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EXPERIMENTAL DETERMINATION OF MATERIAL PARAMETERS OF THE HUMAN TIBIA

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An individual approach to fracture therapy requires not only knowledge of trauma surgery but also expertise in mechanical aspects. In order to understand and optimise the process of fracture healing, it is necessary to deal with the origin of the fracture.
Only with the help of experimentally supported material models can the mechanical behaviour of bones be meaningfully simulated and corresponding predictions made possible. The basis is the fracture generation and the behaviour of the bone under different loading conditions. Therefore, a testing device was designed and built to generate reproducible and predefined human cadaveric tibiae fractures.
The specimens come from body donations. Before the experiment is performed, a computer tomography (CT) scan including a 6-rod calibration phantom for bone density is made from the lower leg. The segmentation of the CT stack forms the basis to build the 3D model for the simulation and is equipped with the bone mineral density information based on the calibration phantom. The model is passed to a high-quality finite element meshes generator. The image processing was done in Simpleware ScanIP™.

The fracture events are performed on the self-designed testing device (see Figure 1 a) and the fracture event takes place due to superimposed compressive and torsional loads. Two six-axis force sensors (3) are measuring the forces during the experiment.
After soft-tissue removal and foot exarticulation, the human tibiae are equipped with a so-called Speckle pattern for the evaluation via digital image correlation (DIC). All experiments are performed on the testing device and recorded by corresponding high-speed cameras including real-time triggering.

The specimens are clamped into an individual complex clamping system (4). To generate realistic fractures data from Orthoload™ [1] are applied to the testing device and are scaled with the body weight of the donors. Longitudinal loads are applied by pre-compressing one axis with the stepper motor and the screw drive (1&6). The spiral fracture is caused by the torsion axis with the direct drive and the leading bellow coupling (1&2).
The axial loading corresponds to the maximum forces acting during a step forward based on the scaled Orthoload™ [1] data and then torsion is applied until fracture.
The experiments are evaluated using a combination of the measuring sensors and the DIC evaluation [2]. The DIC process starts with a reference image of the undeformed specimen and calculates the surface displacements and strains with respect to the images of the deformed states.

Reproducible distal tibiae fractures were produced (see Figure 1b & c) as statistical fractures for the further workflow of testing new trauma implants. It is possible to make a statement about the limit loads before failure. Through the evaluation material parameters of the bones yields additionally.

An essential part of fracture healing is the understanding how the event happened and which fracture morphology arises. Information is provided by taking into account realistic load cases on a whole bone.

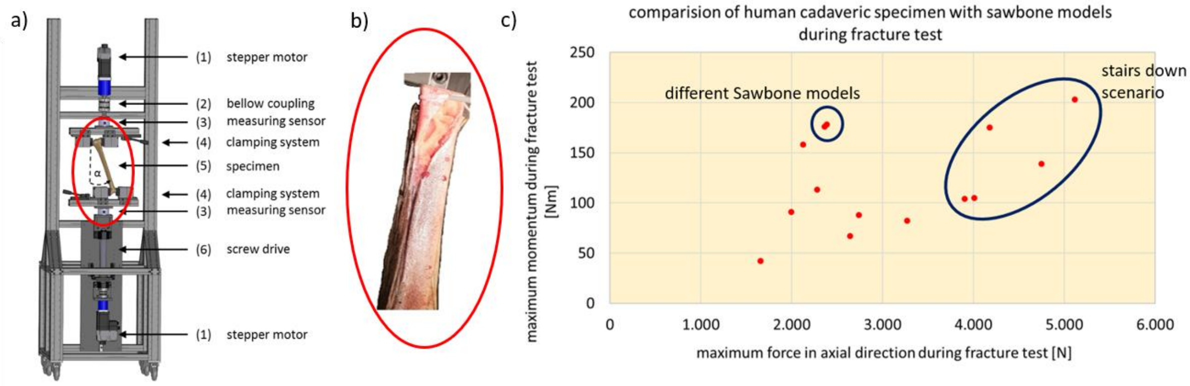

Figure 1 a) Testing device b) Spiral fracture c) Results for a series of complex distal tibia fractures

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REFERENCES

[1] https://orthoload.com/

[2] https://www.dantecdynamics.com/solutions-applications/applications/biomechanical-biomaterial-testing/