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Biomechanical assessment of spinal alignment: Evaluating the interplay between pelvic incidence, T1 pelvic angle, and C2 plumbline in 27 models

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Background: The interaction between PI, T1 Pelvic Angle (T1PA), and the cervical C2 plumbline is of paramount importance in achieving balanced spinal alignment.

Research question: Analyze the impact of varied PI, T1PA, and C2 plumbline configurations on spinal stability and alignment using data derived from 27 biomechanical models.

Design: Biomechanical modeling analysis

Methods: 27 biomechanical models representing various combinations of PI (high, medium, and low), target T1PA (10°, 15°), and adjustments to the C2 plumbline (through hips, 0°). Three corrective strategies were implemented for each model: PI-10 = Lumbar Lordosis (LL) (less curved), PI = LL (ideally curved), and PI+10 = LL (more curved).

Results: One of the strategies consistently resulted in higher T1 slope values across all PI groups, while another strategy showed lower PI-LL values, suggesting possible misalignment. T1 slope outcomes revealed no significant difference across the PI groups, suggesting that the strategies applied do not lead to significantly varied results in this parameter. Concordance analysis demonstrated a moderate positive correlation between PI and T1PA. Cluster analysis categorized the strategies into three groups, with Cluster 0 showing balanced outcomes, while Clusters 1 and 2 exhibited deviations that may lead to adverse effects. Principal component analysis highlighted that cervical alignment measures, particularly T1-CL and C2 Slope, were the primary drivers in differentiating the strategies.

Discussion: This study underscores the importance of optimizing PI over C2 plumbline adjustments in achieving favorable spinal alignment, particularly with respect to T1PA. While some strategies provide better stabilization, others frequently lead to misalignment. Clinical interventions should prioritize PI adjustments, especially in high PI cases, to achieve optimal spinal correction. Strategies leading to lower PI-LL values should be approached with caution.