Three-Dimensional Correction of Juvenile Scoliotic Spine: Finite Element Study

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Disclosures: Ardalan S. Vosoughi (N), Ali Kiapour (N), Aakash Agarwal (N), Vijay K. Goel (Spinal Balance, OsteoNovus, Turning Point, Depuy, SI Bone, Apex/Spine/Medyssey, Spine Soft Fusion, Spinal Elements, AO Foundation/FORE, K2M, NIH, NSF, Third Frontier Program, ODSA)

ABSTRACT INTRODUCTION: Scoliosis treatment in juvenile patients is controversial due to different factors. Curve pattern, progression velocity and timing of spinal fusion are critical factors for the treatment of scoliosis in juveniles [1]. It has been proposed that surgical correction could be a favorable choice for the treatment of scoliosis in progressive juvenile spines [1]. This three-dimensional deformity can be treated thanks to different surgical corrections. Cotrel-Dubousset (CD) surgical technique has laid the foundation for scoliosis correction in juvenile and adolescent scoliotic spine [2]. The CD technique is based on placing of two curved rods on the instrumented spine with pedicle screws or hooks [3]. The aim of this study was to develop a three-dimensional detailed finite element model of juvenile scoliotic spine to simulate the main steps of CD surgical correction.

METHODS: An FE model of T1-S1 right thoracic scoliosis spine (9 years and weighing 22 kg) was used in this study. S1 was allowed only coronal rotation, and superior surface of T1 was constrained in the transverse plane. According to CD surgical technique, T4, T7, T9 (apical vertebra) and T11 vertebrae on the concave side and T4, T8 and T11vertebral bodies on the convex side were instrumented using titanium alloy (Ti-6Al-4V) monoaxial pedicle screws. The 5.5 mm rods were contoured according to the desired sagittal profile. To represent different corrective forces, convex rod was less bended at the apex. The facetectomy and ligament dissection of the fused levels was simulated using deleting the proper elements. Rods were assigned CoCr (E=220000, Poisson's ratio=0.3) material properties. The surgical simulation began with concave rod placement. Rod placement (starting from the most cranial and caudal pedicle screw tulip heads) on the pedicle screws was simulated using individual translators and appropriate coordinate systems. Using these connectors, the distance between the rod and tulip heads reduced to zero (Figure 1). After placement of each tulip head on the rod, a cylindrical linkage was activated between the rod and screw tulip heads allowing to rotate and translate in local coordinate system directions (T4 linkage was only allowed rotation). Next, the concave rod was rotated 90 degrees until the predetermined sagittal profile was achieved on the spine (Figure 1). Then, the rod was locked in all screw tulip heads representing the set screw being completely tightened and rotation was inactivated. After placement of the concave rod similar approach was used to place the convex rod into the screw tulip heads (Figure1).

RESULTS SECTION: After concave rod insertion, the T1-S1 height was increased 10 mm (from 324 mm to 334 mm) and the Cobb angle decreased from 51 degrees to 42 degrees. The maximum von Mises stress on the pedicle screws and the rod was 166 MPa and 106 MPa, respectively. The T1-S1 height did not change significantly after rod rotation, however, the Cobb angle decreased to 25 degrees. Maximum von Mises stress on the rod and pedicle screws was 156 MPa and 132 MPa, respectively after this maneuver. The predetermined sagittal profile was achieved after the surgery maneuver (Figure 2).

DISCUSSION: This study focused on the main intraoperative steps of the CD surgery technique on osteoligamentous juvenile scoliotic spine. Each of the steps consisting of first rod insertion, rod rotation and second rod insertion contributed to scoliosis correction. The concave rod insertion led to the maximum increase in height. The maximum correction of the thoracic Cobb angle was during the concave rod rotation which was in agreement with literature [4]. The axial vertebral rotation was not altered significantly after the surgery maneuver. Such an FE simulation of different surgical steps can provide an insight into intraoperative effects of each step on the scoliosis correction. The predictive information can enable clinicians to come up with effective treatment outcomes.

SIGNIFICANCE: This computational approach provides insight to clinicians and researchers about the importance of each step of the surgery and can be a useful tool for surgeons to understand the biomechanics of the correction as a function of different surgical approaches and instrumentation.

REFERENCES: 1) Charles YP, Spine, 2006 2) Dubousset J, Clin Orthop Relat Res, 1991 3) Gardner-Morse M, J. Biomechanics, 1994 4) Driscoll M, BioMed Research Int, 2013

IMAGES AND TABLES:

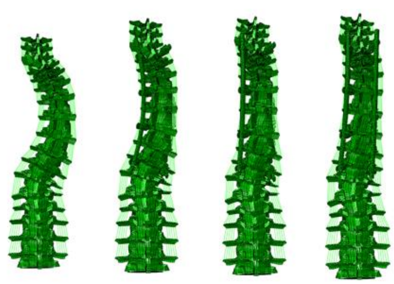

Figure 1. Surgical Simulation Steps (from left to right: intact spine, first rod insertion, rod rotation, second rod insertion)

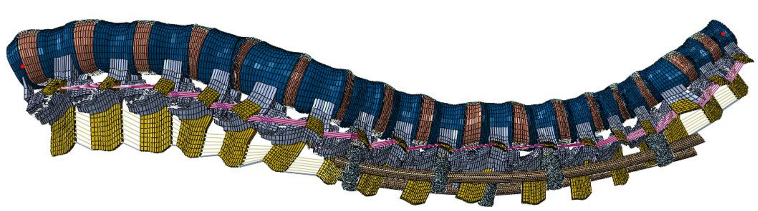

Figure 2. Corrected scoliotic spine after the surgery (sagittal view)