3D Printing and the New Materials in Medicine

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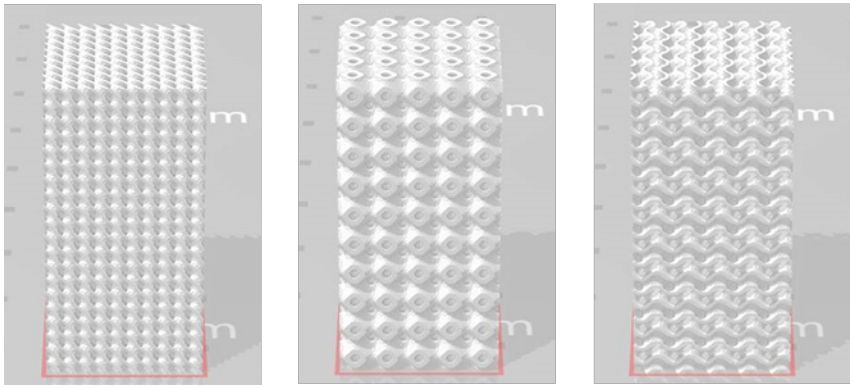
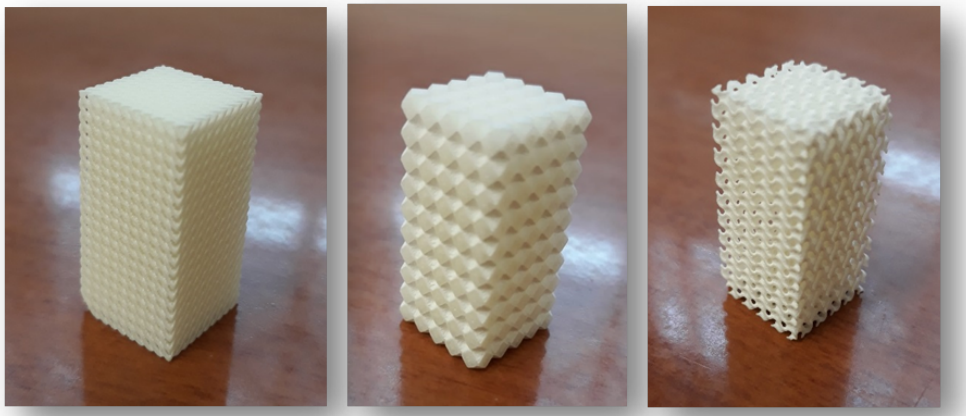
3D PRINTING

- 3D printing or additive manufacturing is a process of making 3D objects from a digital file.
- The creation of a 3D printed object is achieved using additive processes.
  - Laying down successive layers of material until the object is finalised.
  - Each of these layers can be seen as a thinly sliced cross-section of the object.

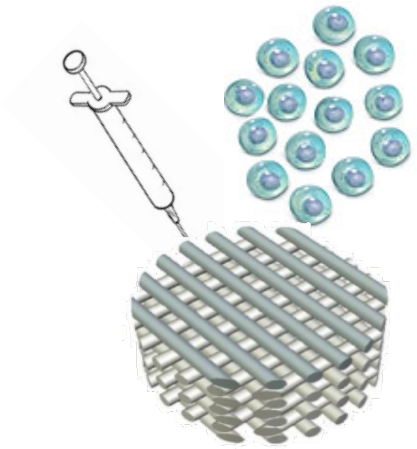
3D PRINTING

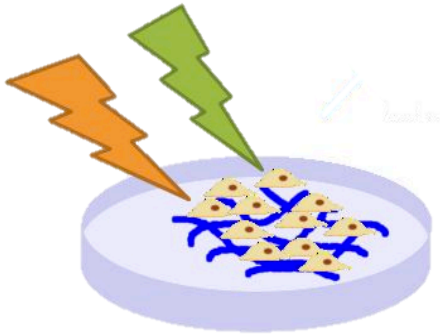




TISSUE ENGINEERING

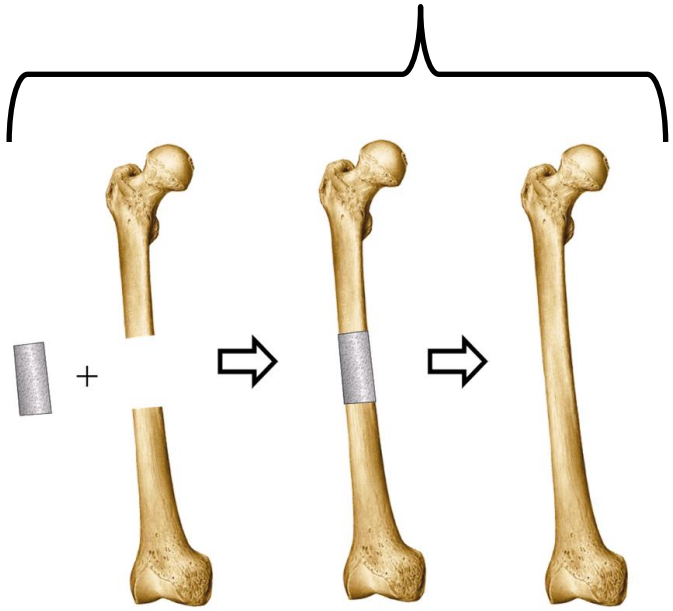
- The goal of Tissue Engineering (TE) is to design and assemble functional constructs that restore, maintain, or improve damaged tissues.
  - TE combines scaffolds, cells, and biologically active molecules into functional tissues.
  - Scaffolds are used in TE as hosts for cell seeding and proliferation





TISSUE ENGINEERING

- 3D printing and TE are often related
  - Research has been focused on finding the best scaffold for each specific application, depending mainly on:
    - Geometry/design
    - Mechanical properties
    - Biodegradation rate
  - Computer methods are essential to start (and evaluate) the process

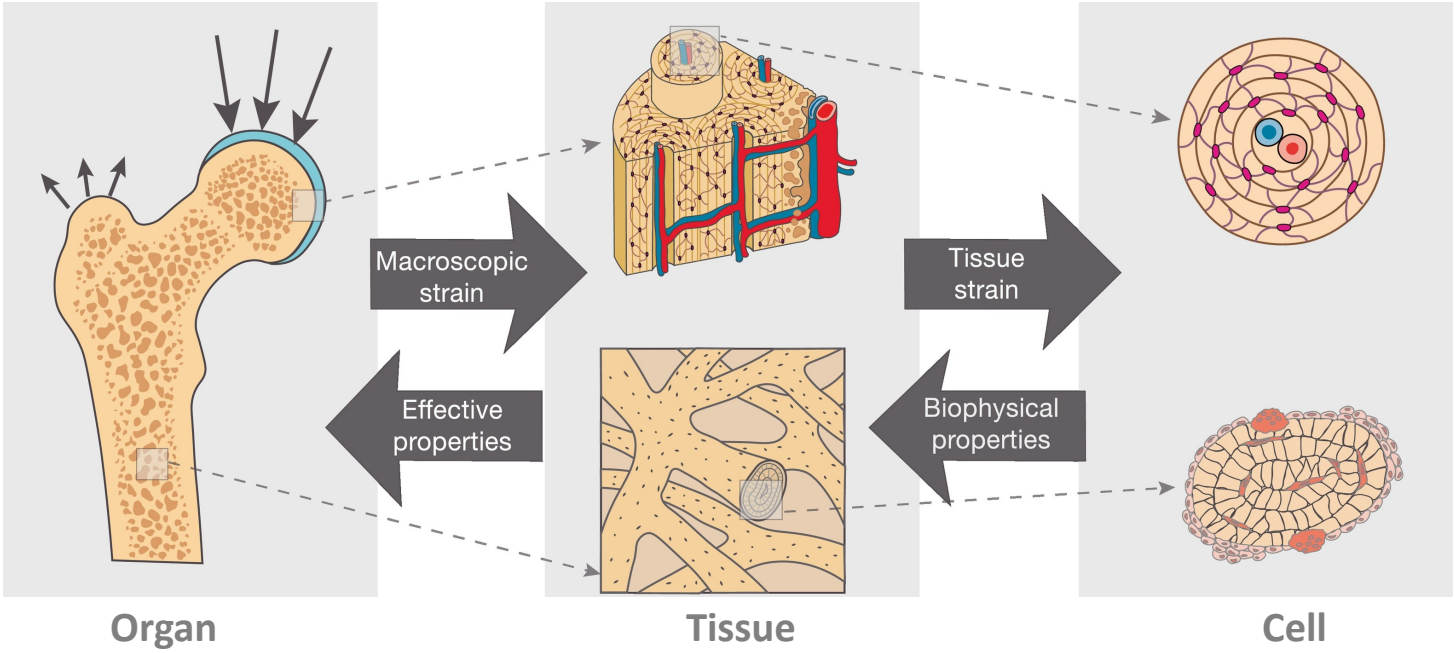


TISSUE ENGINEERING

- Computational modelling ensures geometrical accuracy for the implants
- Numerical simulation allows for the prediction of tissue response upon implantation:
  - Cell differentiation and profileration
  - Biodegradation/biointegration
  - Mechanical overloading
  - Bone remodelling/healing

MECHANOBIOLOGY

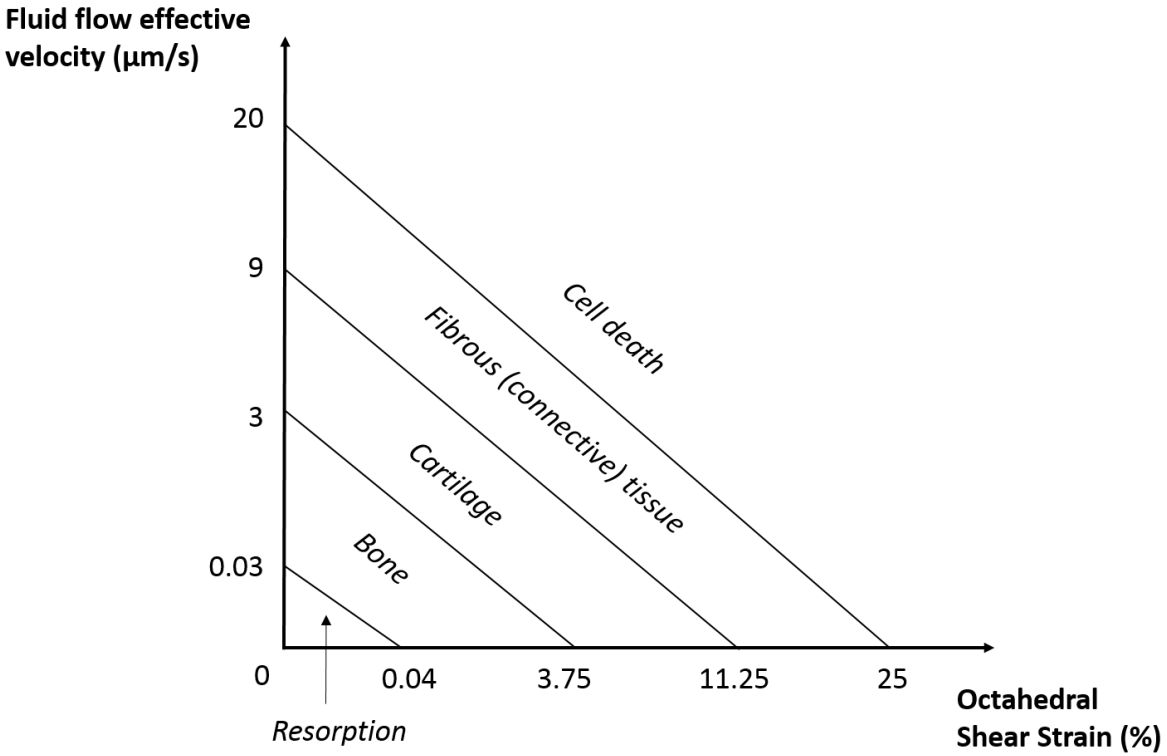
- Cells respond to both biochemical and biophysical stimuli, across different levels:



Adapted from Garcia-Aznar et al., 2021

MECHANOBIOLOGY

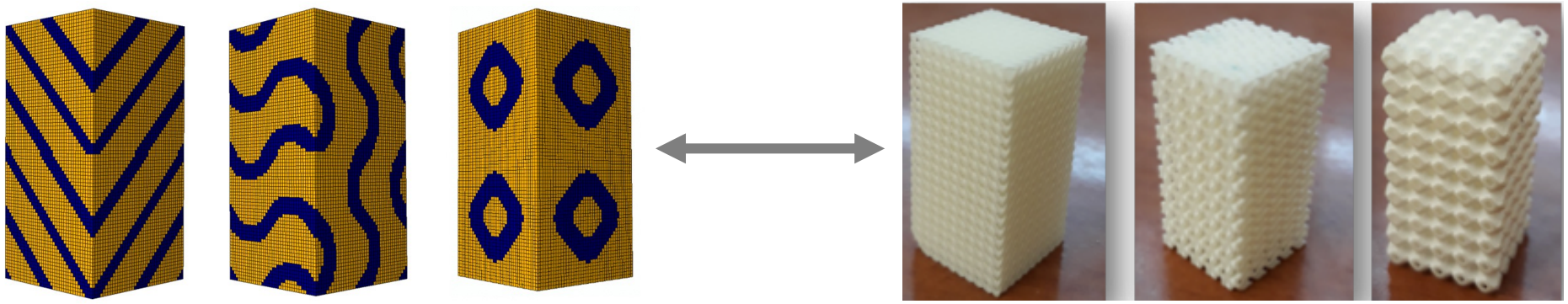
- It is then possible to go from the macromechanical stimuli to the micromechanical responses of the cells:



Mechano-regulatory pathway diagram from Lacroix and Prendergast (2002), updated by Castro and Lacroix (2018)

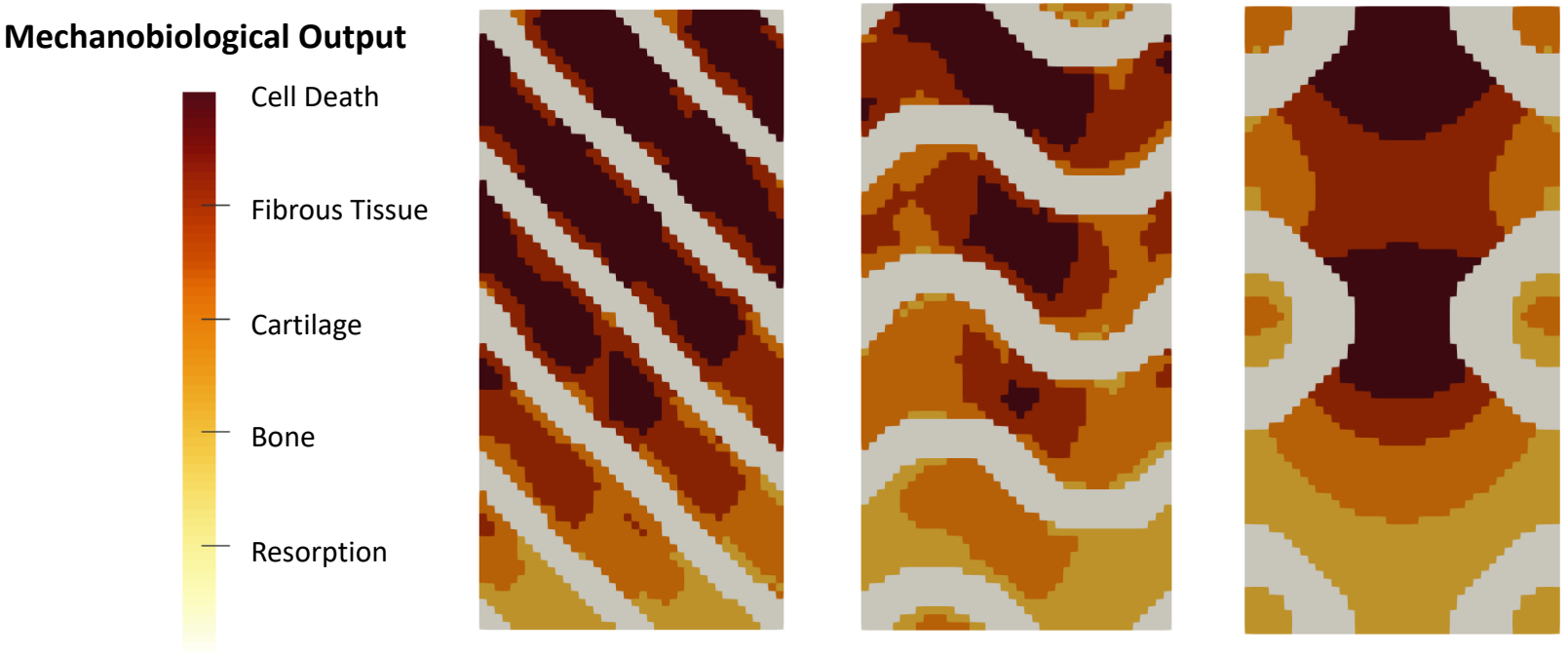
IMPLANT DESIGN

- With 3D Printing, it is possible to fabricate the most adequate structures to each situation:
  - Constant feedback for design requirements
  - Evaluation of materials



IMPLANT DESIGN

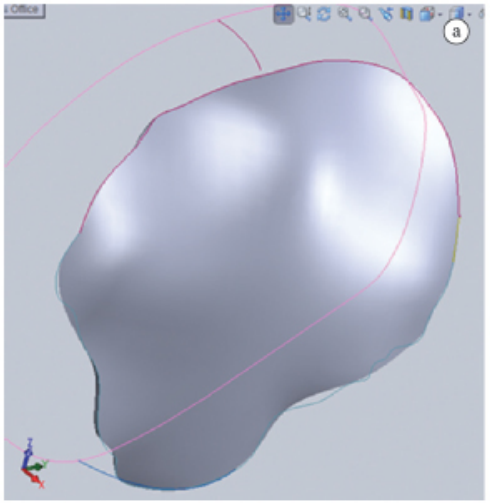
- With 3D Printing and numerical simulation, it is possible to predict the mechanobiology environment:

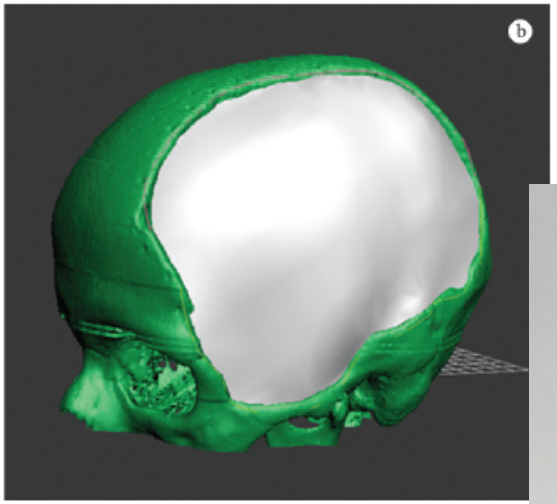


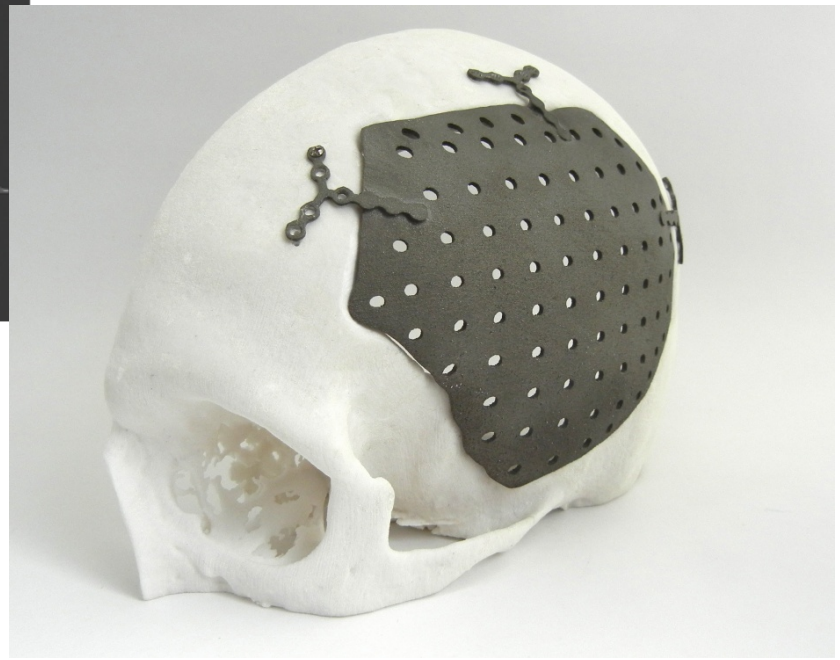
Adapted from Castro et al., 2020

IMPLANT DESIGN

- From 3D modelling to fabrication:

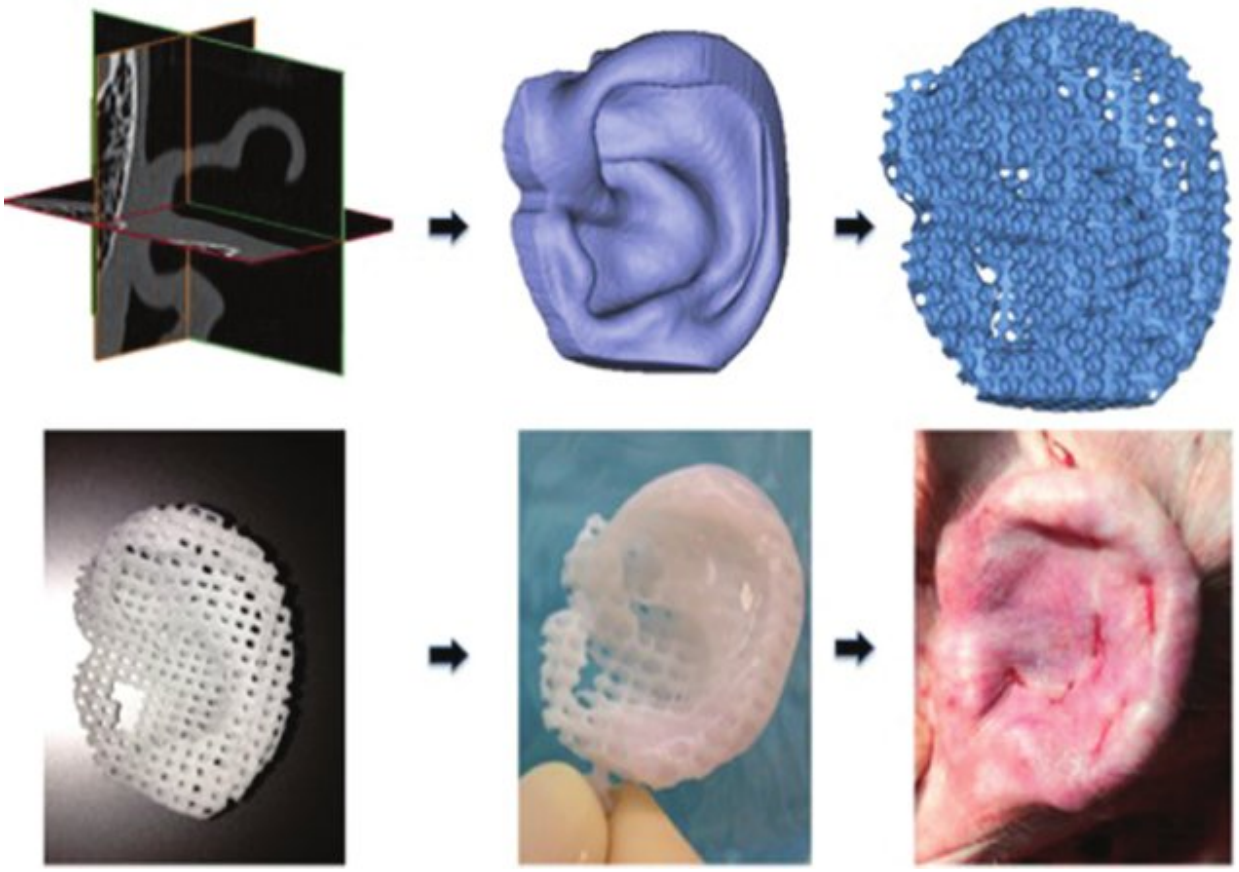






IMPLANT DESIGN

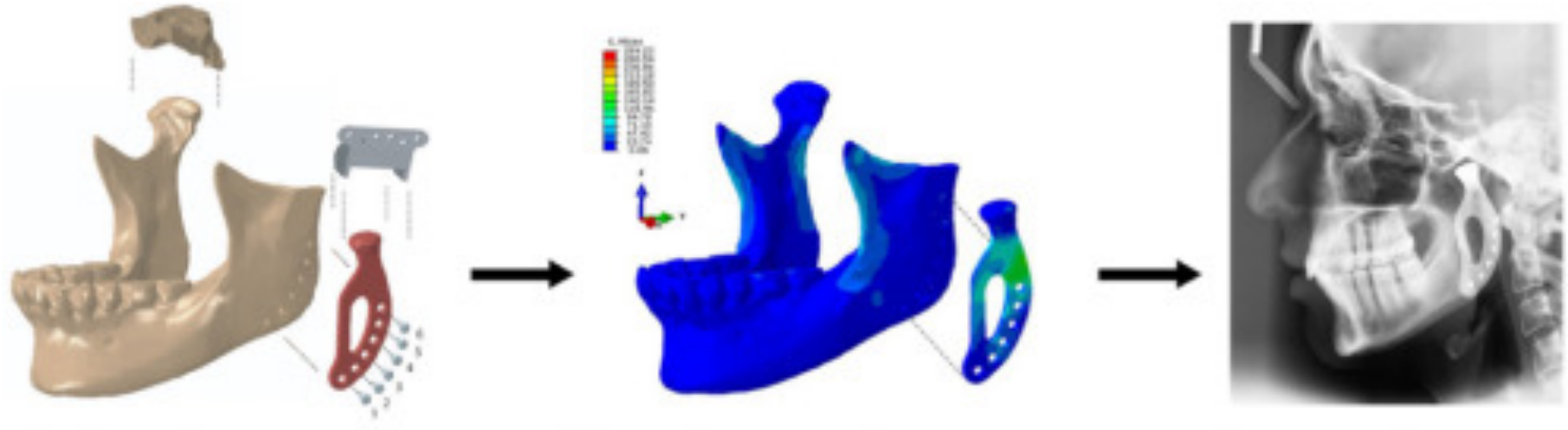
- From medical imaging to implantation:



Adapted from Zopf et al., 2014

IMPLANT DESIGN

- From 3D modelling to implantation:



Adapted from Ackland et al., 2017

CONCLUSIONS

- Different techniques come together towards better (than ever) biomedical devices:
  - ➢ Tissue Engineering & Mechanobiology predict what is needed to replace a tissue or promote its regeneration
  - ➢ Implant Design starts in medical imaging and goes through numerical simulation before reaching the fabrication stage
  - ➢ 3D Printing allows for the accurate fabrication of the solutions
- New materials and designs result from this integrated framework

ACKNOWLEDGEMENTS

✓ Thank you for your attention!

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