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Hydrogels with Enhanced Biomechanical and Mechanobiological Properties

Dominique P. Pioletti[1 *]

[1]Laboratory of Biomechanical Orthopedics, Institute of Bioengineering, EPFL, 1015 Lausanne, Switzerland.

[*]Corresponding Author: Dominique Pioletti. Email: dominique.pioletti@epfl.ch.

Abstract: From a mechanical point of view, articular cartilage can be considered as a viscoelastic porous material. Its dissipation capabilities are therefore central for its functional behavior. Based on this observation, we focused our studies of dissipative aspects in cartilage either from a biomechanical or mechanobiological point of view. In particular, we capitalized on the new obtained insight of dissipative behavior or sources in materials for the development of functional biomaterials for cartilage tissue engineering. We pioneered in proposing dissipation as a mechanobiological variable for cartilage tissue engineering [1]. As can be observed on Fig. 1, a correlation exists between the energy dissipated during cyclic loading and chondrogenesis marker.

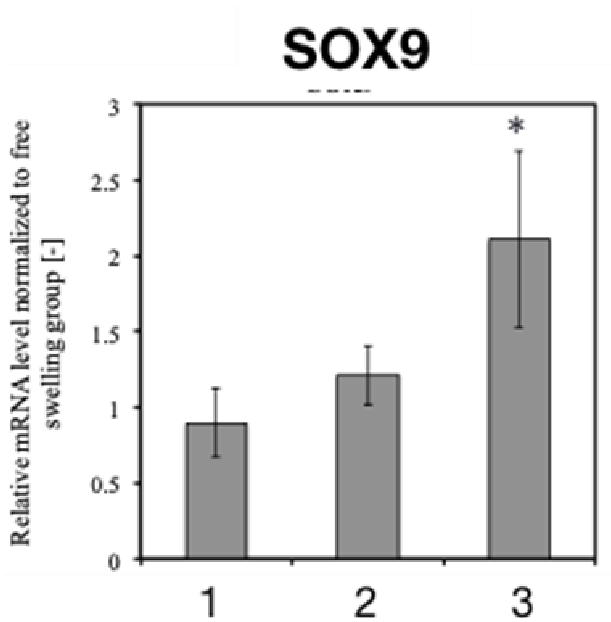

Figure 1: SOX9 expression of chondro-progenitor cells seeded on mechanically stimulated hydrogels presenting increased dissipation values (1: lowest, 3 highest) (modified from [1]).

However, in our past work, we considered the dissipation (obtained from the hysteresis loading-unloading curves) as a global variable without discriminating between the different sources of dissipation. Dissipation can be generated from different phenomena (fluid-solid interaction, bulk intrinsic viscosity, friction between nanofibers etc.). In parallel, we recently developed several hydrogels with enhanced mechanical [2] and adhesive [3] properties by relying on the control of dissipation sources during the material deformation. In Figure 2 a clear correlation was observed between the bulk dissipation of hydrogels presenting a similar composition (only dissipation sources were different for these hydrogels) and their corresponding adhesion strength to cartilage. Finally, by independently controlling the solid versus fluid parts of the dissipation source in hydrogels, we observed that the latter was indeed responsible to induce chondrogenesis when hydrogels seeded with chondro-progenitors cells were mechanically stimulated.

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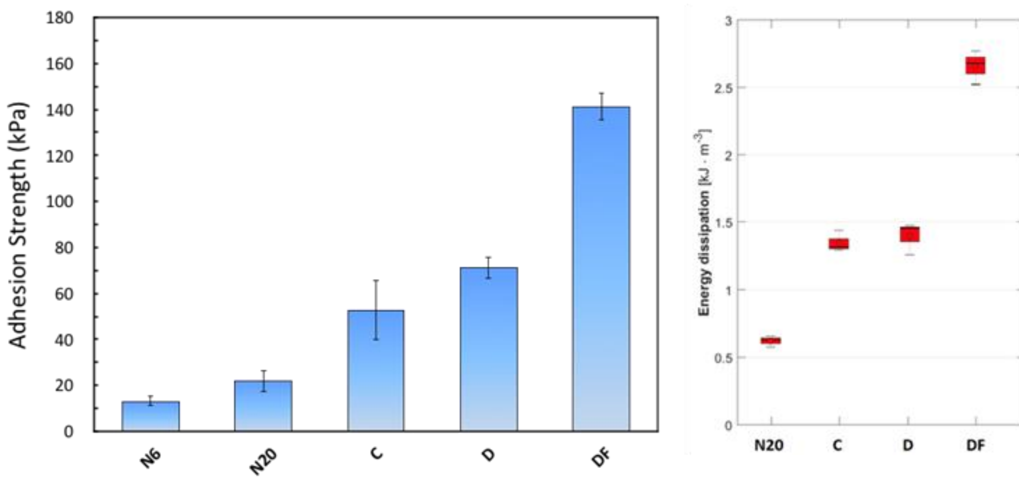

Figure 2: left) Adhesion strength on cartilage of different developed hydrogels and right) corresponding hydrogel bulk dissipation clearly showing a correlation between adhesion strength and dissipation value.

The incorporation and control of different dissipation sources in hydrogels was therefore key to obtain simultaneously adequate biomechanical and mechanobiological properties.

The next step of our research is to combine the different hydrogel developments so that we could obtain hydrogels presenting simultaneously: i) mechanical characteristics close to human cartilage, ii) high adhesion strength on cartilage, iii) mechanobiological characteristic favoring chondrogenesis.

Keywords: Dissipation sources; hydrogel; mechanobiology; cartilage.

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