Effect of Mechanical and Chemical Process Variation on Antibacterial Activity of Polydopamine Coating

S. Fonseca[1], N. Fontaine[2,3], M.P. Cayer[1], J. Robidoux[1], D. Boudreau[2,3], D. Brouard[1]

[1]Medical Affairs and Innovation, Héma-Québec, Québec, QC, Canada
[2] Chemistry Department and [3]Center for Optics, Photonics and Lasers (COPL), Université Laval, Québec, QC, Canada

Background

Low bacterial load and adhered biofilms are challenges to current tests and prophylactic measures which can result in health-care-associated infections (HAIs). It has been shown that the risk of HAIs can be reduced when antibacterial coatings are applied to the surface of medical devices. The aim of this study is to optimize the antibacterial efficacy of polydopamine (PDA) coatings as a potential material for the prevention of HAIs.

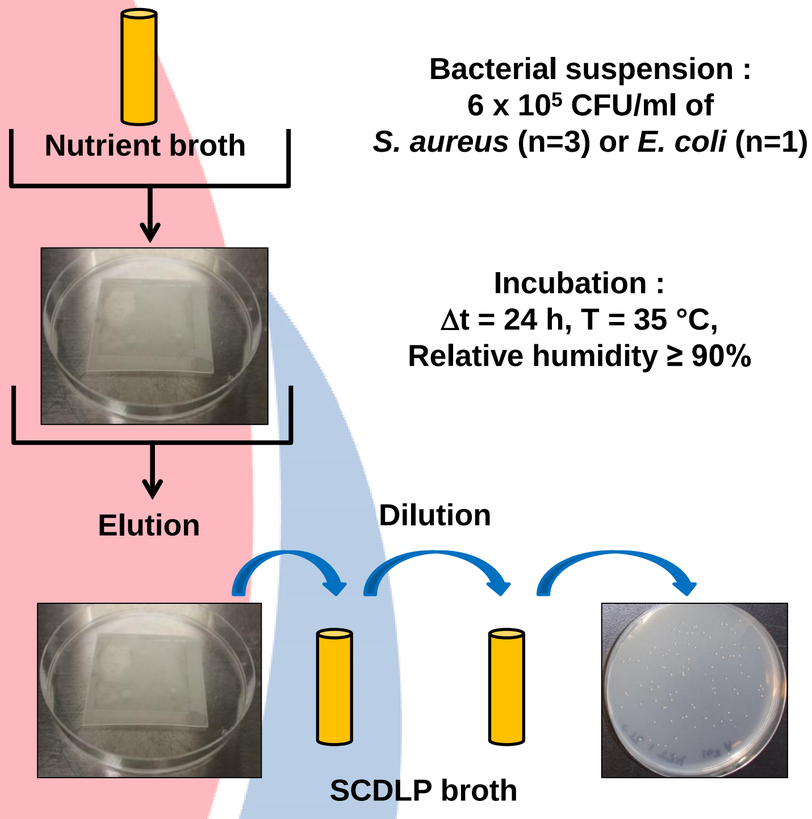
Scheme 1. Antibacterial polydopamine preparation.

Study design

Table I – Polymerization reaction parameters for the synthesis of PDA coatings

Varied reaction conditions		Fixed reaction conditions
Dopamine concentration	1 mg/ml 2 mg/ml 3 mg/ml 2 mg/ml, solution change after 3 h€	7 h reaction, room temperature, 65 RPM, horizontal sample
Stirring condition	0 RPM 30 RPM 65 RPM 90 RPM	2 mg/ml dopamine, 7 h reaction, room temperature, horizontal sample
Sample orientation	Horizontal Vertical	2 mg/ml dopamine, 7 h reaction, room temperature, 65 RPM
Time of reaction	0.5 h 3 h 7 h 24 h	2 mg/ml dopamine, room temperature, 65 RPM, horizontal sample

€ The dopamine solution was replaced after 3 h with a fresh 2 mg/ml dopamine preparation and the reaction was resumed (2 mg/ml, two coating steps).



Scheme 2. Antibacterial activity of the polydopamine coating tested according to ISO 22196:2011 standards against *S. aureus* and *E. coli*.

Results

UV-Visible Spectrophotometry

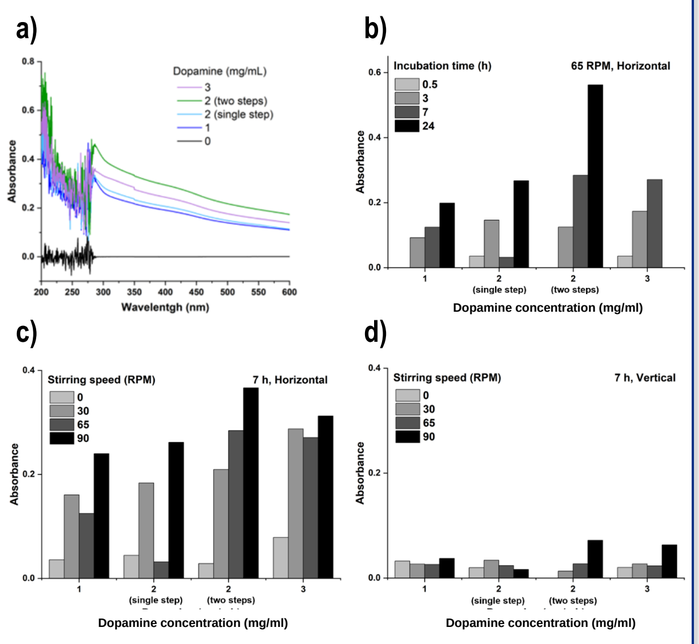


Fig. 1. Dopamine polymerization under various reaction conditions (n = 1). a) UV-visible spectra of PDA treated silica glass slides. **b)** Impact of the incubation time on dopamine polymerization. **c)** Impact of stirring speed on dopamine polymerization in a horizontal or **d)** vertical position.

Atomic Force Microscopy

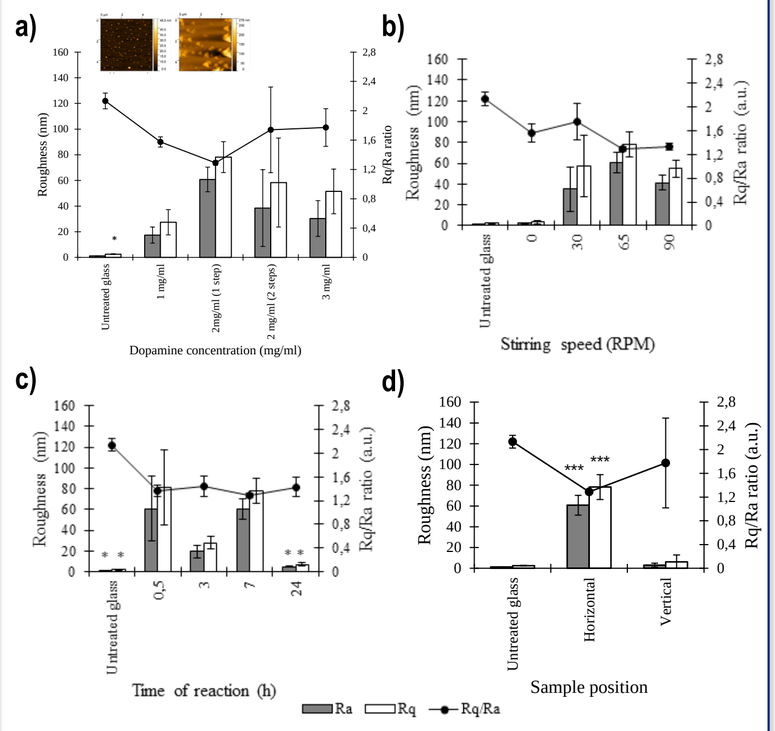
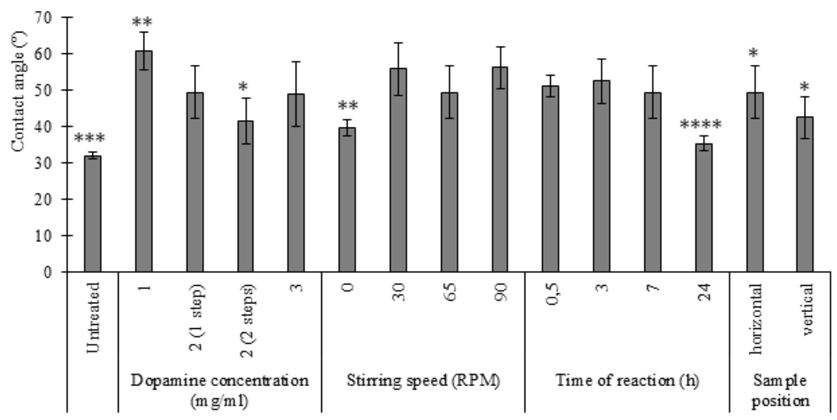


Fig. 2. Surface roughness of PDA-treated silica glass slides (n = 1) incubated with various a) dopamine concentrations, b) stirring speeds, c) reaction times and d) orientations. * $p < 0.05$, *** $p < 0.001$ when compared untreated and PDA-treated samples.

Contact Angle Measurements



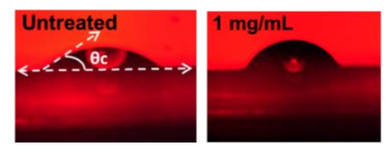


Fig. 3. Water contact angle (θc) measurements of untreated and PDA-treated silica glass under various conditions (n = 1). * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$, **** $p < 0.0001$ when compared to other samples of the same set of reaction conditions and including untreated sample.

Antibacterial Activity

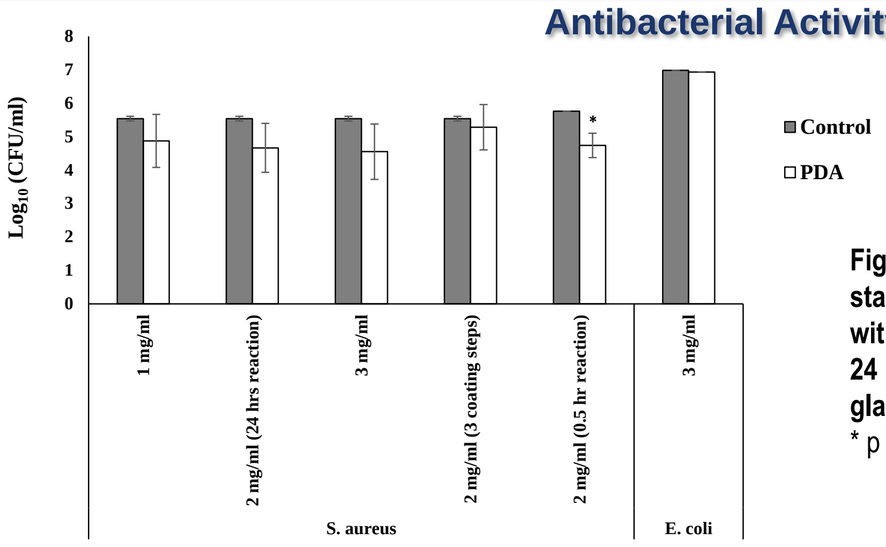


Fig. 4. Logarithmic bacterial growth (mean ± standard deviation) in nutrient broth (1/500) with an inoculum of 5.8 log CFU/ml after 0.5 to 24 h in direct contact with PDA-treated silica glass (*S. aureus*, n = 3; *E. coli*, n = 1). * $p < 0.01$ compared to the untreated sample.

Table II – Cytotoxicity of PDA coating against L929 cells*

Dopamine concentration (mg/ml)	MTT¥	Viability (%) AO/DAPI	Viability (%) 7-AAD
Untreated	N/A	94 ± 2	92 ± 3
1	98 ± 18	96.5 ± 0.3	97 ± 1
2 (single coating step)	100 ± 19	97 ± 2	97 ± 1
3	95 ± 15	94 ± 2	95 ± 2
2 (three coating steps)	98 ± 17	94 ± 4	98 ± 1

* Mean results ± SD; n=3; N/A = not applicable.
¥ If viability is reduced to < 70 % of the control, it has a cytotoxic potential according to ISO 10993-5.

Conclusion

The antibacterial efficacy of polydopamine coatings appear to be linked to thickness and roughness, two parameters that may affect the surface wettability and, in turn, bacterial adhesion. Polydopamine could be employed to limit HAIs, although its antibacterial properties need to be further improved.

Acknowledgements

COPL
HÉMA-QUÉBEC
UNIVERSITÉ LAVAL