid construct combining lumbar pedicle screws and thoracic sublaminar UC.

all-pedicle screw constructs while providing equivalent results in the frontal plane [6–9]. The Universal Clamp (UC) (Zimmer Spine, Bordeaux, France) is a sublaminar implant introduced by Mazda [7] in 2003 to mediate periapical posteromedial translation. The sublaminar insertion of the polyester bands is straightforward, similar to that of Luque wires, but, with use of the soft polyester bands instead of metal wires, complications sometimes associated with Luque wires have not been observed [10,11]. Furthermore, the band offers a higher surface of bony contact than the wire, thus allowing higher reduction forces[12]. Despite the reported safety of the bands, some surgeons remain reluctant at the idea of approaching the canal because of the potential neurological complications reported with the Luque wiring [13]. A possible alternative would be to place the band around the transverse processes instead of the laminae. Subtransverse wiring has already been reported as a safe and effective technique in deformity correction [14–16], but the use of subtransverse bands has not been previously reported in the literature.

The purpose of the present study was to compare the safety and efficacy of the two types of polyester band fixation in the surgical treatment of AIS.

2. Materials and methods

2.1. Patients

Following institutional review board approval, data was retrospectively reviewed in two different spinal units using hybrid constructs. Unit one used sublaminar fixation and unit two used subtransverse process fixation of the periapical polyester bands. In group 1, 20 consecutive patients operated in unit 1 were included. Inclusion criteria were: thoracic AIS (Lenke 1 to 4), progressive idiopathic deformity greater than 40° and a minimum of two years' follow-up. Patients with non-idiopathic scoliosis or Lenke 5 and 6 deformities were excluded. Patients with severe AIS, with a Cobb angle greater than 60° were also excluded. In group 2, 20 patients operated in unit 2 were matched for age and Lenke type.

2.2. Operative procedure

During the procedure, spinal cord function was monitored in all cases with somatosensory/motor-evoked potentials. In all cases, pedicle screws were used in the lumbar spine (L1 to L4), with monoaxial screws on the convex side and polyaxial screws on the concave side. In group 1, thoracic levels were instrumented with sublaminar UCs on the concave side and 1 sublaminar UC on the apical vertebra on the convex side (Fig. 1). In group 2, periapical thoracic levels were instrumented with two UCs placed around transverse processes on the concave side to enhance the cantilever reduction force and one pedicle screw was used on the convex side to further consolidate the instrumentation (Fig. 2).

For both groups, 5.5 titanium rods (Zimmer Spine, Bordeaux, France) were used and fusion was achieved using decortication and autograft.

2.3. Radiographic measurements

Measurements were made using anteroposterior and lateral long-length standing radiographs preoperatively, postoperatively and at latest follow-up. All films were digitized then analyzed by the same investigator using the previously validated Spine Balance (Surgiview, Paris, France) software [17].

Radiographic analysis included frontal Cobb angles of each curve, thoracic kyphosis (measured from the upper endplate of T5 to the lower endplate of T12) and rotation of the apical vertebra (RVA) using Perdriolle's method [18].

In addition, the following ratio was calculated [19]:

- Cincinnati Correction Index (CCI) = postoperative correction/preoperative flexibility;
- RVA correction (%) = (preoperative RVA-postoperative RVA)/preoperative RVA × 100.

2.4. Statistical analysis

Paired-samples *t* tests were used to analyze differences between preoperative and postoperative measurements within each group. Comparisons between the two groups were performed using unpaired *t* tests. All statistical tests were 2-tailed, and a $P < 0.05$ was considered significant. All statistical analyses were conducted using SPSS version (SPSS Inc; Chicago, IL).

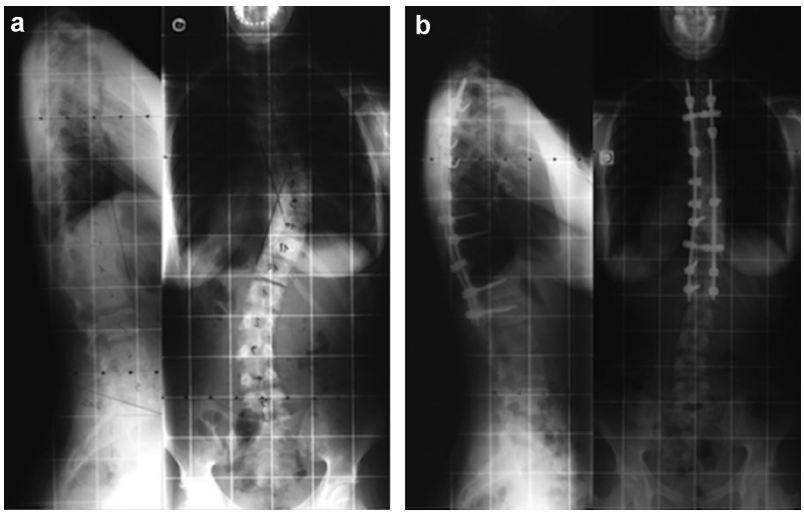

Fig. 2. A 16-year-old girl with AIS (a) operated on with a hybrid construct using the UC around the transverse process on the apical vertebra (b).

3. Results

3.1. Demographic data and curve classification

Twenty patients were included in each group with similar demographic data (Table 1).

The two groups were also comparable regarding Lenke curve classification distribution: 10 Lenke type 1 in group 1 and 8 in group 2, 7 Lenke type 2 in each group, 1 Lenke type 3 in each group, 1 Lenke type 4 in group 1 and 3 in group 2.

Preoperative frontal Cobb angles of the two groups were similar (Table 1). Sagittal modifiers were comparable in the two groups (Table 1). In each group, there were 7 patients (35%) who had kyphosis < 20° preoperatively. Preoperative RVA was statistically greater in group 1 ($P = 0.0001$).

The number of levels fused was 12.3 (± 0.8) in group 1 with an average of 6 UCs (3 to 7), which was statistically greater than in group 2 in which 9.5 (± 2.3) levels were fused ($P < 0.0001$) and 2 UCs were used per patient. The distribution of upper and lowest instrumented vertebras is described in Table 2. The distribution was similar in both groups for the upper level. The lowest instrumented vertebra (LIV) was more distal in group 1 than in group 2. For both groups, the LIV chosen was always the stable and neutral vertebra located one level above the first mobile disc on the bendings. In group 1, no selective thoracic fusion ending on T12 or L1 was performed. Thus, the anchor density was lower in group 2 as shown in Table 2.

Table 1
Demographical data and preoperative Cobb angles.

	Sublaminar bands Group 1	Subtransverse bands Group 2	*P*
Age (years)	14.6 ± 1.9	14.8 ± 2.0	ns
Gender	17 females, 2 males	15 females, 4 males	ns
Follow-up (months)	28.6 ± 6.3	29 ± 4.9	ns
Proximal curve Cobb angle (°)	28.9 ± 13.6	29.5 ± 10.3	ns
Main curve Cobb angle (°)	55.2 ± 23.6	55.7 ± 14.3	ns
Distal curve Cobb angle (°)	34.4 ± 13.4	34.9 ± 14.9	ns
Kyphosis (°) T5-T12	24.8 ± 14.3	24.7 ± 9.4	ns

Table 2
Instrumentation details.

	Group 1	Group 2	*P*
Number of levels fused	12.3 ± 0.8	9.5 ± 2.3	< 0.05
Upper instrumented vertebra			
T1	10%	0	ns
T2	16%	10%	ns
T3	42%	58%	ns
T4	32%	16%	ns
T5	0	16%	ns
Lowest instrumented vertebra			
L1	0	59%	< 0.05
L2	10%	16%	< 0.05
L3	68%	16%	< 0.05
L4	22%	0	< 0.05
L5	0	9%	< 0.05
Anchor density (number anchors/number level fused)	1.53 ± 0.14	1.28 ± 0.22	< 0.05

3.2. Operative procedure and curve correction

Average operative time and blood loss were similar in the two groups (Table 3).

Corrections obtained in the frontal plane are shown in Table 4. Cobb angle were similar in both groups preoperatively, postoperatively and at latest follow-up for the proximal and for the main

Table 3
Operative procedure data (mean ± standard deviation).

	Sublaminar bands	Subtransverse bands	*P*
Mean operative time (min)	235 ± 35	240 ± 30	ns
Mean blood loss (mL)	840 ± 102	780 ± 130	ns

Table 4
Postoperative and follow-up Cobb angles.

	Group 1	Group 2	*P*
Proximal curve, Cobb angle (°)			
Postoperative	16.8 ± 8.9	20.3 ± 10.3	ns
Follow-up	16.6 ± 8.7	20.7 ± 11.3	ns
Main curve, Cobb angle (°)			
Postoperative	20.9 ± 9.7	25.6 ± 11.4	ns
Follow-up	22.7 ± 10.1	24.2 ± 10.1	ns
Distal curve, Cobb angle (°)			
Postoperative	10.2 ± 6.6	19.8 ± 8.9	< 0.05
Follow-up	9.7 ± 7.8	17.9 ± 7.7	< 0.05

Table 5
Cincinnati Corrective Index (CCI).

CCI	Group 1	Group 2	*P*
Proximal curve	6.1	4.7	ns
Main curve	1.6	0.9	ns
Distal curve	1.5	0.6	< 0.05

Table 6
T5-T12 kyphosis.

KyphosisT5-T12 (°)	Group 1	Group 2	*P*
Preoperative	24.7 ± 9.4	24.8 ± 14.3	ns
Postoperative	29.6 ± 11.1	26.3 ± 7.1	ns
Follow-up	30.8 ± 9.7	27.8 ± 6.8	ns

curve. Furthermore, the CCI was similar in both groups for the proximal and the main curve (Table 5). For the distal curve, correction was better achieved in group 1 ($P < 0.05$).

Results obtained in the sagittal plane are reported in Table 6. No difference was found between the two groups. At latest follow-up, all patients had normal kyphosis (> 20°). The average increase in kyphosis for the patients who had a preoperative kyphosis < 20° was 12.7° ± 10.4 and 15.9° ± 7.1° in groups 1 and 2, respectively ($P > 0.05$).

The average correction of RVA was 65.8% ± 29.1% in group 1 and 55.8% ± 36.4% in group 2 ($P > 0.05$) but the difference became significant at latest follow-up ($P = 0.01$): 65.8 ± 29.1% in group 1 and 39.7 ± 31% in group 2 (Table 7). The ratio correction of RVA/number of bands was greater in group 2 ($P = 0.009$).

3.3. Complications

No significant change of the monitored potentials was recorded in either group. In group 2, there was one superficial wound infection, which was successfully treated by surgical debridement and 3 months of antibiotics. No complications occurred intraoperatively. In particular, no transverse or lamina fracture was observed during insertion of the bands or correction maneuvers. Subtransverse process use of the UC resulted in no postoperative pleural effusion. At final follow-up, there was no significant loss of correction, and no case of pseudarthrosis was observed.

4. Discussion

Many authors have reported excellent frontal and axial correction of AIS using all-pedicle screw constructs, but their ability to improve hypokyphosis is less satisfactory [19–22]. Surgeons applying posteromedial translation (PMT) with hybrid constructs have consistently achieved good results in terms of both Cobb angle correction and final kyphosis [6,9,23,24]. Various types of hybrid constructs have been described associating lumbar pedicle screws and thoracic hooks or sublaminar wires or cables. Polyester bands provide a safe alternative to sublaminar (Luque type) wires as well as an increased surface of bony contact allowing higher reduction forces [7]. The soft UC was designed to avoid neurological complications during insertion or removal and to the polyester band avoids adverse effects related to the presence of wires under the lamina [12,13]. The efficacy and safety of sublaminar bands have already been reported for the correction of AIS [10,11]. Ilharreborde also pointed out the reduction in operative time and blood loss in comparison to a group of patients treated with thoracic hook hybrid constructs [10]. In addition, the polyester bands indications have recently been extended to traumatology, with promising results [25,26].

However, approaching the canal carries a potential risk of neurological injury. In addition, placing the band around the transverse process, more lateral than the lamina, might provide greater leverage for correcting the axial deformity. For both of these reasons, fixation around the transverse process was experimented in this study. Biomechanical analysis of calf thoracic vertebrae has shown that subtransverse process fixation with 5 mm bands and stainless steel wire have equivalent stability [15]. It has also been reported that sublaminar and subtransverse process wires offered similar results for the correction of AIS in the frontal plane [14,16]. However, in his work, Akmese [16] also reports a greater number of complications with the sublaminar technique. This result might be due to the fact that metallic wires are used in this study. The soft end of the polyester band was designed to avoid such complications. Moreover, metallic wire may have a tendency to cut through the bone during correction and explain why transverse process fractures were observed in 12% of the patients in one report [14]. The polyester band used around the transverse process, with greater surface of contact with the bone, has been demonstrated to provide biomechanical advantages over wires [12], but their results in such clinical use had never been assessed.

Table 7
Axial correction of the apical vertebra (mean ± standard deviation).

	Sublaminar bands	Subtransverse bands	*P*
Preoperative (degree)	23.2 ± 10.0	10.8 ± 6.2	0.0001
Postoperative correction (%)	65.8 ± 29.1	54.4 ± 42.7	NS
Last follow-up correction (%)	65.5 ± 28.7	47.9 ± 31.7	NS

4.1. Surgical correction

Mean frontal correction achieved in both groups at latest follow-up was not significantly different, 62.5% ± 19.4% and 54.1% ± 17.4% respectively in accordance with previous reports of sublaminar bands [12]. Correction achieved for the distal curve was greater in group 1 because selective thoracic fusion was never performed in group 1. Moreover, distal curve correction was achieved with the pedicle screws in both groups and not with the polyester bands that were used exclusively at the thoracic levels. The difference observed is independent from the type of band fixation used. Moreover, we calculated the CCI, which takes into account the preoperative curve flexibility and the CCI was similar in both groups for the proximal curve and for the main curve.

Thoracic kyphosis was restored in both groups. At latest follow-up, all patients had a thoracic kyphosis > 20°. Mean kyphosis was 30.9° ± 9.7° in group 1 and 27.8° ± 6.8° in group 2 with no statistical difference. Patients with preoperative kyphosis < 20° gained 12.7° ± 10.5° and 15.8° ± 7.1° in groups 1 and 2, respectively. This indicates that the thoracic transverse process is resistant enough to pull back the spine as reported by Csernatony in a biomechanical cadaveric study [27]. The greater leverage provided by the transverse process probably may explain why similar correction was achieved despite the fact that fewer bands were used in group 2.

The percentage of RVA correction was similar in both groups although the preoperative apical rotation was significantly greater in group 1. The ratio between correction of RVA and the number of bands used was statistically greater in the subtransverse process group ($P = 0.009$), in which fewer bands were used, but always at the apical vertebra. This also indicates that subtransverse process bands provide greater leverage and similar correction when they are placed around the apical vertebra. At latest follow-up, a significant loss of correction was observed for the RVA in group 2 compared to group 1. This could question the stability of the implant but there was no loss of correction in terms of Cobb angle.

4.2. Limitations of the study

There are some weaknesses in this study. First, it was retrospective and the size of the samples was relatively small. However, the efficacy of sublaminar bands has already been demonstrated in a large prospective study and the aim of this comparative study was to report preliminary results of a new fixation and reduction technique with polyester bands. In addition, the follow-up period was short (30 months), even though it is now accepted that loss of correction after fusion in AIS primarily occurs during the first postoperative year and that results of spine surgery can be reliably evaluated radiologically after a minimum follow-up of 2 years [28]. The patients included presented a moderate deformity, with a mean Cobb angle of 55°, and the present results need to be further confirmed for severe and more rigid spinal deformities. The efficacy of subtransverse bands also needs to be assessed in indications other than AIS, such as neuromuscular scoliosis, or in pathological conditions in which poor bone mineral density is encountered. Moreover, there were some discrepancies between the two groups regarding the number of band used and the number of level fused. However, even though the number of bands was different all in all, the number of periapical bands was identical with 2 to 3 periapical bands used. Moreover, the influence of the number of bands on postoperative correction has never been established.

5. Conclusion

This study confirmed the efficacy of polyester bands for sagittal correction, and showed that the bands can be used around the subtransverse processes in the thoracic spine in moderate AIS. Moreover, subtransverse process bands provide greater correcting potential for apical vertebral rotation than sublaminar bands.

Disclosure of interest

Brice Ilharreborde: consulting for Zimmer Spine; Keyvan Mazda: consulting for Zimmer Spine. The other authors declare that they have no conflicts of interest concerning this article.

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