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S14

INVESTIGATING THE EFFECTS OF DYNAMIC IMPACT LOADS ON A STRUCTURALLY ADAPTED FE-MODEL OF THE FEMUR

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GOAL

Improve the quasi-static finite element femur model to account for dynamic impact loads

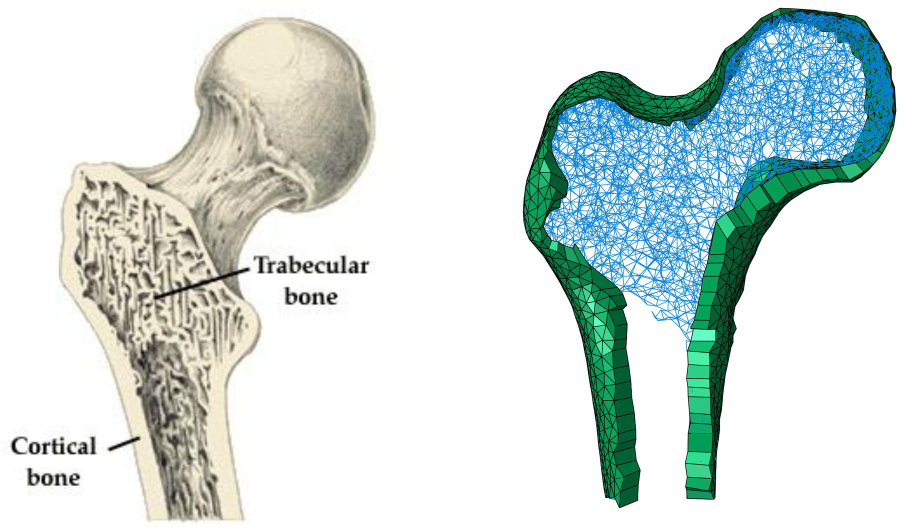
WHY?

- Account for high loading rates – the typical loads causing fracture
- Accurate fracture prediction – establish treatment and mitigation strategies

HOW?

- Develop a new material model, where fracture is represented by plasticity
- Validate new model with data obtained from mechanical testing

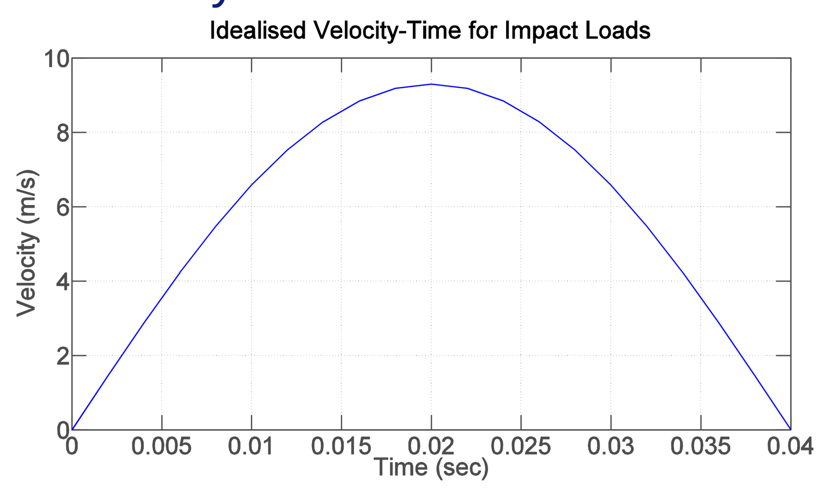
QUASI-STATIC FINITE ELEMENT FEMUR MODEL



- Femur (thigh bone) model developed by Phillips (2015) treats bone as a structure
- Shell (green) and beam (blue) elements represent outer and inner bone respectively
- Created by biological process of adaptation: Element thicknesses adapted in order to optimise material use
- Validation with real bone – adapted model matched overall bone architecture and predicted failure load and location

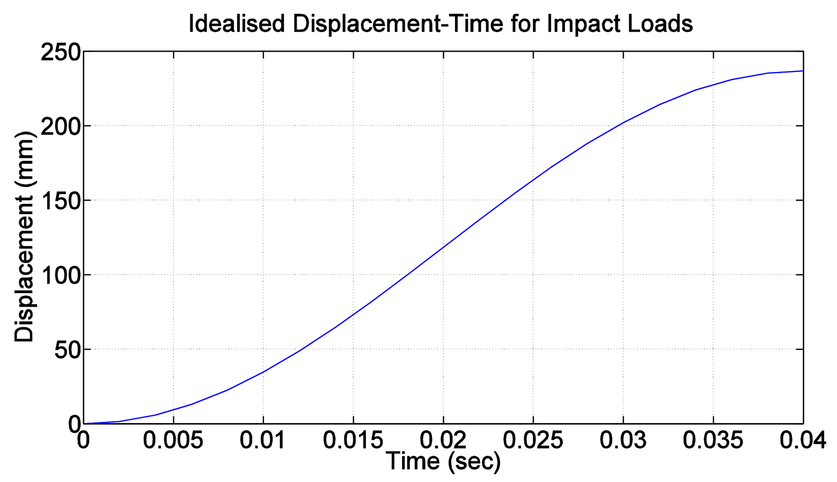
DYNAMIC IMPACT LOADS

- Dynamic impact loads = high loading rates, ie. high velocities, acting over a short period
- Velocity curves idealised as half-sine wave, converted to displacements, and input into model



(Velocities)

Converted



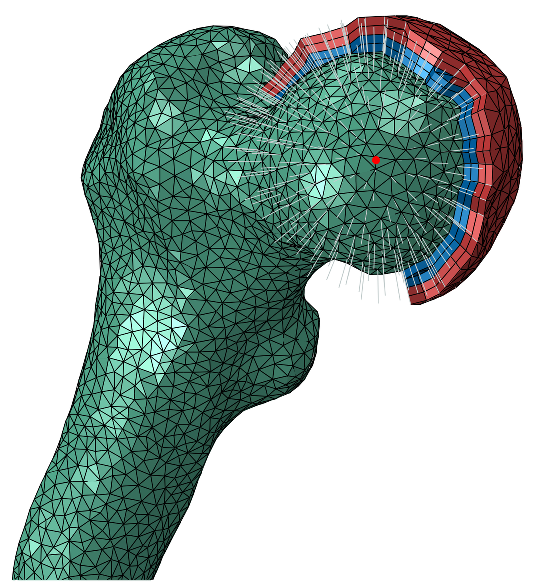
(Displacements)

Drives

MODEL

LOADS AND BOUNDARY CONDITIONS

- Point loads cannot be used as an accurate loading scenario
- In-vivo, any impact must propagate through layers of tissue
- Load applicators and boundary condition fixators introduced – artificial constructs to model biological conditions
- A force applied at a reference point distributes the load evenly over the bone



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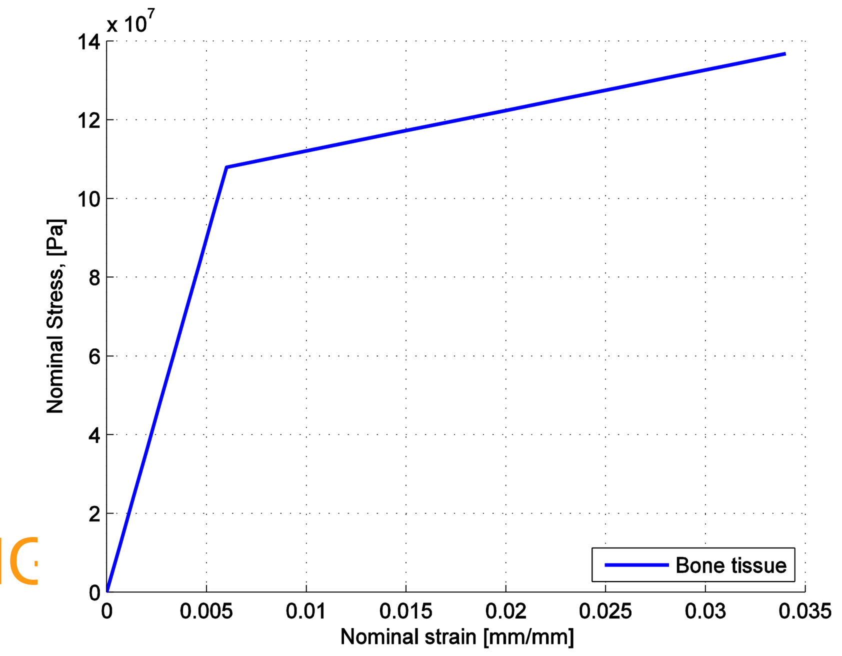
(Constitutive relation)



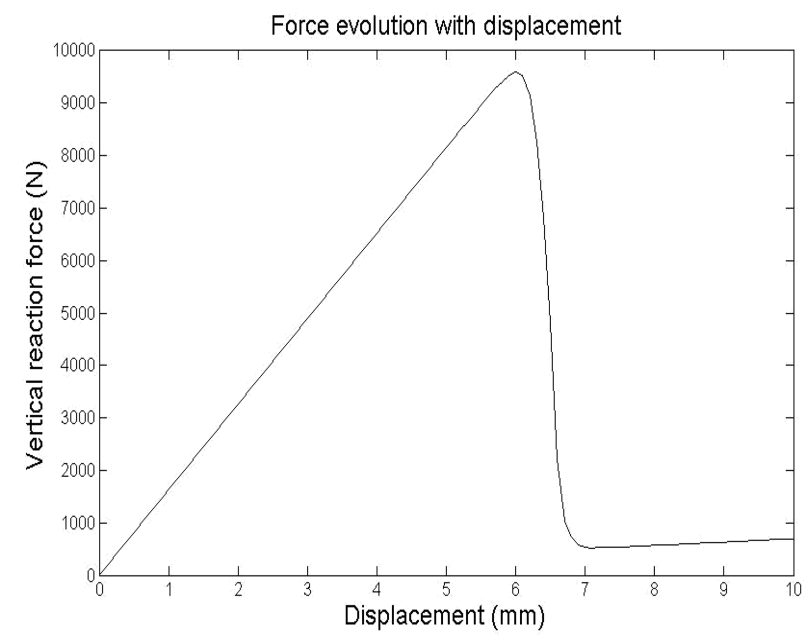
BONE FRACTURE

- Bone fracture modelled using bi-linear plasticity
- Plastically straining elements = fracture
- Simple isotropic model
- Anisotropy on geometric- and material- levels accounted for through system connectivity

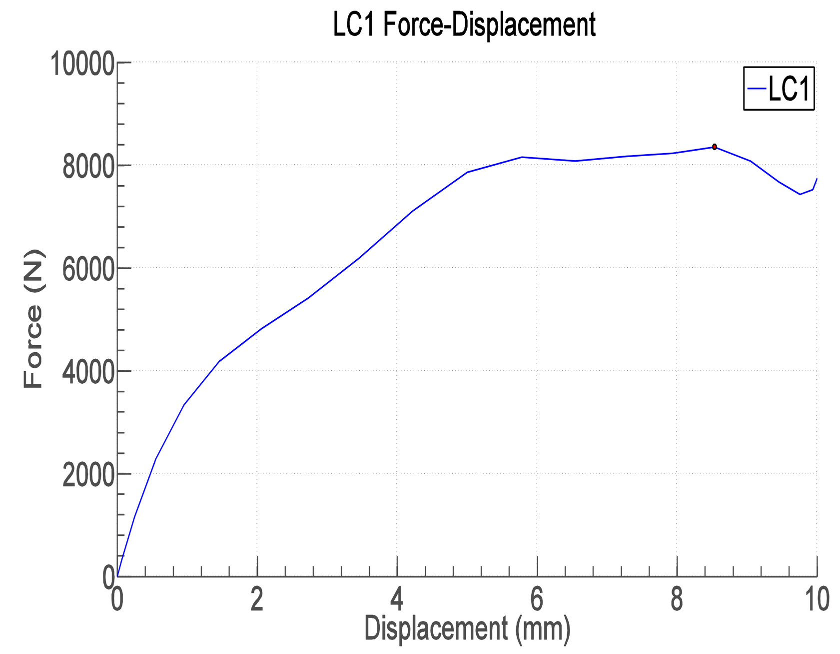
VALIDATION WITH MECHANICAL TESTING

- The plastic material model under dynamic impact load
- Validated by comparing to experimental results for a neck-of-femur fracture (Crisotfolini, 2007).
- Fracture load 8.2 kN lies within the range 6.2-12.4 kN
- Quasi-static and dynamic load-displacement curves also agree

(Cristofolini, 2007)



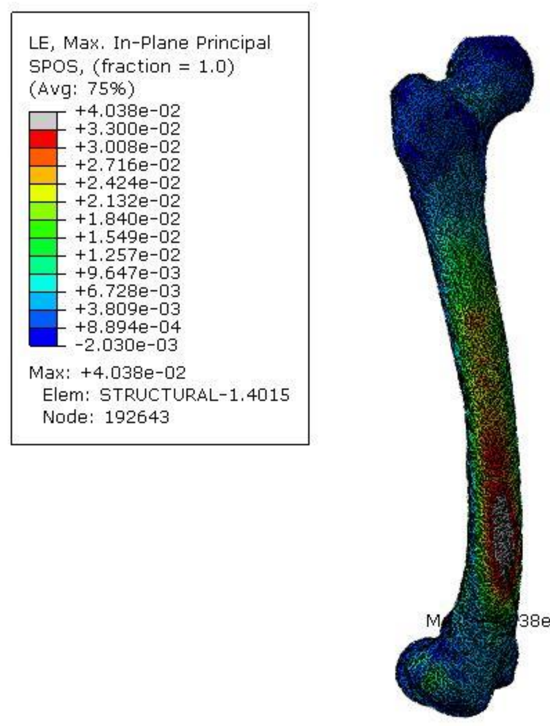
(Villette, 2014)

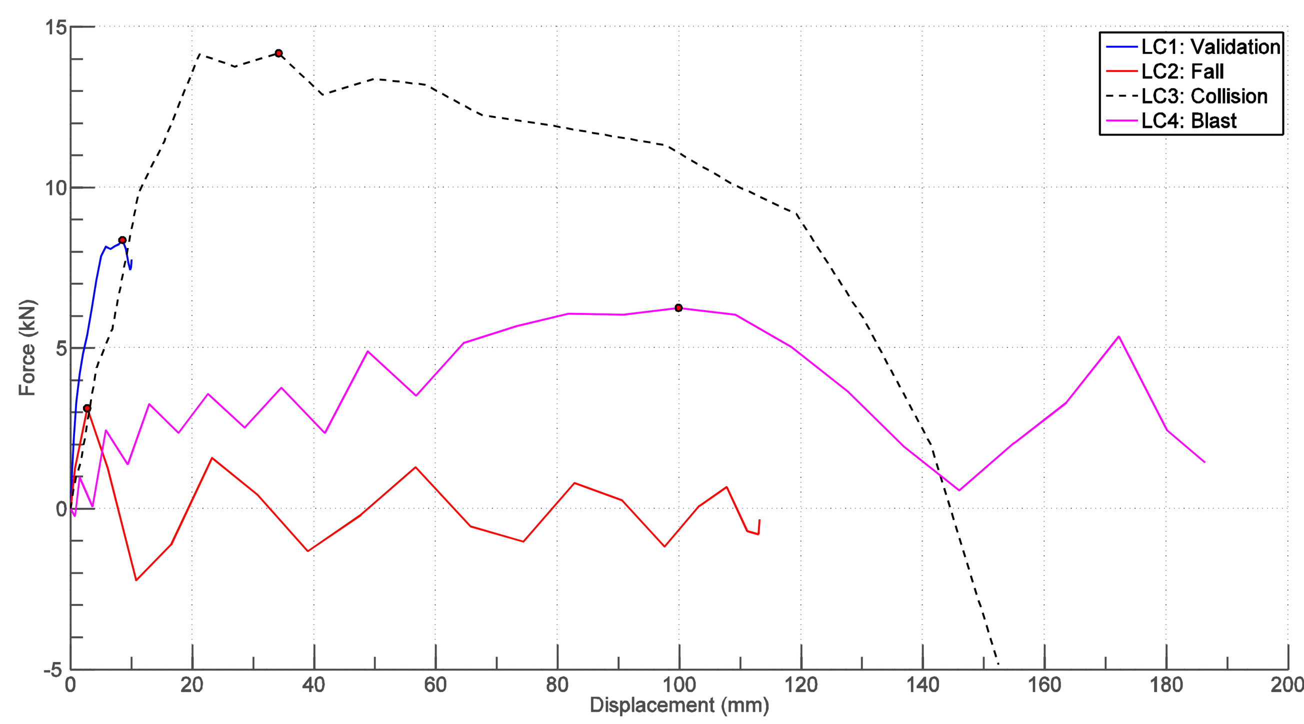


(Results - Dynamic)

RESULTS

- Three load cases: 1) Fall; 2) Collision; 3) Solid blast loading
- Estimates of fracture load are made from the force-displacement diagrams and contour plots





(Force-Displacement)

CONCLUSIONS

- The four load cases respond somewhat favourably to preliminary investigations into bone fracture
- Further development of proposed method could lead to a model exhibiting accurate prediction capabilities and use in orthopaedic practice.

REFERENCES

Cristofolini, L., Jusczyk, M., Martelli, S., Taddei, F., and Viceconti, M. (2007). In Vitro replication of spontaneous fractures of the proximal human femur. Journal of Biomechanics, 40(13):2837-2845.

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