Distant transport of antimicrobial protection by implantable polymeric meshes

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Introduction

Implantable polymeric meshes provide structural support, reinforce soft tissues, promote regeneration in patient with tissue defects and can inhibit device infections, if combined with a drug-eluting component that sustains the local delivery of antimicrobial agents. In this context, uniform antimicrobial distribution and homogenous elution in the surgical pocket and implant surrounding are vital for infection prevention.

Objective: We extensively evaluated the interaction mechanisms between water-soluble antimicrobial molecules and polymeric meshes throughout *in silico*, *in vitro* and *in vivo* assessments.

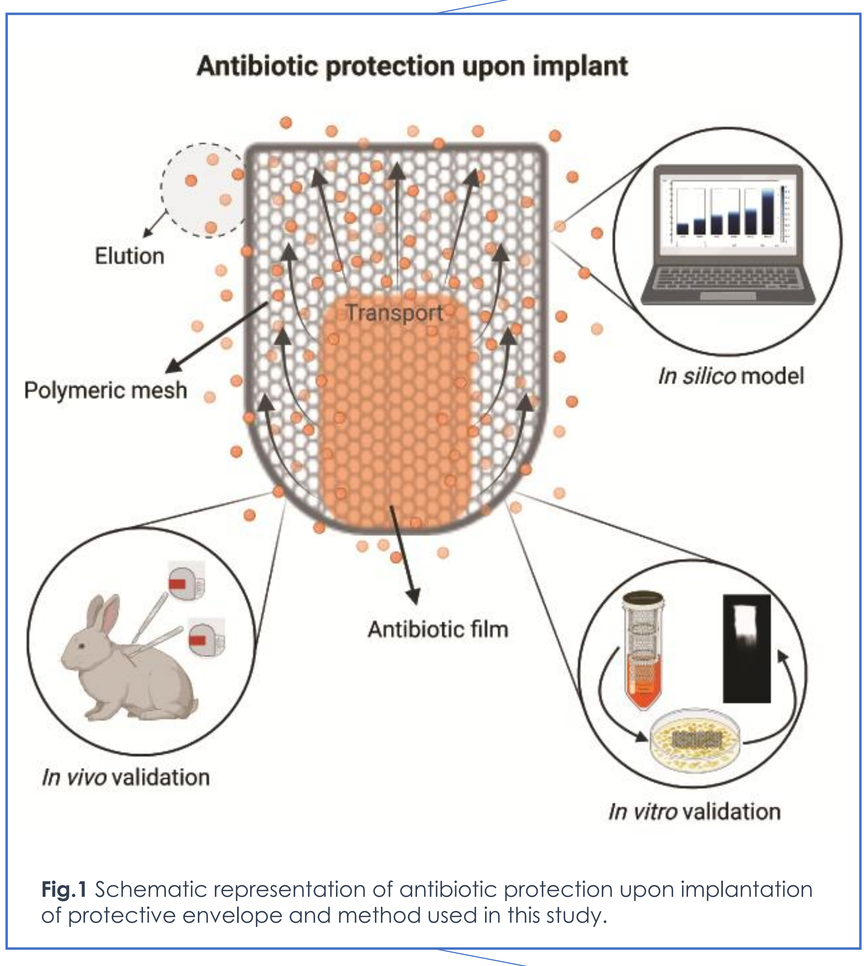


Fig.1 Schematic representation of antibiotic protection upon implantation of protective envelope and method used in this study.

Method

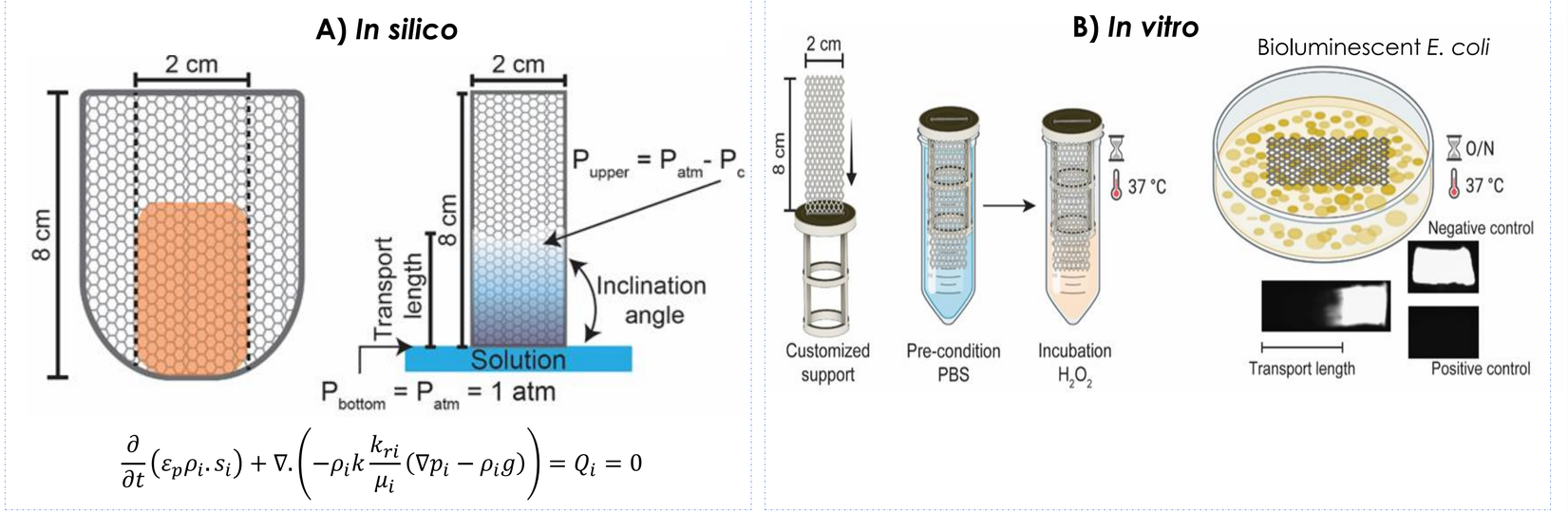


Fig.2 The methods used in unravelling the underlaying mechanisms of interaction between water-soluble antimicrobials and polymeric meshes. **A)** structural model and boundary conditions for *in silico* studies. **B)** *In vitro* antimicrobial activity of the transported antimicrobial agents against bioluminescent *E. Coli*. **C)** *Evaluation of the homogenous and uniform distribution of minocycline and rifampin antibiotics in a complex in vivo model.*

Results: Predictive model and validation

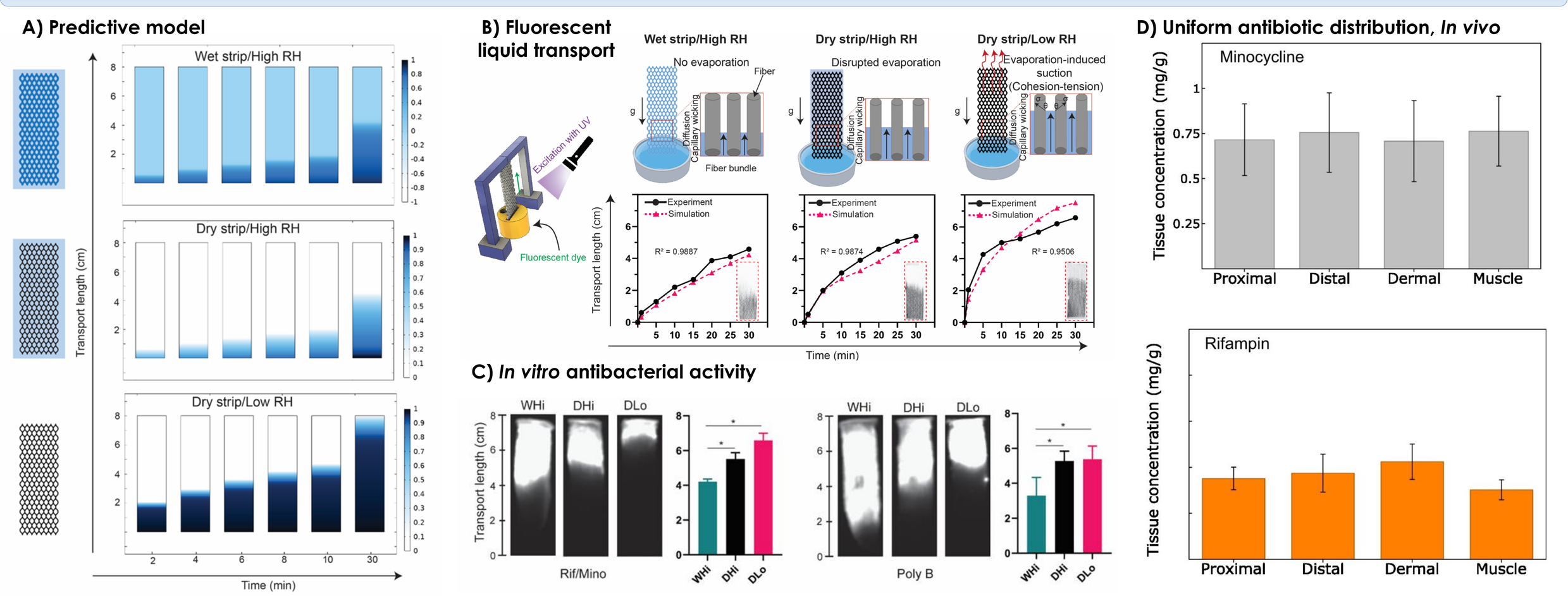


Fig.3 A) In silico analysis of liquid transport in wet strip at high RH, dry strip at high RH and dry strip in low RH. **B)** Custom-made experimental setup for evaluation of fluorescent liquid transport in mesh. The experimental values (black) were then compared to the corresponding simulation conditions (pink dashed). **C)** Transport length of Rif/Mino and Poly B in wet strip high humidity (Whi), dry strip high humidity (DHi) and dry strip low humidity (DLo) showing the effect of environmental conditions. (*) $p<0.05$. **D)** Quantification of minocycline and rifampicin in tissue samples, showing similar antibiotic concentration independently on the sample origin.

Conclusion

The proposed Multiphysics model captures the interplay between material microstructure, local tissue environment and drug transport phenomena. *In silico* experiments provide mechanistic insights into how polymeric mesh distributes antimicrobial activity. The results were validated by demonstrating the functional capacity to inhibit and kill bacteria in distal locations. This work underscores how predictive models can accelerate biomaterials innovation and ensure reproducibility in translational applications.

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