Can Integrated Planning with the Gap Score and Sagittal Simulation Using Surgimap Improve Sagittal Alignment and Reduce Complications in Adolescent Idiopathic Scoliosis Surgery? A Retrospective Case-Matched Study of 100 Patients

Cesare Faldini, Giovanni Viroli, Matteo Traversari, Marco Manzetti, Alberto Ruffilli

INTRODUCTION:

Adolescent idiopathic scoliosis (AIS) is a complex three-dimensional spinal deformity. While surgical correction has significantly evolved in terms of safety, instrumentation, and coronal plane restoration, optimal sagittal alignment remains a critical challenge. The sagittal profile plays a central role in postural balance and functional outcomes, and its disruption may lead to mechanical complications, compensatory malalignment, and decreased quality of life. Traditional surgical planning often emphasizes coronal correction, potentially underestimating the importance of preoperative parameters guiding sagittal alignment.

The Gap Score is a validated metric that quantifies the deviation between the patient's actual and ideal spinopelvic alignment, offering a practical tool to guide realignment goals. Surgimap, a preoperative planning software, allows simulation of sagittal correction and mechanical outcomes. This study aimed to evaluate whether integrating the Gap Score and virtual simulation into the surgical planning process can enhance sagittal alignment and reduce complication rates in AIS surgery. We hypothesized that this combined approach would result in more physiological spinal profiles and fewer junctional issues postoperatively.

METHODS:

This retrospective case-matched study included 100 AIS patients who underwent posterior spinal fusion at a single institution. Patients were divided into two groups based on the planning strategy adopted. Group 1 (n=50) included patients operated between 2018 and 2020, who received standard preoperative planning based primarily on coronal and axial parameters. Group 2 (n=50) consisted of patients operated between 2020 and 2022, who underwent enhanced planning incorporating the Gap Score and sagittal simulation using Surgimap.

Matching criteria included age, Lenke curve type, Cobb angle magnitude, curve flexibility, and preoperative sagittal alignment. All patients underwent posterior instrumentation using high-density pedicle screw constructs, with standard correction maneuvers including concave translation and direct vertebral derotation. The surgical team remained consistent across both cohorts. Inclusion criteria were: age 10–18 years, diagnosis of AIS, minimum two-year radiographic and clinical follow-up.

Radiographic outcomes were measured preoperatively and at last follow-up, including thoracic kyphosis (T5–T12), cervical lordosis (C2–C7), sacral slope (SS), and Cobb angle. Complications such as proximal or distal junctional kyphosis (PJK, DJK) and adding-on were also recorded.

RESULTS:

Demographic and baseline radiographic characteristics were comparable between groups. In Group 1, the mean Cobb angle improved from 64° to 18°, while in Group 2, it improved from 63° to 20°, indicating similar coronal correction. However, sagittal plane outcomes showed notable differences. Thoracic kyphosis improved from 9° to 16° in Group 1 and from 10° to 26° in Group 2 ($p<0.05$), indicating significantly better restoration of physiological kyphosis with the planning-simulation approach.

Cervical lordosis evolved from a kyphotic alignment of 11° to 3° in Group 1, whereas in Group 2, it changed from 10° of kyphosis to 14° of lordosis ($p<0.05$), suggesting reversal of compensatory mechanisms. Sacral slope remained largely unchanged in Group 1 (44° to 43°), while it significantly decreased in Group 2 from 43° to 36° ($p<0.05$), indicating reduced pelvic anteversion and better global alignment.

In terms of complications, Group 1 experienced three cases of mechanical junctional problems (one PJK, one DJK, one adding-on), whereas no such complications were observed in Group 2 ($p>0.05$). Although this difference did not reach statistical significance, it suggests a favorable trend.

DISCUSSION AND CONCLUSION:

This study supports the hypothesis that a more comprehensive and individualized preoperative planning strategy—based on quantifiable targets such as the Gap Score and refined through simulation with tools like Surgimap—can lead to superior restoration of sagittal alignment in AIS surgery. The improved thoracic kyphosis, reestablished cervical lordosis, and reduced pelvic compensation observed in Group 2 reflect a closer return to physiological spinopelvic balance.

These changes are clinically relevant, as abnormal sagittal profiles are associated with increased energy expenditure, chronic pain, and long-term disability. Additionally, the absence of mechanical junctional complications in the planning-simulation group suggests that restoring proper sagittal alignment may have a protective effect on adjacent spinal segments.

While the sample size limits definitive conclusions regarding complications, the radiographic findings and consistent surgical technique across groups highlight the effectiveness of the integrated planning approach.

Future prospective studies with larger cohorts and long-term follow-up will be essential to confirm these findings and evaluate the impact on quality of life, functional outcomes, and revision rates. Nonetheless, our results encourage the routine integration of sagittal-focused planning into surgical workflows for AIS.