Using Near-Infrared Light Responsive 4D Printing Nano-Architecture With Controllable Transformation To Combat The Opioid Epidemic

Abstract

More than 70,000 Americans died from a drug overdose in 2017.

The economic burden of prescription opioid use in the U.S. is $78.5 billion yearly, accompanied by:

- Increasing number of post-surgical analgesia requirements with addiction risk
- Need for minimizing surgery recovery time, infections and prosthesis requirements
- Need for innovation in pain therapeutics

Our 4D printing platform allows to resolve this by:

- Embedding a non-addictive analgesic molecule with self-assembled nano-composite molecular delivery system to form an on-demand drug release system.
- Production of 3D printed structures at macro, micro, and nanometer scales, responsive to near-infrared radiation (NIR) applied from outside a patient’s body, resulting in a transformative drug delivery system in a patient’s body.
- NIR is regarded as a human benign energy form capable of efficiently penetrating tissue with no biological harm when compared to other energy sources.
- 4D printing is an additive manufacturing process used to fabricate a pre-designed, self-assembling structure with the ability to dynamically transform over time in response to therapeutic requirements, allowing to take almost any shape or form.

The above schematic of 4D printing demonstrates a dynamically controllable transformation of the custom 3D printed, NIR light sensitive shape memory polymers. The nano composite, being a nanostructure that can take shape of a self-assembled biodegradable polymer coupled with thermally responsive graphene, after printing has an initial shape, once exposed to NIR illumination (a photo thermal triggered process) allows the release of a non-opioid analgesic w/other therapeutics on demand embedded in the hydrophobic core in the cylindrical shape. This allows creation of implantable medical devices such as bone screws, with simultaneous analgesia capability. The NIR can be applied by an external device, for example in form of a watch or wearables to release or collect molecules within the body and prevent/reverse opioid overdoses. This enhances drug therapeutic monitoring for antibiotics, anti-clotting and analgesic agents. The technology can encompass 4D transformation of hip implants, knee replacement, bone grafts, ligament grafts and arthritic or wrist implants to provide on demand delivery of medications.

Data & Results

- Our study demonstrated that these materials can take implantable shapes by 4D printing an in vitro, proof of concept brain model, using neural stem cells to create the neural tissue construct.
- With appropriate printability, high mechanical strength, conductivity, and cell growth, 16% nano composite ink was used. The brain construct incubated in culture medium exhibited an excellent shape fixation-NIR triggered 3D recovery process.
- The printed nano composite exhibited high potential in neural engineering due to it’s ease of operation, high biosafety, NIR sensitivity, remote and dynamic control and spatiotemporal synergy.
- Lowest possible graphene will be used in in-vivo implantation. Use of biodegradable polymer are required for next study, to quantify drug release and correlation to disease reversal in-vitro as establishing cell assays to verify in vitro to in vivo using small order animals (rats), including verifying using in vivo using large order animals (sheep).

Method

Impact

Interstellar will kickstart a new generation of life saving medical devices by:

- Replacing the need for pacemakers by contributing to autonomous beating of cardiomyocytes, and promoting electro active tissue regeneration for myocardial damage prevention in an infarction. This is possible due to the 3D printed nanostructures such as nano films, nanorods, nanotubes, nano platelets, etc. and/or graphene as an electrically active component that can electrically stimulate cells such as neurons and cardiovascular cells.
- Using signal transmission of neural cells via the technology, we will enhance therapeutics of Alzheimer’s and Parkinson’s disease. The self-assembling biodegradable polymers can be coupled with artificial intelligence, in a brain or neural interface on a nano or micrometer scale to improve electroactivity of engineered tissue without need for a stimulation device.
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