Additive Layer Manufacture for Healthcare Applications

Professor Kenny Dalgarno
School of Mechanical and Systems Engineering
Newcastle University

Outline

- Look at the application of additive manufacturing techniques in two healthcare applications:
  - Foot and ankle-foot orthoses
  - Tissue engineering for osteoarthritis

Newcastle University

Foot and ankle-foot orthoses

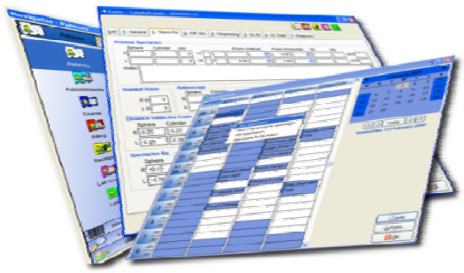
a-footprint

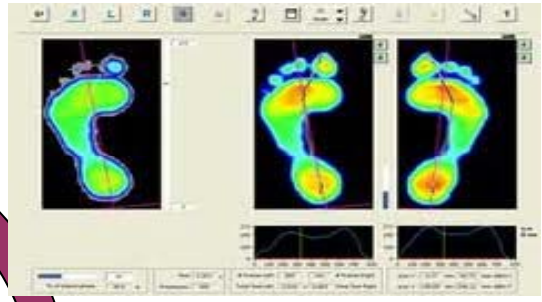
www.afootprint.eu

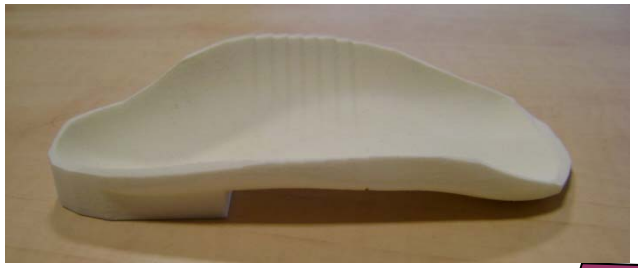
Ankle & Foot Orthotic Personalisation via Rapid Manufacturing
NMP2-SE-2009-228893 led by Jim Woodburn at GCU

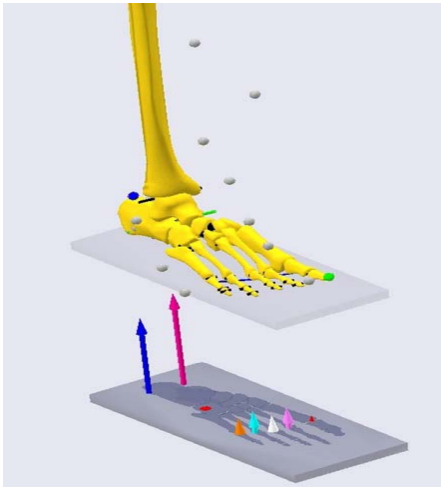
Newcastle University

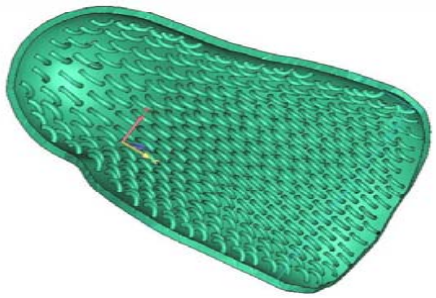
a-footprint integrated model





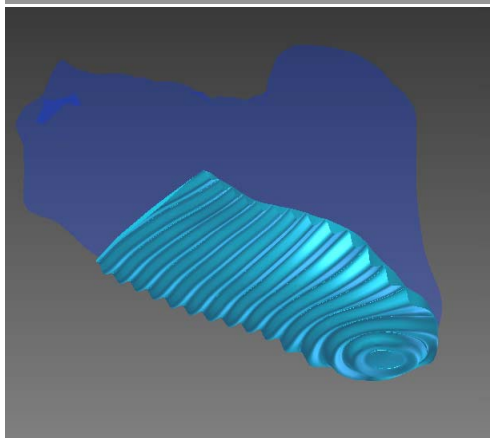


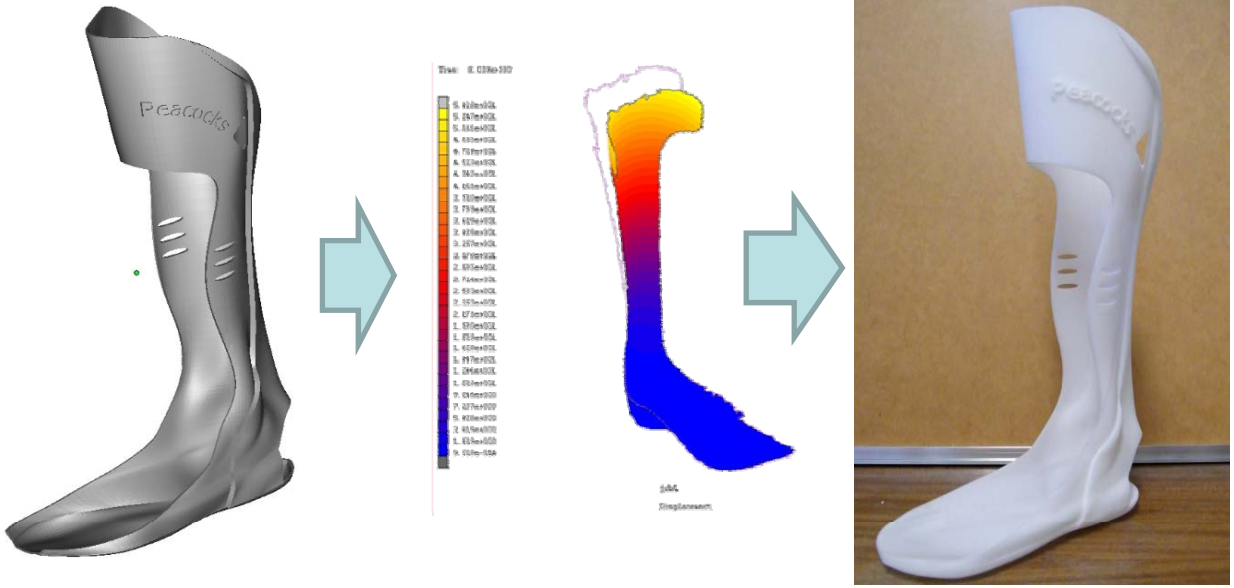




Newcastle University

Why additive manufacture?





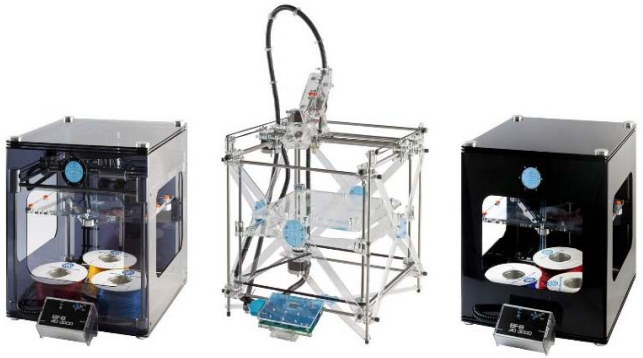
Newcastle University

About Additive Manufacturing

- High end
  > €200k

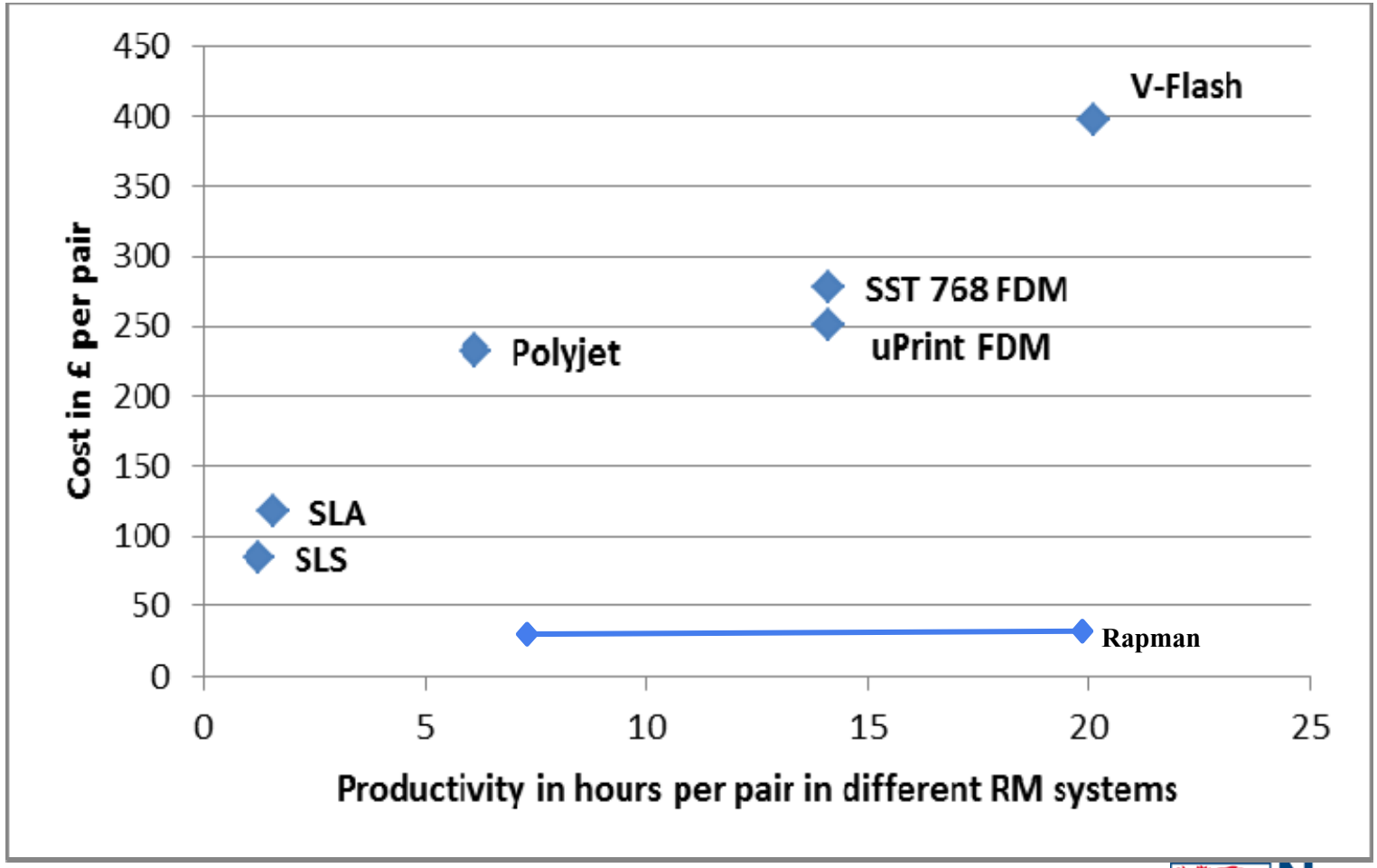
- Mid-moderate
  €20k – €200k

- Low cost
  €1k - €20k



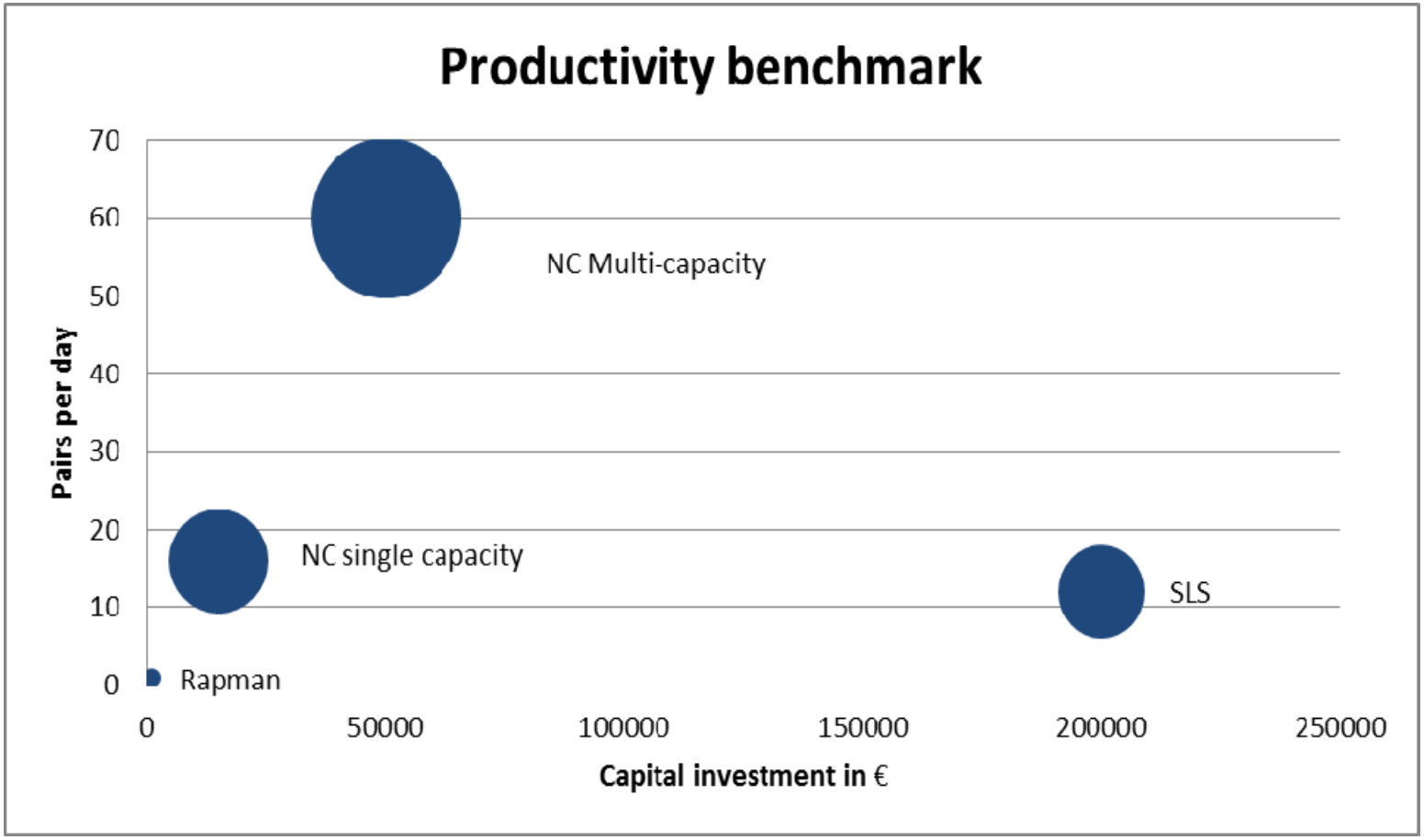
Newcastle University

Benchmarking Machines for FOs



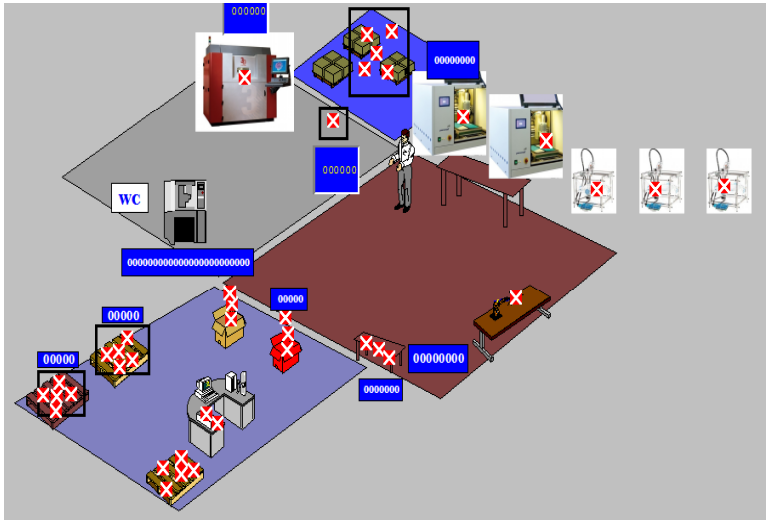
Newcastle University

How does it compare to machining?



Newcastle University

Best of both worlds – hybrid approach

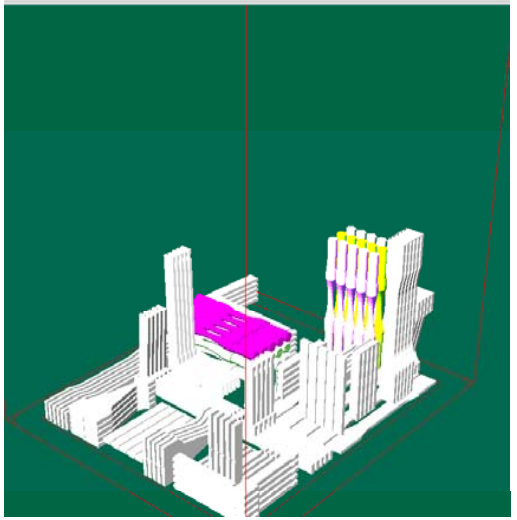


Newcastle University

Need a Quality System

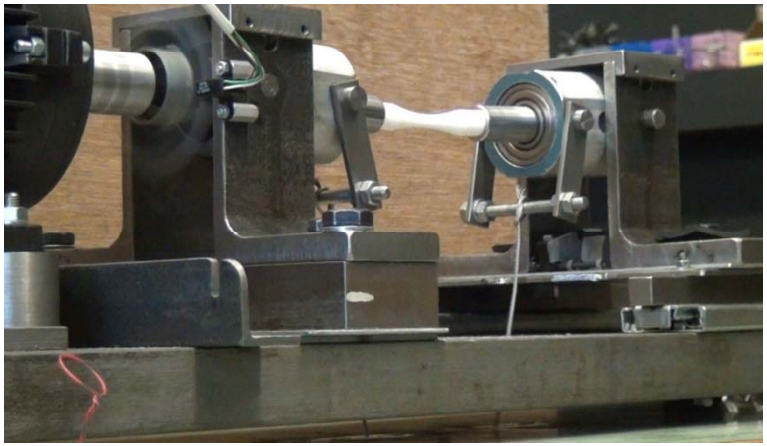
Quality Assurance System being developed as part of demonstrator facility based at Peacocks Medical Group – what's the minimum you can measure to be sure an SLS build is good?

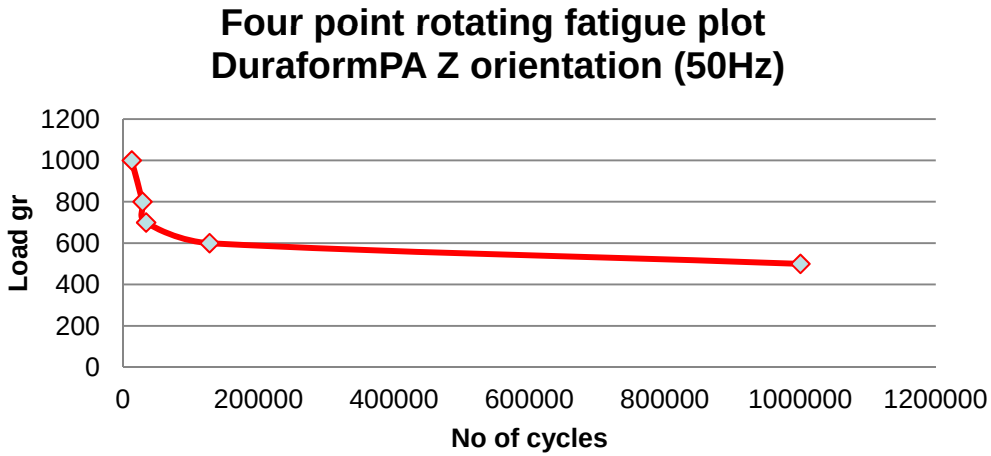
- Powder management & control
- On-site benchmark part mechanical testing

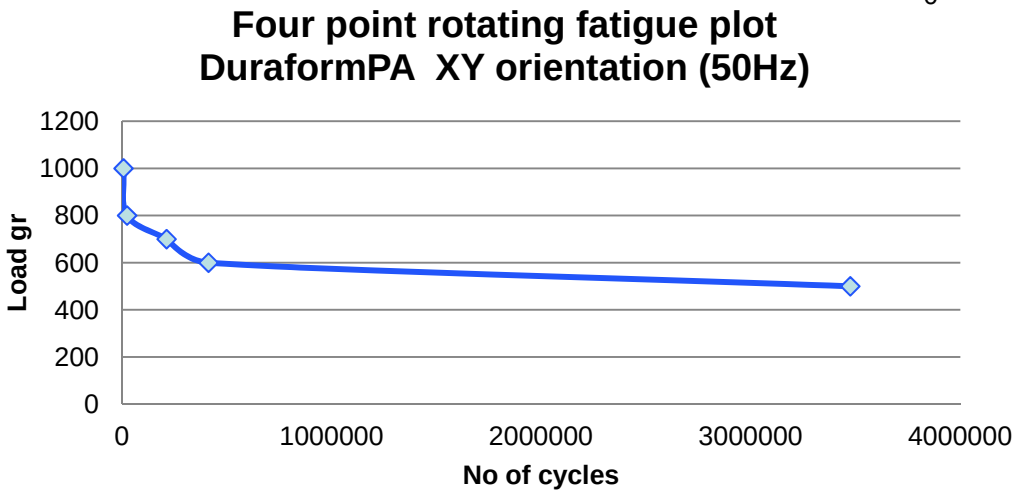


Newcastle University

Fatigue







Newcastle University

Tissue Engineering

- Two projects:
  - Arthritis Research UK Tissue Engineering Centre
    - Led by Andrew McCaskie at Newcastle University
    - Aim to provide practical tissue engineering solutions for bone/cartilage interface
  - Restoration, FP7-NMP-2011-SME-5-280575

RESTORATION

Resorbable Ceramic Biocomposites for Orthopaedic and Maxillofacial Applications

Arthritis Research UK

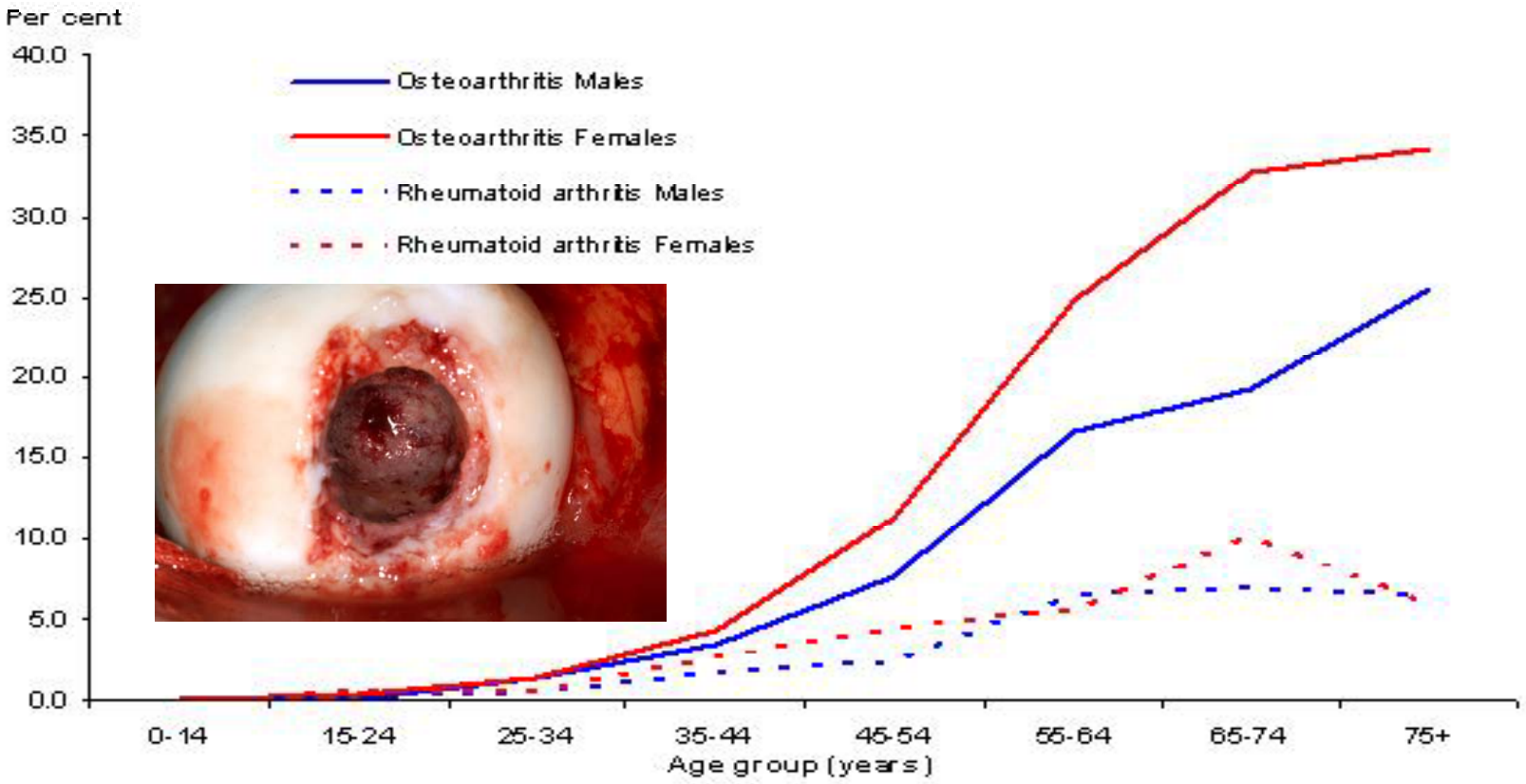
Newcastle University

University of Aberdeen

Keele University

The University of York

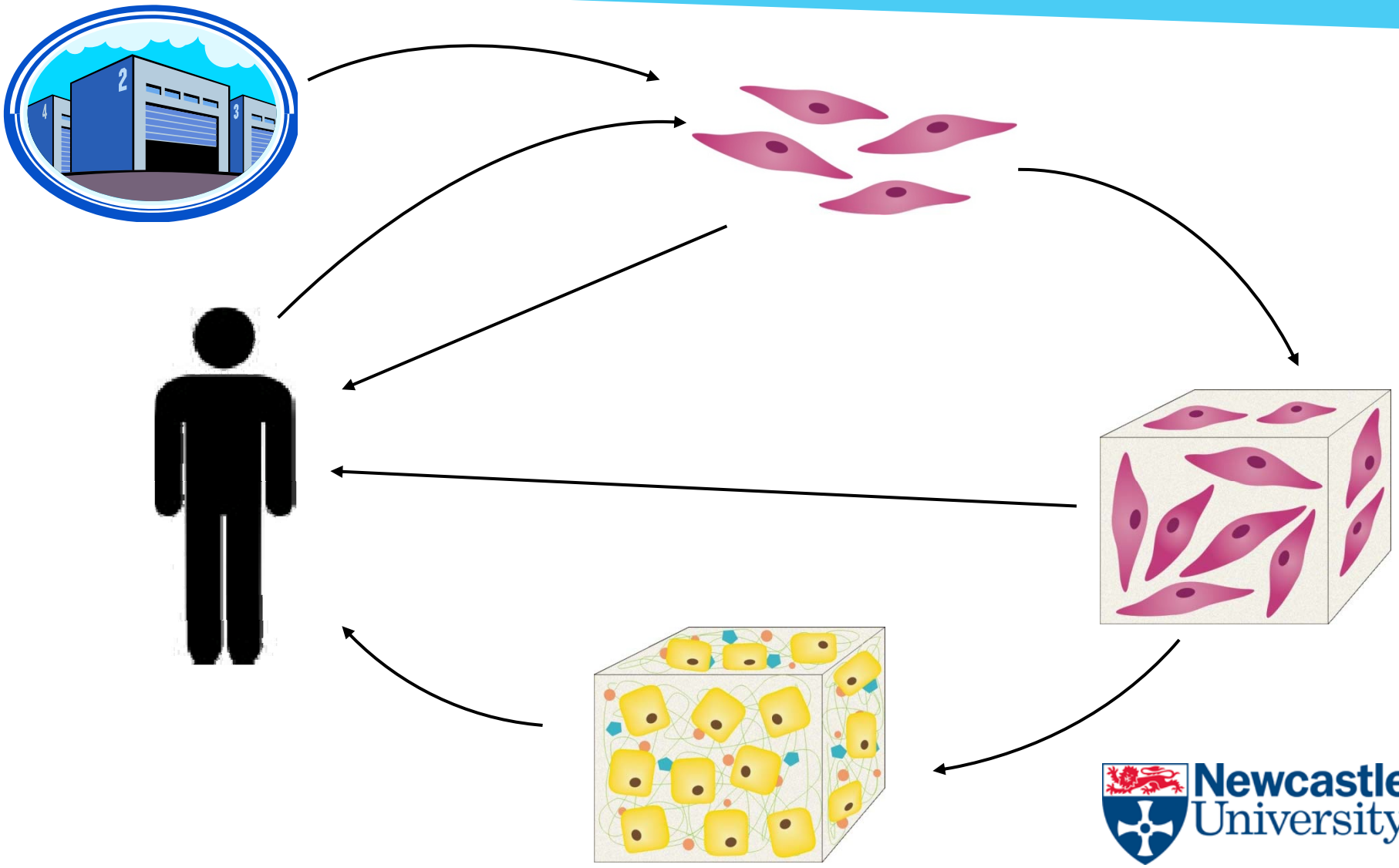
Osteoarthritis



Age-specific prevalence of osteoarthritis and rheumatoid arthritis, Australia, 2004-05
Source: AIHW analysis of ABS 2004-05 National Health Survey.

Newcastle University

How might tissue engineering work in practice?



What does “practical” tissue engineering mean?

- For most people: early stage interventions with injectable or minimally invasive approaches
  - small or injectable scaffolds
  - functionally gradient

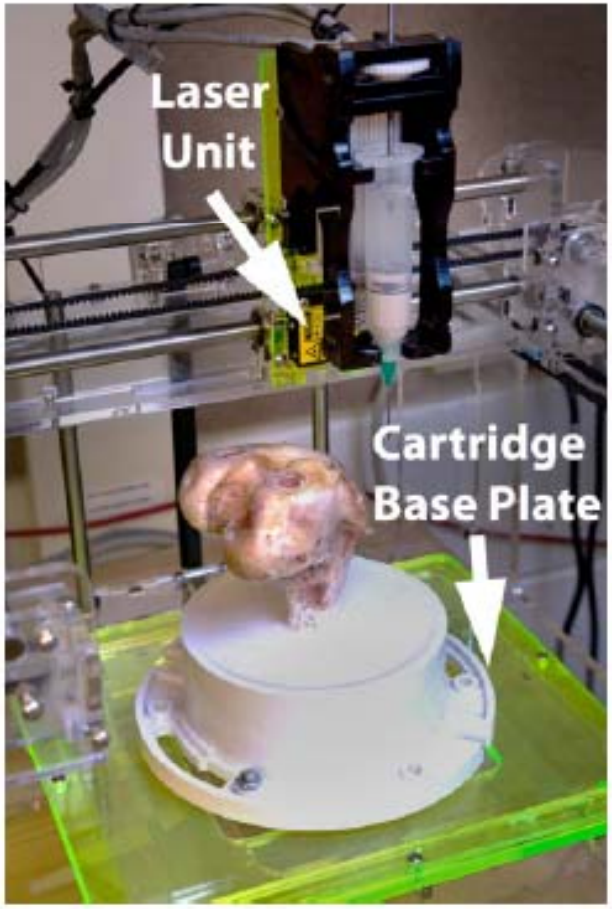
- Where it’s needed, move to larger, probably customised, approaches
  - personalised scaffolds, again functionally gradient

Scaffold Functional Requirements

- Appropriate mechanical properties
- Defined topology – generally highly porous to support tissue integration, cell transport, nutrient supply
- Appropriate surface properties and surface chemistry
- Bioactive: able to resorb at a similar rate to that at which the natural tissue grows
- Bioceramics, biopolymers, and polymer-ceramic biocomposites the starting materials

Newcastle University

Additive manufacture in the knee?



IOP Publishing — Biofabrication

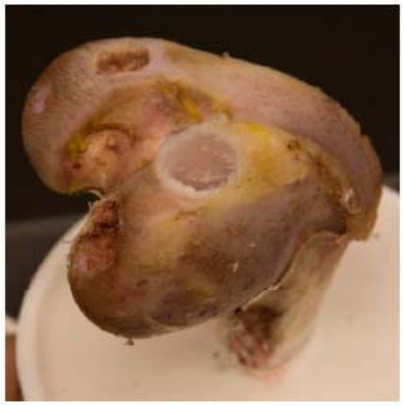
Biofabrication 2 (2010) 035004 (12pp) doi:10.1088/1758-5082/2/3/035004

Additive manufacturing for *in situ* repair of osteochondral defects

Daniel L Cohen[1], Jeffrey I Lipton[1], Lawrence J Bonassar[1,2] and Hod Lipson[1,3,4]

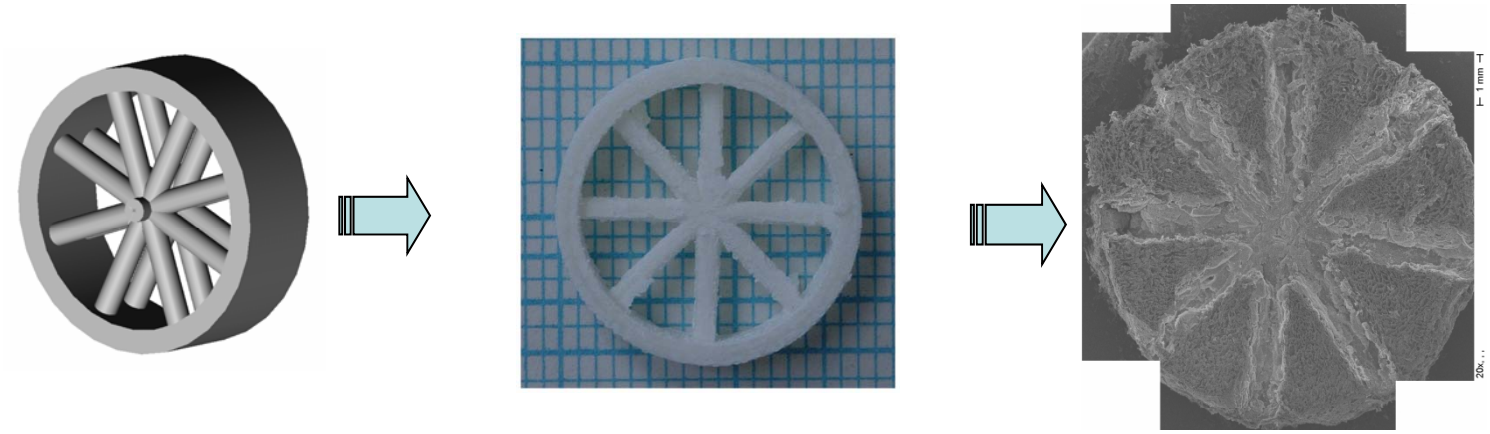
[1] Cornell University, Mechanical and Aerospace Engineering, Ithaca, NY, USA
[2] Cornell University, Biomedical Engineering, Ithaca, NY, USA
[3] Cornell University, Faculty of Computing and Information Science, Ithaca, NY, USA

E-mail: dlc44@cornell.edu, jil26@cornell.edu, lb244@cornell.edu and hod.lipson@cornell.edu



Arthritis Research UK · Newcastle University · University of Aberdeen · Keele University · The University of York

3D Printing Moulds for Collagen



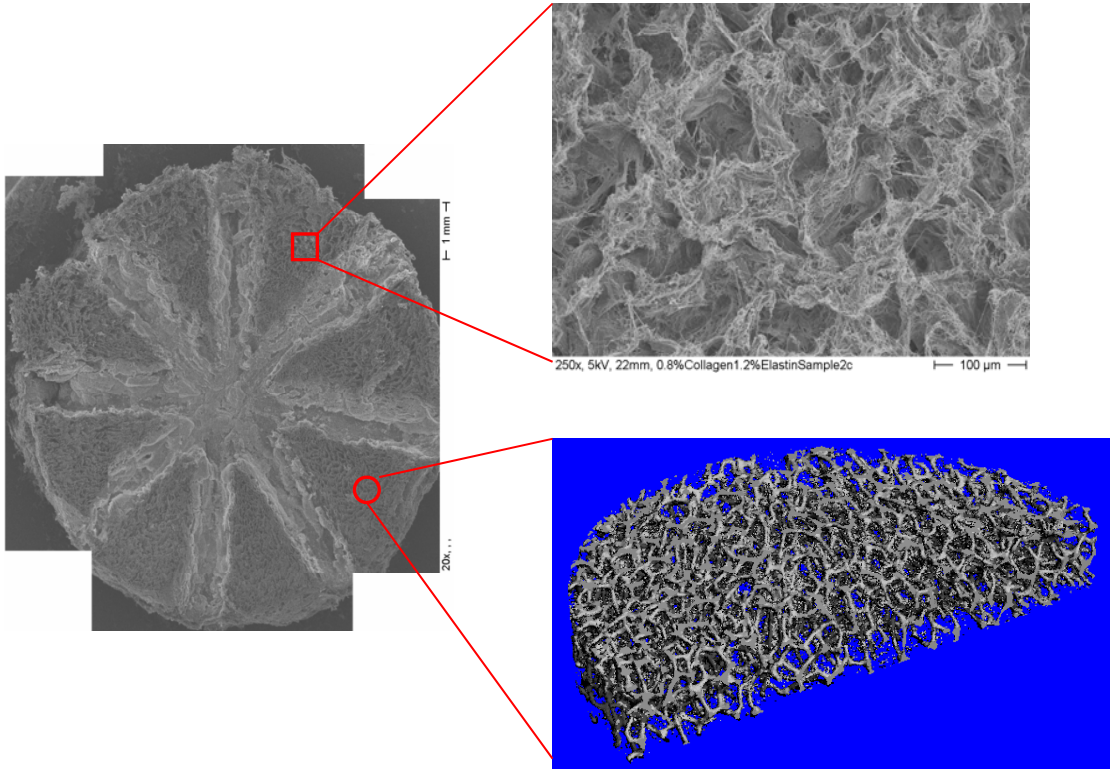
CAD Design	Negative Mould	Scaffold

Features:

- **Pre-defined channels; with highly porous structured matrix;**
- **With suitable chemistry for tissue growth – Collagen+ HA**
- **Controlled degradation rate;**
- **No toxic solvent involved.**

Arthritis Research UK · Newcastle University · University of Aberdeen · Keele University · The University of York

3D Printing Moulds for Collagen



SEM Examination

Micro-CT

Arthritis Research UK

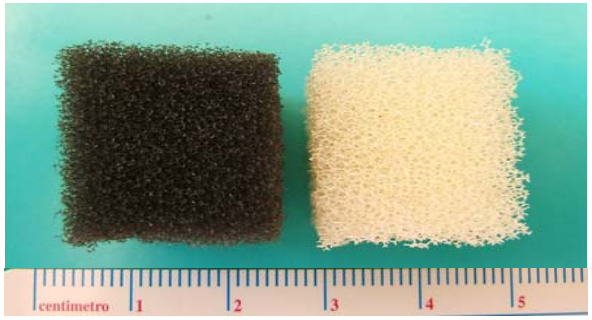
Newcastle University

University of Aberdeen

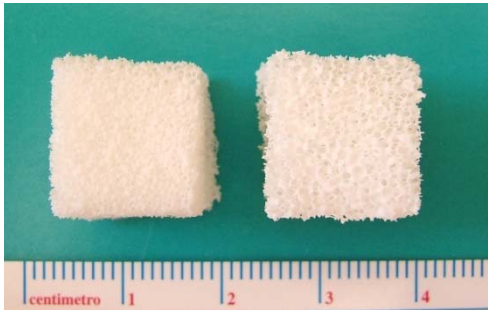
Keele University

The University of York

Highly Porous Bioceramic

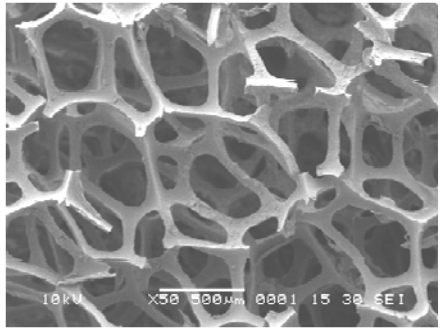


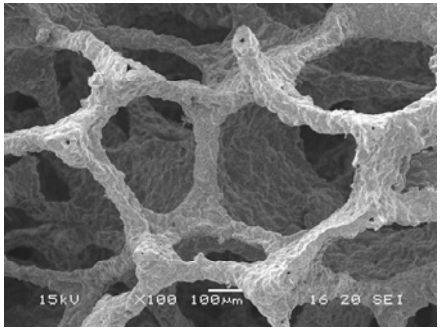
Replication method

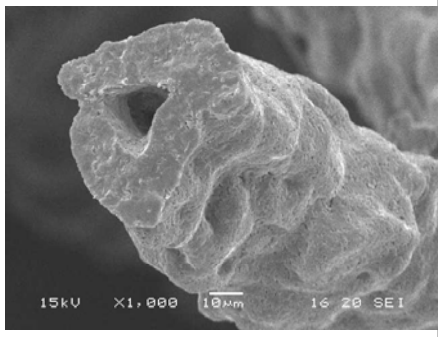


polyurethane foams

glass-ceramic scaffolds

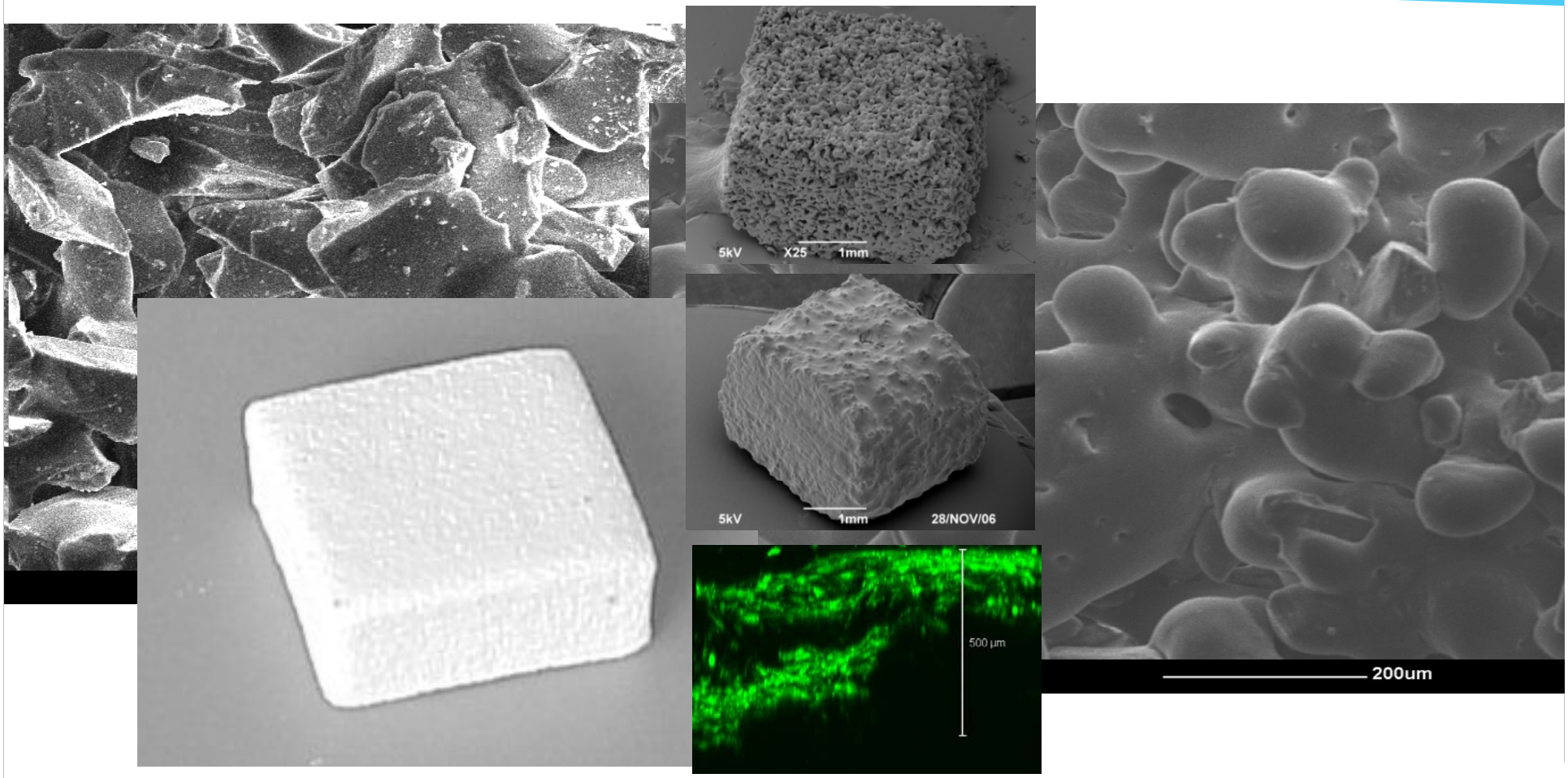






Arthritis Research UK
Newcastle University
University of Aberdeen
Keele University
The University of York

Apatite wollastonite glass ceramic scaffolds made using additive manufacture



Arthritis Research UK
Newcastle University
University of Aberdeen
Keele University
The University of York

Targets

Year	1	3	5
Cells	Adult autologous MSC	Best autologous and allogeneic MSC's	Improved allogeneic MSC's
Scaffold	None/ Bioceramic	Functionally Gradient Hydrogel/ Bioceramic Composite	Improved Functionally Gradient Hydrogel/ Bioceramic Composite
Delivery	ACI/ Arthroscope for Knee	Injection/ Arthroscope for Knee & Hip	Injection/ Arthroscope for Knee, Hip & Ankle

Arthritis Research UK Newcastle University University of Aberdeen Keele University The University of York

Conclusions

- Additive Manufacture:
  - Machines are getting better, cheaper and quicker
  - Most materials can be processed to most shapes in research labs
  - Applications growing but need systems level evaluation
  - Bioprinters a growing research area – printing structural and functional materials alongside cells and bioactive agents to create complex gradient structures in clinic for regenerative medicine
- For healthcare applications integration and everyday usability and reliability are key

Newcastle University

Acknowledgements

- Oana Bretcanu, Chaozong Liu, Andrew McCaskie, Mark Birch, Javier Munguia; Newcastle University
- Paul Genever, Jennifer Dyson; York University
- David Wood, Xuebin Yang; Leeds University
- Jim Woodburn, Scott Telfer; Glasgow Caledonian University
- Jari Pallari; Peacocks Medical Group


Questions?