The Universal Clamp hybrid system: a safe technique to correct deformity and restore kyphosis in adolescent idiopathic scoliosis

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Abstract

Purpose Adolescent idiopathic scoliosis (AIS) is a tridimensional deformity characterized by coronal and sagittal profiles changes. We present a series of 62 patients affected by AIS and treated by thoracic Universal Clamps and transpedicular lumbar screws hybrid system.

Methods Mean age was 13 years. Average pre-operative Cobb angle was $63^\circ \pm 12^\circ$. Patients were divided into two groups depending on the kyphosis angle: lower than 45° (51 patients, 82.3 %, mean $21^\circ \pm 3^\circ$) and higher than 45° (11 patients, 17.7 %, mean $62^\circ \pm 6^\circ$).

Results The average percentage of coronal correction was 70 ± 3 % (mean post-operative Cobb angle $19^\circ \pm 4^\circ$, $P < 0.001$). In patients with pre-operative physiological thoracic kyphosis–hypokyphosis, we observed an increase in the average value ($32^\circ \pm 4^\circ$, $P < 0.001$), while in patients with pre-operative hyperkyphosis, mean decrease of thoracic kyphosis was $19^\circ \pm 3^\circ$ ($43^\circ \pm 4^\circ$, $P < 0.001$).

Conclusions This case-series study showed the efficacy and safety of Universal Clamp hybrid system in correcting coronal deformity and restoring physiological thoracic kyphosis in patients affected by AIS.

Keywords Adolescent idiopathic scoliosis · Universal Clamp · Coronal correction · Thoracic kyphosis

Introduction

Adolescent idiopathic scoliosis (AIS) is a tridimensional deformity that affects the trunk height changing both in coronal and sagittal profiles, with usually a loss of thoracic kyphosis and lumbar lordosis and a trend to cervical kyphosis. The aim of surgical treatment is both to correct the deformity in the coronal plane and to restore a physiological sagittal alignment. Indeed, restoring physiological thoracic kyphosis should reduce the incidence of adjacent segment degeneration and progressive junctional malalignment [1–4]. Various systems have been reported for correction of AIS, among which the all-screw construct is commonly considered the gold standard. However, this system has some limitations: a significant decrease in thoracic kyphosis [5], the difficulty of thoracic screw placement [6, 7] because of the smaller pedicle size and the wide variation in his morphological characteristics due to the vertebral dystrophy observed in the concavity of scoliosis [8–10], and the potential complications, such as neurologic lesions, vascular injuries, pleural tears and increased radiations exposure. As demonstrated by Mazda et al. [11, 12], the Universal Clamps (sublaminar acrylic loops, UC) hybrid technique appears safe and effective in correcting both coronal and sagittal profiles. Compared to sublaminar wires, UC can be inserted with less canal invasion, having less risk of spinal cord injuries, and having a larger surface of bony contact allowing higher reduction forces. Therefore, while the coronal correction is equivalent to the all-screw or previously described hybrid constructs, the posteromedial translation performed by UC enhances correction in the sagittal plane. The aim of this study is to demonstrate the validity of UC hybrid construct in a perspective series of patients affected by AIS.

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Materials and methods

Between January 2007 and January 2011, we operated 62 patients (55 F, 7 M) affected by AIS. The study was approved by the local Ethics Committee of our Institution, and all patients gave a specific informed consent. Data were prospectively collected in all patients. The mean age was 13 years (range 11–17). All patients had progressive spinal deformity greater than 45° and were braced before surgery. According to the Lenke classification, scoliosis were divided in type 1 (31 patients, 50 % of sample), type 2 (2 patients, 3.2 %), type 3 (10 patients, 16.1 %), type 4 (1 patient, 1.6 %), type 5 (3 patients, 4.8 %), and type 6 (15 patients, 24.1 %). The average pre-operative Cobb angle was $63^\circ \pm 12^\circ$. The mean thoracic kyphosis, measured on lateral radiographs from the upper endplate of T5 to the lower endplate of T12, was $29^\circ \pm 7^\circ$. Patients were divided into two groups depending on the kyphosis angle: lower than 45° (51 patients, 82.3 %, mean $21^\circ \pm 3^\circ$) and higher than 45° (11 patients, 17.7 %, mean $62^\circ \pm 6^\circ$). All patients were treated by posterior access using a hybrid system consisting in lumbar pedicle screws, thoracic UC and a conventional pedicle-transversal claw at the upper vertebrae of the constructs (Fig. 1). The Universal Clamp® (Zimmer Spine, Bordeaux, France) is characterized by three components: a woven polyester band (Dacron), a titanium alloy (or stainless steel) clamp, and a locking screw (titanium alloy or stainless steel). In two patients with pre-operative rigid hyperkyphosis, we performed a two-stage surgery (anterior approach, Halo traction for 15 days and finally posterior surgery). Before surgery, patients performed X-rays controls (AP, LL, bending tests),

MRI, and collected three units of autologous blood. In order to reduce intra-operative blood loss we used tranexamic acid (30 mg/kg in 15 min of anesthesia induction, then 1 mg/kg in the remaining time of the intervention until 5 hours thereafter). Perioperative (30 days) results were evaluated in terms of deformity correction, operative time, and blood loss. Clinical and radiographic follow-up controls were performed at 1, 3, 6 months and 1 year after surgery. No sensitive/motor-evoked potentials were used in this study, but intra-operative “wake-up” test was performed in all patients.

Statistical analysis

Data are expressed as mean $\pm$ DS; statistical analysis was performed with the paired *t* student's test. Significance was set at $p < 0.05$.

Results

The average percentage of coronal correction was 70 ± 3 % (mean post-operative Cobb angle $19^\circ \pm 4^\circ$, $P < 0.001$). The mean operative time was 210 ± 30 min, the mean blood loss was 600 ± 100 ml, and the mean radiation exposure time of 5 ± 1.5 s. In order to enhance the posteromedial translation effect of UC to improve coronal correction and reduce rib hump prominence in Lenke type 1 scoliosis with a pre-operative Cobb angle $>90^\circ$ (3 patients, 4.8 %), we performed concave ribs sections at the apical level. In the sagittal plane, we observed a common trend to maintain or restore the physiological

Fig. 1 Lenke type 6 scoliosis in a 14-year-old female. Surgical correction of both coronal and sagittal profiles by hybrid construct using thoracic Universal Clamps and lumbar pedicle screws. The high implant density is apparent on the correcting rod

Table 1 Summary of operative data

Total number of patients	62
Female (%)	55 (88 %)
Male (%)	7 (12 %)
Mean age (range)	13 (11–17)
Pre-operative Cobb angle (mean $\pm$ SD)	$63^{\circ} \pm 12^{\circ}$
Post-operative Cobb angle (mean $\pm$ SD)	$19^{\circ} \pm 4^{\circ}$
% of correction (mean $\pm$ SD)	70 ± 3 %
Pre-operative thoracic kyphosis (mean $\pm$ SD)	$29^{\circ} \pm 7^{\circ}$
Pre-operative physiological thoracic kyphosis–hypokyphosis (51 patients) (mean $\pm$ SD)	$21^{\circ} \pm 3^{\circ}$
Post-operative physiological thoracic kyphosis–hypokyphosis (mean $\pm$ SD)	$32^{\circ} \pm 4^{\circ}$
Pre-operative thoracic hyperkyphosis (11 patients) (mean $\pm$ SD)	$62^{\circ} \pm 6^{\circ}$
Post-operative thoracic hyperkyphosis (mean $\pm$ SD)	$43^{\circ} \pm 4^{\circ}$
Operative time (min; mean $\pm$ SD)	210 ± 30
Blood loss (ml; mean $\pm$ SD)	600 ± 100
Radioscopy time (s; mean $\pm$ SD)	5 ± 1.5
% of complications	8

values in all patients. In patients with pre-operative physiological thoracic kyphosis or hypokyphosis, we observed an increase in average value ($32^{\circ} \pm 4^{\circ}$, $P < 0.001$), while in patients with pre-operative hyperkyphosis, the mean decrease in thoracic kyphosis was $19^{\circ} \pm 3^{\circ}$ ($43^{\circ} \pm 4^{\circ}$, $P < 0.001$). Moreover, in patients with pre-operative thoracic kyphosis $>70^{\circ}$ (2 patients, 3.2 %), Ponte type osteotomies were performed at apical levels. No intra-operative complications occurred. In the post-operative period, we recorded pleural effusion in three cases and intestinal disorders in two cases (8 % of complications). Mean follow-up time was 36 months (range 12–60). No loss of correction neither proximal junctional kyphosis occurred. No implant failure was recorded. At 1-year follow-up, we observed one case of lumbar adding-on in a type 3 Lenke scoliosis (1.6 %). No re-intervention was required. Results are summarized in Table 1.

Discussion

All-screw construct is currently considered the gold standard in AIS surgical treatment, providing a great deformity correction especially in coronal plane. However, the primary goal in AIS surgery is to correct not only the frontal deformity, but also restore or preserve the physiological sagittal profile [13]. Vora et al. [5] observed that pedicle screw constructs increase the lordosis of the thoracic spine. Decrease in thoracic kyphosis has been associated with an increased risk of progressive junctional kyphosis at both extremities of the fused spine [2]. This decrease was not

observed in patients treated by hybrid constructs [14]. Di Silvestre et al. [15] demonstrated that severe curves could be amenable to hybrid instrumentation that produced analogous results to the screws-only constructs concerning patient satisfaction. Particularly, Luhmann et al. [16], in a comparison between hybrid and all-pedicle screw systems in a series of Lenke 1A and 2A curve patterns, reported a significant increase in thoracic kyphosis in hybrid group. Since 2006 in neurological scoliosis and from 2007 in idiopathic forms, we have used an hybrid system consisting in lumbar polyaxial pedicle screws, thoracic Universal Clamps and a claw at the upper end of the fusion area. The Universal Clamp was introduced as an alternative to sublaminar wiring, pedicle screws or hooks, to bind vertebrae to fusion rods in spinal osteosynthesis. The UC technique was widely described both in adolescent idiopathic [11, 12] and neurological [17, 18] scoliosis. The learning curve period is usually shorter for surgeon who has experience in segmental spine instrumentation procedures [19] and posterior approaches [20]. The main advantage of UC is the larger surface area of contact between the polyester band (with its own intrinsic strength to failure and low creep under static load) and the lamina. This construct allows the application of greater spinal deformity reduction forces without laminar fracture and also the possibility of applying these forces progressively. In our series, we reported a mean percentage of correction of about 70 % in coronal plane, a value quite similar to that obtained with all-screw assembly. No lamina breakage or UC slippage was observed. In main thoracic scoliosis with a pre-operative Cobb angle $>90^{\circ}$, we performed concave ribs sections to strengthen the posteromedial translation effect of UC. However, the major challenge in scoliosis surgery is to establish the entity of good correction [13, 21]. Few supplemental degrees of frontal correction may provide an overcorrection of spinal deformity or creation of iatrogenic thoracic hypokyphosis. The pedicle screw misplacement rate reaches 10 % in the hands of the best spine surgeons, mostly caused by the smaller thoracic pedicle size and the wide variation in his morphological characteristics due to the vertebral dystrophy observed in the concavity of scoliosis [7]. The better coronal deformity correction achieved by all-screw constructs, due to the ability to place more fixation points within the thoracic Cobb measure, is counterbalanced by potential increased costs and risks. Nevertheless, positioning of more fixation points (hooks or wires) into the hybrid constructs may show a similar coronal correction [15]. Moreover, Clements et al. [22] demonstrated the correlation of scoliosis curve correction with number and type of fixation anchors. The number of fixation anchors place per available anchors sites was defined “implant density”. Higher implant density on the correcting rod provides a higher structural curve correction

Fig. 2 The posteromedial translation effect of Universal Clamp. In **a** and **b** the length of the polyester bands represents the distance between the prebent correcting rod and the spine. By applying two transverse connectors to the two rods, the spine translates

posteromedially toward a square construct, thus decreasing the length between the correcting rod and the spine (**c**). The direction of corrective force is in the posteromedial plane (**b**)

than higher density on the stabilizing rod. In our series, we performed all-levels instrumentation, with an implant density of about 90 % on the correcting rod and about 50 % on the stabilizing rod.

Recently, some authors reported the difficulty of restoring physiological thoracic kyphosis in AIS patients treated by selective posterior thoracic fusion with all-screw constructs and direct vertebral derotation [23, 24]. Restoring an optimal sagittal alignment reduces the incidence of adjacent segment degeneration and proximal junctional kyphosis [1–4]. In our study, we observed a common trend to maintain or restore the physiological thoracic kyphosis in all patients. Particularly, in cases with pre-operative physiological thoracic kyphosis or hypokyphosis, we reported an increase in average value, obtained by performing an early UC translation just on the prebent correcting rod before correction maneuvers, and then progressively translating of the spine in the sagittal plane toward a square construct created by applying two transverse connectors to the two rods (Fig. 2). Instead, in patients with pre-operative hyperkyphosis, we observed a mean decrease in thoracic kyphosis of about $19^\circ \pm 3^\circ$. In

this group, to reduce hyperkyphosis, we removed the facet joints and soft tissue (supraspinous and interspinous ligaments, ligamentum flavum and facet joint capsule) between the posterior elements, allowing a greater compression along the length of the posterior column. In two cases with pre-operative thoracic kyphosis $>70^\circ$ Ponte type osteotomy was additionally performed at apical levels.

These data show the effectiveness of UC in improving thoracic kyphosis, confirming that hybrid constructs can enhance sagittal correction and might reduce the risk of subsequent proximal junctional kyphosis [2, 5]. Also Sale de Gauzy et al. [25] observed that, UC hybrid construct safely provides satisfying coronal correction while consistently improving thoracic kyphosis in patients with pre-operative hypokyphosis. Moreover, Mazda and co-workers [26] showed that flattening of the thoracic and cervical curvatures observed in AIS can be improved postoperatively when the UC posteromedial translation technique is used. To preserve a physiological sagittal balance in adolescents is also important in their adulthood, considering that the aging of the spine is often associated with a gradual development of an anterior spine–pelvis imbalance,

characterized by a combination of increased thoracic kyphosis and decreased lumbar lordosis offset by gradual posterior tilting of the pelvis [27], with a strong correlation with adult quality-of-life [28].

In our series, no loss of correction occurred at 1-year follow-up except of one case of lumbar adding-on phenomenon due to a too much selective fusion area. The mean follow-up was 36 months, but it is now accepted that loss of correction after fusion in AIS primarily occurs during the first post-operative year [25]. However, this follow-up is lower than that reported for all-screw instrumentations, and this is a limitation of our study. Rate of complications was low (8 %), without neurological injuries in all cases. Neurological injuries were evaluated clinically in terms of appearance of post-operative neurological deficit or differences between pre- and post-operative neurological status, and surgically as spinal cord damage by intra-operative “wake-up” test. Transcranial somatosensory/motor-evoked potentials were not used, and this is the other shortcoming of the present study.

Conclusion

This case-series study showed the effectiveness and safety of Universal Clamp hybrid system in correcting coronal deformity and restoring physiological thoracic kyphosis in patients affected by AIS. This report confirms previous data reported in the literature. Therefore, Universal Clamps represent a valid alternative to pedicle screws in thoracic fixation, providing a quite similar coronal correction and a better sagittal balance control, reducing neuro-vascular risks with shorter operative time, lower intra-operative blood loss and radiations time exposure. No changes in correction were observed at follow-up controls, representing a great advantage for the future of patients in adulthood. These features, together with other intrinsic characteristics of UC (very low profile, the possibility of post-operative imaging—i.e., CT scanning and MRI—with poor artifacts), the very short learning curve and the lower costs, at least in some Countries, respect to all-screw constructs, allow to consider the UC hybrid system a safe, effective, reliable and less expansive technique to treat AIS.

Conflict of interest None.

References

1. Hwang SW, Samdani AF, Tantorski M, Cahill P, Nydick J, Fine A, Betz RR, Antonacci MD (2011) Cervical sagittal plane decompensation after surgery for adolescent idiopathic scoliosis: an effect imparted by postoperative thoracic hypokyphosis. *J Neurosurg Spine* 15:491–496. doi:[10.3171/2011.6](https://doi.org/10.3171/2011.6)
2. Kim YJ, Lenke LG, Bridwell KH, Kim J, Cho SK, Cheh G, Yoon J (2007) Proximal junctional kyphosis in adolescent idiopathic scoliosis after 3 different types of posterior segmental spinal instrumentation and fusions: incidence and risk factor analysis of 410 cases. *Spine* 32:2731–2738
3. Ghiselli G, Wang JC, Bhatia NN, Hsu WK, Dawson EG (2004) Adjacent segment degeneration in the lumbar spine. *J Bone Jt Surg Am* 86:1497–1503
4. Ilharreborde B, Morel E, Mazda K, Dekutoski MB (2009) Adjacent segment disease after instrumented fusion for idiopathic scoliosis: review of current trends and controversies. *J Spinal Disord Tech* 22:530–539. doi:[10.1097/BSD.0b013e31818d64b7](https://doi.org/10.1097/BSD.0b013e31818d64b7)
5. Vora V, Crawford A, Babekhir N, Boachie-Adjei O, Lenke L, Peskin M, Charles G, Kim Y (2007) A pedicle screw construct gives an enhanced posterior correction of adolescent idiopathic scoliosis when compared with other constructs: myth or reality. *Spine* 32:1869–1874
6. Senaran H, Shah SA, Gabos PG, Littleton AG, Neiss G, Guille JT (2008) Difficult thoracic pedicle screw placement in adolescent idiopathic scoliosis. *J Spinal Disord Tech* 21:187–191. doi:[10.1097/BSD.0b013e318073cc1d](https://doi.org/10.1097/BSD.0b013e318073cc1d)
7. Upendra BN, Meena D, Chowdhury B, Ahmad A, Jayaswal A (2008) Outcome-based classification for assessment of thoracic pedicular screw placement. *Spine* 33:384–390. doi:[10.1097/BRS.0b013e3181646ba1](https://doi.org/10.1097/BRS.0b013e3181646ba1)
8. Ebraheim NA, Lu J, Yang H, Heck BE, Yeasting RA (1997) Anatomic considerations of the second sacral vertebra and dorsal screw placement. *Surg Radiol Anat* 19:353–357
9. Esses SI, Sachs BL, Dreyzin V (1993) Complications associated with the technique of pedicle screw fixation. A selected survey of ABS members. *Spine* 18:2231–2238
10. Vaccaro AR, Rizzolo SJ, Allardyce TJ, Ramsey M, Salvo J, Balderston RA, Cotler JM (1995) Placement of pedicle screws in the thoracic spine. Part I: morphometric analysis of the thoracic vertebrae. *J Bone Jt Surg Am* 77:1193–1199
11. Mazda K, Ilharreborde B, Even J, Lefevre Y, Fitoussi F, Penneçot GF (2009) Efficacy and safety of posteromedial translation for correction of thoracic curves in adolescent idiopathic scoliosis using a new connection to the spine: the Universal Clamp. *Eur Spine J* 18:158–169. doi:[10.1007/s00586-008-0839-y](https://doi.org/10.1007/s00586-008-0839-y)
12. Ilharreborde B, Even J, Lefevre Y, Fitoussi F, Presedo A, Penneçot GF, Mazda K (2010) Hybrid constructs for tridimensional correction of the thoracic spine in adolescent idiopathic scoliosis: a comparative analysis of universal clamps versus hooks. *Spine* 35:306–314. doi:[10.1097/BRS.0b013e3181b7c7c4](https://doi.org/10.1097/BRS.0b013e3181b7c7c4)
13. Winter RB, Lonstein JE, Denis F (2007) How much correction is enough? *Spine* 32:2641–2643
14. Lowenstein JE, Matsumoto H, Vitale MG, Weidenbaum M, Gomez JA, Lee FY, Hyman JE, Royce DP Jr (2007) Coronal and sagittal plane correction in adolescent idiopathic scoliosis: a comparison between all pedicle screw versus hybrid thoracic hook lumbar screw constructs. *Spine* 32:448–452
15. Di Silvestre M, Bakaloudis G, Lolli F, Vommario F, Martikos K, Parisini P (2008) Posterior fusion only for thoracic adolescent idiopathic scoliosis of more than 80 degrees: pedicle screws versus hybrid instrumentation. *Eur Spine J* 10:1336–1349. doi:[10.1007/s00586-008-0731-9](https://doi.org/10.1007/s00586-008-0731-9)
16. Luhmann SJ, Lenke LG, Erickson M, Bridwell KH, Richards BS (2012) Correction of moderate (<70 degrees) Lenke 1A and 2A curve patterns: comparison of hybrid and all-pedicle screw systems at 2-year follow-up. *J Pediatr Orthop* 32:253–258. doi:[10.1097/BPO.0b013e3182471c74](https://doi.org/10.1097/BPO.0b013e3182471c74)
17. La Rosa G, Giglio G, Oggiano L (2011) Surgical treatment of neurological scoliosis using hybrid construct (lumbar transpedicular

- screws plus thoracic sublaminar acrylic loops). *Eur Spine J* 20: S90–S94. doi:[10.1007/s00586-011-1751-4](https://doi.org/10.1007/s00586-011-1751-4)
18. La Rosa G, Giglio G, Oggiano L (2012) Sagittal profile control in patients affected by neurological scoliosis using Universal Clamps: a 4-year follow-up study. *Eur Spine J* 21:S32–S36. doi:[10.1007/s00586-012-2237-8](https://doi.org/10.1007/s00586-012-2237-8)
 19. Luque ER (1989) Segmental spinal instrumentation in neuromuscular scolioses. *Orthopade* 18:128–133
 20. Cotrel Y, Dubousset J (1984) A new technic for segmental spinal osteosynthesis using the posterior approach. *Rev Chir Orthop Repar Appar Mot* 70:489–494
 21. Imrie M, Yaszay B, Bastrom TP, Wenger DR, Newton PO (2011) Adolescent idiopathic scoliosis: should 100% correction be the goal? *J Pediatr Orthop* 31:S9–S13. doi:[10.1097/BPO.0b013e3181fd8a24](https://doi.org/10.1097/BPO.0b013e3181fd8a24)
 22. Clements DH, Betz RR, Newton PO, Rohmiller M, Marks MC, Bastrom T (2009) Correlation of scoliosis curve correction with the number and type of fixation anchors. *Spine* 34:2147–2150. doi:[10.1097/BRS.0b013e3181adb35d](https://doi.org/10.1097/BRS.0b013e3181adb35d)
 23. Mladenov KV, Vaeterlein C, Stuecker R (2011) Selective posterior thoracic fusion by means of direct vertebral derotation in adolescent idiopathic scoliosis: effects on the sagittal alignment. *Eur Spine J* 20:1114–1117. doi:[10.1007/s00586-011-1740-7](https://doi.org/10.1007/s00586-011-1740-7)
 24. Schmidt C, Liljenqvist U, Lerner T, Schulte TL, Bullmann V (2011) Sagittal balance of thoracic lordoscoliosis: anterior dual rod instrumentation versus posterior pedicle screw fixation. *Eur Spine J* 20:1118–1126. doi:[10.1007/s00586-011-1784-8](https://doi.org/10.1007/s00586-011-1784-8)
 25. Sale de Gauzy J, Jouve JL, Accadbled F, Blondel B, Bollini G (2011) Use of the Universal Clamp in adolescent idiopathic scoliosis for deformity correction and as an adjunct to fusion: 2-year follow-up. *J Child Orthop* 5:273–282. doi:[10.1007/s11832-011-0357-z](https://doi.org/10.1007/s11832-011-0357-z)
 26. Ilharreborde B, Vidal C, Skalli W, Mazda K (2013) Sagittal alignment of the cervical spine in adolescent idiopathic scoliosis treated by posteromedial translation. *Eur Spine J* 22:330–337. doi:[10.1007/s00586-012-2493-7](https://doi.org/10.1007/s00586-012-2493-7)
 27. Lafage V, Schwab F, Skalli W, Hawkinson N, Gagey PM, Ondra S, Farcy JP (2008) Standing balance and sagittal plane spinal deformity: analysis of spinopelvic and gravity line parameters. *Spine* 33:1572–1578. doi:[10.1097/BRS.0b013e31817886a2](https://doi.org/10.1097/BRS.0b013e31817886a2)
 28. Lafage V, Schwab F, Patel A, Hawkinson N, Farcy JP (2009) Pelvic tilt and truncal inclination: two key radiographic parameters in the setting of adults with spinal deformity. *Spine* 34:E599–E606. doi:[10.1097/BRS.0b013e3181aad219](https://doi.org/10.1097/BRS.0b013e3181aad219)
 29. Remes V, Helenius I, Schlenzka D, Yrjönen T, Ylikoski M, Poussa M (2004) Cotrel-Dubousset (CD) or universal spine system (USS) instrumentation in adolescent idiopathic scoliosis (AIS): comparison of midterm clinical, functional, and radiologic outcomes. *Spine* 29:2024–2030