Mechanobactericidal Activity on Escherichia coli and Fibroblast Biocompatibility of PMMA Nanostructures – A Multimodal and Imaging Analysis

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The rise of multidrug-resistant (MDR) bacteria demands new antimicrobial strategies to limit colonization and biofilm formation. MDR infections currently cause around 700,000 deaths per year worldwide, with projections reaching 10 million annually by 2050. This "silent pandemic" threatens healthcare systems and global development, particularly in Intensive Care Units, where pathogens persist for months on surfaces and medical devices. Controlling surface-mediated spread is therefore essential.

Nanostructured bioinspired surfaces offer a promising chemical-free approach to prevent bacterial adhesion and mechanically disrupt cells.These biomimetic surfaces act passively by imposing physical stress on bacterial envelopes, reducing contamination and interfering with biofilm formation (a).

This study investigates the antibacterial performance of polymethyl methacrylate (PMMA) surfaces patterned via EBL with nanogratings and nanopillars arranged in Square and Triangular geometries. The morphological and nanomechanical responses of Escherichia coli were analyzed using Atomic Force Microscopy, Ultra High-Resolution Scanning Electron Microscopy, and Focused Ion Beam milling. A significant decreas of bacterial adhesion and induced marked morphological damage, including deformation, volume collapse, and membrane rupture were observed. AFM force spectroscopy revealed reduced Young's modulus and increased adhesion forces in bacteria exposed to nanostructures, supporting a mechano-bactericidal mechanism driven by membrane tension and mechanical stress.

Crucially, biosafety assays with NIH/3T3 fibroblasts confirmed high cell viability and enhanced spreading on nanopatterned PMMA, demonstrating cytocompatibility. Overall, the results provide direct evidence that geometry-driven mechanical inactivation can effectively

kill bacteria while supporting mammalian cell growth, highlighting the potential applications of these surfaces in medical devices and healthcare environments (b).

a) P. Pellegrino, I. Farella, V. De Matteis, M. Cascione, M. Calcagnile, S.Villani, L. Vincenti, P. Alifano, F. Quaranta, R. Rinaldi; *Morphological and mechanical variations in E. coli induced by PMMA nanostructures patterned via electron beam lithography: An atomic force microscopy study*, Surfaces and Interfaces, 56, (2025), https://doi.org/10.1016/j.surfin.2024.105707

b) P. Pellegrino, I. Farella, V. De Matteis, M. Cascione, S. Villani, M. Calcagnile, L. Vincenti, A. Bianco, P. Alifano, A. Della Torre, C. Demitri, R. Rinaldi, *Geometry-driven mechanobactericidal activity on Escherichia coli and fibroblast biocompatibility of PMMA nanostructures fabricated by electron beam lithography,* Materials Today Nano, Volume 34 (2026), https://doi.org/10.1016/j.mtnano.2026.100851.

Short bio:

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