How Does Thoracic Scoliosis Surgery Affect Thoracolumbar Spinal Flexibility And Lumbar Intradiscal Pressure? An In Vitro Study Confirming The Importance Of The Rib Cage

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INTRODUCTION: Finding the optimum surgical approach for individual adolescent idiopathic scoliosis patients is challenging, especially in case of thoracic scoliosis, where the rib cage represents an additional influencing factor. For surgical derotation of rigid thoracic curves, most often posterior spinal osteotomies are performed, subsequently locked by long posterior spinal fixation. However, a fundamental biomechanical basis for this procedure is still missing. The aim of this experimental study therefore was to investigate if thoracic spinal osteotomies and concave rib osteotomies are adequate for surgical derotation of the thoracic spine and to explore potential effects of posterior fixation on thoracolumbar segmental flexibility and lumbar intradiscal pressure.

METHODS: Six fresh frozen human thoracolumbar spine and rib cage specimens (26-45 years, two female / four male) without clinically relevant deformity were tested after approval by the ethics committee of Ulm University. Specimens were loaded quasi-statically with pure moments of 5 Nm in flexion/extension, lateral bending, and axial rotation using a well-established spine tester [1] (Fig. 1). Optical motion tracking (Vicon MX13) of all segmental levels (C7-S) and intradiscal pressure measurements (FISO Technologies Inc.) of the lumbar spine (L1-L5) were performed (1) in intact condition, (2) after Schwab grade 1 [2], (3) Schwab grade 2 [2], and (4) left rib osteotomies [3] at T6-T10 levels, as well as (5) after posterior spinal fixation with pedicle screw-rod instrumentation at T4-L1 levels. For statistical evaluation of differences between testing conditions, SPSS 27 was used by means of Friedman's ANOVA with Bonferroni-Dunn post-hoc correction and pairwise comparisons, together with additional pairwise Friedman test without post-hoc correction to identify effects besides multiple group comparisons. The significance level was set at 0.05.

RESULTS SECTION: Schwab grade 1 osteotomies did not affect the total range of motion (C7-S), whereas Schwab grade 2 osteotomies increased the range of motion in axial rotation significantly ($p<0.05$) but solely slightly (+3%) compared to the intact condition. Left rib osteotomies led to significantly ($p<0.05$) increased total range of motion (C7-S) in axial rotation compared to both intact (+6%) and Schwab grade 1 condition (+6%). Posterior fixation caused significant ($p<0.05$) total range of motion (C7-S) decreases compared to all previous conditions, with highest decreases in axial rotation (up to -38%). Schwab grade 1 and 2 osteotomies did not significantly ($p>0.05$) affect segmental ranges of motion. Left rib osteotomies significantly ($p<0.05$) increased ranges of motion in flexion/extension at T3-T4, T11-T12, and L1-L2 levels, but not at the treated levels T6-T10. In lateral bending, left rib osteotomies caused significant ($p<0.05$) range of motion increases at the treated levels T6-T7 and T8-T9. Posterior spinal fixation significantly ($p<0.05$) reduced ranges of motion at the instrumented levels (T4-L1), caused significant ($p<0.05$) range of motion increase at the upper adjacent levels T2-T3 and T3-T4, and led to significantly ($p<0.05$) increased ranges of motion in lateral bending in the lumbar spine at levels L2-L3, L3-L4, and L4-L5. Significant ($p<0.05$) intradiscal pressure increases were detected after posterior fixation at the lower adjacent level L1-L2 in flexion and left lateral bending.

DISCUSSION: Schwab grade 1 and 2 osteotomies did not result in adequate thoracic spinal flexibility increase in this in vitro study, questioning the impact of isolated posterior spinal releases for surgical derotation, in contrast to additional concave rib osteotomies. Subsequent posterior fixation caused increased flexibility in the upper adjacent segments, potentially explaining frequently reported complications such as adjacent segment disease or proximal junctional kyphosis. Moreover, increased lumbar spinal flexibility in lateral bending as well as increased intradiscal pressure in flexion and lateral bending following posterior fixation might negatively affect coronal and sagittal balance of the spine. Future studies should also investigate effects of different spinal osteotomies and fixation techniques on scoliotic spines, as well as effects of fixation levels, implant types, and rod materials and diameters.

SIGNIFICANCE/CLINICAL RELEVANCE: Spinal and costal osteotomies are frequently used for surgical derotation of adolescent idiopathic scoliosis. However, surgeons still predominantly rely on their experience and subjective feeling regarding the benefit of these procedures. This experimental study therefore provides a detailed insight into biomechanical effects of surgical treatment of adolescent idiopathic scoliosis.

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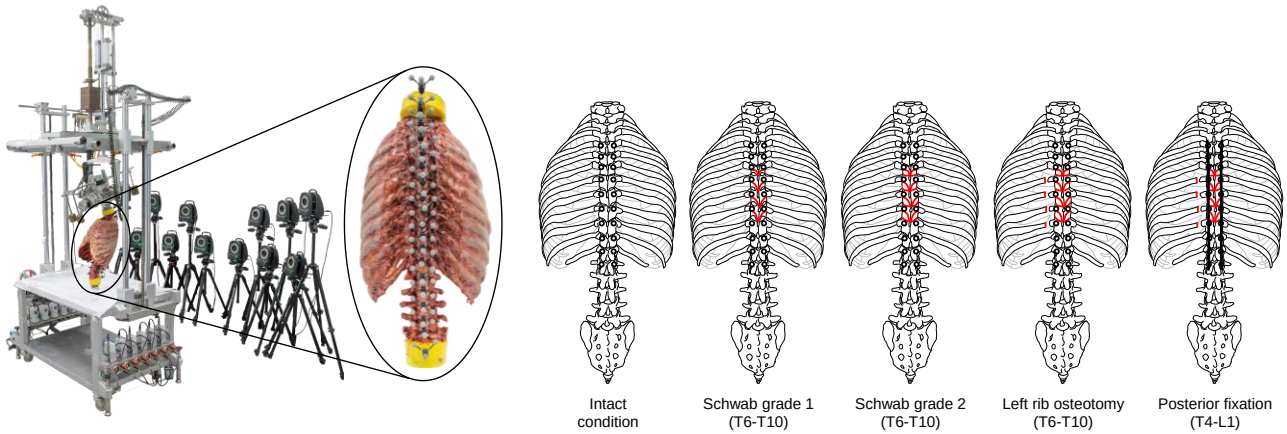

Figure 1. Illustration of the experimental setup (left) and overview of the testing steps (right).