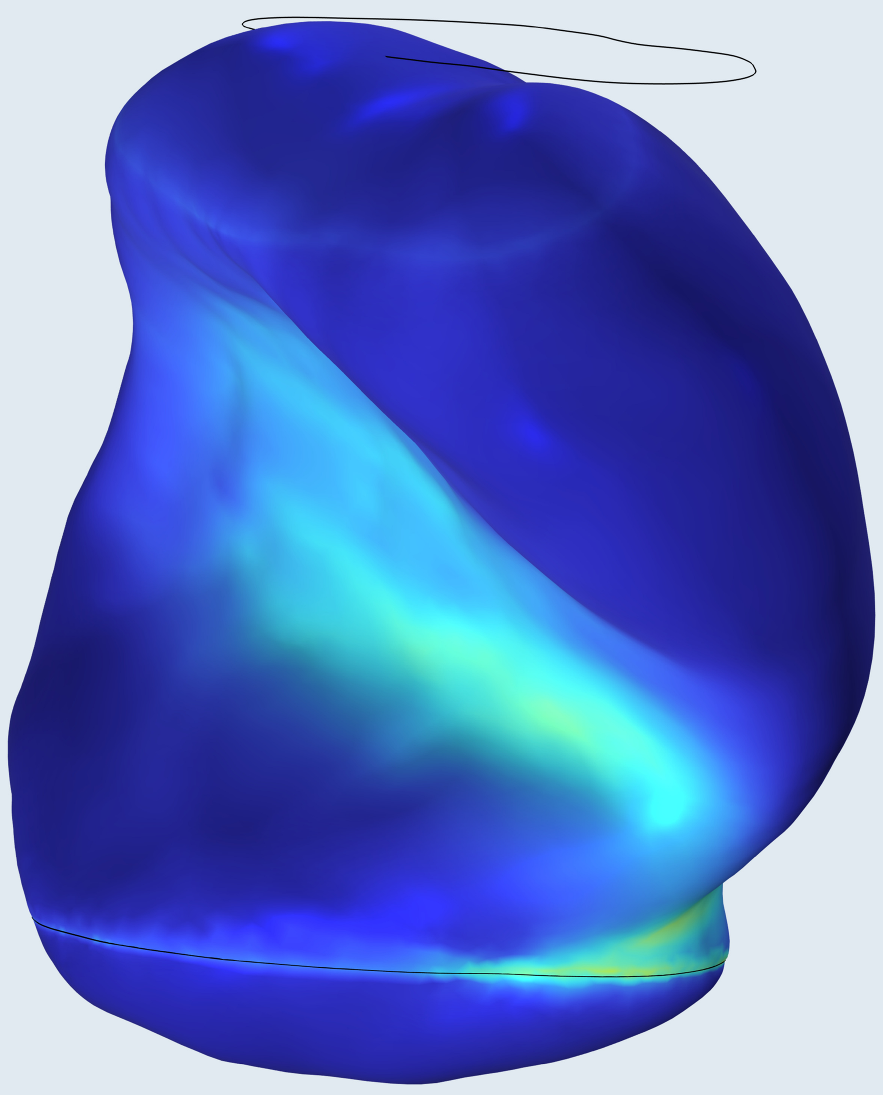

3-D Modeling of Stresses and Strains in Accessory Carpal Bone Under Maximum Compressive Loading

The objective of this study is to create a 3D FEM model to simulate the accessory carpal bone in horses under maximum compression. The focus lies on the creation and validation of the model through an FEM study.

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Introduction & Goals

When treating fractures of the accessory carpal bones in horses, it is important to understand the forces that implants (screws and plates) must withstand. The etiology of the fracture is not fully understood, but their high incidence during exercise suggests a relation to biomechanical forces. (Ref. 1) Detailed descriptions of the intact and fractured accessory carpal bone's morphology and functional anatomy, which is crucial for stable fracture fixation, are lacking. (Ref. 2)

Therefore, the purpose of this study is to develop and validate a simple 3D FEM model that can be used for initial investigations to understand the etiology of the fracture and for the selection and placement of implants for stable fracture fixation of the accessory carpal bone.

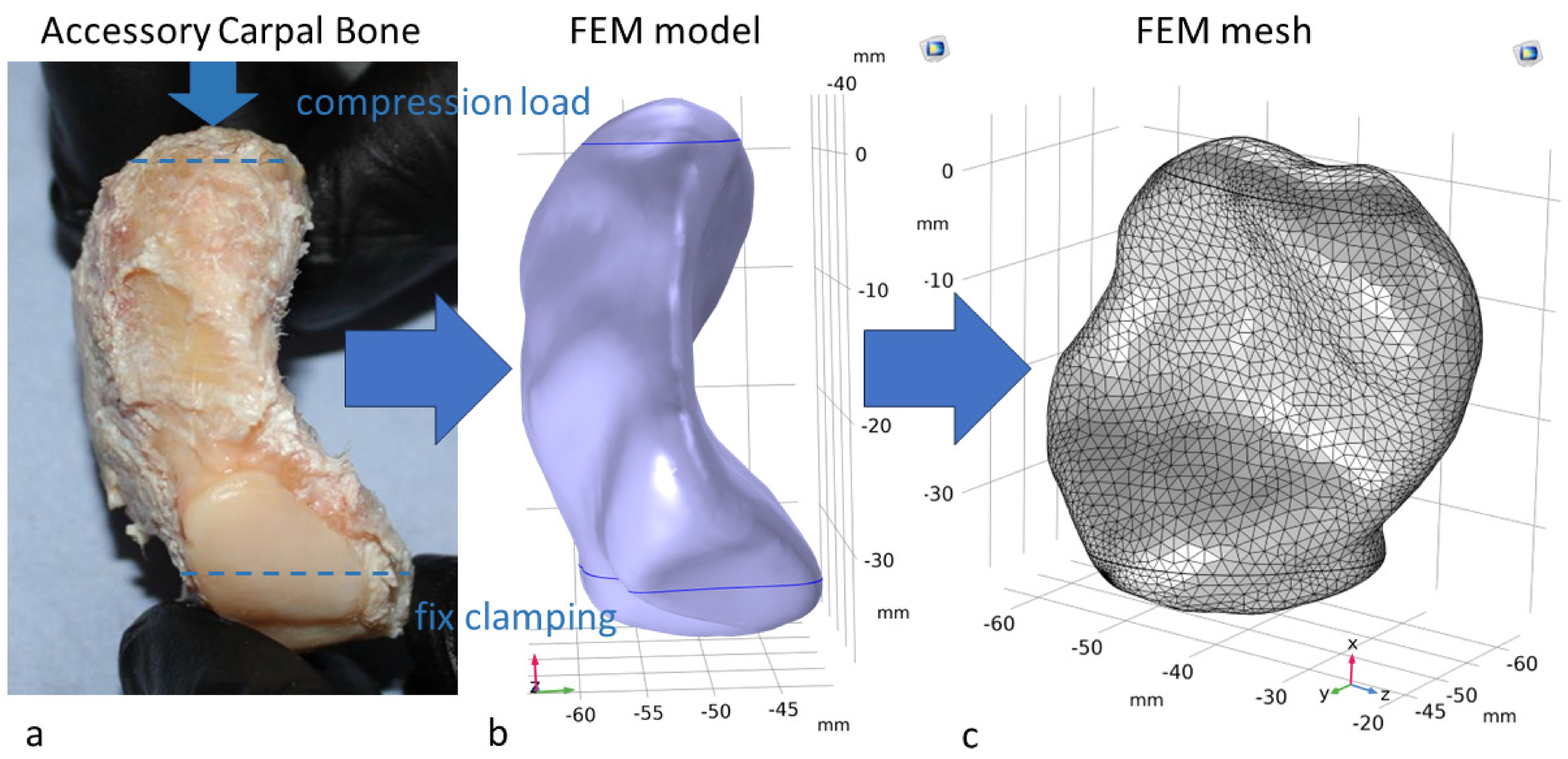

FIGURE 1. a.) Equine accessory carpal bone, b.) FEM model with boundary conditions and c.) FEM mesh.

Methodology

To determine the maximum strength, experimental compression (force-to-failure) tests were conducted on equine accessory carpal bones (n = 8), using a four-column testing machine. Subsequently, a 3D FEM model was created based on the compression tests. CT scans were utilized to convert the morphology of the bone into a step file. The boundary conditions corresponded to those from the compression tests (Figure 1). The obtained force-to-failure values were used as boundary loads. For the description of the bone, a hyperelastic material model according to neo-Hookean was defined. Since the material parameters are unknown stresses, deformations and strains were determined with different Young's moduli (E = 4 GPa – 30 GPa) and a constant Poisson's ratio of v = 0.4.

Results

The results from the compression tests revealed average force-to-failure values of F_{mean} = 11.46 +/- 2.49 kN. The calculated stresses ranged from σ = 500 – 3000 MPa, depending on the Young's modulus used. The highest stresses occurred in both, the bone fracture, typically in a vertical level between half and two-thirds of the bone, and in the area where the bone is clamped in the testing machine (Figure 2a).

The simulated deformation behaviors matched those obtained from the experimental compression tests (Figure 2b). Thus, the comparison of the simulated deformations with those from the experimental tests helped narrow down the Young's modulus range (E = 4 GPa – 6 GPa).

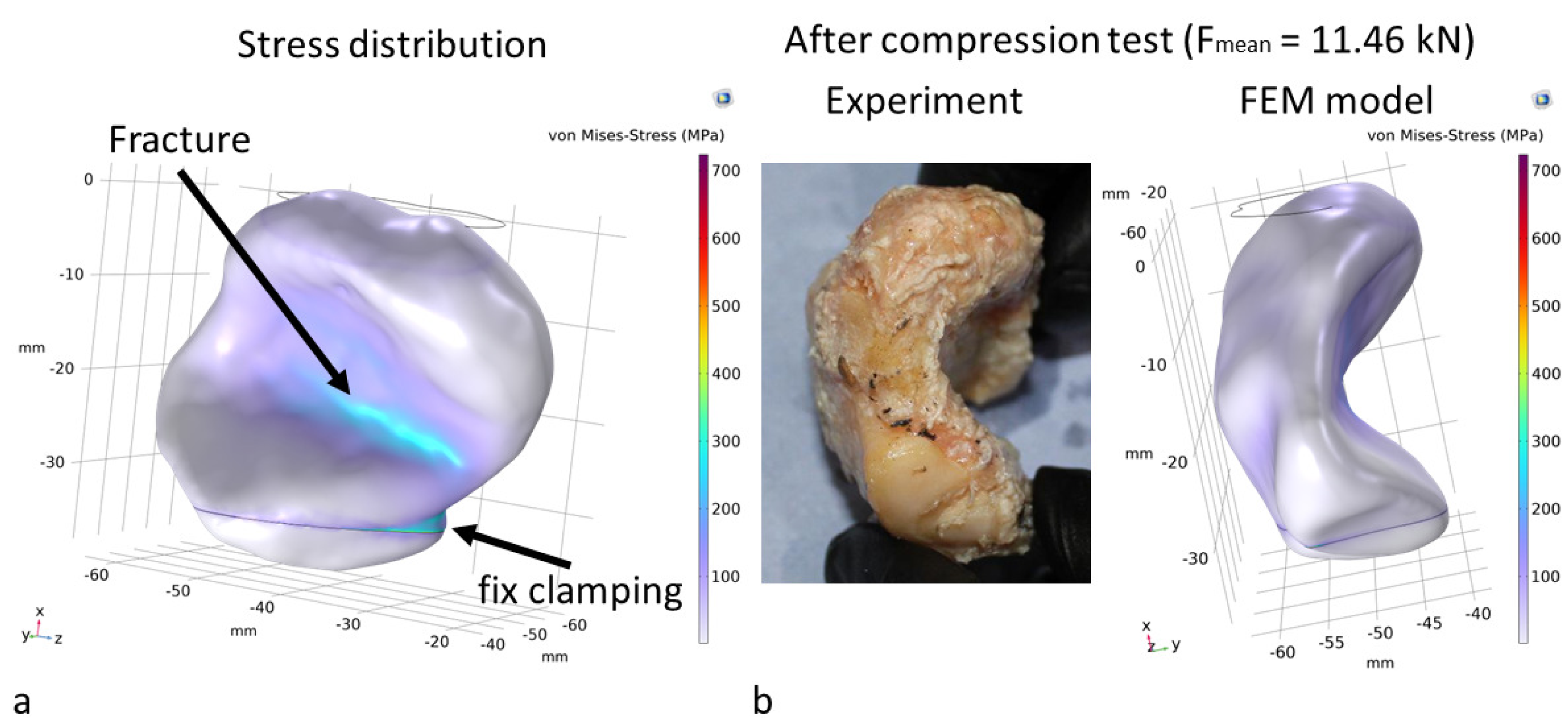

FIGURE 2. After compression of the bone: a.) simulated stress distribution and b.) comparison between experiment and simulation. (Material parameter: E = 5 GPa, v = 0.4)

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