

Sagittal Alignment Restoration in Adolescent Idiopathic Scoliosis Surgery: Accuracy of Sagittal Planning Evaluation through a Novel Scoring System

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INTRODUCTION:

Surgical techniques for adolescent idiopathic scoliosis (AIS) correction have proven highly effective in achieving substantial three-dimensional deformity correction, even in severe cases. Modern instrumentation systems offer excellent reproducibility and safety, with reliable outcomes even in the hands of less-experienced surgeons. However, sagittal plane correction remains more challenging, and its results are often suboptimal. Multiple studies have highlighted the issue of iatrogenic sagittal malalignment and thoracic hypokyphosis, the so-called "thoracal flatback" that has been associated with an increased risk—up to threefold—of early disc degeneration in the unfused cervical and lumbar segments at mid- to long-term follow-up. Given these concerns, there is growing interest in the restoration of physiological sagittal alignment after AIS surgery. Nonetheless, preoperative sagittal planning and postoperative assessment of sagittal alignment remain poorly systematized in both clinical and radiographic workflows. The aim of this study was to assess the effectiveness of preoperative sagittal planning using Surgimap software in restoring ideal alignment parameters tailored to each patient, based on individual pelvic morphology (specifically pelvic incidence). The radiographic parameters selected to evaluate pre- and post-operative sagittal alignment were sacral slope (SS), global thoracic kyphosis (TK), global tilt (GT), and T1 slope (T1S)

METHODS:

A radiographic retrospective analysis was conducted on 30 consecutive patients with adolescent idiopathic scoliosis (AIS) who underwent one-stage posterior spinal fusion using high-density pedicle screw instrumentation, Ponte osteotomies, and differential rod contouring. Patients with less than 2 years of follow-up were excluded from the analysis.

Based on preoperative full-spine standing lateral radiographs, patient-specific sagittal alignment targets were calculated as follows:

$$\text{Ideal SS} = 0.61 \times \text{PI} + 11.5 \text{ (range } \pm 5^\circ\text{)}$$

$$\text{Ideal TK} = 2 \times (\text{PT} + \text{LL} - \text{PI}) \text{ (range } \pm 5^\circ\text{)}$$

$$\text{Ideal T1S} = 28^\circ \pm 7^\circ$$

$$\text{Ideal GT} = 0.48 \times \text{PI} - 15 \text{ (range } \pm 5^\circ\text{)}$$

Preoperative planning was performed using Surgimap software to simulate sagittal realignment based on these individualized targets. Postoperative standing lateral radiographs obtained at 2-year follow-up were evaluated to assess whether the planned alignment targets had been achieved.

A scoring system was developed based on the four selected parameters (SS, TK, GT, T1S): each parameter was assigned a score of 1 if the postoperative value fell within the defined range, and 0 otherwise. The total score ranged from 0 to 4 for each patient.

To assess changes in sagittal alignment goal attainment, preoperative and postoperative total scores were compared using the Wilcoxon signed-rank test.

RESULTS:

Preoperative analysis showed that the majority of patients had low sagittal alignment scores, indicating an important sagittal malalignment in the sense of anteversion, thoracic ipokyphosis and negative global spino-pelvic alignment prior to surgery. Specifically, 13.3% of patients had a preoperative score of 0 (no parameter within target range), 66.7% had a score of 1, 16.7% had a score of 2, and 3.3% had a score of 3. No patient had a perfect alignment score preoperatively. At 2-year follow-up, all patients showed improved sagittal alignment. 23.3% of patients achieved a postoperative score of 1, 30.0% scored 2, 26.7% scored 3, and 20.0% of patients achieved the maximum score of 4, meaning all sagittal parameters fell within the individualized target ranges. The mean improvement across the whole cohort was +1.33 score points, with a maximum observed improvement of +4 points. 21 patients (70.0%) showed a measurable improvement, with 6 patients improving by +1 point (20%), 11 patients improving by +2 points (37%), 2 patients improving by +3 points (7%), 2 patients improving by the maximum of +4 points (7%). Two patients exhibited a decrease in alignment score postoperatively.

The improvement in sagittal alignment score attainment between pre- and postoperative assessments was statistically significant ($p < 0.01$, Wilcoxon signed-rank test)

DISCUSSION AND CONCLUSION:

Surgimap-based preoperative planning showed acceptable results in restoration of physiologic sagittal alignment in AIS patients treated surgically, resulting in promising radiographic outcomes at 2-year follow-up. The large majority of patients exhibited a moderate to strong improvement in sagittal alignment. Importantly, among patients with the lowest preoperative scores (0 or 1), 40% achieved a postoperative improvement of ≥ 2 points, highlighting the effectiveness of

individualized planning even in cases with marked preoperative sagittal malalignment. The scoring system proposed in this study represents a simple, fast, cost-effective, and reproducible tool not only for preoperative planning, but also for objective postoperative assessment of sagittal alignment since it evaluates both alignment of the fused spine and compensatory mechanisms. Its implementation may facilitate standardization of sagittal plane pre-operative planning in AIS surgery and could serve as a practical metric in both prospective and retrospective research settings. Future studies could leverage this system to correlate radiographic sagittal alignment restoration with long-term clinical outcomes and re-assess sagittal malalignment in historical AIS patients cohorts. This study is limited by its exclusively radiographic nature; clinical outcomes were not assessed and should be addressed in future longitudinal investigations.

