
PERIPROSTHETIC FRACTURE MODELLING USING A COMBINED FINITE ELEMENT – SMOOTH PARTICLE HYDRODYNAMIC METHOD

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Biomechanics**

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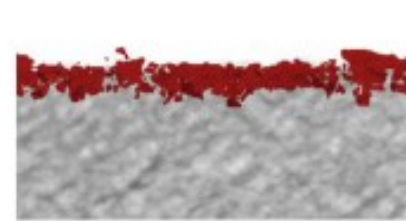


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- Third most common reason for revision surgeries (*Maier, 2015*)
- High rate of PFFs during the early postoperative (EP) period (*Abdel et al., 2016*)
- Computer models help to predict EP fractures
- Due to the lack of bone ingrowth in EP period the interface mechanics is decisive



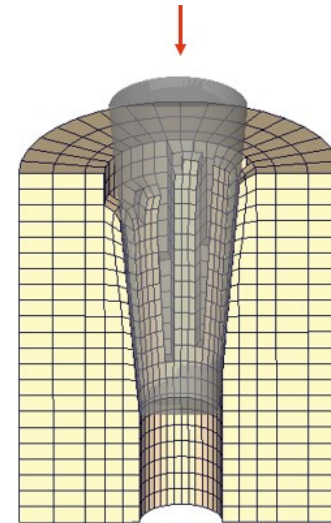
- Highly deformed trabecular bone transforms into bone debris.
- Previous studies use element erosion strategy (*Miles et al, 2015; Ovesy, 2020*).
- Element erosion cause unphysical material loss.



■ Bone Debris

Bone debris formations

(*Bätz et al., Clin. Biomech., 73: 234-240, 2020*).

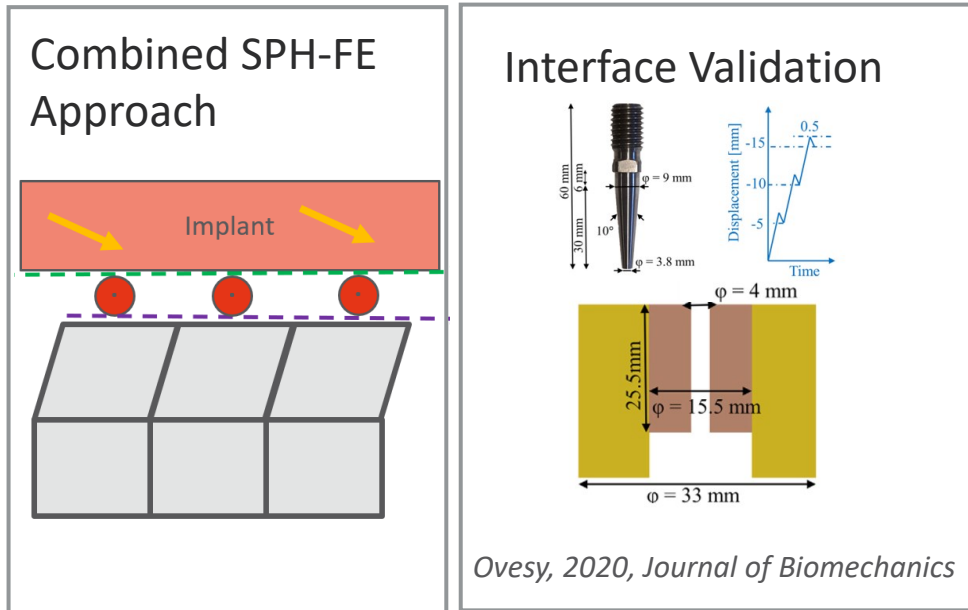


Element erosion

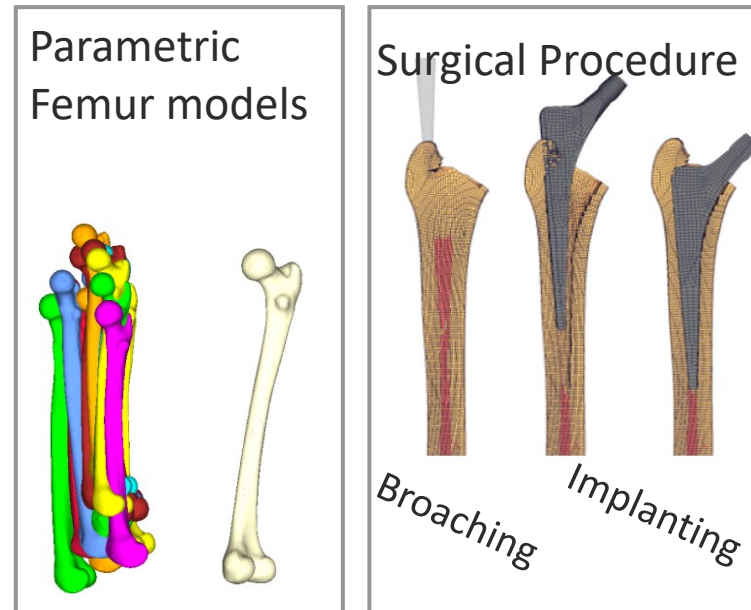
Aim:

Develop and validate a model to predict PPFs using a combined approach based on finite element (FE) and smoothed particle hydrodynamics (SPH) methods

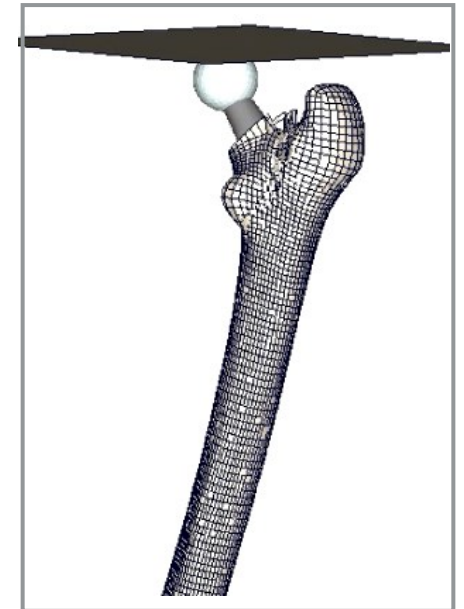
Interface Modeling



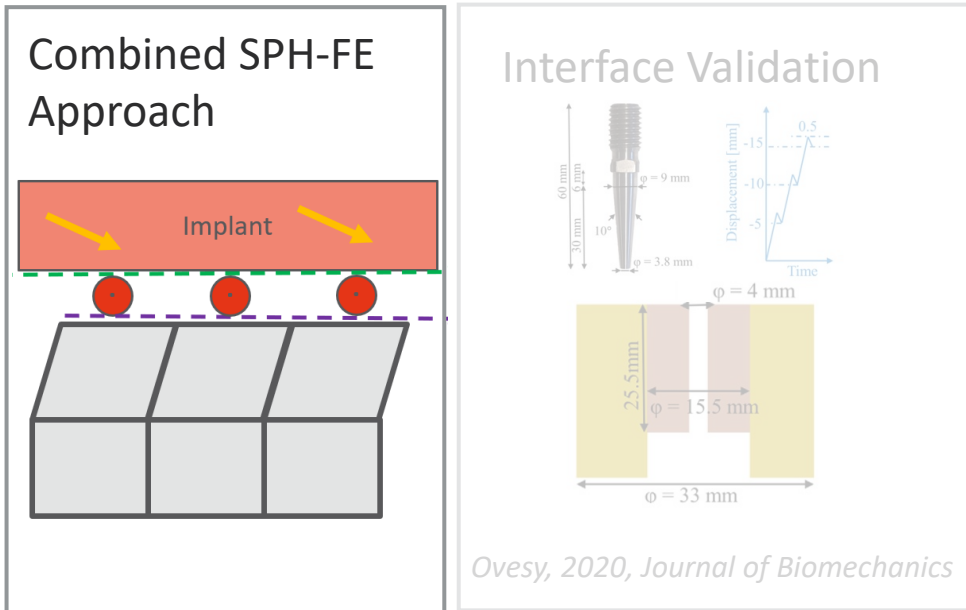
Implanted Femur



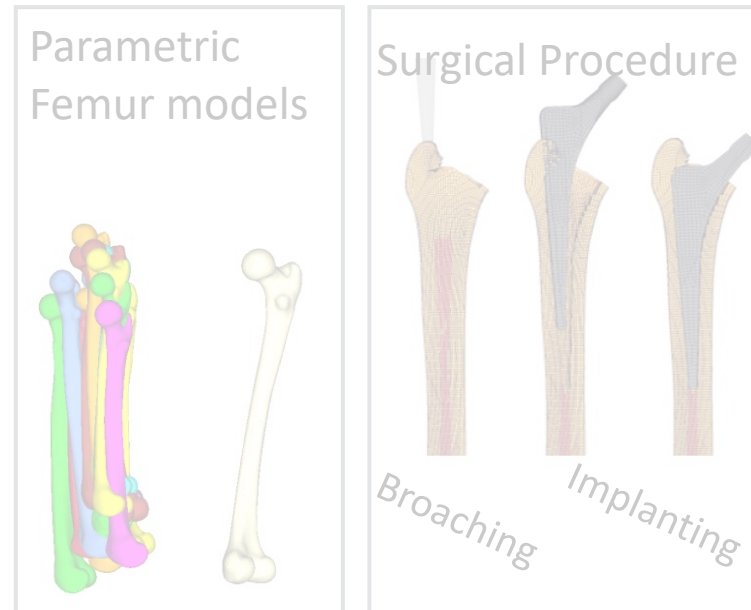
PPF Verification



Interface Modeling

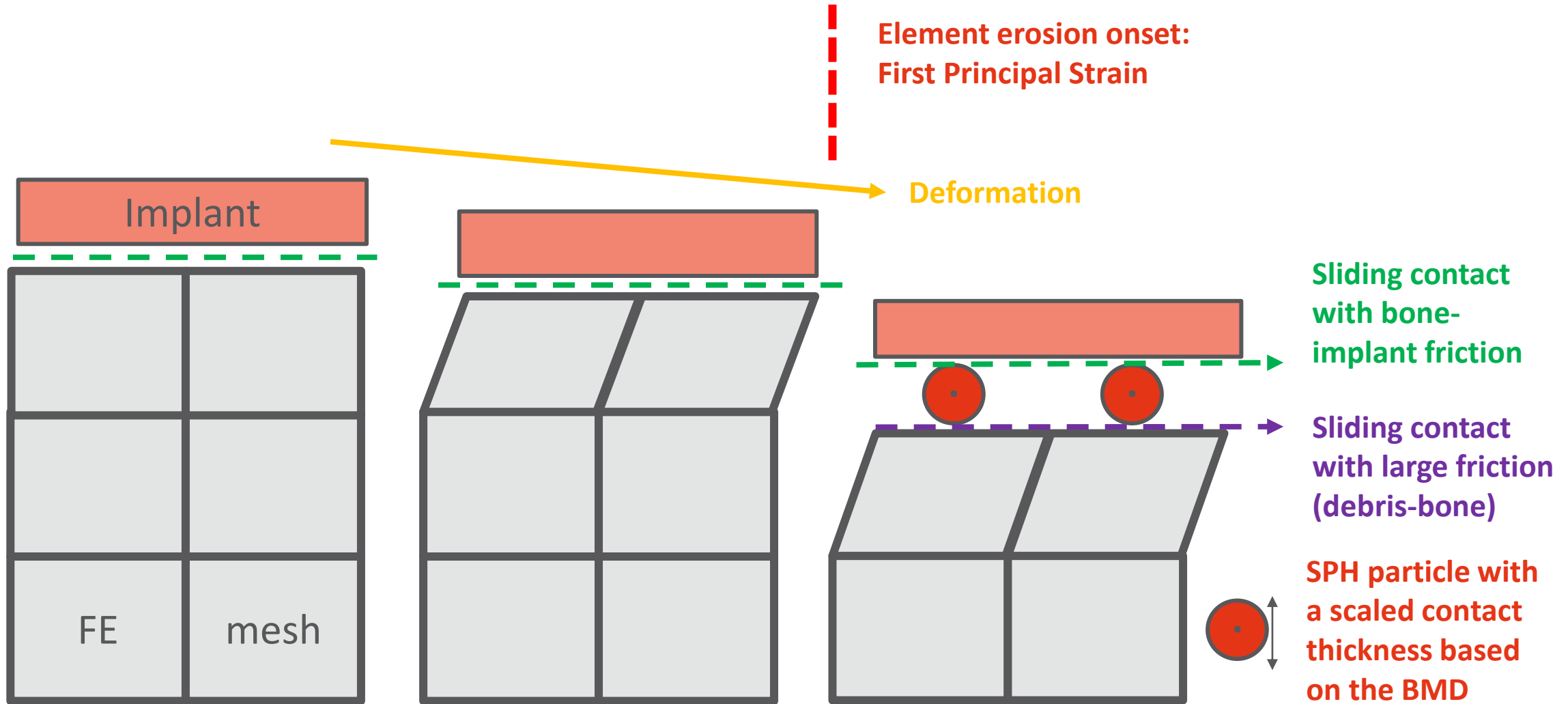
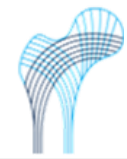


Implanted Femur

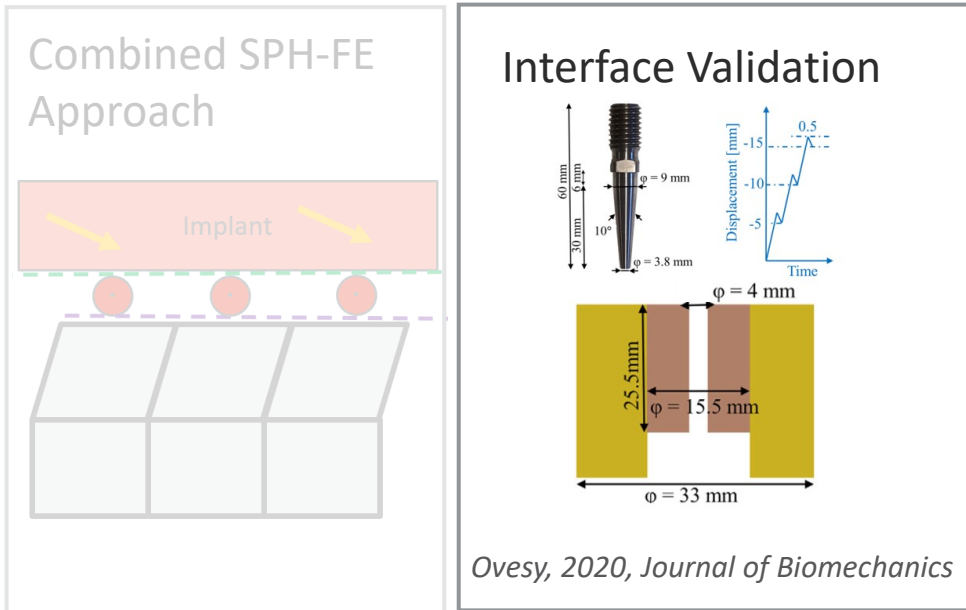


PPF Validation

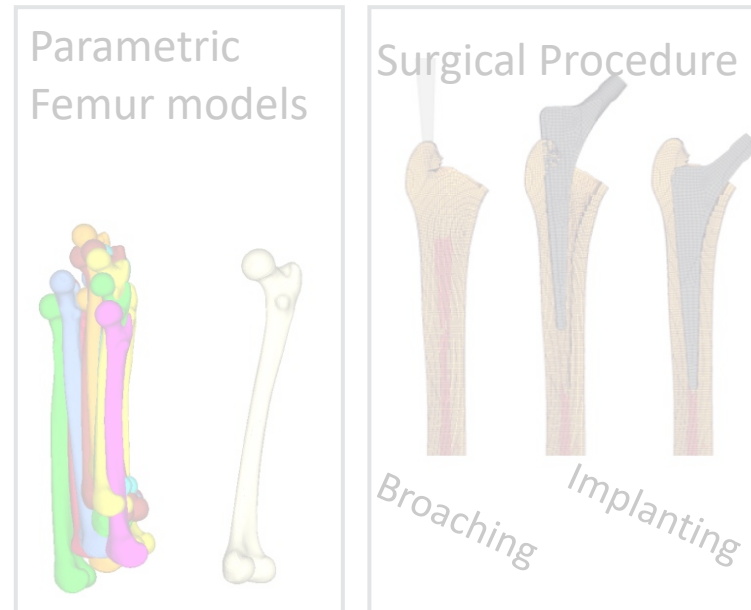




Interface Modeling



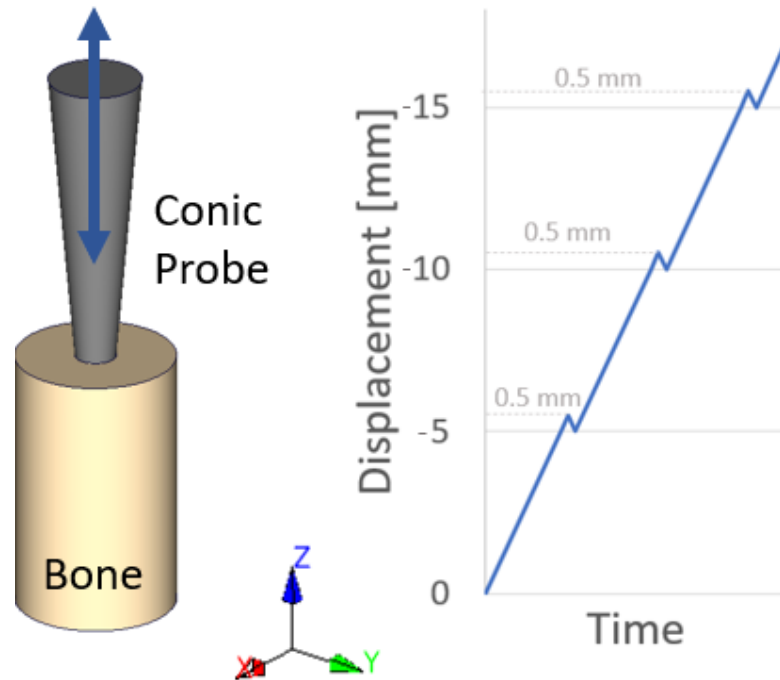
Implanted Femur



PPF Verification



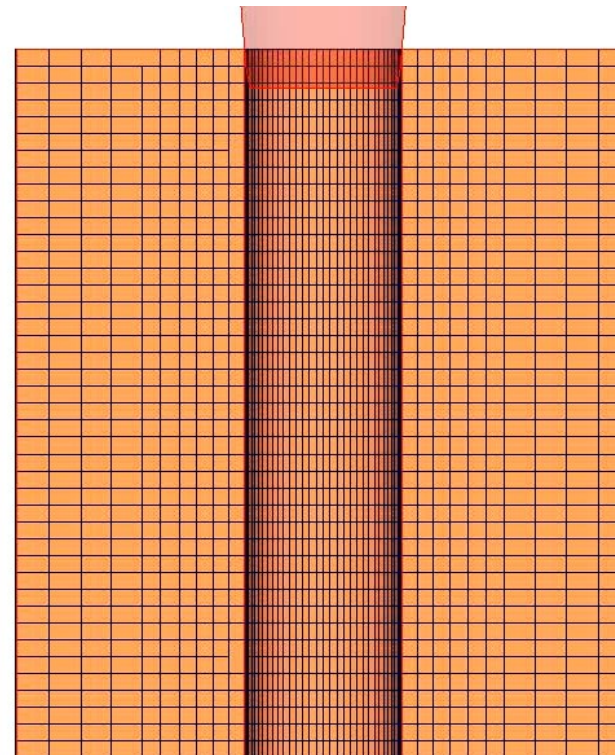
Simplified stem insertion experiment presented by Ovesy (2020)



BV/TV: %29.9

$\mu = 0.20$ (Damm et al., 2015; Grant et al., 2007)

Generated SPH particles with eroded elements



Investigated Parameters

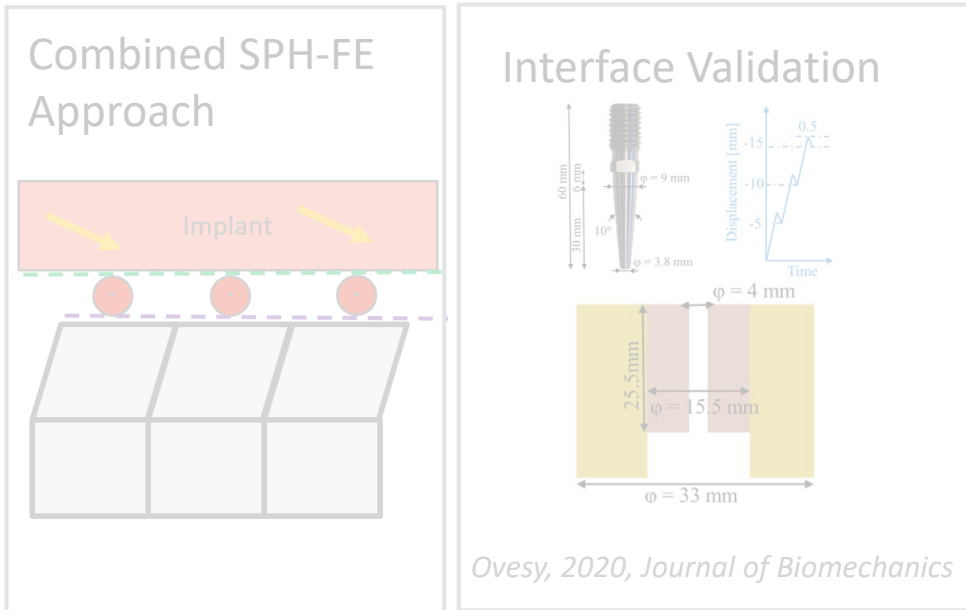
Erosion onset:

0.07, 0.13, 0.19 (Jungmann, 2011)

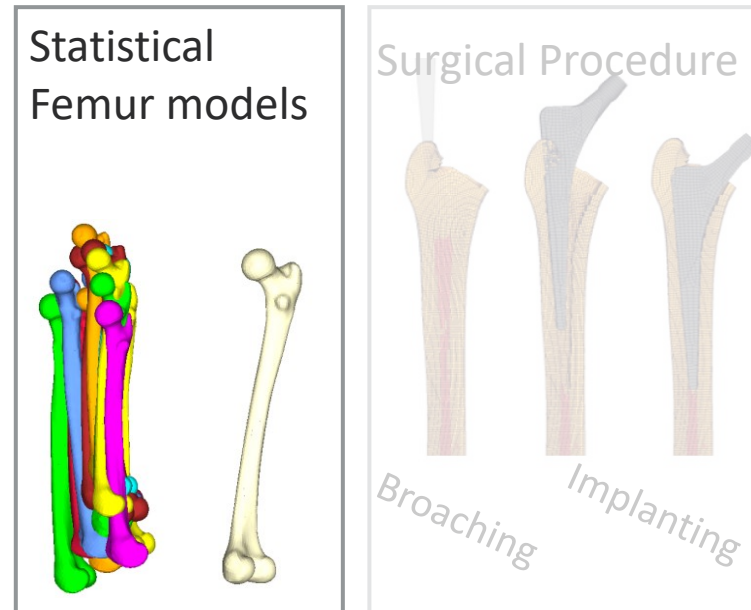
SPH resolution:

None, 1, and 4 SPH particles per eroded element

Interface Modeling



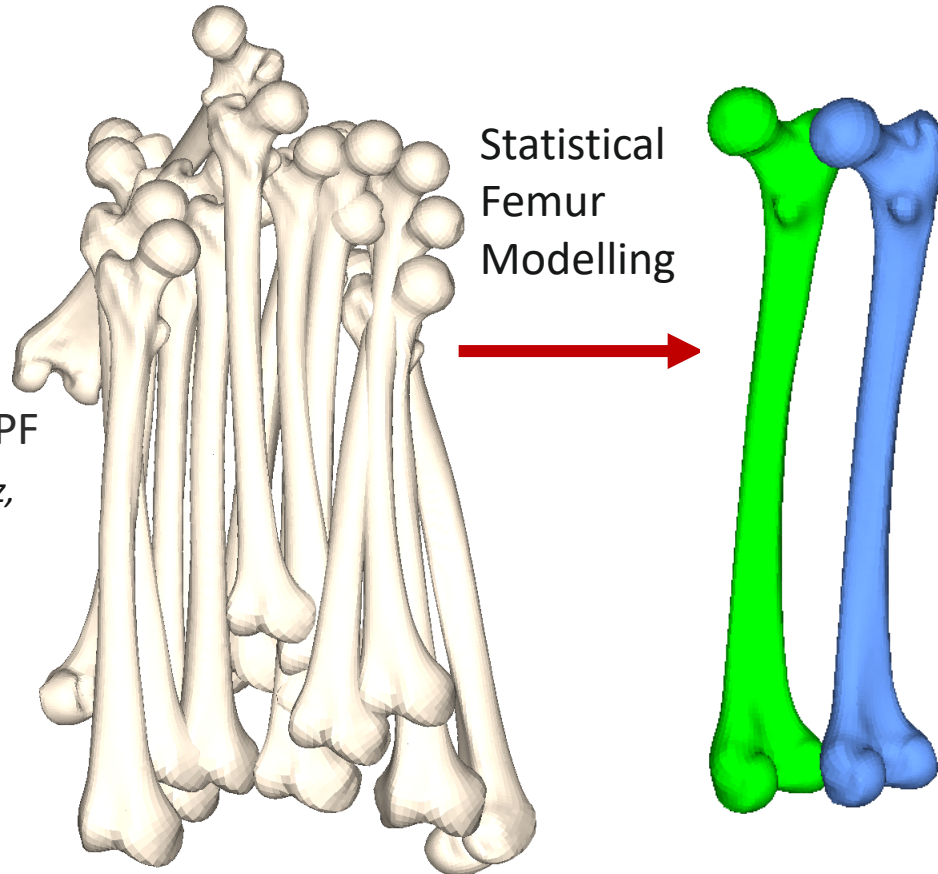
Implanted Femur



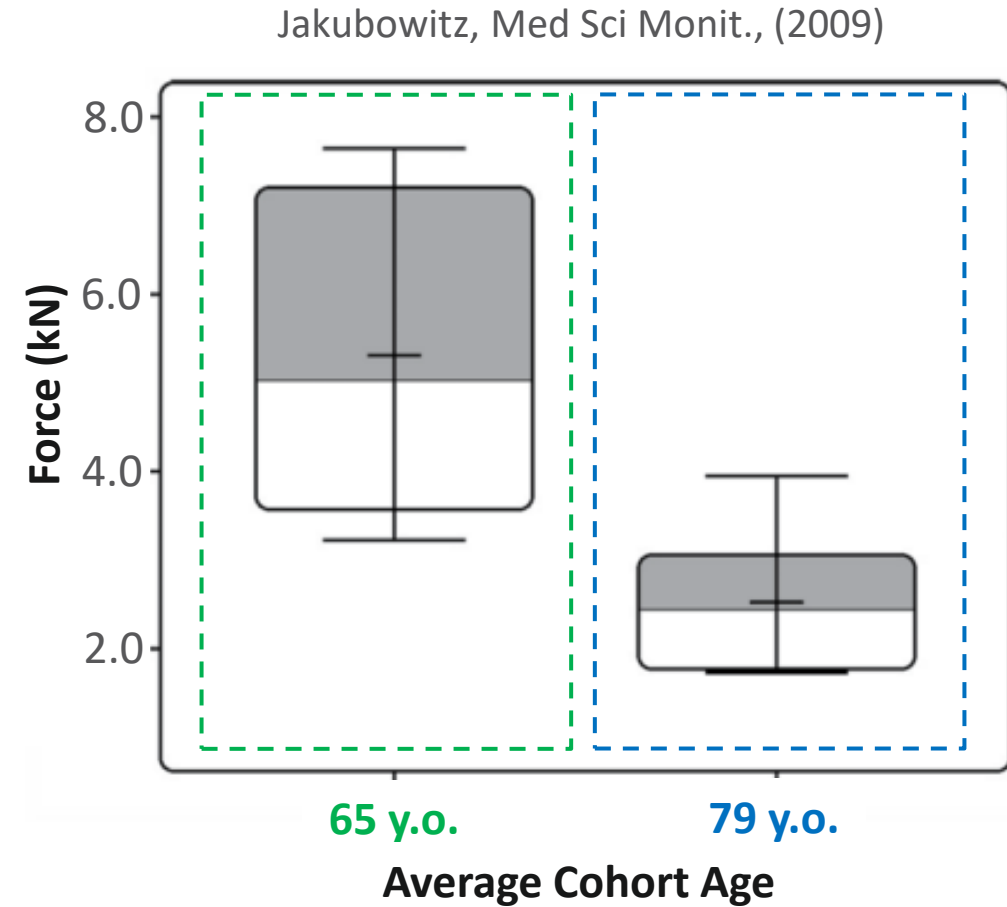
PPF Validation



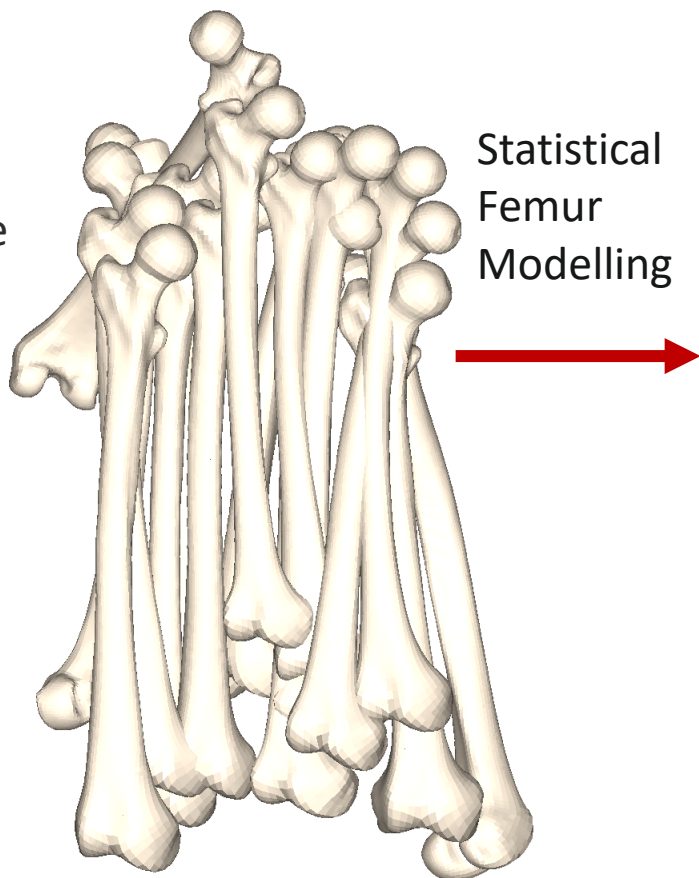
- Female femurs
- Age: 65 and 79 y.o.
- Cohort averages for PPF experiments (*Jakubowitz, 2009*)



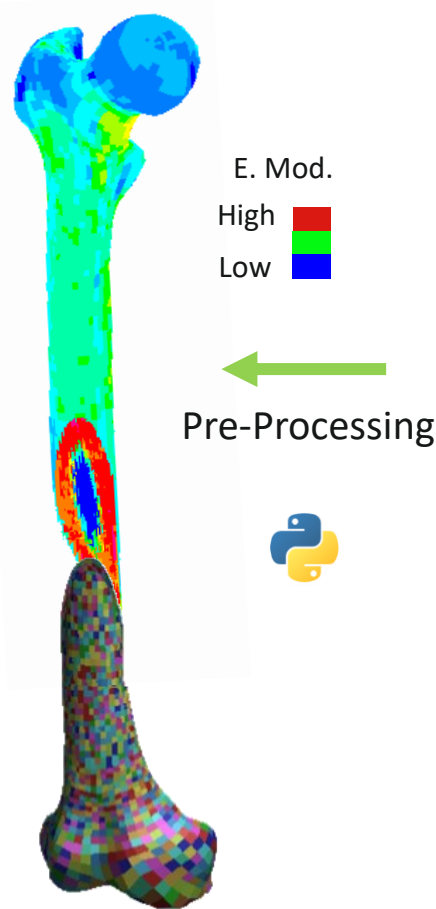
N:18





- Asymmetric Crushable foam -> Trabecular bone
- Asymmetric metal plasticity -> Cortical bone

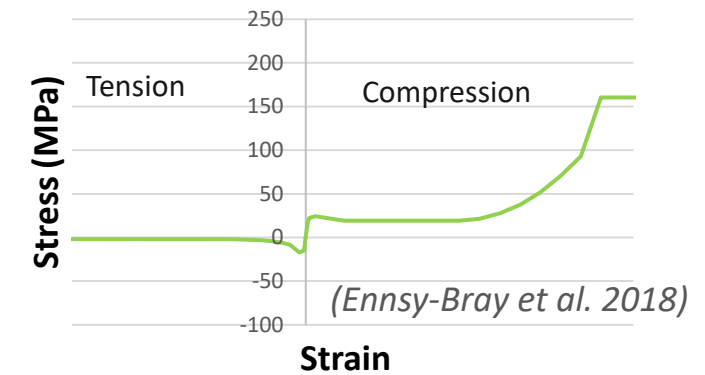


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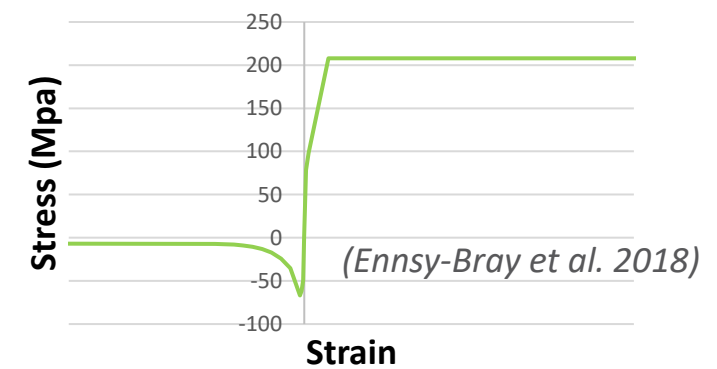


E. Mod.
High 
Low 

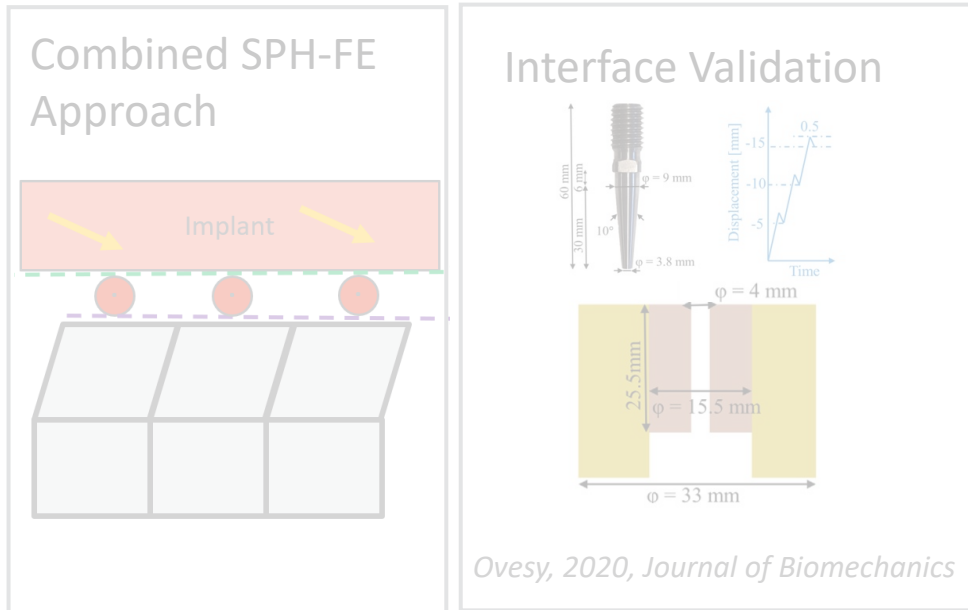
Trabecular Bone: Crushable Foam



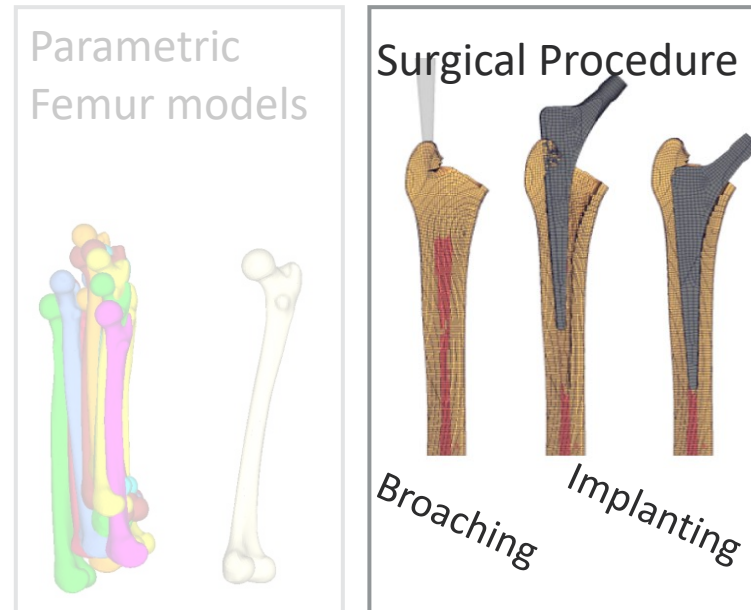
Cortical Bone: Metal Plasticity



Interface Modeling

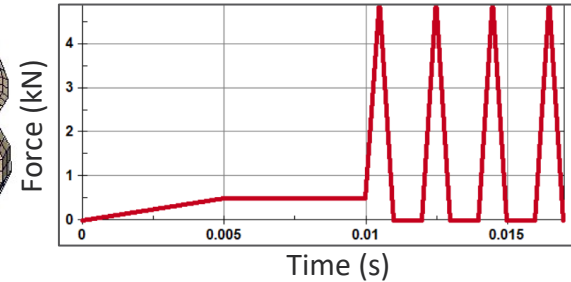
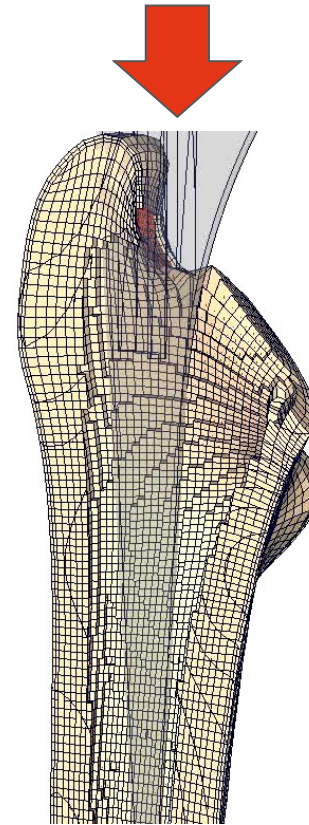
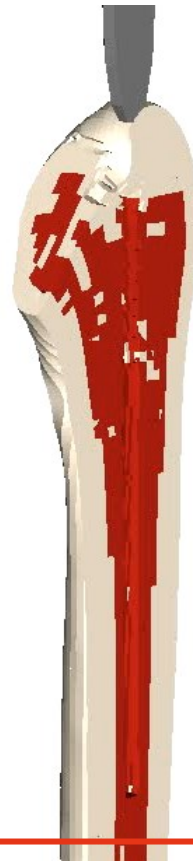
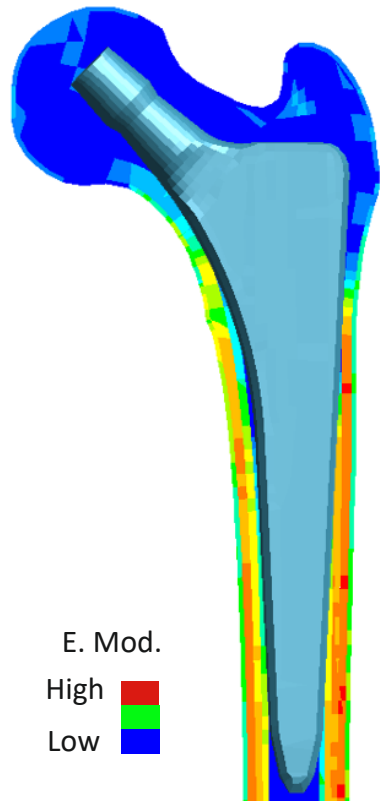


Implanted Femur



PPF Validation



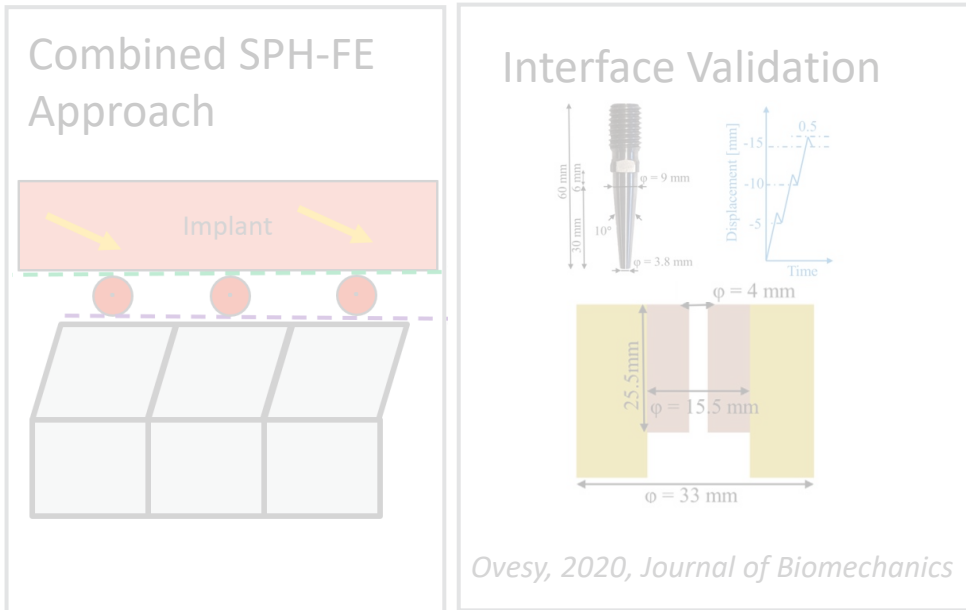


Stems were positioned considering the cortical fitting and the hip center of rotation.

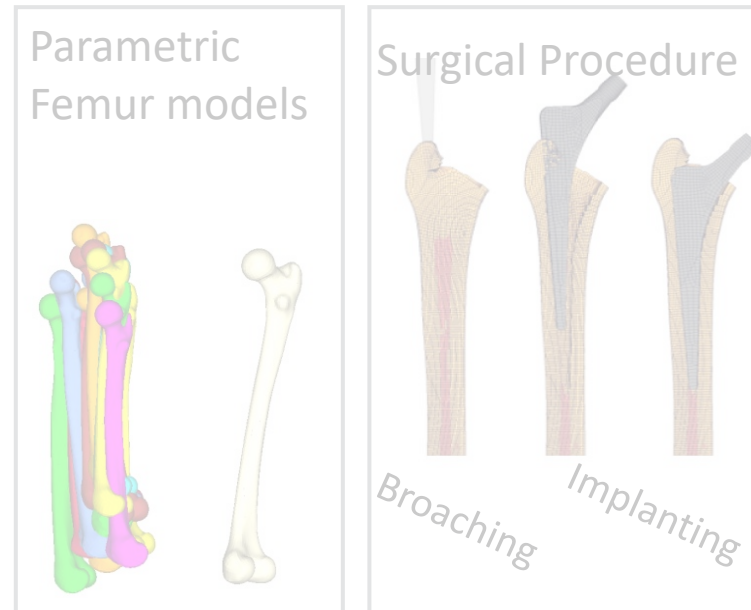
A free-moving broach interacts with the mechanical properties. (Bätz, 2019)

Stems were inserted applying the hammering forces from literature. (Tijou, 2018)

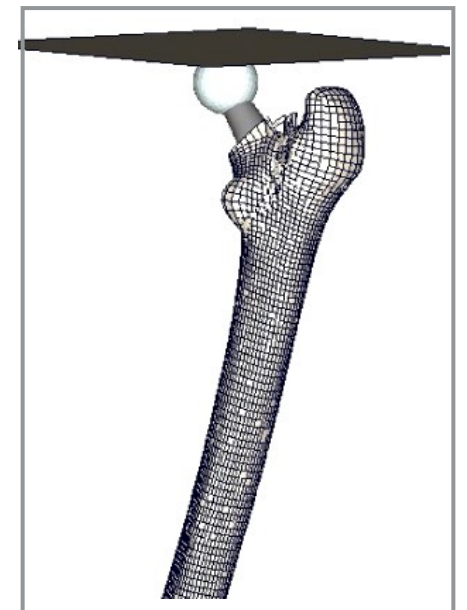
Interface Modeling

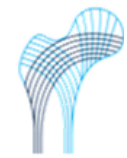


Implanted Femur



PPF Verification





CLS-Spotorno:

Rough blasted micro porous surface
(Aldinger et al., 2009)

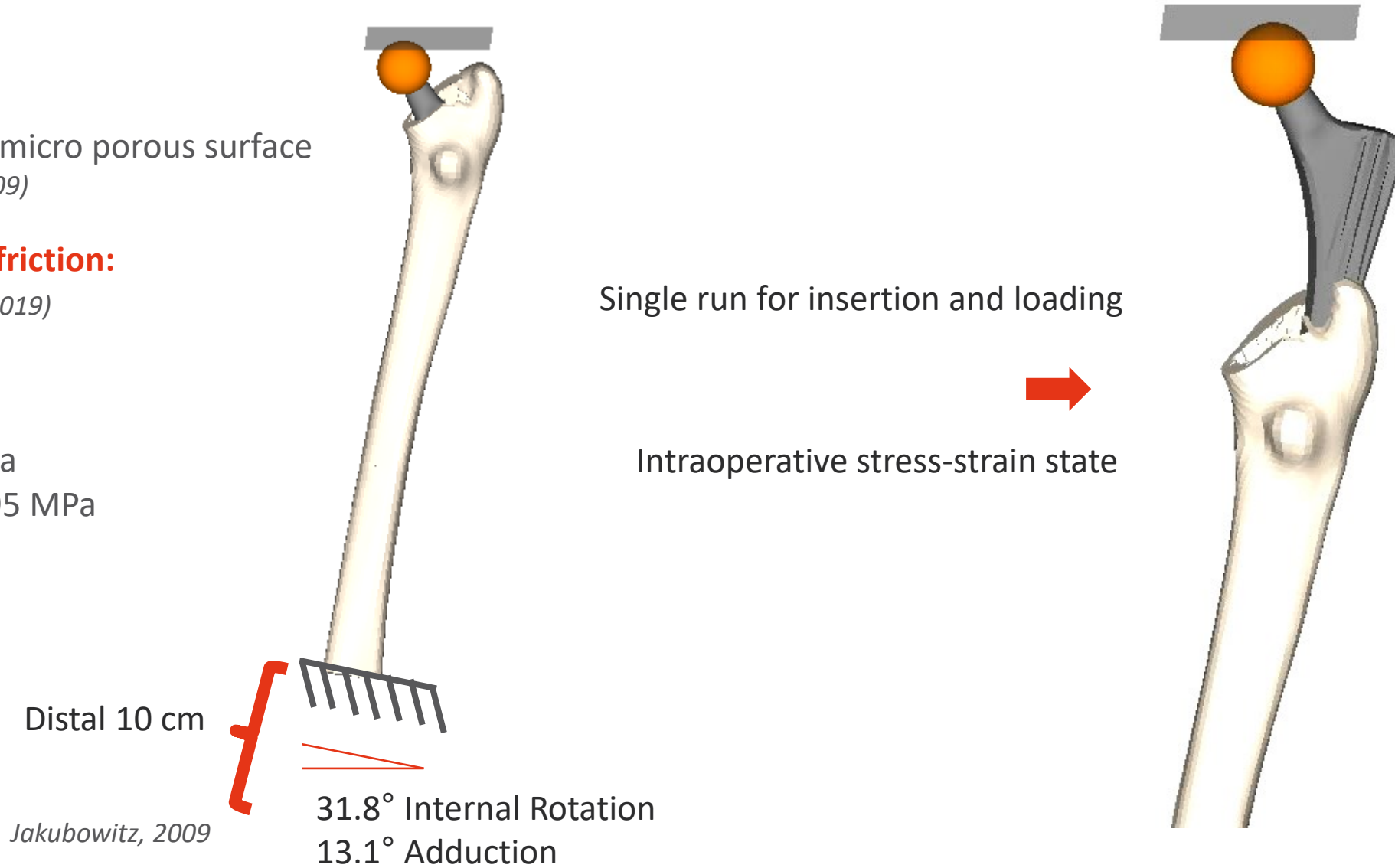
Bone-Implant friction:

$\mu = 0.45$ (Gao, 2019)

Titanium:

E Mod.: 100GPa

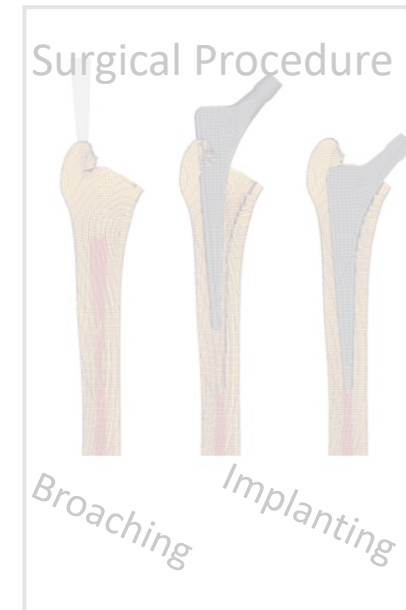
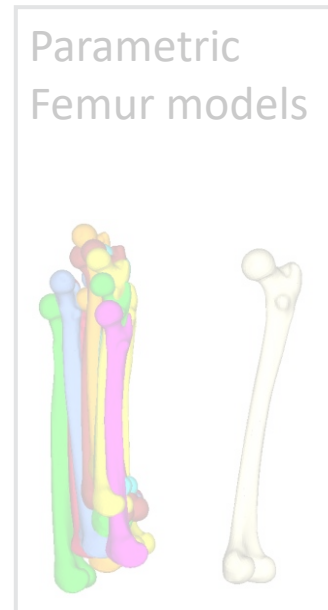
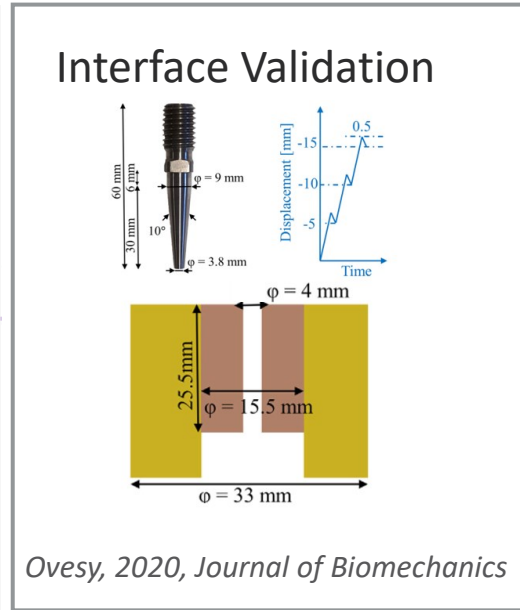
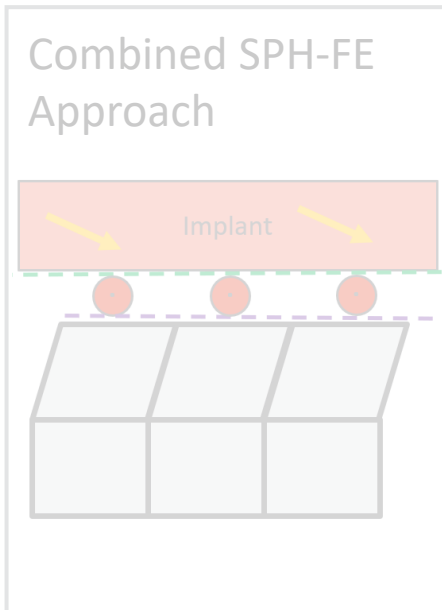
Yield Stress: 795 MPa



Interface Modeling Results

Implanted Femur

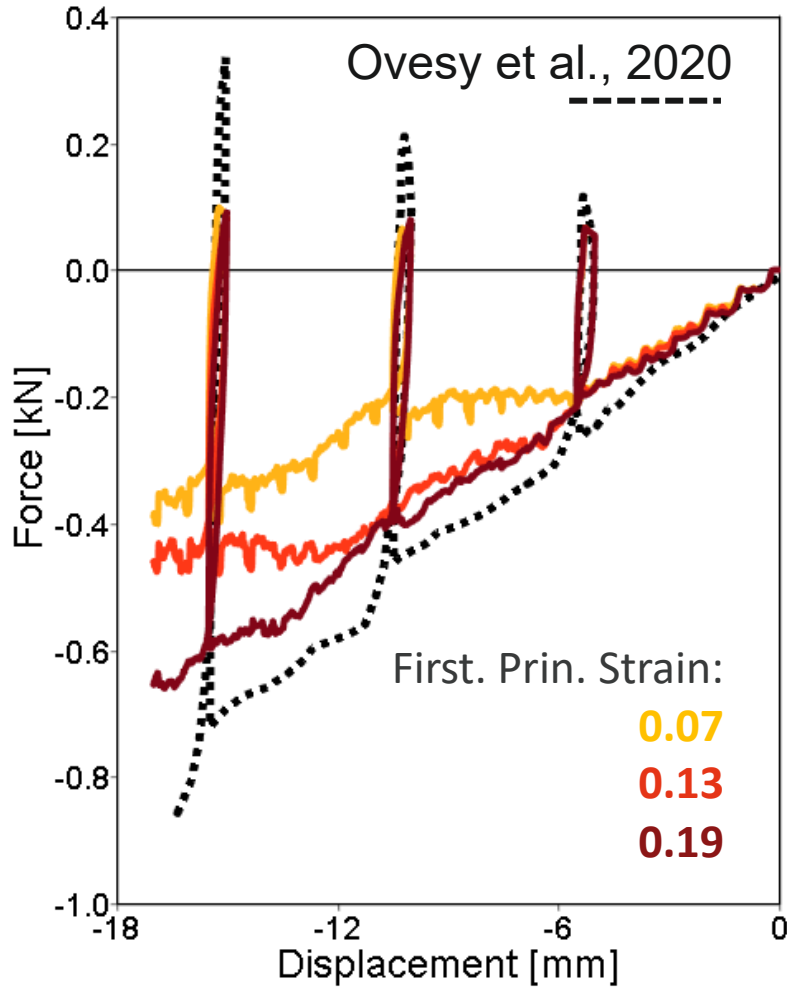
PPF Verification



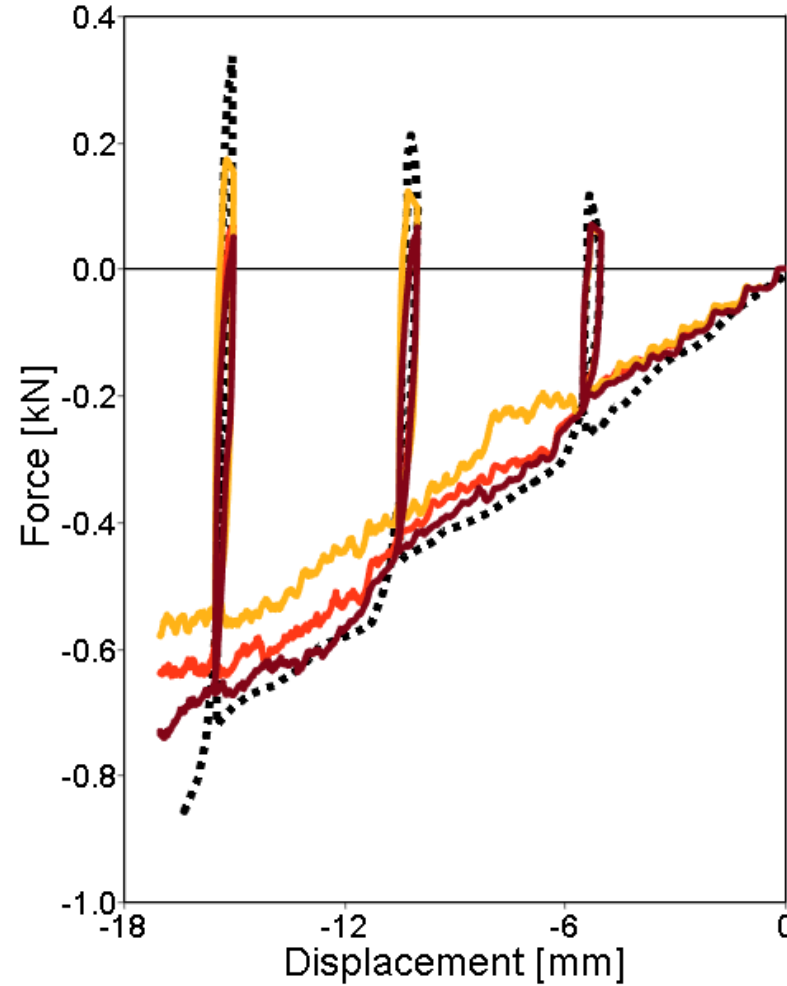
RESULTS - INTERFACE MODELING



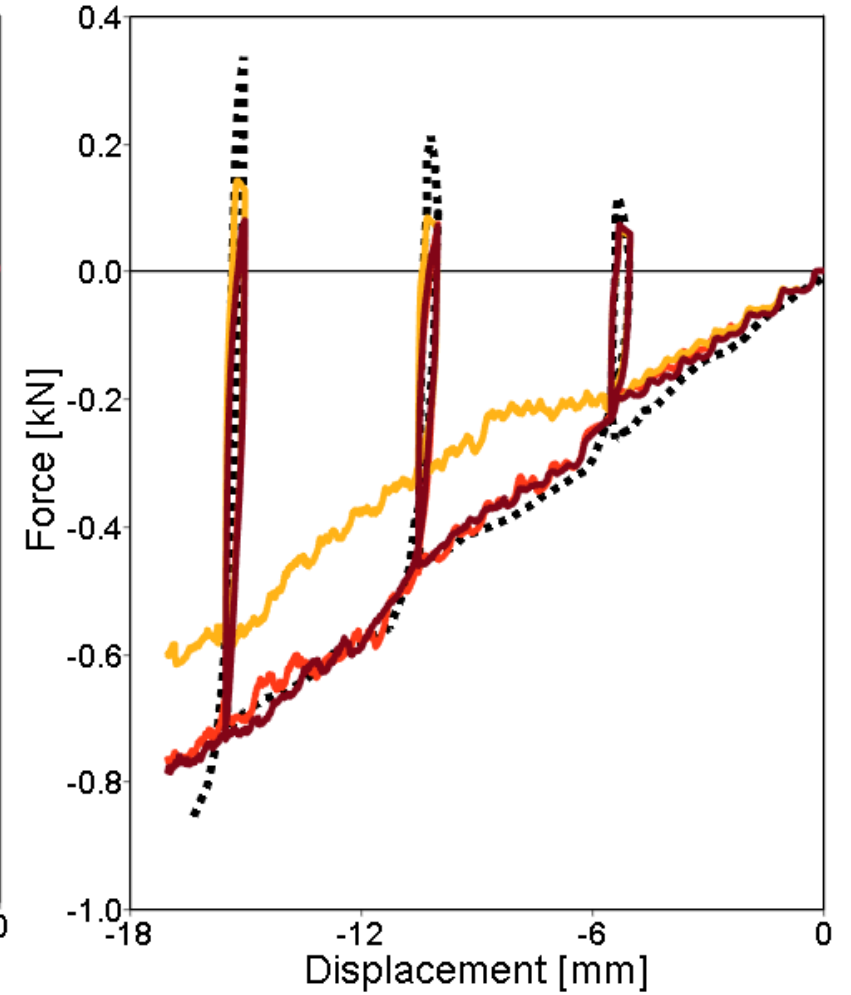
No SPH



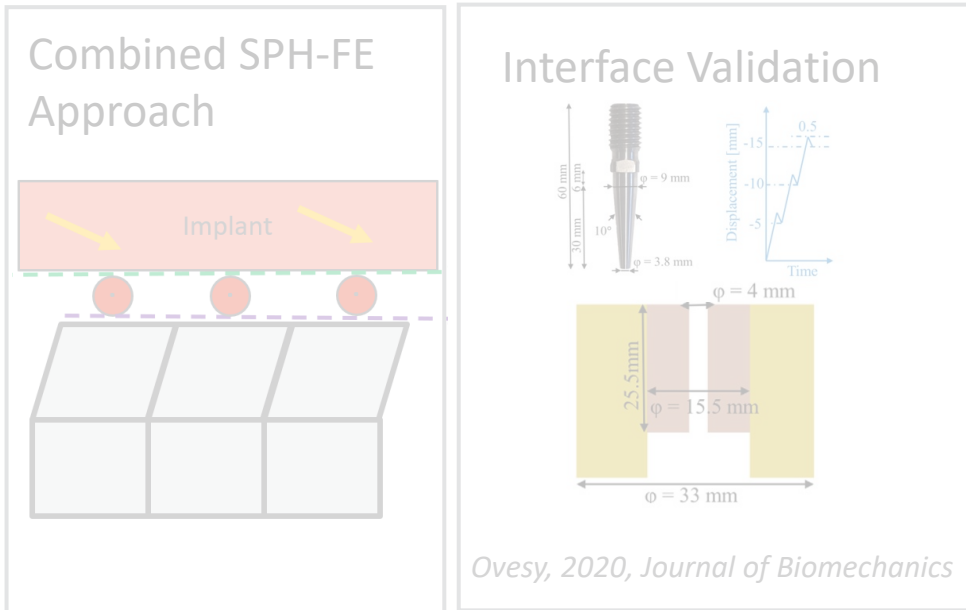
SPH pro Elem.: 1



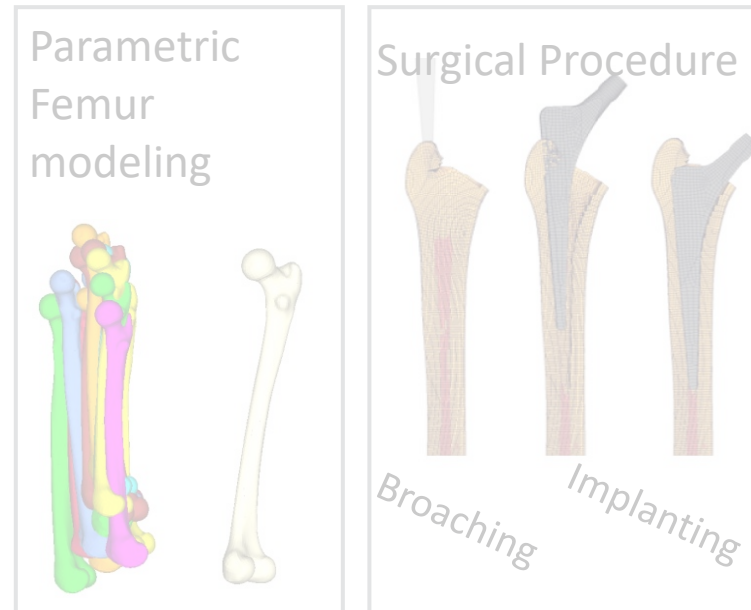
SPH pro Elem.: 4



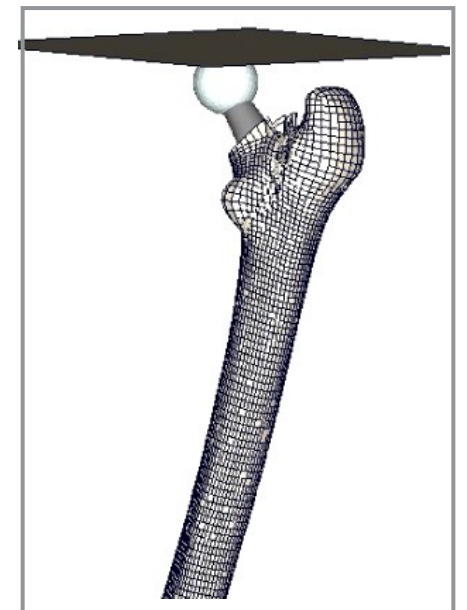
Interface Modeling Results



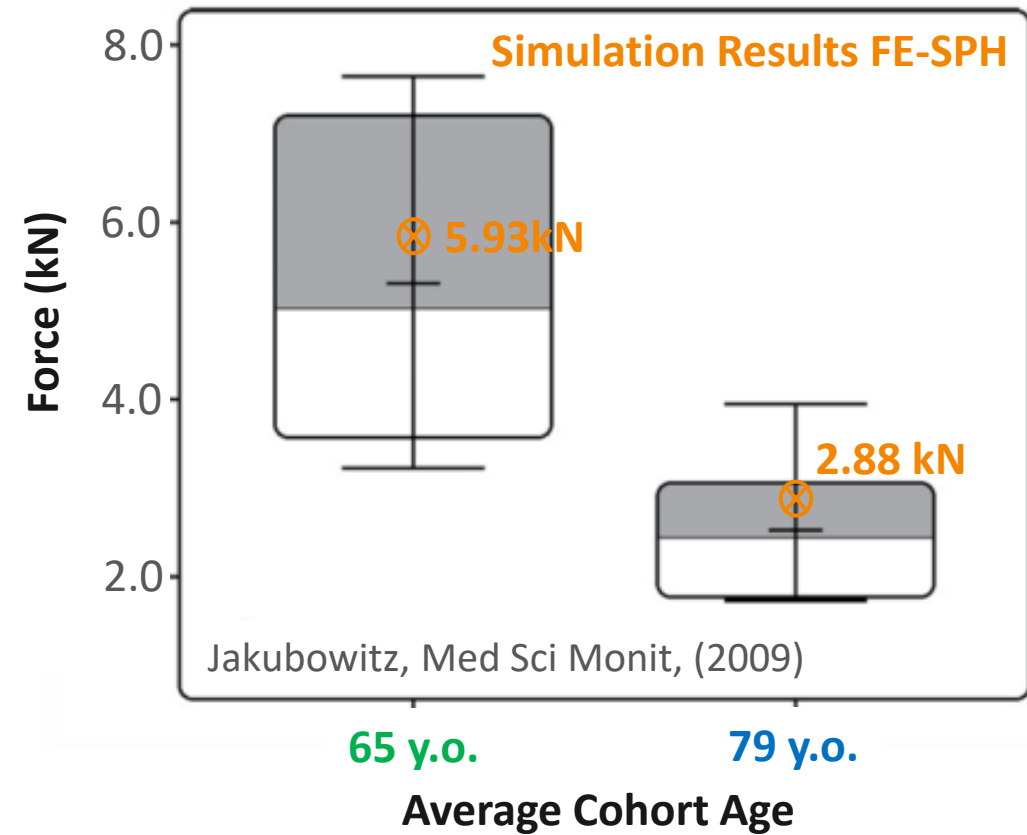
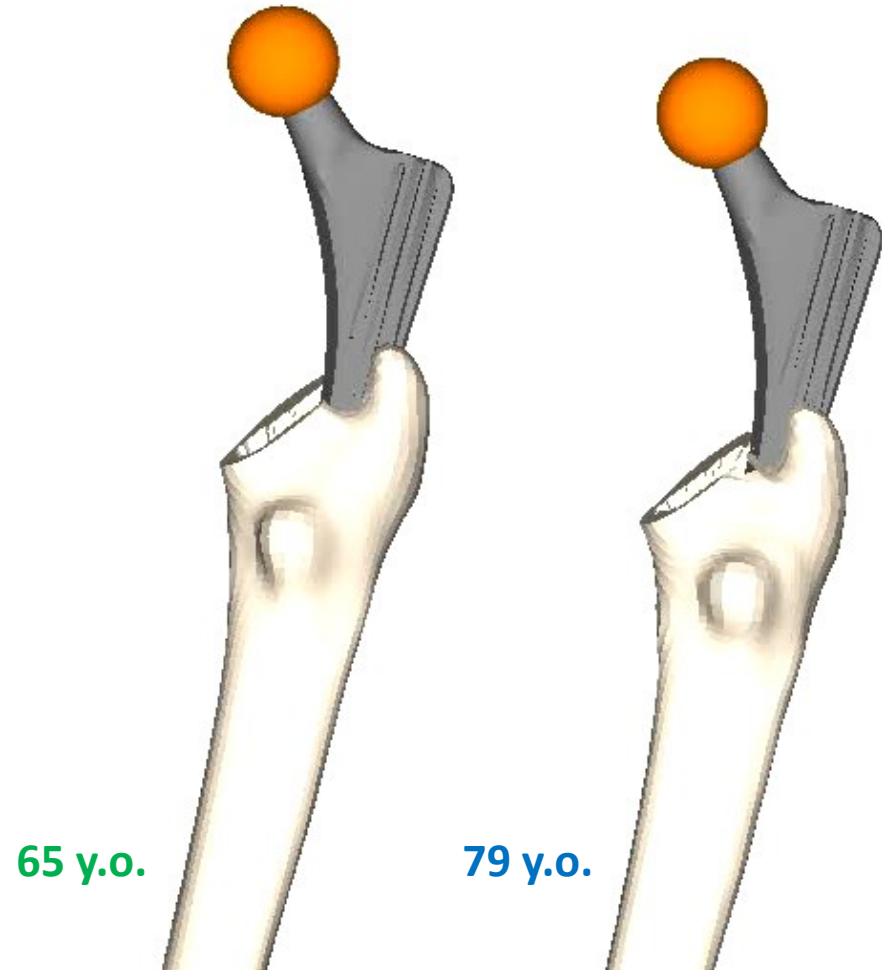
Implanted Femur



PPF Verification Results



RESULTS - PPF VERIFICATION



Age	Experiments (sd.)	Simulation	Error (%)
65 y.o.	5.02 (1.82) kN	5.93 kN	11.98%
79 y.o.	2.42 (0.64) kN	2.88 kN	14.53%

- ➔ • Combined SPH-FE approach can represent the stem insertion experiment realistically
- ➔ • Reduced sensitivity on element erosion criteria using the combined SPH-FE approach
- ➔ • PPF simulations provided comparable results with the experiments
- ➔ • Pull out forces were predicted with large error and bone debris mechanics require further research
- ➔ • In near future models will be validated based on ex-vivo experiments
- ➔ • In future developed models can be used to optimize stem designs and the intraoperative procedures which might help to migrate PFFs

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QUESTIONS AND CONTACT

THANKS FOR YOUR ATTENTION

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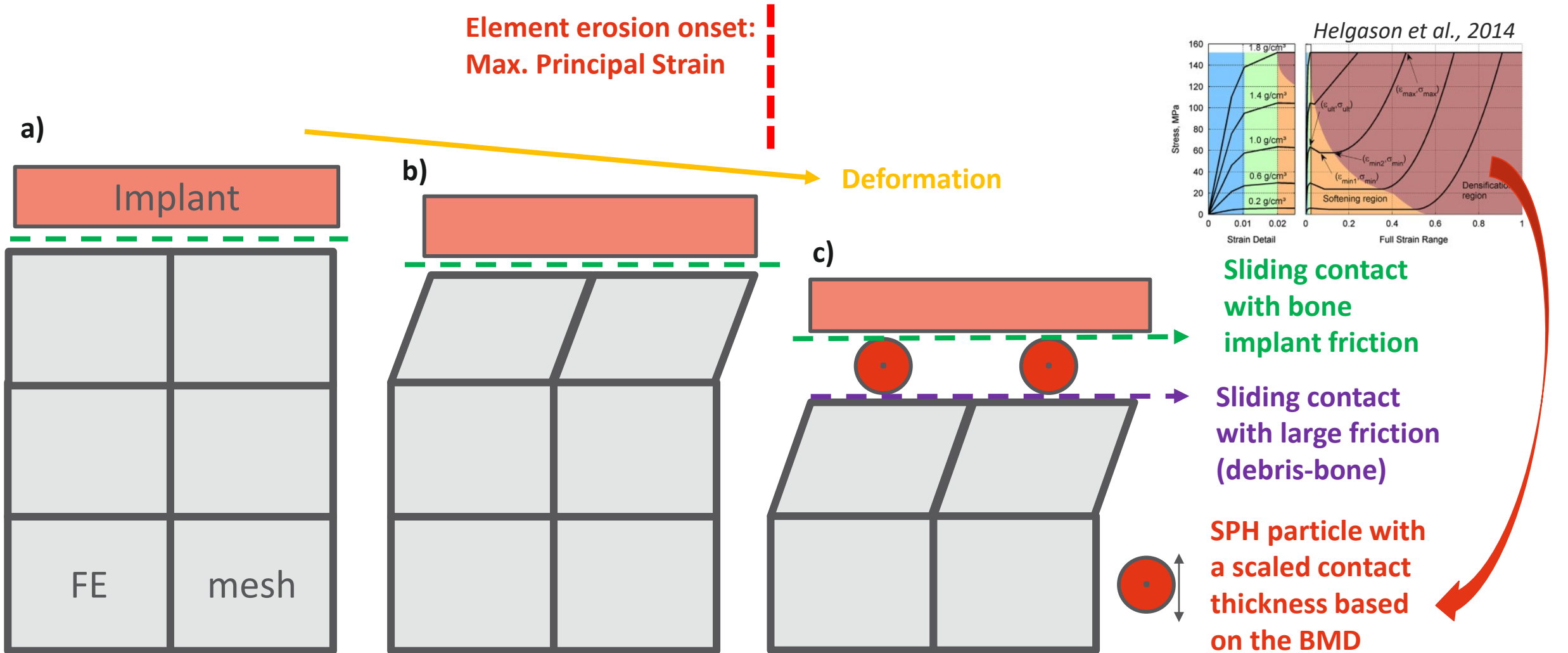
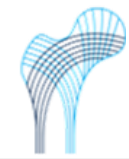


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METHODS – COMBINED SPH-FE APPROACH

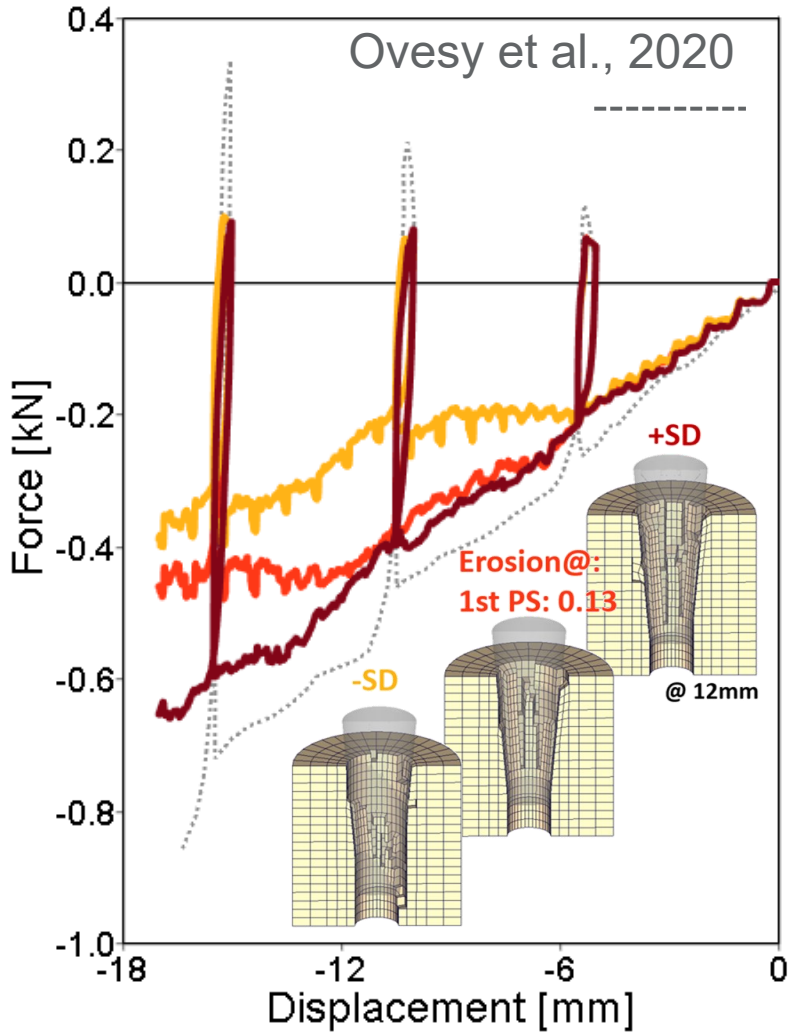


RESULTS - INTERFACE MODELING

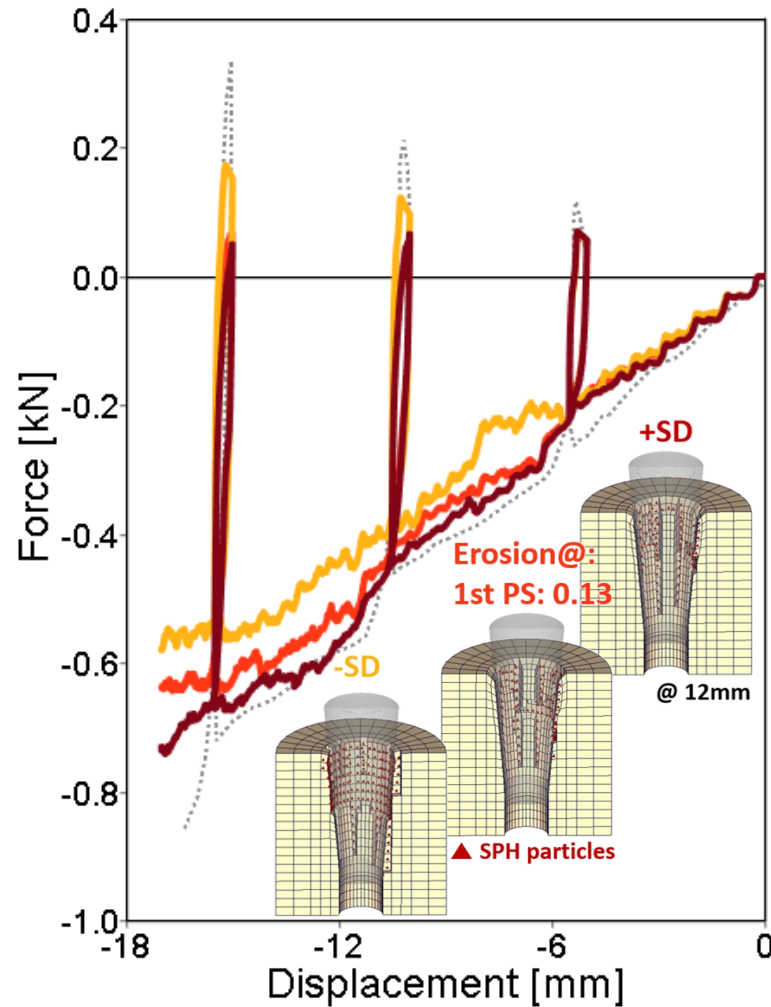


No SPH

Ovesy et al., 2020



SPH pro Elem.: 1



SPH pro Elem.: 4

