Biomechanical rationale of sacral rounding deformity in pediatric spondylolisthesis: A clinical and biomechanical study

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Introduction:
Wedging of the L5 vertebral body and rounding of the sacrum surface are well-known deformities associated with isthmic olisthesis. Sairyo et al.[1] suggested that the deformity occurred secondary to the slippage, and was not the cause of further slippage. Our hypothesis is that mechanical stress increased at the growth plate with spondylolysis during lumbar motion may cause growth plate dysfunction leading to rounding deformity of the sacrum dome.

In the clinical part of the current study, we first described two pediatric cases that showed natural normalization of the rounding deformity. In the biomechanical part, we evaluated the stresses in anterior upper corner of the vertebral body at the caudal adjacent level of spondylolysis using finite element (FE) analysis.

Methods:
Three-dimensional FE pediatric lumbar models of the L3-L5 segment were utilized, Figure 1. Unlike the adult model, this pediatric model had growth plates and cartilaginous apophyseal rings.[2,3] Stress distributions were analyzed in response to 341N axial compression and 10N.m moment in flexion, extension, lateral bending, and axial rotation. Bilateral spondylolysis was created in the model at L4. The stress results from the bilateral defect model were compared to the intact model predictions and correlated to the sacral rounding deformity seen in patients.

Results:
Clinical study
There were two patients with deformity of anterior upper corner at S1 (rounding deformity) at initial visit, Figure 2. They stopped sports activities and took conservative treatment using a corset. Twelve month later, the rounding deformity healed, indicating that the deformity is reversible in the pediatric cases.

Biomechanical study
Higher stresses were observed in the spondylolytic pediatric model as compared to the intact model at the growth plate, apophyseal ring and osseous endplate in all loading modes, Figure 3. Specifically, in the spondylolysis spine, mechanical stress at the growth plate in anterior upper corner during lumbar motion increased when compared with the intact pediatric spine, Figure 4.

Figure 1: Lt: Sagittal section of the pediatric FEM of L3–L5. Rt: Location of the apophyseal bony ring and growth plate (red lines).

Figure 2. Two cases of spondylolisthesis patients in whom rounding deformity of sacral dome that healed with time.

Figure 3. Lt: Von Mises stress contour plot in flexion on the mid-sagittal sectional plane of the (a) intact model and (b) spondylolysis model at L4. Rt: Top view of sagittal section at the L5 cranial growth plate and apophyseal ring.

Figure 4. Highest von Mises stresses calculated at the growth plate, apophyseal bony ring and osseous endplate of the anterior area in intact and spondylolytic spines. During lumbar motion, the stress increased in the lumbar spondylolysis model when compared to the intact one. (Apo. Ring apophyseal bony ring)

Conclusion:
We first demonstrated that in pediatric patients with isthmic spondylolisthesis, rounding deformity of the sacrum dome can be reversed. In the second part, biomechanical data suggest that it occurs due to slippage of the growth plate, stresses become higher in that region. Repetitive mechanical stress at the growth plate during the daily sports activities may cause growth plate dysfunction leading to rounding deformity of the sacrum dome. Reducing the mechanical stress by stopping any sport activity and wearing a trunk brace may restore the normal function of the growth plate with the subsequent normalization of the rounding deformity.

Reference: