The Impact of Screw Density Pattern and Differential Rod Contouring on Coronal Plane AIS Correction

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Summary

This study explores the effects of differential rod contouring angles on biomechanical outcomes in adolescent idiopathic scoliosis (AIS) correction across three implant density patterns: alternate, convex alternate, convex peri-apical dropout. Using patient-specific computational models, we identify the threshold angles were further increases in rod contouring yield diminished returns in coronal plane correction.

Introduction

Differential rod contouring (DRC) and implant density patterns are pivotal in optimizing surgical outcomes for AIS. Excessive rod angulation can lead to diminishing returns and increased mechanical stress. Implant density patterns – ranging from high-density configurations, which enhance stability to low-density patterns, which reduce surgical risks – also influence biomechanical performance. This study evaluates how varying contouring angles and screw density patterns impact biomechanical stability and correction efficiency. Thus, we aim to determine how the law of diminishing return in AIS post-surgical correction is impacted by these factors.

Methods

Computer models of 10 Lenke 1 AIS cases were developed from pre-operative x-rays (MT Cobb = 62.5° ± 7.1°; MT Kyphosis = 17.3° ± 12.1°; Apical Axial Rotation = -16.7° ± 6.7°). MSC Adams was used to simulate the primary correction maneuvers with the concave rod first technique. Uniaxial screws were placed along the spine following the alternate, convex alternate, and convex peri-apical dropout screw density patterns. Cobalt-chrome (CoCr) of 5.5 mm each were used to model the concave and convex rods. Concave (35°, 55°, 75°, and 85°) and convex (15°) rods of various combinations were modeled for each rod contouring angle.

Results and Discussion

For all screw density patterns, significant reductions in MT Cobb percent correction were observed beyond a concave rod angle of 55° ($p < 0.05$) (Figure 1). Conversely, MT kyphosis correction improved with increasing rod angulation, demonstrating the importance of balancing sagittal and coronal corrections. Axial rotation correction remained consistent across all patterns and rod configurations ($p > 0.05$). These results emphasize the critical threshold of 55° for optimizing outcomes without diminished correction in the sagittal plane and excessive stress on the implants.

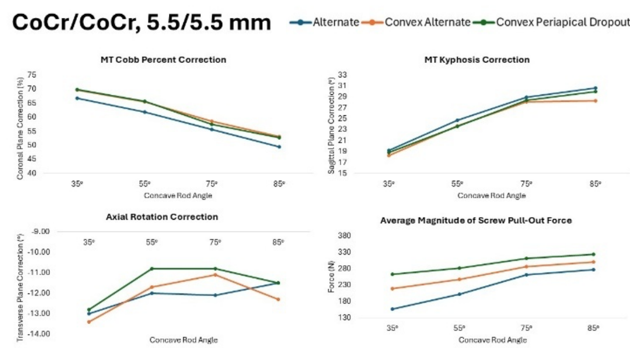

Figure 1: Average simulated correction in all three anatomical planes and screw pull-out force for the implant density patterns.

Implant density patterns, although less impactful on spinal alignment across all planes, significantly influences screw pull-out forces. Higher density patterns, such as convex peri-apical dropout, produced larger pull-out forces compared to alternate and convex alternate patterns. This aligns with biomechanical findings that have shown that although increased screw density enhances correctional stability it comes at the cost of higher stress on the screws [1].

Conclusions

This study highlights the importance of balancing rod contouring angles with screw density patterns in AIS surgical planning. Regardless of implant density pattern, the differential rod contouring achieves optimal biomechanical performance when concave angulation is limited to 55°, ensuring effective coronal plane correction and stable sagittal alignment while minimizing screw pull-out forces. Higher density screw patterns provide enhanced stability but come with increased biomechanical stress, requiring careful consideration of implant configurations. These findings offer actionable guidelines for optimizing surgical outcomes in AIS patients.

Acknowledgments

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References

[1] Wang, X et al. (2023). *Spine Deform*, **11**: 1317-1324.