Dielectrophoretical fabrication of hybrid carbon nanotubes-hydrogel biomaterial for muscle tissue engineering applications

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Tissue engineering aims to fabricate the tissues and organs in vitro as replacements for damaged tissues and organs in the body. Scaffolds are used to provide cells with a suitable growth environment, optimal oxygen levels, and effective nutrient transport as well as mechanical integrity. Hydrogels as widely used scaffolds for tissue engineering applications aim to provide such conditions for the cells so that they can assemble to form tissues. However, it is difficult to obtain a single hydrogel that meets all desirable properties. In particular, hydrogels generally are not conductive and they lack good mechanical properties. Composite materials combine at least two separates materials to produce a new material with superior properties to those of the individual components. Carbon nanotubes (CNTs) are very attractive materials due to the high-aspect ratio, conductivity, and mechanical strength.

Here, dielectrophoresis (DEP) approach is used to align the CNTs within the hydrogel. This approach enabled us to make different CNTs alignments (e.g., vertical or horizontal alignments) within the hydrogel using different electrode designs or configurations. We have fabricated a hybrid anysotropical biomaterial with improved conductivity and mechanically reinforced. Anisotropically aligned CNTs showed considerably higher conductivity compared to randomly distributed CNTs dispersed in the hydrogel and the pristine and non-conductive hydrogel. The hybrid showed also a viscoelastic behavior that is suitable for the soft tissue engineering applications. Skeletal muscle myofibers were then fabricated on these hybrid biomaterials and electrically stimulated. Analysis of the tissues by gene expression related to the muscle cell differentiation and contraction demonstrated superior maturation and functionality. Owing to high electrical conductivity of aligned GelMA-CNTs hydrogels and the viscoelastic properties, the engineered muscle tissues cultivated on these materials demonstrated superior maturation and functionality particularly after applying the electrical stimulation compared to the corresponding tissues obtained on the pristine GelMA and randomly distributed CNTs within the GelMA hydrogel.