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## A 3D Surface Topography-Derived Method for the Aesthetic Evaluation of Trunk Asymmetry in AIS

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### Background

Aesthetics is a main goal of idiopathic scoliosis treatment, whether surgical or not. Trunk asymmetry is the main determinant of the aesthetic concern in Adolescent Idiopathic Scoliosis (AIS), affecting clinical evaluation and treatment planning. Probably the most widely used objective measure of aesthetics is the Trunk Aesthetic Clinical Evaluation (TRACE), but its global scores lack sensitivity to change and to detect regional imbalances. There is a need for more objective, standardized, and regionally oriented aesthetic measures.

### Study Design

Retrospective cross-sectional study

### Objective (s)

This study sought to develop an objective, regionally oriented aesthetic measure for quantifying trunk asymmetry in AIS using surface topography and to explore its correlation with TRACE and standard clinical measures in patients with AIS.

### Methods

AIS patients ( $n=107$ ; Cobb:  $19^{\circ}$ – $43^{\circ}$ ; TRACE: 25.1–82.4) were selected from the ISICO database, comprising thoracic ( $n=92$ ), thoracolumbar ( $n=41$ ), and lumbar ( $n=45$ ) curves. Standing 3D surface scans were analyzed by reflecting the surface model across the mid-sagittal plane. Trunk asymmetry was quantified by calculating the volumetric deviation (mm) between the original and mirrored surfaces, representing the left-right discrepancy within the transverse plane. This deviation was summarized using the Root Mean Squared Error (RMSE), representing global asymmetry. To evaluate regional aesthetics, scans were segmented into overlapping Thoracic (upper 50% of the trunk), Thoracolumbar (middle 40%), and Lumbar (lower 50%), with independent RMSE values calculated for each. The method's validity was assessed by correlating RMSE with TRACE, scoliometer-based ATR, and radiographic Cobb angles. Multiple regression identified predictors of regional and global asymmetry ( $p < 0.05$ ).

### Results

Pearson correlations revealed strong associations between thoracic measures (Thoracic ATR and hump) and surface asymmetry ( $r$  up to 0.64). Primary Cobb angles ( $r = 0.34$ – $0.45$ ) and TRACE scores (Rasch and Total score) ( $r = 0.29$ – $0.36$ ) were also reliable predictors, while anthropometric variables showed weaker correlations ( $|r| \leq 0.25$ ). Lumbar RMSE was less sensitive to clinical predictors than other regions. Multiple regression showed that combining clinical and radiographic predictors significantly enhanced predictive power. The Thoracolumbar model achieved the highest accuracy ( $R^2 = 0.473$ ), followed by Thoracic (0.400) and Global (0.393). Significant predictors across all models included the primary Cobb angle, Thoracic ATR, Lumbar angle, and TRACE total score ( $p < 0.05$ ).

### Conclusion(s)

Currently, there is no standardized aesthetic evaluation tool. The absence of a real gold standard for the aesthetic measures is a challenge to planning proper diagnostic studies. Nevertheless, this opens the opportunity to explore other options that should be evaluated comparatively according to their clinimetric characteristics. The 3D-derived RMSE could constitute a good option and showed in this study good global and regional correlations with some clinical and radiographic parameters.

### Clinical significance

This tool provides a novel, objective, and non-invasive alternative to subjective aesthetic scales, allowing for better regional monitoring and more precise treatment planning.