How do tension band implants change the stress distributions in the femoral growth plate?

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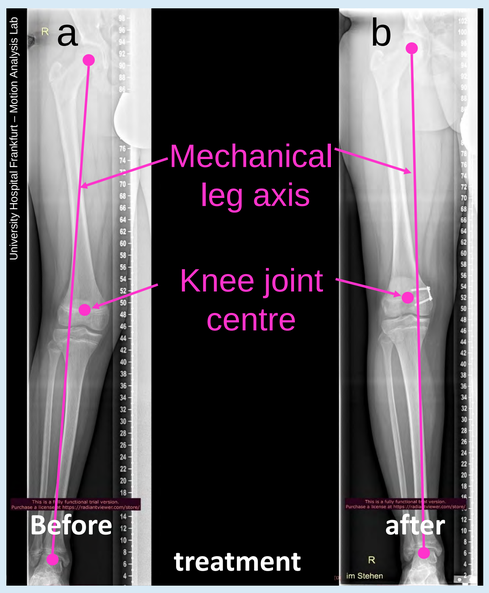
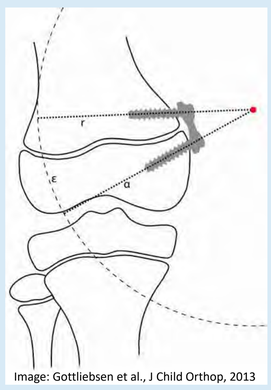
Background





Tension band implanted in the distal femur

- Correction of the mechanical leg axis by **guided growth** in adolescents using **tension band implants**
- **"Rebound effect"** in 50% of patients [1]
- Treatment based on basic findings by Hüter [2], Volkmann [3] and Frost [4]: **mechanical loading ⟷ length growth of bones**

Objective

- Which changes of the locally varying mechanical loading are caused by insertion of a tension band implant?

➢ Improvement of treatment planning

Hypothesis

The implant

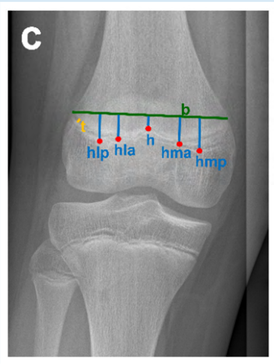
- **increases static compression**
- **reduces cyclic change** of loading during gait

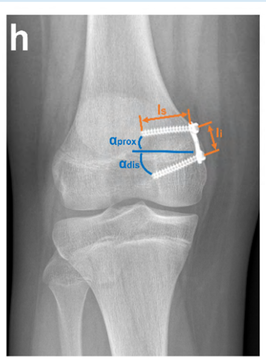
} **decrease of growth rate**

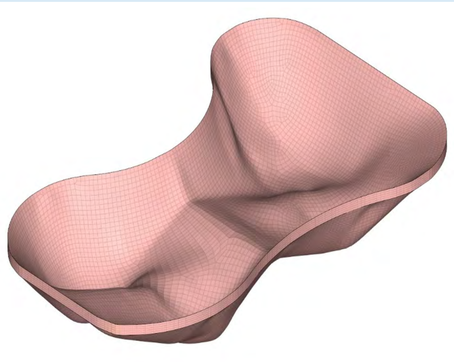
Personalized finite element analyses

- Comparison of **distributions of compressive stresses** in the growth plate: **without imlant ⟷ with implant**
- 4 knees of 3 patients (11, 13, and 14 years at the start of treatment)
- **Start** of treatment & **end** of treatment

3D geometry and implant position



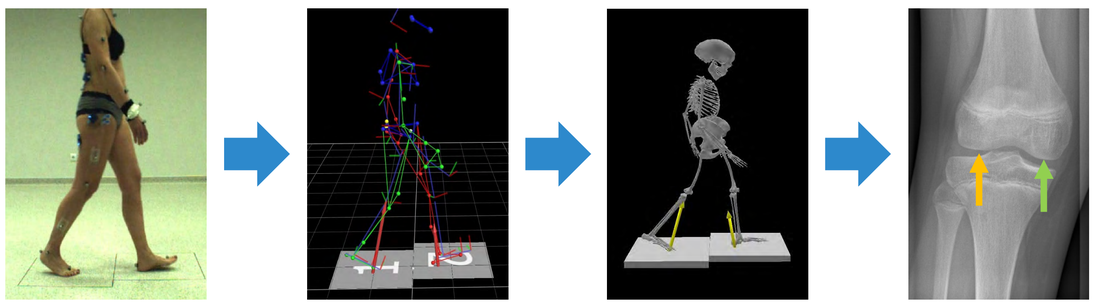




- Individual geometrical parameters from **2D-radiographs**
- 3D information from age matched open source MRI

➢ Personalized, but **not patient-individual 3D-geometry** of the growth plate

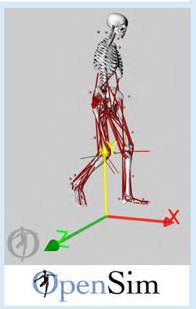
Boundary conditions



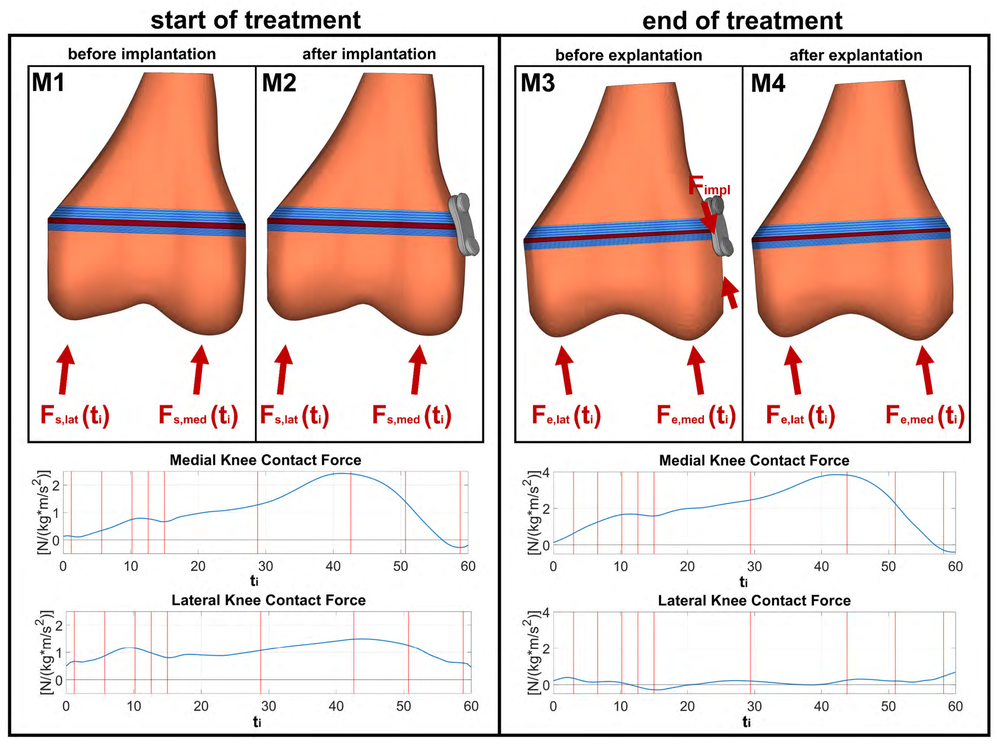
- **Gait analyses** at the start & end of treatment
- **Full body musculoskeletal model** of Lerner [5] (OpenSim 3.3)

➢ inverse kinetics → **medial & lateral knee reaction forces**

Material models: Linear elastic acc. to [6], [7]
Pretension force of the implant acc. to [8]

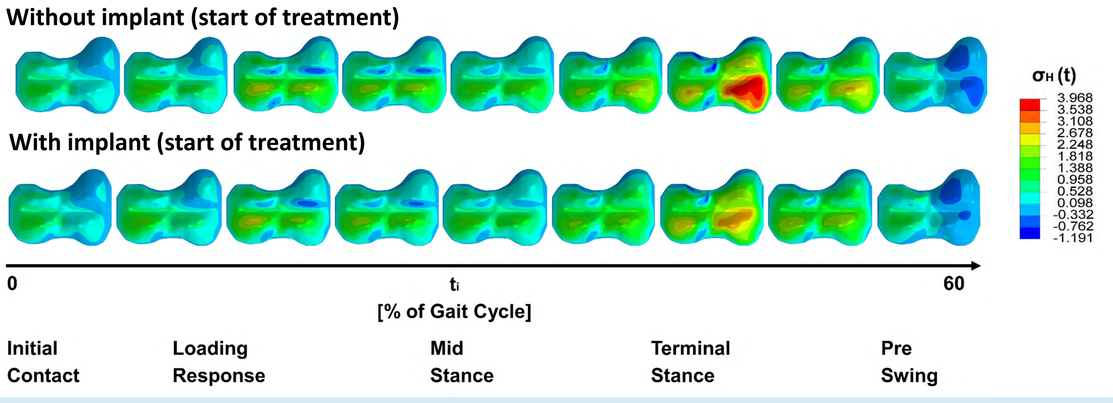


Overview of models and load cases (for each knee)



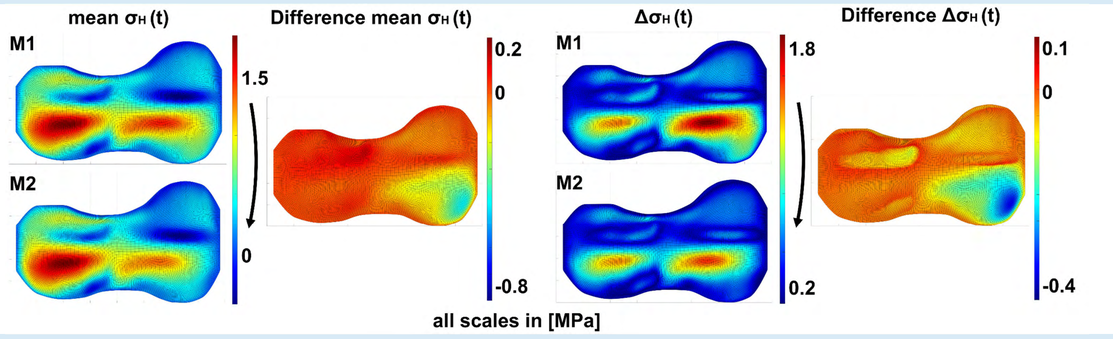
Results

Hydrostatic (compressive) stress (σ_H) distributions

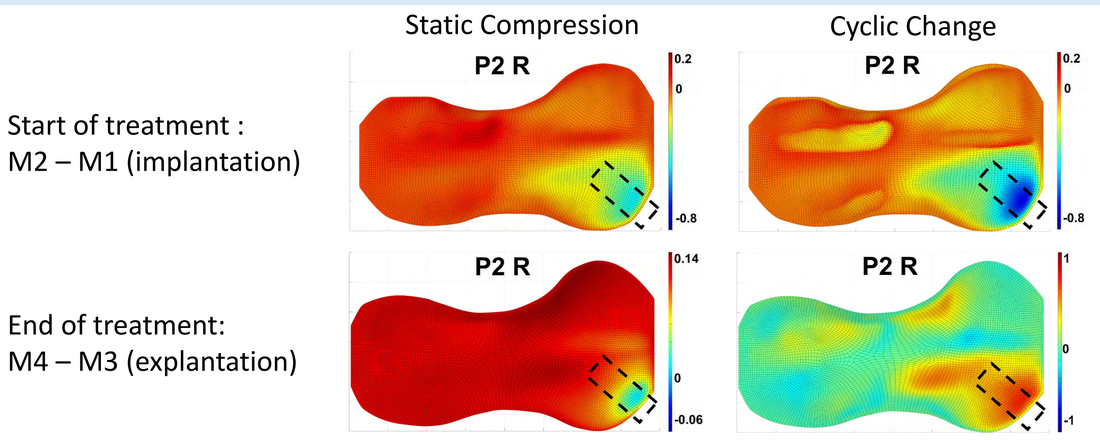


Change in mechanical loading due to the implant

- **Mean** (mean σ_H) and **cyclic change** ($\Delta\sigma_H$) of stresses during gait cycle
- Difference plots: **without imlant ⟷ with implant**



Exemplary results: change of mean and cyclic loading



Summary and Outlook

- At the end of treatment, tension band **implants increase static compression** and **reduce the cyclic change of loading**
  → reduction of growth rate in the implant region
- At the **start of treatment, static compression is decreased** on the implant side
- **Fully patient-individual FE models** are necessary in future studies to **relate stress distribution** and **resulting bone growth**

References

[1] Stief et al. (2021) Der Orthopäde
[2] Hüter C. (1862) Virchows Arch.
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[4] Frost H. M. (1979) Calcified tissue int.
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