Kingston University London

SIMBIO-M 2018

INJECTION OF BONE CEMENT INTO OSTEOPOROTIC FEMORA ALONG CURVED CANALS

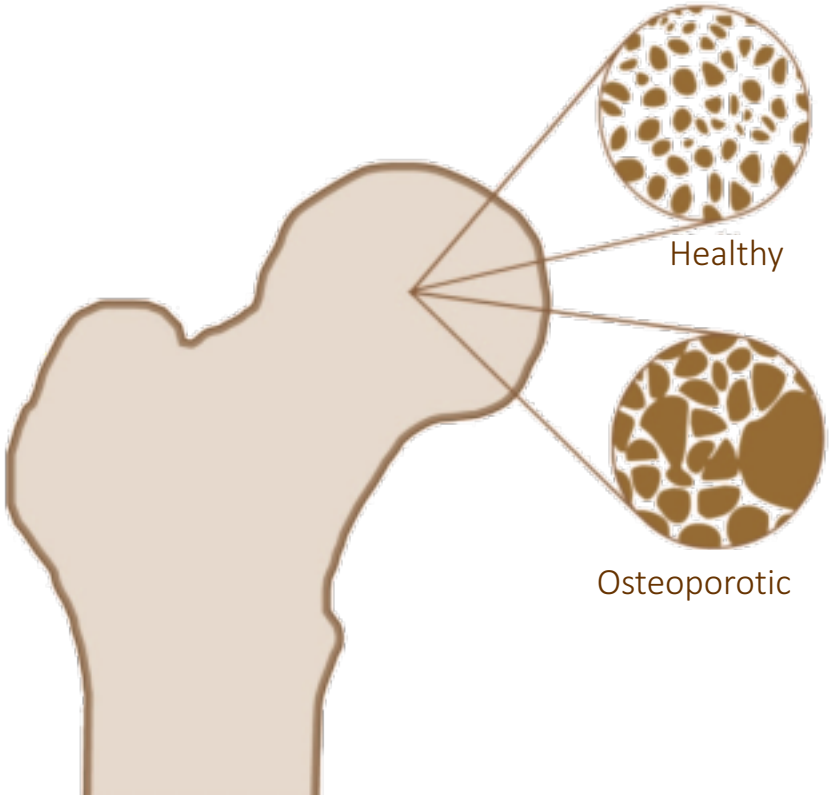
María E. Santana Artiles and Demetrios T. Venetsanos

June 2018

1 INTRODUCTION. OSTEOPOROSIS

Osteoporosis

Disease characterized by reduction of bone mineral density and micro-architectural deterioration of bone tissue → Increase the risk of bone fracture → **Hip**



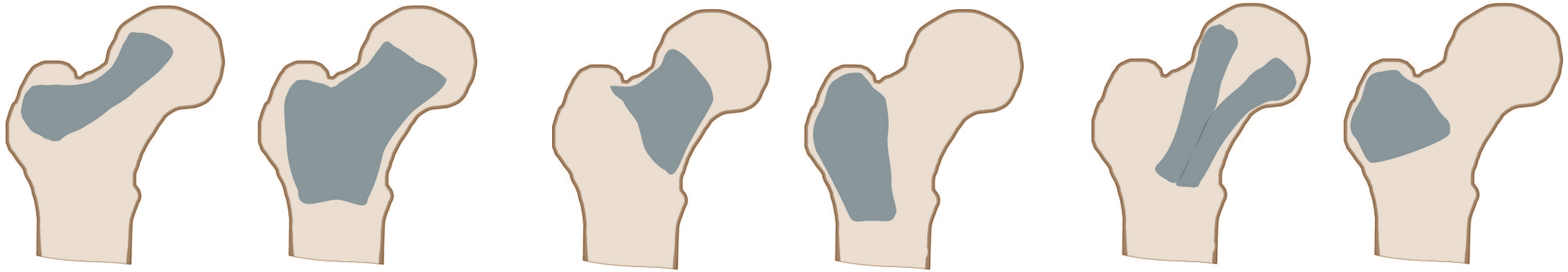
Current **treatments**

- Protective devices
- Special diets / exercises
- Pharmacological treatments

Alternative treatment → **Femoral augmentation**

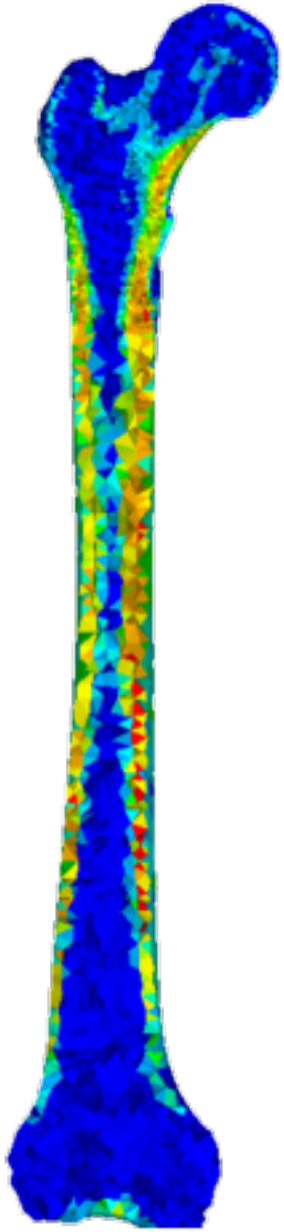
2 PROBLEM STATEMENT. FEMORAL AUGMENTATION

- Augmentation of the **proximal femur** by injecting **bone cement**
  - Risks involved
    - Large amounts of cement can lead to osteonecrosis
    - Leakage of cement can cause embolism
    - Suboptimal injection can result in stress concentration

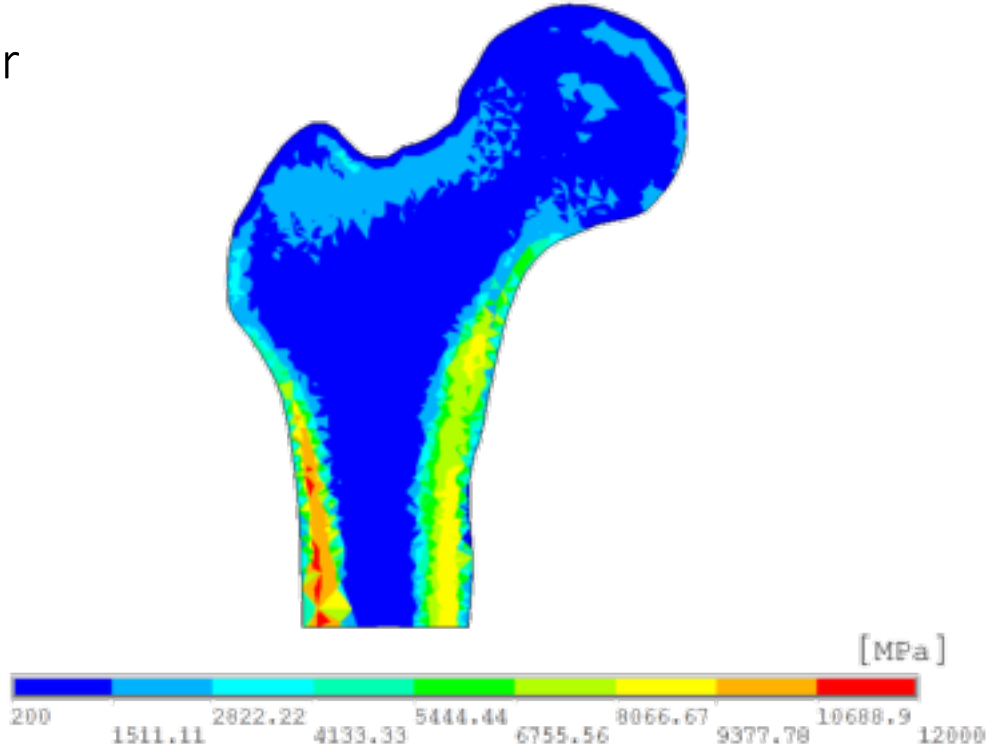


- Optimum bone cement volume and location to strengthen the femur
- Clinically feasible bone cement distribution

3 MODEL DEVELOPMENT

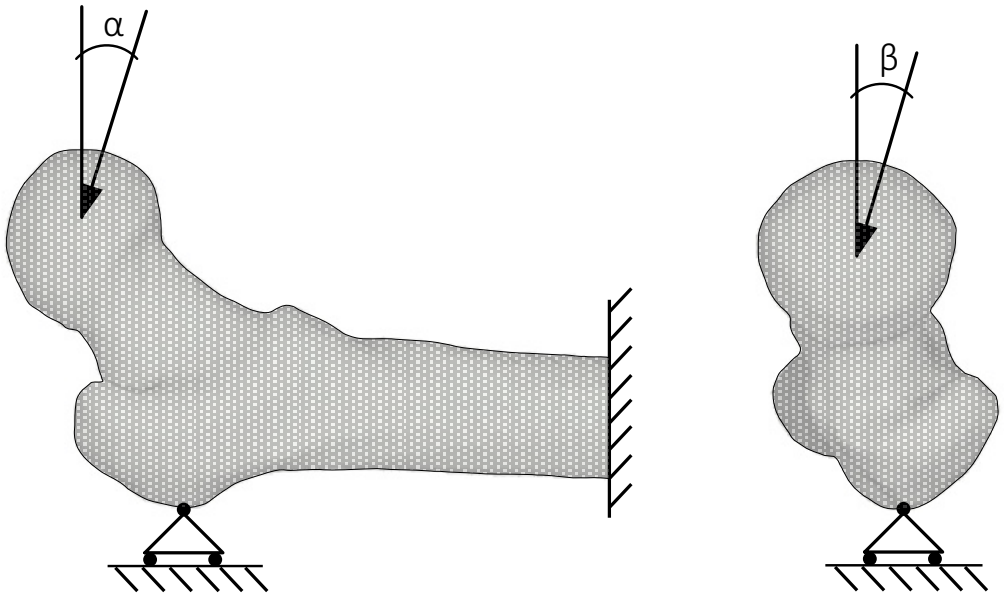


- Femur osteoporotic model (T-score -2.5)
- Inhomogeneous isotropic material properties mapped from CT scan (BoneMat)
- Region of interest (ROI): proximal femur
- Average values of the elastic modulus
  - Cortical bone: 7.5GPa
  - Trabecular bone: 1GPa
- Constant Poisson's ratio: 0.3



4 YIELD LOAD PREDICTION

- Boundary conditions: lateral fall on the greater trochanter



Applied load

- Plane angles
  - 15° in frontal direction (β)
  - 10° in transverse direction (α)
- Initial load: 2000N (increases in steps of 2.5%)
- Failed elements: yield strain criteria

- Linear Static **Finite Element Analysis** → Osteoporotic femur **yield load** → 2625N

5 FEMORAL AUGMENTATION. OPTIMIZATION

- Increase the osteoporotic femur yield load by at least 100% (F_{TARGET}) using the **minimum** amount of **bone cement** possible

- Optimization algorithm:

Divide the external target load (F_{TARGET}) into steps

Define Region of Interest (ROI)

***For** each load step (until F = F_{TARGET})*

Conduct a Linear Static FE analysis

Find elements violating strain criterion

% failed elements = Elements violating strain criterion / Elements in the ROI

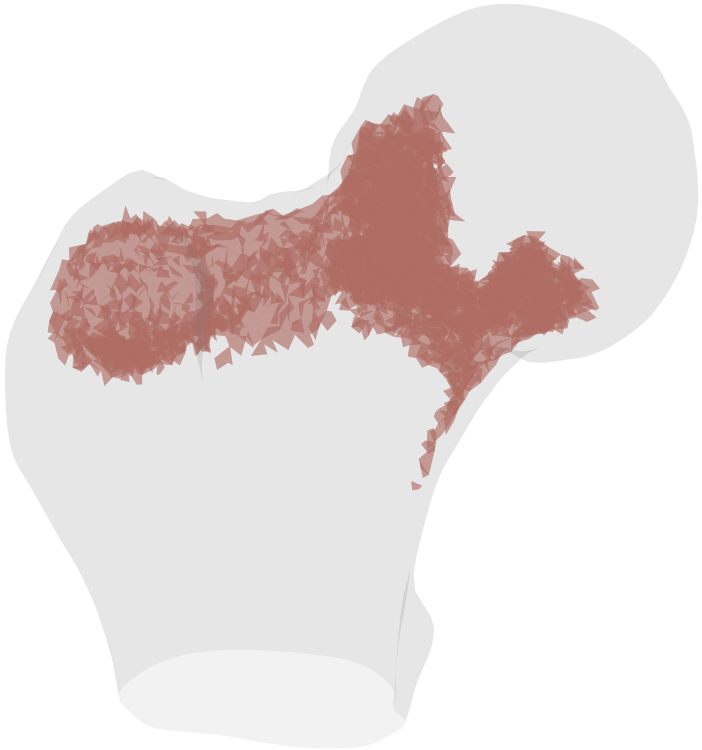
Assign augmented material properties to failed elements

***Repeat** until % failed elements < 1*

5 FEMORAL AUGMENTATION. OPTIMIZATION

- Increase the osteoporotic femur yield load by at least 100% (F_{TARGET}) using the **minimum** amount of **bone cement** possible

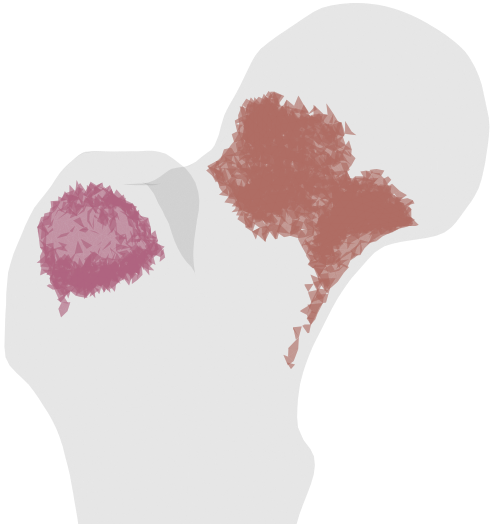
- Optimization algorithm:



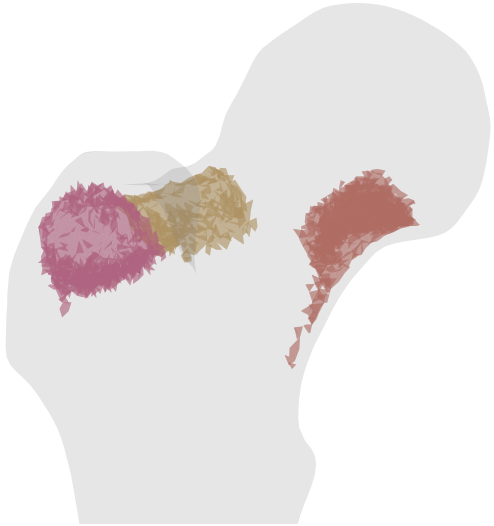
12ml bone cement
100% increase yield load

6 FEMORAL AUGMENTATION. INJECTION PATH

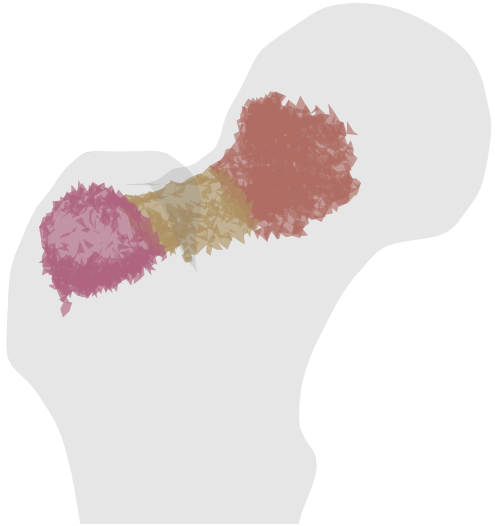
- Optimization result is not clinically feasible → Simple injection path
  - Divide the optimum distribution in two/three regions



Straight line



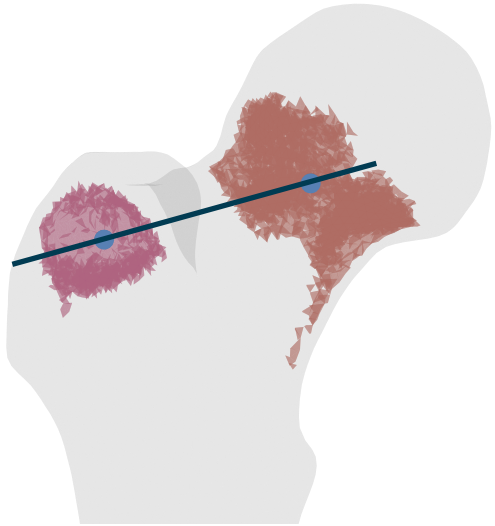
Concave-down curve



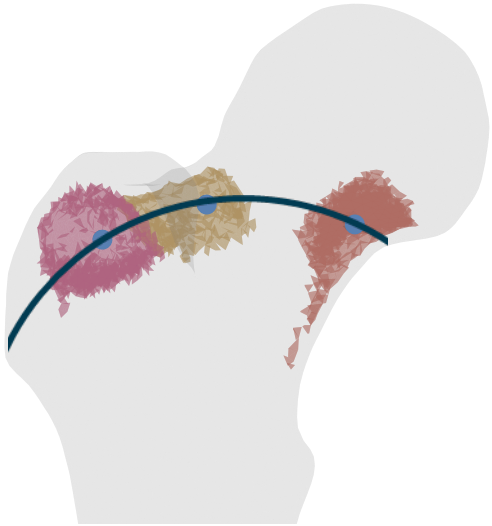
Concave-up curve

6 FEMORAL AUGMENTATION. INJECTION PATH

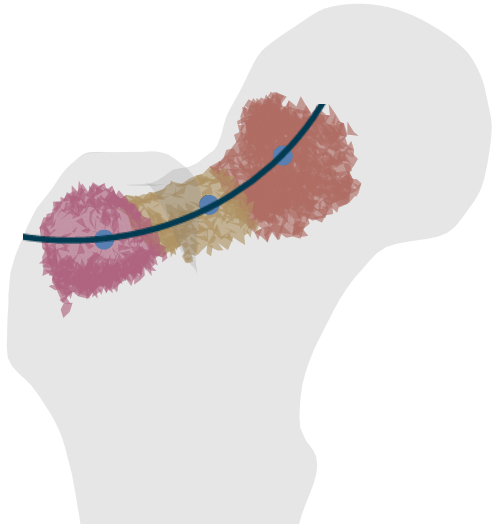
- Optimization result is not clinically feasible → Simple injection path
  - Divide the optimum distribution in two/three regions
  - Calculate the centroid of each region



Straight line



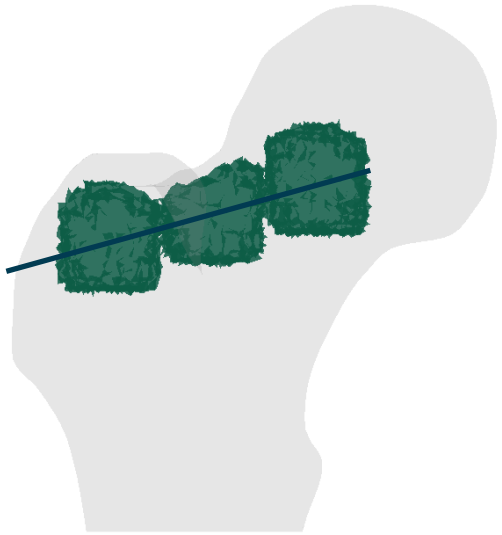
Concave-down curve



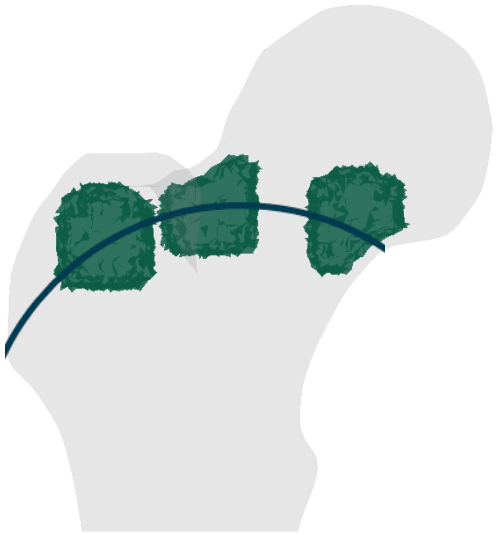
Concave-up curve

6 FEMORAL AUGMENTATION. INJECTION PATH

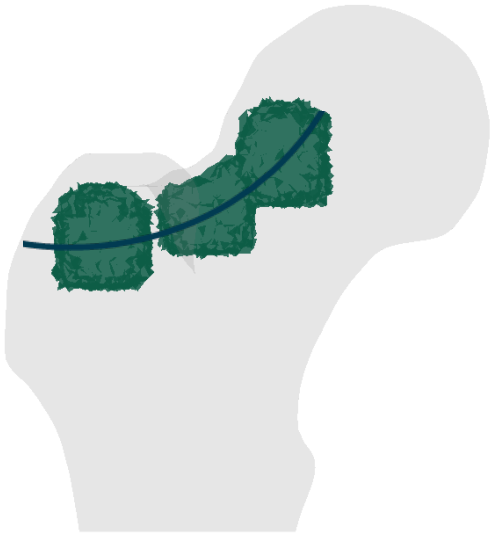
- Optimization result is not clinically feasible → Simple injection path
  - Divide the optimum distribution in two/three regions
  - Calculate the centroid of each region
  - Place one sphere of bone cement at the centroid of each region



Straight line



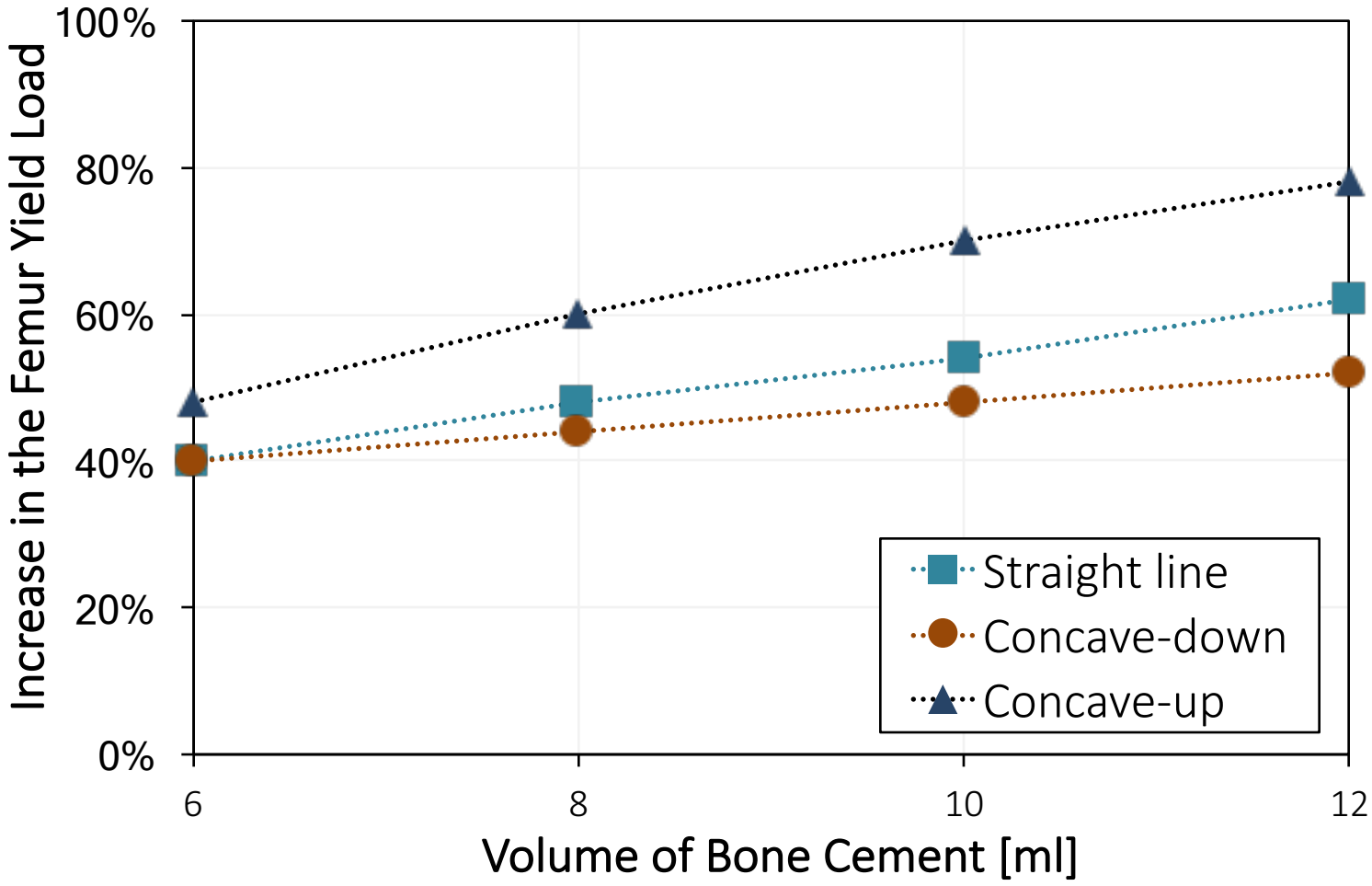
Concave-down curve



Concave-up curve

6 FEMORAL AUGMENTATION. INJECTION PATH

- Change the radius of each sphere for different levels of augmentation



7 CONCLUSION AND FUTURE WORK

- Simplified bone cement pattern that could be reproduced using minimally invasive surgery
- Drilling a concave-down curved canal could provide up to 52% increase in the yield load
- Drilling a straight canal could provide up to 62% increase in the yield load
- Drilling a concave-up curved canal could provide up to 78% increase in the yield load
- Future work
  - Augmentation filling a canal instead of three separate injections
  - Fluid simulation to understand how the bone cement would spread
  - Explore the behaviour of the augmented bone under impact loads
  - Experimental validation

Kingston University London

SIMBIO-M 2018

INJECTION OF BONE CEMENT INTO OSTEOPOROTIC FEMORA ALONG CURVED CANALS

María E. Santana Artiles and Demetrios T. Venetsanos

June 2018