Training and force adaptability of 3D-bioprinted biological actuators based on skeletal muscle tissue

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Current robotics systems are facing many challenges in a world that requires them to adapt to different environments and interact with humans and other living organisms. For this reason, many recent advances in material science have opened up the possibility of combining biological systems with artificial materials to obtain hybrid bio-robotic devices that can offer complex capabilities, like self-healing, high adaptability and response to different stimuli. Several groups have developed hybrid bio-actuators based on cardiac and skeletal muscle cells, which, in particular, have shown three-dimensional architectures and some of the commented complex behaviours.

In parallel, the 3D bioprinting technique has emerged as a powerful tool for the development of functional three-dimensional tissues and, in particular, skeletal muscle tissue. Although 3D printing of artificial materials has been used to fabricate scaffolds or molds for hybrid bio-actuators, 3D bioprinting of skeletal muscle tissue, together with soft skeletons, has not been reported in the field of hybrid bio-robotics. Here, we present our recent advances in the fabrication of 3D bioprinted hybrid bio-actuators based on skeletal muscle tissue, taking advantage of the unique versatility, rapid-prototyping and simplicity of the technique. We report a full characterization and optimization of the printing from the material point of view, but also paying special attention to the biocompatibility, as well as differentiation, maturation and alignment of cells inside the bioprinted hydrogel.

We take advantage of the multi-material printing capabilities of the technique to 3D-bioprint a hybrid biological actuator whose contractions can be completely controlled by external electric fields. We prove the adaptability of the hybrid bio-actuator applying training protocols at different frequencies and with different stiffnesses of the mechanical constraints. By analysing the expression of maturation-related proteins and the evolution of the force with time, we find that these bio-actuators can adapt to the requirements of the performance according in several ways. In particular, medium frequencies show the greater improvement beyond the natural maturation, while low and high frequencies cannot produce a sufficiently large improvement. These results will help understand the training capabilities of future bio-hybrid actuators and acquire basic knowledge on the behaviour of 3D-engineered skeletal muscle tissue.

References


Figures

Figure 1. a) Image of a 3D-bioprinted bio-actuator composed of two PDMS posts and a skeletal muscle tissue ring. b) After applying electric pulse stimulation, the force exerted by the tissue can be calculated by measuring the deflection of the posts, c) and its evolution with time can be studied.