Spinal Hemiepiphysiodesis: Initial Biomechanical Conditions that Modify Growth

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**Introduction:** With the goal of preventing spine deformity progression without arthrodesis, methods of mechanically altering spine growth asymmetrically are under investigation. The objective is to create an appropriately controlled and distributed compressive stress gradient to the growth plate without otherwise critically changing the biomechanics and biology of the intervertebral joint. One hypothesis of the mechanism of curve creation is that it is largely driven by a static baseline compressive stress gradient across the growth plate. Instruments designed to change the physial static stresses also alter the static and dynamic stresses transmitted to the disc. Quantification of bilateral disc stresses and biomechanical properties before and after instrumentation is required to compare models, evaluate risks, as well as better understand immediate post-operative conditions.

In previous studies, significant kyphoscoliotic curvatures were induced in normal porcine spines (1). The mechanism of curve creation included decreased physeal hypertrophic zone and disc heights (2). Intra-operative bilateral compressive stresses and in vivo physiological stresses have been reported in this model (3). The purpose of this study was to determine if staple implantation caused biomechanical gradients. The hypotheses were that implantation immediately a) alters stiffness asymmetrically, b) decreases ranges of motion, c) creates a gradient in the disc baseline static compressive stress, and d) moderately decreases peak dynamic compressive stresses.

**Materials and Methods:** Normal skeletally immature porcine thoracic spines were harvested (IACUC-approved) and stored frozen until testing. Four single motion segments were resected and mounted into a materials test system. Specimens were tested before and after insertion of a staple designed to constrain intervertebral joint displacement on one side. The custom stainless steel staples were attached to adjacent vertebrae with bone screws as previously described (1). Specimens were tested in left and right lateral bending, flexion and extension. Load-displacement curves were recorded. Displacement ranges and rate were controlled; five cycles were applied and the fifth loading cycle was analyzed. Tangent stiffness, secant stiffness, and range of motion were calculated. Differences between intact and stapled were determined using t-tests.

In separate tests, five single motion segments, custom stress sensors (2) were inserted into left and right sides of the annulus. Specimens were tested before and after insertion of a custom stainless steel staple. Axial compression of ~400 N was applied; displacement range and rate were controlled. Compressive stiffnesses were also determined.

**Results:** Stapling increased the secant stiffness significantly, by 42%, in side bending, with the greatest difference in ipsilateral side bending, but not significantly in flexion or extension. Tangent stiffness decreased 24% after stapling in side bending and 18% in flexion/extension. Range of motion decreased 63% after stapling in side bending and 28% in flexion/extension, while remaining significantly greater than zero in all loading modes.

Staple implantation increased the baseline compressive stress by 0.10 MPa (± 0.03). After stapling, mean peak dynamic compressive stress was 77% of control. Mean tangent modulus was 81% of control.

**Discussion:** Unilaterally constraining spine motion segments altered the stiffness and range of motion without immobilizing the joint. The static compressive stress increase corresponded to magnitudes reported in in vivo studies under surgical conditions (3). Hemiepiphysiodesis stapling increased baseline static stress at time of implantation to levels reported to slow growth (e.g., 4) but not cause disc degeneration (5-9). It also decreased peak dynamic compressive stresses, but not strongly.

Factors that affect motion segment biomechanical properties include implant material, blade cross-section, base thickness, insertion location and depth. The baseline stress increase was likely due to the angle between the blades, which drew vertebrae together during insertion, while the cantilevered blades transmitted most peak dynamic compressive stresses. While the effect of these initial conditions on the biology and biomechanics long-term is not yet known, the results may be used to guide implant development and evaluate *ex vivo* mechanical test conditions. This study defines at least one set of biomechanical initial conditions that will likely lead to asymmetric growth modification of the spine.

**References:**

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