Regenerative Medicine Bioconjugated Hydrogel Scaffolds

Subjects: Chemistry, Medicinal
Contributor: Vittoria Chimisso

Materials used for regenerative medicine purposes pose a series of challenges in terms of biocompatibility, adaptability and functionality. A way to design functional and compatible materials that mimic soft tissue is to exploit synthetic hydrogels. To widen their activity scope, hydrogels can be coupled with molecular cues to promote tissue regeneration or trigger regeneration processes. Within this entry we asses the criteria to choose the design of a bioconjugated for regenerative medicine purposes, giving relevant examples from the current literature.

Keywords: hydrogel, regenerative medicine, biomolecules

1. Introduction

The aim of regenerative medicine is to restore and rebuild damaged or dead tissue by providing molecular signals that promote tissue growth, whilst granting physical support to the cells to proliferate.[1][2] Achieving this, however, comes with a series of challenges, both in terms of signal delivery and of scaffold properties. The influx of molecular signals to the tissue can not be delivered all at once, but is required to stay constant overtime, to promote a homogeneous and sustained growth.[3] Thus, even though research has made outstanding progress with sustained release technologies, these tend to clash with the majority of the scaffolding technology proposed so far. In fact, most of formulation products can release a drug overtime whilst preventing its degradation, but are formulated in a way that they are not capable of mimicking soft tissue properly. This means that once the molecular cue is inserted in a wrong support within the body, the body will start rejecting it, causing inflammation and allergic reactions.[4]

2. Hydrogels

Hydrogels are a class of materials that posses similar mechanical properties to soft tissue and can deliver cues over time. Hydrogels are 3D crosslinked polymeric networks fully swollen in their volume by water, which can be tailored to mimic the extracellular matrix.[5] They are characterized by a soft and elastic structure, with high porosity which involves not only adaptability to the surrounding environment, but also bioavailability of small molecules. Since hydrogels seemed to be perfect candidates to be used in regenerative medicine, the latest efforts in the field were directed to design hydrogels that would satisfy a long list of requirements in terms of biocompatibility, adaptability and chemical functionality. In general, a hydrogel scaffold should fulfill these 3 requirements:

1. Provide support to the new tissue whilst making space for it by degrading naturally if necessary.
2. Mimic the mechanical properties of the tissue, in terms of softness, strength and elasticity.
3. Provide conditions and molecular signals for cell growth, differentiation and proliferation.

Hydrogels composed of synthetic polymers can be chemically designed to degrade at a controlled pace, by just inserting cleavable segments.[6] The same way, tailoring the nature of the monomers, crosslink density and chemistry and chain architecture, the resulting gel can possesses mechanical properties that are made similar to the environment in which the hydrogel should be used.[7] One of the main functional advantages that comes with synthetic polymers is that monomers with different funcitonalities can be combined resulting in gels that are responsive to several stimuli at the same time,being able to change their swelling, mechanical properties and physical properties according to the environmental conditions. This allows to use these materials for in situ gel formation, or in situ/on demand release.[8][9] Hydrogels and thei micro to nanosized counterpart, microgels, can release on demand small drugs[10], proteins[11] and ions[12] whilst maintaining functionality and biocompatibility. A hydrogel that has perfect mechanical properties but is not able to deliver a molecular cue will not promote cellular growth and correct tissue regeneration. Proteins, growth factors, small peptides and nucleic acids are all molecular signals that cells receive and to which they respond by differentiating, growing and proliferating. All these cues are however very difficult to be directly delivered to the target, and require a formulation that sets them free at the target whilst protecting them and preventing them from degradation. Thus, combining these molecules with hydrogels provides a system in which the synthetic scaffold sustains the tissue while it is growing.

Carefully choosing the right combination of scaffold and biomolecular cue allows to promote tissue regeneration whilst minimizing invasive surgery and painful side effects.

References

1. Marta Calvo Catoira; Luca Fusaro; Dalila Di Francesco; Martina Ramella; Francesca Boccafoschi; Overview of natural hydrogels for regenerative medicine applications. *Journal of Materials Science: Materials in Medicine* **2019**, *30*, 115, 10.1007/s10856-019-6318-7.
2. Nasim Annabi; Ali Tamayol; Jorge Alfredo Uquillas; Mohsen Akbari; Luiz E. Bertassoni; Chaenyung Cha; Gulden Camci-Unal; Mehmet R. Dokmeci; Nicholas A. Peppas; Ali Khademhosseini; et al. 25th Anniversary Article: Rational Design and Applications of Hydrogels in Regenerative Medicine. *Advanced Materials* **2013**, *26*, 85-124, 10.1002/adma.201303233.
3. Kesireddy, Venu.; Kasper, F.Kurtis; Approaches for building bioactive elements into synthetic scaolds for bone tissue engineering.. *J. Mater. Chem.* **2016**, *4*, 6773-6786, .
4. Bernard, Melisande; Jubeli, Emile; Pungente, Micheal; Yagoubi, Najet; Biocompatibility of polymer-based biomaterials and medical devices-regulations, in vitro screening and risk-management. *Biomater. Sci.* **2018**, *6*, 2025-2053, .
5. Innocenzi, Plinio. A sol and a gel, what are they? In The Sol-to-Gel Transition; Springer: Berlin/Heidelberg, 2019; pp. 1-6.
6. Mathew Patenaude; Todd Hoare; Injectable, Degradable Thermoresponsive Poly(N-isopropylacrylamide) Hydrogels. *ACS Macro Letters* **2012**, *1*, 409-413, 10.1021/mz200121k.
7. Vittoria Chimisso, Miguel Angel Aleman Garcia, Saziye Yorulmaz Avsar, Ionel Adrian Dinu and Cornelia G. Palivan; Design of Bio-Conjugated Hydrogels for Regenerative Medicine Applications: From Polymer Scaffold to Biomolecule Choice. *Molecules* **2020**, *25(18)*, 4090, https://doi.org/10.3390/molecules25184090.
8. Jeong-A. Yang; Junseok Yeom; Byung Woo Hwang; Allan S. Hoffman; Sei Kwang Hahn; In situ-forming injectable hydrogels for regenerative medicine. *Progress in Polymer Science* **2014**, *39*, 1973-1986, 10.1016/j.progpolymsci.2014.07.006.
9. Zhang, Hongbin; Zhao, Chen; Cao, Hui; Wang, Guojie; Song, Li; Niu, Guogang; Yang, Huai; Ma, Jie; Zhu, Siquan; Hyperbranched poly(amine-ester) based hydrogels for controlled multi-drug release in combination chemotherapy. *Biomaterials* **2010**, *31*, 5445-5454, .
10. Zhang, Jiaxin; Sun, Rui; DeSouza-Edwards,O. Arun.; Frueh, Johannes; Sukhorukov, B. Gleb; Microchamber arrays made of biodegradable polymers for enzymatic release of small hydrophilic cargos.. *Soft Matter* **2020**, *16*, 2266-2275, .
11. Wenjing Xu; Andrey A. Rudov; Ricarda Schroeder; Ivan V. Portnov; Walter Richtering; Igor I. Potemkin; Andrij Pich; Distribution of Ionizable Groups in Polyampholyte Microgels Controls Interactions with Captured Proteins: From Blockade and “Levitation” to Accelerated Release. *Biomacromolecules* **2019**, *20*, 1578-1591, 10.1021/acs.biomac.8b01775.
12. Vittoria Chimisso; Csaba Fodor; Wolfgang P. Meier; Effect of Divalent Cation on Swelling Behavior of Anionic Microgels: Quantification and Dynamics of Ion Uptake and Release. *Langmuir* **2019**, *35*, 13413-13420, 10.1021/acs.langmuir.9b02791.

Retrieved from https://encyclopedia.pub/entry/history/show/6536