Influence of femoral de-rotation osteotomies on gait pattern, growth plate stresses and femoral growth trends in children with torsional deformities

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Summary

Femoral de-rotation osteotomies (FDO) alter the gait pattern and thus potentially the mechanical loading on bones and further growth trajectories. We analyzed data of patients before and after FDO and found that the surgery changed the gait pattern but not growth plate stresses and growth trends.

Introduction

Bone growth and shape is, amongst other factors, determined by mechanical loads experienced during daily activities such as walking. Torsional femoral deformities are common in various clinical conditions and can lead to pain, altered gait and are a risk factor for osteoarthritis [1]. FDOs are used to correct them. How these surgeries affect bone loads and therefore further potential growth is not known. To close this research gap, we quantified bone loads and estimated growth trends before and after FDOs using our recently developed multi-scale mechanobiological simulation workflow [2].

Methods

Three-dimensional gait analysis (3DGA) data, including marker trajectories and ground reaction forces, was recorded before (10.2±8.4 months) and after (18.4±14.2 months) an intertrochanteric FDO of ten patients with idiopathic torsional deformities aged 13.4±1.8 years at the surgery. So far, five femurs (2 with increased anteversion angle (AVA) (44.5° and 59.7°) and 3 with decreased AVA (-2.5°, -2.6° and 8.2°) were analyzed for this abstract. Magnetic resonance images (MRIs) were recorded before the surgery. MRIs were used to quantify AVA, neck-shaft-angle, inter-epicondylar distance and tibial torsion to personalize musculoskeletal models. For the post-surgery models, we adjusted the AVA based on the surgery report. Subsequently, these models and the pre- and post-surgery 3DGA data were used to calculate joint angles, muscle forces and joint contact forces using OpenSim [3,4]. The root-mean-square-difference (RMSD) between patients' and typically developing children' joint angles (from Koller et al. (2024)) was quantified for pre- and post-surgery data.

For each femur, a subject-specific finite element model (FEM) was created with our previously developed GP-Tool [5]. A second FEM was created by virtually performing surgery on the segmented femur. Muscle and joint contact forces from the musculoskeletal simulations (pre- and post-FDO) were applied as nodal forces. Shear and compressive stresses in the growth plate were quantified and used to calculate the osteogenic index [6]. Subsequently, growth trends, i.e. change in AVA, were predicted based on the osteogenic index and our recently calibrated mechanobiological model [2].

Results and Discussion

The RMSD of joint kinematics to healthy individuals decreased significantly in all patients from 12.4±3.4° to 7.9±2.5° indicating that the surgery improved the patients' gait pattern. The hip joint contact force and its orientation in respect to the femur's coordinate system changed in all participants. Interestingly, the osteogenic index, and therefore shear and compressive stresses were very similar before and after surgery. Furthermore, the predicted change of AVA did not significantly change due to the surgery (Figure 1).

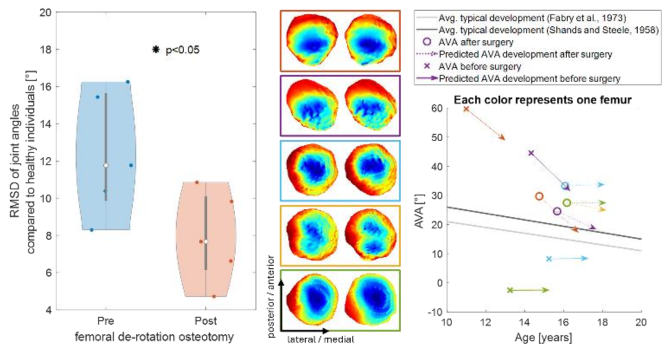

Figure 1: Left: RMSD of hip, knee and ankle joint angles compared to healthy children before and after surgery. Middle: Osteogenic index (red = promoted growth; blue = inhibited growth) within the proximal growth plate before and after surgery. Right: Femoral anteversion angle (AVA) and the predicted change of AVA within the following two years before and after surgery. Each color represents one femur.

Conclusion

This is the first study which showed how FDOs influence growth plate stresses and femoral growth trends. Our workflow can be used to select the ideal timing for the FDO and identify patients where an over- or under-correction of the AVA is required to achieve the desired long-term outcome.

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