Tension-Band Plates' Effect on Femoral Growth Plate Mechanical Loading during Guided Growth in Coronal Plane Deformities

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INTRODUCTION: One of the primary causes of osteoarthritis is a pathological loading of the knee joint, for example, due to malalignment of the leg axis [1]. Correction of knee malalignment through guided growth using a tension-band plate is a common therapeutic approach to prevent knee osteoarthritis and other ailments. This technique is based on the Hueter-Volkmann law which states that bone length growth is restricted by compression and stimulated by tension [2]. The influence of the implant on the growth plate's locally varying mechanical loading has not yet been investigated. This study combines load cases from the gait cycle with customized geometry to examine the mechanical effects of tension-band plates.

METHODS: Personalized finite element models of four distal femoral epiphyses of three individuals receiving guided growth intervention were generated. These models simulated characteristic load cases from the participants' gait cycle in a quasi-static manner. The gait cycle was analyzed before implantation as well as prior to explantation, with knee contact forces calculated through musculoskeletal simulation [3]. The load cases were simulated both with and without the implant to separate the implant's impact from that of other factors. Morphological characteristics of the growth plates were acquired from radiographs of the participants' knees. Three-dimensional geometries were constructed utilizing Magnetic Resonance Images of age-matched individuals [4]. Models' boundary conditions were obtained from instrumented gait analyses [3] and literature [5].

RESULTS SECTION: The stress distribution in the growth plate was heterogeneous and depended on the geometry. In a sub-study, it was demonstrated that the growth plate experiences varying stresses for identical load cases but distinct geometry [6]. Additionally, the inclusion of modeled components, such as the Ring of Lacroix, have an impact on the stress in the growth plate. In the region of insertion, the implants produced localized static stress and decreased the rate of cyclic loading and unloading, both leading to a decrease in the growth rate. On the opposite side of the growth plate, increased tension stress was observed, which is considered to promote growth.

DISCUSSION: Personalized finite element models can estimate local static and cyclic loading changes on the growth plate caused by the implant. This knowledge could be useful in the future for controlling growth modulation and preventing the malalignment's recurrence after the treatment. However, achieving this necessitates a fully participant-specific model based on load cases and 3D geometry.

SIGNIFICANCE/CLINICAL RELEVANCE: Knee osteoarthritis is the most common joint disease and the cause of chronic pain and disability in the United States and other developed nations [7]. Our study provides a method to better understand the knee osteoarthritis risk factor "malalignment of the knee" and to optimize the outcome of guided growth intervention.

REFERENCES:

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FIG 1: Models simulated at different time points during the guided growth treatment with characteristic load cases from gait analyses; M1 and M2: knee with malalignment before the treatment, M1 without, M2 with implant. M3 and M4: knee with corrected axis at the end of treatment, M3 with implant under prestresses, M4 without implant. Models were created for 3 different participants (4 knees, 3 right, 1 left) [6]

FIG 2: Hydrostatic and Octahedral Shear Stress in growth plate at one load step during the gait cycle in M1 – M4. M1 shows stress before treatment, M2 shows direct influence of implant, M3 shows high compression at the end of treatment, M4 shows outcome of stresses in the growth plate after treatment [6]