Liesegang Structures and Self-Organization for Smart Biomaterials

Facchinetti, Alessia (School: Istituto Tecnico Industriale G. Omar)
Bonomelli, Victoria (School: Istituto Tecnico Industriale G. Omar)
Mazzini, Matilde (School: Istituto Tecnico Industriale G. Omar)

This project investigates Liesegang-type self-organization phenomena for the development of functional biomaterials for bone regeneration and controlled drug delivery. The experimental procedures are based on reaction–diffusion systems in gelled media. The periodic precipitation of the Liesegang rings was obtained in gel media with transition metal systems ($CuSO_4$ / NH_4OH in agar). Subsequently, calcium phosphate-based systems were studied via the counter-diffusion of $CaCl_2$ and Na_2HPO_4 in agar gel, with the aim of obtaining structures similar to hydroxyapatite. The use of a modified two-dimensional configuration in Petri dishes allowed for the formation of discrete mineralized "island"; instead of the typical Liesegang rings. The analytical techniques employed in this work include atomic absorption (AA) spectroscopy for the quantification of the distribution of Ca^{2+} ions and UV-Vis spectroscopy for assessing ibuprofen's loading and release. Data show that the formation of these patterns depends strongly on pH, temperature, reagent concentration, and gel density. Drug release tests reveal rapid drug delivery in the first 4 hours (going from 5% to 42%), followed by a slower, diffusion-controlled release, reaching approximately 85% depending on the conditions. The results indicate that Liesegang-type self-organization can be controlled to produce biomimetic hydroxyapatite structures with tunable morphology and functional properties. In conclusion, this approach represents a promising strategy for the development of advanced biomaterials for bone tissue engineering and localized drug delivery, with potential applications in orthopedics, dentistry, and personalized regenerative medicine.

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