NORTH CAROLINA AGRICULTURAL AND TECHNICAL STATE UNIVERSITY

Nanobio architecture (multi-scale assembly / bio-inspired assembly)

Center of Excellence in Product Design and Advanced Manufacturing (CEPDAM)

AGGIES DO

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University Distinguished Professor
Director – CEPDAM

Outline

- Nanoscale topographical and biochemical signaling
- Hybrid Nanoscale Bio-Additive Manufacturing
- AI in NanoBiomanufacturing
- Cybersecurity and Privacy in Biomanufacturing

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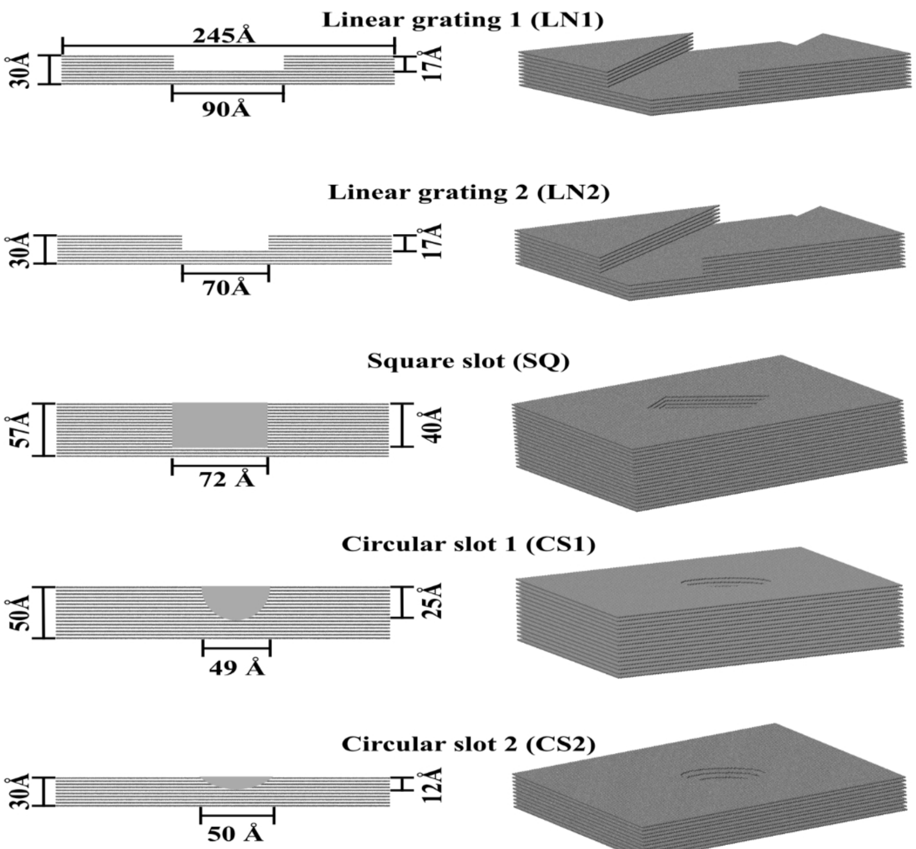
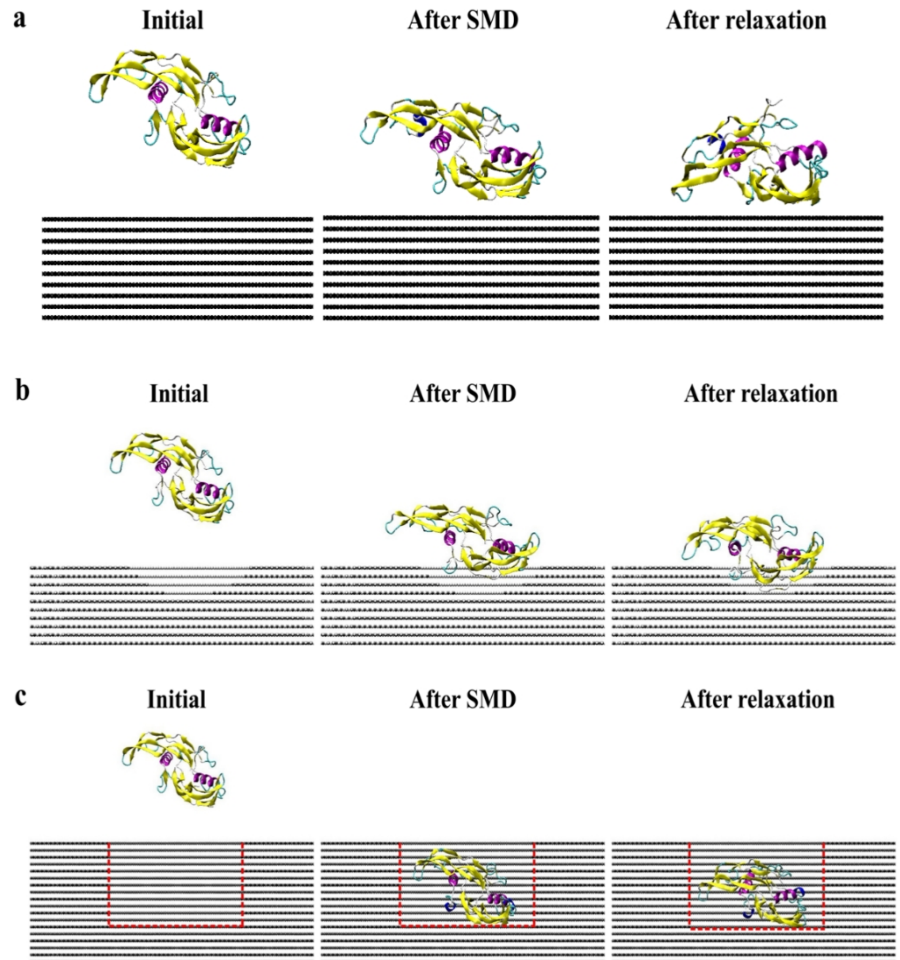
Nanoscale Topographical Effects on the Adsorption Behavior of Bone Morphogenetic-2 on Graphite



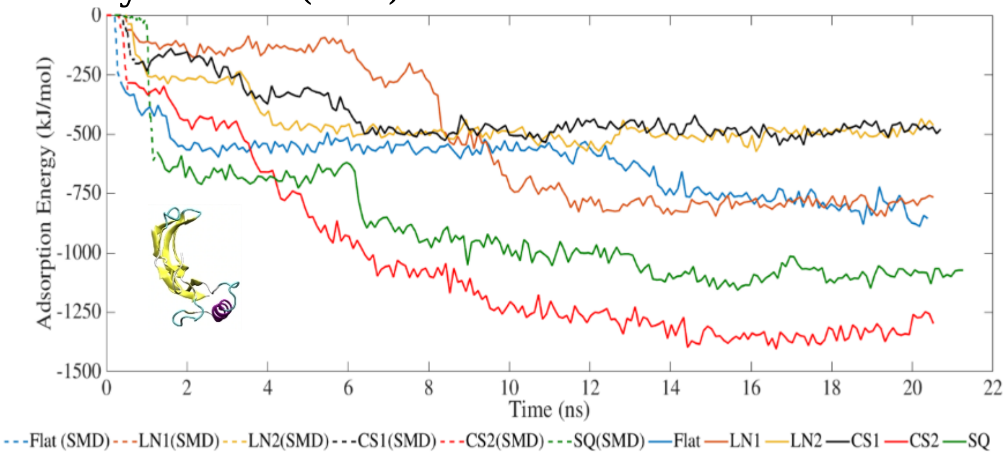


AGGIES DO

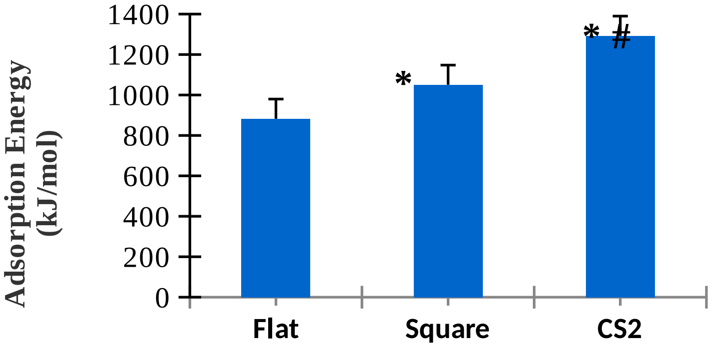
I. Marquetti and S. Desai, “Nanoscale Topographical Effects on the Adsorption Behavior of Bone Morphogenetic Protein-2 on Graphite,” *Int. J. Mol. Sci. 2022, Vol. 23*, p. 2432, 2022.

Nanoscale Topographical Effects on the Adsorption Behavior of Bone Morphogenetic-2 on Graphite

- Investigate the influence of different nanoscale topographical patterns of graphite on the protein adsorption of bone morphogenetic protein-2 (BMP-2) using molecular dynamics (MD).



Adsorption energy between BMP-2 protein and graphite substrate



Comparative of adsorption energies for flat, square and CS2 graphite substrates ($p<0.05$)

Hybrid Nanoscale Bio-Additive Manufacturing for Tissue Engg.

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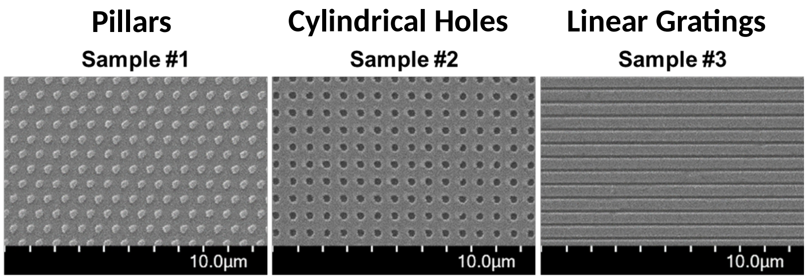
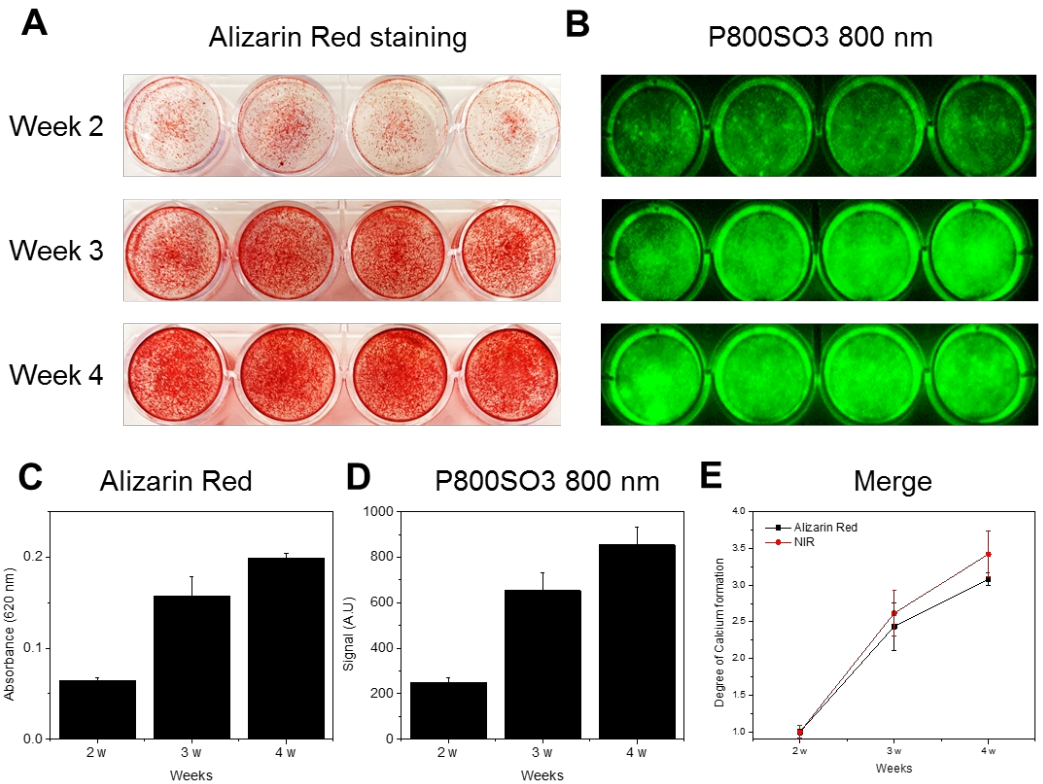
- Effect of nanoscale topographies on osteogenic differentiation of human bone marrow-derived mesenchymal stem cells (BM-MSCs).
- Quantification of the mineralization by the alizarin red staining assay and NIR fluorescence imaging for nanopatterns showed higher mineralization for osteogenic lineages.



Nanoscale topographies imprinted for osteochondral regeneration



Osteogenic differentiation of BM-MSCs. (A) Alizarin Red (B) NIR fluorescence. Quantification of mineralization by (C) Alizarin Red assay (D) NIR fluorescence (E) Comparison between Alizarin Rad assay and NIR fluorescence imaging analysis.

AGGIES DO

- Parupelli, S. K., Saudi, S., Bhattarai, N., & Desai, S. (2023). 3D printing of PCL-ceramic composite scaffolds for bone tissue engineering applications. *Int. J. Bioprint*, 9(2), 0196.

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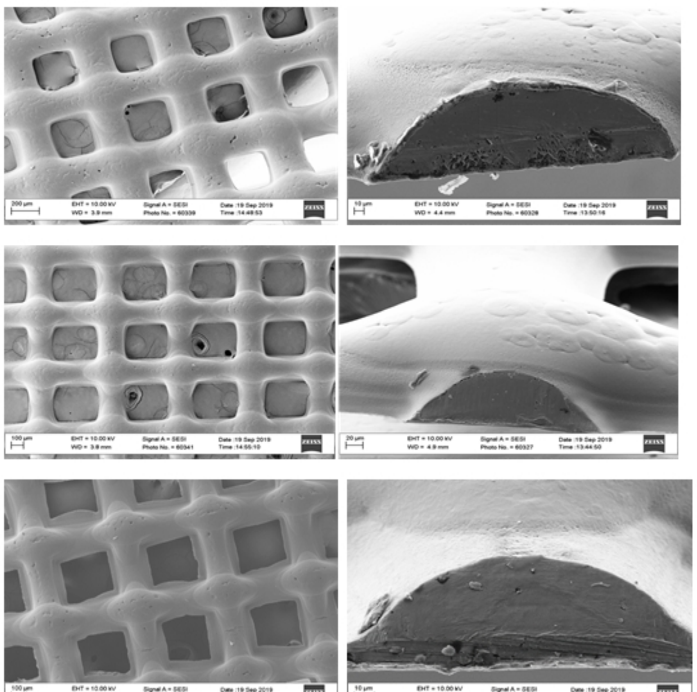
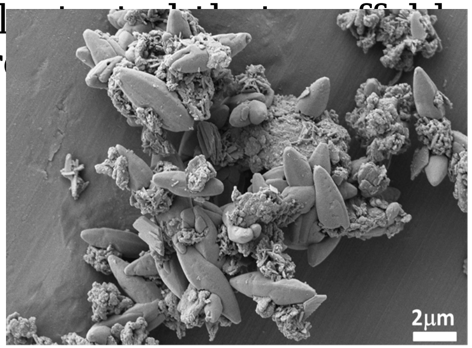
Understanding Cellular Proliferation with novel Calcium Magnesium Phosphate (CMP) and polymer composites for 3D Bioprinting

- Understanding the effect of bio-ceramic content on the mechanical properties, biodegradability, and bioactivity of fibroblast cells on the composite scaffold.

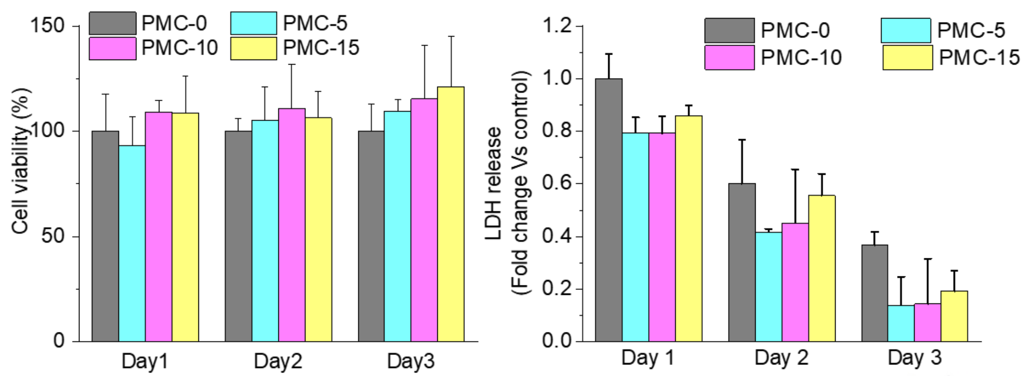
- Cell viability and LDH cytotoxicity assays ill[...] mimicked the natural ECM for cell attachment and pr[...]



CMP-PCL, PCMP5 and PCMP 10 composite 3D printed scaffolds



Ca3(PO4)2 and spindle shaped Mg3(PO4)



Viability of cell using Alamar Blue assay (left) and LDH cytotoxicity (right). Data represent the mean ± S.D. (n = 3)

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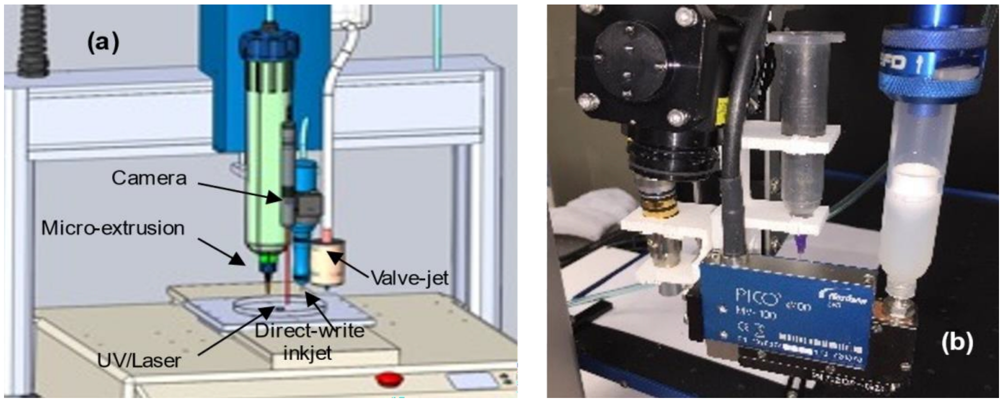
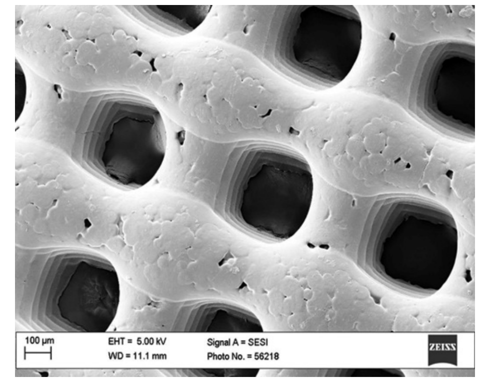
3D printed drug-eluting bioactive multifunctional coatings

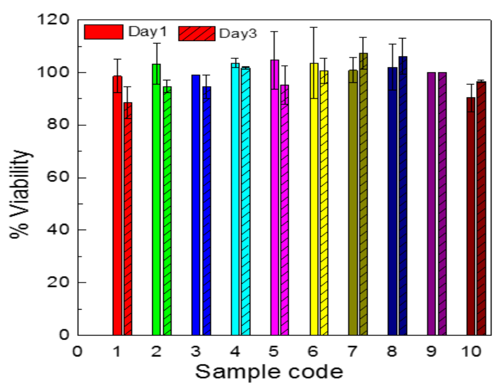
- Promote osseointegration and anti-bacterial activity with amorphous calcium phosphate (ACP) and vancomycin therapeutic agents.



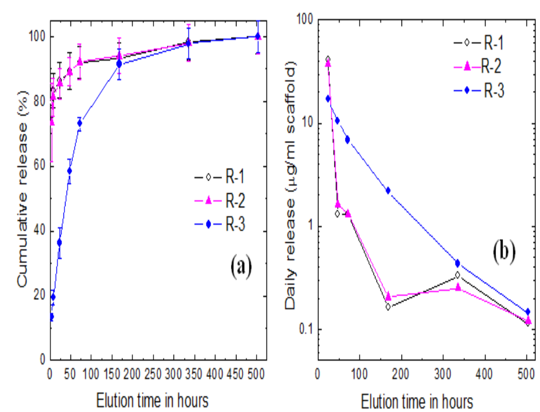
Custom 3D inkjet printer for biomedical applications



3D-printed scaffold ECM



***In vitro* MC3T2 cell viability**



Vancomycin release kinetics

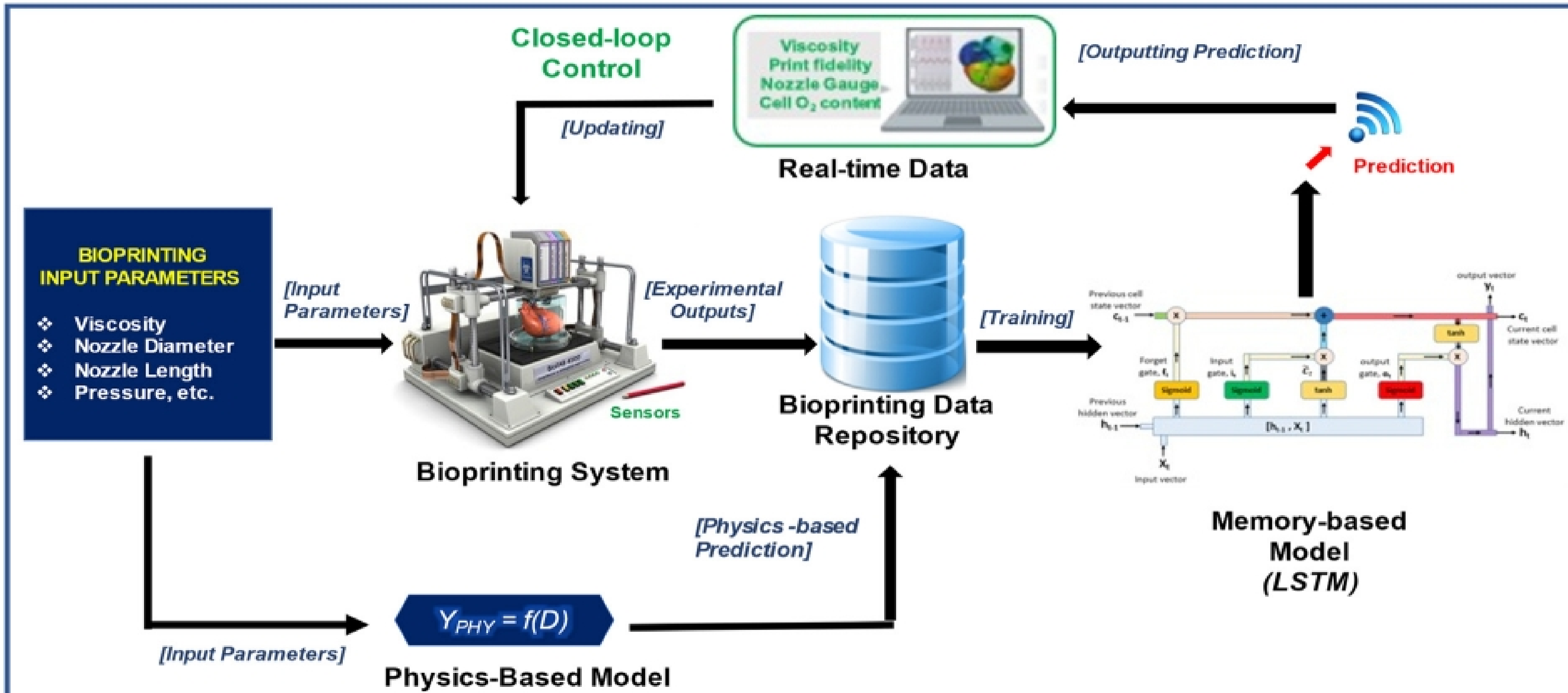
AGGIES DO

Adarkwa, E., Roy, A., Ohodnicki, J., Lee, B., Kumta, P. N., & Desai, S. (2023). 3D printing of drug-eluting bioactive multifunctional coatings for orthopedic applications. *International Journal of Bioprinting*, *9*(2).

Physics-based and data-driven modeling for biomanufacturing 4.0

- Bioprinting is transforming regenerative medicine, but also highlight its sensitivity to process parameters, material formulations, and environmental conditions.

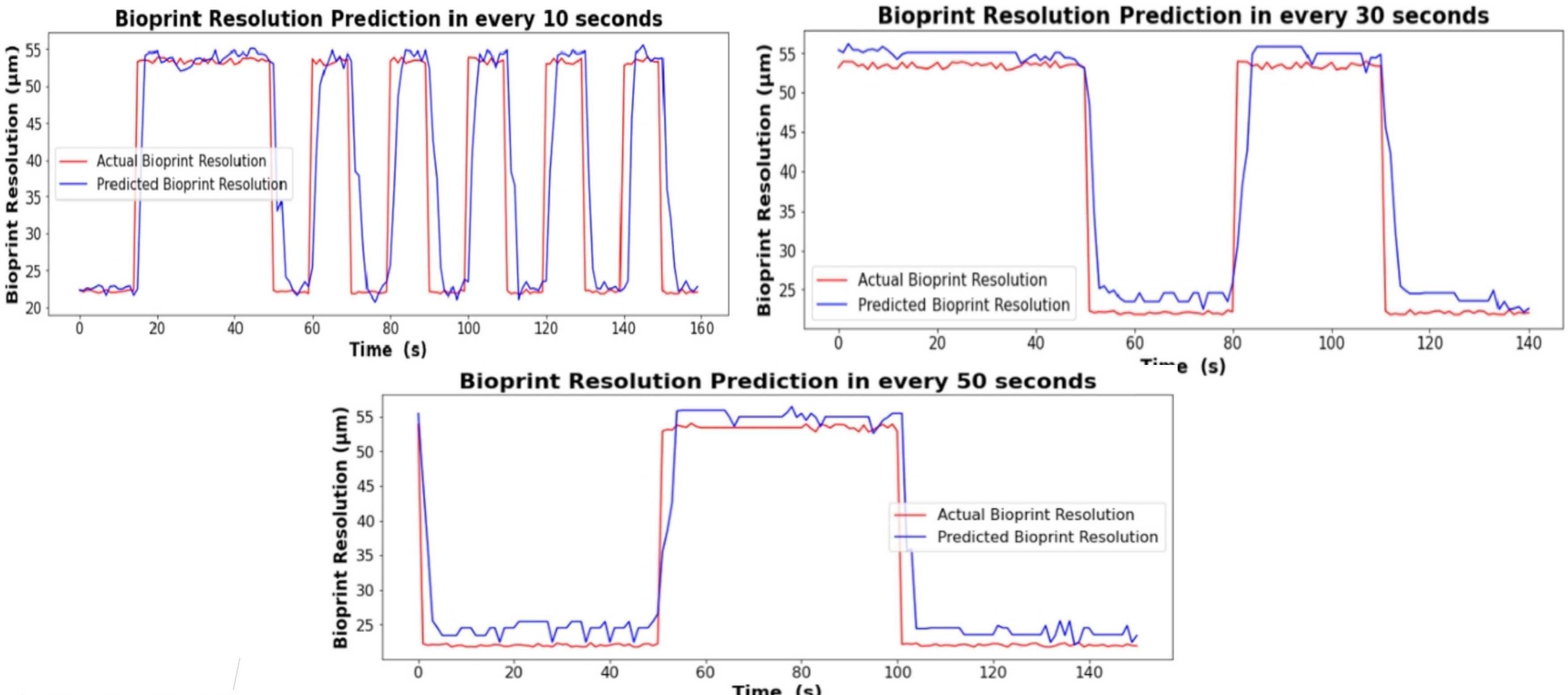
- Integration of physics-based model with a data-driven Long Short-Term Memory (LSTM) network that aims to enhance predictive capabilities in



Ogunsanya, M., & Desai, S. (2023). Physics-based and data-driven modeling for biomanufacturing 4.0. *Manufacturing Letters*, *36*, 91-95.

- LSTM model effectively tracked resolution of the bioprinted construct, particularly at shorter intervals (10 seconds), slight lags were observed at longer intervals (30 and 50 seconds).

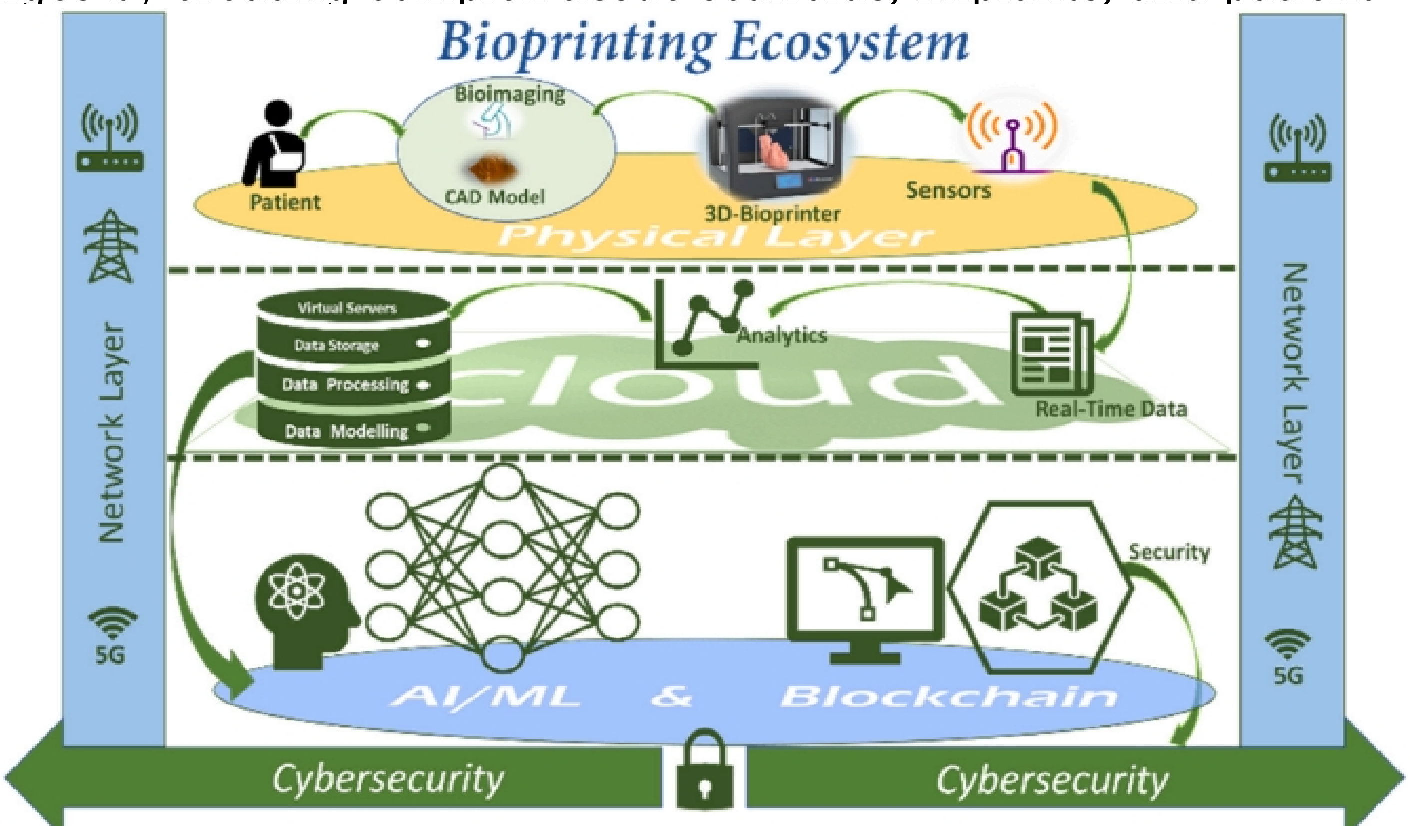
- Findings suggest that while shorter interval tracking might be more accurate, longer intervals could offer a viable trade-off between resolution accuracy and



Bioprinting resolution from IoT sensor against LSTM predictions for (a) 10 s, (b) 30 s, and (c) 50 s feedback.

Cybersecurity and Privacy in Biomanufacturing

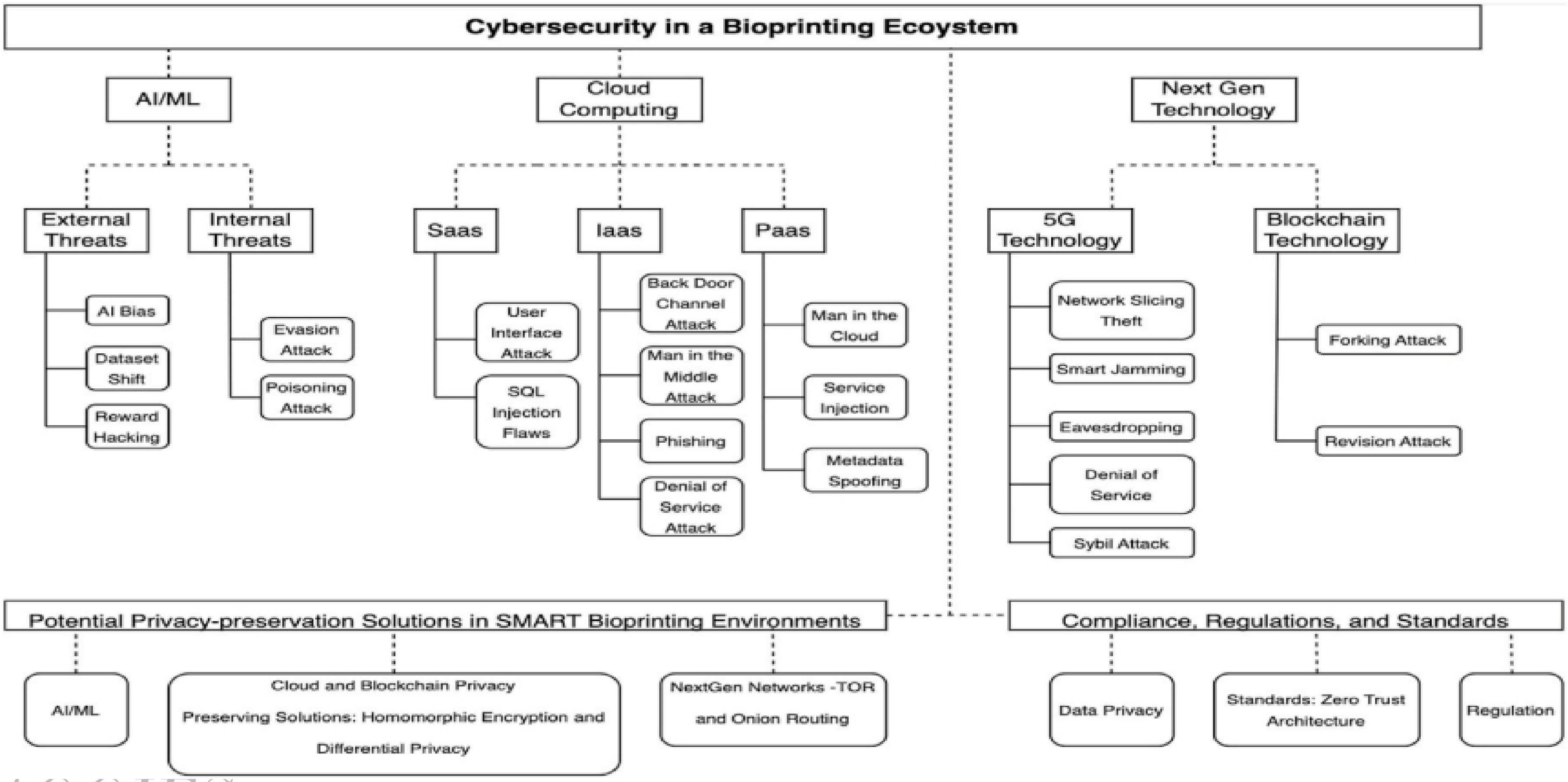
- Evolution of bioprinting is enabled by integrating Internet of Things (IoT), Cloud Computing, AI/ML, NextGen Networks, and Blockchain.
- Multilayered smart bioprinting ecosystem that addresses various medical challenges by creating complex tissue scaffolds, implants, and patient-specifi



Isichei, J. C., Khorsandroo, S., & Desai, S. (2023). Cybersecurity and privacy in smart bioprinting. *Bioprinting*, e00321.

Taxonomy of Cybersecurity in a Bioprinting Ecosystem

- Potential threats, vulnerabilities, and attacks in AI/ML, cloud computing, networks, and blockchain was conducted in respect of cybersecurity challenges



Future Directions

- Physics and data-driven hybrid models
- Integration of real-time monitoring and control with AI tools
- Security protocols in Nano-Biomanufacturing
- Regulatory standards addressing recent trends