Abstracts of the 25th Annual Meeting of the Swiss Society of Spinal Surgery (SGS)

Adolescent Session

3D-Printed Polyamide-12 Mesh Brace for Adolescent Idiopathic Scoliosis: A Preclinical Validation and Clinical Pilot Study

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Objective: Conventional polyethylene (PE) braces for adolescent idiopathic scoliosis (AIS) are effective but can be bulky and uncomfortable, potentially compromising patient adherence. 3D-printed Polyamide-12 (PA12) mesh technology offers a personalized, lighter, and more breathable alternative. This study aimed to validate the mechanical properties of PA12 mesh against conventional PE, demonstrate that its stiffness can be precisely engineered using computational modeling, and report initial clinical outcomes in a pilot cohort of AIS patients.
Methods: The study comprised a preclinical validation and a clinical evaluation. First, tensile tests were performed to failure on standardized "dog-bone" samples of solid PA12, meshed PA12, and solid PE to compare stiffness, strength, and failure strain. Concurrently, Finite Element Analysis (FEA) of a representative mesh unit was used to predict how varying the triangle width (2-18 mm) would tune the brace's apparent stiffness. A retrospective case series was then conducted on 35 consecutive AIS patients (83% female; median age: 12.2 years; median Risser 0) treated with the custom PA12 mesh brace. The primary outcome was the change in major Cobb angle over a median follow-up of 33.0 months. Statistical significance was assessed via paired t-tests or Wilcoxon signed-rank tests.
Results: PA12 mesh exhibited 56% greater ultimate tensile strength than PE (31.6 versus 20.2 MPa). Computational modeling established 5.52-mm triangular aperture width matched PE stiffness. Twenty percent of patients required surgical intervention during follow-up. Non-operative patients (n=28) demonstrated initial curve correction of 55.9% at two months ($p<0.001$). Final follow-up revealed sustained correction with mean Cobb angle reduction from 25.5° to 17.1° ($p<0.001$).
Conclusion: PA12 mesh orthoses achieve mechanical properties equivalent to standard PE braces with superior material strength. Lightweight, breathable, and custom-fittable, these braces offer tunable stiffness despite brittleness and rare degradation. Clinical outcomes in skeletally immature AIS patients compared favorably with standard conservative therapies. These results warrant prospective controlled trials to establish long-term efficacy and patient-reported outcomes.

See graphics on next page

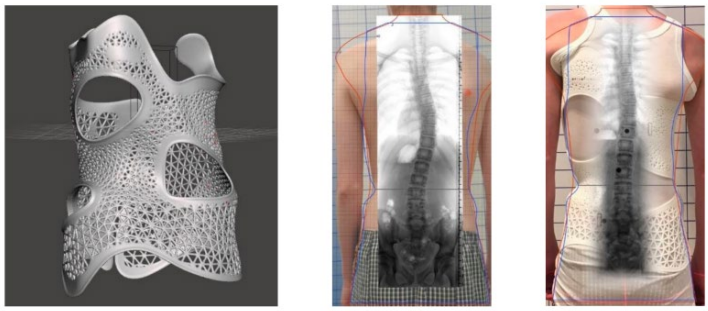

Figure 1. Planning and digital modeling of a 3D mesh brace with clinical application.

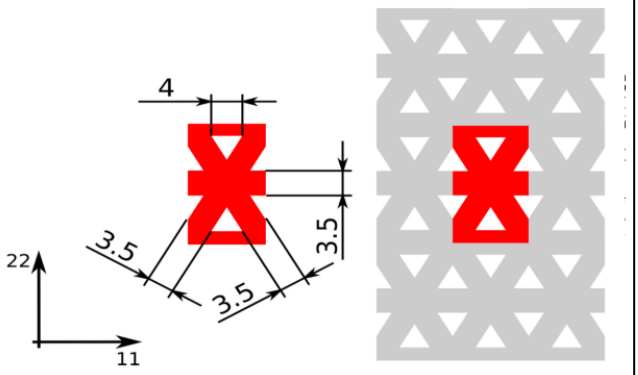

Figure 2. The mesh unit cell (red). The triangle width (4 mm shown) was varied (0-18 mm), while the bridge width and thickness remained constant at 3.5 mm.

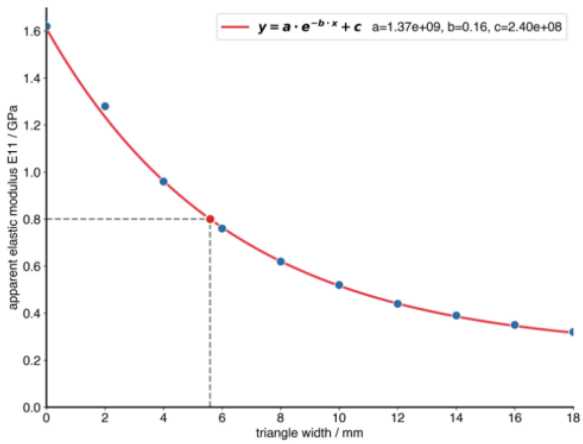

Figure 3. A logarithmic decrease (red curve) is seen in stiffness (E11) of the PA12 mesh as the triangle width increases. A 5.5 mm triangle width yields a mesh with stiffness equivalent to that of solid PE (red point).

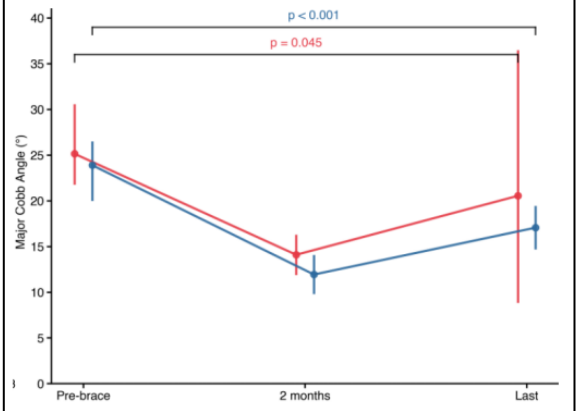

Figure 4. Changes in mean major Cobb angle for non-surgically treated (blue) and whole cohort (red).

Monitoring curve progression in adolescent idiopathic scoliosis: rasterstereography shows limited sensitivity compared to radiography in brace-treated patients

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Objective: The present study aimed to evaluate rasterstereography and scoliometer measurement responsiveness in detecting curve progression in a large cohort of AIS patients with a follow-up time of > 6 months and comparing brace-treated and non-braced patients.

Methods: We included consecutively AIS patients who underwent same-day rasterstereography, scoliometer and radiography evaluations from 2016 to 2018, with at least 6 months between visits. Each patient's major scoliosis curve was evaluated using their Cobb angle (CA) from radiography, their scoliosis angle (SA) from rasterstereography and their axial trunk rotation (ATR) angle from scoliometer measurement. Patients were separated into brace-treated and non-braced groups. Progressive curves were defined by an increase in CA ≥ 5°. The area under the curve (AUC) of non-parametric receiver operating characteristics (ROC) curves was used to assess responsiveness of SA and ATR in detecting progressive curves. We reported sensitivity and specificity.
Results: One-hundred-and-eleven AIS patients (55 brace-treated, 56 non-braced) were evaluated, of whom 17 (16%) had progressive curves: 10/55 (18%) brace-treated and 7/56 (13%) non-braced patients. We found poor AUC and sensitivity (< 50%) in detecting progressive curves among brace-treated patients. However, we found a good AUC (> 75%) and moderate sensitivity (< 70%) in detecting progressive curves among non-braced patients.
Conclusion: Rasterstereography and scoliometer measurements both showed poor and moderate sensitivity in detecting curve progression in brace-treated and non-braced AIS patients, respectively. This suggests that rasterstereography should not be used to monitor curve progression among AIS patients to reduce their exposure to radiation, particularly among brace-treated patients. Presents results adds to ongoing debates about surface topography's role in AIS monitoring, particularly for braced patients where torso shape changes may confound measurements. Although rasterstereography and scoliometer lacks sufficient sensitivity to serve as a standalone monitoring tool, these results identify untreated patients as the most promising target population for future technological refinements of surface topography.

Vertebral tethering's effect on lumbar spine development in adolescent patients with lumbosacral transitional vertebrae: a comparative case–control study

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Objective: The aim of this study was to analyse vertebral body shapes on the latetal view of subjects with symptomatic lumbosacral transitional vertebrae (LSTV) and compare them to radiologically normal asymptomatic subjects.
Methods: We compared skeletally mature adolescents with LSTV and sacralisation of L5 against asymptomatic controls. Spinopelvic parameters and vertebral wedging were compared for all lumbar vertebrae using their full-spine, sagittal plane, standing radiographs taken from 2015–2023. Multivariate logistic regression (adjusted for PI) was used to control for spinopelvic confounding, while intergroup differences in wedging and L1–S1 lordosis were assessed via two-tailed Student's t-tests.
Results: The LSTV group (n = 19, mean age 15.4 ± 1.4 years) exhibited significantly higher PI and L1–S1 lordosis ($p < 0.01$) than the control group (n = 17, mean age 14.7 ± 1.7 years), with comparable sex distribution in both cohorts. Univariate regressions showed that vertebral wedging angles were significantly higher among LSTV patients than controls at all vertebral levels. Multivariate regressions adjusted for PI found no statistical difference in L1–S1 lordosis between the two groups ($p=0.872$). However, L5 remained significantly more wedged ($p=0.017$) among LSTV patients.
Conclusion: Findings suggested morphological adaptations at the transitional level, with higher L5 wedging angles among LSTV patients than among controls, independently of PI. LSTV acts as a posterior tether, modulating vertebral growth during development, potentially part of hyperextension mechanisms occurring above the transitional level to compensate for reduced mobility in the L5–S1 segment and hypoplastic discs. Longitudinal studies could help evaluate spinopelvic development over time among LSTV patients.