Over 35° of Concave Rod Contouring Results in a Diminished Return in Coronal Plane Correction in AIS

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Summary

This study evaluated the law of diminishing return in differential rod contouring for adolescent idiopathic scoliosis (AIS) posterior spinal fusion. Aggressive concave rod bending beyond 35° resulted in a significant plateau in coronal plane correction. In contrast, sagittal correction increased significantly with concave rod bending, which was further amplified by convex rod bending.

Introduction

Managing correction across all three anatomical planes through differential rod contouring presents a challenge in posterior spinal fusion for AIS. This study sought to assess the extent to which increasing the pre-contouring angle (kyphosis/sagittal plane contouring) of the rod no longer enhances 3D correction and to identify the point where no additional correctional benefit is achieved.

Methods

A computer model of the spine was developed from pre-surgical x-rays using ten Lenke 1 AIS cases (MT Cobb = 62.5° ± 7.1°; MT Kyphosis = 17.3° ± 12.1°; Apical Axial Rotation = -16.7° ± 6.7°). Primary correction maneuvers, starting with the concave rod translation technique, were simulated in MSC Adams. Bilateral uniaxial screws were positioned from T4 to L1, and cobalt-chrome/titanium rods measuring 5.5/5.5 mm were used (concave/convex). Differential contouring angles were tested for the concave rods (35°, 55°, 75°, and 85°) and the convex rods (15°, 30°, and 45°).

Results and Discussion

A notable reduction in coronal plane correction occurred once the concave rod bending exceeded 35° ($p < 0.05$), regardless of the convex rod (Figure 1). Between 35° and 55°, a significant decrease in mean Cobb angle correction was evident, indicating a clear diminishing return in increasing rod bending. This is consistent with the literature which has shown that minimal differential rod bending results in more effective coronal plane correction [1]. Simultaneously, a significant increase in the kyphosis angle ($p < 0.05$) was observed when concave bending surpassed 55°, compared to the pre-operative kyphotic presentation. These trends underline a trade-off between coronal and sagittal plane corrections, influenced by rod contouring.

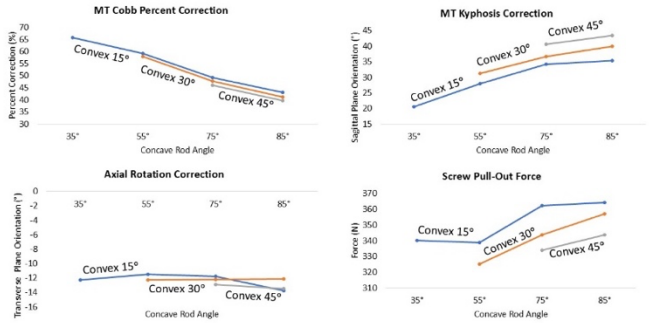

Figure 1: Average simulated correction in all three anatomical planes and average magnitude of the screw pull-out force.

Axial rotation correction and screw pull-out force showed minimal changes, even with over-contoured rods ($p > 0.05$). This suggests that while extreme contouring primarily impacts coronal and sagittal plane adjustments, its influence on axial mechanics and screw stability remains limited.

The findings highlight the importance of balancing the extent of rod contouring to achieve desired outcomes in three-dimensional spinal correction. Optimal Cobb angle correction occurs with moderate rod angulation, whereas more aggressive contouring favors the restoration of thoracic kyphosis [2]. This trade-off demonstrates the principle of diminishing returns: excessive rod bending beyond a certain threshold yields a reduction in coronal correction while imposing higher sagittal plane corrections.

Conclusions

Increased differential rod contouring angles significantly diminishes coronal plane correction. Smaller rod bending angles give better advantages to those with normo-kyphotic curves whereas hypo-kyphotic curves benefit from more aggressive rod bending but at the cost of less coronal plane correction.

Acknowledgments

This research was made possible by the collaboration between Akron Children's Hospital and Polytechnique Montreal.

References

[1] Pesenti S et al. (2020), *BJJ,* **102:** 376-382.
[2] Gay M et al. (2023), *Spine Deform*, **11**: 1309-131.