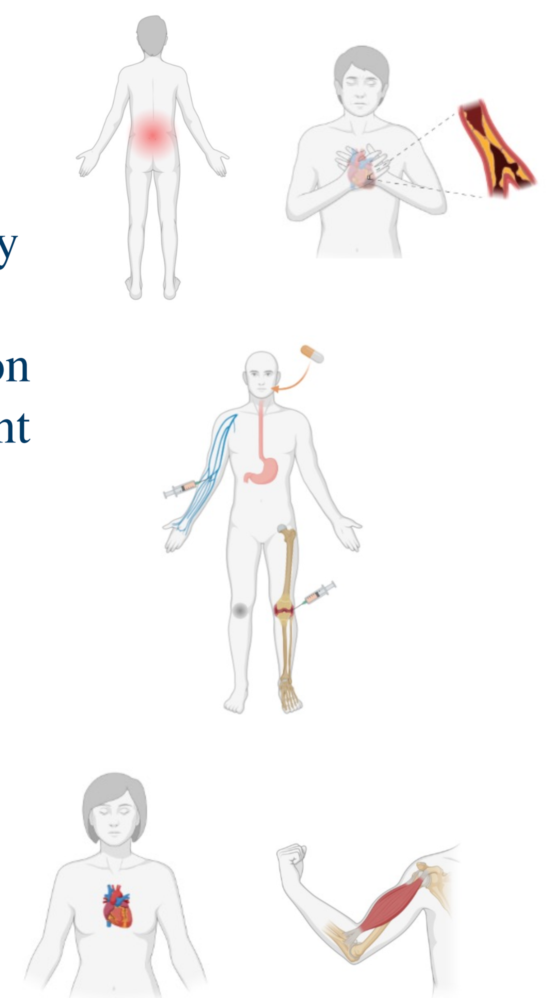
Printable Bioscaffolds Using Ti_3C_2 MXene for Musculoskeletal Tissue Engineering

Annaka Tibbits[1], Miranda L. Nelson [2], Hailey M. Burgoyne[3], Naqsh E. Mansoor[3] , Fereshteh Rajabi-Kouchi[3], Raquel Montenegro-Brown[3], David Estrada[3-5]
[1]Department of Biomedical Engineering, Grand Canyon University, Phoenix, AZ 85017
[2]Biomedical Engineering Doctoral Program, Boise State University, Boise, ID 83725
[3]Micron School of Materials Science and Engineering, Boise State University, Boise, ID 83725
[4]Center for Advanced Energy Studies, Idaho Falls, ID 83401
[5]Idaho National Laboratory, Idaho Falls, ID 83402

BOISE STATE UNIVERSITY

I. Introduction



Problem
- Musculoskeletal injury and disease are the top causes of physical disability throughout the world
- 1 in 6 people suffer from severe physical disability

Current Solutions & Drawbacks
- Pain management injections → Temporary solution
- Physical therapy and exercise → Lengthy treatment
- Relaxation techniques and acupuncture → Less helpful for severe cases

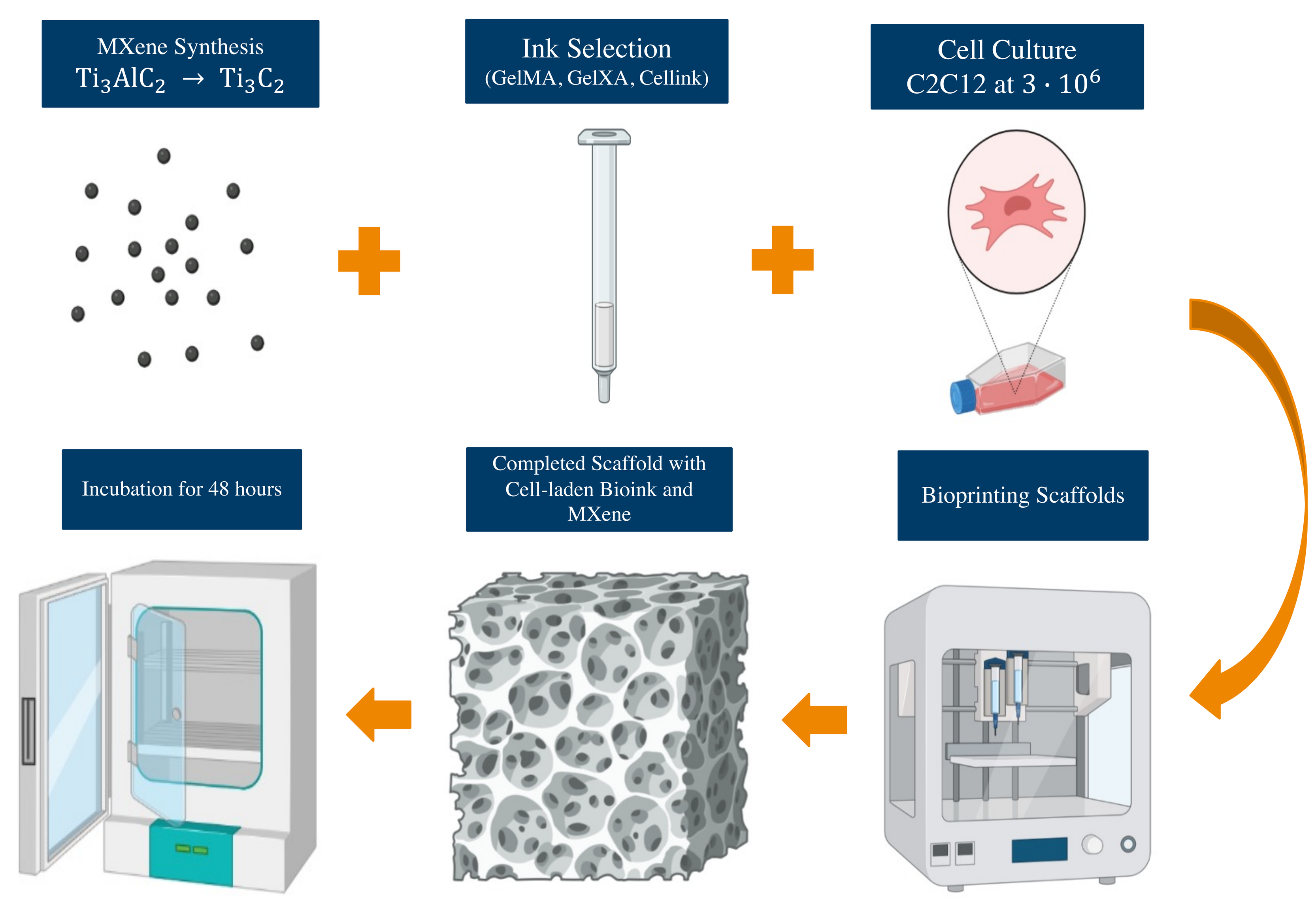
Proposed Solution & Why
- Implantable cell-laden bioscaffolds → Specific to patient, long-term solution, one time fix

Challenge
- A conductive environment is necessary for electrical stimulus to promote cell growth → Current hydrogel inks are not conductive

Purpose: Using Titanium Carbide (Ti_3C_2) MXene to enhance electrical conductivity in printable bioscaffolds to allow cells to grow and differentiate in an effort to create implantable musculoskeletal tissue grafts.

II. Methods

Scaffold Development Process



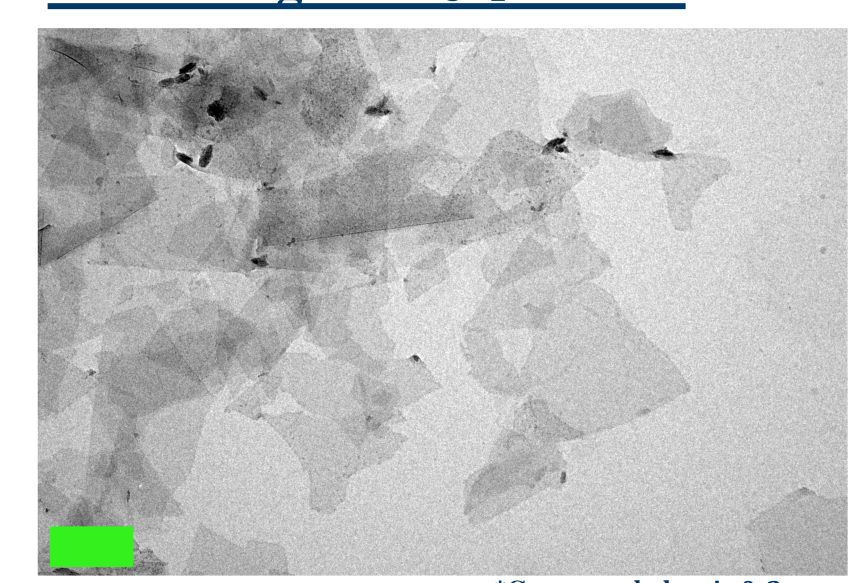
Characterization Methods

Ti_3C_2 MXene	TEM and SEM
Conductivity	Van Der Pauw Method with a 4-Point Probe
Cell Viability	Live/Dead Staining with Fluorescent Imaging

Crosslinking Methods

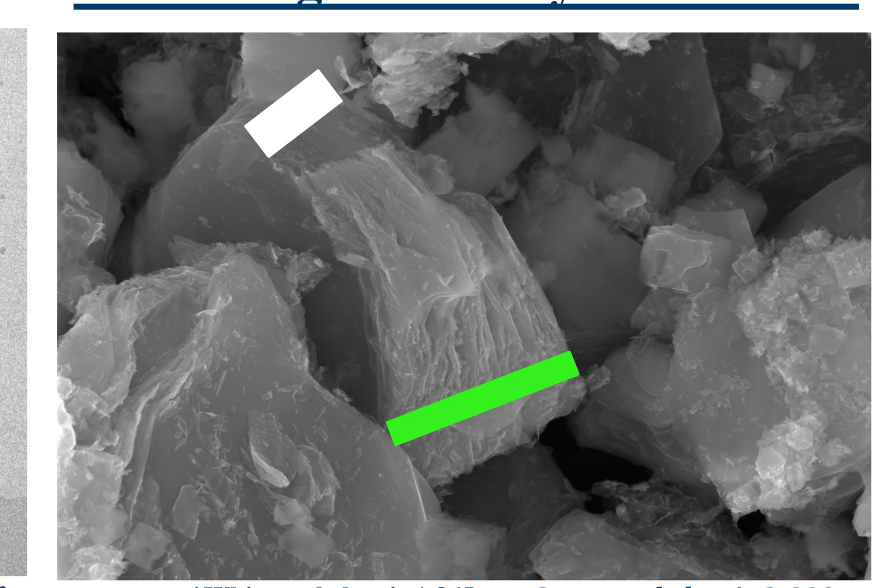
Ink Type	UV Cross-linking	Chemical Cross-linking
GelMA	✓	
GelXA	✓	✓
Cellink		✓

TEM Image of Ti_3C_2 MXene



*Green scale bar is 0.2 µm

SEM Image of M-Layered MXene



*White scale bar is 1.865 µm, Green scale bar is 3.930µm

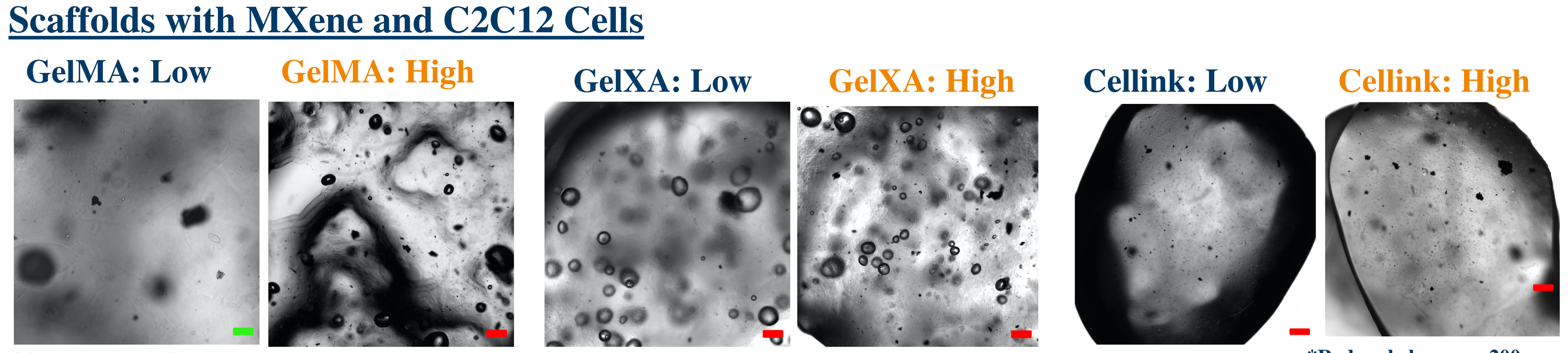
III. Results/Discussion

GelMA Results
- Did not crosslink well with higher concentrations of Ti_3C_2 MXene
- Printed better with higher dilution ratio (10:2)

GelXA Results
- Gel contained unavoidable air pockets due to composition
- Cells migrated outside the scaffold

Cellink Results
- Crosslinked well, especially with higher Ti_3C_2 MXene concentrations
- Had the best cell viability

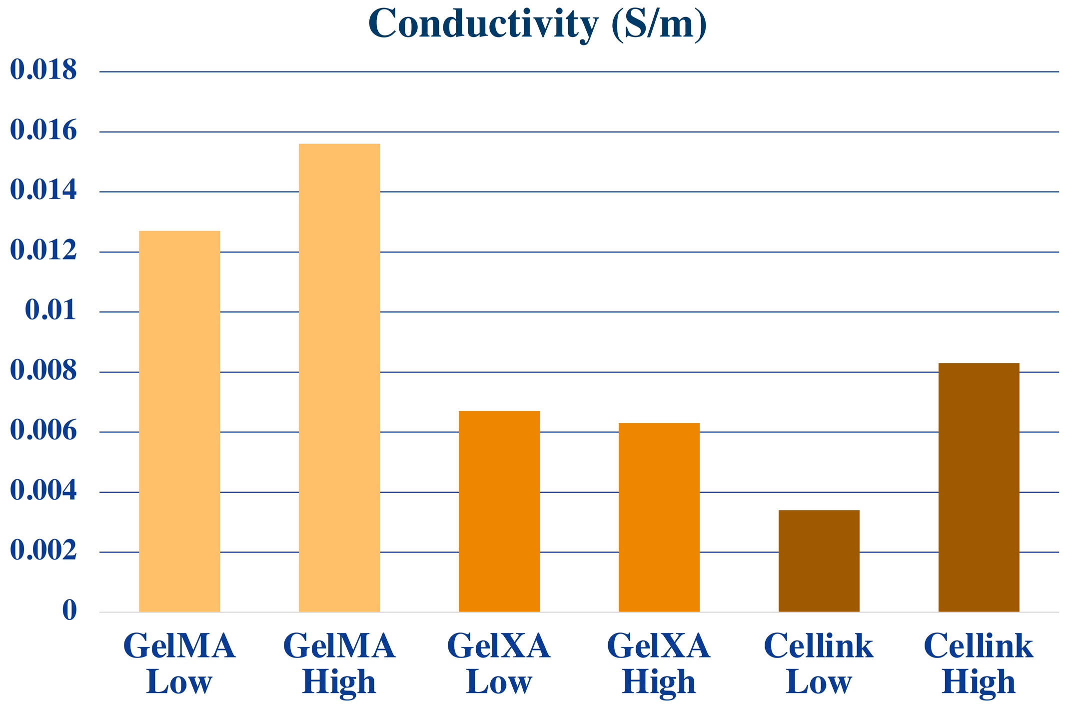
Scaffolds with MXene and C2C12 Cells



*Green scale bar is 100 µm

*Red scale bars are 200 µm

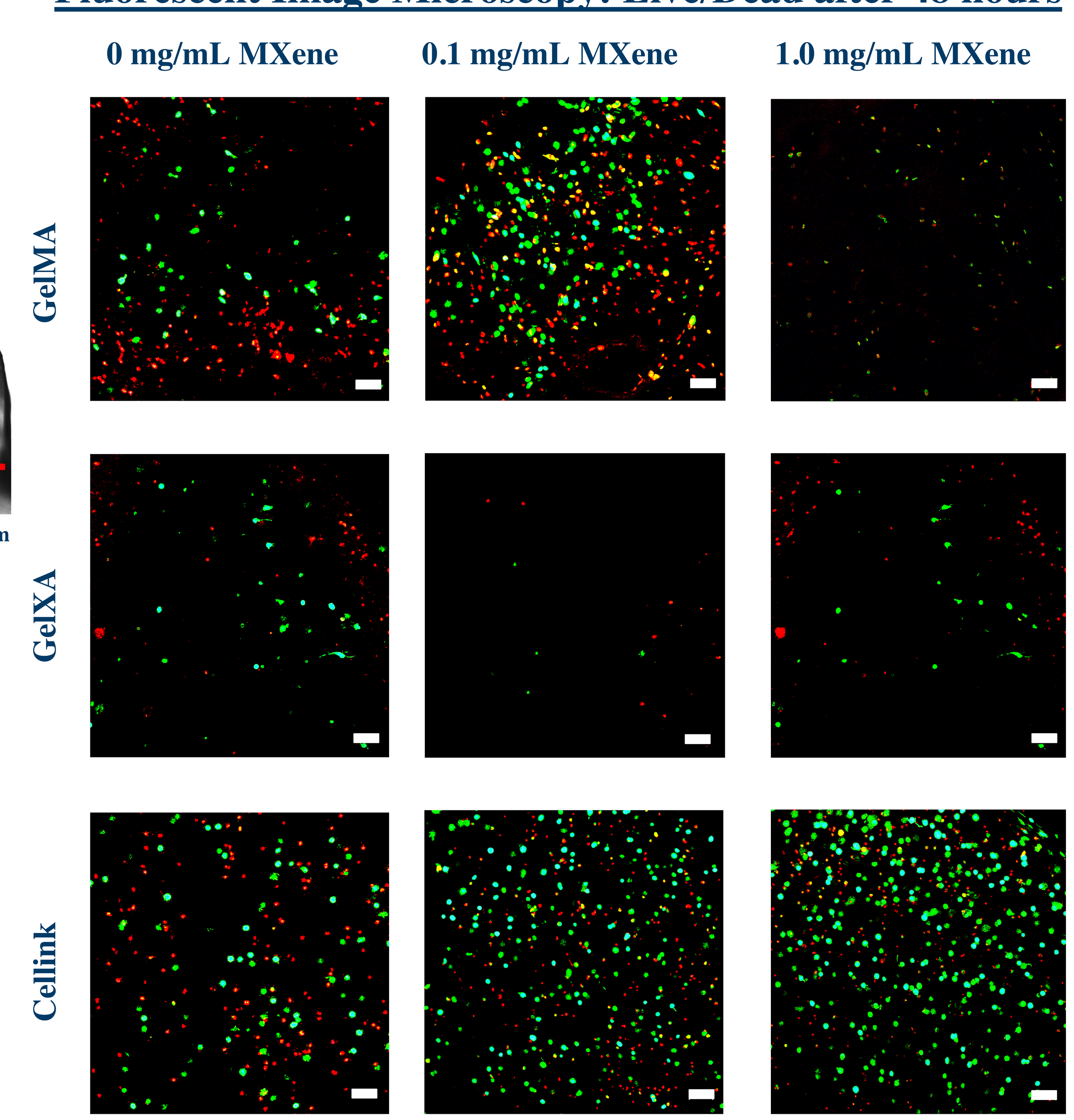
Conductivity of Scaffolds with MXene



Rating from Best (1) to Worst (3) Results

Ink Type	GelMA	GelXA	Cellink
Printability	2	3	1
Cell Viability	2	3	1
Conductivity	1	3	2

Fluorescent Image Microscopy: Live/Dead after 48 hours



*White scale bars are 100 µm

IV. Conclusion/ Future Work

Conclusion

Overall, 1.0 mg/mL MXene with Cellink had an optimal outcome for allowing the cells to grow, duplicate, and maintain viability while sustaining an adequate conductive environment to preserve optimal functionality of the cells as well as helping the myotubular fibers to elongate.

These results can aid in the process of developing a conductive printable bioscaffold to electrically stimulate cells, promoting differentiation which can ultimately lead to an implantable device that is a more effective form of treatment than those currently available.

Future Work & Related Hypotheses
- Testing for cell viability after a longer period of time → Cell viability will be lower after a longer timeframe
- Testing higher concentrations of MXene in Cellink to see effects of conductivity and cell viability → Higher concentrations of MXene will increase conductivity and decrease cell viability
- Testing structural integrity of cross-linking via nanoindentation tapping methods → Cellink will have the best structural integrity after chemically cross-linking
- Using differentiation media on scaffolds → Cells will turn into Musculoskeletal cells
- Testing for gene expression using PCR → PCR will reveal that the cells are able to differentiate into Musculoskeletal cells on the scaffold

V. References/Acknowledgments

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[1] https://doi.org/10.1021/acsbiomaterials.1c01193
[2] www.biorender.com
[3] www.sciencedirect.com/topics/engineering/tissue-engineering

Email: annakartibbits@gmail.com
LinkedIn:
Corresponding Email: daveestrada@boisestate.edu