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# Simultaneous Double Rod Rotation vs. Simultaneous Double Rod Translation Techniques for Kyphosis Restoration in Hypo-Kyphotic Adolescent Idiopathic Scoliosis

**Alberto Ruffilli, Fabrizio Perna, Niccolò Stefanini, Alessandro Panciera, Giuseppe Geraci, Fabio Vita, Francesca Vannini* and Cesare Faldini**

Rizzoli Orthopedic Institute, Bologna BO, Italy

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Correspondence should be addressed to
Francesca Vannini, Italy
E-mail: france_vannini@yahoo.it

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## Abstract

**Purpose:** Hypo-kyphosis is a natural consequence of the coronal impairment of Adolescent Idiopathic Scoliosis (AIS) and it is one of the most important parameters predicting long term spinal outcome. Despite been considered the better option for AIS surgical correction, Pedicle Screws (PS) have been widely associated with a hypo-kyphotic effect. Aim of this study is to retrospectively compare results of two different surgical techniques using high-density PS in order to identify the better procedure for kyphosis restoration in hypo-kyphotic patients.

**Methods:** Retrospective analysis of two groups of 18 hypo-kyphotic AIS patients undergone surgical deformity correction with one of two different surgical techniques: Simultaneous Double Rod Rotation (SDRR) and Simultaneous Double Rod Translation (SDRT). Pre- and postoperative clinical and radiological values were compared.

**Results:** The mean follow-up was 3 years. Mean preoperative Cobb angle was 69.5° in the SDRR group and 66.2° in the SDRT group. Average postoperative Cobb angle was respectively 16.4° and 14.3° (p=0.22). Mean preoperative kyphosis angle was 13.8° and 13.2° respectively in SDRR and SDRT group. Average postoperative values were 17.5° and 21.4° respectively (p=0.0002). Apical vertebral rotation shown significant improvements with an average correction rate of 58% in both groups. At the last follow-up no screw pull-out, non-union or deformity progression have been recorded.

**Conclusion:** Both SDRR or SDRT techniques have shown to be effective for AIS correction achieving good clinical and radiological results on all three planes with low rate of complications. SDRT technique shown to be related with improved sagittal values compared to SDRR technique.

## Keywords

Rib-Hump; Sagittal Balance; Spine Deformity; Surgical Technique; Vertebral Rotation

## Introduction

Adolescent Idiopathic Scoliosis (AIS) is a three-dimensional deformity with coronal, sagittal and axial impairment. Purpose of the surgical treatment is to correct the deformity obtaining a stable balanced spine on all three planes preserving mobile segments of the lumbar spine when possible [1]. Modern fixation techniques using pedicle screw constructs have been associated with the highest correction rates on coronal plane achieving even more than 70% of correction [2]. Various corrective maneuvers have been described for frontal plane correction such as: cantilever reduction, rod rotation, translation and in situ rod bending alone and in combined forms. Although, there were not significant differences on coronal correction rates among the aforementioned techniques [3-6]. Therefore the improvements in correction rates on the frontal plane seem to be related with the screws despite the technique used [7].

Hypo-kyphosis is a common deformity in patients with AIS and it has been related with anterior imbalance and progressive decompensation [8,9]. In recent years increased attention has been addressed to physiological sagittal contour restoration, but results are still inconclusive [10]. Sagittal spinal alignment seems to be one of the most important parameters predicting long term spinal surgery outcome [11-13]. Furthermore, sagittal decompensation was linked to fixation failure, higher non-union rate and pain [11]. Nonetheless, several recent articles reported a lordogenic effect of posterior instrumentation, especially if pedicle screw are used [2,8,10,14]. Lowenstein et al., found an average decreased kyphosis on postoperative follow-up of 10° [10]. Similar results were found by Kim et al., with an average decrease of 9° when pedicle screws were used [2]. However, other authors presented opposite results such as Suk et al., whom reported TK increase of 5° in a large series of 203 patients with 5 years follow-up [15]. Nevertheless, pedicle screw constructs are still related with the best overall corrective results for AIS surgery [6,10,16,17]. Therefore, the reduction maneuvers can be the determining factor for postoperative sagittal values.

In order to better control the deformity on the sagittal plane in hypo-kyphotic patients two different techniques have been described in literature: the Simultaneous Double Rod Rotation Technique (SDRR) and the Simultaneous Double Rod Translation Technique (SDRT) [18-20]. Major presumed advantage of the simultaneous dual rod procedure, whether using the rotation or the translation technique, is related to the wider forces distribution during the corrective maneuvers that could reduce the risk of lateral screw break-out or screw pull-out. Both techniques have been used by the authors in the last 6 years. In a previous study, we reported the results of AIS correction using simultaneous dual rod and en-bloc direct vertebral rotation technique without distinction between SDRR and SDRT [7] but no statistically significant increase on the average postoperative kyphosis values compared to preoperative have been recorded. The aim of this study is to retrospectively compare outcomes of SDRR and SDRT techniques in order to evaluate the efficacy of these techniques to improve sagittal correction in case of hypo-kyphotic AIS patients.

## Materials and Methods

Data from the medical records and radiographs of sixty-one consecutive patients affected by AIS and operated on between January 2010 and December 2014 from the same surgeon at our institute were retrospectively evaluated. There were 38 patients surgically treated with SDRR and 23 with SDRT. The choose between the two techniques have always been made randomly. Inclusion criteria were: patients with hypo-kyphotic AIS (less than 20° on T5-T12 kyphosis); patients undergone surgical treatment with SDRR or SDRT techniques; Lenke type 1, 3 or 6 AIS; minimum two years follow-up; complete radiographic and clinical evaluation at preoperative and postoperative follow-up. Exclusion criteria were: congenital, syndromic or neuromuscular scoliosis and severe scoliosis with more than 100° on coronal Cobb angle; moreover, we decided to exclude patients with Lenke curve type 2, 4 and 5 because of possible bias when evaluating the sagittal plane alignment due to the presence of structured upper thoracic or lumbar deformity or both. Twenty-eight patients in the SDRR group and 18 patients in the SDRT group were considered eligible for this study. In order to adequately compare the two groups only the first 18 patients of the SDRR group were considered. Hence, a total of 36 patients were retrospectively evaluated. Analysis of changes in post-procedural clinical and radiological results was performed and differences between the two groups were compared.

Standard standing long-cassette anteroposterior and lateral radiographs were evaluated for coronal Cobb angle and T5-T12 thoracic kyphosis angle. Passive bending radiographs were used to evaluate the rigidity of the curve, classify the deformity according to Lenke and to assess the fusion area.

Sagittal Vertical Axis (SVA) was used to evaluate the sagittal balance whereas the distance from the C7 Coronal Plumb Line (C7PL) to the Central Sacral Vertical Line (CSVL) was used for global coronal balance assessment. MRI was always performed preoperatively in order to exclude congenital intramedullary anomalies. Image slices of the apical vertebrae were later used in order to compare Apical Vertebral Axial Rotation (AVAR) with the post-operative CT control using the method described by Aaro and Dahlborn [21,22]. The angle of rotation of the apical vertebra was measured using the angle between the

junction of the laminae, the middle of the vertebral body and the sagittal plane both on MRI and CT scan.

Clinical evaluation was performed using the Scoliosis Research Society outcome instrument score (SRS-22). Pre- and postoperative radiographic measurements and clinical outcome were compared using matched-pairs analysis. A p-value threshold $< 0.05$ was chosen to define statistical significance.

## Surgical Technique

Intraoperative spinal cord monitoring by Somatosensory Evoked Potentials (SEPs) and Motor Evoked Potentials (MEPs) was provided in all patients throughout the operation.

A standard posterior midline incision was made from one level above and one below the uppermost and the lowermost instrumented vertebra respectively. The transverse processes were then exposed bilaterally. The facets and their articular process included in the fusion area except the uppermost level were removed in order to facilitate the identification of the entry points, promote arthrodesis and allow an easier deformity correction. Uniplanar pedicle screws were placed at each level on both sides of the curve using drill assisted technique [23]. Poliaxial pedicle screws were used in the two uppermost levels in case of severe rigid deformity when the rod resulted too far to be engaged.

For SDRR technique (Legacy Deformity - Medtronic) two 5.5 mm CoCr rods bent to the desired shape of the anticipated thoracic kyphosis were placed on both sides of the curve. The two rods were then simultaneously gently rotated in a counter clockwise direction by 90° by two surgeons transforming the deformity on the frontal plane into the desired kyphosis on the lateral plane. In this case the deformity correction occurs during the rods rotation that applied to the spine an upward-pushing force in a posteromedial direction (Figure 1). En-bloc DVR was performed in all cases. When the most proximal and distal anchors were fixed, the screw derotators were placed at each level of the deformity on both sides of the curve and then rotated in a clockwise direction using the neutral vertebrae as anchor points. Screws heads were tightened. Then decortication followed and bone graft was applied.

In case of SDRT technique (Mesa Deformity - K2M) two 5.5 mm CoCr rods were also used. They were bent to the desired shape according to the deformity and the desired kyphosis and then inserted into the reduction jacks. The concave side rod was bent more than the convex one in order to better restore the thoracic kyphosis and allow some grade of vertebral rotation. The two rods were then rotated to the desired position on the coronal and sagittal plane without performing any reduction maneuvers. At this point the neutral uppermost and lowermost vertebras were fixed in order to maintain frontal correction and create a foundation. Following this step DVR maneuver was performed using screw derotators while the rods were still far

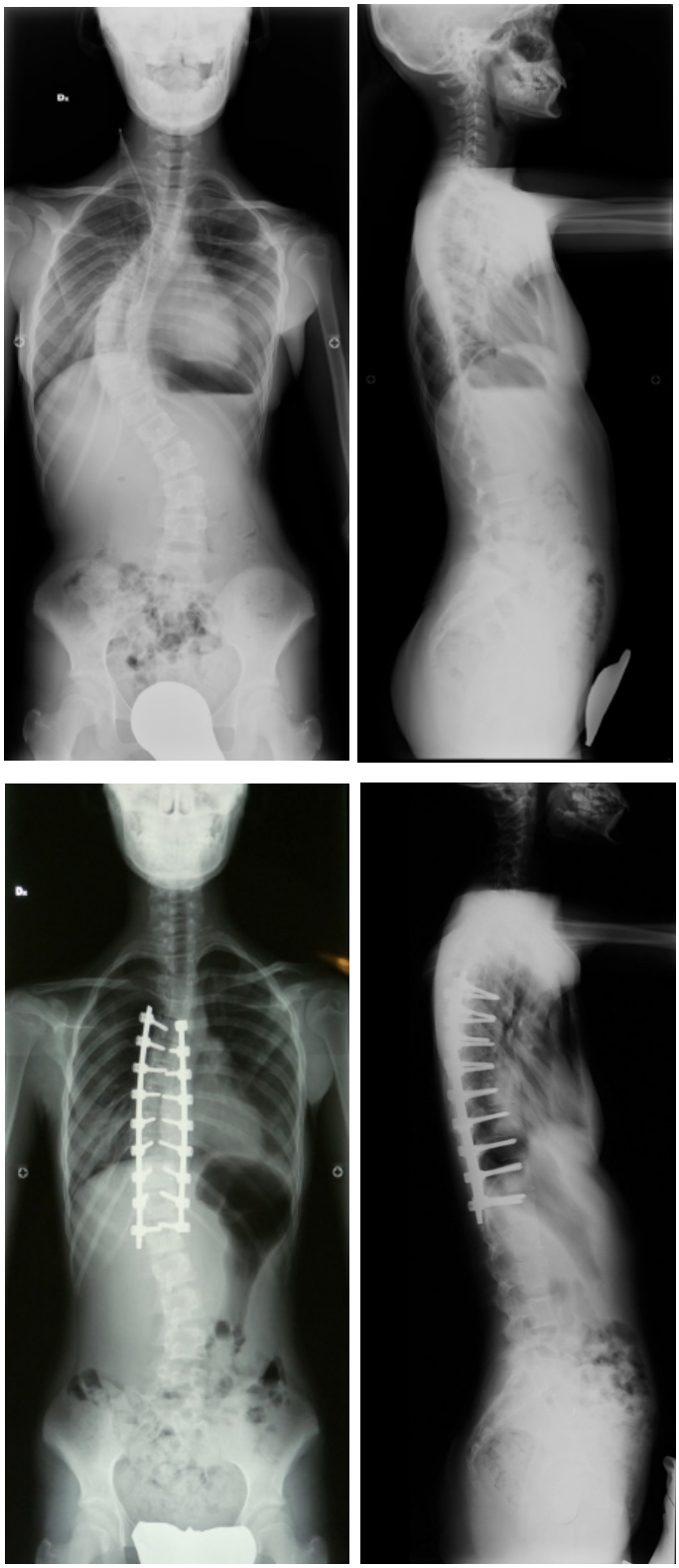

**Figure 1:** Preoperative anteroposterior (1a) and lateral (1b) standing-long cassette radiographs of hypo-kyphotic AIS. Post-operative control (1c,d) after SDRR technique.

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from the screw heads. Then simultaneous gradual tightening of the reduction jacks was performed starting from the apical vertebrae proceeding proximally and distally, allowing the spine to gradually catches the rods (Figure 2).

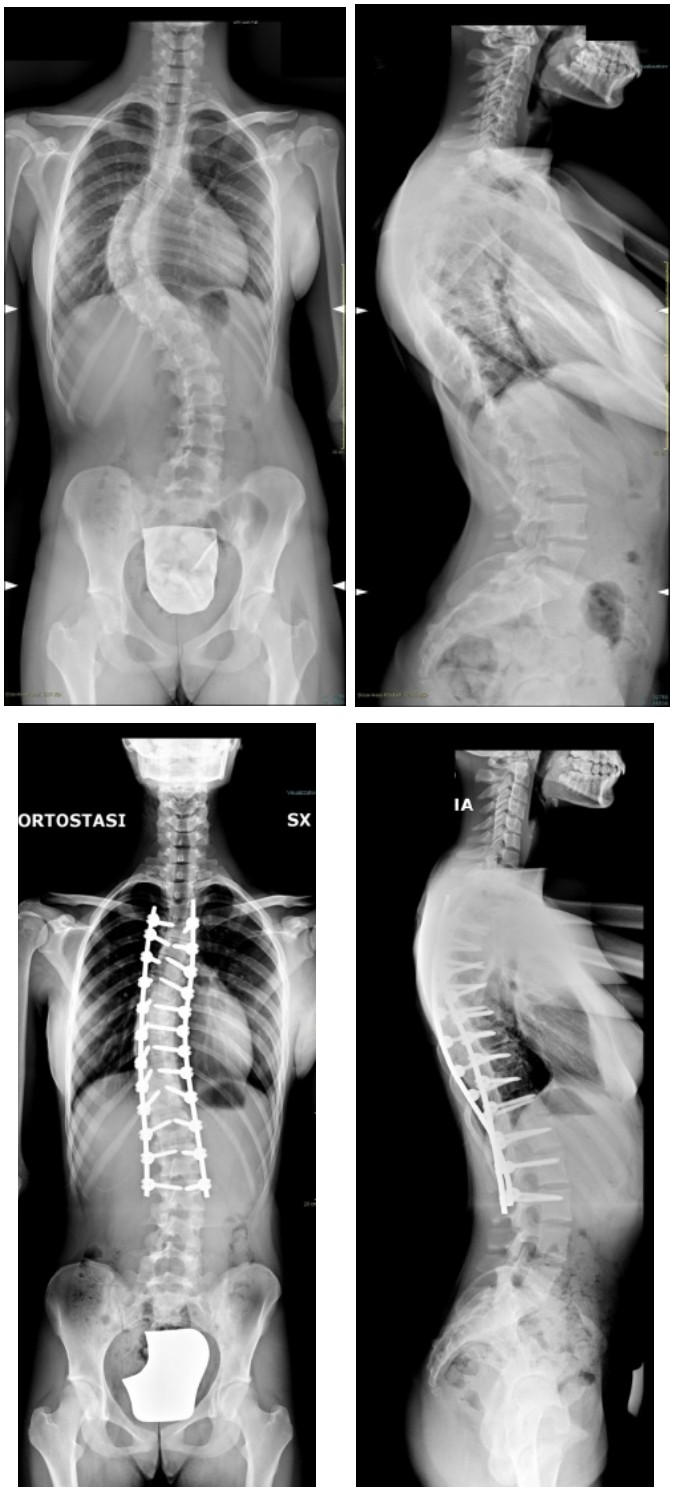


**Figure 2:** Preoperative anteroposterior (2a) and lateral (2b) standing-long cassette radiographs of hypo-kyphotic AIS. Post-operative control (2c,d) after SDRT technique.

Thoracoplasty was not required in any cases neither SDRR nor SDRT techniques. A standard three-point toracolumbosacral orthosis was used in all patients during daily activities for the first 3 weeks and then abandoned gradually during the fourth postoperative week in order to avoid sudden movements and to better control postoperative pain.

## Results

Results were evaluated at a mean follow-up of 3 years (range 2-4). The two groups were comparable in term of demographic data and radiological spinal parameters. There were 3 males and 15 females in SDRR group and 2 males and 16 females in SDRT group. Mean age at the time of surgery was 15.3 ± 3.25 and 15.1 ± 2.1 years respectively in SDRR and SDRT group. Instrumentation consisted of an average of 17.3 (range 12 - 24) pedicle screws in the SDRR group and of an average of 16.8 (range 12 - 21) pedicle screws in the SDRT group. Mean preoperative thoracic Cobb angle was 69.5° ± 11.1° in the SDRR group and 66.2° ± 10.3° in the SDRT group. Average postoperative thoracic Cobb angle was respectively 16.4° ± 5.9° and 14.3° ± 4.3° in the SDRR and the SDRT group with no statistically significant difference (p=0.22). Mean preoperative T5-T12 kyphosis angle was 13.8° ± 4.5° and 13.2° ± 4.7° respectively in SDRR and SDRT group. Average postoperative T5-T12 kyphosis angle was respectively 17.5° ± 3.0° and 21.4° ± 2.7° in SDRR and SDRT group, with a gain of 8.2° against a gain of 3.7° for SDRR, with high statistically significant difference (p=0.0002). Nor the sagittal balance measured by the SVA or the coronal balance measured by the C7PL from the CSVL shown statistically significant change between pre- and post-operative values and between the two groups.

Average preoperative AVAR measured on MRI in the SDRR group was 26.3° ± 3.8° and 25.9° ± 2.8° in the SDRT group. Mean post-operative AVAR on CT scan was respectively 10.9° ± 1.8° and 10.7° ± 2.1° (p=0.79), with an average correction rate of 58% in both groups.

Mean total preoperative SRS-22 score values were 2.6 ± 0.5 and 2.5 ± 0.5 respectively in the SDRR and in the SDRT group with improvement in postoperative values in both group (respectively 4.0 ± 0.4 in the SDRR and 3.8 ± 0.5 in the SDRT group) but without statistically significant difference between the two group (p=0.27). No major perioperative complications occurred in both group. One superficial wound infection developed in both group and one deep wound infection developed in the SDRT group. All infections resolved with surgical debridement and specific antibiotic therapy without implant removal. At the last available follow-up nor deformity progression or screw pull-out or non-union were recorded (Table 1).

| | SDRR | | SDRT | | p |
|---|---|---|---|---|---|
| | Pre-operative | Post-operative | Pre-operative | Post-operative | |
| **Thoracic Cobb angle** | 69.5° ± 11.1° | 16.4° ± 5.9° | 66.2° ± 10.3° | 14.3° ± 4.3° | 0.22 |
| **Kyphosis angle** | 13.8° ± 4.5° | 17.5° ± 3.0° | 13.2° ± 4.7° | 21.4° ± 2.7° | 0.0002 |
| **SVA (mm)** | -7.7 ± 18 | -9.8 ± 17.6 | -5.4 ± 20.5 | 0.7 ± 17.6 | 0.08 |
| **C7PL-CSVL (mm)** | 10.5 ± 20.1 | -2.0 ± 8.2 | 7.8 ± 21.9 | -2.7 ± 9.4 | 0.79 |
| **AVAR** | 26.3° ± 3.8° | 10.9° ± 1.8 | 25.9° ± 2.8° | 10.7° ± 2.1° | 0.79 |
| **SRS-22** | 2.6 ± 0.5 | 4.0 ± 0.4 | 2.5 ± 0.5 | 3.8 ± 0.5 | 0.27 |

**Table 1:** Bold values are statistically significant.

## Discussion

Aim of this study was to evaluate and compare clinical and radiological outcomes of two different technique used for AIS surgery. We found that, despite good clinical and radiological results can be obtained with both SDRR and SDRT technique, the latter demonstrated to be superior regarding kyphosis restoration with better radiological results in hypo-kyphotic patients.

Simultaneous Double-Rod Rotation Technique (SDRR) was first reported by Ito et al., with the intent to increase thoracic kyphosis in patients with AIS. They reported a mean gain of 6.5° from preoperative (mean 15.2°) to postoperative (mean 21.7°) kyphosis values (T5-T12) [20].

Similar results were later reported by Sudo et al., using the same technique. They found an improvement from 11.9° to 20.5° in kyphosis values from preoperative to the last follow-up [19]. In our series of SDRR we found a gain of 3.7° (from 13.8° to 17.5°) which is quite less compared with the aforementioned results. However, we always performed DVR. Indeed, axial rotation needs to push down the spine on the convex side which leads to thoracic segment flattening.

Clement et al., reported the differences between classic Cantilever Reduction (CR) and Simultaneous translation technique on two rods (SDRT) finding better correction of the thoracic kyphosis using SDRT in hypo-kyphotic spine patients with a mean gain of 14° in CR series (from 8° to 22°) and 27° (from 3° to 33°) in the SDRT series [7].

The lower sagittal values achieved among our series could be again related to the DVR.

Because we believe that a lower grade of correction on all three planes could be better than a higher correction rate in only one or two planes, we prefer performing DVR instead of thoracoplasty, despite the lower results on the sagittal plane. Indeed, nearly normal kyphosis restoration in case of hypo-kyphotic scoliosis can be hardly achieved, or may be associated with neurological problems, hence lower grades of correction may be accepted in these cases. Moreover, DVR eliminates the need for more invasive procedures such as thoracoplasty to reduce the rib-hump prominence. Furthermore, in our series uniplanar pedicle screws were applied in all cases which allow an easy engagement of the rod while maintaining enough strength to adequately perform corrective maneuvers and rotate the vertebrae. Recent literature supports the effectiveness of DVR on axial deformity correction. Lee et al., reported a correction rate of 42.5% using DVR [16]. Similar results were also reported by Asghar et al., with a correction rate of 60% [24] and by Kuklo et al., which have reached up to 77.9% of correction [25]. In our series we reported an average correction rate of 58% of the AVAR in both groups. Furthermore, DVR provide good clinical results on rib-hump prominence avoiding additional procedures like thoracoplasty and related complications [16,17].

One of the main limits of the present study is the use of two different axial deformity measurements methods. Indeed, we used MRI on pre-operative and CT on post-operative control to evaluate AVAR. Despite well-established on CT scan, measurements of AVAR have never been validated on MRI. However, we are aware of the superiority of CT scan derived measurements for apical vertebral rotation [22]. Notwithstanding, this procedure increase radiation exposure to paediatric population without significant clinical relevance. Moreover, preoperative MRI is of the utmost importance in order to exclude congenital intramedullary anomalies such as Syringomyelia, Arnold-Chiari malformation, Diastematomyelia, Myelomeningocele and Tethered spinal cord syndrome.

Another limit of the present study is the small number of patients recruited on each group. Indeed, this could lead to an underestimation of statistical relationship between the two groups for those values with less obvious differences. However, we preferred using only case of hypo-kyphotic patients in order to better evaluate efficacy of the two described procedures on the sagittal plane correction.

Considering the results achieved with the SDRT technique we have currently changed our corrective maneuver into SDRT only procedure and we have abandoned the SDRR technique for AIS patients.

In conclusion, considering our results, we can infer that SDRT technique showed better restoration of thoracic kyphosis values in hypo-kyphotic AIS compared to SDRR techniques. However, this study should be reproduced with a larger number of patients.

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