INFLUENCE OF ANISOTROPIC CORTICAL BONE PROPERTIES IN PERIPROSTHETIC HIP FRACTURES

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Ingenieurgesellschaft für Automobiltechnik mbH

JULIUS WOLFF INSTITUT

Impact Mechanics and Material Characterization Group

FORSCHUNGSLABOR FÜR BIOMECHANIK UND IMPLANTATTECHNOLOGIE

28th Congress of the European Society of Biomechanics

July 10 - 12, 2023

INTRODUCTION

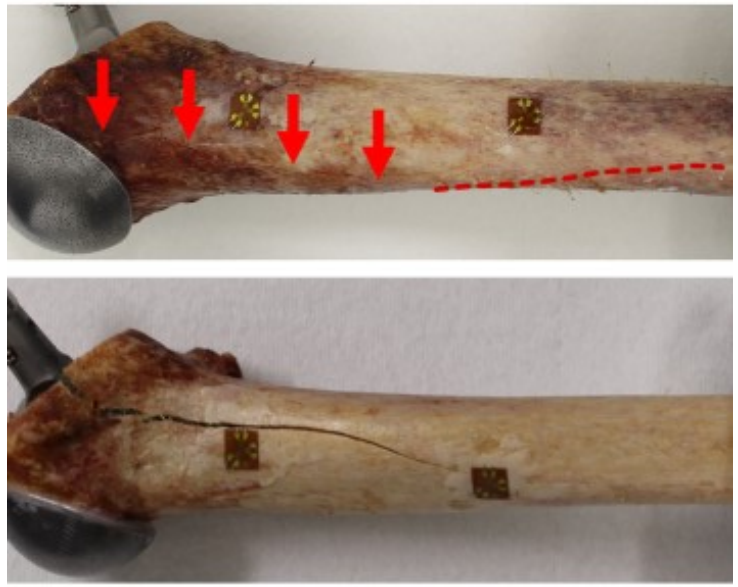
- Third most common reason for revision surgeries *(Maier, 2015)*
- *Associated with high mortality and morbidity rates*
- High rate of PFFs during the early postoperative (EP) period *(Abdel et al., 2016)*
- Computer models help to predict EP fractures

BACKGROUND

- Ex-vivo studies have reported crack propagations parallel to the femoral axis.
- Bone anisotropy might play a role.
- All previous modeling studies relied on isotropic models.
- Role of cortical bone anisotropy in PFFs has not been studied.

Aim of the study:

Develop an anisotropic cortical bone modeling strategy and investigate the influence of cortical bone anisotropy in PFFs.

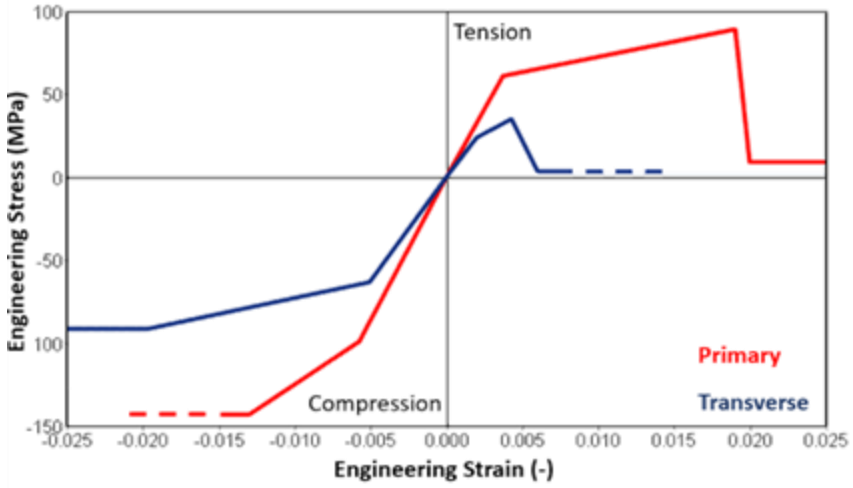


Saemann et al., 2022

Schwarz et al., 2018

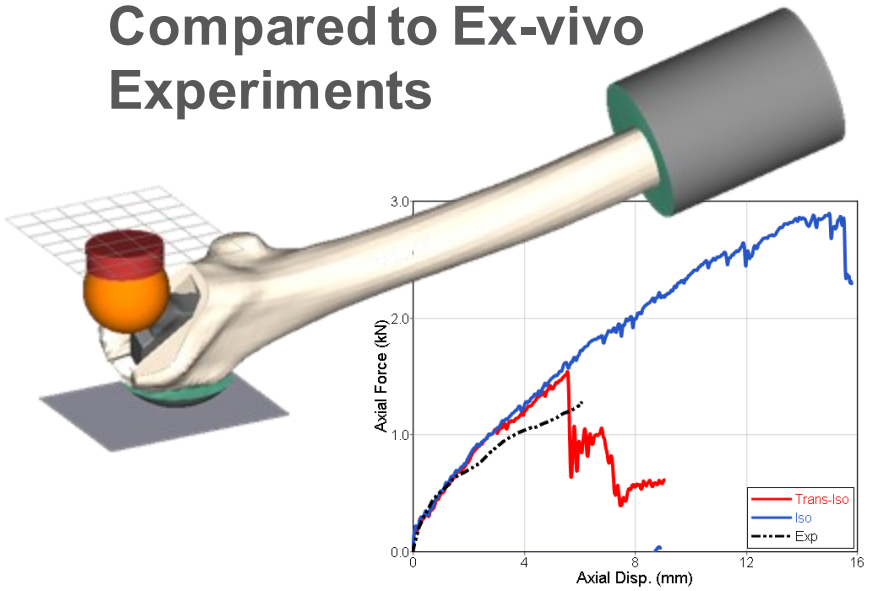
METHODS

Cortical Bone Modeling



Femur Specific Models

Model Assessment Compared to Ex-vivo Experiments



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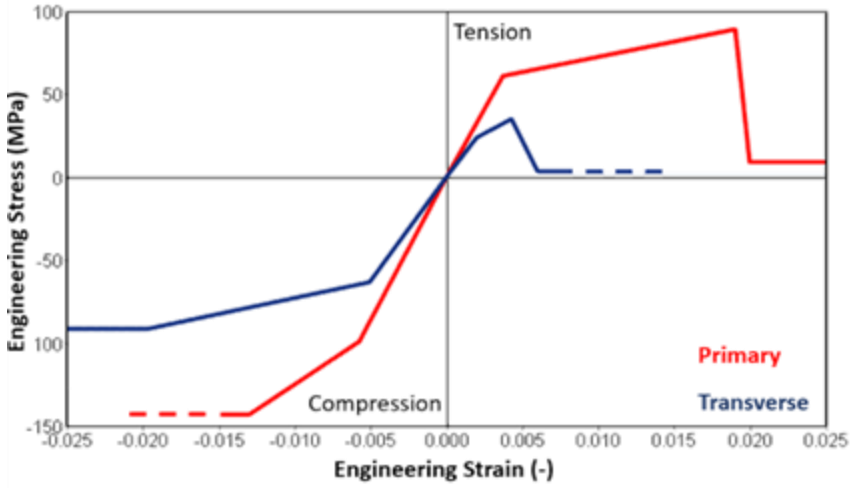

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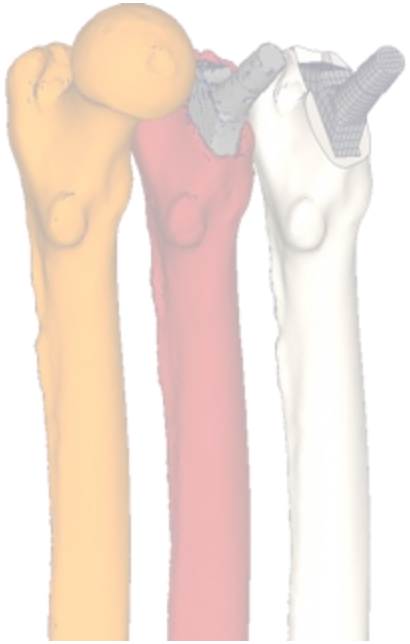

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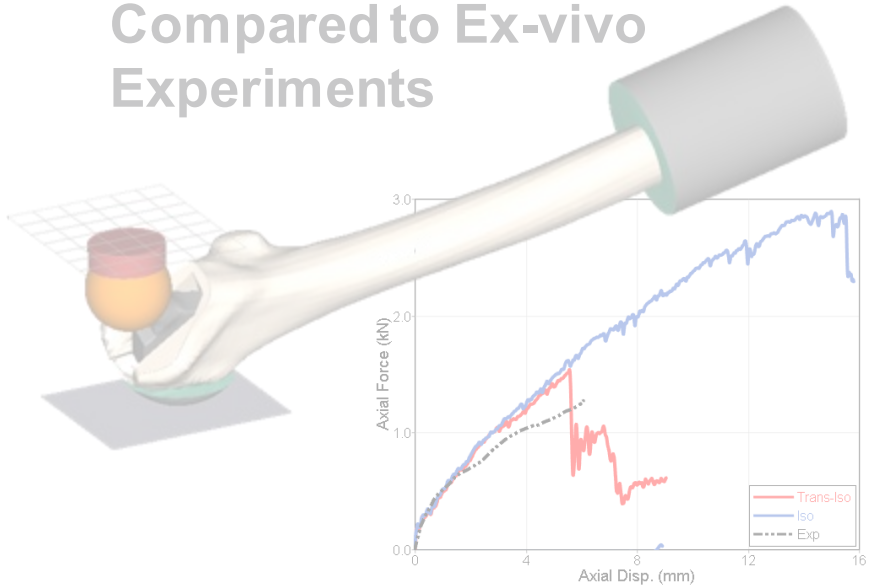
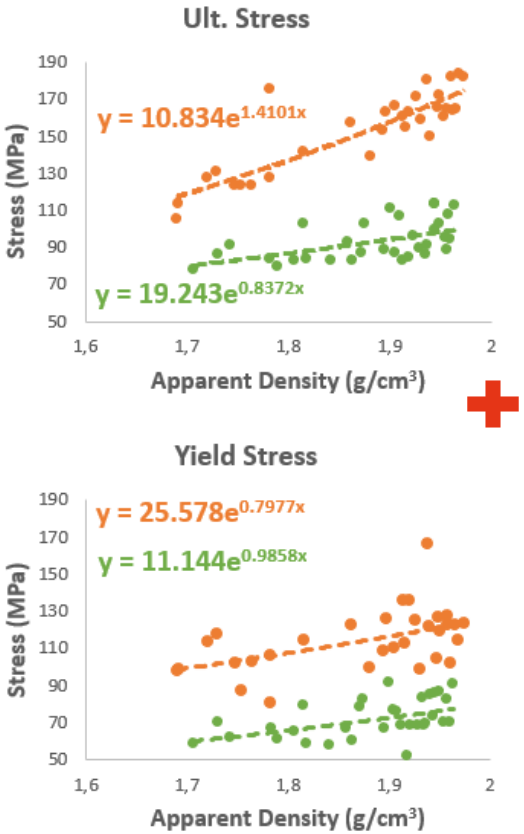
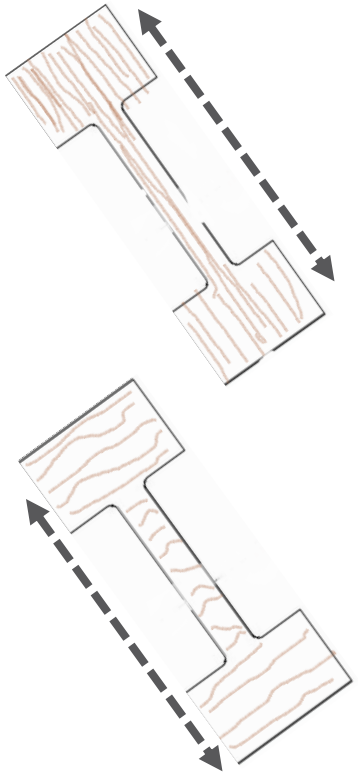
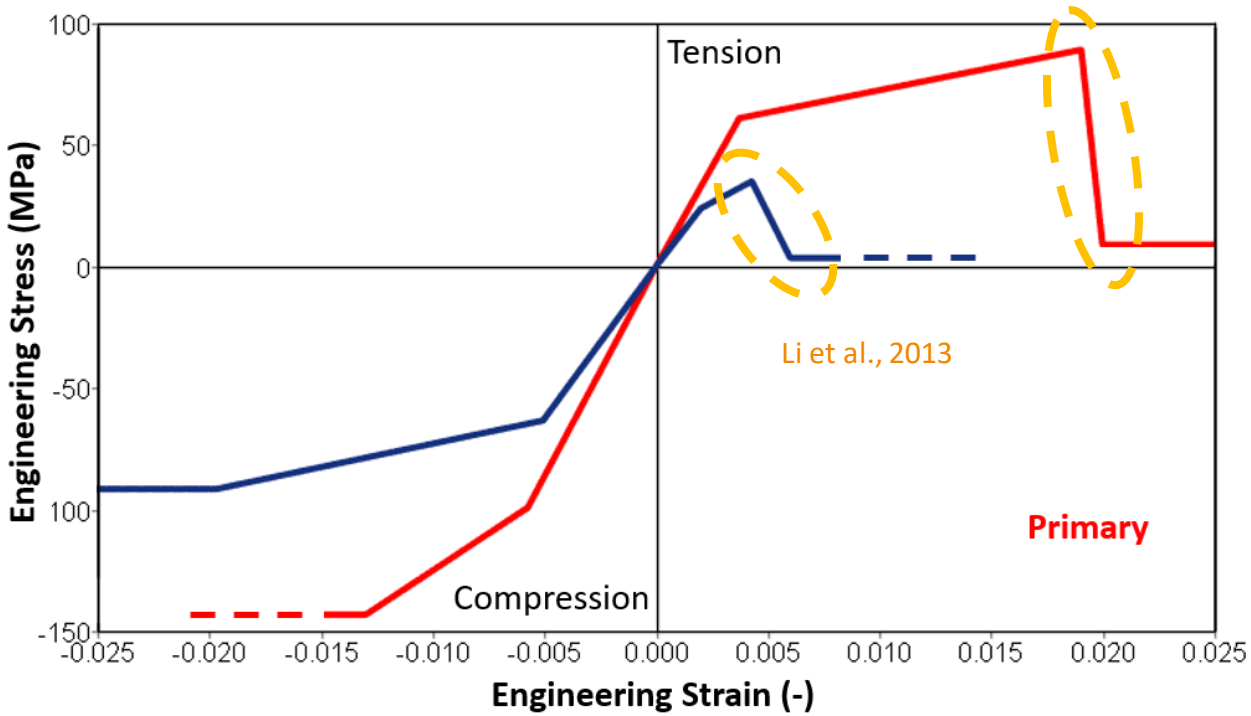


CORTICAL BONE MODELING





For a given density



Transverse/Primary ratio:

Compression: 0.39
Tension: 0.63

Reilly and Burstein, 1975

Axial Compression
Axial Tension

Mirzaali et al., 2016

CORTICAL BONE MODELING

***MAT_COMPOSITE_TABULATED_PLASTICITY_DAMAGE**

Recently developed for composite failure in aerospace applications

CORTICAL BONE MODELING

*MAT_COMPOSITE_TABULATED_PLASTICITY_DAMAGE

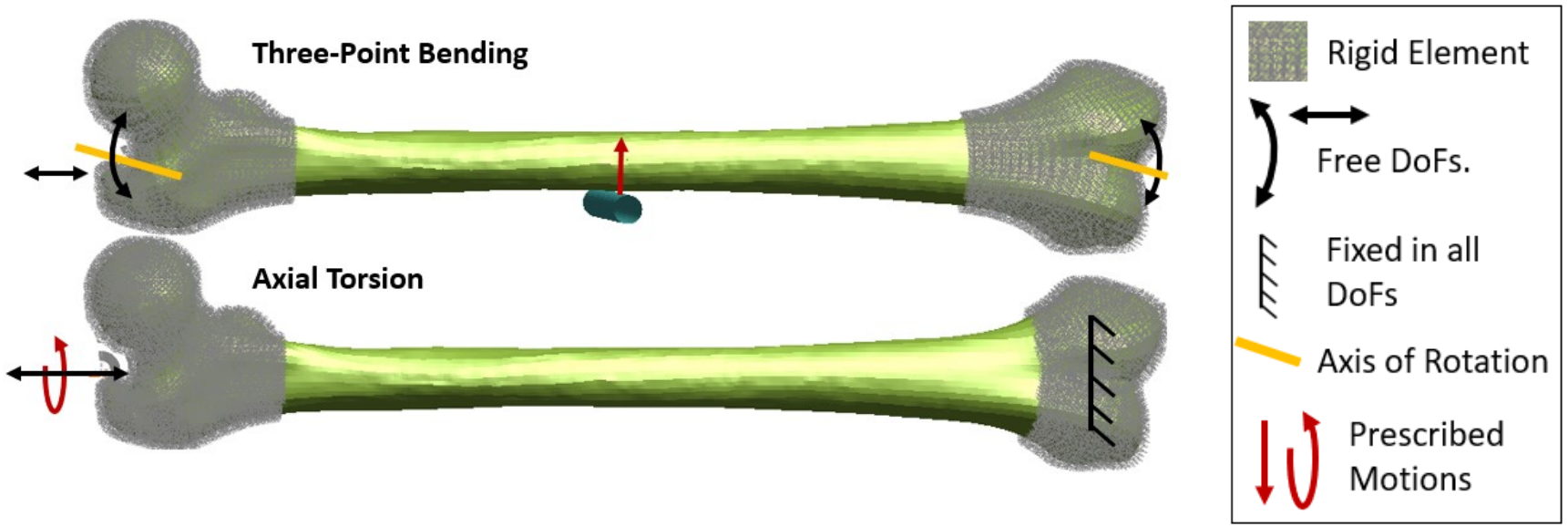
- **Anisotropy**
- **Asymmetry**
- Uncoupled Damage
- Rate dependency

CORTICAL BONE MODELING

*MAT_COMPOSITE_TABULATED_PLASTICITY_DAMAGE

- **Anisotropy**
- **Asymmetry**
- Uncoupled Damage
- Rate dependency

Initial material model verification:



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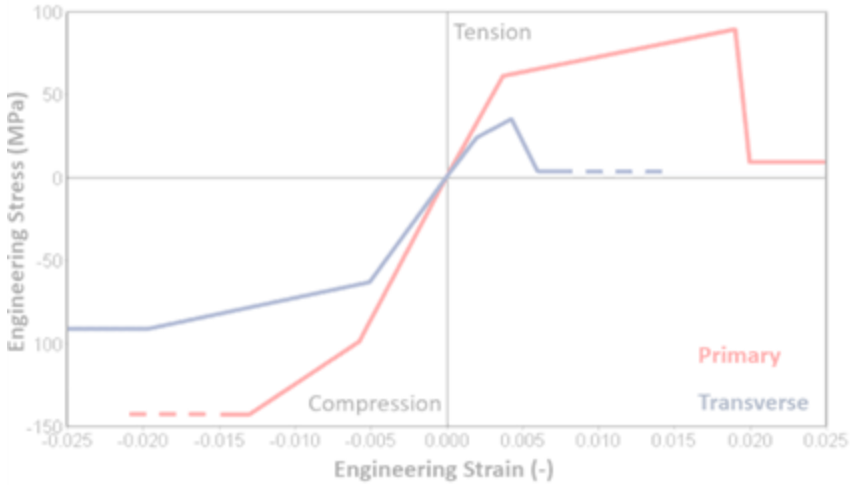
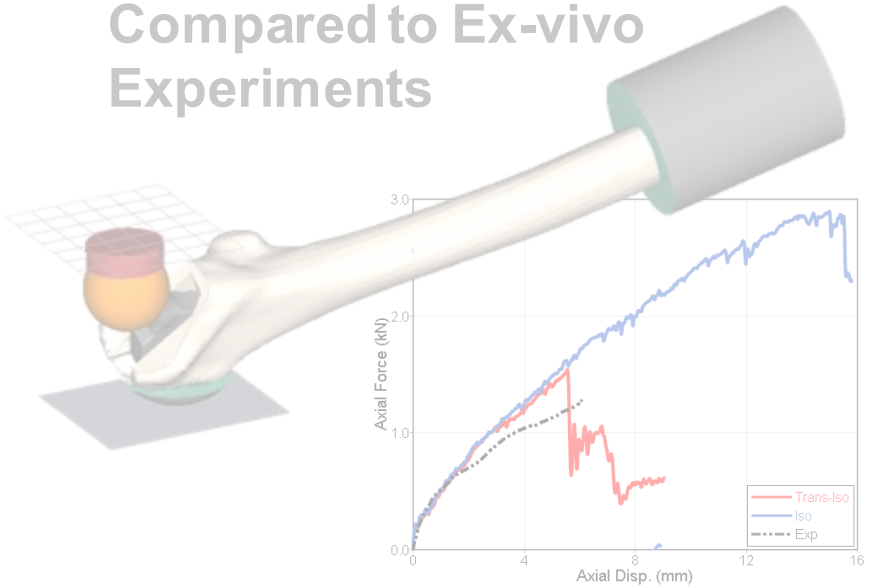


Femur Specific Models

Model assessment Compared to Ex-vivo Experiments



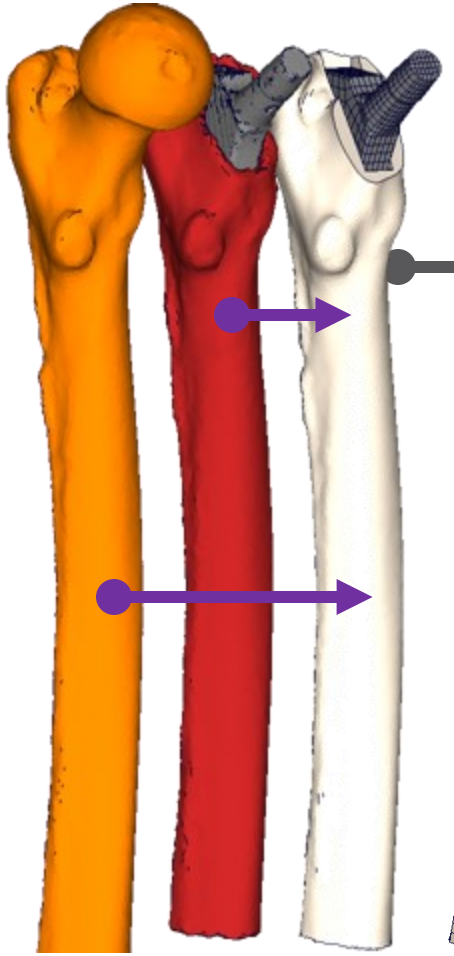
FEMUR SPECIFIC MODELS

Input Data

Saemann et al., 2022

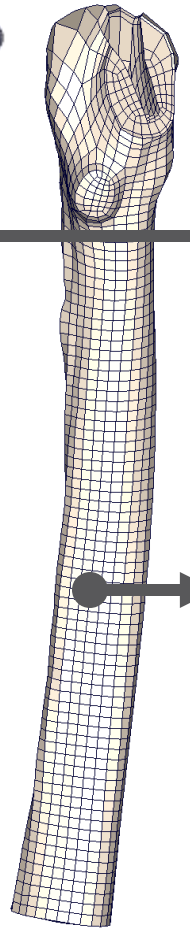
Pre- and post-operative CT scans

a) Segmenting



Pre- and post-operative Segments

b) Morphing



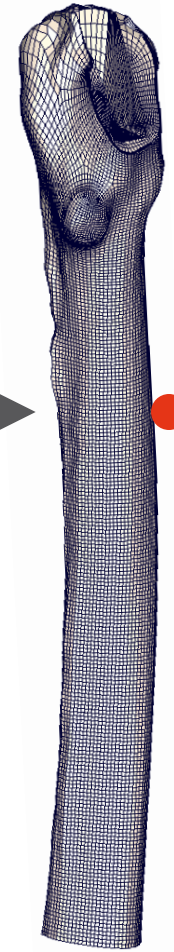
Baseline model

PIPER

Kriging interpolation

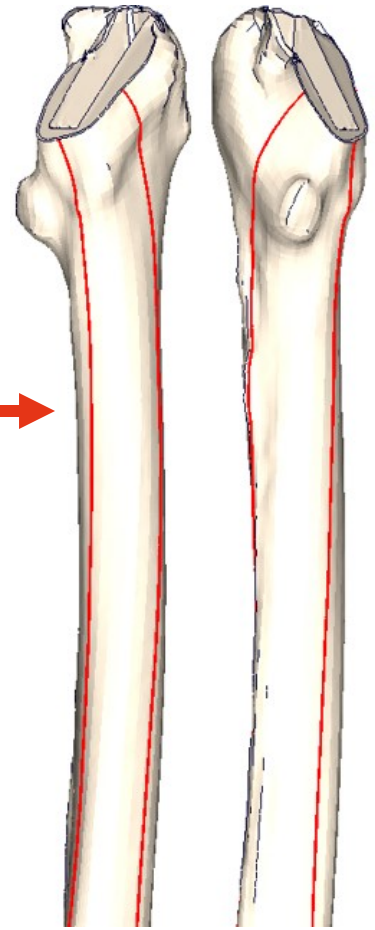
ANSA

Nominal to target morphing



Morphed Model

c) Principal Direction Arrangement



Baca, 2006

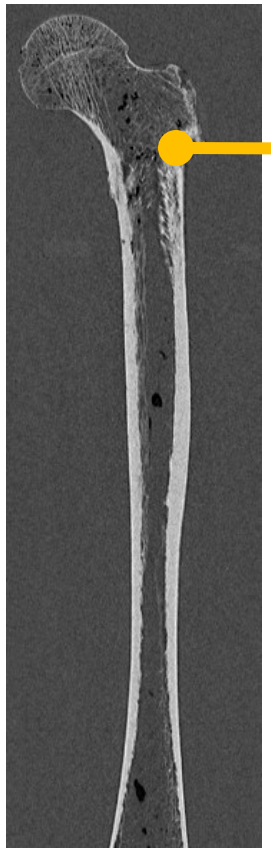
Principal directions

FEMUR SPECIFIC MODELS

d) Material Mapping

e) Material Preprocessing

e) Broaching Simulation

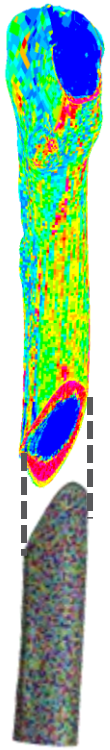


Preoperative CT scans

BONEMAT
Material mapping

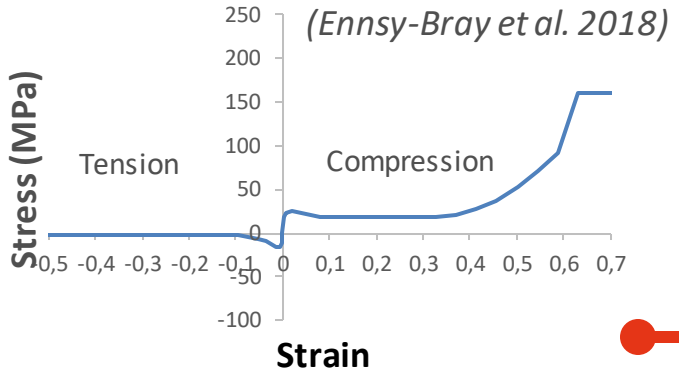
Calibration function
(Saemann et al., 2022)

E (Mpa)

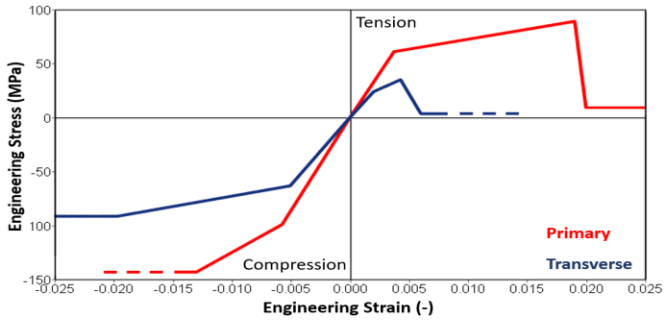


Heterogeneous Femur Models

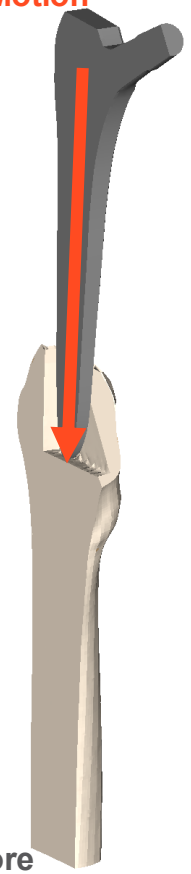
Trabecular Bone: Crushable Foam



Cortical Bone: Anisotropic Composite



Prescribed Motion



Before broaching

Implanted Femur Model

After broaching

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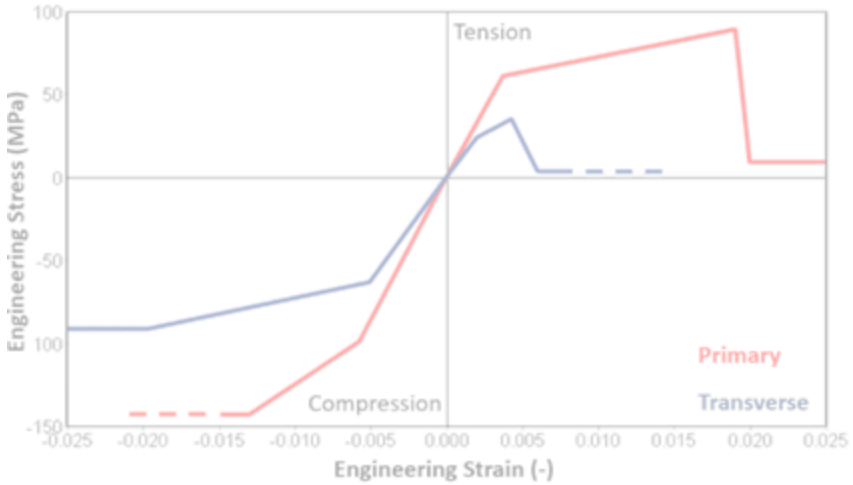

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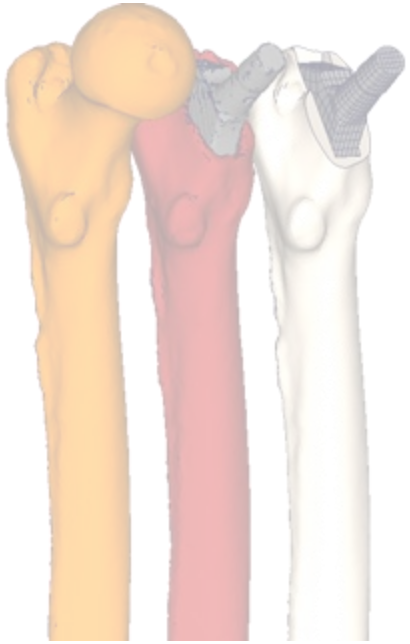

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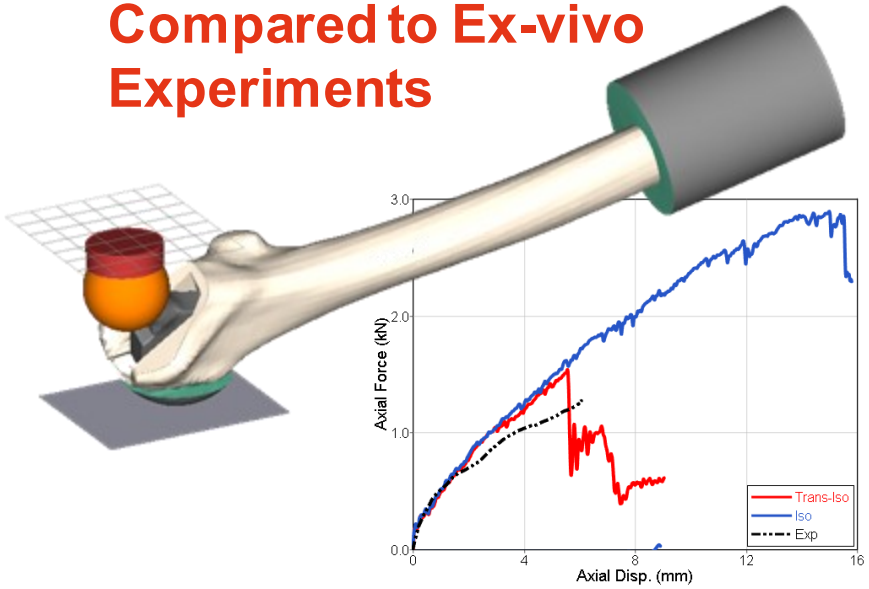
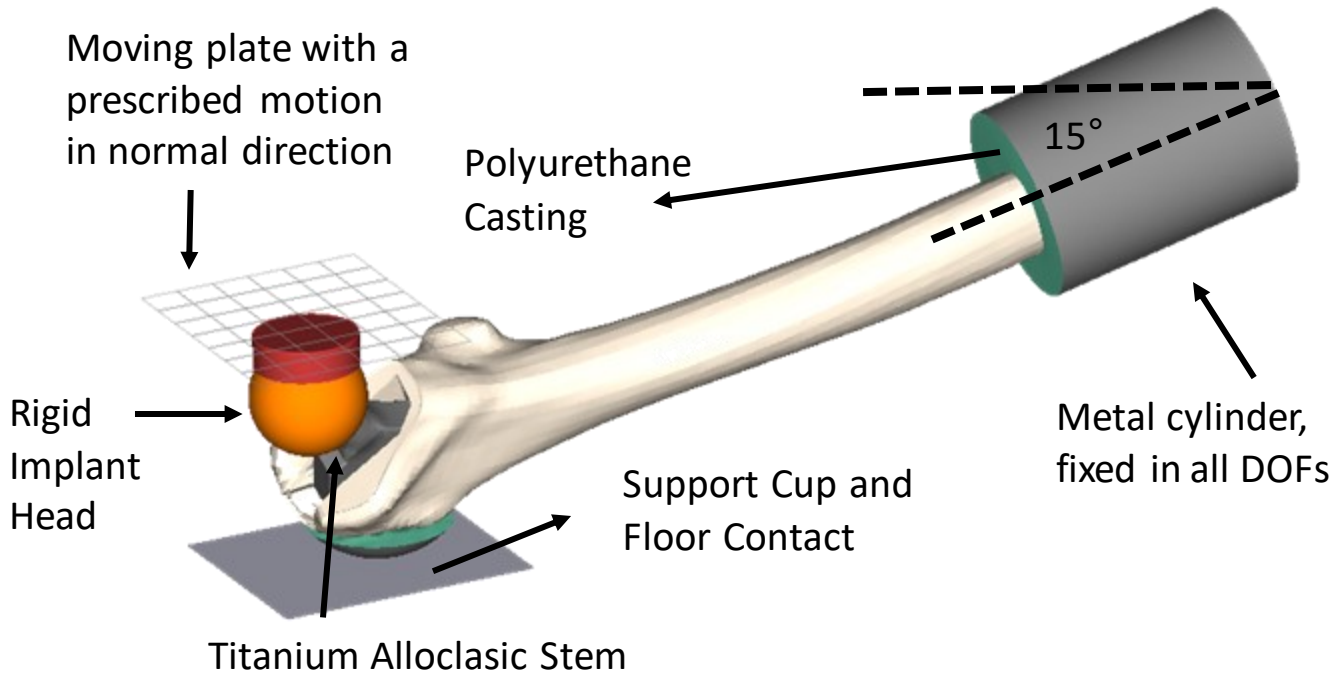


MODEL ASSESSMENT

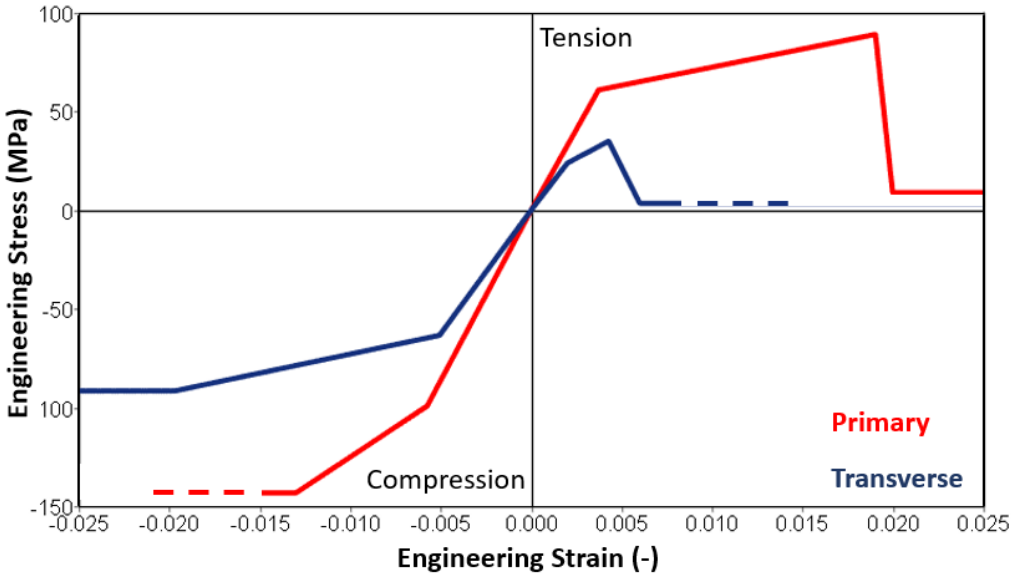
Saemann et al., 2022



Isotropic models were developed, defining all directional scale factors as one.

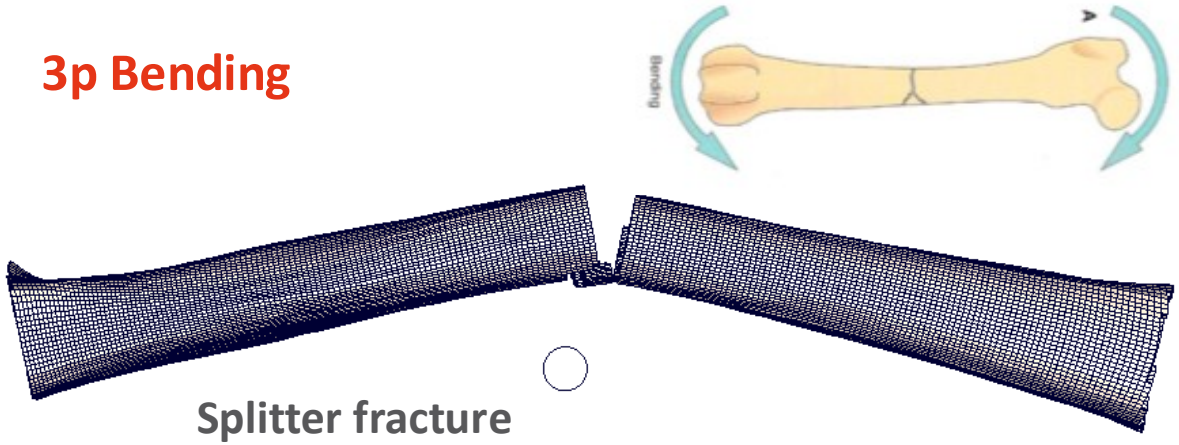
RESULTS - CORTICAL BONE MODELLING

Single Element Tests



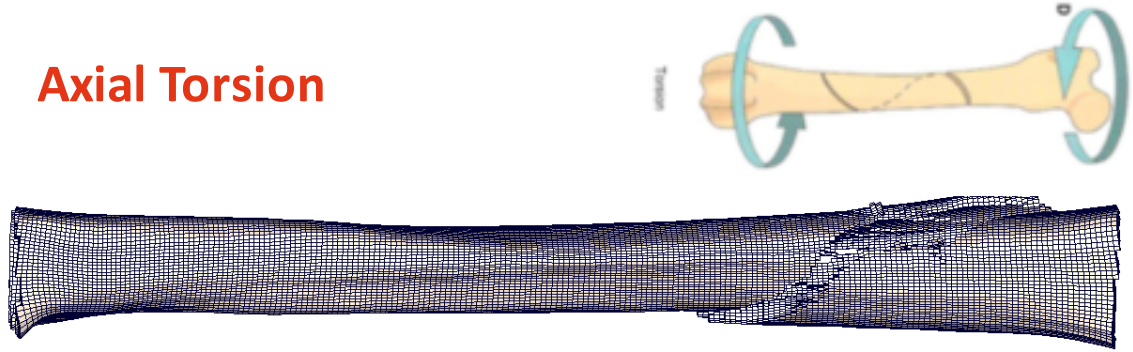
Verification results showed that the developed material model could reflect the expected stress-strain behavior and the femur shaft fractures realistically.

3p Bending



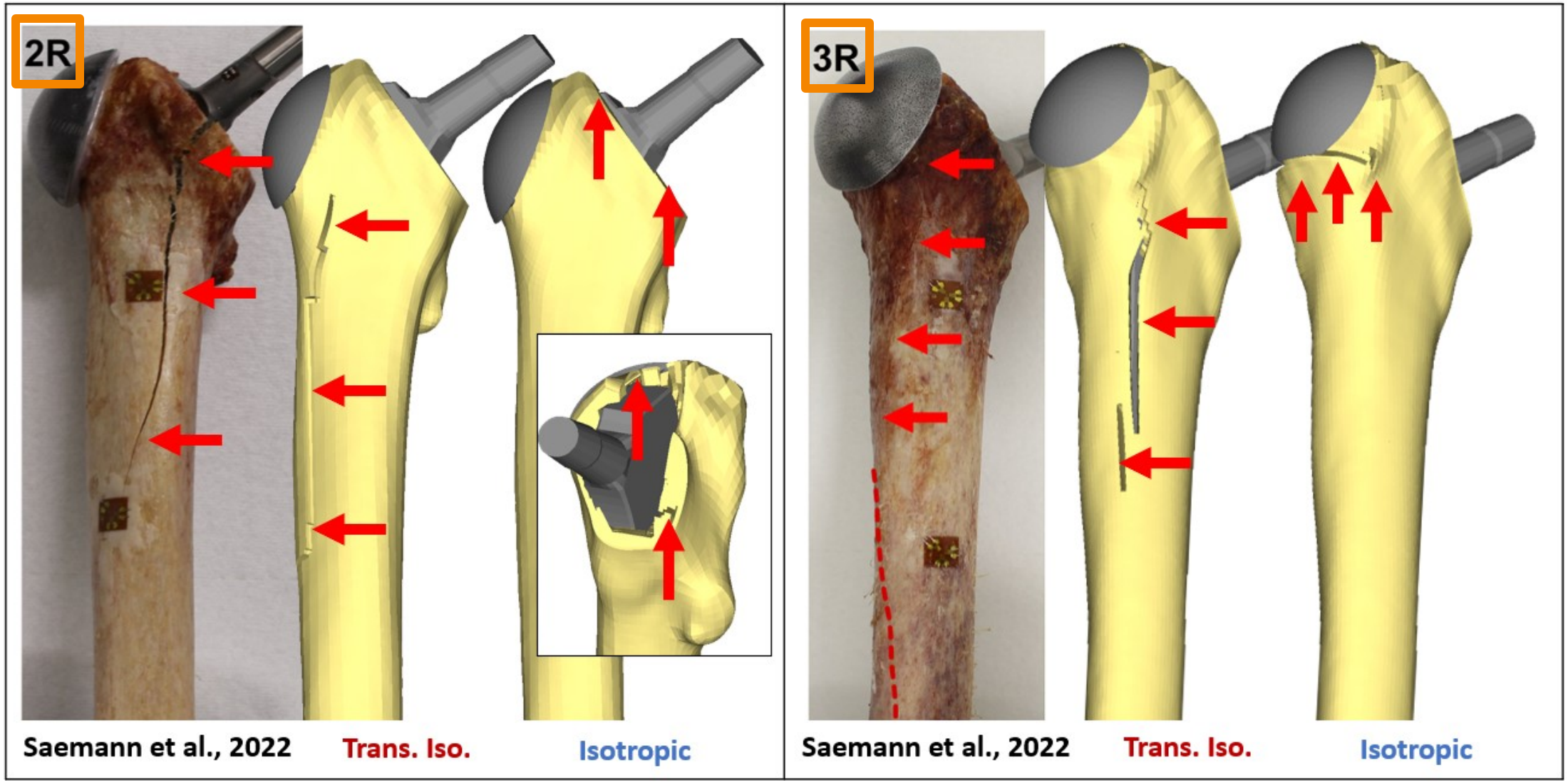
Splitter fracture

Axial Torsion

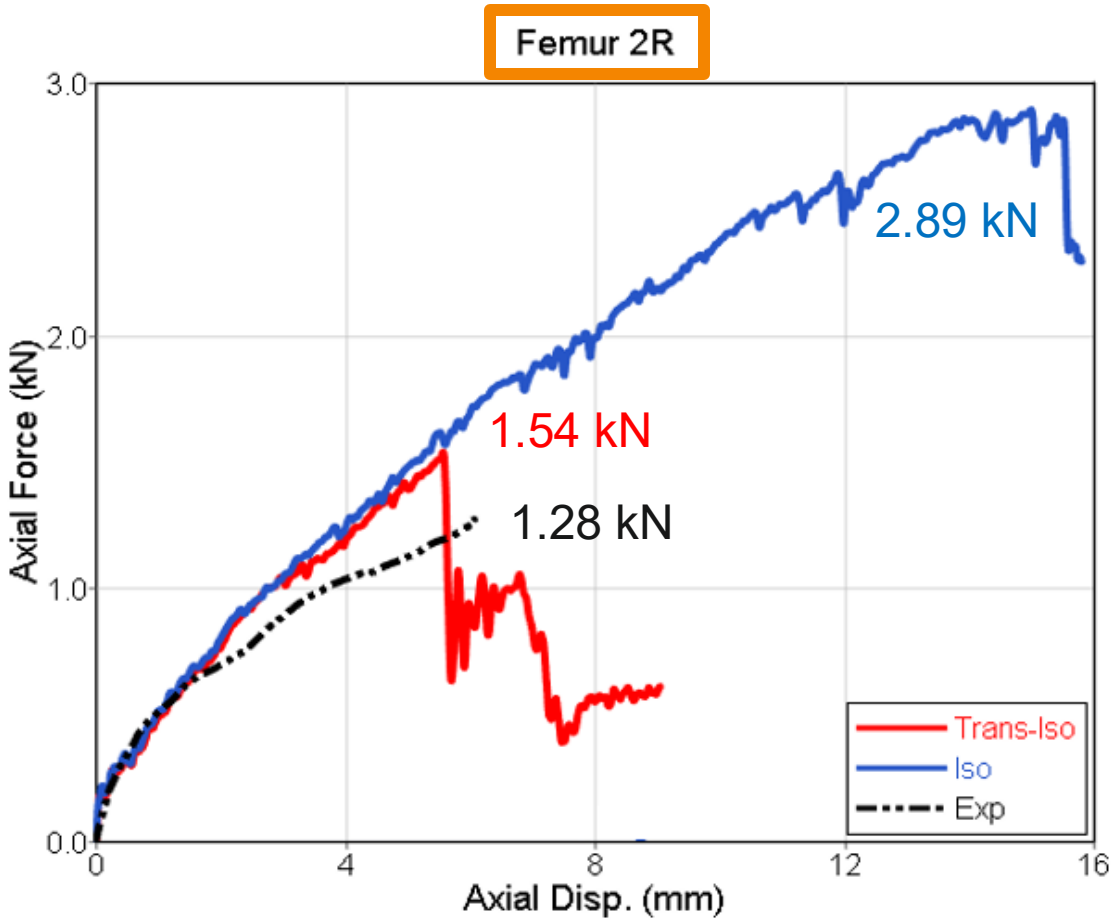


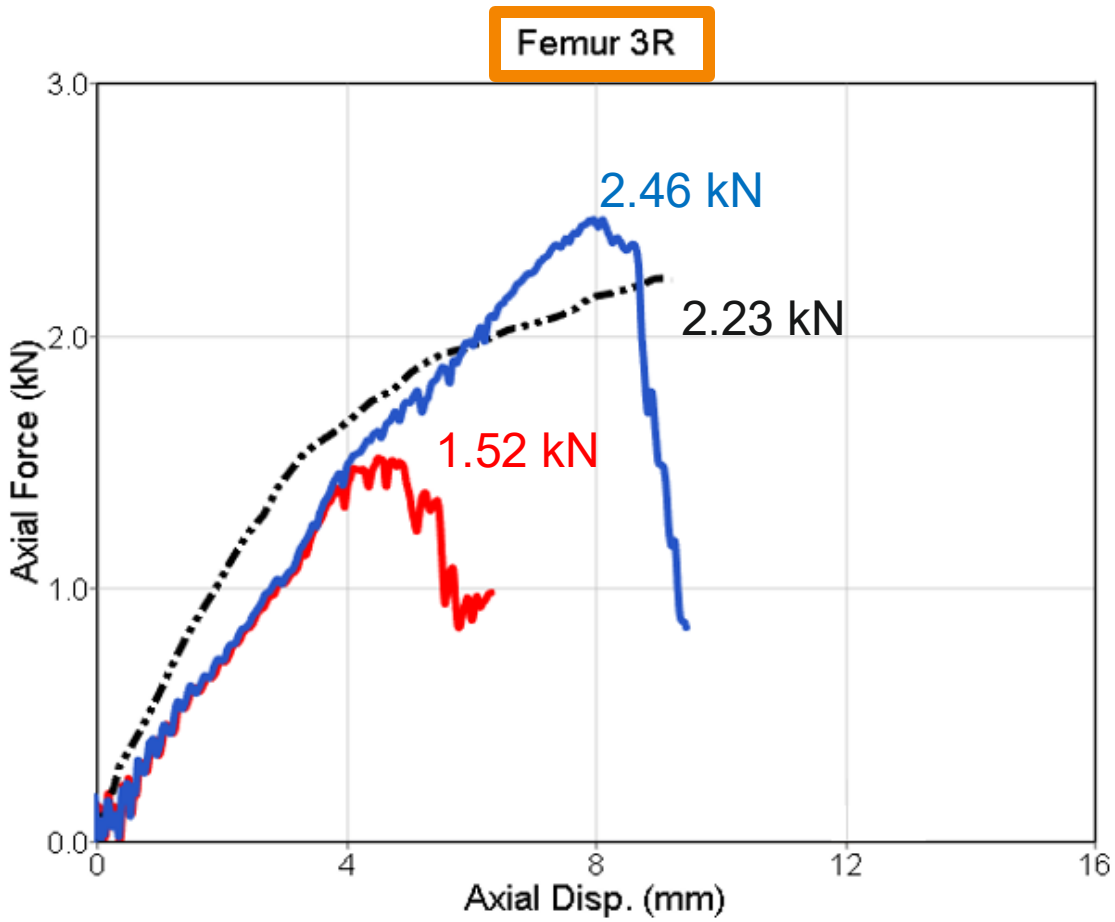
Spiral fracture

RESULTS – FRACTURE PATTERNS



RESULTS – STRUCTURAL BEHAVIOR





On average -> **-12.8%** and **+52.4%**

CONCLUSION AND OUTLOOK

- Developed anisotropic cortical bone model showed realistic fracture patterns under axial torsion and 3p-bending.
- On average, the anisotropic model (-12.8%) better predicted the fracture loading compared to the isotropic model (+52.4%)
- Anisotropic model predicted longitudinal fracture patterns similar to experiments.
- Influence of the stem insertion and the mesh sensitivity has not been investigated.
- Anisotropic model resulted in a -31.8% difference on fracture force prediction compared to Femur 3R.
- In the near future insertion and mesh sensitivity analysis will be included.
- Study will be extended, including the other load cases.

QUESTIONS AND CONTACT

THANKS FOR YOUR ATTENTION

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