

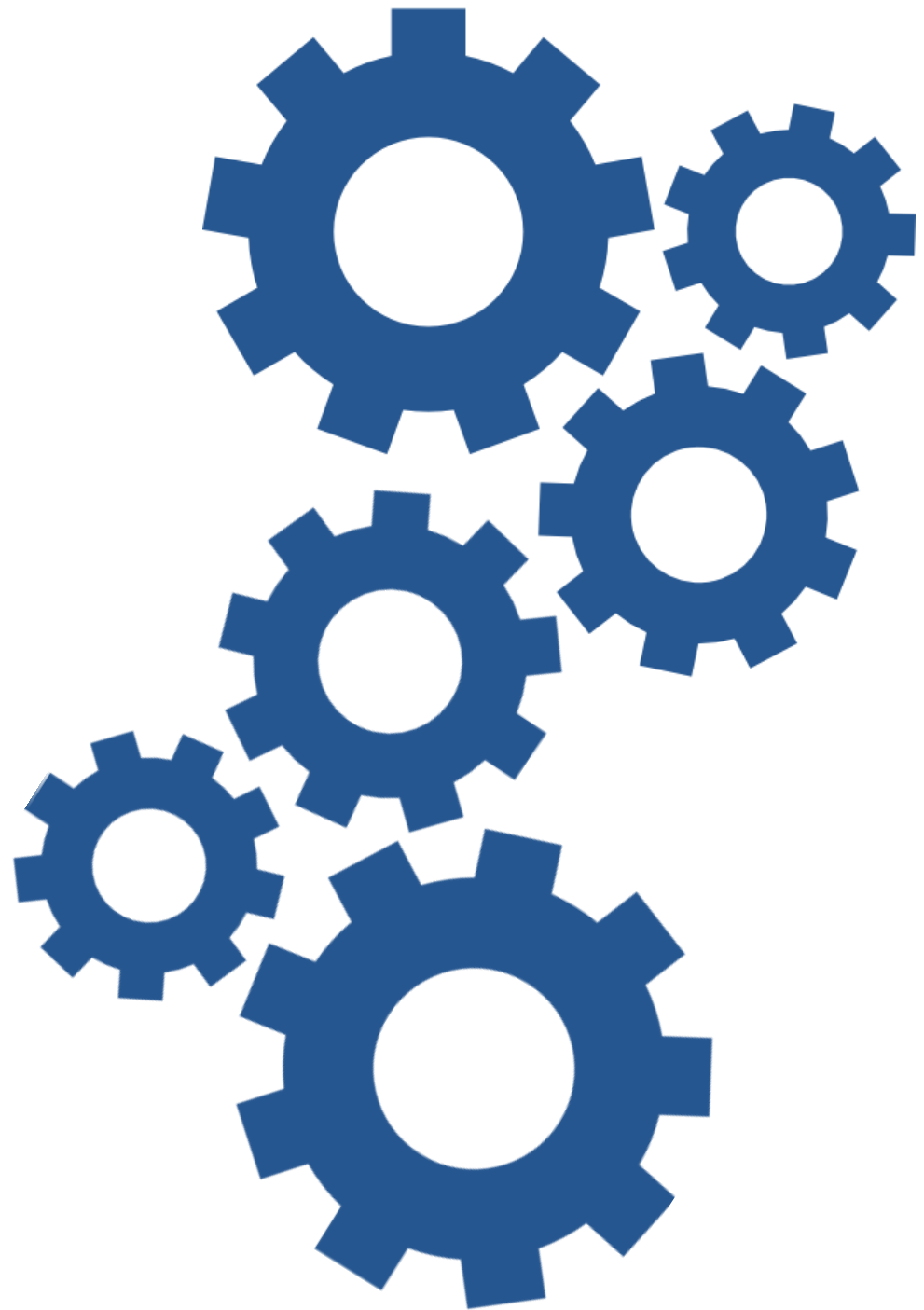
# Master Thesis Proposals



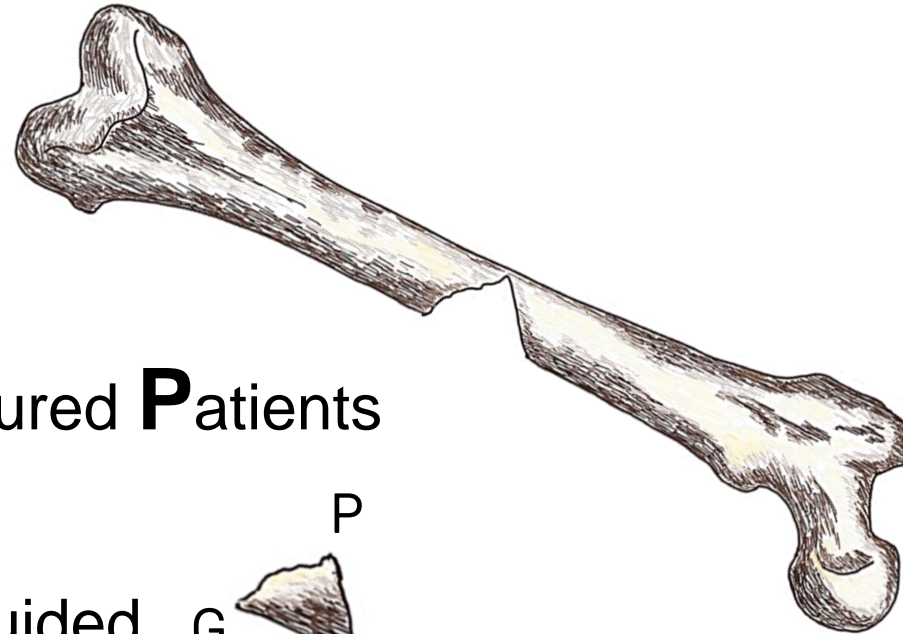
**POLITECNICO**  
MILANO 1863

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# Project GAP



fractured **P**atients

Image-**G**uided **G**  **A**

Computational and Experimental **A**nalysis

Mechanobiology  
vs.  
Mechanics  
Fracture Mechanics

# Project 1: GAP

Period Abroad!



**POLITECNICO**  
MILANO 1863



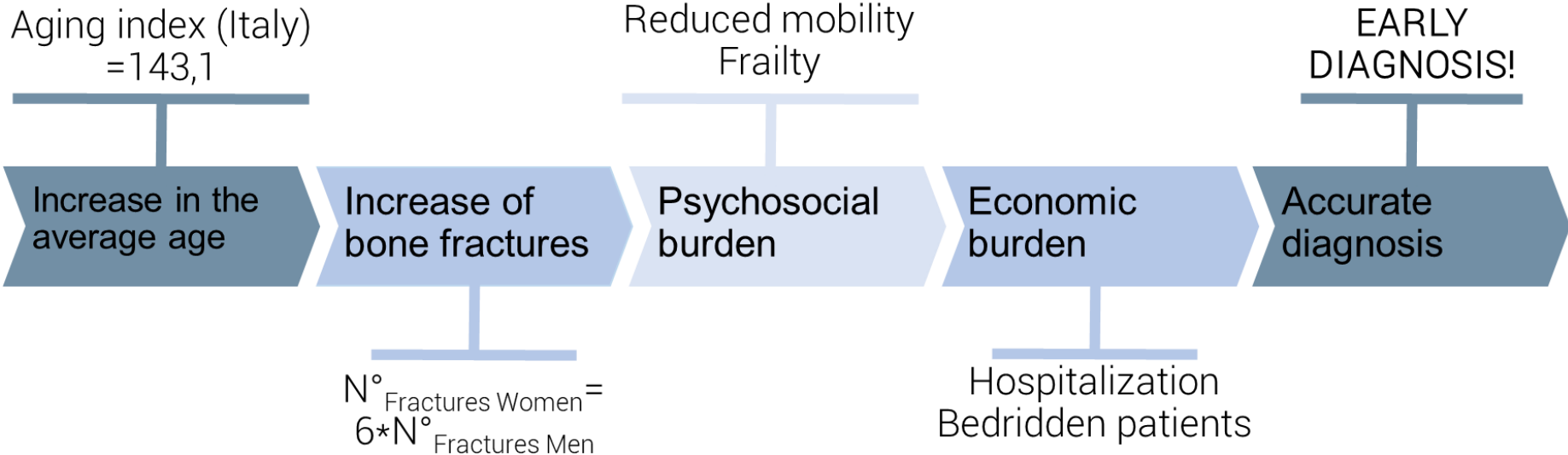
GRUPPO OSPEDALIERO SAN DONATO  
FOUNDATION



Elettra Sincrotrone Trieste

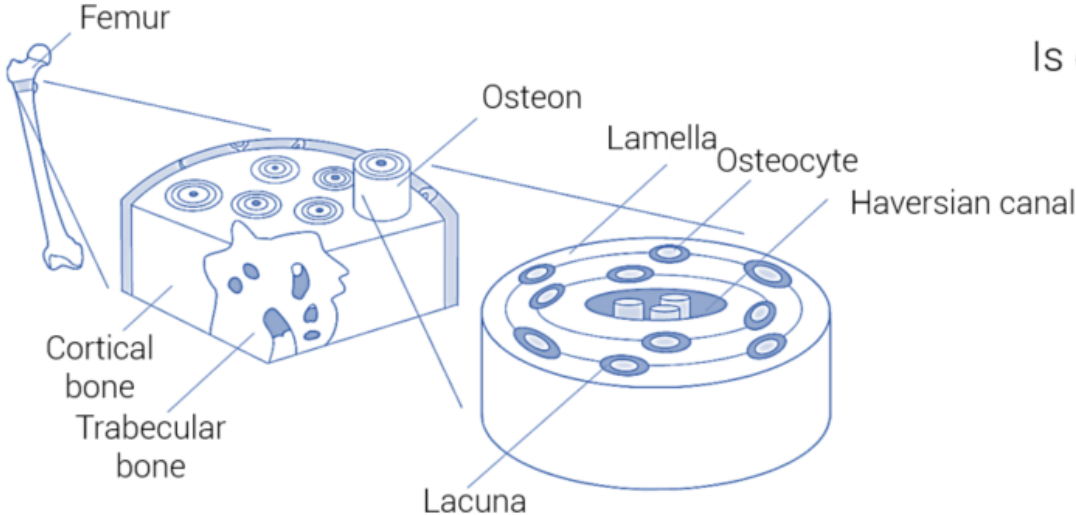
# Project 1: GAP

## Problem definition

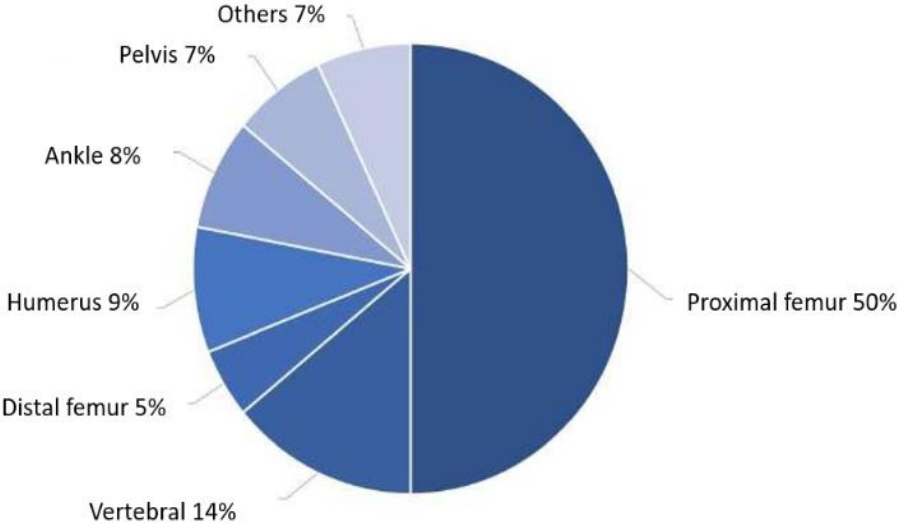


# Project 1: GAP

# Problem definition



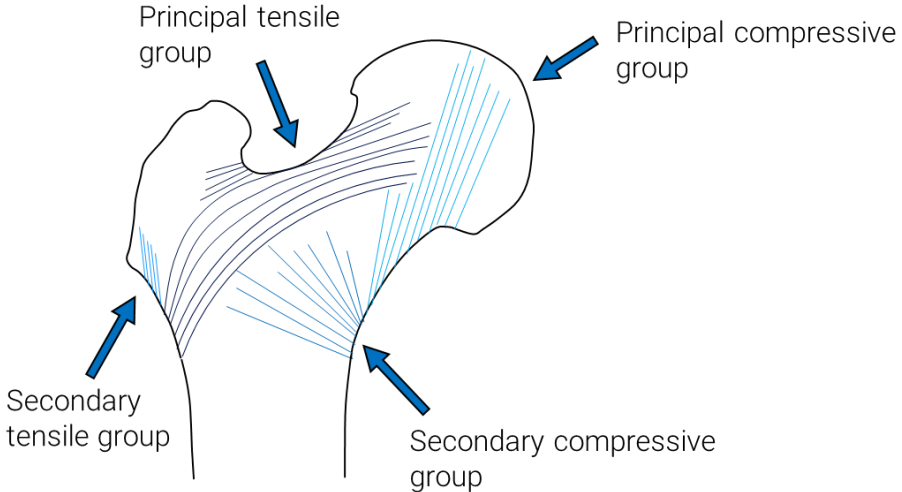
Is damage influenced by micro-structural features (lacunae)?



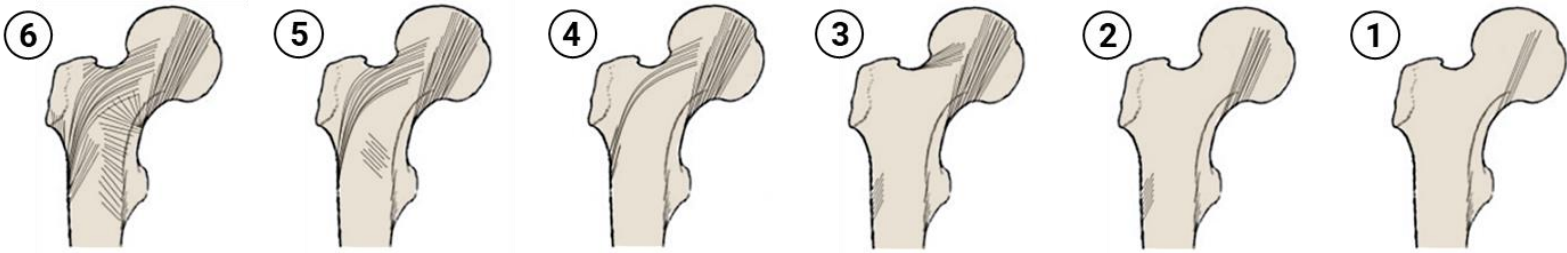
Is it possible to perform an early diagnosis based on micro-scale fragility indexes?

# Project 1: GAP

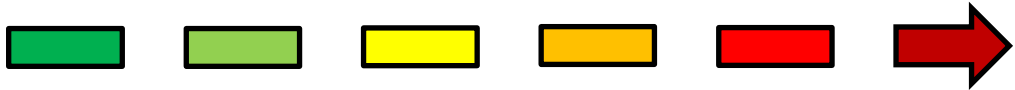
# Problem definition



**Healthy condition**

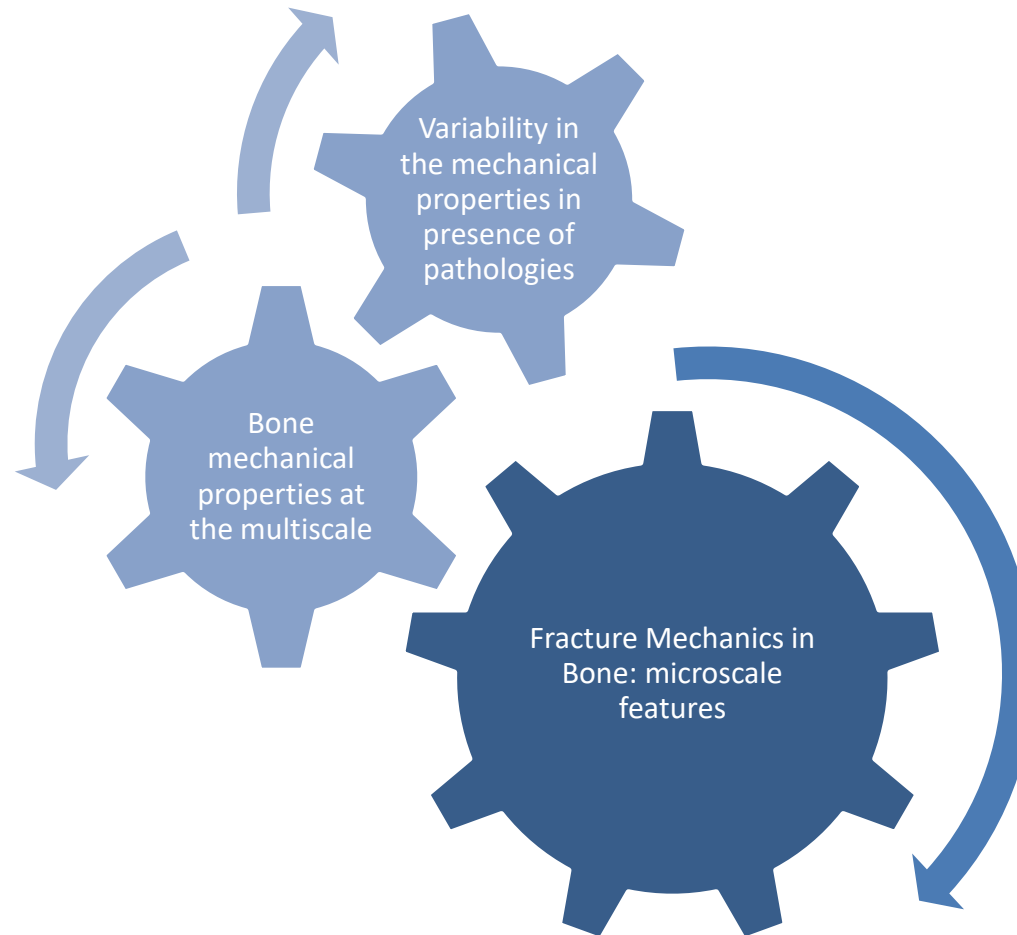


**Osteoporotic condition**



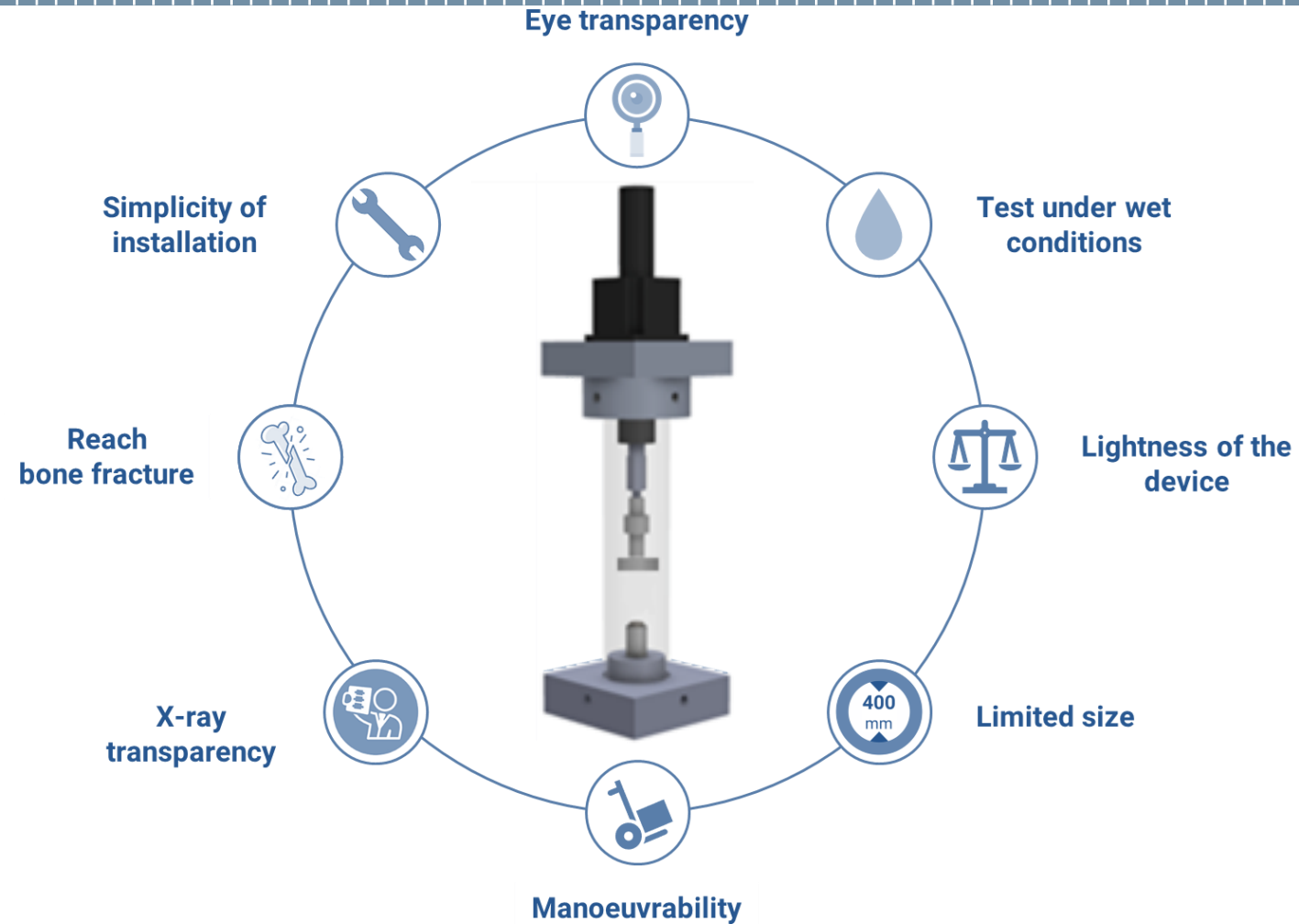
# Project 1: GAP

## Aim and Expectations



# Project 1: GAP

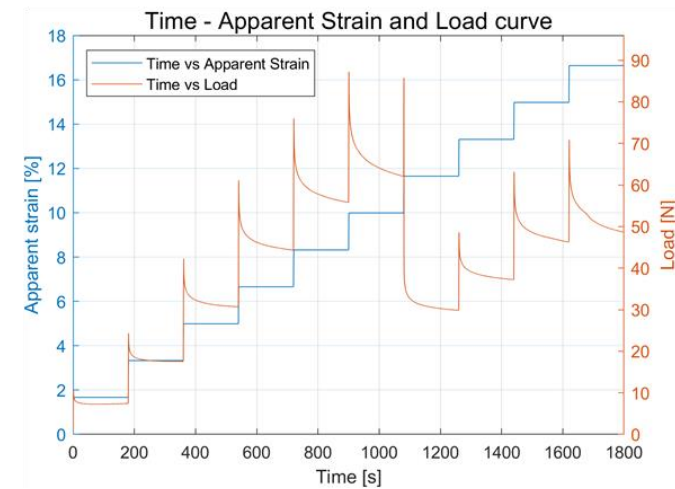
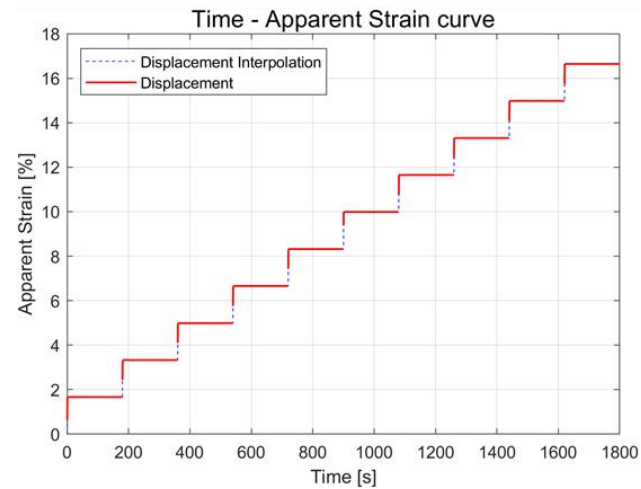
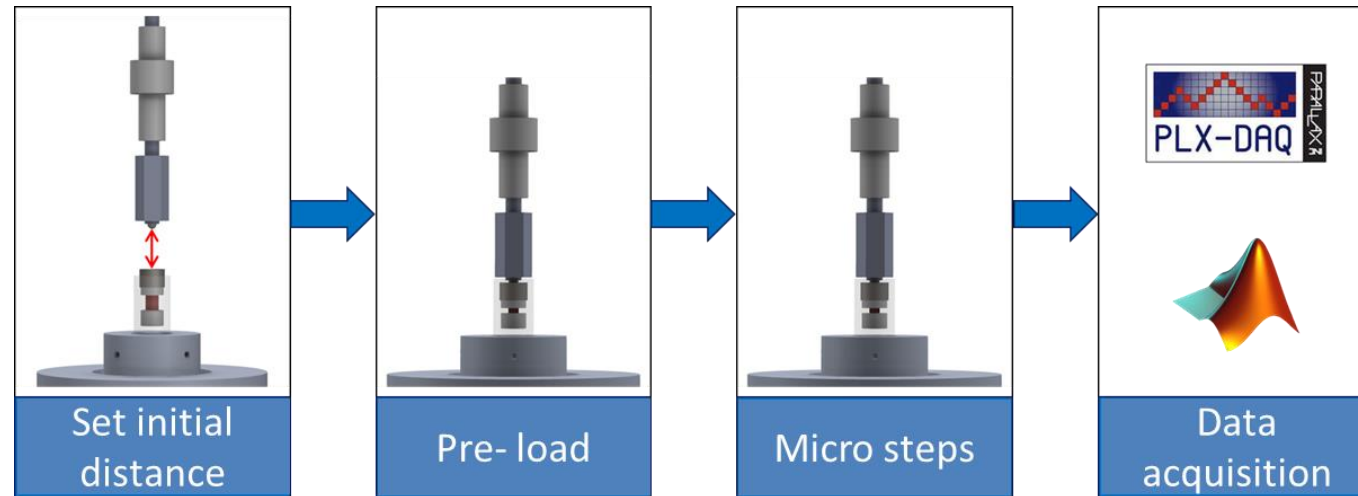
## Experimental section





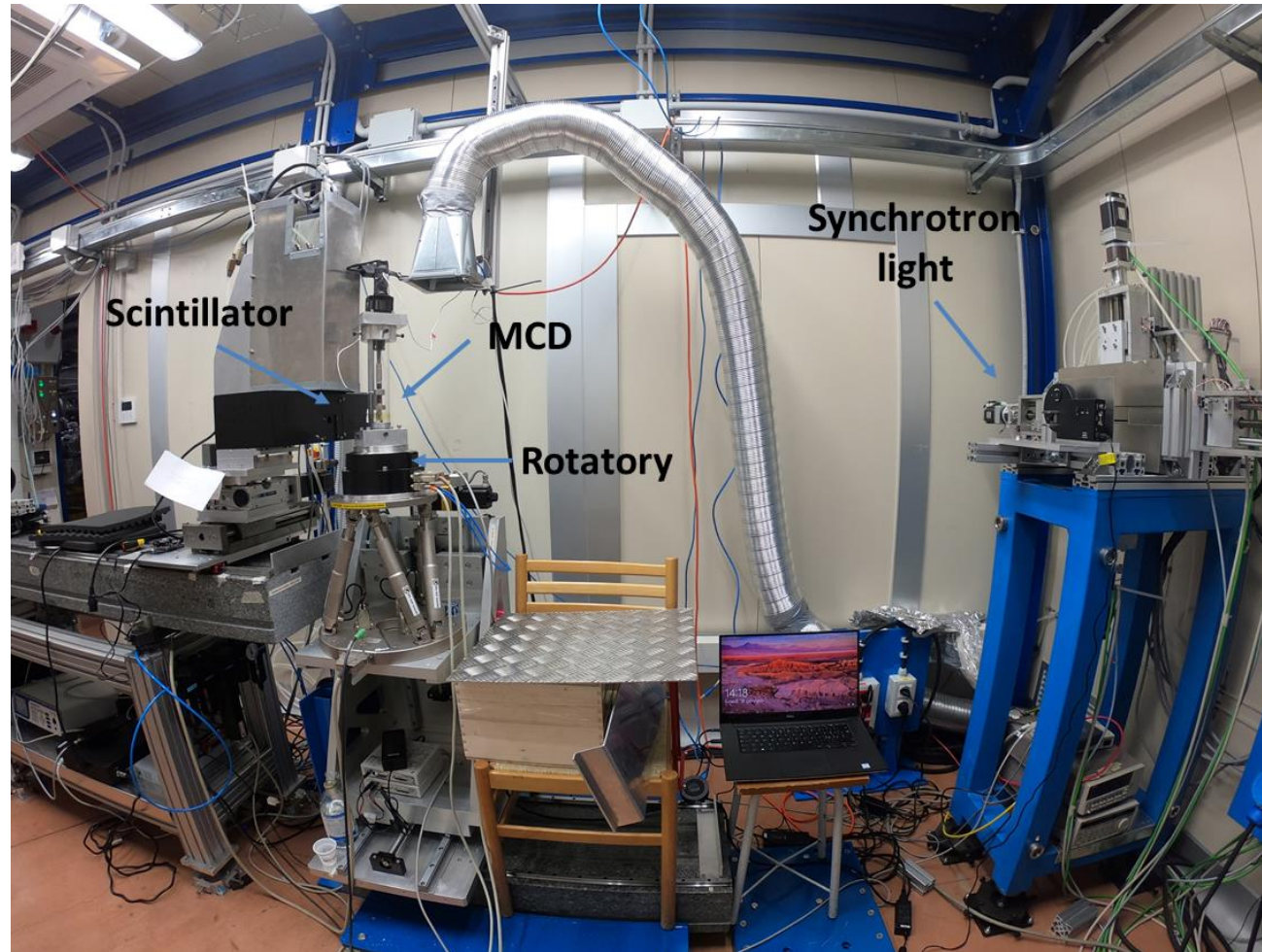
# Project 1: GAP

## Experimental section



# Project 1: GAP

## Experimental section



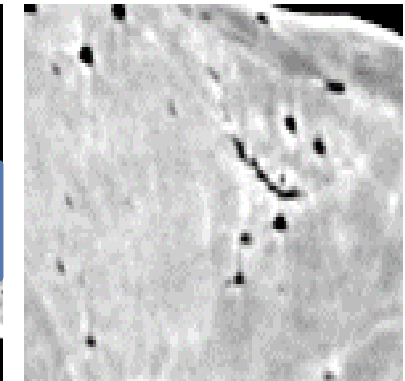
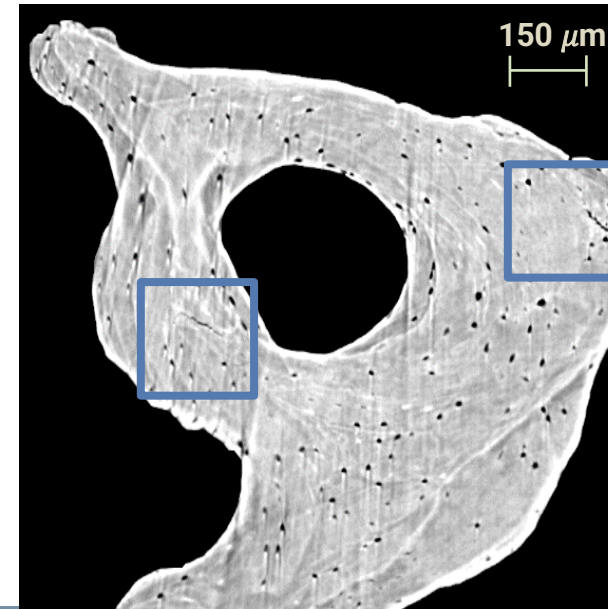
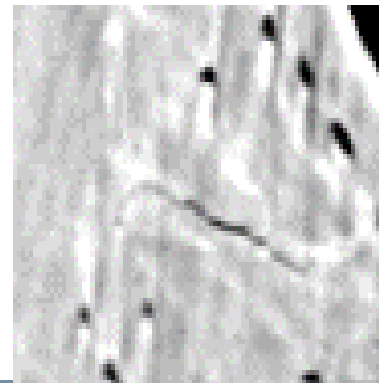
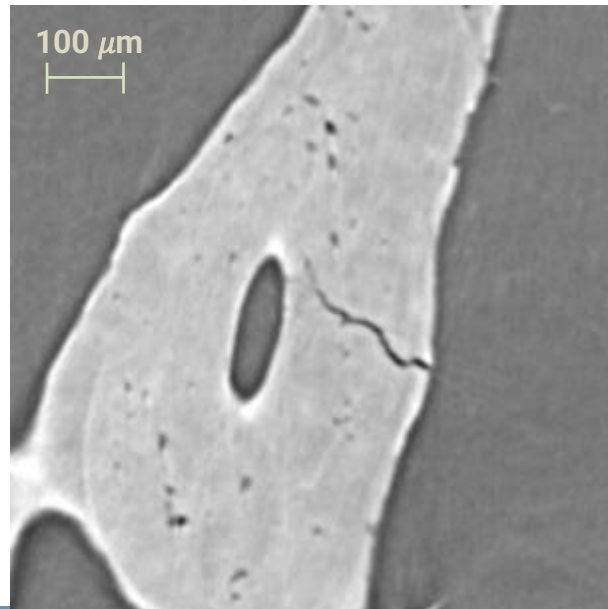
# Project 1: GAP

## Experimental section

Image-Guided Failure Assessment analysis combines the micro-compression test with Synchrotron micro-Computed Tomography to visualise bone internal microstructure, crack initiation, propagation and interaction with the lacunar network.

### Experimental observations

- Crack initiation: inner bone tissue and trabecular boundaries



HEALTHY



OSTEOPOROTIC

# Expected conclusion

## Further developments

Image-Guided Failure Assessment analysis combines the micro-compression test with Synchrotron micro-Computed Tomography to visualise bone internal microstructure, crack initiation, propagation and interaction with the lacunar network.

### Experimental observations

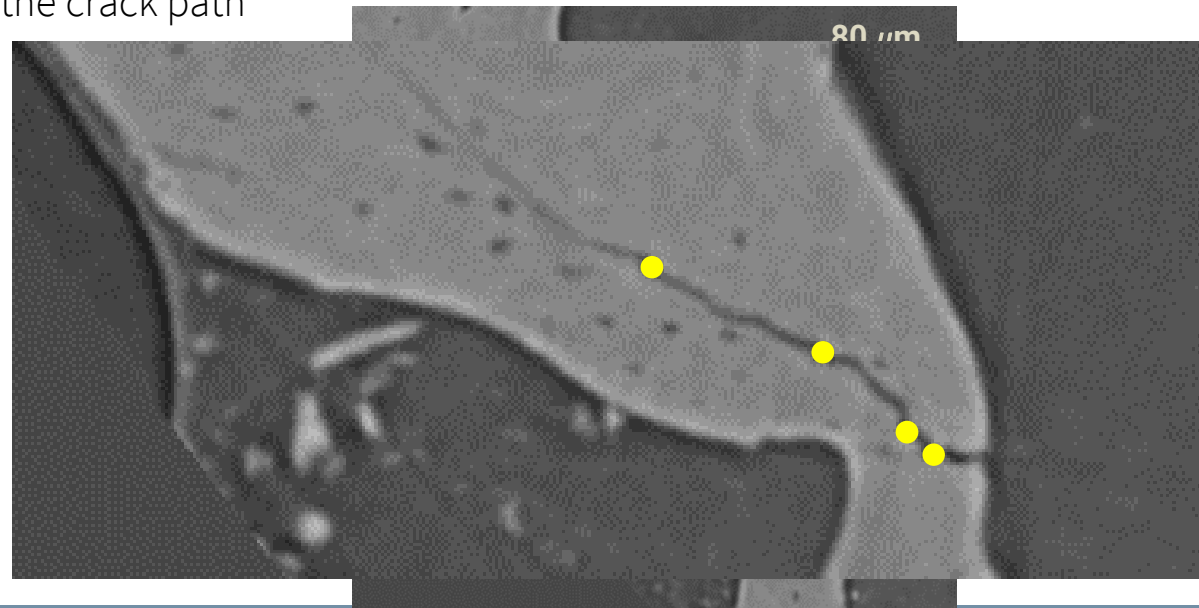
- Crack initiation: **inner bone** tissue and **trabecular boundaries**
- **Lamellar interfaces**: sites influencing crack initiation and propagation
- **Lacunar network** influences the crack path



HEALTHY



OSTEOPOROTIC



# Expected conclusion

## Further developments

Image-Guided Failure Assessment analysis combines the micro-compression test with Synchrotron micro-Computed Tomography to visualise bone internal microstructure, crack initiation, propagation and interaction with the lacunar network.

### Experimental observations

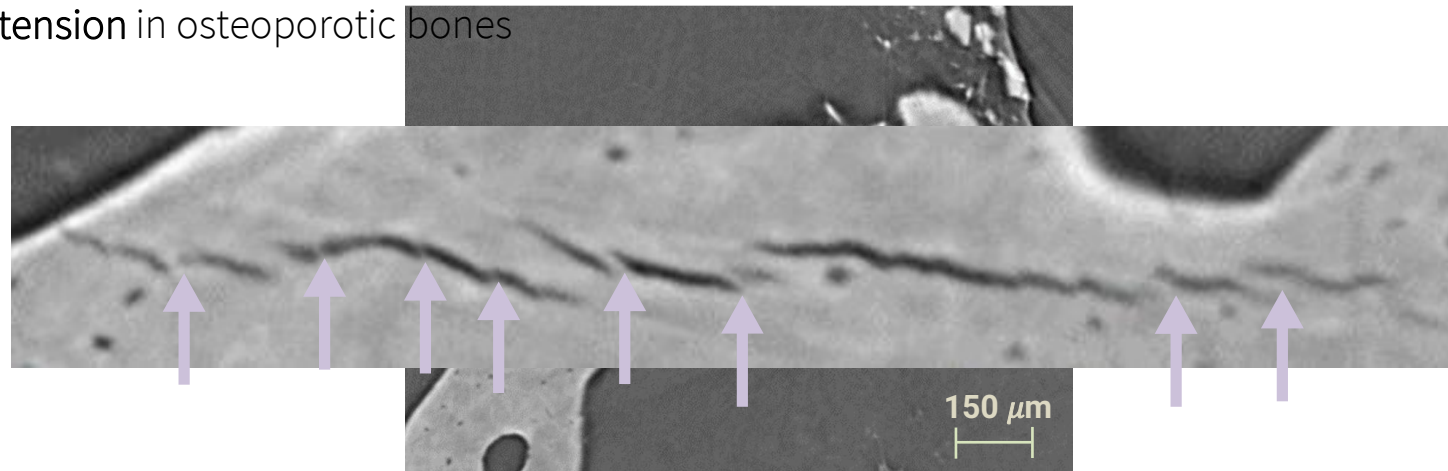
- Crack initiation: inner bone tissue and trabecular boundaries
- Lamellar interfaces: sites influencing crack initiation and propagation
- Lacunar network influences the crack path
- Ligament bridging as toughening mechanism
- Higher crack vertical extension in osteoporotic bones



HEALTHY



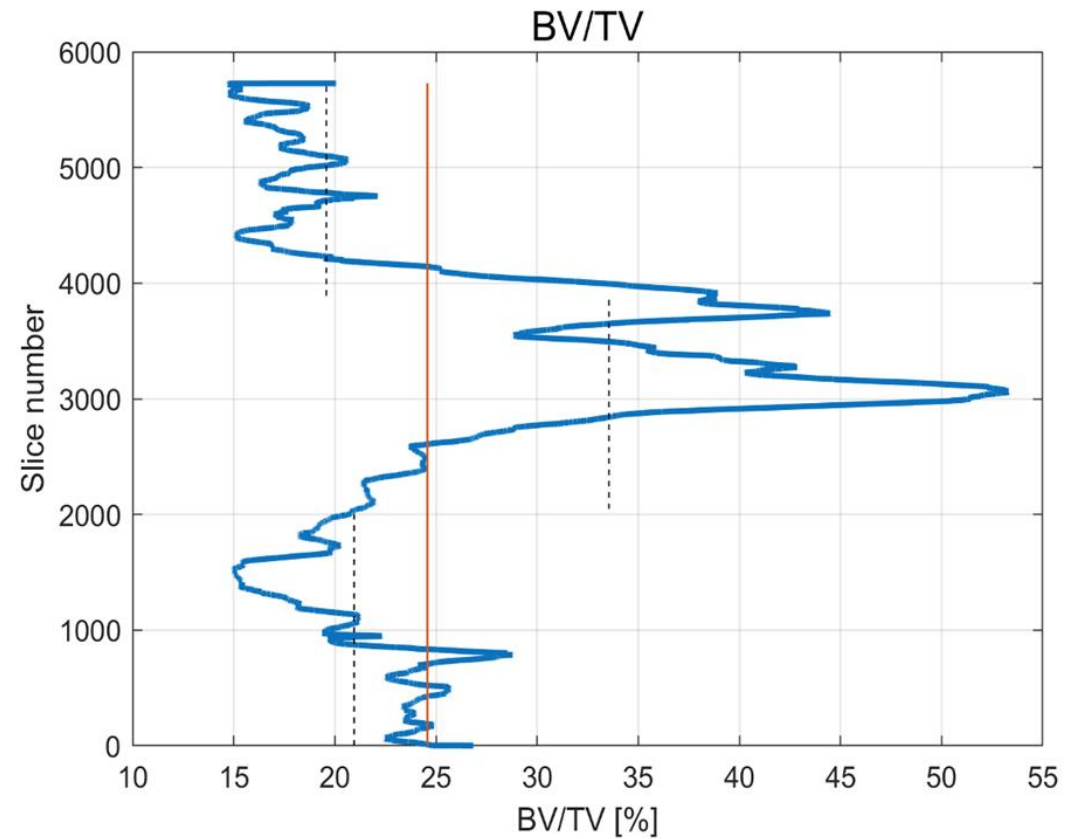
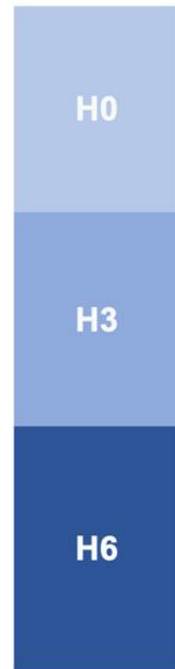
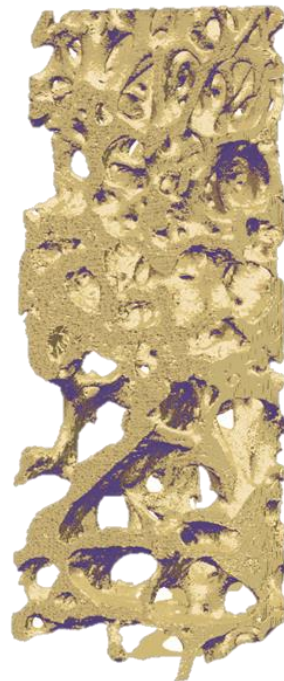
OSTEOPOROTIC



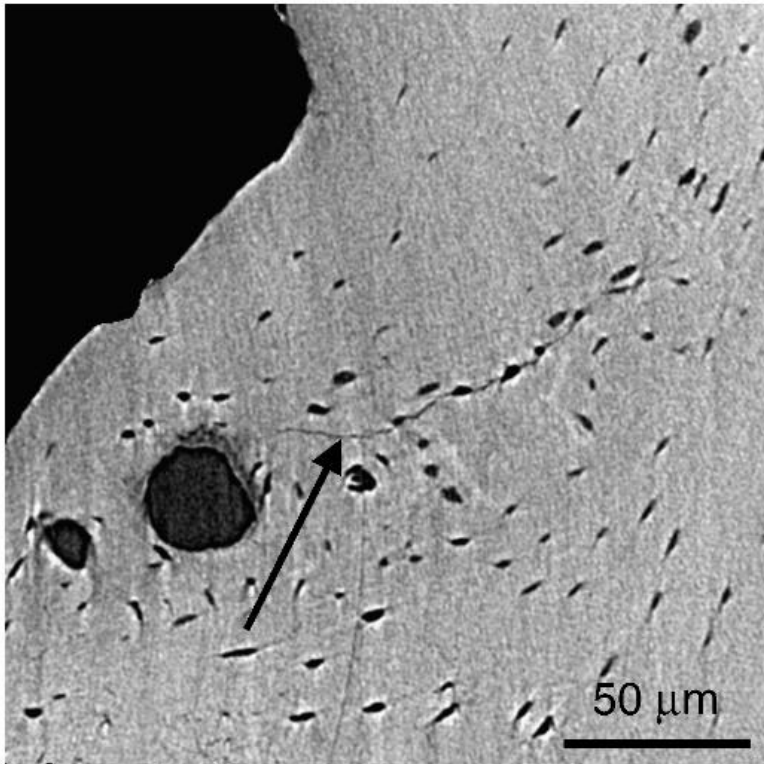
# Expected conclusion

## Further developments

Tomographic images are processed with reconstruction, filtering and stitching procedures to obtain a 3D model of the entire sample, from which the Bone Volume fraction, Bone Volume over Total Volume (BV/TV), is computed.

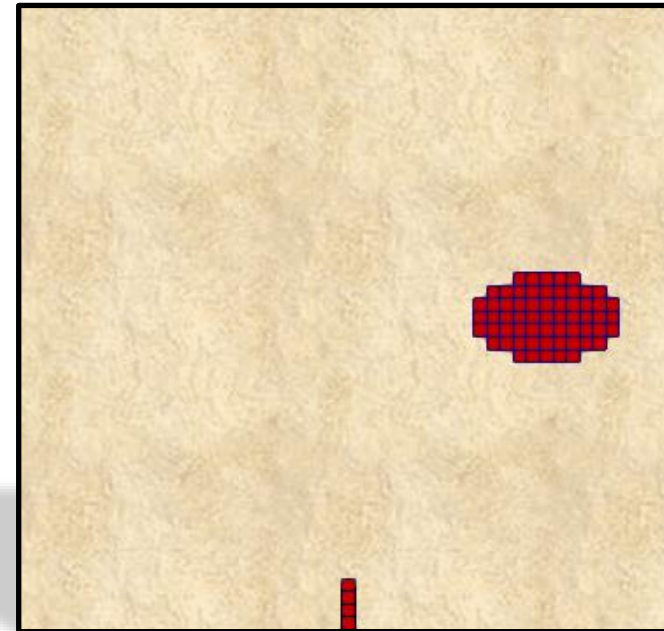


More than 20 000 lacunae/mm<sup>3</sup>



Readapted from Voide et al. (2011)

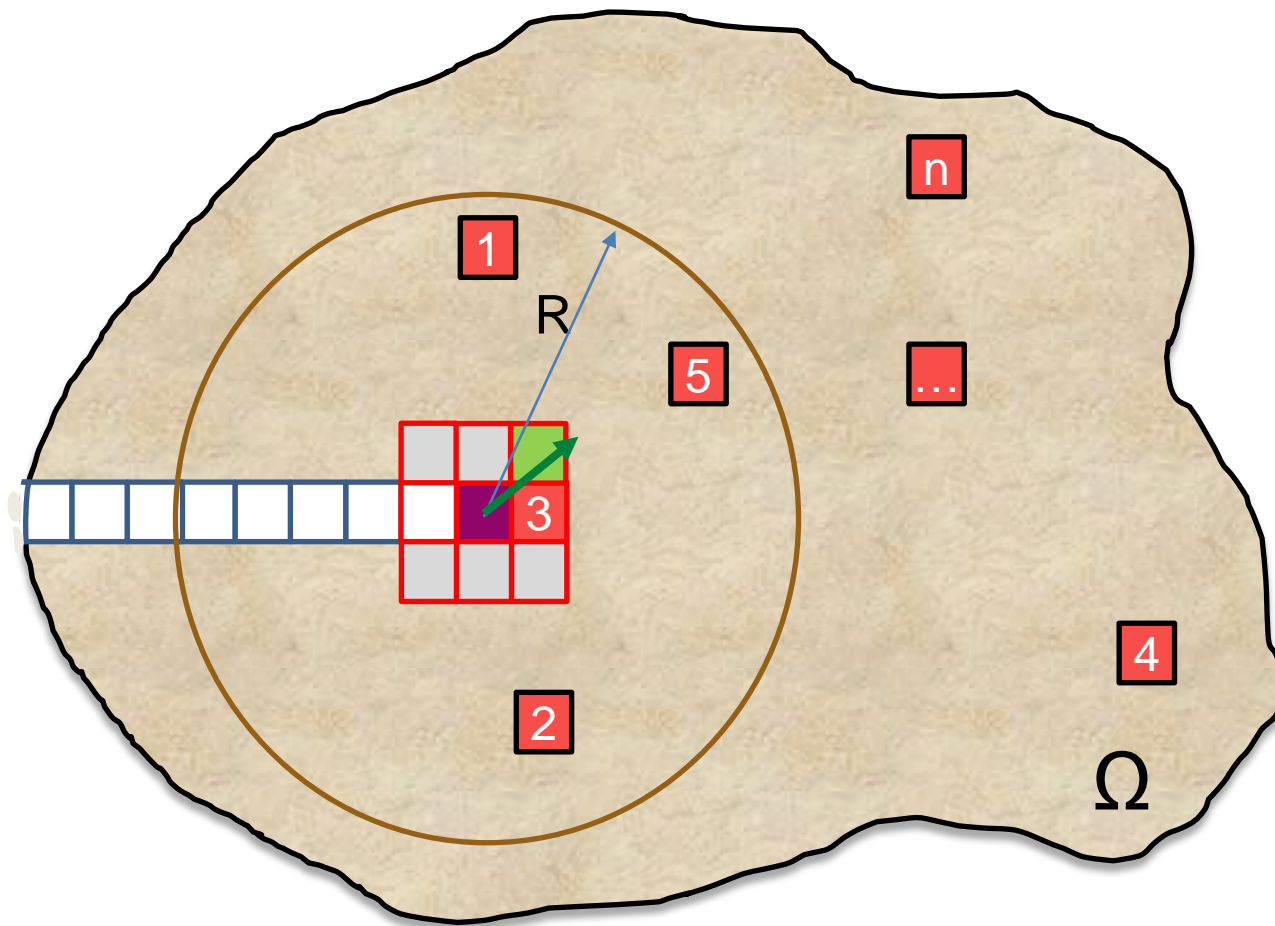
**2 hypothesis:**



Artificial Damage

Lacuna

Bone



- Critical voxels
- Tip
- Sensing region
- Deletion direction vector
- Deleted voxels

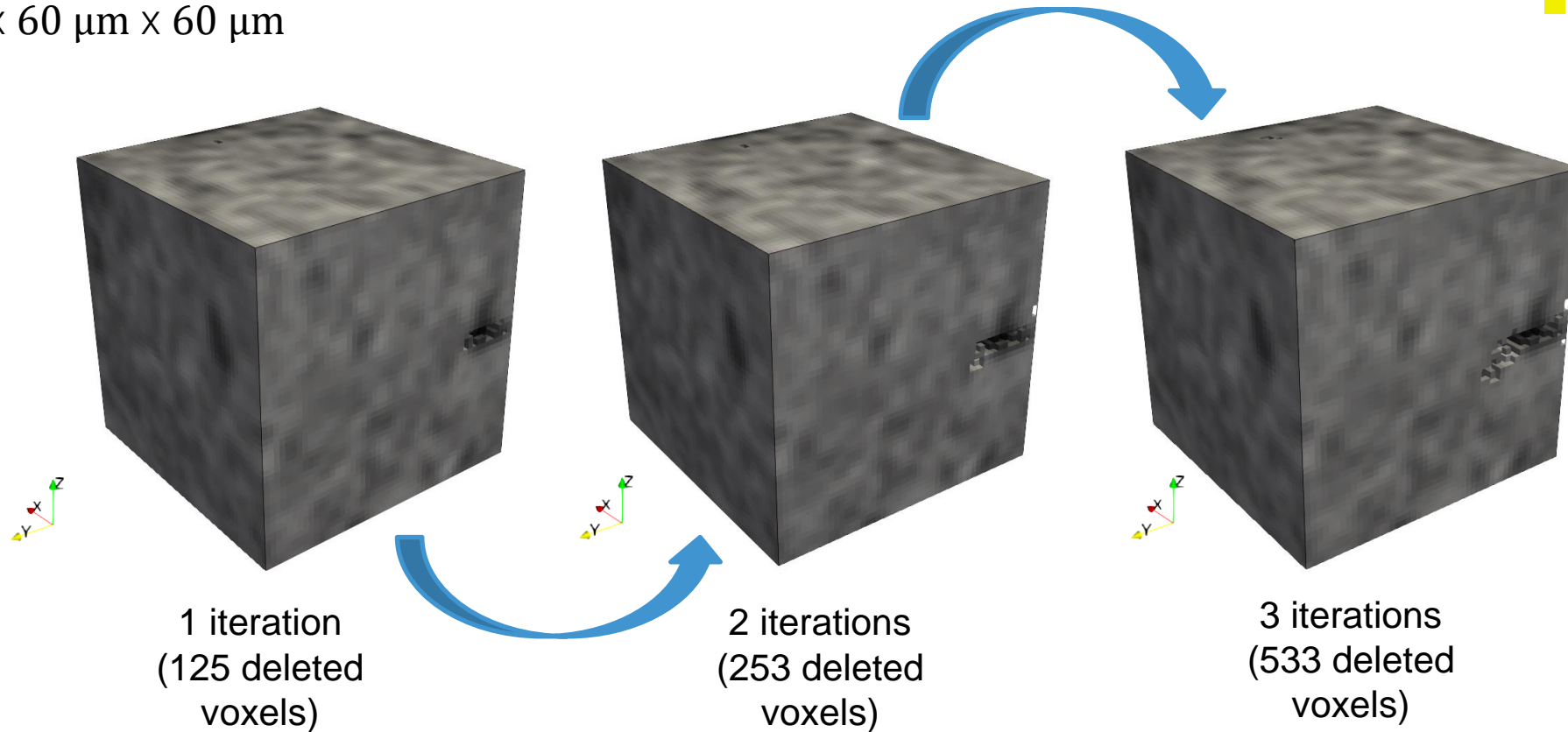


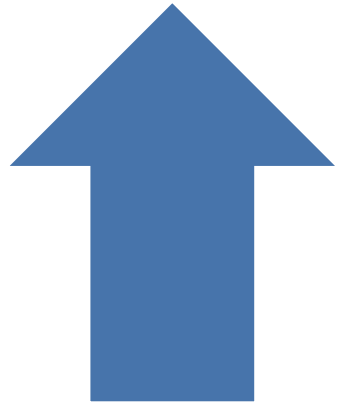
# Project 1: GAP

## Computational section

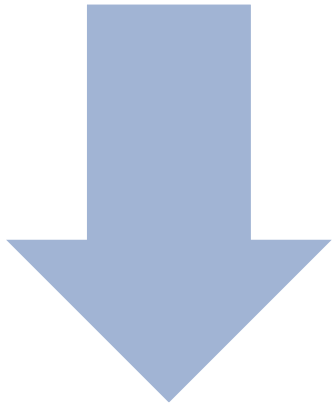
ROI:  $60\ \mu\text{m} \times 60\ \mu\text{m} \times 60\ \mu\text{m}$

■ Damage  
■ Lacunae





Attraction to lacunae  
Second stress limit



Computational time  
increases at every  
iteration

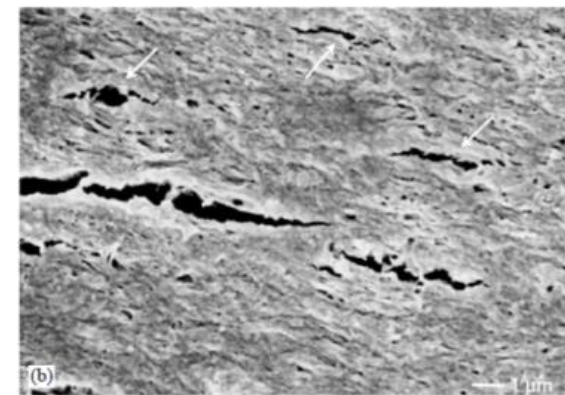
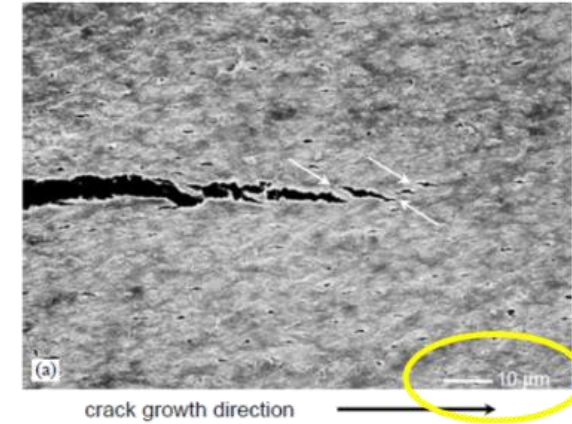
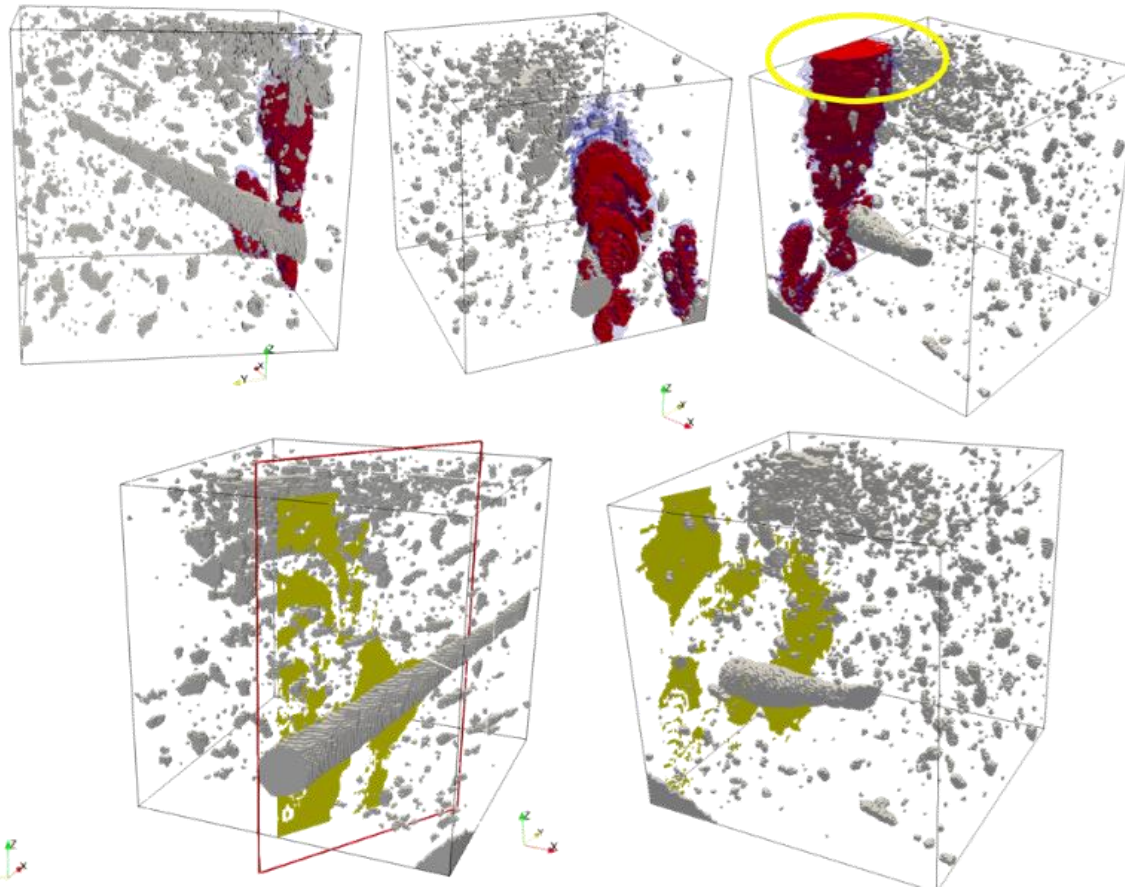
The effect of  
canaliculi is not  
considered

### Crack front model

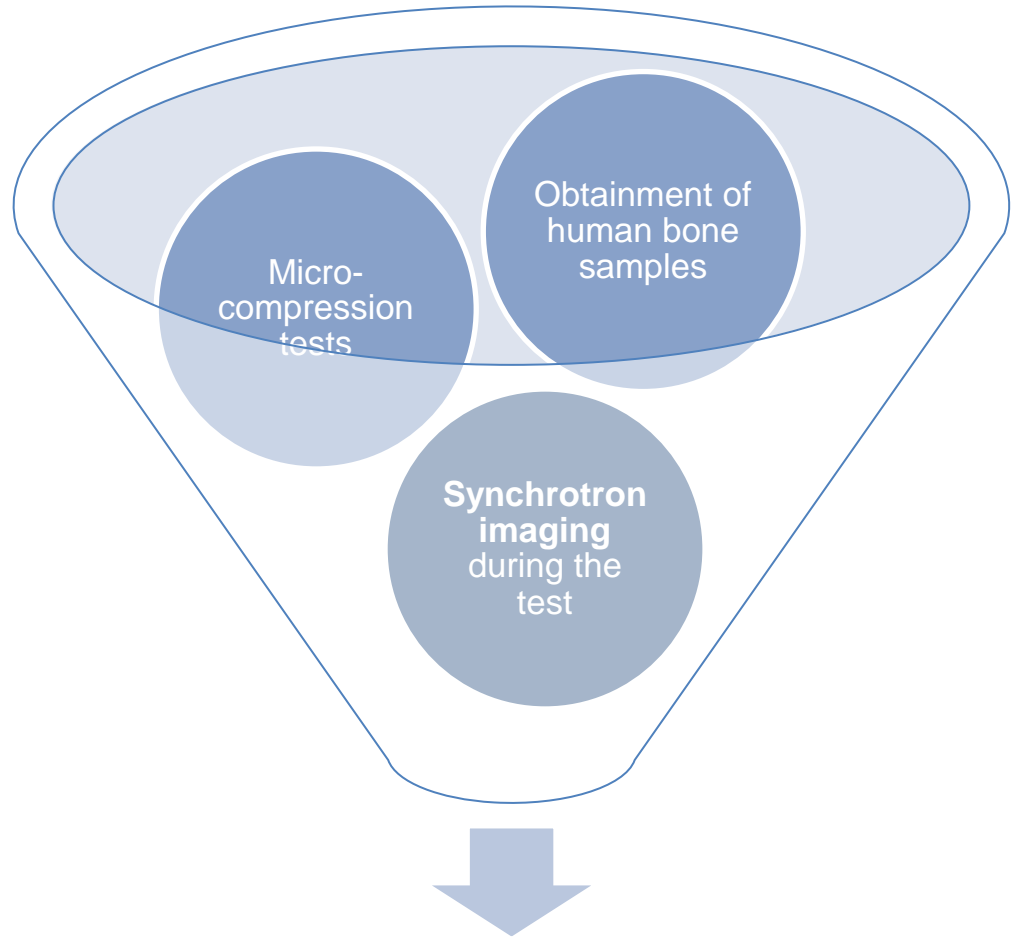


# Project 1: GAP Computational section

## Progressive damage model



# Project 1: GAP Validation



Experimental validation of computational models