Portable Spray Device for Rapid Deposition of Antimicrobial Polyelectrolyte Coatings

Yijie Li, Spartha Medical SAS



Congrès / Congress

IP4H

INNOVATIVE POLYMERS FOR HEALTHCARE

Institut Charles Sadron, Strasbourg

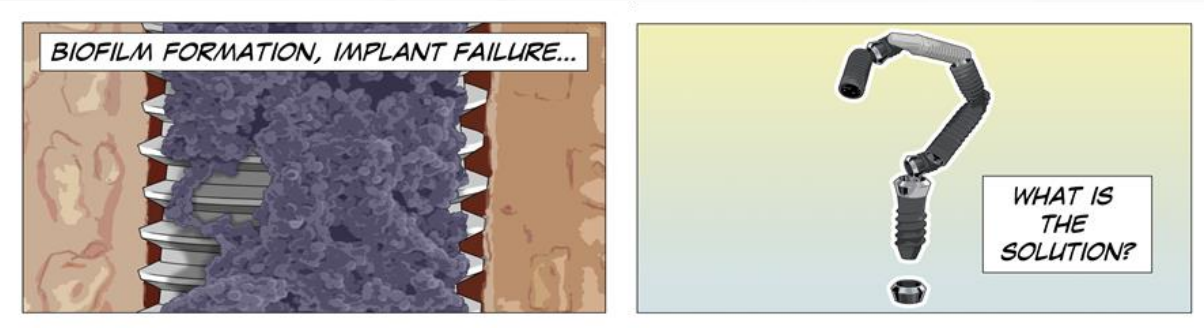
25-26 mars
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2026

With the support of:

Facing challenges

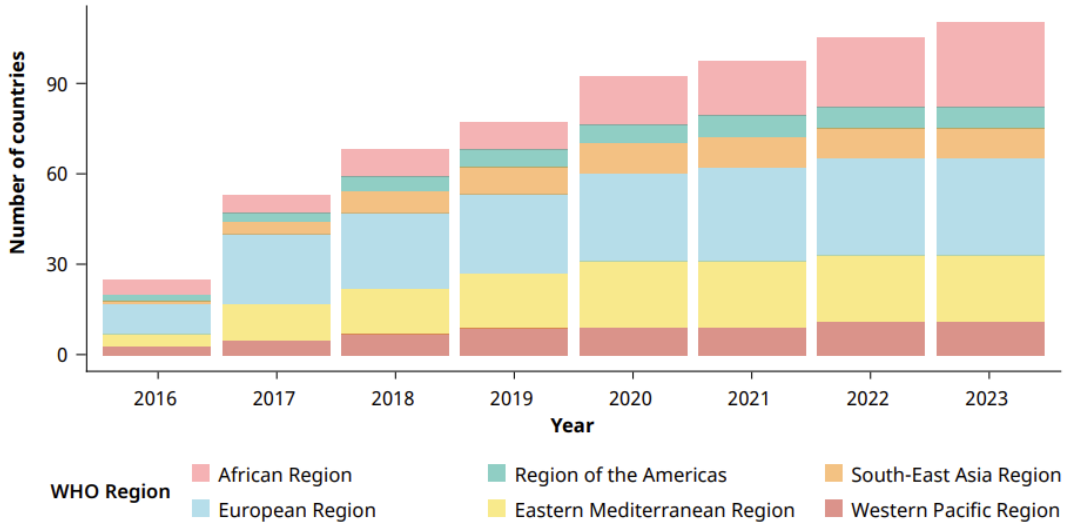
1) Antimicrobial resistance (**AMR**) in the medical field
e.g. **implants fail due to biofilm**

2) Increased risk of **pandemics**, global death rate
(e.g. COVID-19)



Global Antimicrobial Resistance and Use Surveillance System (GLASS)

Figure 1. Numbers of countries that reported AMR data to GLASS, by WHO region, 2016–2023[1]



Numbers of countries include three territories and areas

Global Antibiotic Resistance Surveillance Report 2025: Summary, n.d. [1]



A speed-up version of the Harvard Medical School's footage featuring the evolution of antibiotic resistant *E. coli*. **In 11 days**

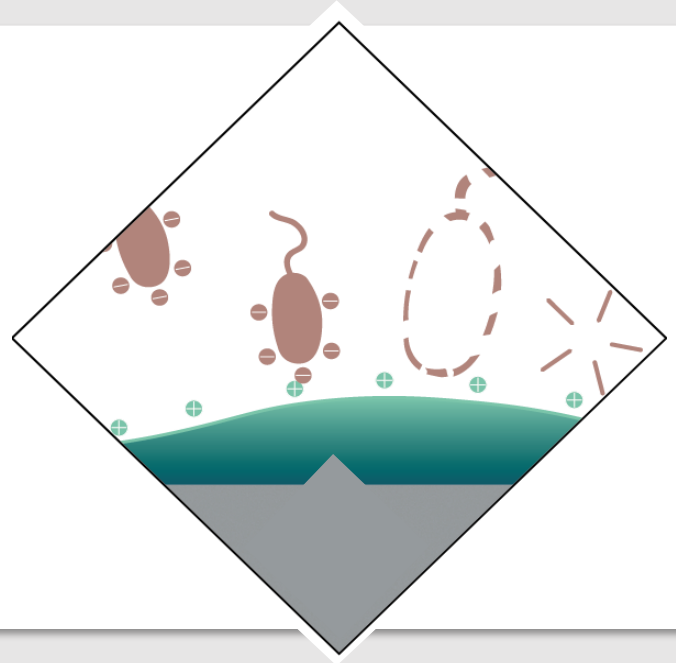
Baym et al. 2016 [2]

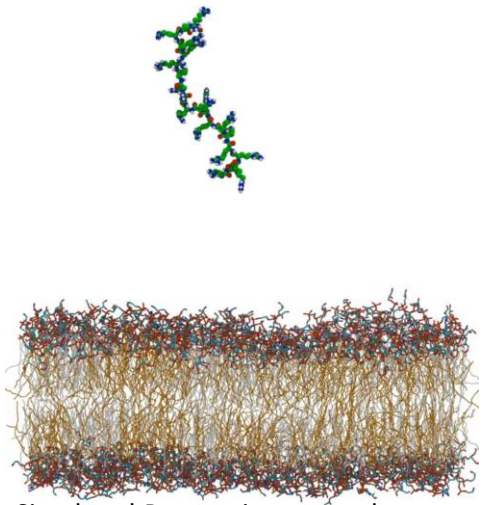
SPARTHA Medical - Our technology

INSERM and **SPARTHA Medical** discovered antimicrobial polyelectrolyte coating in 2016 [3].

The power of polyions

- Nanoscale self-forming multilayers of **polycation (+)** and **polyanion (-)**
- **Contact-killing** mechanism
- **LbL coating method**

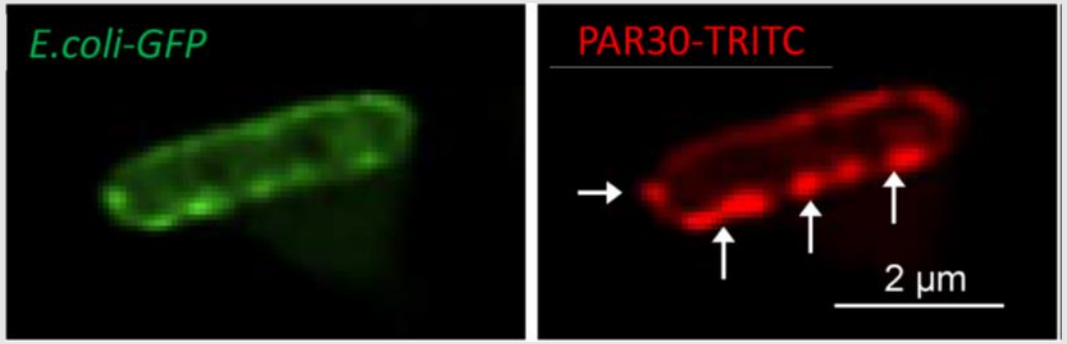




Simulated *P. aeruginosa* membrane

Polyanion with higher molecular weight as the **reservoir** keeps the **mobility** of lower molecular weight **polycation**.

All **bacterial membranes** are **negatively charged**.



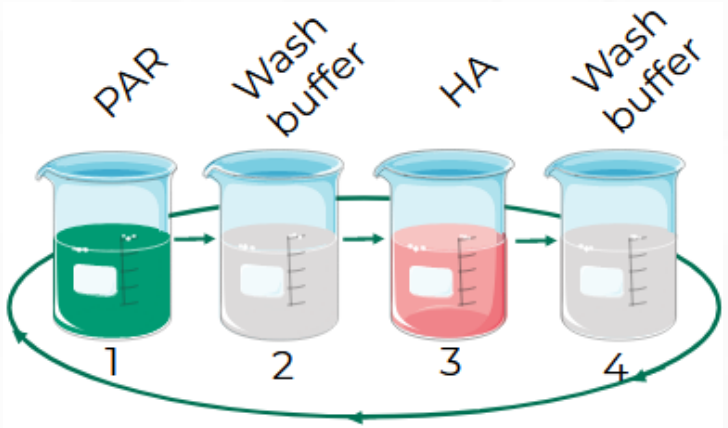
Kocgozlu et al. 2024 [4] Super-resolution confocal microscopy Green fluorescent *E. coli*, red fluorescent labeled PAR30.

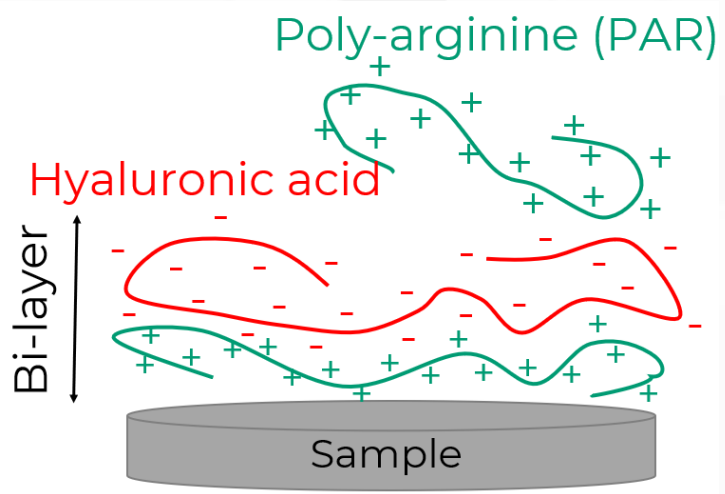
Research topic and project background

Antimicrobial polyelectrolytes multilayer coating

Polyanion: Hyaluronic Acid (HA),
Polycation: Poly(arginine) (PAR), antimicrobial properties
Coating method: Layer-by-Layer (LbL) dipping







Research topics:

- A new method for rapid polyelectrolyte coating application
- New coating method validation

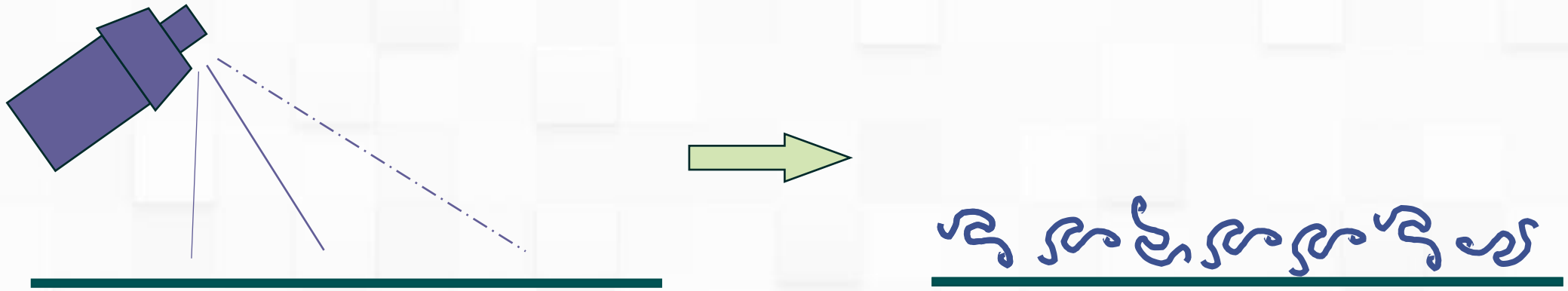
Conventional LbL spray method

Polyanion:
Polycation:
Substrate:

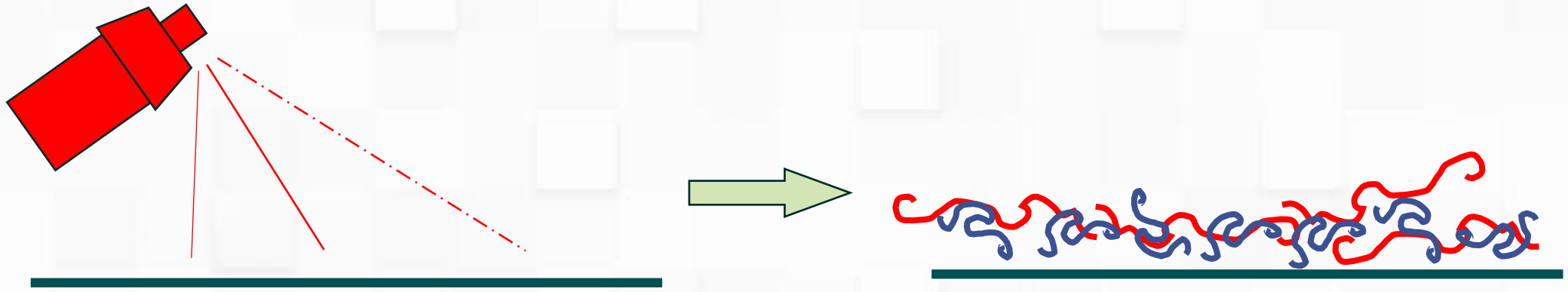
- **Separated bottles**
- **Repeated steps**

It is faster than dip coating but not user-friendly.

Step 1

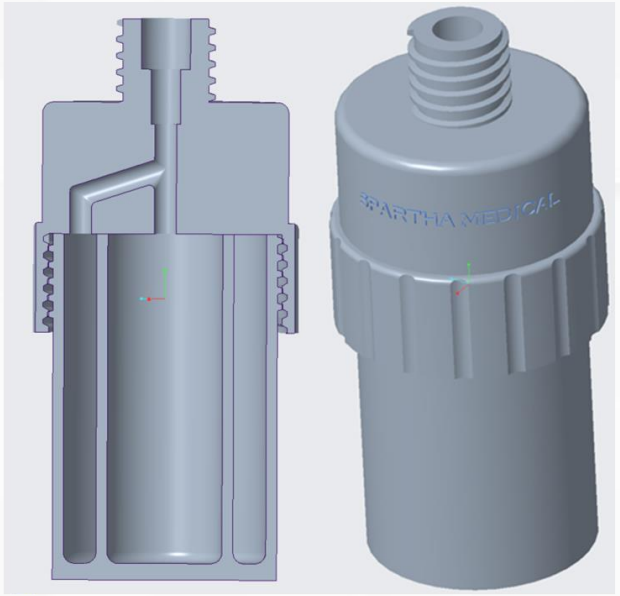


Step 2



Second spray bottle design and prototype

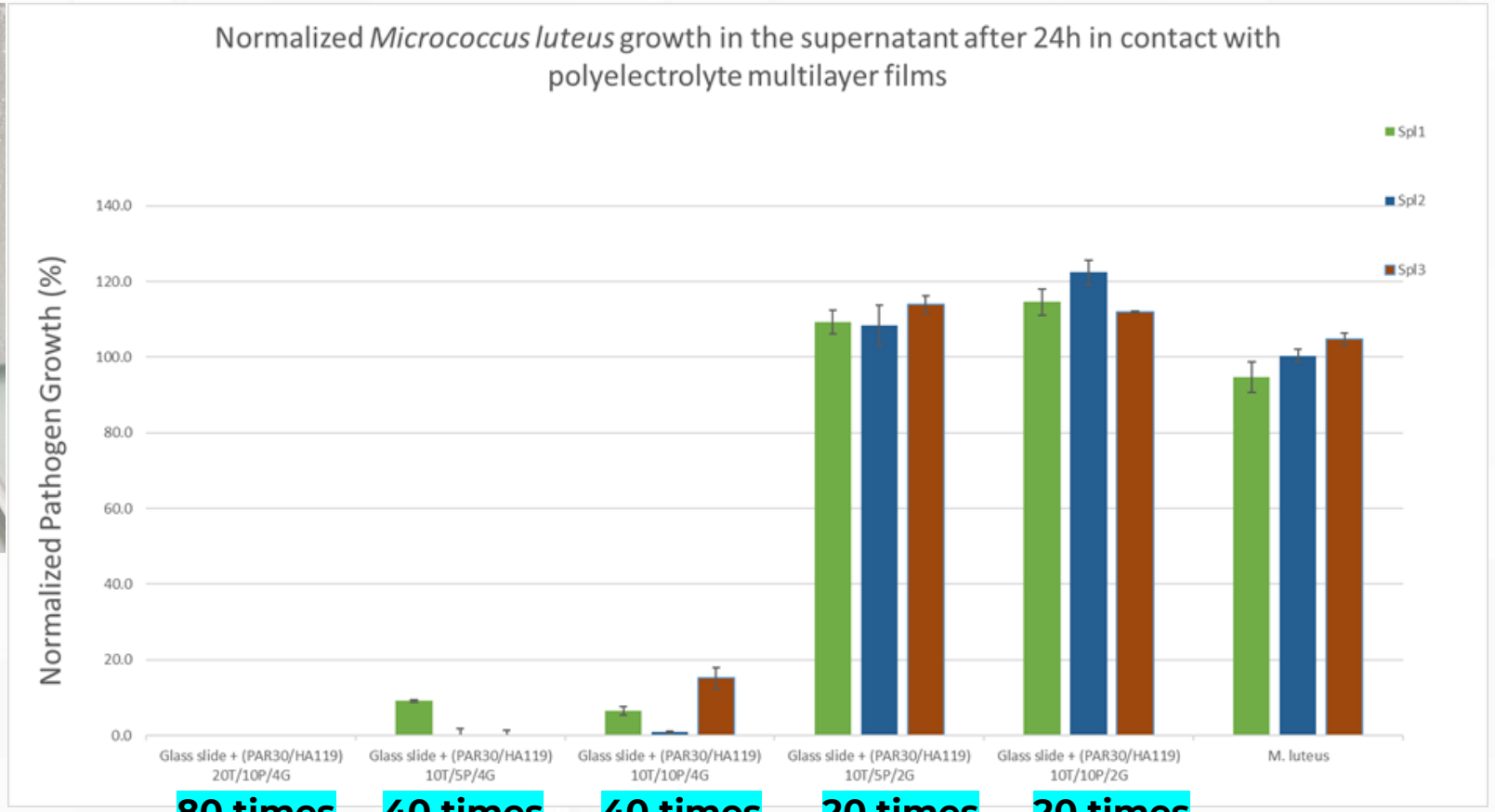
PAR30/HA (0.5mg/mL), *M. luteus B199*, *Glass*



A



B



80 times
10s Pause

40 times
5s Pause

40 times
10s Pause

20 times
5s Pause

20 times
10s Pause

n=1

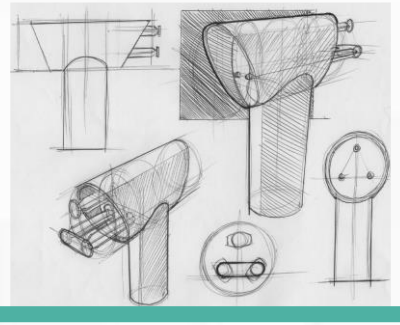
- ✓ Less number of parts
- ✗ High manufacturing cost due to design complexity
- ✗ Too many press on the nozzle to make an effective coating

Spray at least 40 times to form an antimicrobial coating

BIOMATERIALS BIOENGINEERING

SPARTHA MEDICAL

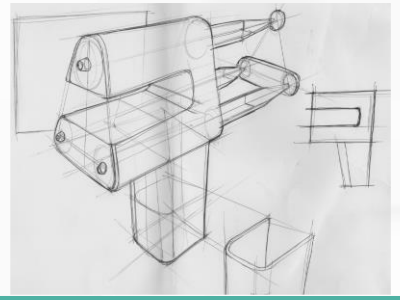
Design A







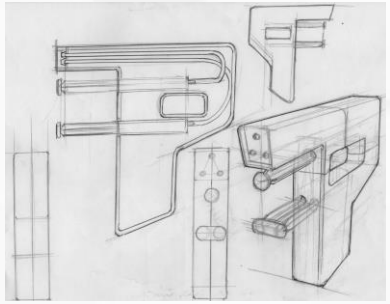
Design B







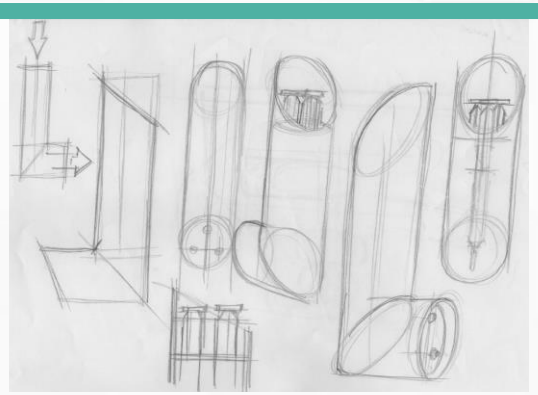
Design C







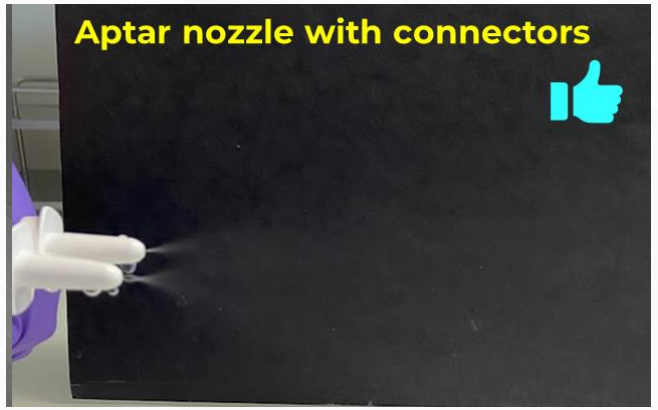
Design D















Connector

Created by Tamim Daoudi

protect | ION

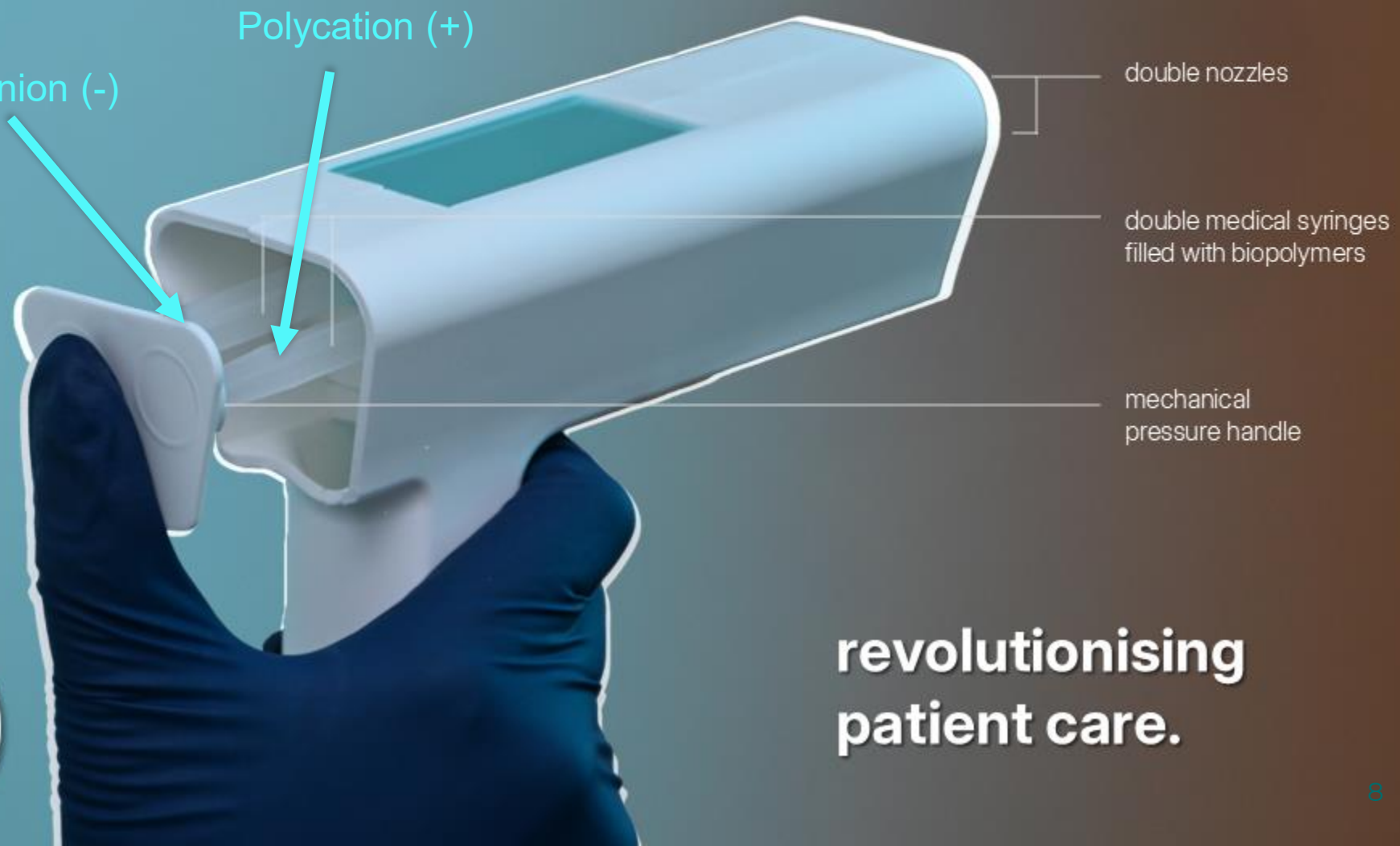
the **patented handheld spray applicator** **(surgical protect|ION)** offers a unique way of being able to treat surfaces with Spartha's customized treatments.

antibacterial effect
multi-resistant Gram+ & Gram- bacteria

water-based
no harmful solvents

biocompatible
no cytotoxicity & non-pharmacological action

biodegradable
no accumulation in the environment



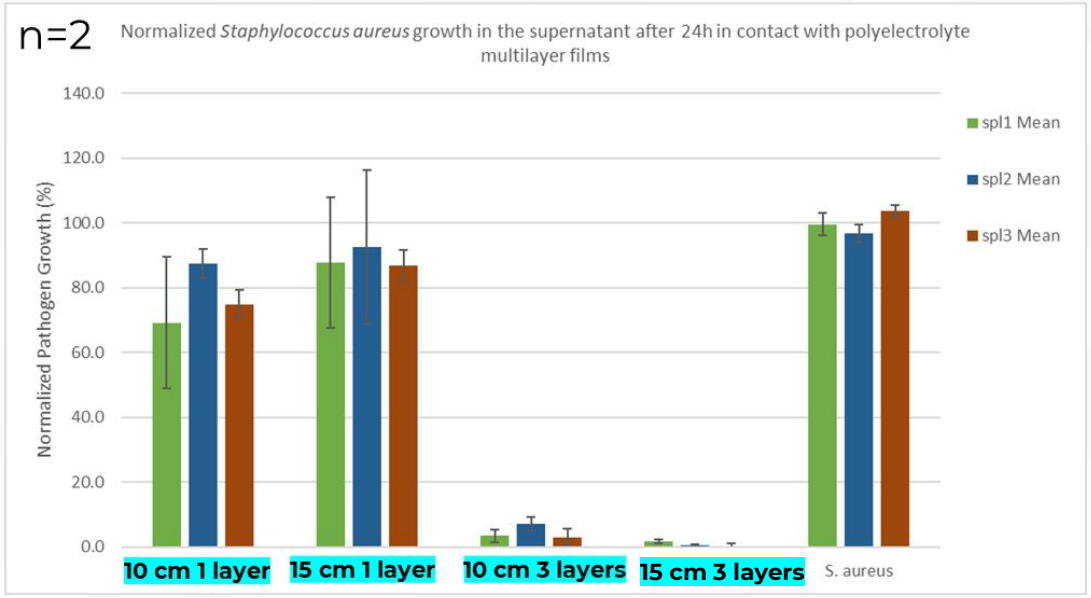
versatility of applications
all materials & living tissues

wound
skin
implants
surfaces

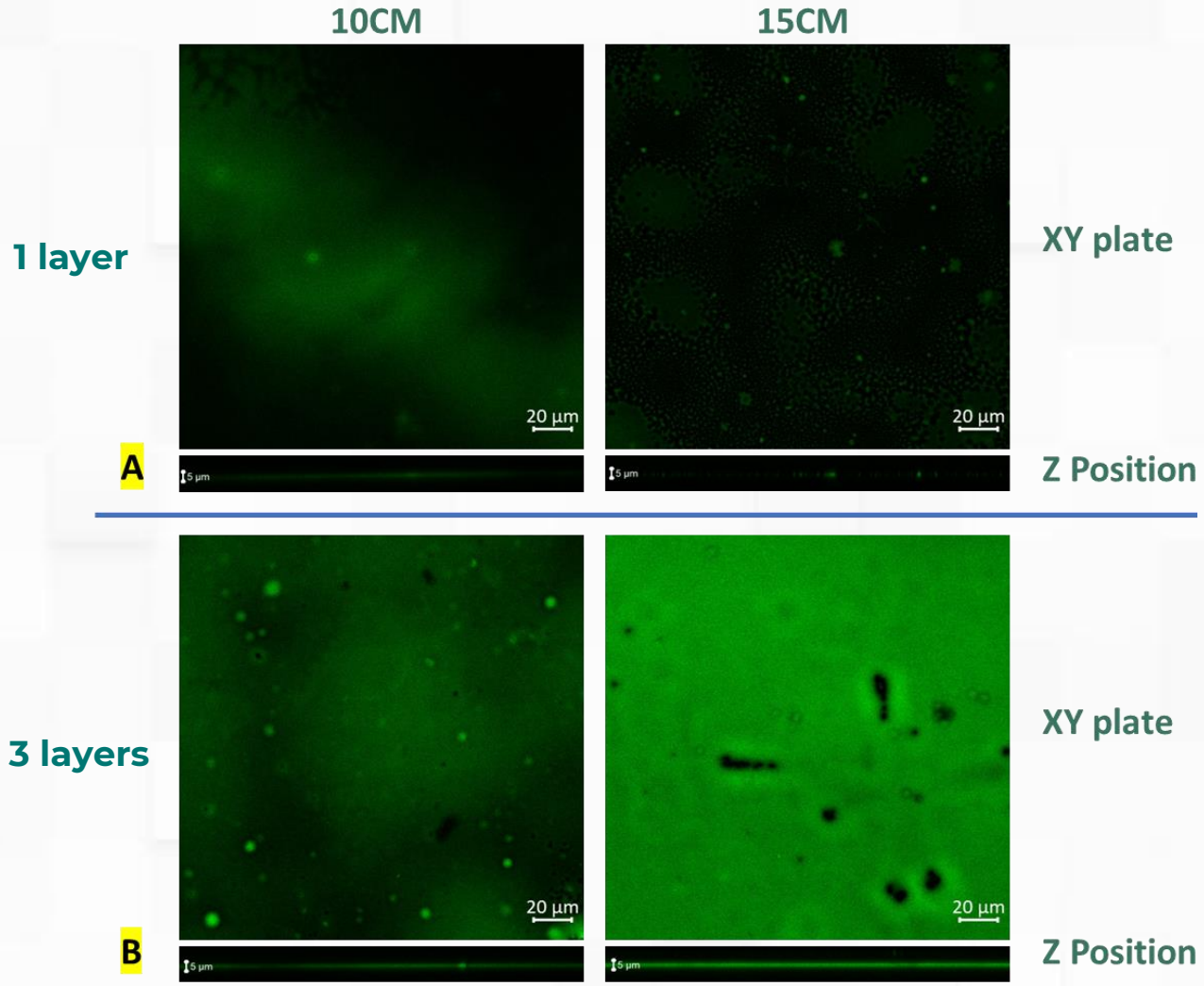
revolutionising patient care.

Antimicrobial results VS *S. aureus ATCC 25923*

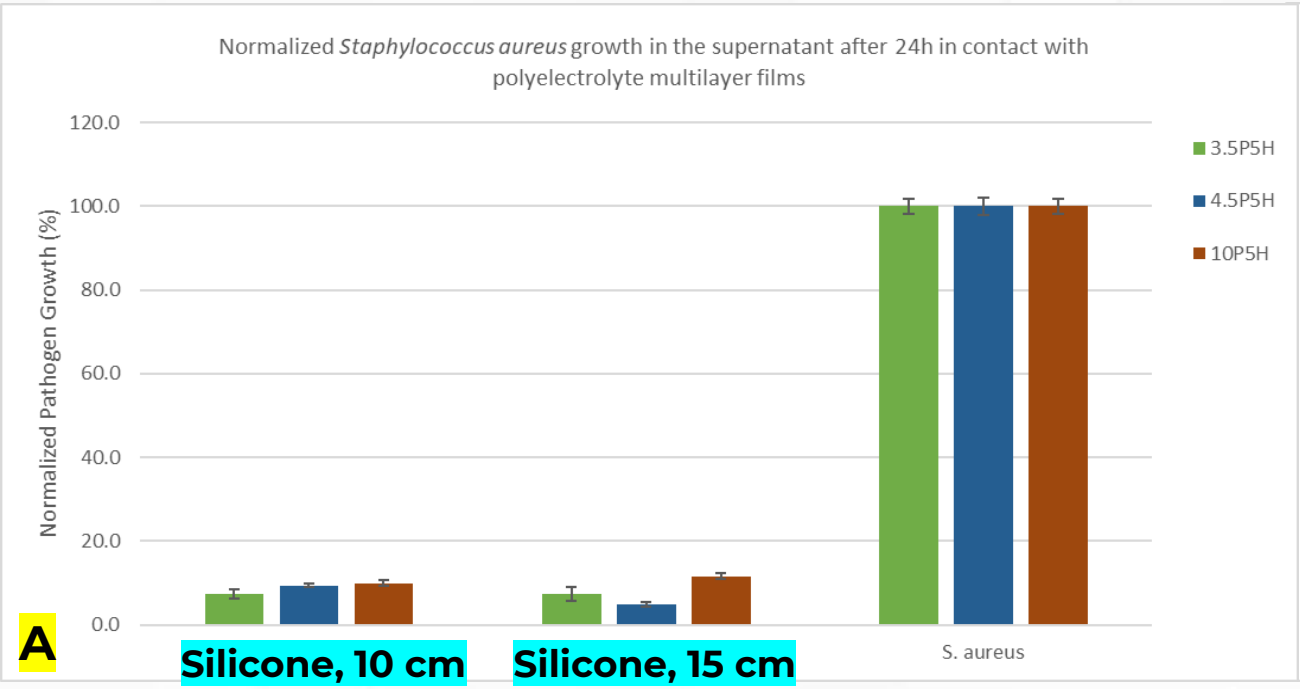
(10 mg/mL ε-PLL + 1 mg/mL HA), Glass



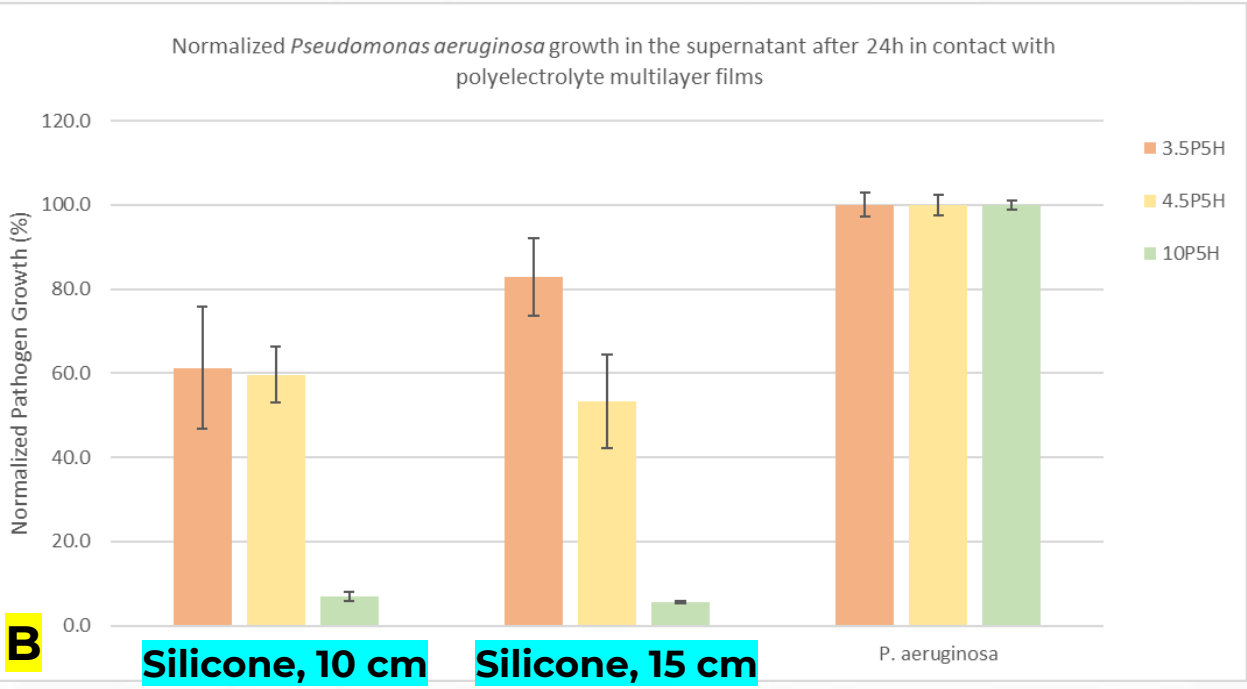




Antimicrobial results VS *S. aureus ATCC 25923* (A), *P. ae ATCC 27853* (B)
(3.5, 4.5, 10 mg/mL PAR30 + 5 mg/mL HA HTL), Medical-grade Silicone



A



B

Coating conditions:

3.5 mg/mL PAR30 + 5 mg/mL HA (3.5P5H)

4.5 mg/mL PAR30 + 5 mg/mL HA (4.5P5H)

10 mg/mL PAR30 + 5 mg/mL HA (10P5H)

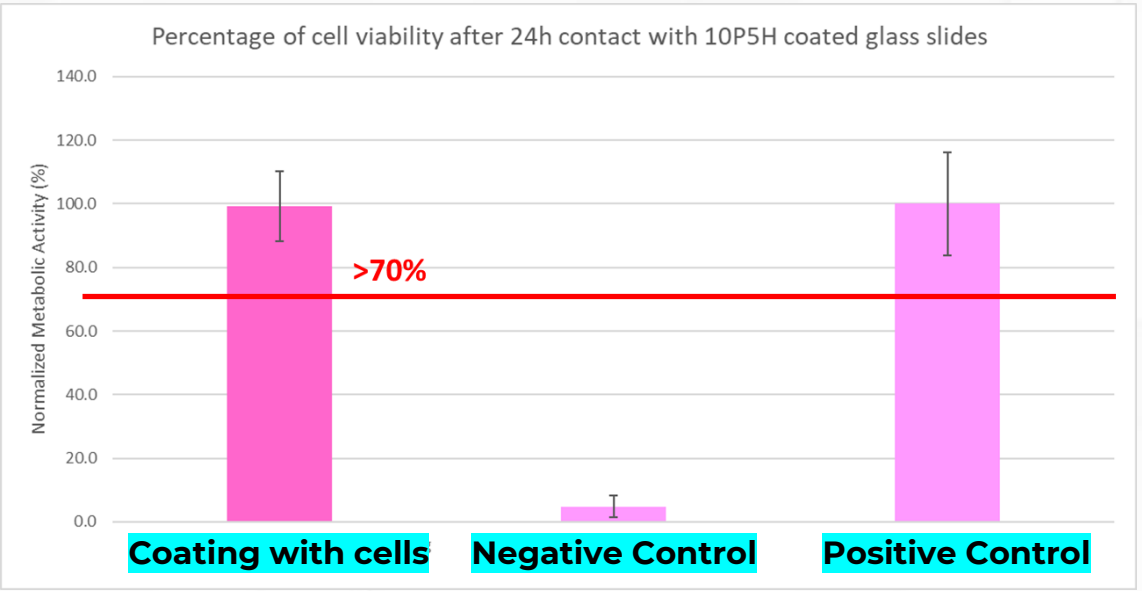


10P5H, spray at **10 cm and 15 cm** is the best coating condition.

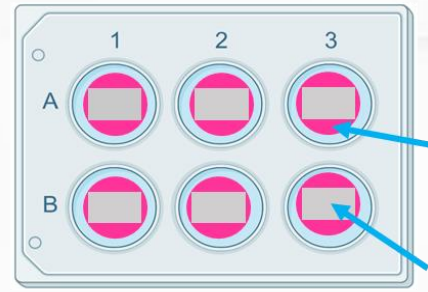
In vitro cytotoxicity on *BALB/3T3*, ISO 10993-5

10 mg/mL PAR30 + 5 mg/mL HA HTL, glass slides

n=3 **No cytotoxicity**



- **Positive control**
  Cell culture medium
- **Negative control**
  20% Dimethyl sulfoxide



1. In the well
2. Under glass slides

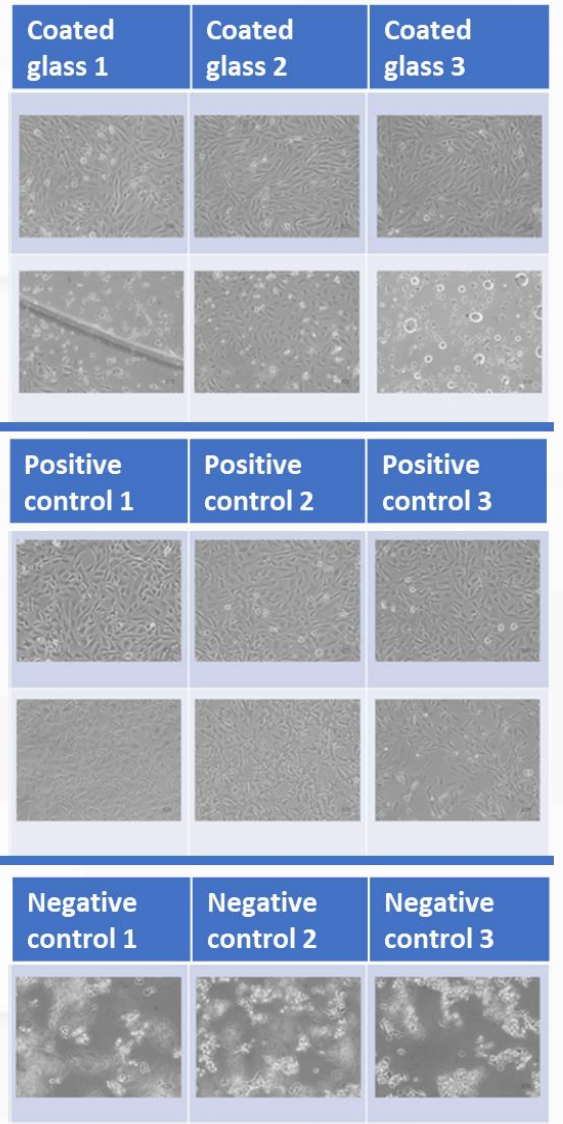
Cells

Glass slides

A. Coating glass

B. Cell culture medium

C. 20% Dimethyl sulfoxide



Experiments were performed by Mme **Lauriane PETIT**



And Mme **Lucie LIEU**

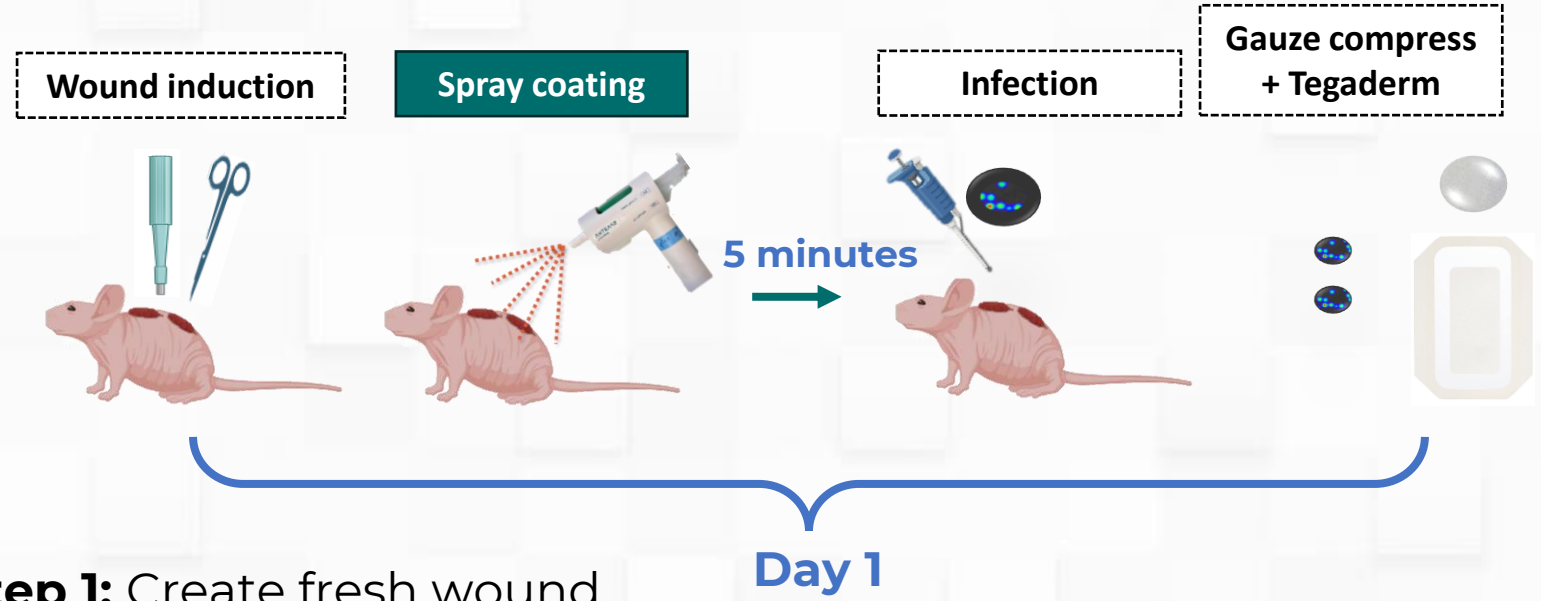


In vivo - Antimicrobial and Inflammatory

Experiments performed by Bioaster, France.

In vivo antimicrobial test:

Bioluminescent Methicillin-resistant S. aureus (ATCC 33591),
***1 x 10⁴* CFU/wound**
SKH1 hairless mouse (strain code 686), Wound diameter: ø 6 mm
10 mg/mL PAR30 + 5 mg/mL HA HTL





Day 2 / Day 3
Bioluminescence imaging

Step 1: Create fresh wound

Step 2: Spray coat wound surface

Step 3: Deposit bacteria solution

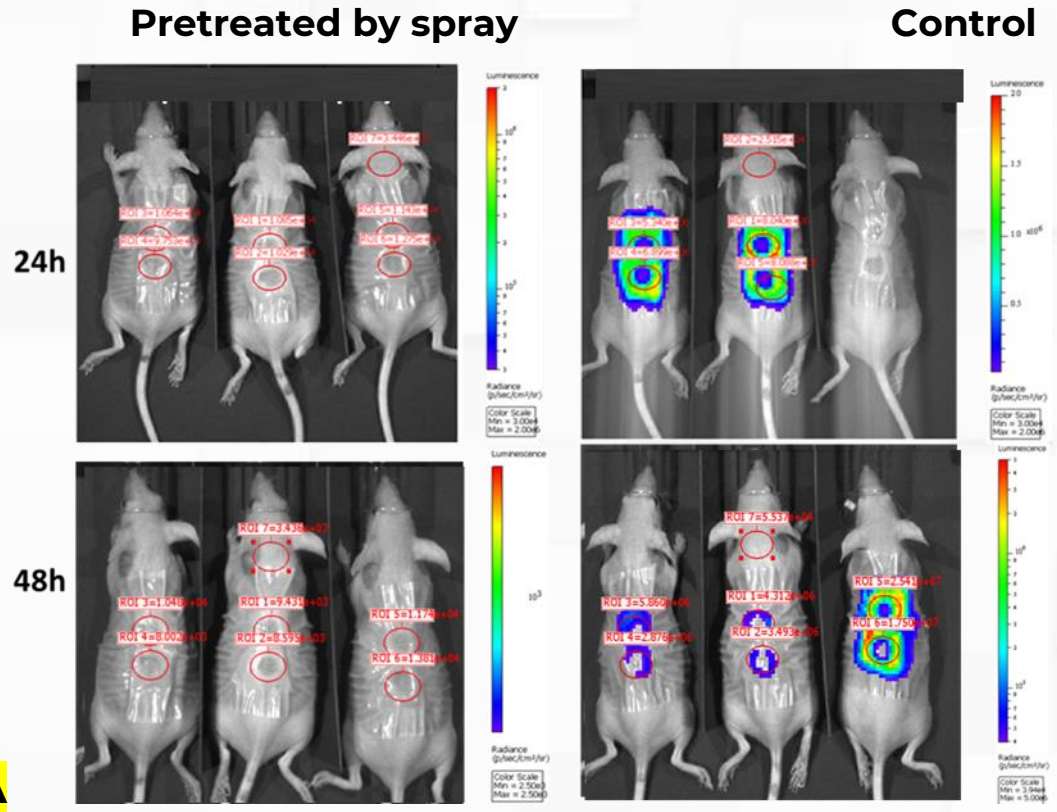
Step 4: Cover the wound with a bandage

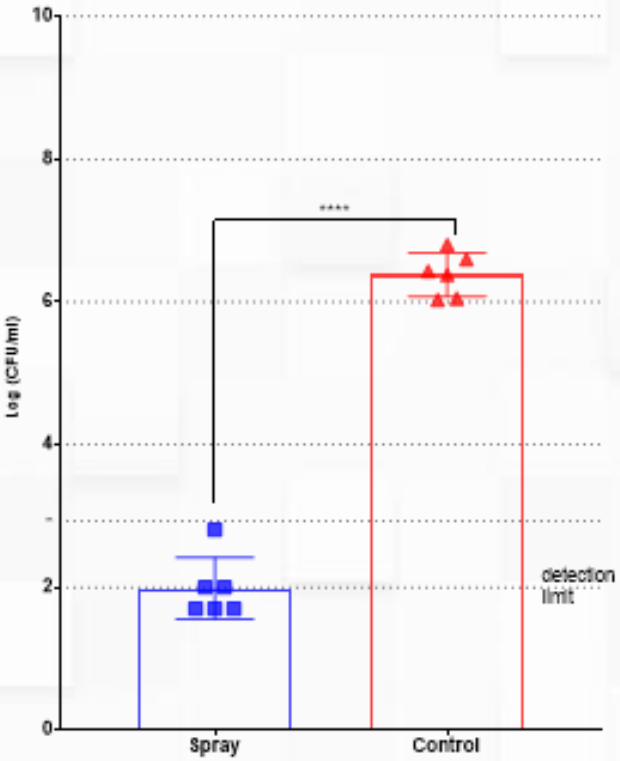
Control group: wounds without spray, step 2 was omitted.

Created by BioRender.com

In vivo antimicrobial test

Bioluminescent Methicillin-resistant S. aureus (ATCC 33591),
***1 x 10⁴* CFU/wound**
SKH1 hairless mouse (strain code 686), Wound area: ø 6 mm
10 mg/mL PAR30 + 5 mg/mL HA HTL





Control: wounds without spray

CFU counting on wounds

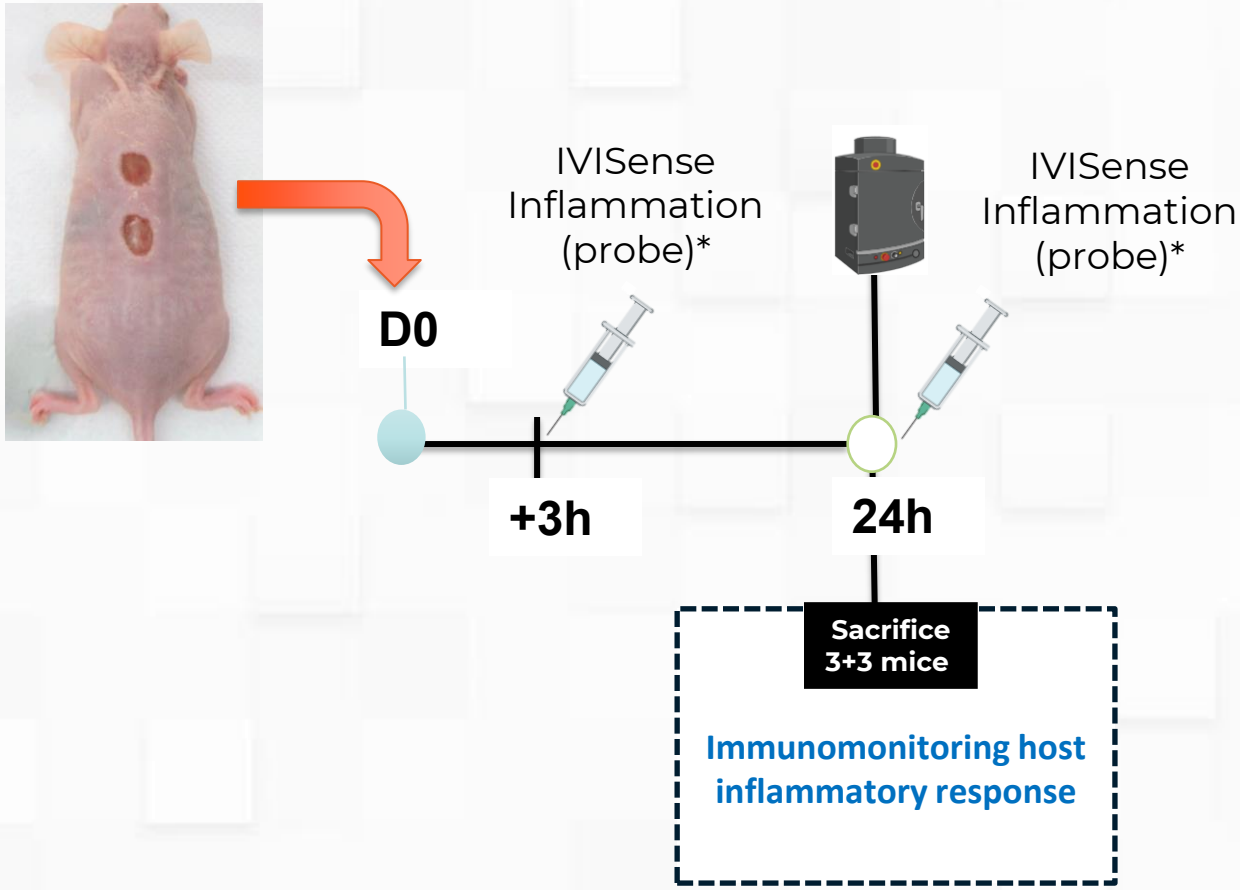
In vivo - inflammatory host response

Experiments performed by Bioaster, France.

In vivo inflammatory host response:

SKH1 hairless mouse (strain code 686), Wound diameter: ø 6 mm

10 mg/mL PAR30 + 5 mg/mL HA HTL



Step 1: wound creation

Step 2: Spray on the wound

Step 3: wound stained by IVISense MMP 750 FAST fluorescent Probe at 3h and 24h

Step 4: observation by bioluminescence

Group A: wound without spray

Group B: wound with spray

Control group: without wound, without spray

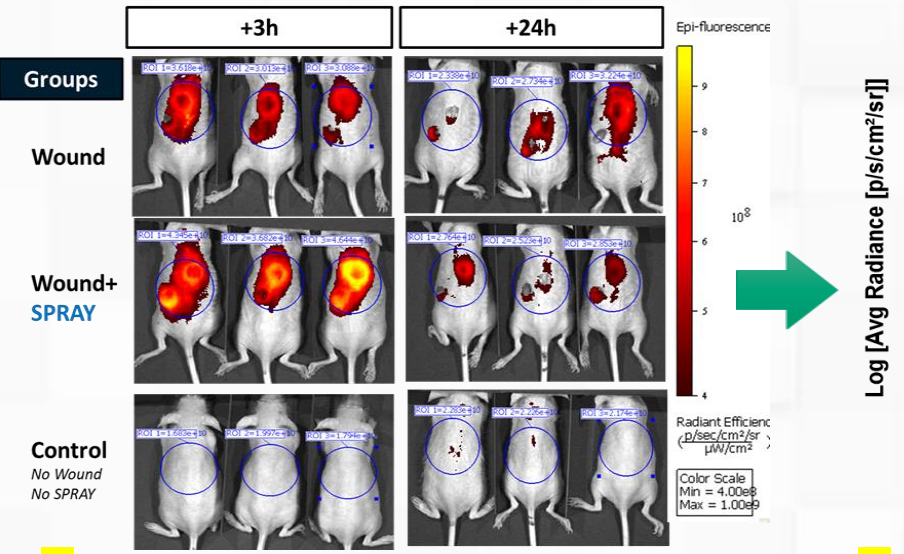
Matrix metalloproteinases interact with IVISense

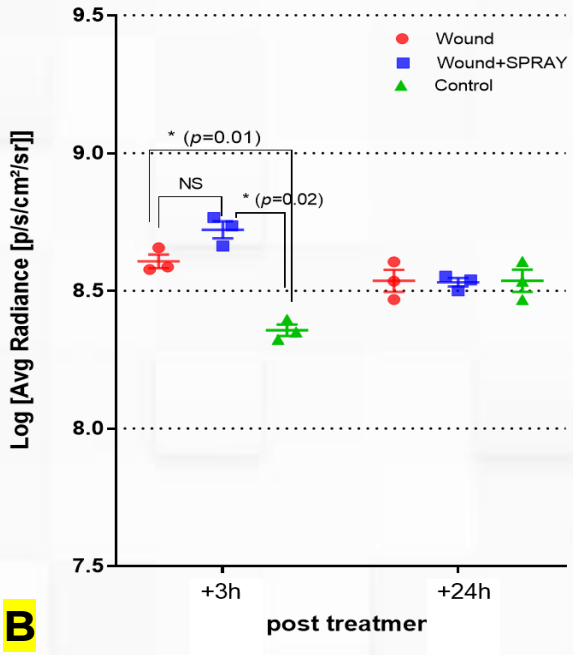
Created by BioRender.com

In vivo inflammatory host response:

SKH1 hairless mouse (strain code 686), Wound area: ø 6 mm

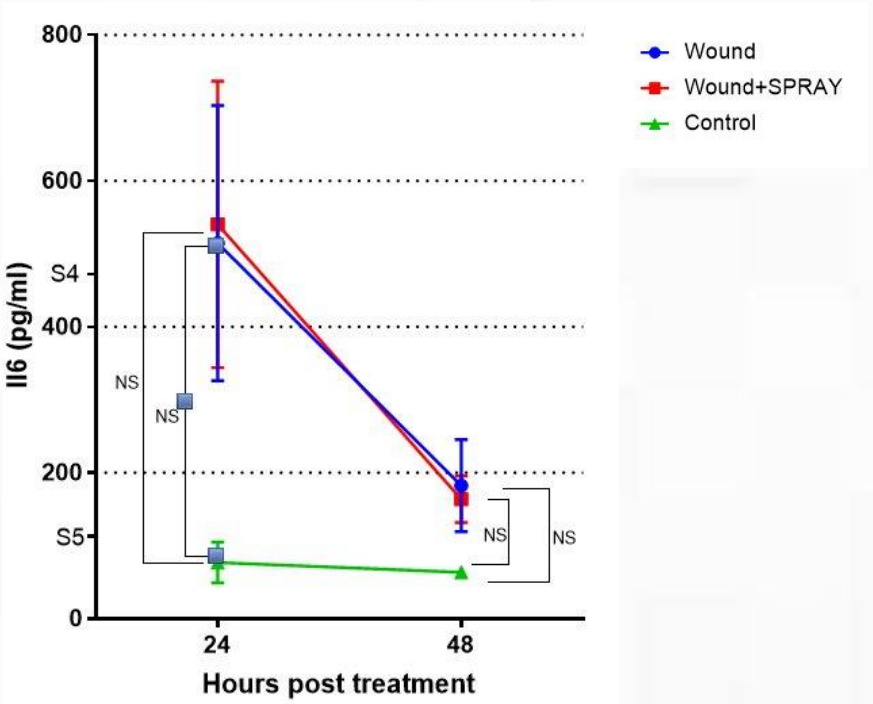
10 mg/mL PAR30 + 5 mg/mL HA HTL





The spray **does not induce inflammatory** reactions after 24h

Detected Interleukin-6 (IL-6):

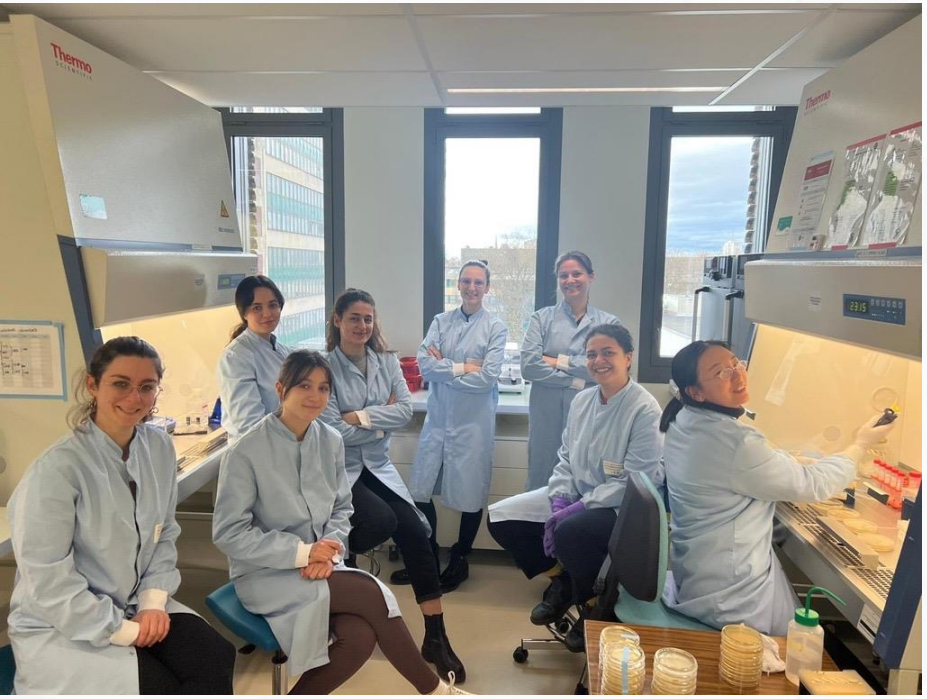


No significant difference was detected between the "Wounds" and "Wounds+Spray" groups

IL6 plays a crucial role in both **acute** and **chronic inflammation response**



Thank you for your attention!





References

[1] Division, A. R. (2025, October 13). Global antibiotic resistance surveillance report 2025: summary. https://www.who.int/publications/i/item/B09585

[2] Baym, M., Lieberman, T. D., Kelsic, E. D., Chait, R., Gross, R., Yelin, I., & Kishony, R. (2016). Spatiotemporal microbial evolution on antibiotic landscapes. Science, 353(6304), 1147–1151. https://doi.org/10.1126/science.aag0822

[3] Mutschler, A., Tallet, L., Rabineau, M., Dollinger, C., Metz-Boutigue, M., Schneider, F., Senger, B., Vrana, N. E., Schaaf, P., & Lavalle, P. (2016). Unexpected Bactericidal Activity of Poly(arginine)/Hyaluronan Nanolayered Coatings. Chemistry of Materials, 28(23), 8700–8709. https://doi.org/10.1021/acs.chemmater.6b03872Rhodes, M. (2016, September 10). A Gorgeous—and Unsettling—Video of Evolution in Action. Wired. https://www.wired.com/2016/09/gorgeous-unsettling-video-evolution-action/

[4] Kocgozlu, L., Mutschler, A., Tallet, L., Calligaro, C., Knopf-Marques, H., Lebaudy, E., Mathieu, E., Rabineau, M., Gribova, V., Senger, B., Vrana, N. E., & Lavalle, P. (2024). Cationic homopolypeptides: A versatile tool to design multifunctional antimicrobial nanocoatings. Materials Today Bio, 28, 101168. https://doi.org/10.1016/j.mtbio.2024.101168