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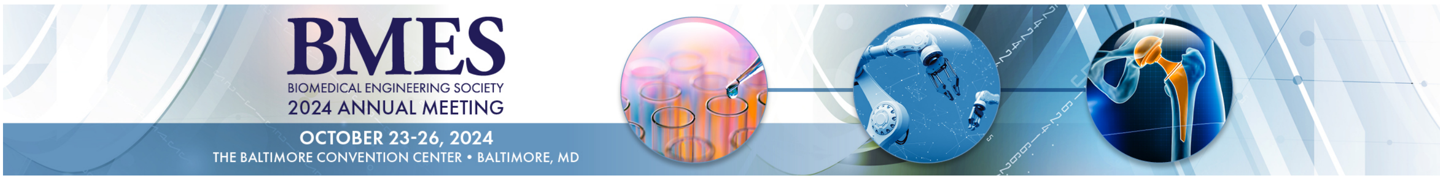

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Thursday, October 24, 2024

10:00 AM – 11:00 AM EST
Biomanufacturing - Poster Session A

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Biomanufacturing

10:00 AM – 11:00 AM EST ★
Poster M18 - A Biohybrid 3D-Printed Muscular Tissue-Electronics Platform for Continuous Musculoskeletal Disease Research
Location: Exhibit Hall E, F & G

Presenting Author: Uijung Yong, PhD (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Donghwan Kim (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Wonok Kang (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Dong Gyu Hwang (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Jihwan Kim (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Jinseon Park (she/her/hers) – Pohang University of Science and Technology (POSTECH)

Co-Author: Hwanyong Choi, BS (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Sung-Min Park (he/him/his) – Pohang University of Science and Technology (POSTECH)

Primary Investigator: Jinah jang, PhD (she/her/hers) – Pohang University of Science and Technology (POSTECH)

Biomanufacturing

10:00 AM – 11:00 AM EST
Cardiovascular Engineering - Poster Session A

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Cardiovascular Engineering

10:00 AM – 11:00 AM EST ★
Poster T11 - 3D Bioprinting-assisted Tissue Assembly to Create Transmurally Oriented Myocardial Fibers on Chamber-like Structure
Location: Exhibit Hall E, F & G

Presenting Author: Dong Gyu Hwang (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Hwanyong Choi, BS (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Uijung Yong, PhD (he/him/his) – Pohang University of Science and Technology (POSTECH)

Co-Author: Donghwan Kim (he/him/his) – Pohang University of Science and Technology (POSTECH)

Primary Investigator: Jinah jang, PhD (she/her/hers) – Pohang University of Science and Technology (POSTECH)

Cardiovascular Engineering

A Biohybrid 3D-Printed Muscular Tissue-Electronics Platform for Continuous Musculoskeletal Disease Research

Uijung Yong[1], **Donghwan Kim**[2], **Wonok Kang**[3], **Dong Gyu Hwang**[4], **Jihwan Kim**[5], **Jinseon Park**[2], **Hwanyong Choi**[5], **Sung-Min Park**[1,2,3,5,6,7], **and Jinah Jang**[1,2,3,4,5,7*]

[1] Future IT Innovation Laboratory (i-Lab), Pohang University of Science and Technology, Pohang, Republic of Korea
[2] School of Interdisciplinary Bioscience and Bioengineering, Pohang University of Science and Technology, Pohang, Republic of Korea
[3] Department of Convergence IT Engineering, Pohang University of Science and Technology, Pohang, Republic of Korea
[4] Center for 3D Organ Printing and Stem Cells, Pohang University of Science and Technology, Pohang, Republic of Korea
[5] Department of Mechanical Engineering, Pohang University of Science and Technology, Pohang, Republic of Korea
[6] Department of Electrical Engineering, Pohang University of Science and Technology, Pohang, Republic of Korea
[7] Institute for Convergence Research and Education in Advanced Technology, Yonsei University, South Korea
[*] Correspondence: jinahjang@postech.ac.kr

Introduction (50-250 words)

Musculoskeletal diseases (MSDs), affecting approximately 1.71 billion people globally, can be driven by diverse causes such as aging, injury, genetic factors, and lifestyle-related conditions like obesity. The emergence of 3D-engineered muscular tissues offers a promising tool to overcome the limitations posed by traditional animal models and 2D cell cultures, which often fail to mimic the complex biological and biochemical behaviors of human tissues accurately. However, despite the advantages of these 3D models, conventional methods for evaluating muscle function (*e.g.*, optical imaging and biochemical assays) remain inadequate for continuous monitoring of physiological signals. This study introduces a state-of-the-art biohybrid 3D-printed muscular tissue-electronics platform, specifically designed to address these challenges. By enabling real-time, continuous monitoring of muscle contractions and electrophysiological signals, this platform aims to revolutionize the field of musculoskeletal research, providing a more scalable and accurate approach to understanding MSDs.

Materials and Methods (50-250 words)

3D printing of rib-shaped multielectrode (RME)

Utilizing the biohybrid 3D printing technology, this study developed a muscular tissue-electronics platform integrated with sensory capabilities. We 3D-printed RMEs using a conductive hydrogel based on PEDOT:PSS. To protect the electrodes and ensure biocompatibility, a passivation layer of poly(ethylene-co-vinyl acetate) was applied.

3D bioprinting and differentiation of engineered muscle tissue (EMT)

We engaged in 3D bioprinting of EMT directly onto the RMEs and a previously developed bipillar-grafted strain gauge sensor, which is designed to monitor muscle contraction forces accurately. This integration aims to enhance the EMT's functionality by allowing real-time and direct measurement of both electrical signals and the contraction of the EMT. The bioink used for this process was a composite of C2C12 myoblast cells and porcine muscle-derived decellularized extracellular matrix, which provides the native muscle environment to the cells. For the maturation of muscle cells into functional myotubes, a two-stage culturing process was employed. From day 0-6, the printed structures were cultured in growth media to promote cell proliferation. Subsequently, from day 6-14, the media was switched to differentiation media, fostering the differentiation of myoblasts into myotubes, crucial for achieving functional muscle contractions.

Circuit design for precise sensing

To capture the *in vitro* skeletal muscle's action and field potentials accurately, a measurement circuit was designed with a high sampling rate of 0.125 µs/sample and a low noise level of 5 µVpp. This configuration ensures the detailed and reliable detection of muscle electrical activities, crucial for assessing physiological properties and potential pharmaceutical applications.

Results, Conclusions, and Discussions (50-350 words)

Evaluation of PEDOT:PSS electrodes

The PEDOT:PSS electrodes were evaluated to determine their suitability for integration into the muscular tissue-electronics platform. Through impedance spectroscopy, rheology, and cyclic voltammetry tests, the electrodes demonstrated excellent electrical conductivity and mechanical stability, confirming their effectiveness in recording and stimulating muscle activity without degrading signal quality.

Simulation and insulation assessment of 3D-printed RME

Simulations of the 3D-printed RMEs were conducted to evaluate the impact of their integration on the measurement of EMT contraction forces by the BPSG sensor. These simulations aimed to assess how the RMEs influence the sensor's ability to capture precise contraction data under physiological conditions. We also performed that the RMEs maintained their structural integrity and function without electrical leakage, ensuring safe and effective long-term use in biological environments.

Biocompatibility and IF staining of 3D-bioprinted EMT

During the development of the 3D-bioprinted EMT, comprehensive biocompatibility tests were conducted to ensure that the process of bioprinting the tissue onto the sensors, as well as the integration of the tissue with the sensors, was biocompatible. These tests confirmed that the entire integration was non-toxic and supportive of cell growth and proliferation, essential for maintaining the functionality and longevity of the muscle fibers. Immunofluorescence (IF) staining further validated the correct alignment and differentiation of muscle fibers within the EMT, highlighting its potential for accurate disease modeling and drug testing.

Sensing response to acetylcholine in EMT

The platform's capability to detect and measure physiological responses was tested by exposing the EMT to acetylcholine, a critical neurotransmitter in muscle contraction. The results showed that the EMT responded predictably to acetylcholine, demonstrating the platform’s potential for studying neurotransmitter dynamics and assessing drug effects on muscle tissues.

These findings underscore the potential of the developed EMT-electronics platform to serve as a sophisticated tool for musculoskeletal research, offering enhanced capabilities for continuous, real-time analysis of muscle physiology under various experimental and clinical conditions. The platform not only provides a more realistic model for studying muscle diseases but also opens new avenues for personalized medicine applications.

Acknowledgements

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Figure

Figure 1. Schematic diagram of the biohybrid 3D-printed muscular tissue-electronics platform for musculoskeletal disease research