



10th World Congress of Biomechanics

JULY 11 – 15, 2026 | VANCOUVER, CANADA

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ABSTRACT BOOK

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Engineered 3D Scaffolds for Modeling Dermal Tissue Regeneration and Macrophage Immune Dynamics

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Introduction

Subcutaneous implants trigger immune reactions mediated by macrophages, making effective tissue repair essential to re-establish the native dermal environment. Three-dimensional (3D) *in vitro* microstructured scaffolds represent valuable platforms for studying these processes, as they enable the reconstruction of microvascular networks. Upon proper modulation of their physicochemical features, they can play a key role in directing macrophage behavior.

Methods

3D scaffolds were fabricated by two-photon polymerization of the biocompatible photoresist SZ2080 and presented small ($15 \times 15 \times 15 \mu\text{m}^3$) [1] and large ($50 \times 50 \times 20 \mu\text{m}^3$) [2] pores. Human dermal fibroblasts (HDF) and HUVEC were cultured in 50×50 scaffolds integrated into a Miniaturized Optically Accessible Bioreactor (MOAB, Figure 1A), perfused at 5 $\mu\text{L}/\text{min}$, and administered with VEGF (50 ng/mL) and TGF- β 1 (5 ng/mL). RAW264.7 macrophages were polarized with lipopolysaccharide (M1) or interleukin-4 (M2) in both scaffolds (Figure 1B). Co-cultures were stained for collagen I and CD31 at day 7, inducible nitric oxide synthase (iNOS, M1, Figure 1C), and arginase 1 (Arg1, M2) and acquired by confocal laser scanning microscopy (CLSM). Cytoskeletal changes and metabolic activity of macrophages were analyzed.

Results

The perfused setup provided a robust model of dermal regeneration with the development of early tubular formations ($128.1 \pm 8.6 \mu\text{m}$) and increased deposition of collagen I upon VEGF administration. Both scaffolds markedly influenced macrophage shape,

organization, and metabolic activity in static conditions. In the presence of chemical stimuli, 50×50 pores produced a modest increase in Arg1 expression (+5%), suggesting a shift toward an anti-inflammatory phenotype. Conversely, 15×15 pores strongly enhanced iNOS levels (+121%), promoting a marked pro-inflammatory response.

Discussion

The integration of the 3D scaffolds into the MOAB enabled the generation of a dermal perivascular microenvironment that closely resembles physiological conditions. Thanks to their adjustable architectural features, the scaffolds allowed precise modulation of macrophage functions. Upcoming studies will further explore macrophage dynamics within the perfused bioreactor, in presence of chemical cues.

Images (Optional)

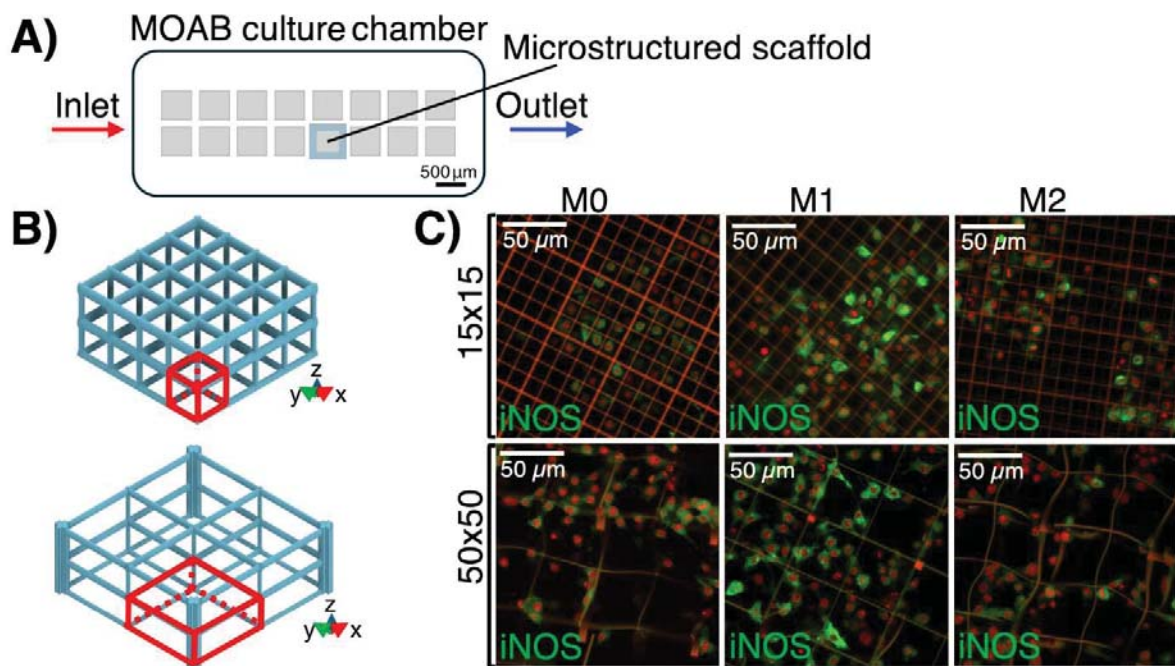


Figure 1: A) Scheme of the MOAB microstructured cell culture chamber. B) CAD of 15×15 (above) and 50×50 (below) scaffolds. C) CLSM images of RAW264.7 (M0, M1, M2) cultured in 15×15 and 50×50 scaffolds (iNOS, green; nucleus, red).

References (Optional)

- [1] Chiara Martinelli *et al.*, Mater Today Bio, 2025, 35, 102328
- [2] Chiara Martinelli *et al.*, Lab Chip, 2025, 25, 423-439

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Session Category

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