

Additively manufactured implants with multifunctional surfaces

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Aging happily...

- Thanks to an orthopaedic implant



Additively manufactured implants

- Customised implants
- Enhanced porosity and surface area

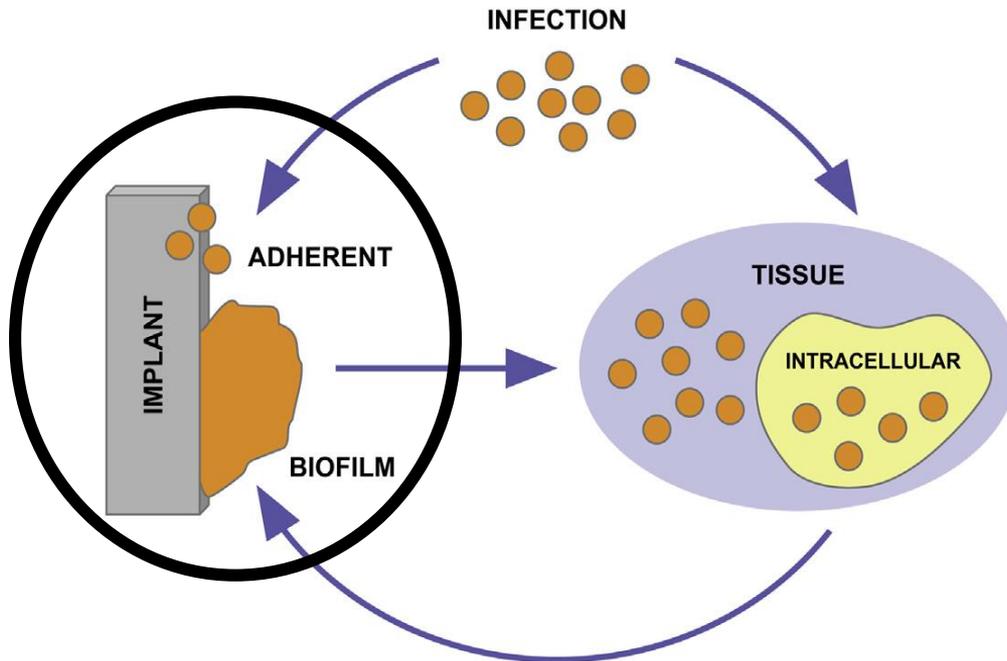


Design by Eline Kolken

©Marieke de Lorijn

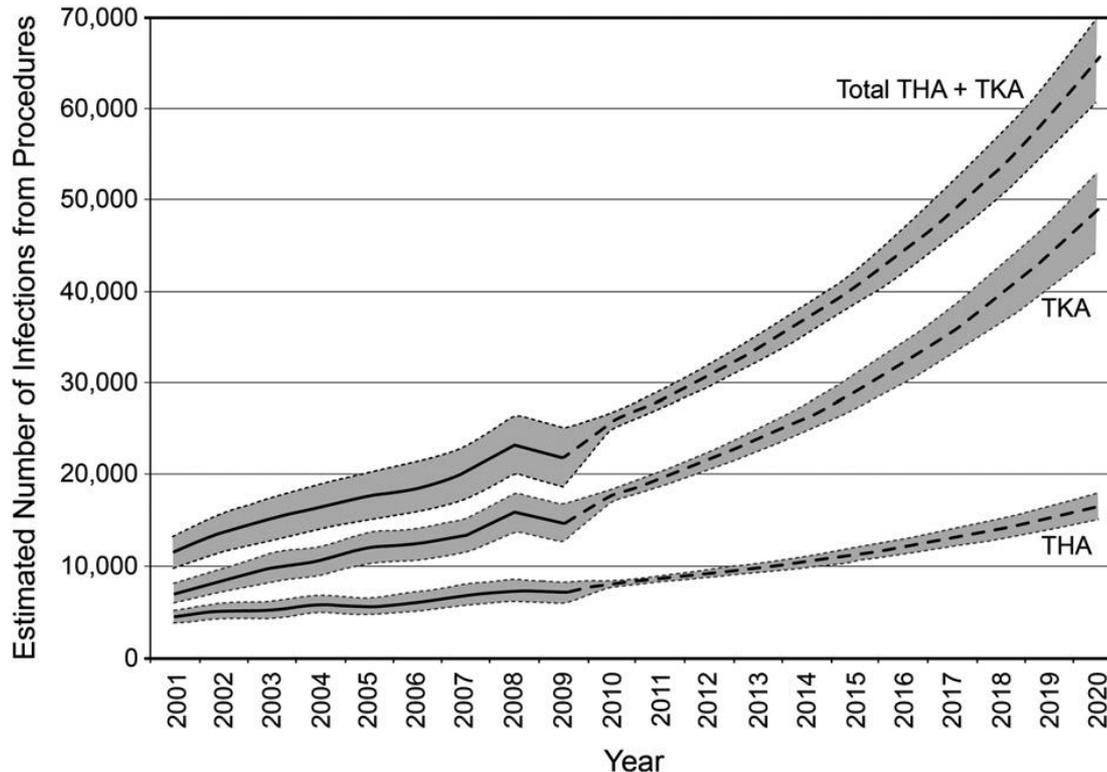
Implant-associated infection

- Bacteria form biofilm and infect surrounding tissue
- 1-2% of implants become infected



Implant-associated infection

- 1-2% of implants become infected



Kurtz, *J Arthr.*, 2012

Aseptic loosening

TABLE REASONS FOR REVISION OR RE-SURGERY IN PATIENTS WHO UNDERWENT A HIP REVISION ARTHROPLASTY IN THE NETHERLANDS IN 2016 (N=3,836).

Reasons for revision	Proportion ¹ (%)
Loosening of acetabulum component	22.4
Dislocation	19.3
Infection	19.3
Loosening of femur component	18.7
Inlay wear	18.5
Peri-prosthetic fracture	12.3
Girdlestone situation	6.1
Symptomatic MoM inlay	4.0
Peri-articular ossification	2.3
Other	10.6

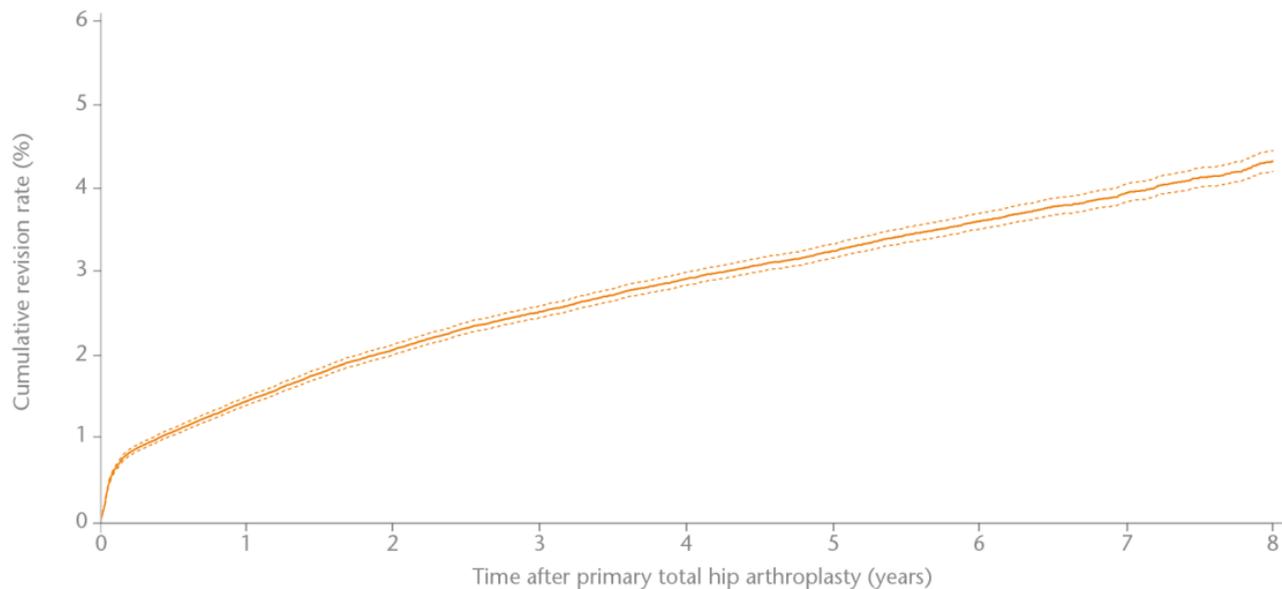
¹ One patient may have more than one reason for revision or re-surgery. As such, the total proportion is over 100%.

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Revision surgeries

- 1.3% of total Dutch population

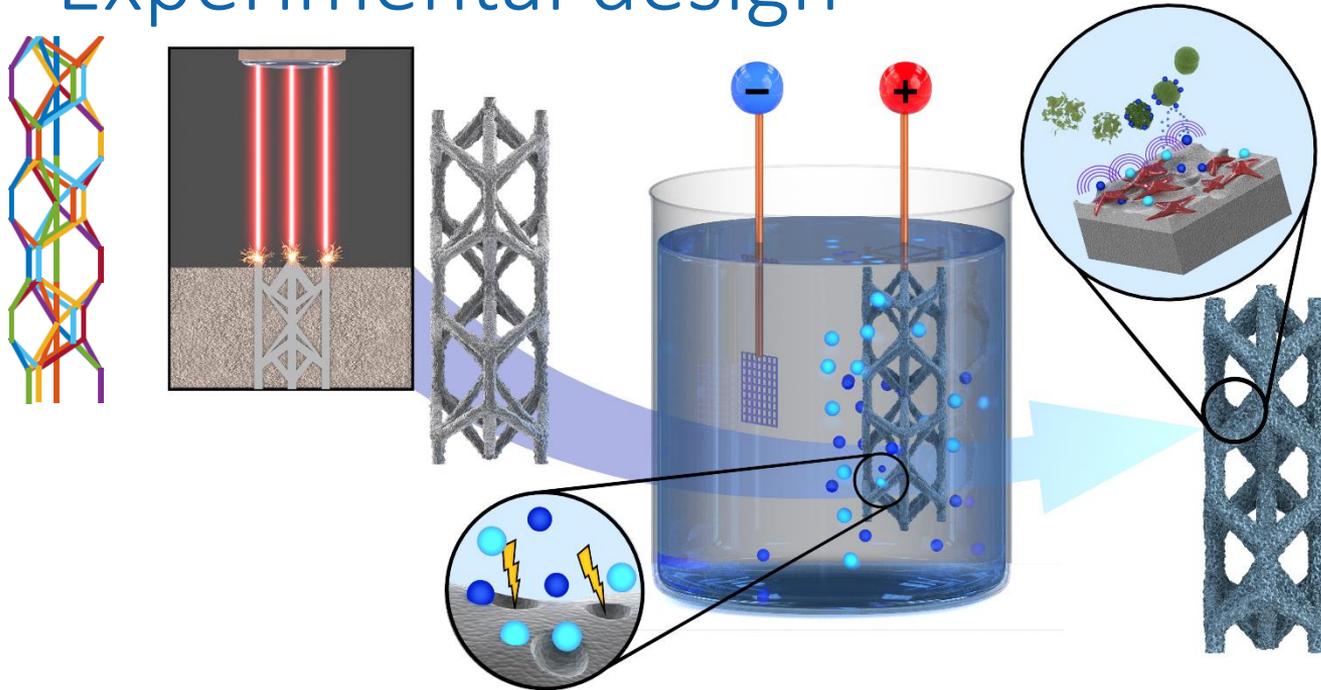
FIGURE CUMULATIVE REVISION PERCENTAGE OF TOTAL HIP ARTHROPLASTIES IN THE NETHERLANDS IN 2007-2016 (N=227,301).



Aim

Synthesize bone implants to prevent infection
and implant loosening

Experimental design



Additive
Manufacturing

Surface
Biofunctionalization

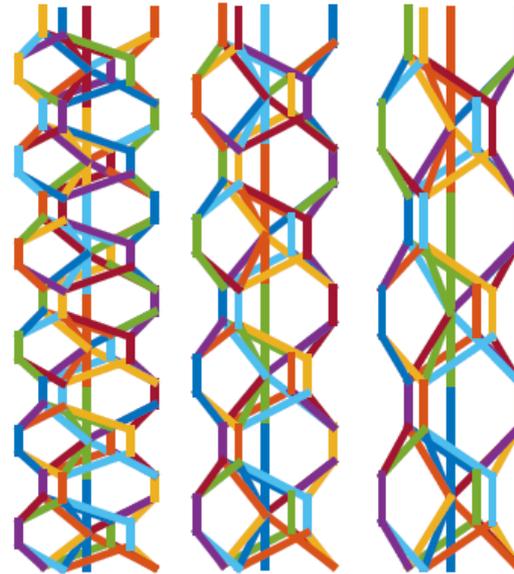
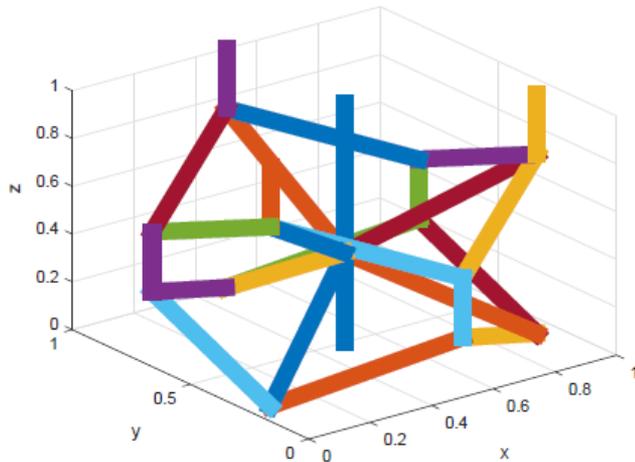
Multifunctional
bone implants

Rational design

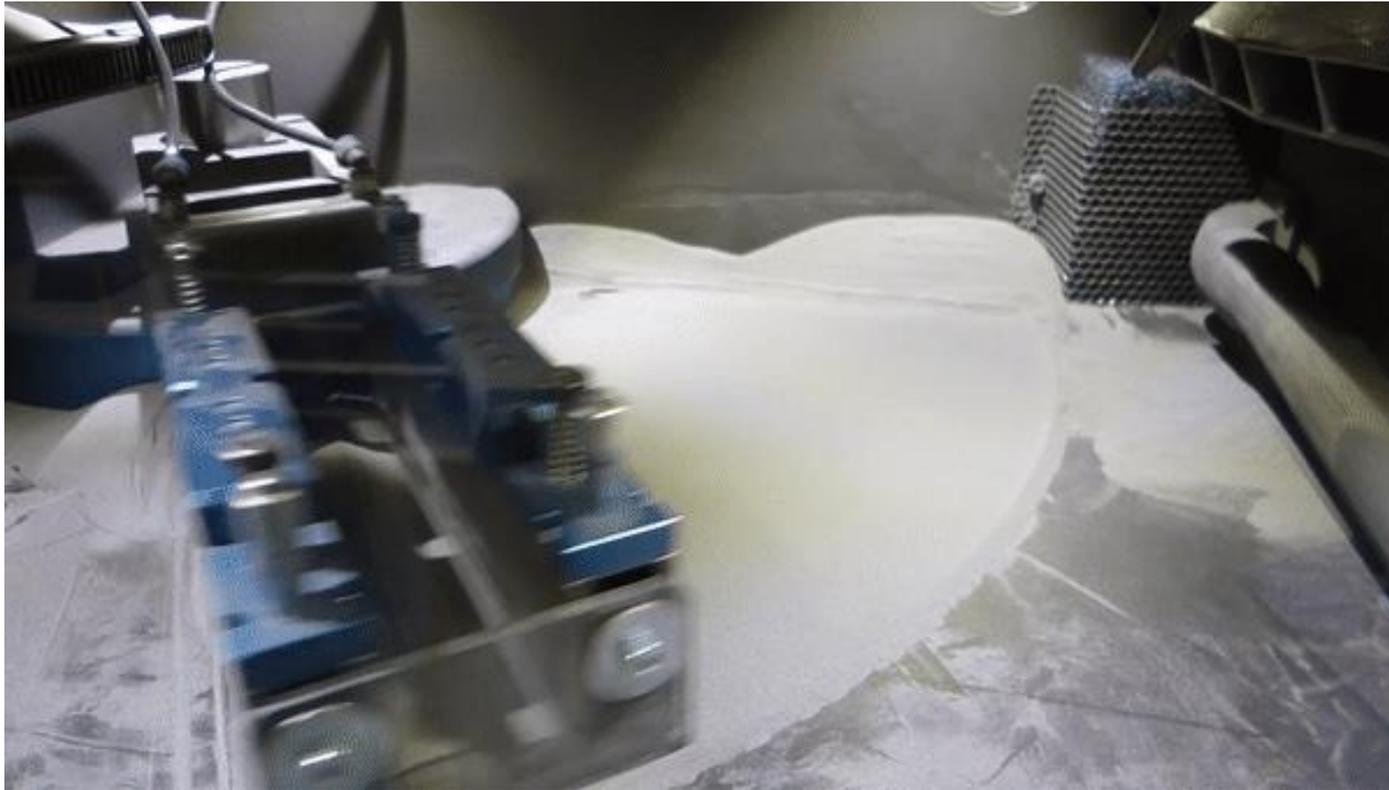


Rational design

Aspect ratio	1.0	1.5	2.0
Surface area compared to solid wire	3.75	3.35	2.73
Porosity (%)	14.4	30.6	37.6



Selective Laser Melting (SLM)



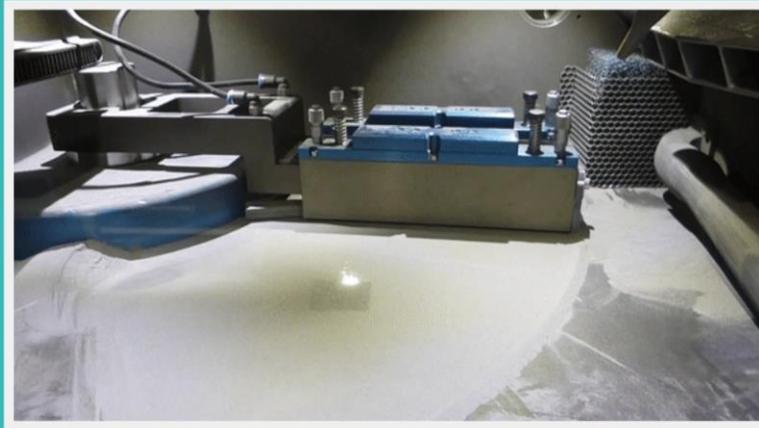
Porous Solid



Plasma electrolytic oxidation (PEO)

- Electrochemical surface treatment
- Silver, copper and zinc nanoparticles to create multifunctional surface

Additive manufacturing

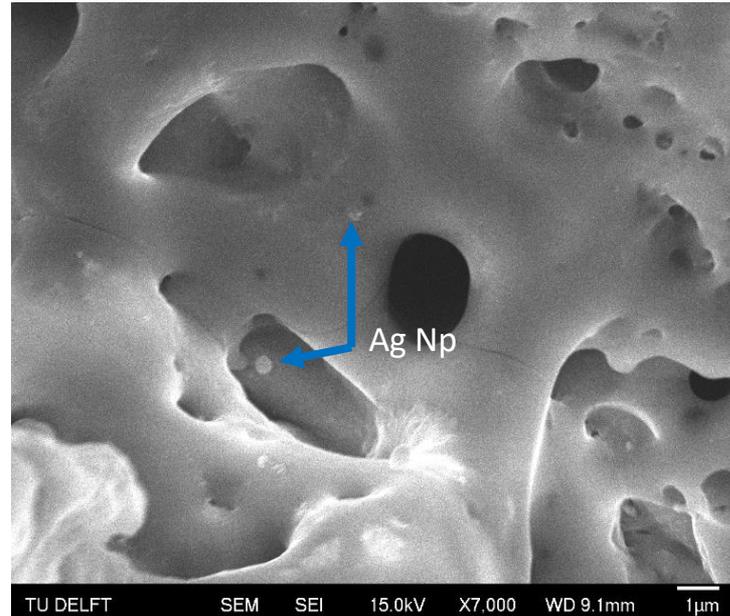
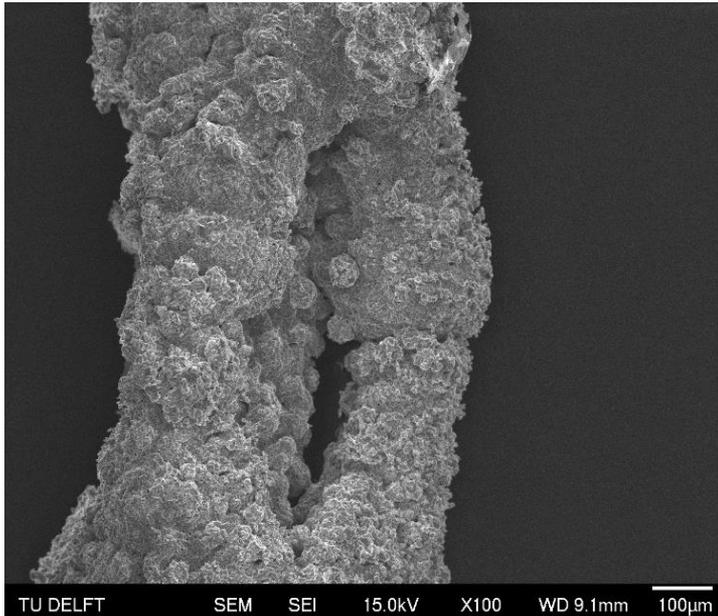


PEO



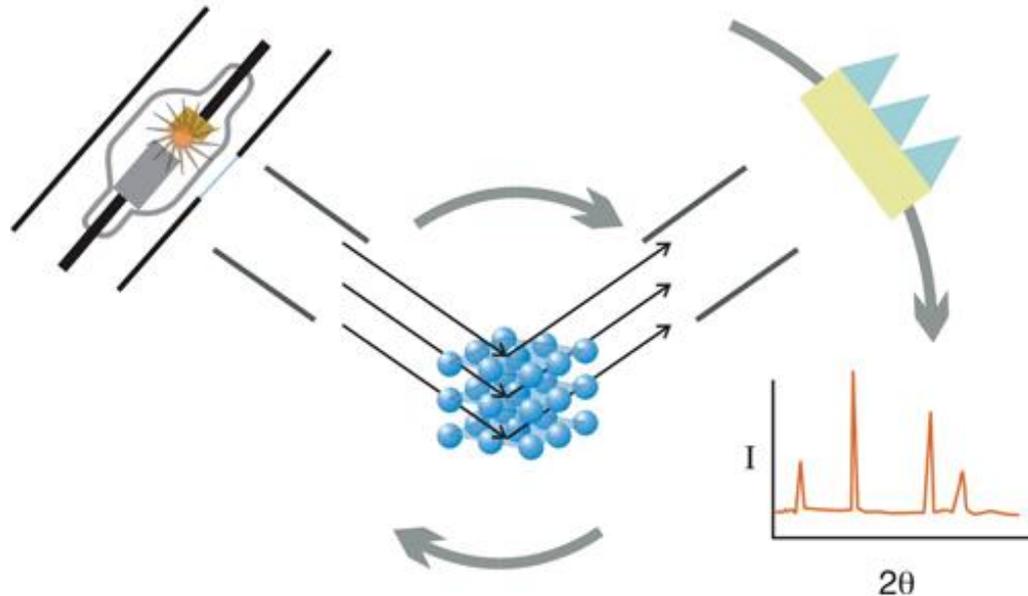
Biomaterial characterisation

- Highly porous surface with nanoparticles



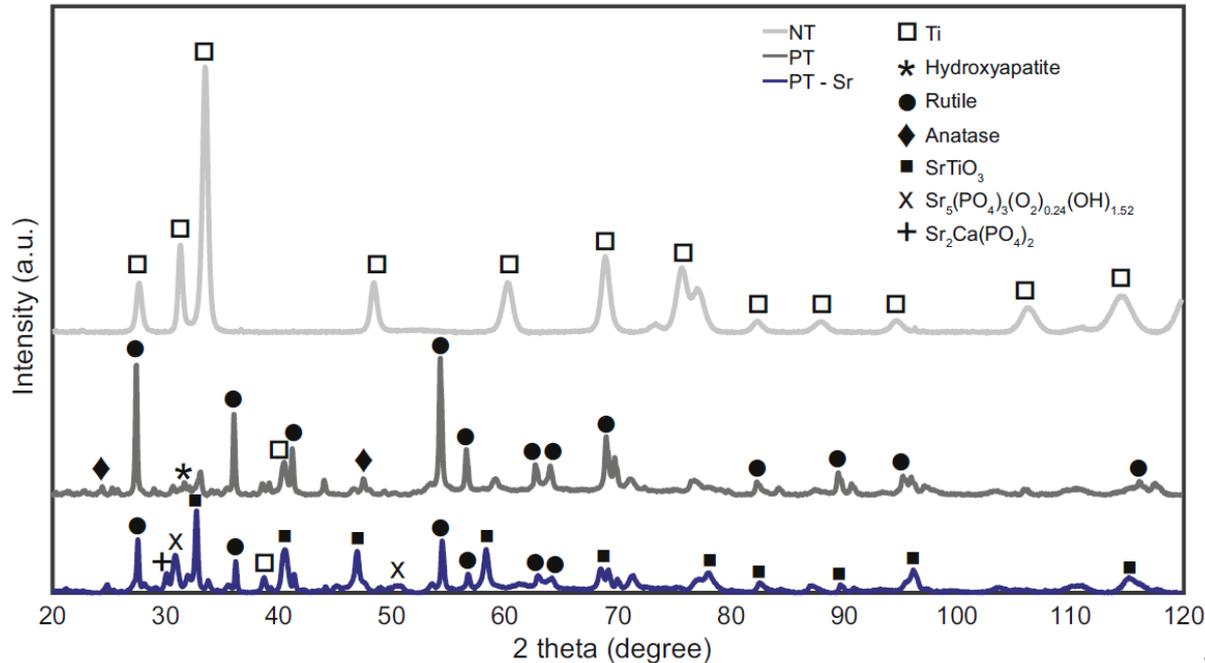
Phase composition: X-ray diffraction

- X-ray beam fired at biomaterial
- Sample rotates and intensity is collected at different angles
- Phases can be detected according to peaks



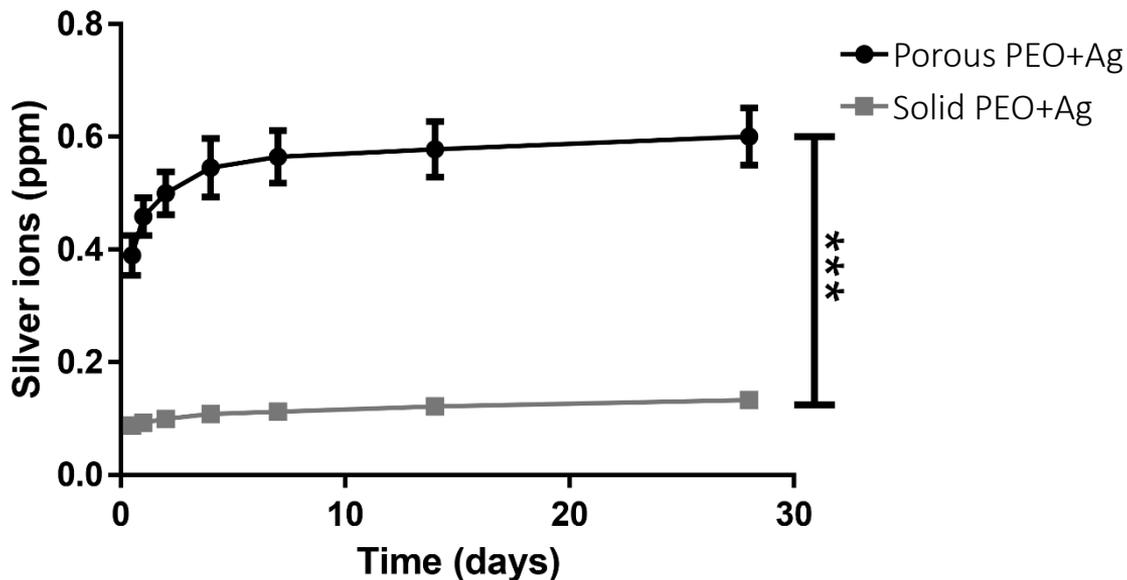
Phase composition

- Ca/P phases, including hydroxyapatite
- Addition of strontium in PEO electrolyte results in Sr/P/Ca phases

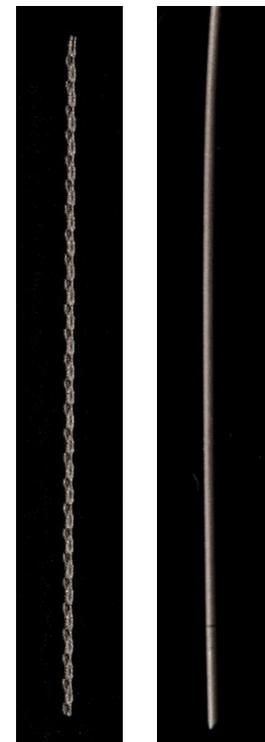


Silver ion release

- Increased Ag ion release from porous compared to solid implants

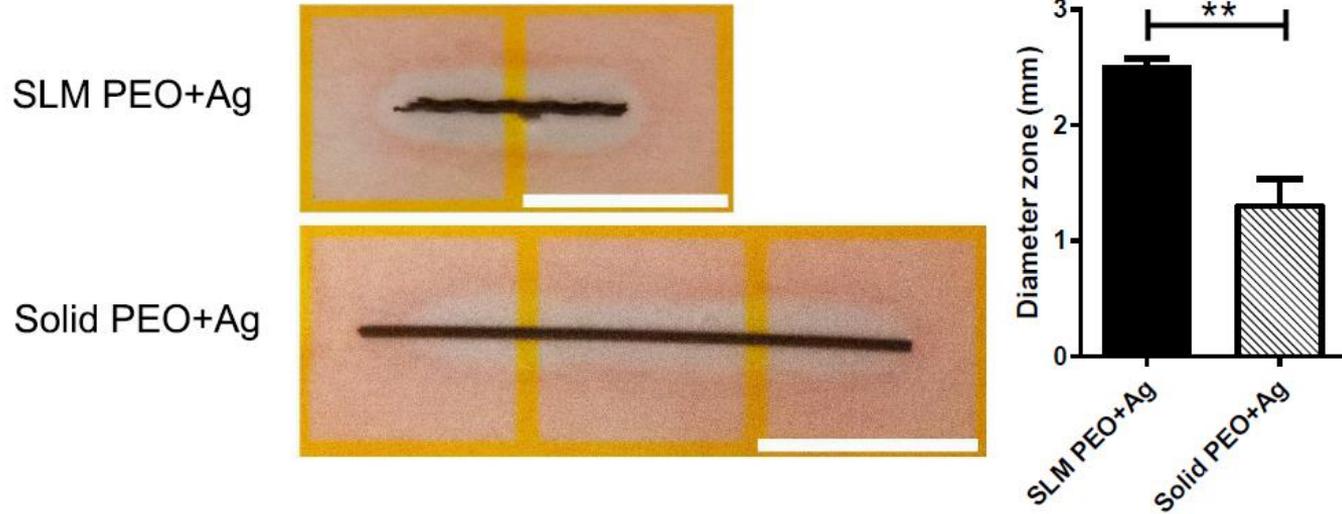


Porous Solid

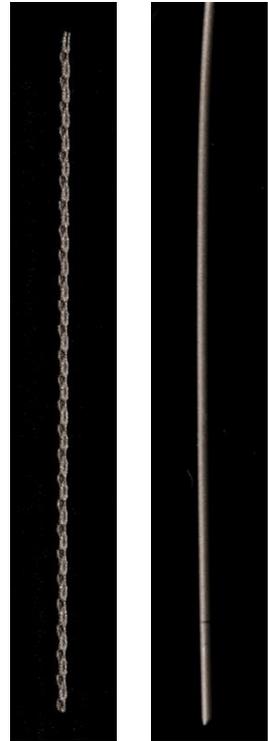


Antibacterial zone of inhibition

- Larger zone for porous compared to solid implants

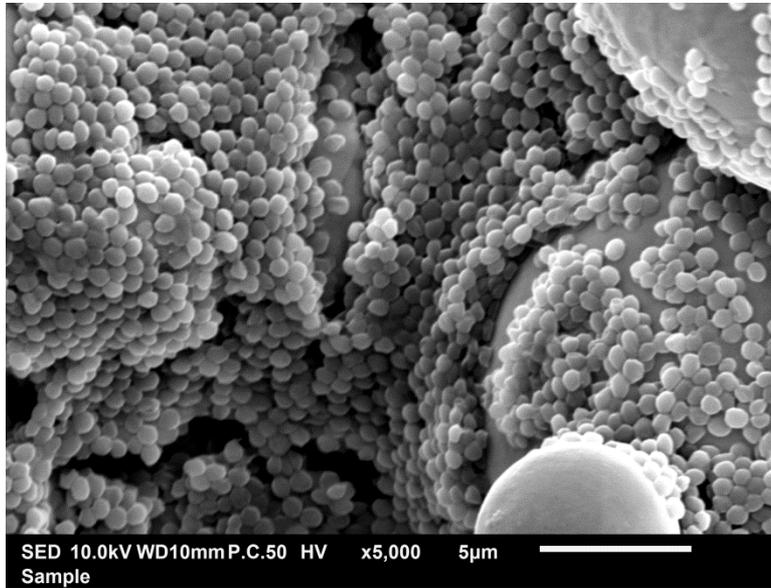


Porous Solid

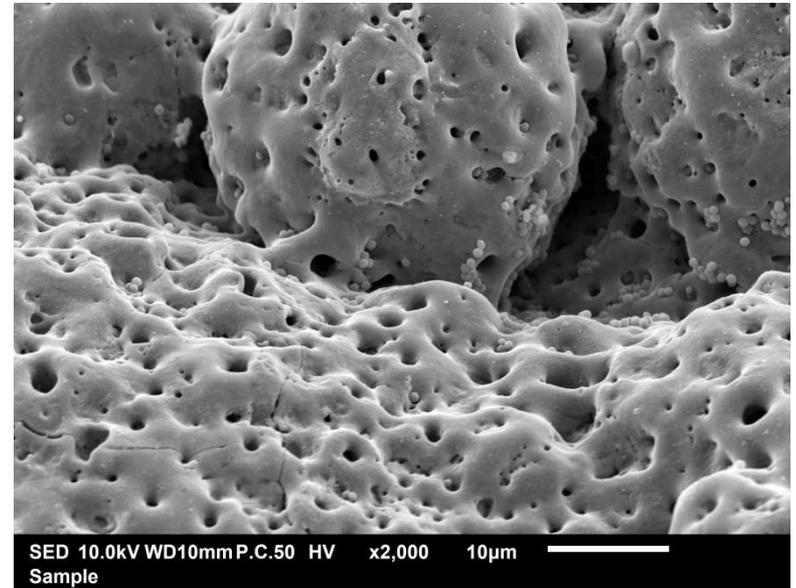


Prevention biofilm formation

Untreated

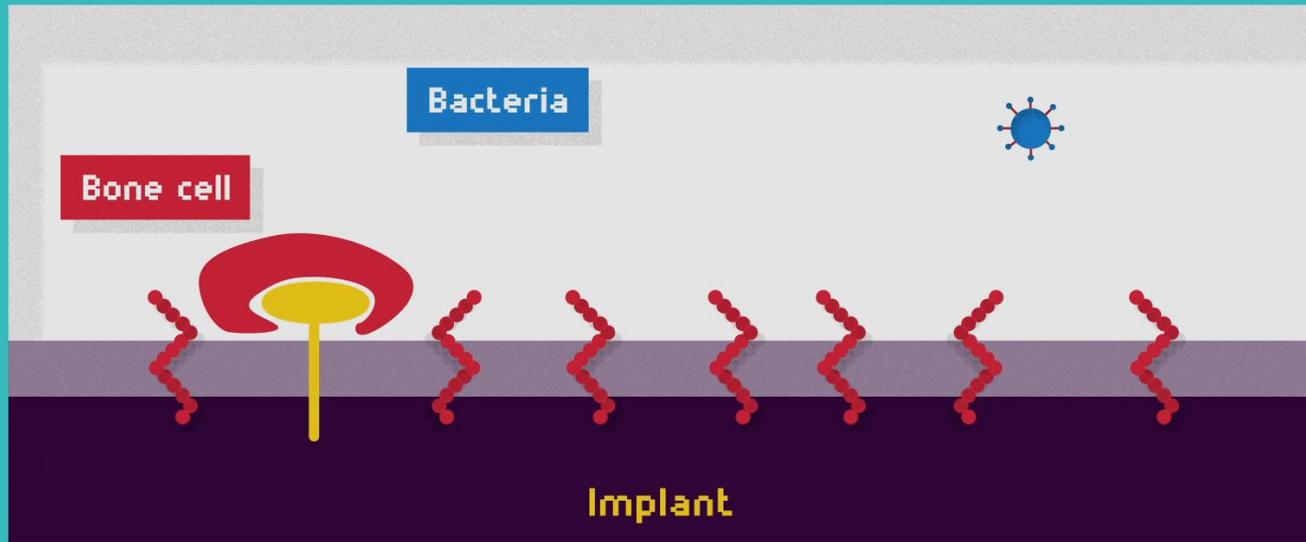


PEO treated surface

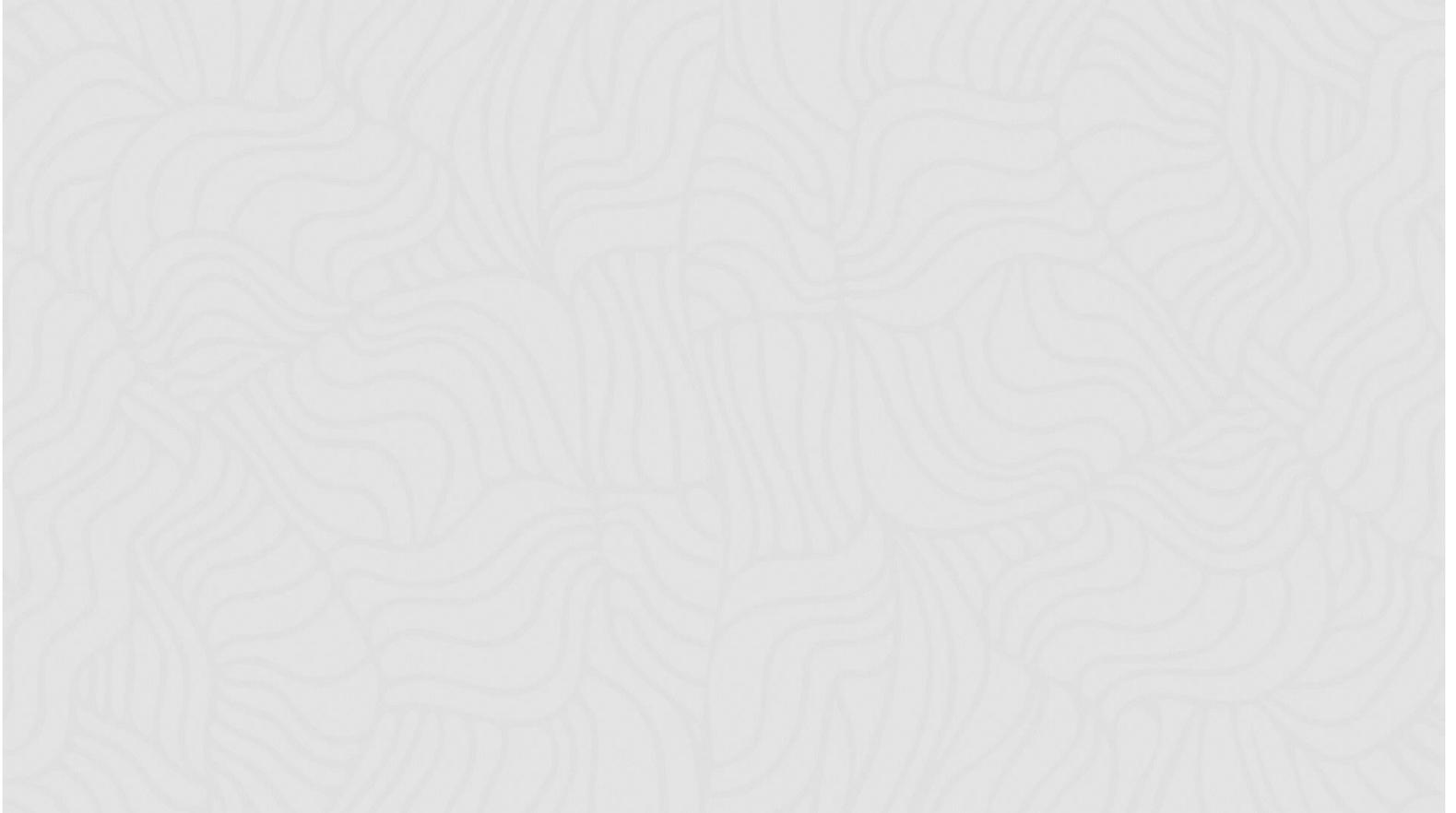


- Methicillin-resistant *Staphylococcus aureus* (MRSA) after 48 h

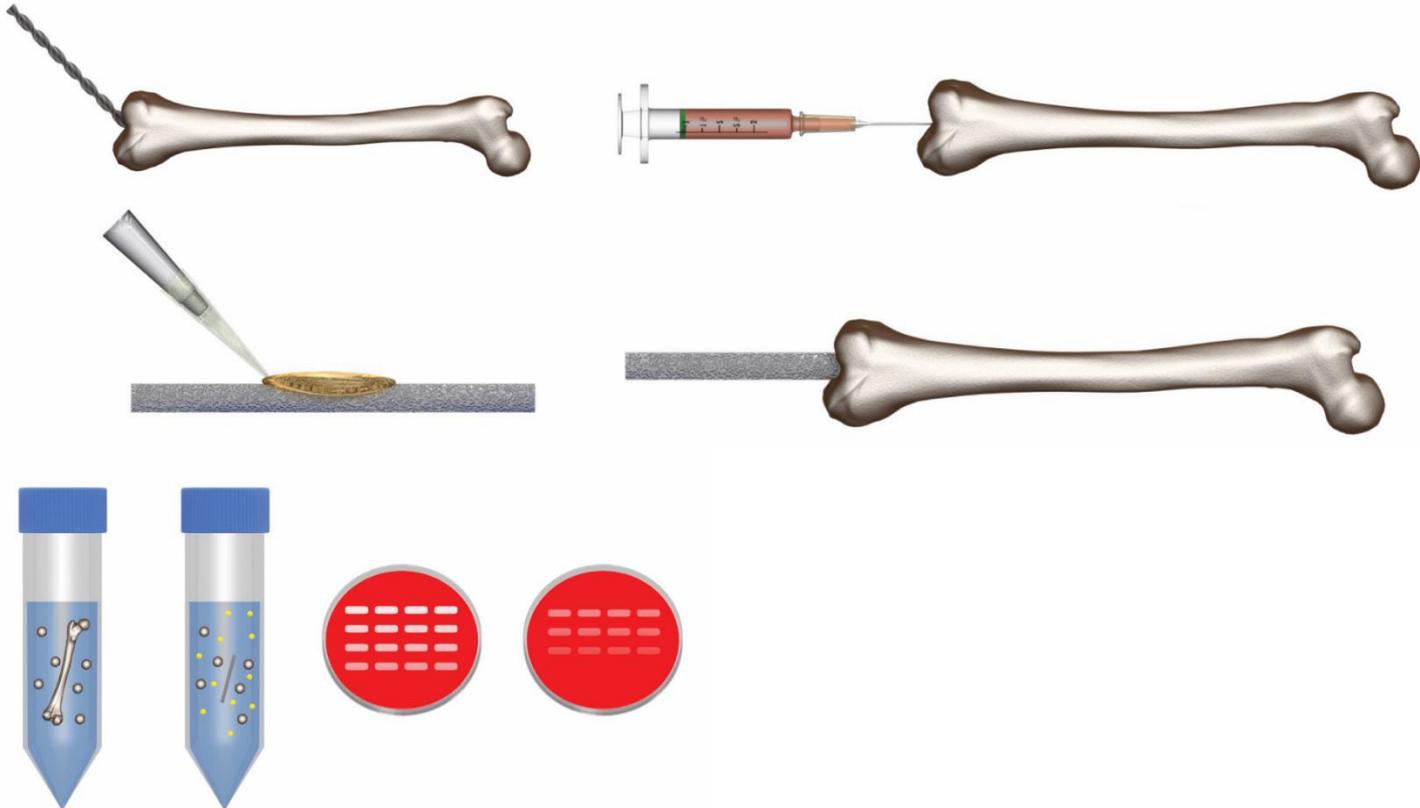
Selfdefending surface



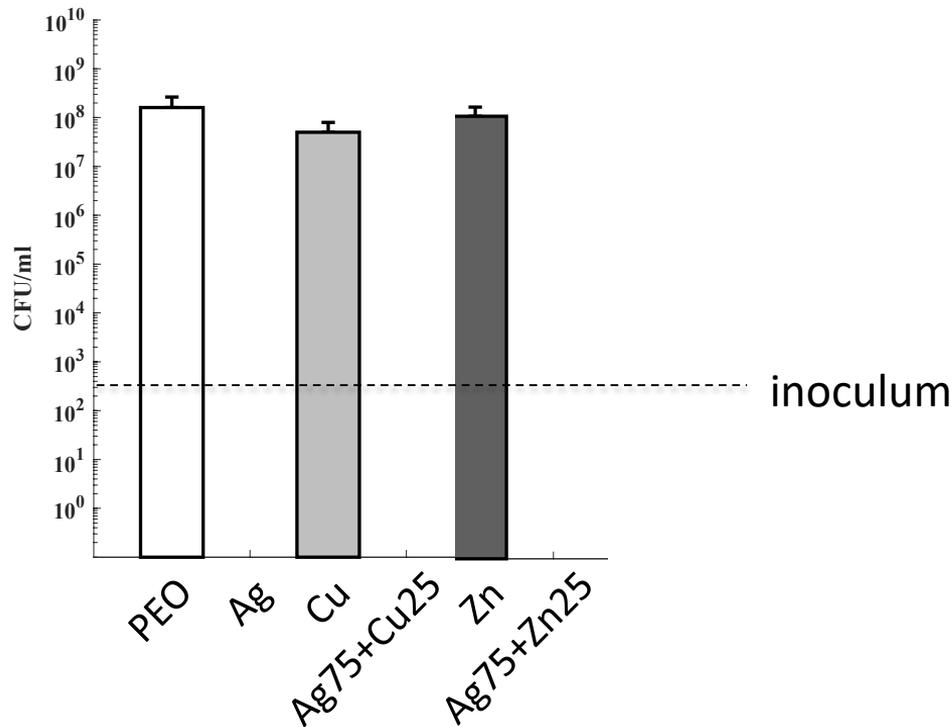
Overview



Ex vivo bone infection model

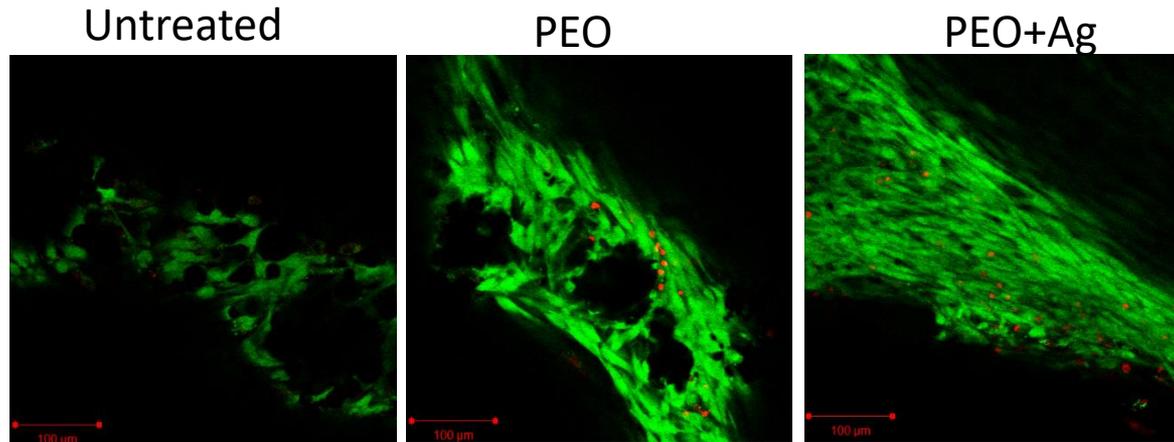


Multifunctional implants reduce bacterial growth *ex vivo*



- MRSA after 24 h

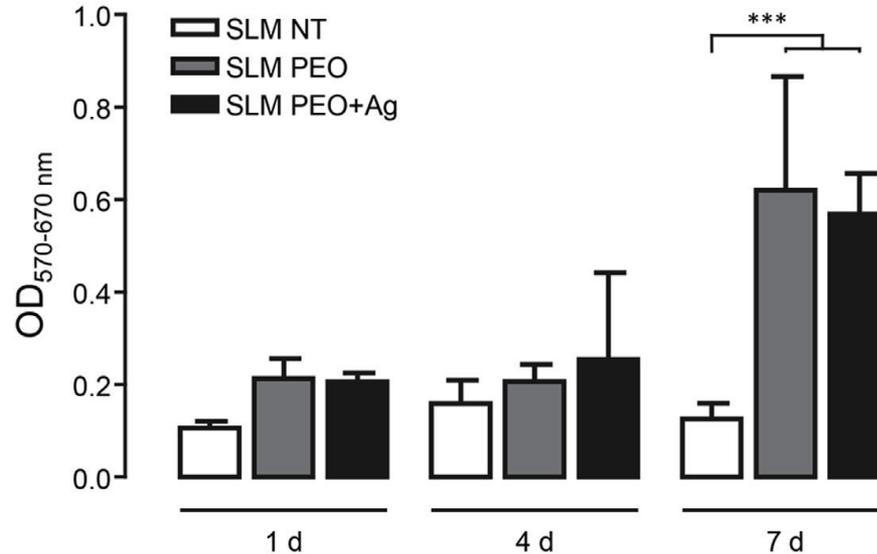
Multifunctional implants are not cytotoxic



- Human Mesenchymal Stem Cells (MSCs) after 24 h

- **Alive**
- **Dead**

Multifunctional implants enhance cell activity



Discussion

- Duration of biological properties
- Explore PEO parameters
- Translate research into clinically relevant implants



Conclusion

Rationally designed, additively manufactured implants



Surface biofunctionalization with Ag, Cu and Zn nanoparticles



Multifunctional implants



Implant functioning and longevity↑

Lecture Universiteit van Nederland



- “Wat hebben Japanse origami en botimplantaten met elkaar gemeen”?
- <https://universiteitvannederland.nl/college/wat-hebben-japanse-origami-en-botimplantaten-met-elkaar-gemeen>
- With Sebastien Callens

Thank you!

