ASSESSMENT OF STEM DESIGN ON EARLY POSTOPERATIVE PERIPROSTHETIC FEMUR FRACTURES

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IMMC

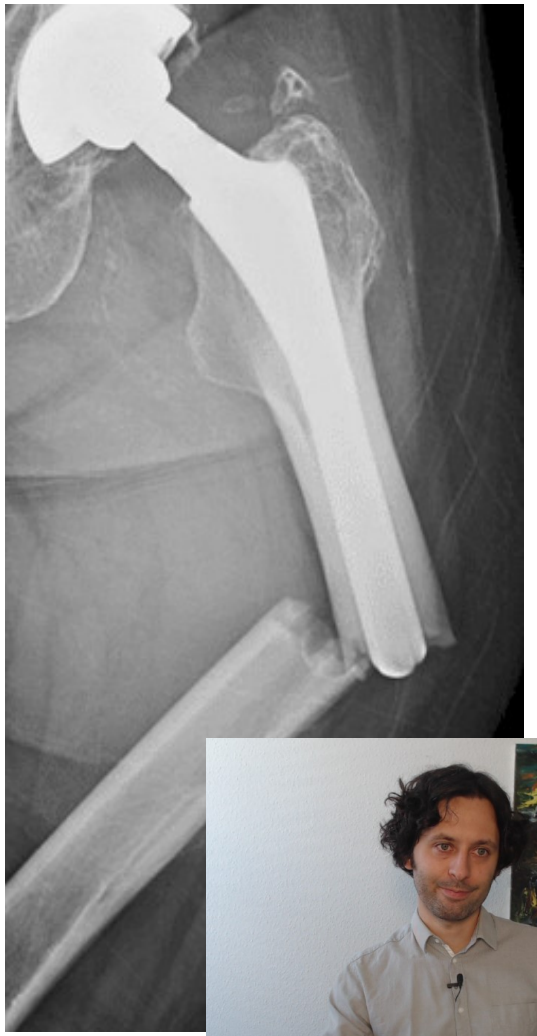
Impact Mechanics and Material Characterization Group

INTRODUCTION

- Periprosthetic femur fractures (PFFs) are the third most common reason for revision surgeries *(Maier, 2015)*.
- Mostly due to low energy falls and physiological load cases like stumbling *(Carli, et al., 2017).*
- Increased intraoperative and early postoperative PFF rate with cementless double wedge compared to tapered stem designs *(Carli, et al., 2017).*

Aim:

- To compare the early postoperative PFF behavior of cementless double wedge and tapered stem designs using simulation models.



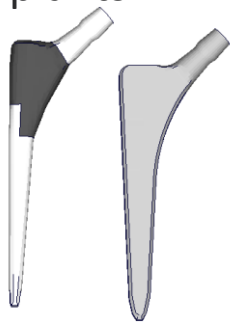
Contact: oezguer.cebeci@iatmbh.com

METHODS

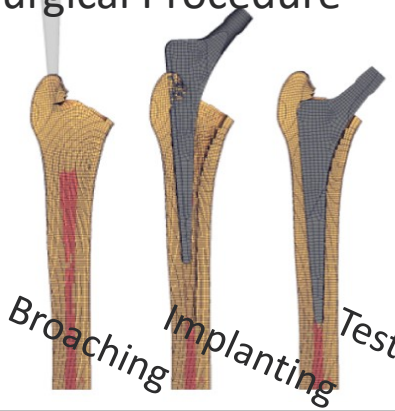
Implanted Femur

Femur Model

Generic Implants

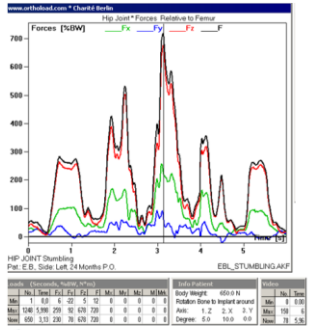


Surgical Procedure

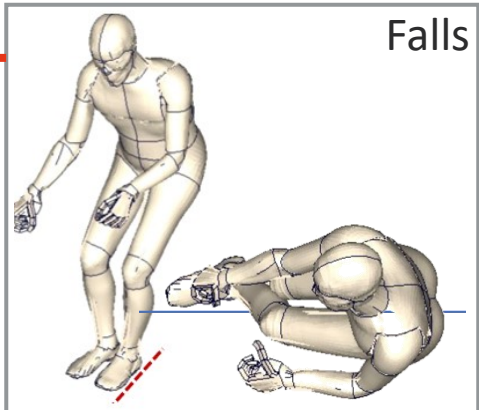


Loading

Stumbling

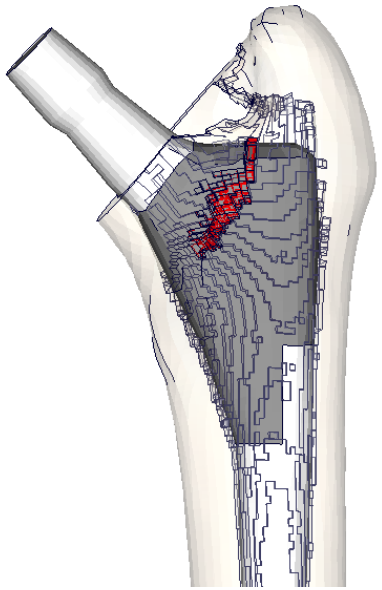


Falls



Fracture Assessments

Intraoperative



Postoperative

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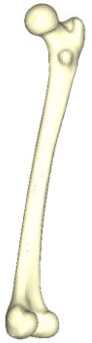
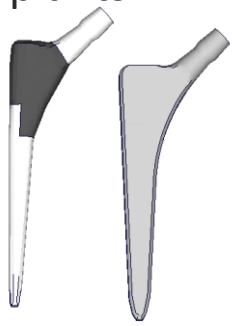
METHODS

Implanted Femur

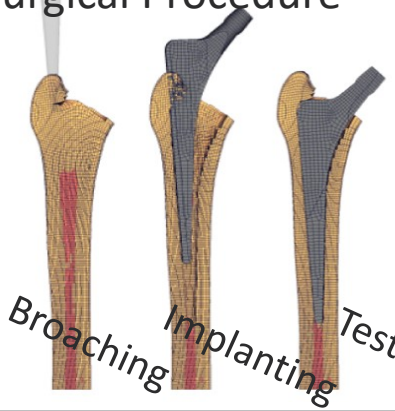
Femur Model



Generic Implants



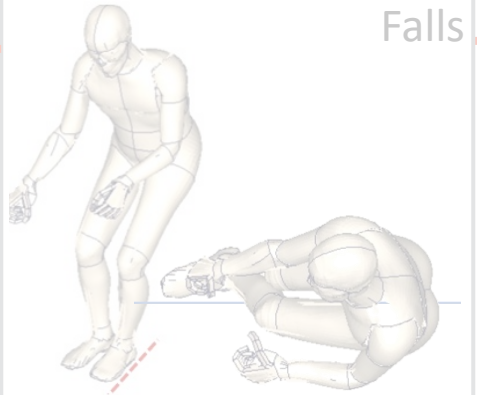
Surgical Procedure



Loading

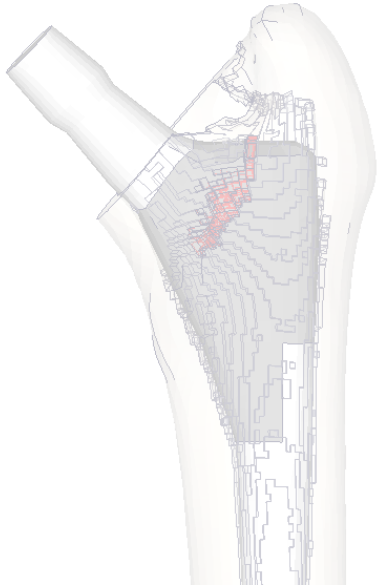
Stumbling

Falls



Fracture Assessments

Intraoperative



Postoperative

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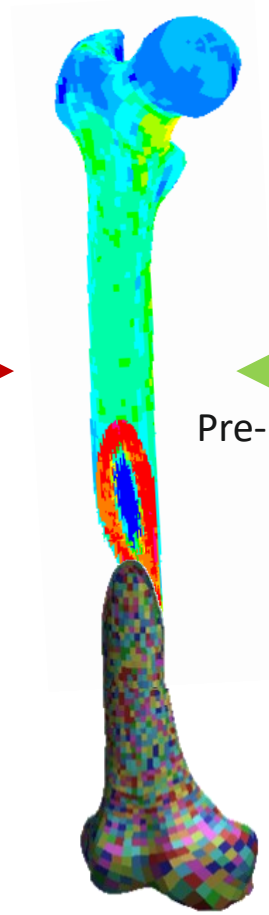
METHODS – FEMUR MODELS

- Female femur
- Age: 75, Stature: 154cm, BMI: 21
- Asymmetric Crushable foam -> Trabecular bone
- Asymmetric metal plasticity -> Cortical bone

N:18

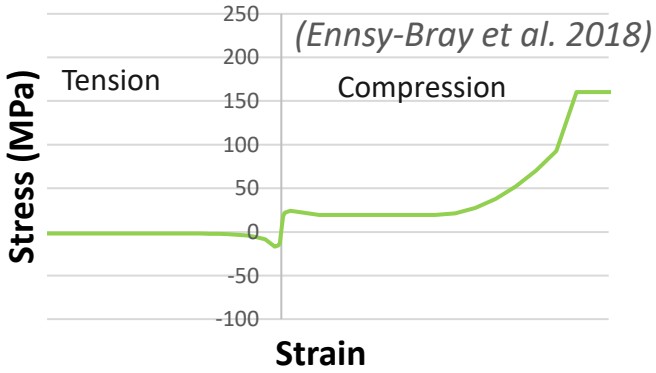
Statistical Femur Modelling



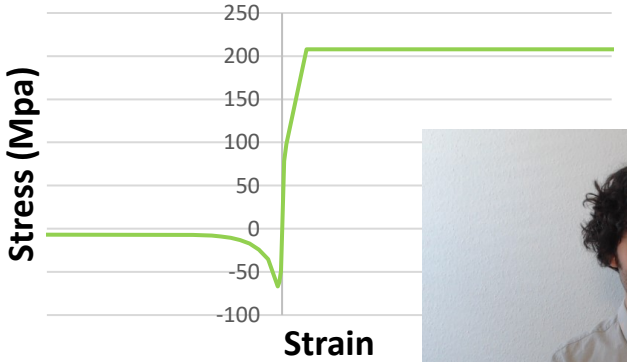
E [Mpa]

Pre-Processing

Trabecular Bone: Mat_Fu_Chang_Foam



Cortical Bone - Mat_Plasticity_Comp._Tens.



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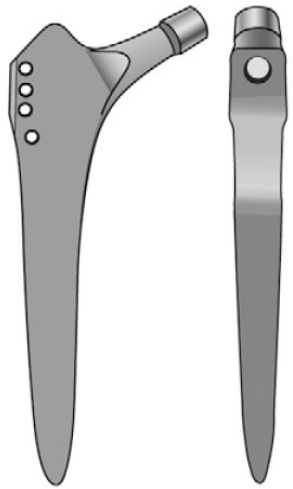
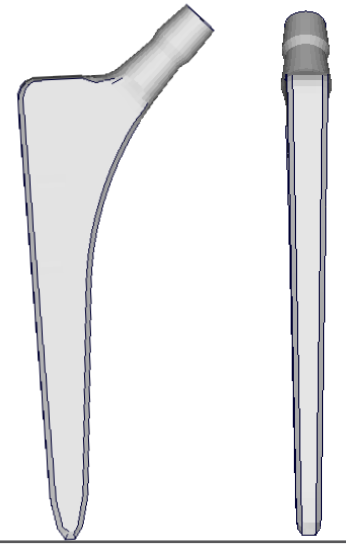
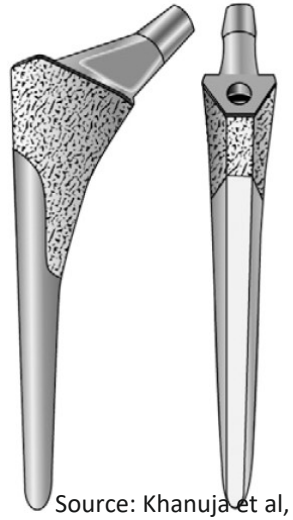
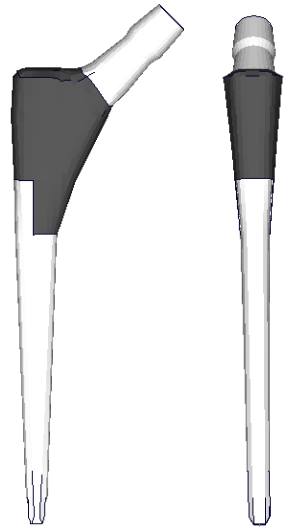
METHODS – GENERIC IMPLANTS

		Generic Description	Example	Generic Designs
Tapered	• Long, consistent taper in both the medial-lateral and the anterior-posterior plane • Metaphyseal-diaphyseal fixation • TiAl6Nb7 • Grit-blasted surface (Friction constant of 0.45) (Gao, 2019)	 Source: Khanuja et al, 2011	 Source: ALLOCLASSIC HIP SYSTEM, Surgical Procedure	
Double Wedge	• Proximal cortical contact in anterior-posterior and medial-lateral planes • TiAl6Nb7 • Polished surface and rough proximal coating (Friction Constants of 0.15 and 0.65)(Gao, 2019)	 Source: Khanuja et al, 2011	 Source: Trabecular Metal Primary Hip Prosthesis Surgical Technique	

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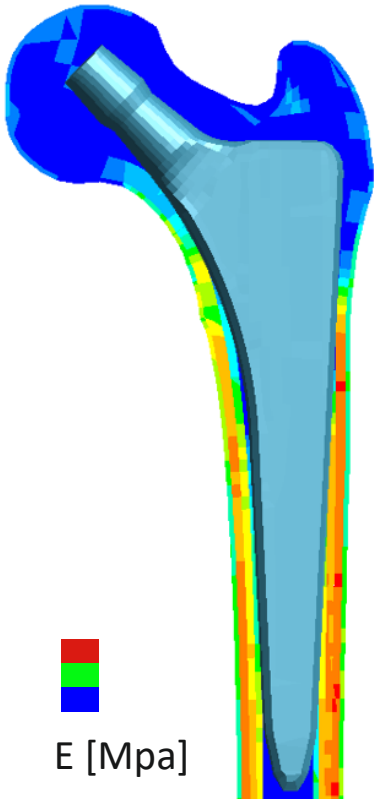
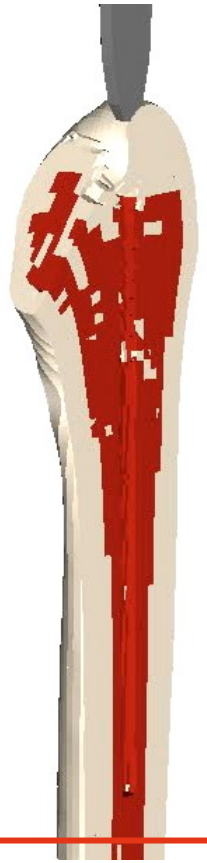
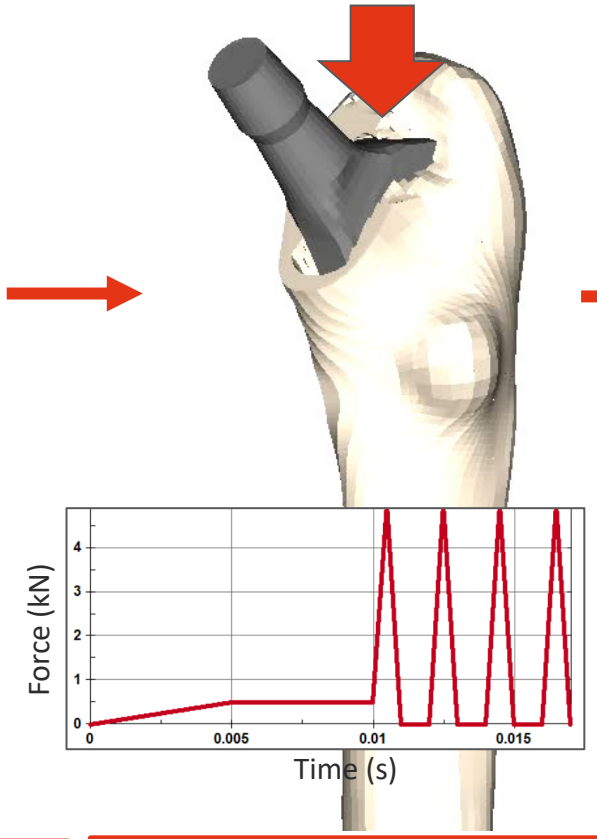
METHODS – VIRTUAL IMPLANTING



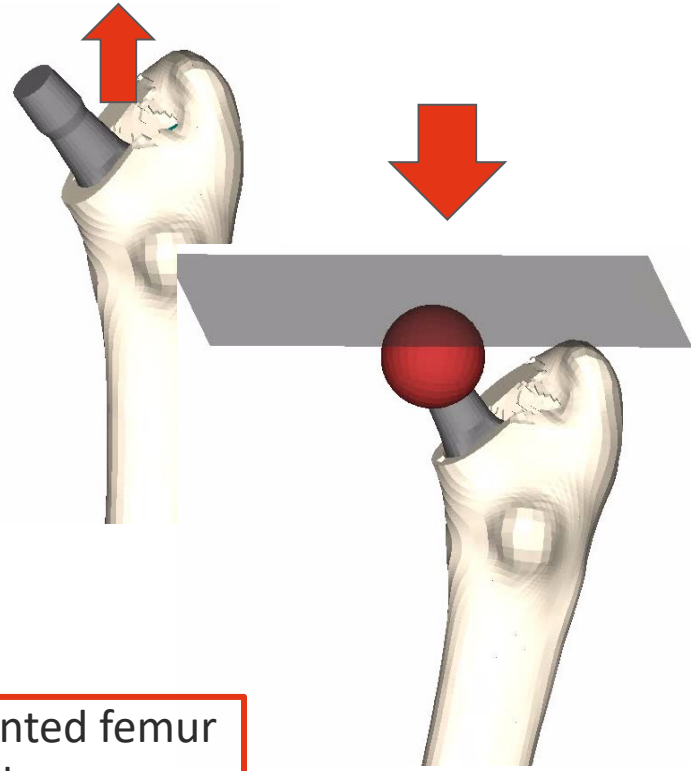
Stems were positioned considering the cortical fitting and the hip center of rotation.



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



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



Implanted femur models were compared with the literature in pullout and axial compression load cases.
(Jakubowitz, 2009)

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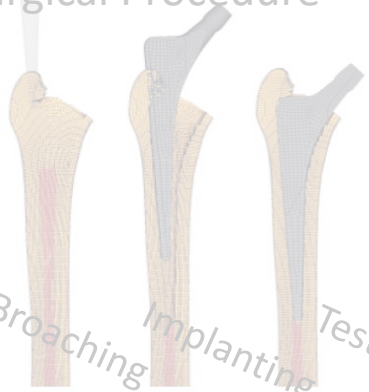
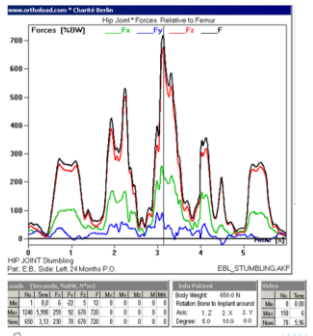
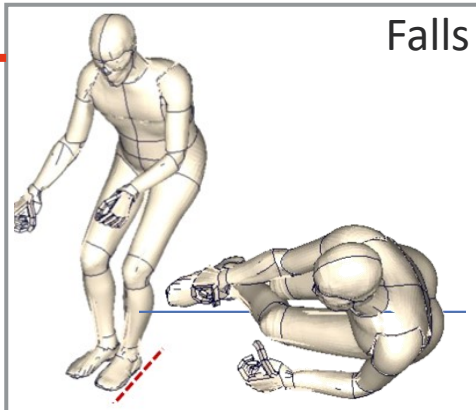


Loading

Stumbling

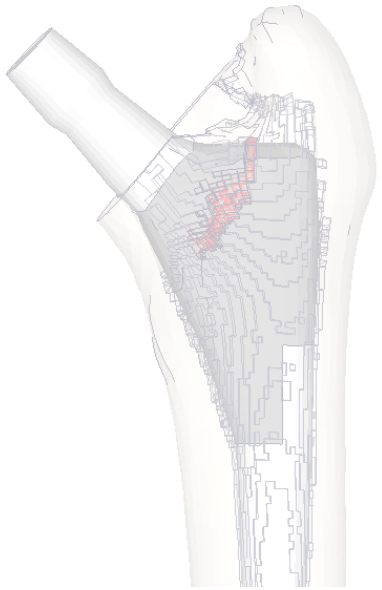


Falls



Fracture Assessments

Intraoperative



Postoperative

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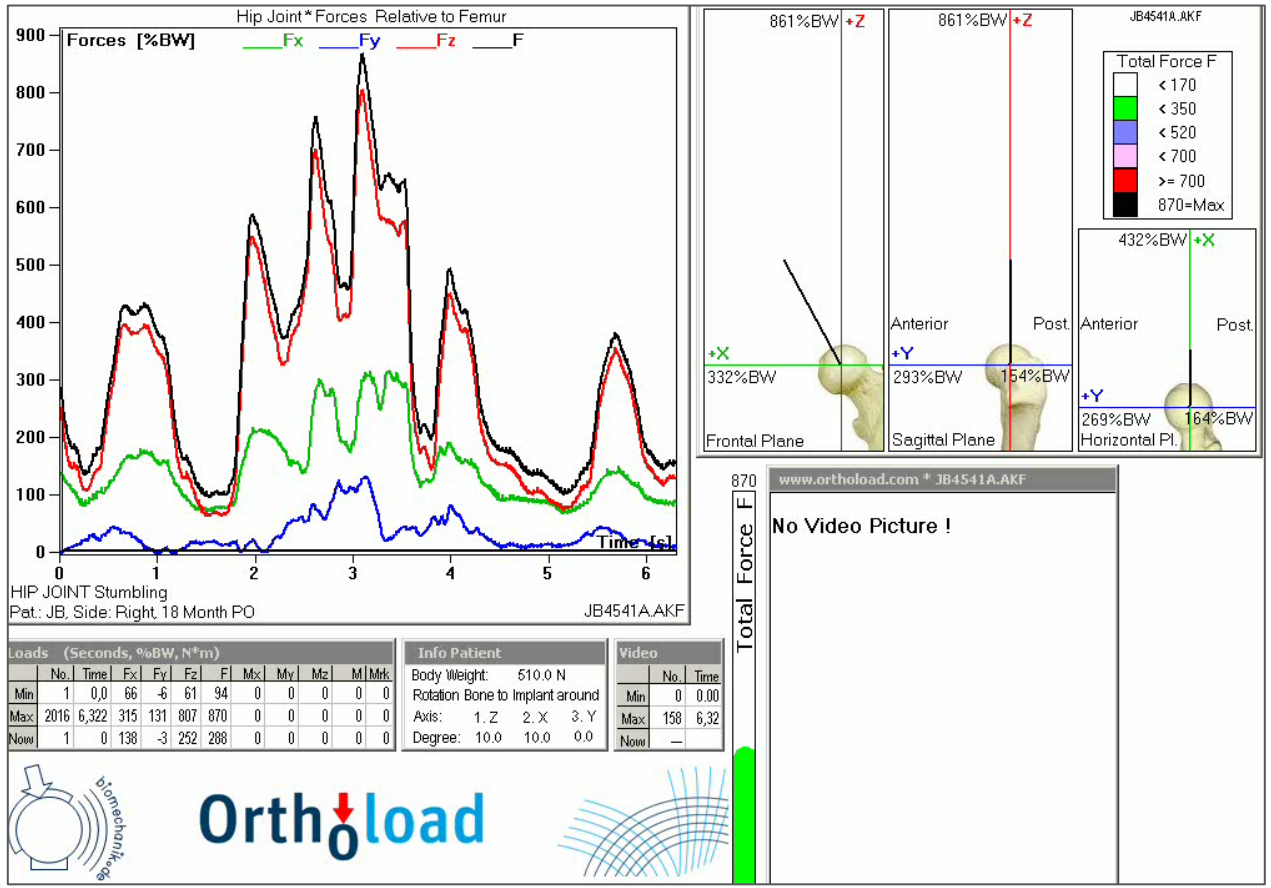
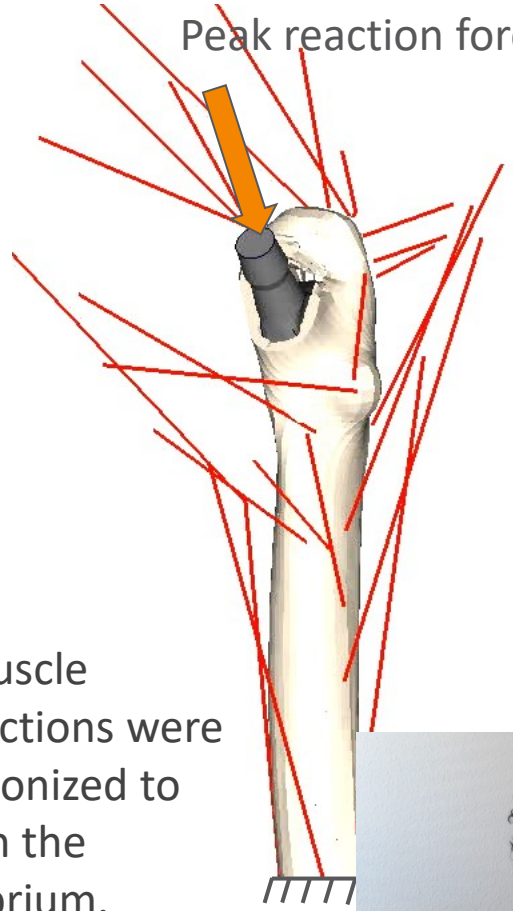
METHODS – STUMBLING LOAD CASE

Stumbling load cases were address based on the telemetric implant measurement of the ORTHOLOAD Team.



Peak reaction forces (8.7 BW)



Hip muscle contractions were synchronized to sustain the equilibrium.

Source: https://orthoload.com/database/?implantId=12&activityId=30&activityIndentationLevel=0&parameterId=1&parameterIndentationLevel=-1&patientId=jb4&fileId=jb4541a&fileType=t&selectBox=file

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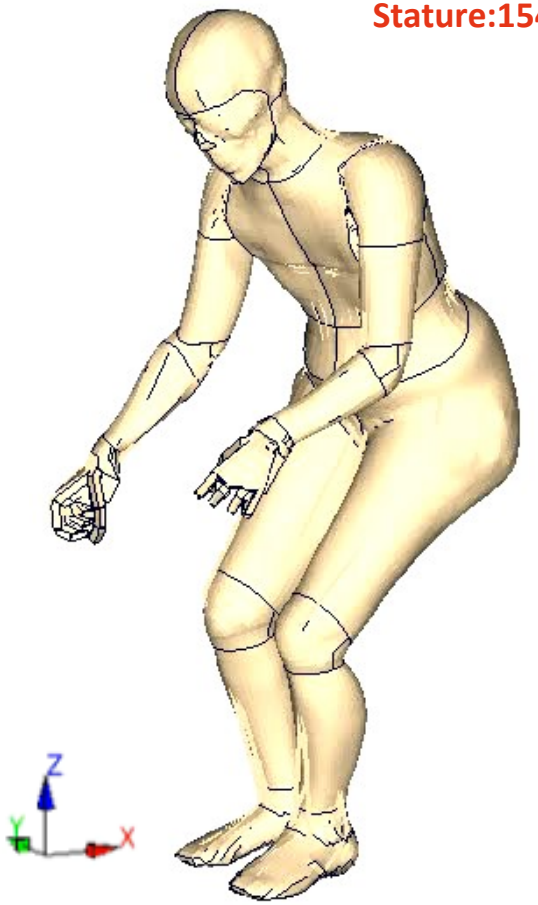
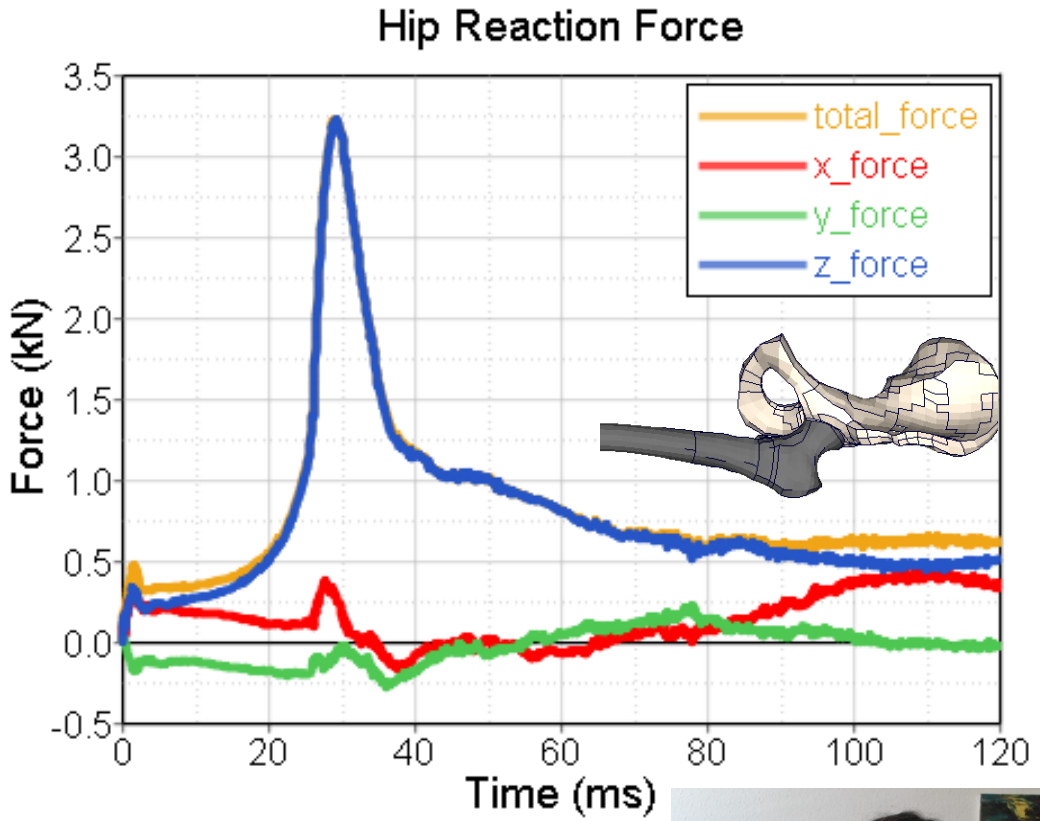
METHODS – FALL LOAD CASE

Stature:154 cm, BMI:21



(Cebeci, 2020)



Fall-induced hip reaction forces were determined based on fall simulations from stranding height using human body models.

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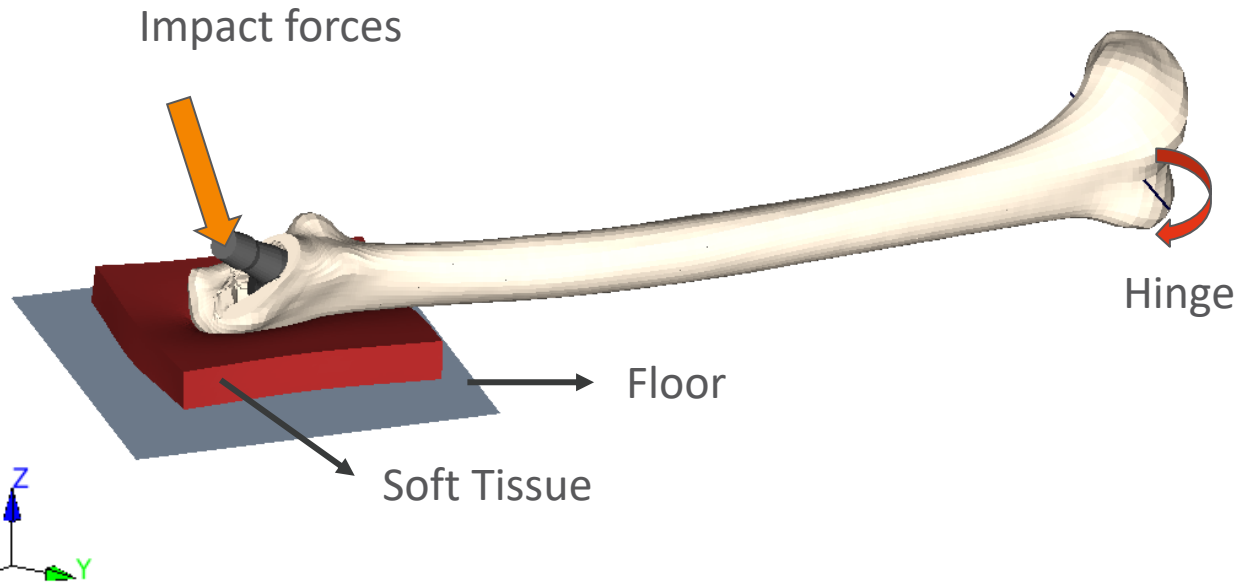
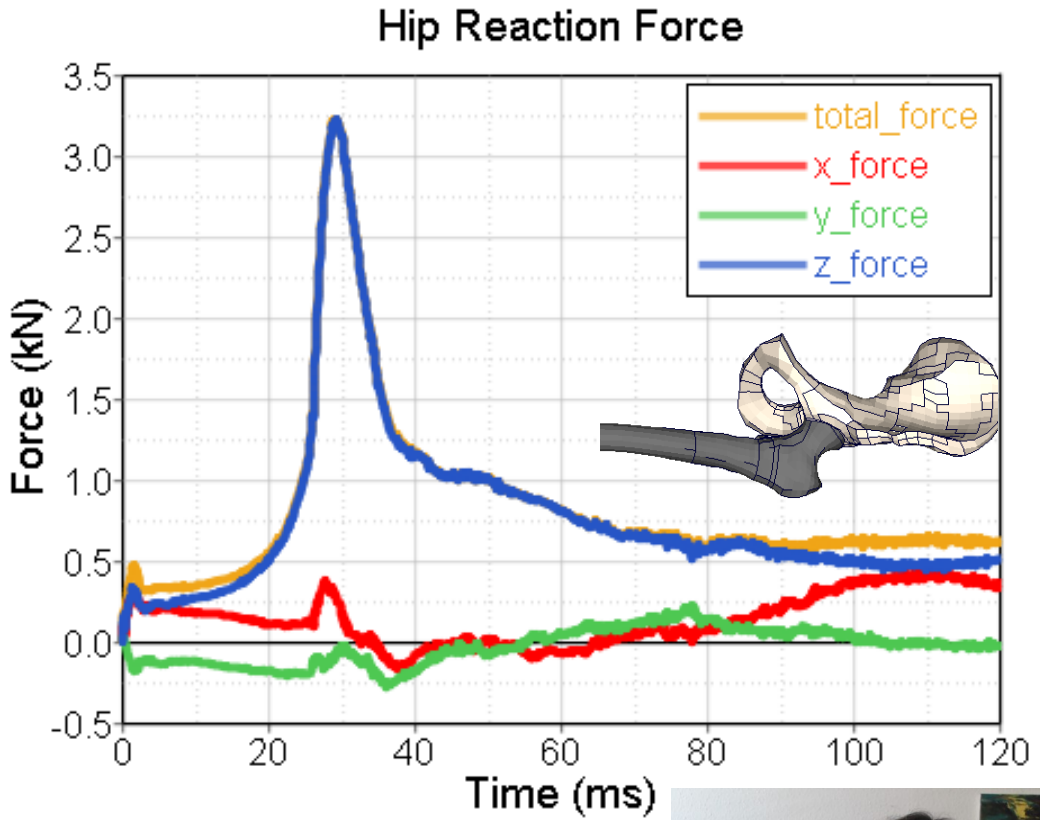
METHODS – FALL LOAD CASE





Measured forces were applied on the implanted femurs in a separate simulation where the implanted femurs were positioned based on the impact configuration.

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Femur Model

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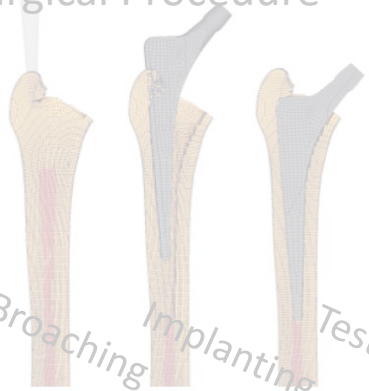
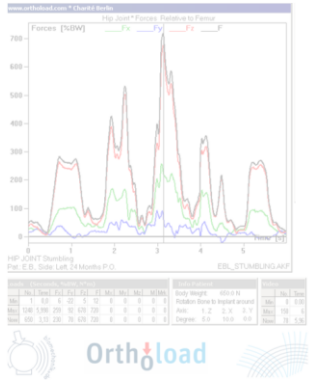
Surgical Procedure

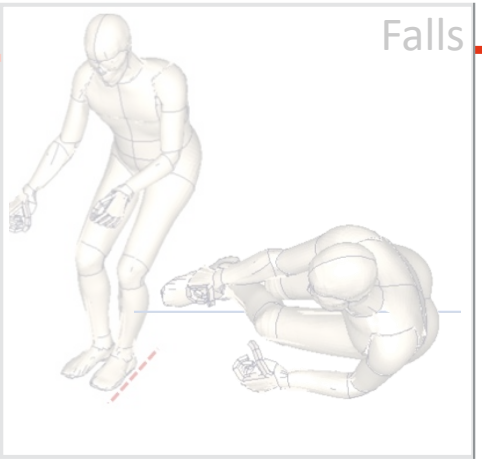


Loading

Stumbling

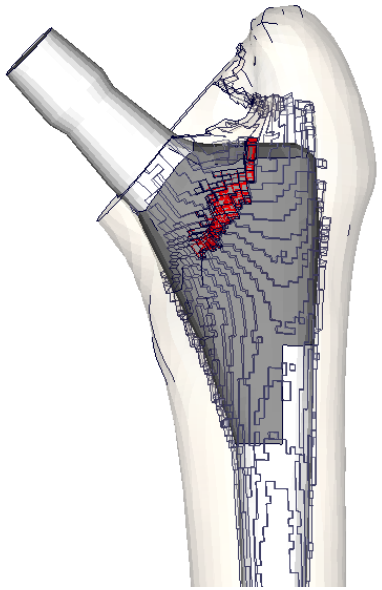


Falls



Fracture Assessments

Intraoperative



Postoperative

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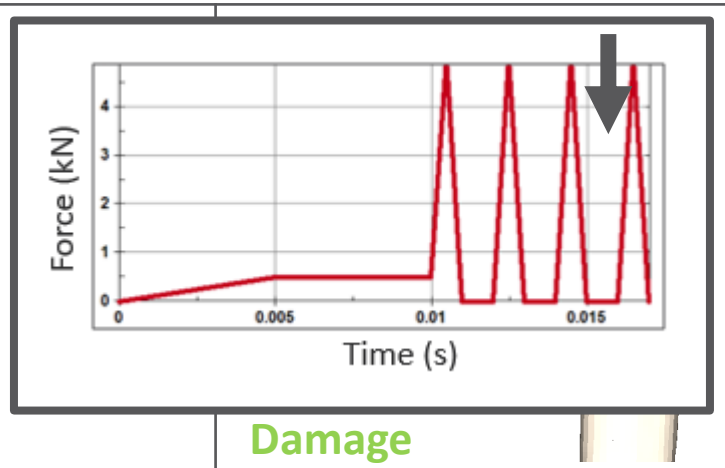
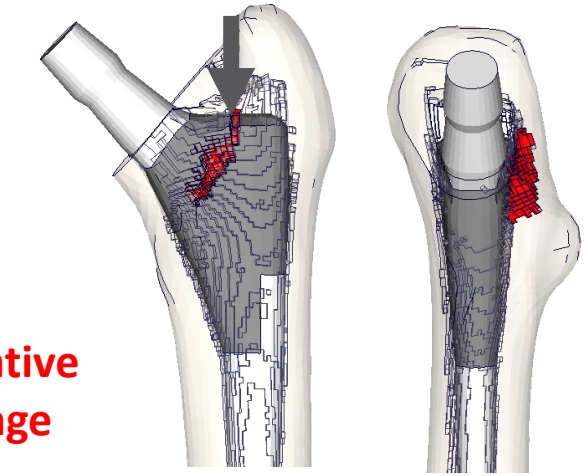
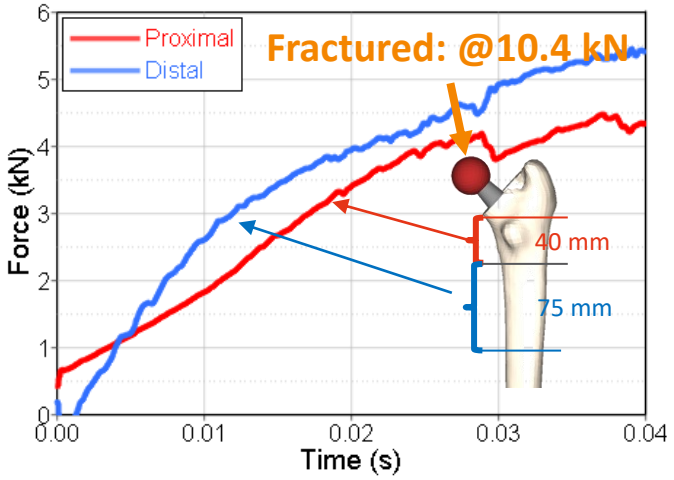
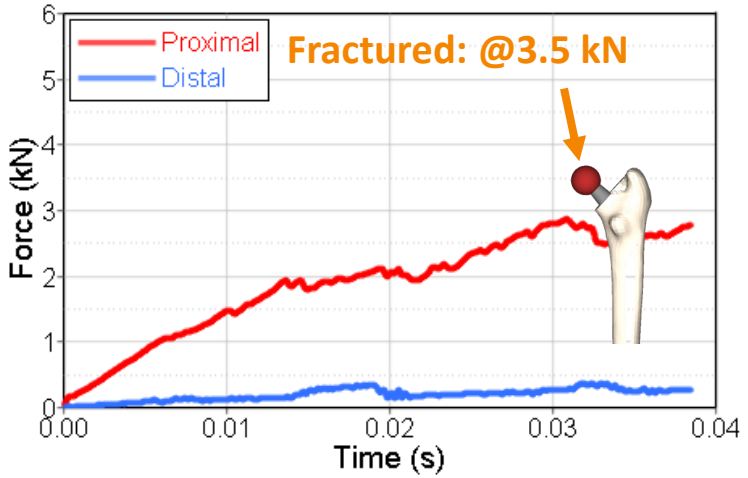
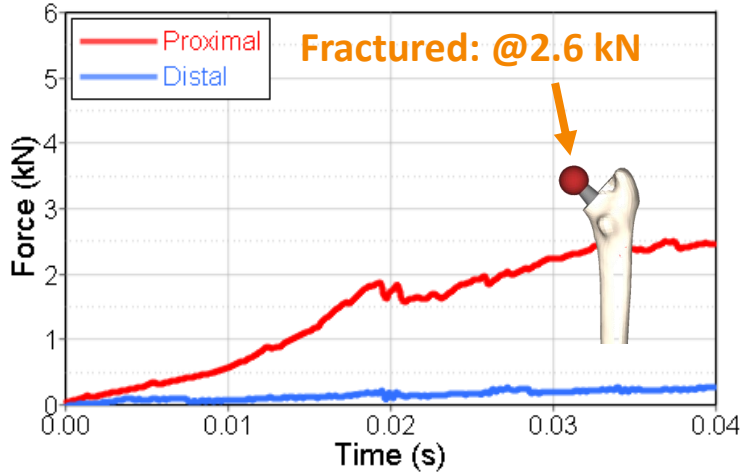
RESULTS - INTRAOPERATIVE

	Tapered - 5kN hammering *(Tijou, 2018)*	Double Wedge - 1kN hammering	Double Wedge - 2kN hammering
Intraoperative	No Intraoperative Damage 	 Damage	Intra-operative Damage 
Postoperative Axial Compression			

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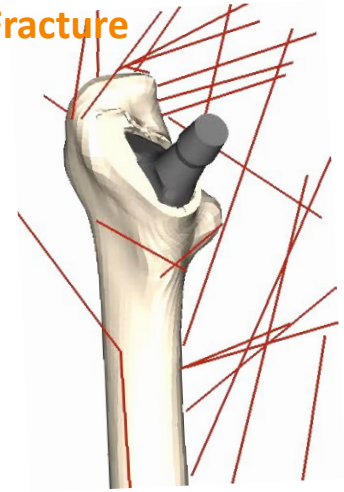
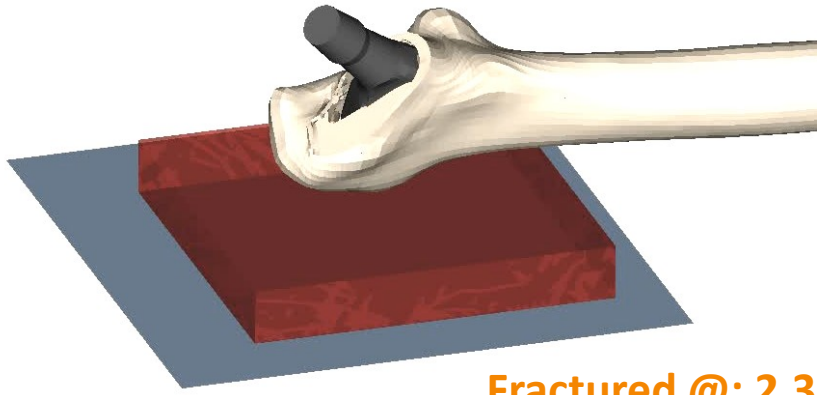
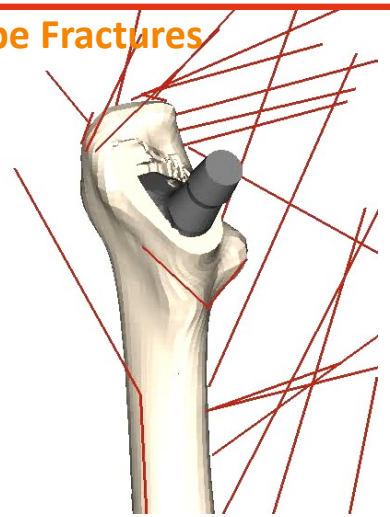
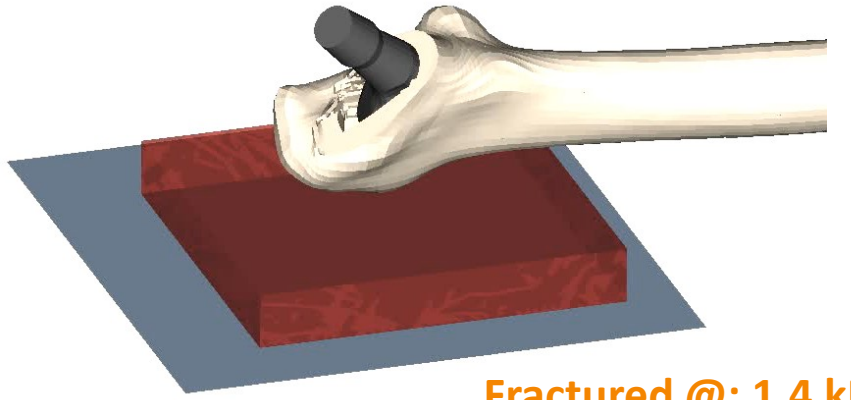
RESULTS - POSTOPERATIVE

	Stumbling	Lateral Fall
Tapered (5kN)	No Fracture 	A2 and B Type Fractures  Fractured @: 2.3 kN
Double Wedge (1kN)	B Type Fractures 	A2 and B Type Fractures  Fractured @: 1.4 kN

- Double Wedge design showed increased fracture risk under stumbling conditions.
- Under lateral fall, although both designs resulted in fractures, the tapered design showed slightly increased strength.

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CONCLUSION

- Intraoperative effects were included in fracture simulations.
- Simulation results showed the different load transfer mechanisms between the stem designs.
- Simulation results quantified the femoral strength reduction due to the intraoperative damage.
- Double wedge design showed an overall increased fracture risk.
- Results were in line with epidemiological observations.
- Developed models can be used to optimize stem designs and the intraoperative procedures which might help to migrate PFFs

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LITERATURE

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QUESTIONS AND CONTACT

THANKS FOR YOUR ATTENTION

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