Biomechanical Stability Optimization in Preoperative Planning for Tibial Plateau Fractures

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Purpose: Complex tibial plateau fractures challenge orthopaedic surgery, with plate and screw fixation strategies still debated. Finite element modeling (FEM) can quantitatively evaluate various osteosynthesis constructs under physiologic loads. Aiming to improve conventional preoperative planning by using FEM as a measure for assessing and optimizing biomechanical performance, we hypothesized that optimized osteosynthesis configurations provide greater stability than standard approaches.

Methods: Six human cadaveric tibias with Schatzker IV fractures (Rimasys, Germany) underwent a CT scan, after which the tibia fragments were segmented and realigned. Fractures were fixed with a medial variable angle locking plate (Pangea, Stryker, Switzerland), and initially positioned based on standard surgical planning by a fellowship-trained surgeon. FEM was used iteratively to optimize plate and screw placement. Stability was assessed by biomechanical simulations in Abaqus (Simulia, Dassault Systèmes, France). Knee joint reaction forces were scaled according to patient weight, and patient-specific Hounsfield-Unit–derived bone material properties were applied to the 3D model.

Results: Mean maximal displacement magnitude decreased significantly from the initial configuration to the optimized configurations (MInitial = 1.171 mm, SD = 0.431, MOptimized = 0.658 mm, SD = 0.185, p = 0.01), significantly reducing maximal displacement without altering the mean amount of screws used (MInitial = 11, SD = 1.265, MOptimized = 11, SD = 0.894, p = 0.5) but slightly reducing individual screw count (MInitial = 2.3, SD = 0.516, MOptimized = 1.83, SD = 0.753, p = 0.08).

Conclusion: Optimizing plate and screw positioning significantly reduced displacement compared to conventional planning, especially in initially unstable constructs (see figure). Finite element analysis (FEA) data offer valuable insights into fracture stability, aiding patient-specific surgical planning.

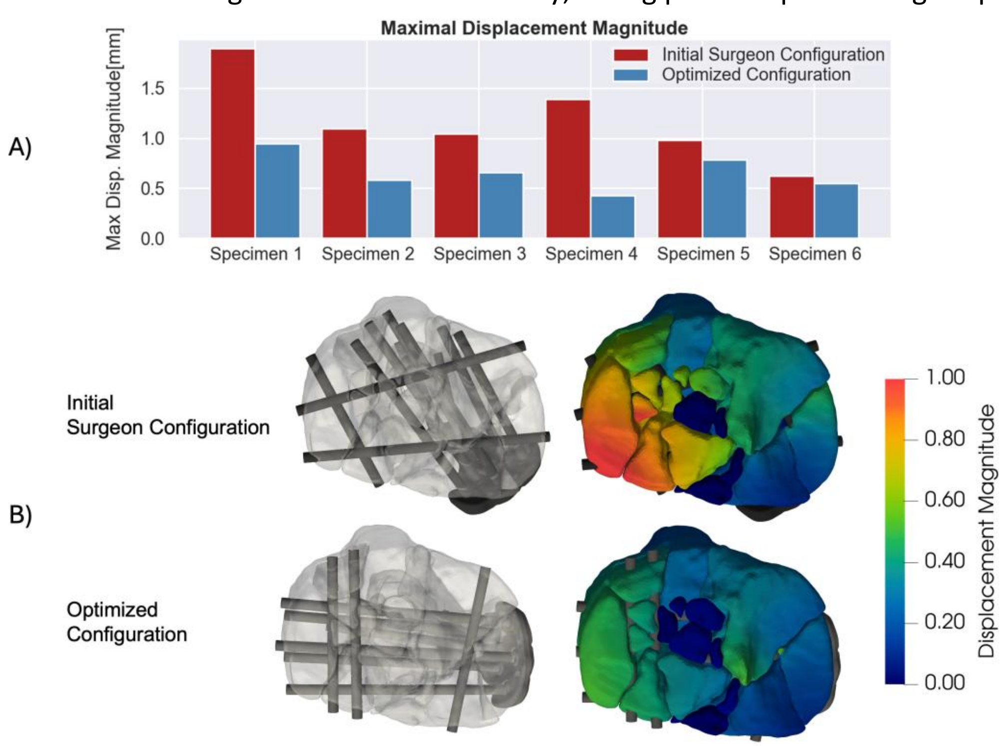

Figure 1: A) Shows the maximal displacement value per specimen per configuration.
B) Shows the configuration (left) and the biomechanical stability (right) of the initial surgeon configuration (top) and the optimized configuration (bottom) for one sample specimen.