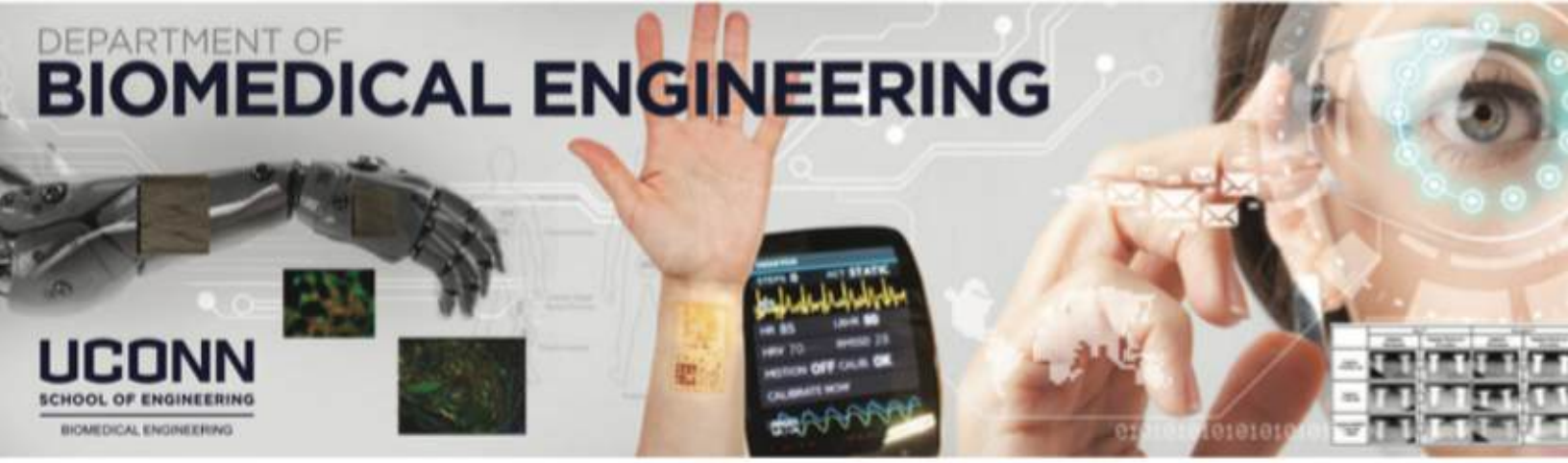
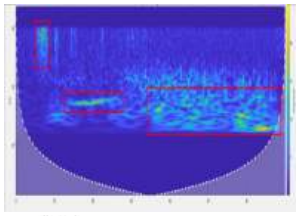
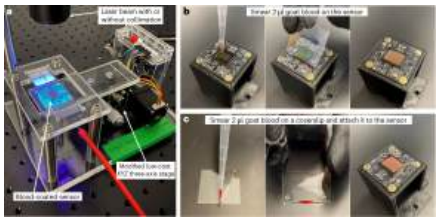
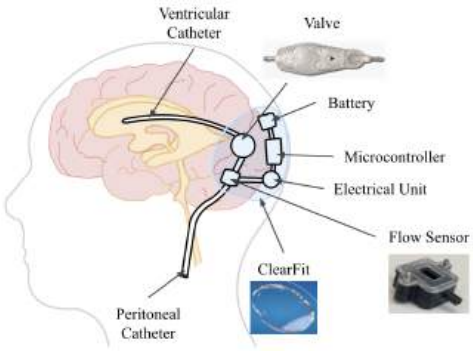
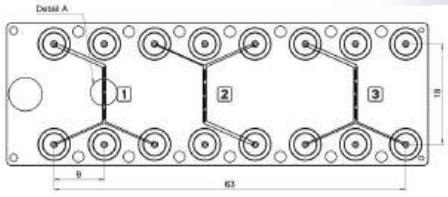
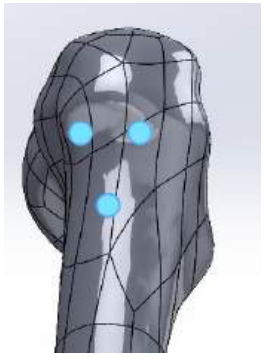
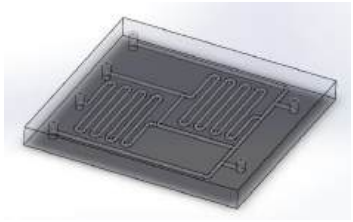
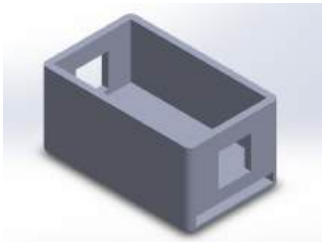


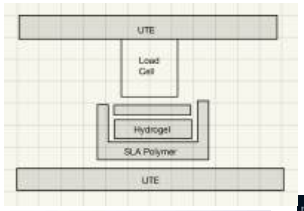
BME SENIOR DESIGN PROJECTS

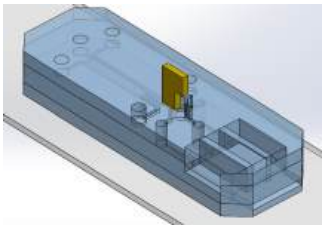
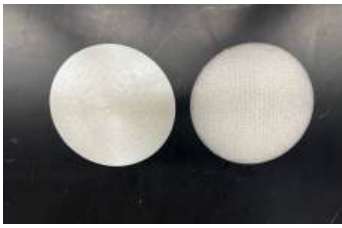
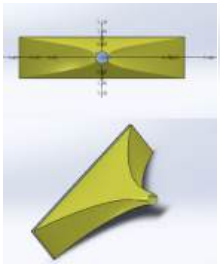
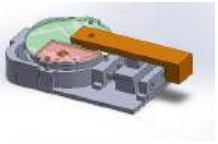
Spring 2024

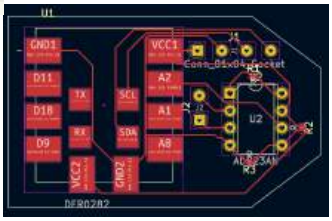


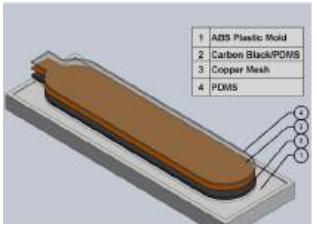



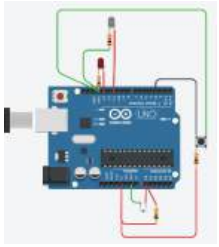





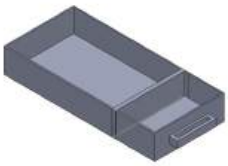
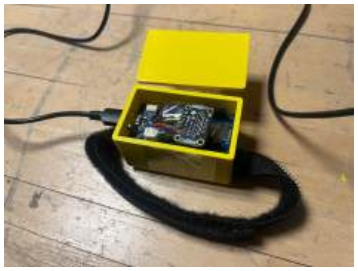







BME Senior Design Project at UCONN

On behalf of the faculty, staff and students of UCONN's Biomedical Engineering (BME) Department, we would like to welcome you to our annual Demo Day on April 26th 2024. The BME Department hosts this event to recognize the accomplishments of our BME undergraduate students. These project demonstrations and presented brochure of abstracts represent year-long efforts by our undergraduate students on their Senior Design Projects.

The BME Senior Design at UCONN course is intended to engage students in a meaningful experience by bringing together concepts and principles learned in the biomedical engineering curriculum, extend this theory to practical application, then to plan and construct a finalized product. Our BME students advance their proficiency and practice innovation and application during a two-semester, senior-year course sequence on biomedical engineering design, where students are immersed in a design experience. An emphasis is placed on learning the design process within the framework of an engineering team with a particular focus placed on the creation of a functional prototype. The experience is comprehensive and reflects all aspects of the engineering design process as well as common industry practices. Problem solving for open-ended, complex and sometimes incompletely defined system is the ultimate challenge faced within this experience and, in its successful completion; the design is often viewed as a student's first professional BME achievement.

We hope that you enjoy your visit to Demo Day event in Gampel Pavilion and we look forward to meeting you in person. If you have questions about any of our tracks or courses, please feel free to contact us directly.

Sincerely,
Professors: Krystyna Gielo-Perczak, Patrick Kumavor, Fayekah Assanah, Yupeng Chen, Kazunori Hoshino, Liisa Kuhn, Syam Nukavarapu, Hugo Posada-Quintero, and Guoan Zheng
and
Teaching Assistants: Gilberto Martins Filho, Jaewook Jung, Venkat Kidambi, Riley McNaboe, and Michael Schneider

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BME Senior Design Project at UCONN

Design of a Microfluidic Device for the Assembly of Nanoparticles

Team 1

Abigail Egan, Kevin Trainor, Ashaleigh Pitter, Michelle Nguyen, Emily Losiewicz; Yupeng Chen, Ph.D.

Nanomedicine Lab; Biomedical Engineering Department

University of Connecticut; Storrs, CT 06269 USA

Abstract **- The purpose of this design project is to create a microfluidic device that will assemble Janus based nanoparticles for the purpose of carrying mRNA and similar counterparts in a patient's body. Janus nanoparticles have two or more chemical composites in one structure [1]. The duality of this allows for the use of two therapeutic agents in one nanoparticle. This allows for enhanced targeting specificity, reduced drug dosage, and regulated drug release [2]. The microfluidic device will consist of a herringbone mixer chip with nuclease-free water as the solvent and siRNA as the cargo. The structure of the chip will allow the solvent and the cargo to flow through the tubing and mix accordingly to create the Janus nanoparticle. The formed Janus nanoparticle will be utilized in the body to fulfill therapeutic purposes by interacting with its surrounding environment. The result of this project will provide valuable information in regards to effective methods to assemble Janus nanoparticles and furthermore produce a successful and efficient procedure to form nanoparticles for a drug delivery system.**

Keywords - Microfluidic, Herringbone Mixer Chip, Janus Nanoparticles, Drug Delivery

1. Introduction

Microfluidic devices allow the precise assembly of the Janus Base Particles through the flow of various fluids through its structure. Both the shape of the channels, the flow rate of the fluids, and the interactions between the input fluid can be precisely controlled in order to refine nanoparticle assembly. [3]

Particle size can drastically affect a particle's cytotoxicity and penetration through cellular membranes. So more homogeneity in nanoparticle production can lead to more tunable delivery into cells. The objective of this design project is to test a commercial microfluidics device and quantify the best flow rates of the various fluids to encapsulate mRNA in the Janus based nanoparticles.

2. Methods

The proposed microfluidic device represents a sophisticated platform designed for the controlled synthesis of Janus nanoparticles. This system will utilize a herringbone mixer chip, which is designed with specific entry and exit points for fluid flow, as seen in Figure 1.

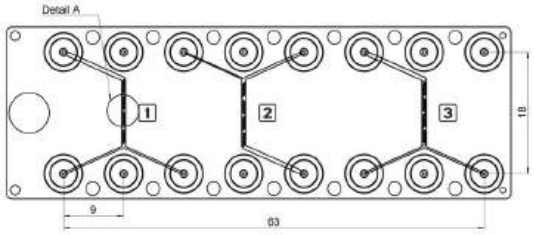

Figure. 1. Diagram of the herringbone mixer chip design [4].

Nuclease-free water will be used as the solvent, while siRNA will be used as the cargo. The structure of the chip ensures the seamless flow of both the solvent and cargo through the microchannels, promoting precise mixing and enabling the formation of the Janus nanoparticles. Male luer plugs will be incorporated into the design to ensure a secure and leak-free connection within the chip, allowing for controlled movement of the nuclease-free water and siRNA through the system. The male luer plugs will be inserted into the small ports of the chip to establish a connection between the external tubing and microfluidic channels within the channel. Figure 2 shows the male luer plugs that will be used to create a seamless connection between solvent, cargo, and chip.

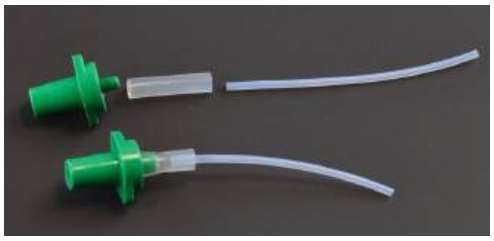

Figure 2. Male luer plugs that will be used to provide connection between the mixture and chip [5].

PTFE (polytetrafluoroethylene) tubing will serve as the channel through which the solvent and cargo will flow into the chip. It enables for the smooth flow of fluids without any interference, allowing for the precise mixing of the components within the chip. The PTFE tubing will be attached to one end of the male luer plugs.

Once the Janus nanoparticles are synthesized, they will demonstrate the potential to engage with the surrounding biological environment and can be utilized to achieve desired therapeutic outcomes.

3. Simulation/Expected Outcomes

Simulations and expected outcomes will play a pivotal role in ensuring the efficacy and safety of the microfluidic device. Computational simulations, conducted using advanced software like COMSOL Multiphysics, will be employed to model the fluid dynamics within the microfluidic channels. These simulations will optimize the flow characteristics, ensuring uniformity and precise control of the nanoparticle assembly. The simulations will determine the ideal channel geometries and operating conditions to achieve consistent nanoparticle sizes and compositions by analyzing factors such as pressure differentials, flow rates, and particle interactions. Finite Element Analysis (FEA) simulations will be utilized to assess the stress distribution across critical components, like the Herringbone Mixer Chip and the PTFE tubing, validating their structural integrity under varying operating pressures. Experimental validation, employing techniques such as microscopy and spectroscopy, will corroborate the simulation findings, confirming the successful encapsulation of RNA cargos and the uniformity of the Janus nanoparticles that will be produced. These simulation-driven validations will ensure the device's functionality and reliability, crucial for producing and utilizing Janus base nanoparticles in their intended applications.

4. Future Work

By March 2024 the nanodevice will be assembled and placed through appropriate testing. This nanodevice will be able to successfully create Janus based nanoparticles that encapsulate RNA for delivery into the system. This device will be built and tested in UConn's Nanomedicine Lab. Computational simulations, as well as other simulations and experimental techniques will be employed to ensure the nanodevice is working properly and creating the needed nanoparticles. The percent of nanoparticles that contain the RNA will be calculated and compared to ensure the highest percentage are being created throughout the testing process. This nanodevice will improve the process for creating nanoparticles and help make advances in nanomedicine.

5. Acknowledgements

We would like to thank Yupeng Chen and Jinjin Zhai for providing us with assistance with their input on our device design, appropriate testing and materials, and providing us with resources in the Nanomedicine Lab.

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Smartphone Application for Light Strength Control for Electroretinography

Team 2

Ryan Daddona, Nicholas Cavoli; Hugo Posada-Quintero, Ph.D.
Biomedical Engineering Department
University of Connecticut; Storrs, CT 06269 USA

Abstract **–** The objective of this design project is to create an Android smartphone application designed for performing a standard Electroretinogram (ERG) in adherence to the International Society for Clinical Electrophysiology of Vision (ISCEV) standards [1]. The application's primary functionality involves the measurement of the patient's pupil diameter to determine the appropriate level of retinal illuminance. The ERG will specifically emulate a Light-adapted 30 Hz ERG (LA 30Hz ERG) using LEDs, and the flash strength will comply with clinical standards. To achieve precision and accuracy, the flash strength will be meticulously calibrated utilizing a LUX sensor integrated with an Arduino. This calibration process ensures that the correct amount of light is emitted during the ERG procedure. The LUX sensor, incorporated with an Arduino, serves as a crucial component, providing real-time feedback about the intensity of light as well as safety protocol. The integration of these technologies guarantees the reliability and adherence to clinical standards throughout the ERG measurement process.

Keywords – Android Application, Electroretinogram, Pupil Diameter, Light-adapted, Arduino

1. Introduction

Electroretinography (ERG) represents an innovative technique designed to elicit and record the excitation response of the retina in the human eye. As advancements in ERG research unfold, the waveform generated serves as a valuable diagnostic tool, providing insights into a patient's physiological conditions. However, traditional ERG techniques are time-consuming, uncomfortable, and expensive. The ERG app seeks to revolutionize this process, offering a reliable and standardized ERG that can be administered by any healthcare provider. This approach enables efficient screening and early detection of retinal abnormalities, shedding light on potential underlying health conditions, including autism, schizophrenia, Alzheimer's, and diabetic retinopathy [2] [3] [4].

At the core of the ERG app lies image capturing, processing, and data display. Additionally, the app communicates with an external Arduino, facilitating the exchange of necessary data to initiate flashes with appropriate strength and receive wave data. Progress has been deliberate, with the group navigating the complexities of Android Studio's Camera2 API and image storage class, encountering a few challenges in the original design.

The envisioned functionality of the app unfolds in several steps. Initially, a high-quality image of the eye is captured in complete darkness to seize the pupil's most dilated state. Subsequently, employing an image processing algorithm allows for the determination of the pupil's diameter. With this information, the app calculates the optimal amount of light required to flash the eye, transmitting the data to the Arduino. The Arduino, in turn, incrementally adjusts the brightness of the LED until it reaches the clinical standard to perform a Light-adapted 30Hz ERG. This process elicits multiple waves, providing a real-time display on the app's interface.

2. Methods

To obtain an accurate measurement of pupils' diameter under completely dark conditions, our team employs a strategy involving the utilization of an infrared (IR) LED to illuminate the eye for image capture. Leveraging the IR spectrum provides a significant advantage over traditional flash methods since the human eye is not sensitive to IR. This is particularly crucial as it ensures that the eye remains shielded from unnecessary light exposure, preventing any potential disruption to the ERG.

The utilization of the Camera2 API enables low-level interaction with the camera devices on the phone. This API is instrumental in achieving image capture with high quality. It empowers the modification of various camera characteristics, including focus distance, lens calibration, and latency. Access to the phone's

cameras is facilitated through the CameraManager class in Android Studio, creating a camera object that facilitates all necessary processes for capturing an image [5].

Key methods linked with the CameraManager object include getCameraIdList, getCameraCharacteristics, and openCamera. After establishing the camera's functionality, our team initiates a handler thread to execute background processes within the app. In the ongoing testing phase, the camera is activated by a button press. Nevertheless, modifications are anticipated to facilitate image capture as part of the procedural instructions once the electroretinogram (ERG) is initiated.

The Arduino assumes a critical role in the app's functionality, serving to activate both IR and white LEDs while also calculating the approximate retinal illuminance required for the test.

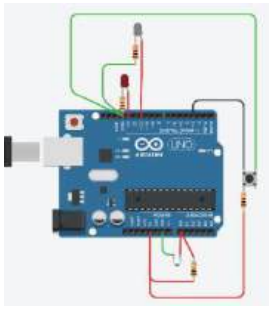

Figure 1 *- The Tinkercad model illustrates the Arduino project setup comprising an Arduino board, an ambient light sensor*

Upon launching the application, the Arduino establishes a connection with the app, initiating the IR LED for the image capture process. Subsequently, the app measures the diameter, transmitting the data to the Arduino, where it calculates the retinal illuminance and initiates a feedback loop. This loop gradually increases the intensity of the white LED until the Lux sensor registers the correct value. Following this, the LED flashes at the determined intensity, pulsating at a rate of 30 Hz until the test concludes. Collaborating with another team, the amplified response is then sent back to the application where it is displayed.

3. Future Work

Once the image is successfully captured, our next step involves holding the JPEG data array in a buffer. Subsequently, image processing will be executed using the Hough Transform algorithm, renowned for its capability to measure pupil diameter with relatively high accuracy.

Working through the pixels of the array derived from the captured image, the algorithm iterates to establish the diameter approximation. With this crucial information in hand, we proceed to calculate the approximate amount of light needed, adhering to clinical standards set at 3 cds*s*m^-2. To convert this to troland seconds, we multiply it by the pupil area in mm^2. This calculation yields the desired retinal illuminance. Utilizing the lux sensor, the LED attached to the Arduino undergoes a gradual brightening process until the appropriate lux level is attained. This meticulous approach ensures that the light intensity aligns with clinical standards for a reliable and accurate ERG test.

Finally, the team will receive Bluetooth data from the electrodes positioned beneath the eye. Further development is required to ensure the app possesses the necessary permissions, ports, and sockets for seamless communication between the Arduino and the phone. Upon successfully receiving the data stream, the points can be plotted in real-time, showcasing both the instantaneous and average ERG.

4. Acknowledgments

We would like to thank the BME department for providing us with the resources to complete the project. Testing, realistic constraints, and device design were aided by Dr. Hugo Posada-Quintero, Ryan Daddona, and Nicholas Cavoli. Special thanks to Guoan Zheng for assistance in Android app development.

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Sensor and Circuit Design for Smartphone Based Electroretinography

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Biosignal Processing and Wearable Device Lab; Biomedical Engineering Department

University of Connecticut; Storrs, CT 06269 USA

***Abstract*– The purpose of this design is to obtain, process, and display an electroretinogram. The design consists of custom flexible carbon black electrodes that read the signal with minimal impedance [1]. The output of the signal was connected to an amplifier and then connected into a microcontroller responsible for ADC conversion. The digital signal will be sent to an Android smartphone where it will be filtered and averaged. Then, the signal will be displayed for the user to view. This device's purpose is to allow physicians to analyze processed signals and use them to diagnose neurodevelopmental disorders such as Autism Spectrum Disorder (ASD) and Attention Deficit and Hyperactivity Disorder (ADHD) [2][3].**

Keywords– Electroretinography, neurodevelopmental disorders, Microcontrollers,

I. Introduction

Electroretinography (ERG) devices function by flashing light in the patient's eye and reading the response from electrodes either in contact with or close to the patient's eye. These devices are predominantly used by optometrists and other physicians for detecting issues with the patient's eye that affect their vision, such as glaucoma, retinitis pigmentosa, and retinal detachment. In more recent studies, ERG measurements have been shown to provide indication of certain neurodevelopmental disorders, including ASD and ADHD [2][3]. With this capability, ERG devices are now an option to use in order to detect these neurodevelopmental disorders in nonverbal patients, namely infants. Early detection of these disorders is crucial for improving a patient's quality of life.

Current limitations with electroretinography devices primarily reside in their high cost and limited availability. The purpose of this device is to circumvent the current cost issue facing many ERG devices by creating a smartphone based alternative. The device will be a small circuit responsible for data collection which sends collected data to the smartphone for processing and display. Since the smartphone would be a separate purchase from the device itself, the cost would be significantly reduced, increasing accessibility.

II. Methods

A. Electrodes

Electrodes for this device will be constructed following a similar procedure found in Noh et al., shown in Fig. 1, barring the electrode area [1]. Electrodes will be fabricated in a 3D printed ABS mold. The first layer will be a CB/PDMS composite, designed to be extremely conductive and waterproof. Atop this layer will sit a sheet of copper mesh soldered to the connection wire. Lastly there will be a layer of PDMS to secure the copper in place and waterproof the electrode. The electrode is cured at 75°C. Three electrodes will be fabricated. These electrodes will be plugged into the amplifier on the PCB.

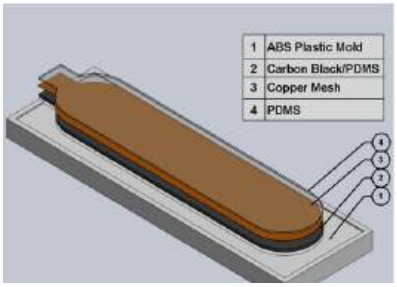


Fig. 1. Diagram of the layers of CB/PDMS electrodes with copper mesh embedded. [1]

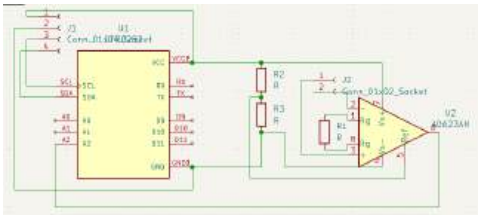
B. PCB and Microcontroller

The PCB for this device, shown in Fig. 2, will contain three main components: amplifier, attachment for lux sensor, and DFR0282 microcontroller. The first component, to which the electrodes connect, is a simple design that will boost the peak to peak voltage of the signal from the order of nanovolts and microvolts and increase it to the order of hundreds of millivolts utilizing an opamp. Next, there will be some solder points where leads from a LTR-329ALS-01 lux sensor will attach. This sensor will be crucial for breaking down strings of signals and averaging them and also for monitoring light level from the phone flashlight.

The microcontroller chosen comes ready to use with a micro USB capable of uploading code to the microcontroller which is compatible with Arduino Leonardo. The primary

responsibility of the microcontroller is for ADC conversion of the analog signal to a digital one capable of being sent to the smartphone via micro USB to USB-C cable. ADC rescaling is important for high signal resolution.

a.



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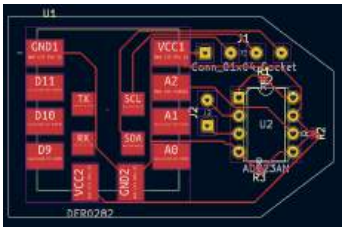

Fig. 2. a. Current PCB schematic. b. Current PCB Footprint This is a work in progress.

C. Post Processing

All of the post processing for the signal will be performed in MATLAB. Simulink will be used with the support packages for Android and Arduino to allow for signal transmission and to power the microcontroller. MATLAB functions can also be directly used in the Simulink program.

The program will contain a digital bandpass butterworth filter that passes frequencies between 0.5 Hz and 300 Hz. This filter should salvage all of the valuable portions of the ERG wave itself. To make the signal even more accurate, ten separate ERG signals will be averaged into one signal. This averaged signal along with the string of ten ERG signals will be displayed on the smartphone UI for the user to examine.

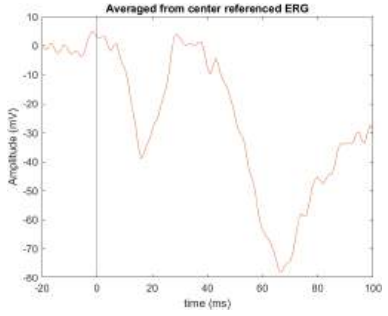

Fig. 3. Sample Averaged ERG signal

III. Expected Results

The expected outputs from this device are accurate ERG responses containing some variation of the main components as shown in Fig. 4. It is important that major structures of the waveform are present as they are necessary for diagnosing ASD and ADHD. For patients with ADHD, the b-wave of the response was found to be much higher than the control, while they are found to be lower in patients with ASD. If our device follows these same trends, it shows that it is functioning correctly.

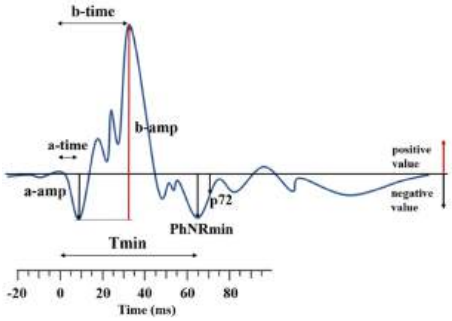

Fig. 4. ERG wave structure with labeled landmarks [2]

IV. Future Work

Over the course of the next semester, a few prototypes of this project will be constructed. PCBs will be fabricated via an online distributor like Xometry and the team will create the electrode in the Biosignals Laboratory. These prototypes will go through rigorous testing. Eventually, the team would like to test the final design on patients in order to test its true accuracy. To do this, the device must be approved to be used on patients. Therefore, safety will be considered at every point of the project.

Acknowledgement

We would like to thank Dr. Hugo Posada-Quintero for providing project guidance and MATLAB assistance. We would also like to thank the Biosignal Laboratory for allowing us to use their workspaces for creating electrodes and testing circuits.

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In-Vitro Model for Investigating the Mechanisms of Traumatic Brain Injuries

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***Abstract*- The purpose of this design project is the development and validation of an *in-vitro* model for investigating the mechanisms of traumatic brain injuries. Our model will consist of SH-SY5Y human neuroblastoma cells encapsulated by a hydrogel mixture of 0.5% alginate-gelatin. Testing will be conducted using a device in which a weighted hammer is pulled back against multiple springs a set distance and released to apply an impact force to the model. Live imaging will be captured in PylonViewer using a high-speed microscope camera. Testing will be done on day 6, where afterwards we will let the cells proliferate for 6 more days to allow us to see if there are any discrepancies in cell growth. The viability assays trypan blue and MTS will later be used for cell counting and further damage analysis.**

1. Introduction

Traumatic brain injury (TBI) is typically caused by a mechanical force or sudden acceleration-deceleration. TBI has gained increased public awareness in recent years with a number of sports-related concussive injuries and military-related blunt/diffuse blast injuries, altogether known to increase the risk of chronic traumatic encephalopathy and other cognitive disorders. Traditionally, animal models have been employed to observe changes in biochemistry, histology, and neurological impairment associated with TBI [1]. These models involve inducing brain injuries in animals through inertial acceleration or direct force application to the brain. [2] This is not the most efficient method due to an inaccurate representation of true force and the invasive and often inaccurate way to study damage done on the brain. We will address this issue by creating a 3D in vitro model of brain tissue using Hydrogels and Sh-SY5Y cells that can be mechanically tested and imaged to study TBI's. The utilization of a novel 3D hydrogel cell culture system offers a more precise and ethically sound means of studying TBI. Specifically, we will use a gelatin-alginate-based hydrogel to encapsulate our cells to test. We will be mechanically testing and imaging using a device created by the Hoshino Lab. This rig is designed to apply a mechanical force to the side of our hydrogel capsule, and as it does, it will image the cells allowing us to view physiological changes.

2. Methods

For our model, our design team will be using a 1% alginate : 1% gelatin mixture to encapsulate SH-SY5Y human neuroblastoma cells. The corresponding procedure continues as follows [3]:

1. Prepare Materials
50mL conical of 0.1M $CaCl_2$ Solution
50mL 10% Transglutaminase Solution
5mL Alginate and Gelatin Solutions
15mL 0.5% Alginate-Gelatin Mixture

2. Steri-Filtration
a. Under a hood, unpackage a sealed Steri-Filter and label appropriately. Use the appropriate filter pore size for the solution being filtered as dictated in the table below.
b. Pour the prepared solution into the filter cup, attach it to the vacuum, and turn on the vacuum. Allow the suction to continue until the filter appears dry.
c. Remove the steri-filter and cap the flask containing the sterile solution.
d. Store sterilized solutions in the 4C refrigerator.

Solution	$CaCl_2$	TG	Alginate	Gelatin
Pore Size (um)	0.22	0.22	0.45	0.22

Table 2.1:Steri-Filter pore size based on filtered solution[3]

3. Hydrogel Formation
a. Pipette 500 µL of the gelatin-alginate solution to the bottom of a labeled 24-well plate.
b. Allow the solution to set in the well plate for 5 minutes at 4C (the refrigerator).
c. Spray the hydrogels liberally with CaCl2 using the small spray bottle to disperse the solution evenly.
d. Allow the hydrogels to set for 15 minutes at 4C (in the fridge). Manually swirl the CaCl2 from time to time.
e. Use a spatula to maneuver around the edges of the gel and lift it from the wells.
f. Pipette 500 µL of additional $CaCl_2$ into the wells ensuring it disperses to the sides, allowing all surfaces of the hydrogel to be exposed to the $CaCl_2$
g. Let rest for an additional 45 minutes at 37C (in the incubator). Manually swirl the $CaCl_2$ from time to time.
h. Aspirate off the excess $CaCl_2$
i. Use a spatula to transfer the gels into a labeled 60 mm petri dish.
j. Add 3-5 mL of the pre-made TG solution to the petri dish, or enough to simply cover the gels.

k. Place in the 37C incubator for 1 hour.
l. After 1 hour, remove the TG and replace with media to cover the gels.

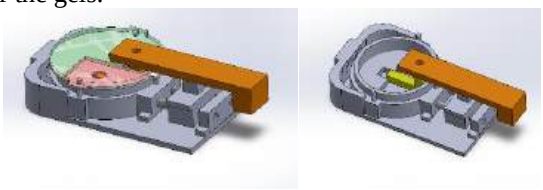

Figure 2.1: SolidWorks Assembly of Hammer and Dish used to strike and hold our model (Cover: Right, Uncovered: Left). [4]

As seen in figure 2.1 above, the dish housing our In-Vitro model will be covered to maintain a closed environment and ensure sterilization during testing.

3. Results/Simulations/Expected Outcomes

Our discussed model will be tested using a rig assembled by Dr. Hoshino's previous senior design group. In their design, a hammer is pulled against a combination of springs and released at a constant distance to provide force to the model. Springs are taught against pegs that extend outwards to increase the amount of tension (as seen in figure 3.1)

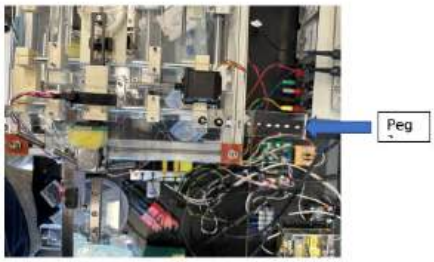

Figure 3.1: Peg Settings for Force Applicator. Springs are pulled back by the hammer against a peg in one of the peg holes seen above. The most distal peg is peg 1, with increasing numbers moving towards the middle [4].

For our experiment, we will test our model with 3 trials: slow, moderate, and fast – pertaining to the speed of the hammer.

	Strain Rate (s^{-1})	Max Acceleration (m/s^2)
Slow: 4 Medium Springs, 6th Peg	14.5308	35.3498
Moderate: 3 Large Springs, 5th Peg	33.1486	83.9558
Fast: 4 Medium Springs, 4th Peg	41.8167	88.3745

Table 3.1: Strain Rate and Max Acceleration for a given spring combination. These numbers were gathered by the previous Senior Design Group [4] and the results we can expect.

4. Conclusions and Future Work

In our experiments, we hope to validate the hydrogel brain model as an adequate model of the human brain during TBI. We expect that the hydrogel model will allow for the testing of neuron viability and damage endured due to the application of force. Due to likely testing only one combination of alginate-gelatin mixture, future work would be focused on the refinement of model composition and prolonged damage analysis on the cells, as we are only able to look at relatively short time frames due to project length constraints.

6. Acknowledgments

We would like to thank our project advisor Dr. Kazunori Hoshino for providing us with all of the resources necessary for our project. Our project would not be possible without the previous works by Dr. Hoshino as well as Brendan Braatz and Marcus Fonseca completed for Senior Design 2023 (Team 10). We would also like to thank Dr. Fayekah Assanah, Trystin Cote, Bryce Bisset, Maddie Pickett, Theresa Shew, and Laura Thurber for providing us with materials and hydrogel preparation procedures from their past Senior Design Project in 2023 (team 8).

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Culture, Imaging, and Characterization of Live 3D Organoids

Team 5

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Abstract **- The primary focus of this project is on the development of tools and methodologies encompassing hydrogel design for mechanical characterization of tumor organoids. The investigation will extend to the exploration of an optimal matrigel-agarose substrate to create a more adjustable and reproducible gel compatible for mechanical testing utilizing a unique micro-tweezer compression apparatus. The compression system will be utilized to delineate any correlation between differences in hydrogel stiffness and the mechanical properties of tumor organoids. Additionally, the correlation between the post-drug administration stiffness of the organoids and the effectiveness of cancer drug treatments will be explored in different mechanical microenvironments. The outcomes of this project will provide researchers with information on gels, imaging, and testing that can be used in future research into biomaterials.**

Keywords - stiffness, hydrogel, characterization, culture, mechanical testing, imaging, drug treatments

I. Introduction

Cancer is the uncontrolled growth of cells to form tumors and their subsequent migration and invasion throughout the body. Approximately two million people are diagnosed with cancer annually, necessitating more advanced research to dissect tumor behavior as a means of developing more effective treatment plans [1]. A burgeoning focus of oncology research is the mechanobiology of tumors and the interaction of tumors with their mechanical microenvironments [2]. The behavior of both cellular and tumor behavior is known to be dictated by many different mechanical factors. One of the factors that is known to be influential in cancer behavior is the stiffness of the surrounding tissue [3]. Therefore, the design of new means for testing tumor stiffness and replicating the typical mechanical conditions present within tumors is a vital aspect of mechanobiology and oncology research.

The objective of this project is to design and construct hydrogels of different stiffnesses that promote the growth of three-dimensional tumor organoids and can be utilized with a novel micro-tweezer compression system. The micro-tweezer compression system has been previously utilized to assess the post-treatment stiffness of tumor organoids as a means of evaluating the efficacy of different cancer treatments. This project will evaluate the effects of different hydrogel stiffnesses on the mechanical behaviors of tumor organoids as a precursor to evaluating the effects of different mechanical environments on the efficacy of cancer treatments.

II. Methods

The cultivation process of MCF-7 cells involves their growth and passage in a typical two-dimensional cell culture to generate a sufficient quantity of cells for further experimentation. This phase is crucial for enabling the observation of organoid development under normal physiological conditions. In addition, MCF-7 cells need to be cultured in a three-dimensional Matrigel environment to observe organoid development and overall health of the cell line.

A specialized procedure involving the combination of agarose and Matrigel to produce hydrogels of varying stiffness for MCF-7 organoids has been developed by the project team. Specifically, the gels to be evaluated will contain 15%, 25%, and 50% matrigel synthesized with 0.5% and 1% agarose. Rheological testing of agarose hydrogels was conducted to ensure that their elastic modulus fell within an appropriate experimental range acceptable for culturing tumor organoids and maintaining a three-dimensional structure for periods of up to ten days. This critical step ensured the reliability and consistency of the hydrogel for organoid development. Should the hydrogel exhibit excessive stiffness, it could potentially impact the morphology and proliferation rate of the organoids, possibly compromising their development. Conversely, insufficient stiffness would render the hydrogel too loose to adequately support the mechanical properties required for mechanical testing using the micro-tweezer compression device. Ultimately, achieving the optimal stiffness balance is crucial for maintaining the integrity of the organoids while facilitating effective mechanical assessments within the hydrogel environment.

A previously made device will be utilized to culture the cells for an extended period of time prior to mechanical testing. The device includes a capillary of cylindrical design which will be filled with the agarose-matrigel hydrogel that houses MCF-7 organoids. The capillary and tumor organoids are to be suspended over a cuvette containing growth media. The device

fulfills a dual role: shaping the hydrogel to maintain its form and enclosing the gel in a suspension for compression testing within the media.

To assess the mechanical properties of tumor organoids, a dual approach is employed. A micro-tweezer mechanical testing setup, developed by Dr. Kazunori Hoshino, will be utilized, alongside the industry-standard compression testing using the TA Instruments HR20 Rheometer. This comprehensive approach enhances the robustness of the mechanical testing, providing a more thorough validation of the obtained results.

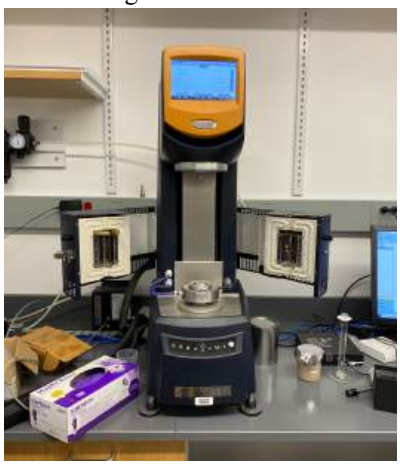

Figure 1. *TA Instruments HR20 Rheometer*

III. Simulations/Expected Outcomes

Initial rheometry testing was performed to test the storage modulus of agarose gels of varying concentrations (0.3%, 0.5%, 2%, and 3%). The storage modulus of the gels indicates their elastic behavior and their stiffness. The ideal range of storage modulus for the gels would be around 0.5 kPa to 1 kPa to replicate the stiffness of tumor tissues to mimic the typical tumor microenvironment [4]. With the direction of the project focusing on 0.5% agarose and 1% agarose, the storage modulus graph displays the data from rheometry testing for 0.5% agarose and 2% agarose (**Figure 2**). The 0.5% agarose gel exhibited a storage modulus of approximately 0.4 kPa, while the 2% agarose gel exhibited a storage modulus of 5 kPa. These results from the initial rheometry testing suggest that the agarose concentrations to produce the final gels should be around the 0.5% to 1% agarose range.

The TA Instruments HR20 Rheometer was used to determine the storage modulus of agarose gels with a range of different concentrations. The results of the testing were analyzed and the optimal agarose concentrations were determined. The rheometer is a part of the dual mechanical testing approach. Dr. Kazunori Hoshino's micro-tweezer mechanical setup will additionally be used to analyze the mechanical properties of the organoids. The values collected from the micro-tweezer testing should correlate with the values obtained from the rheometer as a result of the agarose gels being modeled to mimic the mechanical properties of tumor cells.

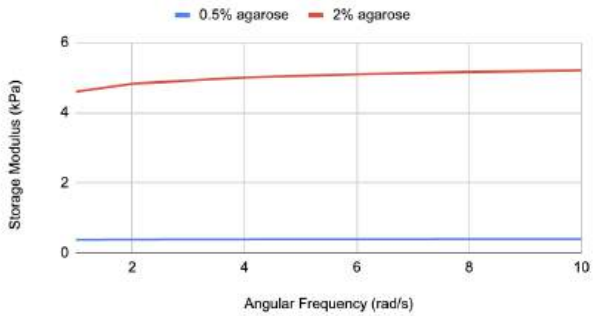

Figure 2. *Storage Modulus (kPa) vs Angular Frequency (rad/s) graph*

IV. Future Work

Beginning in January 2023, cells will begin to be seeded in matrigel-agarose hydrogels of various stiffness to form tumor organoids. The stiffness of the hydrogels will be further confirmed via rheological testing at the Institute of Materials Science at the University of Connecticut. As mentioned, gels synthesized with 15%, 25%, and 50% matrigel with 0.5% and 1% agarose will be evaluated. Ultimately, the obtained results will allow the correlation between the rheological properties of the gel and the stiffness of the tumor organoids to be evaluated after testing with the micro-tweezer device.

V. Acknowledgements

We would like to thank our advisor, Dr. Kanuzori Hoshino, for supplying us with the resources to complete the project, including those regarding cell culturing, hydrogel materials, and imaging. Mechanical testing machinery for the cells was provided by Dr. Dennis Ndaya at the Institute of Materials Science on the University of Connecticut Storrs campus. Special thanks to Carmen Lo, Venkatanathan Kidambi, and Manav Surti for their assistance in the laboratory.

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Design of a Smart Shunt System

Team 6

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University of Connecticut; Storrs, CT 06269 USA

Abstract **- The goal of this design project is to improve the quality of life for hydrocephalus patients. Currently, hydrocephalus patients are using shunts for their treatment. In this design project, the goal is to design a smart shunt system (SSS) within an existing hydrocephalus shunt. Currently, with the shunts, there is no real-time data regarding the flow within the catheter. There is a flow sensor, however, there is no system where the sensor can update the data. In this shunt system, there will be a Bluetooth module run by lithium ion battery, an app, where the data from the flow sensor will be updated regularly, and ClearFit made by Longeviti so ultrasound will be easier. The outcome of this project will make patients' lives easier and safer.**

Keywords – Smart shunt system, Arduino, ClearFit, Bluetooth, Flow sensor, Hydrocephalus

1. Introduction

Hydrocephalus is a disorder involving buildup of cerebrospinal fluid (CSF) in the ventricles of the brain caused by increased production, decreased absorption, or a blockage that leads to obstructed brain functioning or even death. Babies can be born with it or develop it after birth due to genetic defects, infections, brain bleeding, trauma, or tumors, and diagnosis is usually done through imaging techniques such as MRI. Shunts are the most common treatment where a tube drains excess fluid into the chest to be absorbed by the body. Unfortunately, there are limitations to shunts as they fail to consistently drain CSF due to infection or mechanical failure, causing more build-up and many ER visits, which can be extremely taxing for the patient [1].

Thus, innovations for shunt and patient monitoring with customizable modifications can improve the longevity of the implant and quality of life for the patients. The objective of this project is to redesign the shunt system to be more mechanically reliable, long-lasting, and allow for easier imaging to decrease shunt failure and hospital visits. This will be accomplished using more reliable flow sensor components, live updates using a Bluetooth application, and a customizable clear casing for imaging and ease of replacement.

2. Methods

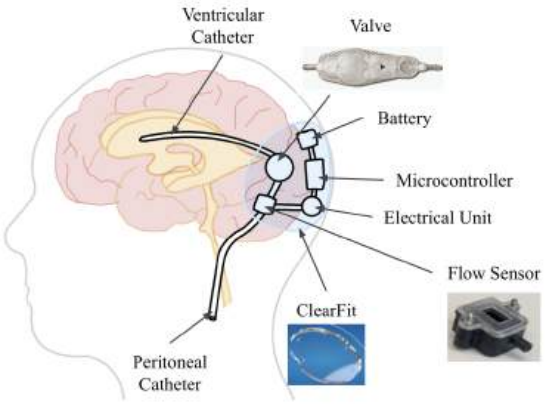

Figure 1- *The design and components for the smart shunt system.*

The design for the SSS consists of the proximal and distal catheter, shunt valve, lithium-ion battery, microcontroller, electrical unit, Bluetooth module, flow sensor created by the 2021 Senior Design team, and ClearFit innovated by Longetivti. To accomplish the design goal, Arduino components will be used to imitate the electrical setup of the SSS. Instead of focusing on five years, the time is constrained to three hours for the prototype process due to the limitation of components.

The following components will be used: Arduino Bluetooth BLE 33, Arduino Uno Rev 3, ambient light sensor (VEML 6030), lithium-ion battery, and infrared lighting emitting diode (MTS0077-843-IR). The MTS0077-843-IR and VEML 6030 will represent the flow sensor and the electrical unit. The energy and capacity of the Arduino electrical setup is calculated by using (1) and (2). Equation (1) is a capacity equation where Q is the capacity (mA/hr), I is current (mA), and t is time (hr). Equation (2) is the energy equation where E represents the energy (W/hr), Capacity(mA/hr) from (1), and V is the voltage (V). This provided the amount of energy and capacity the lithium-ion battery should contain.

$$Q = I * t \quad (1)$$
$$E = Q * V \quad (2)$$

The SSS will use an Arduino serial monitor to code for the Bluetooth module, the VEML 6030, and the MTS0077-843-IR to display real-time data of the flow rate. This will be accomplished when the components are attached to Arduino Uno Rev 3. Solidworks software will be used to customize the ClearFit.

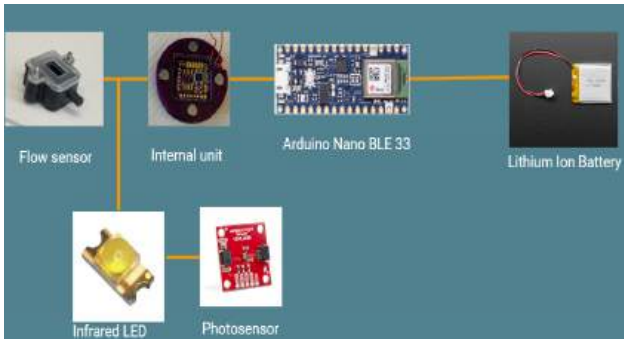

Figure 2- *A flowchart to demonstrate the Arduino electrical components that will be used to demonstrate the requirement for the design.*

3. Simulations/Expected Outcomes

The incorporation of the 2021 Senior Design team's flow sensor, equipped with the new MTS0077-843-IR and VEML 6030, connected to an Arduino BLE 33, promises precise and real-time data. The smart shunt data will be transmitted through the Arduino's Bluetooth capabilities to an Arduino serial monitor display. By molding this technology into the ClearFit which is designed to conform to a part of the patient's skull, the outcome is to seamlessly integrate the smart shunt into the patient's anatomy. The total capacity calculated for three hours is shown to be 275.5 mA/hr and the total energy is shown to be 0.8735 W/hr. These calculations fit into the boundaries of the lithium-ion polymer battery, 500 mA/hr for a total of about 1.9 W/hr. With all components working, the outcome of the SSS would be the ability to measure the flow of fluid and have the data displayed to inform the patient or medical workers if the shunt is working properly. Simulations for the smart shunt have not been able to be done through prototypes because of there being a delay in component shipping.

4. Future Work

The prototype of this project will be built after receiving all the parts necessary. By the beginning of January 2024, the manufacturing of the prototype will be in process.

The device will be built in the University of Connecticut Engineering Machine Shop and Engineer Science Building Laboratory. There will be a procedure written so it can be repeatedly built in case there is any error. There are two parts of manufacturing: the Arduino electrical circuit for the Bluetooth component and the fabrication of ClearFit. The circuit component will be built and tested to make sure there is no error. This innovation will improve the SSS and treatment of hydrocephalus.

5. Acknowledgments

Our team would like to thank our sponsor Yale New Haven. Also, we give thanks to Professor Kazunori Hoshino for aiding us in our device design and structure, allowing the use of his laboratory space, and the knowledge of current equipment.

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3D-Printed Prosthetics for Single Mastectomy Patients

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***Abstract* — Breast cancer remains one of the most common cancer diagnoses faced by women worldwide. Although surgical reconstruction with implantable material is an option for women post-mastectomy, many do not undergo the procedure. Thus, the Biosymmetrix team, in response to the overwhelming and growing need of comfortable and functional external breast prosthetics, intends to create a standard form suitable for single mastectomy patients. Building off previous work in customizable prosthetics built with 3D-printed silicone matrix, modeling and printing software was utilized to generate dimensions suitable for standard forms. Using a mastectomy patient's body scan designed on MeshMixer and TSIM, print designs were assembled. Rapid prototyping using TPU filaments was printed on a standard 3-axis 3D printer and standard prosthetic using silicone was printed on an intelligent, multi-axis printer. To develop a standard form, the project currently has several avenues that require further exploration.**

I. Introduction

Annually, an estimated 297,790 women are diagnosed with breast cancer in the United States [1]. Among these women, more than 100,000 will undergo either a single or double mastectomy where cancerous tissue is surgically removed, with approximately 30% of patients not opting for additional surgical reconstruction with implants [2]. Oftentimes, post-mastectomy, patients may experience a loss in their sense of self and femininity. Thus, such patients require a suitable alternative in order to restore their quality of life. Furthermore, current external breast prosthetics are ill suited for long-wear and aesthetics. Of the ones on the market, the two most popular materials are foam and silicone, both of which have been known to cause discomfort and decreased breathability of the forms [3]. To meet this need, the Biosymmetrix team has developed a novel 3D-printed silicone matrix form that is lightweight and breathable, enhancing comfort and meeting the aesthetic requirements of an external breast prosthesis. These prosthetics have been customized to fit individual patients and the unique contours of their chest wall, making their manufacturing process expensive and time-consuming. This project focuses on building standard forms of various sizes that would be comfortable for single mastectomy patients. The goal is to provide an affordable, breathable, lightweight, comfortable, soft, durable, symmetric, and user-friendly prosthetic that would minimize printing time and decrease the failure rate of printing.

II. Methods

A. 3-D Modeling/Software

Initially, when the focus of this project involved designing custom-made external breast prosthetics, modeling for the external breast prosthetic initially began with the use of 3D scans of single mastectomy patients. These scans were conducted both with the patient's bra on and bra off and uploaded to MeshMixer to create a prosthetic shape that aligned with the patient's chest wall to a close degree. These customized prosthetics were then uploaded to TSIM, the software associated with the 3D printer. On TSIM, a scaffold was generated to then be sent for printing. These prosthetics were specifically modeled with the intention for matching the appearance of each patient's specific chest, as well as using specific scaffolding intended for breathability and optimal wearability.

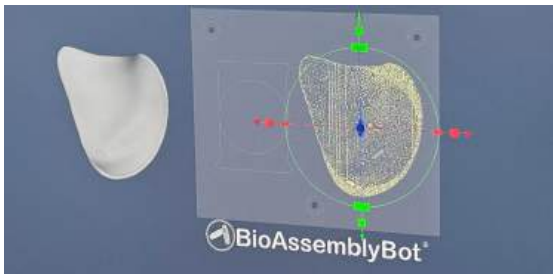

Fig 1. Image of portion of customized scaffold on TSIM

As this project is now focusing on generating a more standard form due to the time-consuming nature and difficulty of creating individualized prosthetics, modeling for this form has now taken a different turn. PrusaSlicer is being used to prototype an initial standardized form to investigate the dimensions necessary to generate an external breast prosthetic. Dimensions for generating a standardized form are being investigated through using the sizing charts of current external breast prosthetics on the market as well as the dimensions of previous customized prosthetics that have been generated. For more final products, MeshMixer will continue to be used to generate more final forms to be printed, which will then be uploaded to TSIM and follow the same methodology as with the customized forms to ready the models for printing.

B. 3-D Printing

Once a 3D design was created, it was printed using the PrusaPrinter, standard 3D 3-axis printer. As a prototype, the designs were first printed using TPU filaments. Printing with a TPU prototype allowed the researchers to verify that the dimensions and the shape of the prosthetic were appropriate. TPU has an overall higher print success rate and allows for rapid prototyping of the new design. The print was completed with an internal scaffold which allowed flexibility, despite the rigidity of the material compared to the silicone. The researchers used a 3D printed scan of a patient's chest wall as a "mannequin" to physically compare the design of the prosthetic. Using the chest wall, the researchers verified that the prototype was appropriately sized and was complementary to the natural breast shape.

After verifying that the design could be successfully printed on the Prusa Printer, the researchers repeated the print on the BioAssemblyBot, a multi axis intelligent robot bioprinter. Using the same 3D print file, the researchers used the standard silicone material to print a prosthetic with an internal scaffold. After printing, the prosthetic was evaluated for overall quality (ex. surface roughness, missing print layers, etc). It also was inserted into a sample bra to see how the design would function while being worn.

Fig 2. Rapid prototyping prosthetic printed using the Prusa Printer with TPU filaments.

Fig 3. Standard prototype prosthetic printed using the BioAssemblyBot with silicone.

One of the goals of the standardized form is to print a curved surface on a flat print stage. Although the BioAssemblyBot printer is capable of multiaxial printing, other standard printers are not. To increase the manufacturing speed, 3 axis printers must be able to print the designs. To overcome this problem, the researchers designed a novel curved printing surface using an oblong sphere shape. The two surfaces were designed on SolidWorks and printed using various methods. Method one printed a PLA curved surface and method two printed a TPU curved surface, both using the PrusaPrinter.

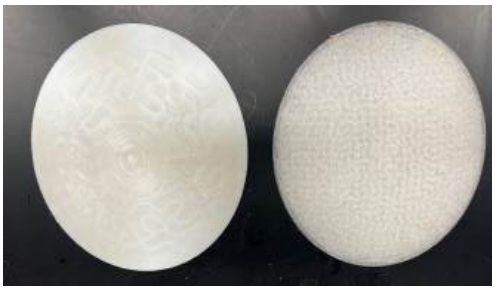

Fig 4. Comparison of the Prusa Printer PLA based curved surface (left image) to BioAssemblyBot TPU based curved surface (right image).

III. Future Work

Currently, the team members have come up with four different designs to determine the best approach and next steps for this project. The four designs are as follows: a flat chest wall form with several cut outs that can be glued together to achieve a curved surface, a lattice of metal wires within the form that patients can adjust to their chest, print the form onto a curved surface, and to print a flat chest wall form and place it on top of a scaffold so that it can cure into the curvature. The chosen breast form design will take into account the effectiveness, the reproducibility, and overall performance of the breast form. From the chosen design, standardized sizes of the breast forms will be designed and printed so that patients and volunteers are able to select from the various sizes according to their cup size. All breast forms and prototypes will be printed using the BioAssembly Bot and Prusa in Dr. Kuhn's Lab in the UConn Engineering Science Building.

Acknowledgement

Ashwini Patel, Mia Haynes, Jamie Trinh, Yukti Ummaneni thank Dr. Liisa Kuhn for her guidance and support for this project. In addition, they express their gratitude to the Beekley Lab for Biosymmetrix and the University of Connecticut Biomedical Engineering Department for their support with funding.

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Jawbone Quality Assessment Using Co-registered Ultrasound Imaging and CT Scan

Team 8

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Abstract – **The goal of this project is to create a method of coregistering Ultrasound (US) and CBCT scan images that is compatible with a custom-designed probe-like tool that is able to capture US images invasively. Integrating these imaging modalities has proven to be a difficult task, however; achieving this feat would be invaluable to the fields of orthopedic and maxillofacial surgery. The design team must ensure that the patient is properly prepared, that all data and findings are properly documented, that follow-up appointments are made when necessary, and that all safety precautions and procedures are met. All of these factors will ensure patient safety and more accurate results. For the imaging process, the design team should begin with ultrasound, as it is easier to manipulate its orientation. After this, the CBCT scan should be performed, and the information from each image should be fused to provide a holistic view of the patient's anatomy. Along with this, a custom probe must be designed to interact with the provided probe allowing for optimal ultrasound images to be obtained.**

Keywords: Biomechanics, Ultrasound, CBCT, Co-Registration, Probe, MATLAB, SolidWorks

1. Introduction

Due to drastic differences in bone compositions from one patient to the next, the importance of analysis within the jawbone with placing implants is imperative for a successful implant design. Jaw bone density analysis, specifically with the help of CT and US scans, plays an important role in the success and longevity of dental implants. It provides crucial information about the quality and quantity of the patient's bone, aiding dentists in determining the ideal implant size, type, and placement location. Insufficient bone density, meaning bone which is too porous, can lead to implant instability and potential failure over time. [1] While a thorough analysis ensures a secure foundation for the implant to integrate with the jawbone, especially if the implant is incorporated into the surrounding jaw bone, the analysis can result in enhanced implant stability and long-term durability. Therefore, accurate jaw bone density analysis is a fundamental step in the implant placement process, directly influencing the implant's longevity and the overall success of the dental restoration. [2]

2. Methods

MATLAB code was used for the overlay of US and CT scan images through a series of preprocessing and calibration steps. Initially, DICOM files containing the ultrasound and CT images are read, and the pixel values are normalized. Calibration parameters, including rotation angles, translation vectors, and scaling factors, are defined. Subsequently, these parameters are utilized to create an affine transformation, which is applied to the ultrasound image to ensure proper alignment with the CT scan. A blended overlay is generated by combining the calibrated ultrasound and CT images. The code concludes by displaying the original ultrasound and CT images, the calibrated ultrasound image, and the blended overlay or the two images for further analysis. A custom made attachment was produced in SolidWorks with the purpose of sitting on top of the transducer in the Ultrasound Handpiece and it's meant to condense the signal the transducer sends out to roughly the area of a 3 mm diameter circle. Along with that, it's planned that the inner opening where the ultrasound waves will be traveling through will be lined with a reflective material as well as be filled with a gel to allow for optimal transduction of energy

through space giving the highest resolution for images.

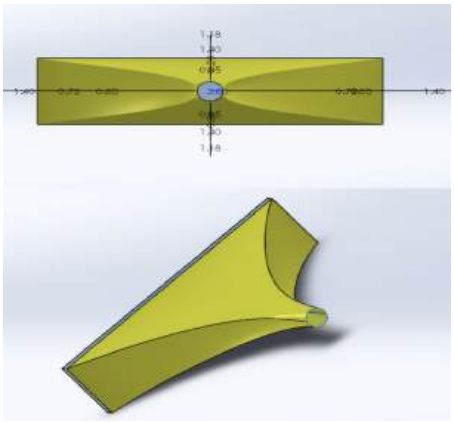

Figure 2 – *3D model of probe attachment showing how the ultrasound waves from the transducer would be condensed down to a circle with a 3 mm diameter.*

3.Current Restraints

The current MATLAB overlay application uses basic image enhancement but lacks advanced methods for superior image quality, especially in 3D reconstruction. The absence of robust algorithms limits its accuracy in representing volumetric structures. The code employs common MATLAB functions for image processing, but it falls short in addressing the complexities of 3D spatial alignment crucial for accurate surgical and augmented reality overlays. Integrating advanced image reconstruction techniques could enhance the application's capabilities. On another note, the custom transducer attachment suggests that the material and shape won't distort the emitted sound waves for ultrasound imaging.

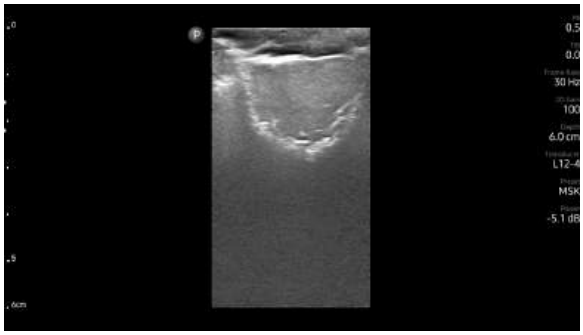

Figure 3 *– Ultrasound Image of Cow Shank*

4. Future Work

By the beginning of March 2024, a prototype of the probe attachment will be 3D printed and testing with it will start, possibly incorporating a 90° bend to make the probe more user friendly. Successful testing will be evaluated on the resolution of the images as well as how repeatable the results are. The device will be printed in the LCIZ and will be tested in Windham, CT. Along with this, obtaining a CT scan of the same exact bone and location will be difficult so the software will be tested with both formats of the images coming from an online database. This way, it will be seen how the program will overlay the two images and success will be measured by accuracy and resolution. The code will also be further edited to include inferred labeling and include a more dimensional overlay capability. The ability to repeat this process can also be repeated to see if the software might struggle with overlaying some images compared to others. Although there is a small amount of research on this topic, the ability to both create a probe attachment which will work with the developed software will certainly be a big use when it comes to analysis of the jawbone for dental implants.

5. Acknowledgments

We would like to thank the project sponsor, Dr. Dennis Flanagan and Windham Dental for supplying the ultrasound probe. In addition, we would like to thank Ramnarayan Krishnamurthy from MathWorks for his mentorship on the software aspect. We would also like to thank Professor Kumavor.

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Antibiotic and Anticancer Drug Screening on a Chip

Team 9

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***Abstract* – The purpose of this design project is to design and build a drug screening device that utilizes a laser and camera system. The general design of this project includes the use of a three axis manual stage, stepper motors, stepper controller, camera, and laser. The primary goal of the design is to make the device small enough to fit in the average person's pocket. The reason why having the device be small enough to fit in someone's pocket is important is because a portable, accurate drug screening system is not widely available in the modern world. With this device, the team plans on looking at cancer cells and their interactions with different drugs. The laser and camera system, along with MATLAB code will be used to facilitate image capture and then the subsequent analysis of them. This process is called ptychography. This method will be employed in the team's design and is defined as the computational process of microscopic imaging [1]. This summary report will go over the general design and purpose of it, the methods used to accomplish the purpose, the expected results, and future work on the design.**

Keywords – Drug Screening, MATLAB, Cancer Cells, Spatial-Domain Coded Ptychography, Portable

I. INTRODUCTION

Traditional drug screening processes have long been characterized by time-consuming and resource intensive methods, often hindered by their inability to mimic the intricate physical conditions within the human body accurately. Issues that current drug screening devices run into are limited physiological relevance, high cost and resource intensity, slow screening processes, challenges in personalized medicine, and lack of standardization [2]. However, this new method of screening on a chip has enabled researchers to miniaturize and replicate complex cellular environments on small chips. By leveraging the precision and scalability of microfluidic systems within these chips, scientists can now recreate the dynamic interplay between cells, tissues, and drug candidates in a controlled and reproducible manner [2]. The key advantage of antibiotic and anticancer drug screening on a chip lies in its ability to provide a more accurate representation of in vivo conditions, allowing for in depth studies of drug effectiveness, toxicity, and mechanism of action [2]. This particular chip enables highly efficient screening, which also allows for the simultaneous assessment of multiple drug candidates against various cellular and molecular targets. The objective of this design is to create an antibiotic and anticancer drug screening device that leads to personalized medicine and accelerated delivery of innovative pharmaceutical solutions. These will allow the medical field to address some of the most pressing global health challenges that society faces today.

II. METHODS

The goal is to create a compact device that uses fourier-domain ptychography (FP) to analyze the effectiveness of anti-cancer drugs. FP presents the opportunity to achieve high-resolution and high-throughput optical imaging while requiring minimal adjustments to current microscopy configurations. The primary principle behind ptychography is to recover detailed structural information from an object by analyzing the diffraction patterns it generates. A probe collects multiple diffraction patterns by moving the sample to different positions with some overlap. The collected diffraction patterns contain information about both the amplitude and phase of the scattered light, unlike traditional detectors that typically only record the amplitude of the patterns. To extract high-resolution structural information, ptychography employs mathematical algorithms for phase retrieval. These algorithms work to recover the phase information from the recorded intensity patterns. Ptychographic reconstruction is an iterative process, where an initial estimate of the object's structure is refined over multiple iterations using phase retrieval algorithms. This iterative approach improves the quality and resolution of the final image [3].

The design consists of a acrylonitrile styrene acrylate 3D-printed housing that protects the stage, light source and mounted camera. The light source is a laser mounted about 15 cm away from the camera lens. A dense monolayer of blood cells is smeared on the lens and then fixed with methanol. This serves as

a high-performance computational bio-lens for the ptychographic reconstruction process. The x and y axes of the stage are controlled by two stepper motors. The stepper motors are connected to a controller that can be operated by laptop or personal computer. A custom made LabVIEW program will be used to create a user-friendly interface that allows users to manipulate the stage. A MATLAB code will also be written to extract the images retrieved from the device and combine them into one high resolution image using FP.

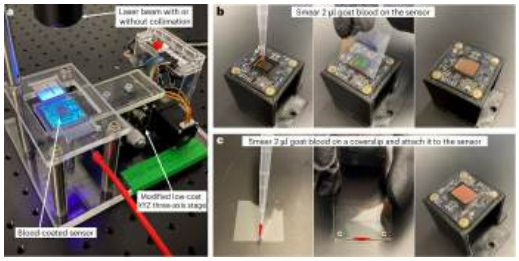

Fig. 1. Device Setup and Sensor Preparation..

III. EXPECTED OUTCOMES

The team expects to produce large-field-of-view and high-resolution images of the biospecimens being tested. A sample image produced of a blood smear slide using the camera is shown in Fig. 1. A zoomed-in image of the white blood cells in the same sample is shown in Fig. 2. The team also expects "to perform high-resolution live-cell monitoring over a large field of view" [1].

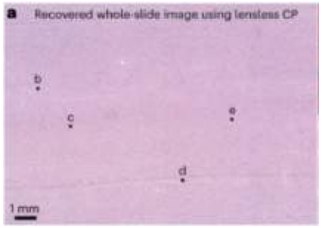

Fig. 2. Whole-Slide Image of Blood Smear Slide.

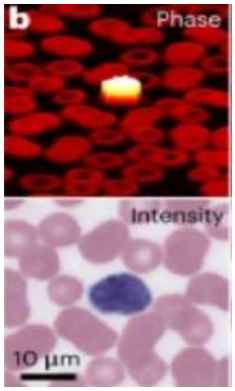

Fig. 3. Zoomed-In View of White Blood Cells in Fig. 2.

IV. FUTURE WORK

The future work planned for the team's project is to first create LabView code to help with controlling the stepper motors to help move the manual stage. The reason why that labview code will be used to move the stage is because LabView has a user-friendly user interface that is more easily understood than running MATLAB code. Another piece of planned work for the future is 3D print various pieces for the design such as a holder for the stepper motor, a sample holder, sensor holder, as well as a base that will be attached to the manual stage to help with the structural integrity. These pieces will be printed out using the printers in Bronwell 213. Additionally, the team will do more research into the type of cancer cells as well as the type of drugs that we will screen. Lastly, the team plans on having a working prototype done by the end of February and to begin testing shortly after.

ACKNOWLEDGMENTS

The team would like to thank the team advisor, Professor Guoan Zheng, Ph.D., for presenting the opportunity to work on this project and for providing guidance and resources required to work on the project. The team would also like to thank Professor Patrick D. Kumavor, Ph.D for facilitating the entire Senior Design process and providing the team with additional resources.

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PCR On a Chip for Covid-19 Testing

Team 10

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Abstract – **The purpose of this design project is to build a PCR testing device which is compact, efficient, and accurate in order to test for Covid-19 and possibly other viruses and diseases. In order to overcome current limitations of PCR testing, our device will be portable and user friendly. The design will use a milling machine controlled by either an Arduino or Raspberry Pi to move the sample to different temperature zones for thermal cycling. TEC coolers and fans will be used for heating and cooling, and will be regulated as necessary by the microcontroller, based on feedback from a temperature sensor. By the beginning of March 2024, testing, prototyping, and troubleshooting will have started to ensure compatibility of various components in order to achieve our final prototype.**

Keywords – *Virus, Covid-19, Thermal Cycling, Polymerase Chain Reaction, Arduino, Portable*

1. Introduction

Polymerase Chain Reaction or PCR is a technique used to isolate and replicate a sequence of DNA or RNA [1]. PCR testing consists of sharp temperature changes to a given sample in order to achieve the desired outcome of genomic replication. The three main phases for PCR testing are denaturation, annealing, and extension. The DNA is first heated to separate the two strands, followed by a cooling phase to anneal the primers to the template strand of DNA, and finally undergoes a moderate temperature increase to bind the DNA polymerase to the primer and add nucleotides to extend the strand [2]. This cycle continues to be repeated until the original DNA sample is sufficiently amplified. This project is aimed to create a device that will allow for simplifying this process which is the number one genetic amplification method worldwide.

The current limitations of Polymerase Chain Reaction Testing range from not being cost effective to the need for complicated laboratory equipment. PCR testing is considered to be too difficult to be readily available, due to the expensive equipment and the need for highly-trained personnel [3]. The objective in this project is to design a PCR testing device that is portable and easy to use in order to improve the PCR testing process. This is especially applicable with the rise of the recent Covid-19 pandemic. This device won't require an experienced operator and it will be portable, allowing it to be more efficient in testing for viruses and genetic defects.

2. Methods

The current design consists of a benchtop miller which will act to move the sample in the x, y and z directions. This full range of motion will allow the movement of the sample between three different thermo controlled ports. Moving between these ports completes the PCR process. The sample will be held by the benchtop miller arm and attached via a 3D printed piece. The ports will be aluminum and the temperature will be controlled using the TEC coolers. Using either Arduino or Raspberry Pi, the benchtop miller may be reprogrammed and receive inputs from the temperature sensor in order to regulate the ports at an optimal temperature.

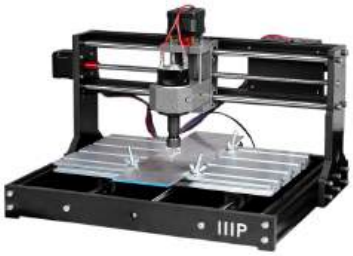

Figure 1 *– Miller that will be repurposed*

After comparing Arduino and Raspberry Pi applications to determine which is a better fit, it will be possible to write a custom made program which receives input from the temperature sensor as well as controls the timing and movement of the sample. After receiving input from the temperature sensor, the custom program will be able to send information to the mechanical relay which controls the TEC coolers for each individual port. The TEC coolers will then adjust the temperature as necessary. Controlling the precise timing of the movement of the sample allows the PCR process to run effectively. A locking mechanism similar to that of a pen will be used in order to apply pressure to the test tube to keep it stationary.

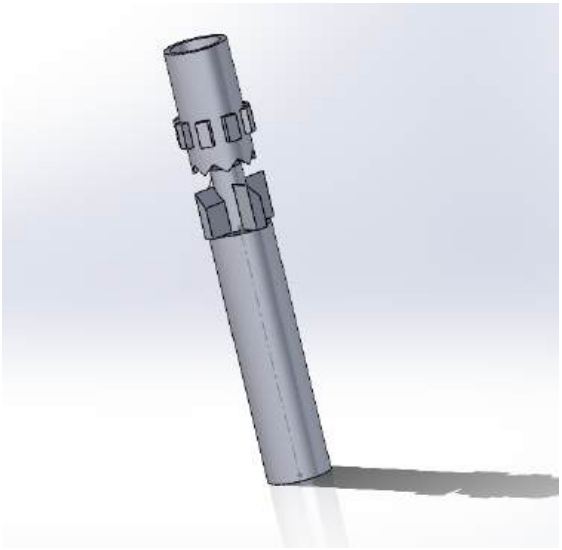

Figure 2 – *Solidworks locking mechanism draft*

3. Simulations/Expected Outcomes

The maintenance of the correct temperature ranges for the three stages of PCR is essential to ensuring the DNA is replicated. The temperature sensor must be tested for accuracy before its use with the sensing of the TEC cooler and fan by testing the reading in air against a calibrated thermometer. After this preliminary testing, the temperature sensor can be used with the sample holder. The communication of the physical device with the Arduino is critical to monitoring the temperature readings. The mechanical relay controls the TEC cooler and fan by getting input from the Arduino on the temperature reading and turning the TEC cooler and fan on or off based on the reading compared to the desired temperature. The holder for the test tube is modeled in SolidWorks to provide a simulation prior to 3D printing the holder. It is crucial that the test tube is fully in contact with the metal base in order to rapidly control the temperature of the sample.

4. Future Work

By the beginning of March 2024, sufficient testing of compatible components will be done for the final prototype design. A coding method for the miller will be selected with professor Zheng's help. This code will be used in order to control specific movements of the miller in the x, y, and z directions, along with the timing and forces required to allow for proper thermal cycling. A platform will be created using 3D printing to hold the electrical components below the miller. This will be made from a temperature resistant plastic. A frame will be made out of this temperature resistant plastic using 3D printing as well. This frame will be responsible for holding the test tube in place as the miller moves.

5. Acknowledgments

We would like to thank Professor Zheng for providing us mentorship in the design and construction of this device. The ordering of device parts was facilitated by Sarah Dunnack.

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Seizure Forecaster for Epilepsy Management

Team 11
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***Abstract* – The purpose of this design project is to develop a deep learning algorithm to predict epileptic seizure likelihood in the nearest future, such that a patient can take preventative measures to suppress it. Time-frequency and time domain inputs, Continuous Wavelet Transform and Entropy-based features (Renyi, Sample, Fuzzy), respectively, are applied to distinguish seizures prior to onset by a Convolutional Neural Network (CNN).**

Keywords – Convolutional Neural Network (CNN), electroencephalography (EEG), Continuous Wavelet Transform (CWT), Entropy (Renyi, Sample, Fuzzy), VGG16, Focal Epilepsy

1. Introduction

Epilepsy, a prevalent neuropathological disorder globally, impacts millions of lives, with 1 in 26 individuals affected in the United States alone. This condition affects over 65 million people worldwide. Thirty percent of epileptic patients are drug-resistant, complicating conventional symptom mitigation. [1] Electroencephalography (EEG) is the gold standard for observing seizures and capturing cerebral cortex activity. Due to the erratic nature of EEG signals, computational methods, particularly deep learning algorithms, have emerged to detect and forecast seizures. A dataset from Physionet, comprising 14 adult patients with focal epilepsy offers us 128 hours worth of potential seizure activity. Within the literature, some deep learning methods use Continuous Wavelet Transform and entropy-based features as valuable inputs. These inputs exhibit high sensitivity percentages (99% and 93% respectively). [2,3,4] Additionally, Convolutional Neural Networks (CNNs) are well-suited for analyzing EEG signals, breaking down inputs into smaller segments and implementing numerous filters for precise feature classification. The algorithm's implications extend beyond drug-resistant patients, providing substantive data for better quality of life by mitigating uncertainty regarding seizure timing. These breakthroughs aid in discovering epilepsy mechanisms, offering a better prognosis and representing a pivotal advancement in seizure management and understanding.

2. Methods

Before processing the EDF files, the data was preprocessed accordingly via EEGlab to remove non-EEG channels and artifacts. The pre-processing pipeline went as followed: removal of epoch baseline (DC offset), 2 Hz high-pass IIR filter (Butterworth, order 6), 90 Hz Low-pass IIR filter (Butterworth - Order 7), 50 Hz Notch filter (order 7), ICA decomposition and removal of non-brain artifacts, and finally re-referencing to common-mode montages.

The data was then processed to define inputs of entropy and power distributions over time, through (Sample, Fuzzy and Renyi) entropies and CWT through MATlab. Sample Entropy quantifies how deterministic a signal is by searching for patterns within two matrices, based on embedding dimensions which incrementally decrease into one representative of the signal. The function is given below (Equation 1), with A and B defined as separate matrices:

$$SampEn = -\ln\frac{A}{B}$$

Fuzzy Entropy quantifies the degree of fuzziness between a given length (mu) through membership functions in fuzzy set theory. It provides the uncertainty of signal. It is often described as an improvement of Sample Entropy, but in literature has been shown to be effective in conjunction with it. The function (Equation 2) is given below:

$$H_d(A) = \frac{2}{n}\sum_{i=1}^{n} |a_i - \mu_{A^d}(a_i)|$$

Renyi entropy is primarily used within quantum informational theory, providing a general measurement of entropy of a probabilistic function, encapsulating Shannon (a = 1), Hartley, Collision and min entropies within a single function. The formula (Equation 3) is given below, with a > 1:

$$\mathrm{H}_\alpha(X) = \frac{1}{1-\alpha}\log\left(\sum_{i=1}^{n} p_i^\alpha\right).$$

Continuous Wavelet Transform was used to assess each channel individually to produce 29 scalograms. Wavelets were particularly useful in describing where power dispersions occur in time, via its properties of time-scaling and dilation of the mother wavelet. The wavelet used in this project Daubechies 2 (db2) is representative of a voltage-transient spike observed within EEG signals. The function (Equation 4) is given below:

$$T(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\, \psi^* \frac{(t-b)}{a} dt$$

1-D wavelet decomposition was performed to produce sub-bands, Delta [0 -4] Hz, Theta [4 - 8] Hz, Alpha [8 - 12] Hz, Beta [12 – 30] Hz, Gamma [30 - 90] Hz used to describe entropic variation within frequencies within 20 second samples. Wavelet scalograms were generated among all channels to demonstrate power distributions over time based on 10 second samples. Analysis of Pre-ictal vs. Ictal vs. Post-ictal is shown below for trends describing the power changes as the patient progresses into a seizure.

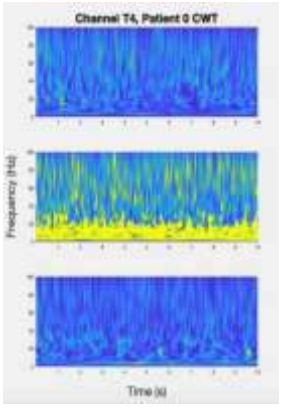

Figure 1 *– CWT scalogram from Patient 00 data. Top: 10 minutes before seizure (Pre-ictal). Middle: during seizure (Ictal). Bottom: 10 minutes after seizure (Post-ictal) .*

3. Expected Outcomes

We aim for a nuanced exploration of our data to enhance our ability to identify seizure onset accurately. Fig. 2 visually highlights key regions crucial for developing a CNN.

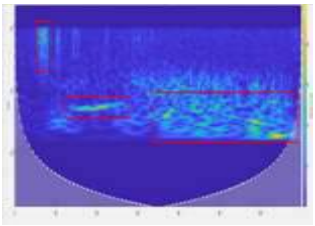

Figure 2 *– CWT scalogram of full seizure (Patient 00) with identifiable features in red*

Notable features include heightened wavelet spectral density frequency (gamma) band near seizure onset, elevated density below 10 Hz in the alpha band 20-30 seconds post-seizure onset, and a progressively increasing density in the delta-theta region. These patterns will guide our decision-making in implementing CNNs, influencing the convolutional layer extraction. Leveraging these distinct patterns, particularly those imperceptible to the human eye, will refine the CNN's capabilities to distinguish critical trends, emphasizing the importance of an informed approach to feature extraction.

4. Future Work

A prototype of the algorithm is set to be completed by April 2024. The total EEG signal's 20-second sample will undergo transformation using entropic statistics, resulting in 1 x 6 vectors based on sub-bands. These vectors will form a 6 x 6 matrix describing vector autocorrelation, which will be formatted into a tensor (6 x 6 x 3) for analysis by a CNN. Additionally, 29 Wavelet Scalograms will be generated through CWT for each of the 29 channels, aggregated into a (244 x 244 x 29) tensor for analysis via a VGG16 CNN network. Implementation will be done using MATLAB as we gather more information on CNN creation and manipulation. Troubleshooting will involve using half of the patient data to identify superior feature sets before finalizing the design. Efficacy quantification of the prototypes will utilize metrics such as sensitivity, accuracy, and false positive rate per hour, comparing results to up-to-date literature. The device aims to enhance understanding and accurate diagnosis of epilepsy and seizure onset.

5. Acknowledgments

We would like to thank our sponsor, NSEC (https://nsec.lab.uconn.edu), the Neural Systems Engineering Control Laboratory at the University of Connecticut for providing us with the resources to complete the project. Testing, realistic constraints and device design were aided by Dr. Sabato Santaniello. We would also like to thank Physionet.com for providing open-source data. MATlab support and access to specialty materials, such as EEGlab, were provided by Dr. David Kaputa.

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Wearable EMG-Controlled Tendon-Driven Prosthetic Hand to Restore Grip Function

Team 12

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***Abstract* – The purpose of this design project is to build a prosthetic hand that can be used by amputees focusing on restoring grip functionality. The proposed solution involves a designed and 3D printed underactuated tendon-driven gripper featuring an electric actuator. The project requires the design of a wearable microcontroller-based system that converts electromyographic signals captured from the upper arm muscles into a force signal to close the gripper. The integrated approach seeks to enhance the overall functionality and user experience of the prosthetic hand, offering a promising avenue for affordability and functionality in prosthetics technology.**

Keywords – 3D Printed, Tendon-Driven, Electric Actuator, Microcontroller, Electromyographic Signals

1. Introduction

Upper limb prosthetics are constantly being redesigned and updated to meet user expectations and provide the best possible experience for the user's needs. Biomedical engineers combine mechanical, electrical, and material engineering, along with an understanding of human physiology to create an artificial limb that mimics the natural arm's movements to improve the functionality of the prosthetic. Many modern solutions utilize actuators in each individual joint to create a heightened level of control.

Current research varies in level of complexity from cheap passive prosthetics to prosthetics with incorporated EMG sensors collecting biological data to produce highly responsive prosthetics that replicate essentially all function of the natural limb whether it be rotation, grip, or singular finger movements.

Despite the amount of research each year into these prosthetics, there remains a lack of prosthetics aimed to restore grip function in an available manner for all demographics. This design features an underactuated one motor gripper created with 3D printed PLA filament creating a simplistic design allowing the device to be easy to repair and manufacture. The objective of this project aims to build a simplistic easily reproducible EMG-controlled tendon-driven prosthetic hand that can restore grip functions for upper limb amputees. The function of the gripper will be tested to hold small everyday household objects.

2. Methods

The design consists of a 3D-printed gripper with two "fingers" which are each composed of two segments. The reach of the gripper is approximately 150mm, with a base width of 90 mm and a maximum thickness of 40mm. The prosthetic houses several 12mm diameter pins that allow the segments to freely rotate to close around an object. The casing design is shown in Fig. (1). The physical gripper components are 3D printed using PLA filament. The parts were printed with a thickness of 5mm and an infill density of 15%. The design features a single motor in the base that closes the gripper using tendons which run through the fingers. The tendons that cause the grip are 4.5 kg test nylon monofilament fishing line. The motor is actuated by a microcontroller stored on the side of the prosthetic gripper featuring an Arduino MEGA 2560.

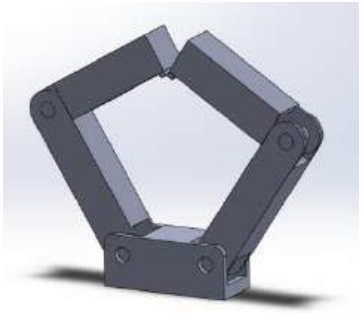

Figure 1 – 3D gripper model (edit)

EMG sensor selected for this project is Myoware 2.0 Muscle Sensor. It offers an Arduino-compactible and upgradable design with reliable sensor performance. The sensor measures and analyzes the muscle activity through electromyography (EMG) signal, and outputs an analog voltage. The sensor offers three output

modes, including raw EMG, rectified, and envelope, among which envelope is used for this project. The Arduino board selected for this project is Arduino Mega 2560. It is a microcontroller that serves as the device for processing signal from the EMG sensor. It uses the EMG sensor output to control the movement and rotation angle of the servo motor. The servo motor selected for this project is SunFounder CN0193. It offers a controllable 270-degree rotation, a maximum torque of 20.5kg•cm, and a speed of 0.18sec/60°. The servo motor rotates a certain degree based on the signal from the Arduino Mega, generating the force to move the pully system in the prosthetic gripper.

3. Simulations/Expected Outcomes

To test the capabilities of Arduino board performing signal processing and actuation controlling, a Simulink model was first implemented. The model reads analog input from Arduino pins, applies lowpass filter to extract the envelop, and maps the value of the input signal to motor angles. The produced angle value is used to output two PWMs to control a DC motor. The Simulink system is shown in figure[2]. The code was later successfully deployed onto Arduino MEGA and the DC motor was able to rotate in opposite directions in response to the raise/fall of the input.

The Myoware EMG sensor is coupled with Arduino Mega to control a servo motor. The system is shown in figure [3] Two data-collecting electrodes are placed on the midline of the bicep muscle belly between the innervation zone. The reference electrode is placed near pectoralis major tendon for minimum noise level during bicep contraction and relaxation. Arduino MEGA reads the MyoWare envelop output through analog pin and outputs to the serial monitor. The serial plotter during one muscle contraction-relaxation cycle is shown in figure[4]. Then the motor is controlled using the an thresholding algorithm.

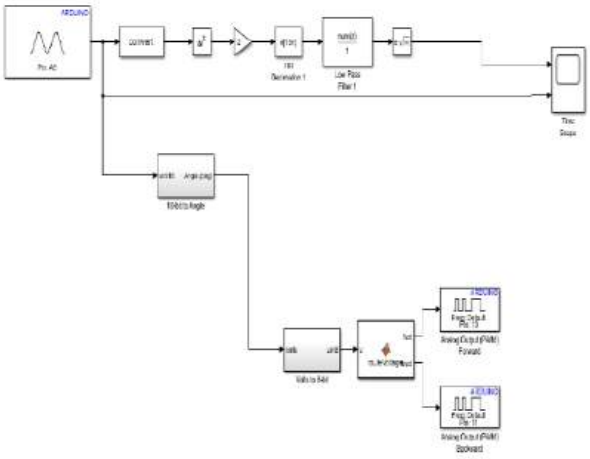

Figure 2 – Simulink simulation used to control DC motor via Arduino MEGA

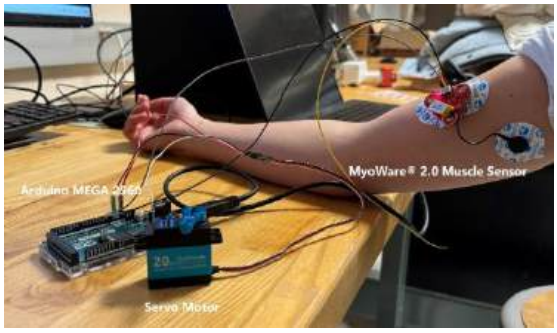

Figure 3 – Current System Setup

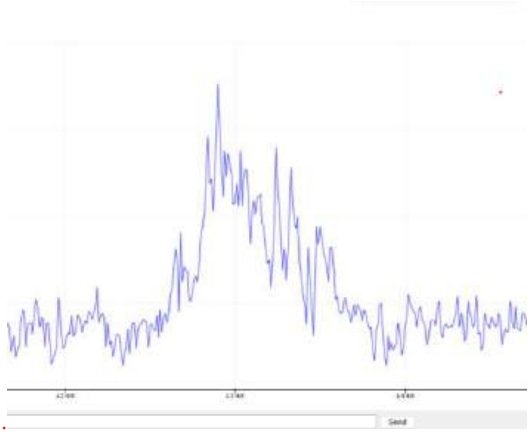

Figure 4 – Arduino MEGA analog reading of MyoWare Envelop Output

4. Future Work

A prototype of the device will be built during spring 2024. The motor of the device will be tested for the maximum force it can generate and the gripper will be tested to determine the maximum weight it can hold. The device body will be 3D printed using Acrylonitrile butadiene styrene (ABS) to increase its resistance to physical impact and tensile strength, making the device more durable. The microcontroller will be upgraded to Arduino Nano ESP32 for higher signal processing capabilities. The signals from Myoware will be transmitted via Bluetooth enabled by Arduino Nano for highest bandwidth and faster data transmission rate.

5. Acknowledgments

We would like to thank our advisor Dr. Sabato Santaniello for aiding with device design, modification, and testing. Resources for completing the project were provided by the Department of Biomedical Engineering.

Portable Insulin Pen

Team 13

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***Abstract* – Diabetes is a disease that affects the body's ability to regulate the insulin levels in the bloodstream that can be affected by many factors such as diet, physical activity, and environmental factors. There are different ways to treat this disease including the use of an insulin pen, this being a more convenient form of treatment. The purpose of this design project is to build an insulin pen that can be used by the client with an active lifestyle, a design that focuses on portability and temperature control. Through the use of computer aided design (SolidWorks), multiple alternative designs were created oriented around aspects after detailed consultation with our sponsor and client. Once a design is chosen and perfected, then we will start 3D printing iterations for further testing and adjusting. After fine tuning and adjusting the prototype, we will begin creating the final design with the use of metal. The result of this project will provide valuable insight for insulin pen manufacturers through a new design focused on portability and more effective cartridge use.**

Keywords – Diabetes, Insulin Therapy, Injection Device, Insulin Cartridge, SolidWorks

1. Introduction

Diabetes, a chronic metabolic condition, manifests as elevated blood sugar levels due to insufficient insulin production or ineffective use of insulin in the body [1]. As of 2023, 38 million US adults have diabetes, it's the eighth leading cause of death in the United States, and in the last 20 years, the number of adults diagnosed with diabetes has more than doubled [1]. This can lead to adverse health conditions such as heart disease, vision loss, and kidney failure [1]. There are a few treatments available to combat this disease including insulin pumps, islet cell transplants, and the use of an insulin pen [2]. Insulin pens offer convenience and accurate dosing, making them a popular and user-friendly alternative to traditional vial and syringe methods [2].

The current limitations in insulin pens make it difficult for people with active lifestyles to carry their insulin pens and cartridges safely. Insulin is also sensitive to temperature, and pens might have limitations in extreme temperature conditions during their activity. The objective of this design project is to create an alternative to insulin pens already out on the market, focusing on portability and temperature control that can still use the same cartridges that are widely available.

2. Methods

The design prioritizes the size and portability of the insulin pen. One of the main constraints was the size of the piston hindering the reduction in size. To combat this, our design utilizes a telescopic piston that is placed on top of the injector mechanism. The telescopic piston will be made of stainless steel. The telescopic design allows the insulin pen to be almost half the size of insulin pens available in the market. The piston will be made to conform to readily available insulin cartridges to ensure maximum accessibility to users.

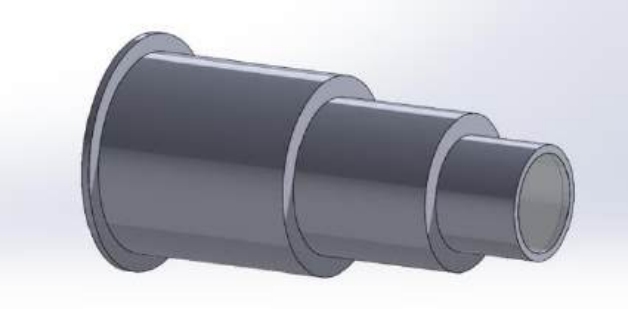

Figure 1 *– SolidWorks prototype of piston design insulin pen*

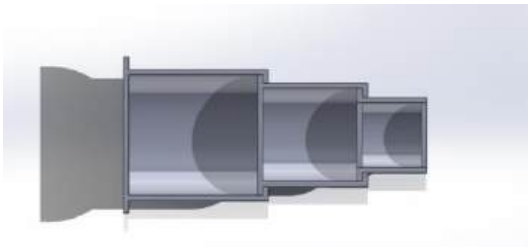

Figure 2 – *Cross-Sectional View of piston design insulin pen*

The piston will be controlled by a screw actuator that will move the piston according to the units of insulin selected by the user. Each unit of insulin corresponds to 0.14mm travelled by the piston. The insulin pen will supply a maximum of 30 units per use, in increments of 0.5 units, allowing for 10 uses until the insulin cartridge needs to be changed.

The casing of the insulin pen will also be made of stainless steel to ensure durability. The insulin pen, spare cartridges and needles will be placed in a small, insulated pack that can be hooked onto a belt.

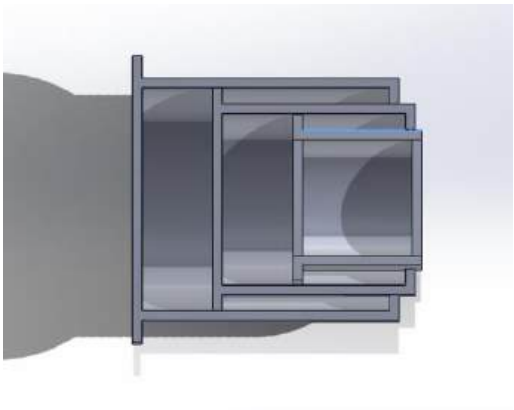

Figure 3 – *Cross-Sectional View of collapsed piston design insulin pen*

3. Simulations/Expected Outcomes

The piston design is significant when designing and simulating our prototype. The team's main priority/design goal is size and portability. Current designs on the market consist of a piston that takes up the majority of the interior of the pen. The piston collapsible to reduce the pen's size when not in use. The piston must also be able to have enough momentum to initiate the injection process. To ensure the strength and stability of the piston it will be constructed from metal instead of plastic. Simulations via SolidWorks were carried out to illustrate and further analyze the sizing, dimensions, and weight of the piston mechanism within the insulin pen. SolidWorks simulations of the stresses and deformation points ensure the success of the prototype's collapsible feature's ability to extend and remain extended at time of injection. A standard FlexPen is approximately 6 inches long in size, the expected model will be reduced by more than half the size when not in use due to the collapsible piston. The button that initiates the injection is located at the top of a standard pen, however, to further reduce the size the future model's button will be located on the side of the pen. The total capacity of the pen will be 300 units using half-unit increments and consist of an audible click when the required dosage is delivered. A small, insulated wallet sized pouch will also be available with the pen to prevent exposure to extreme temperatures when the user is engaging in outdoor/physical activities. The pouch will have an attachment feature allowing the user to clip to their belt, jean loop, etc. for easy accessibility.

4. Future Work

By the beginning of April 2024, a prototype of the device will be built and an insulated pack will be sized to accurately store the pens and cartridges for ease of portability. The main parts of the insulin pen will be created and built at the UConn Engineering Machine Shop. Smaller parts will be created by the team members using Solidworks produced designs and 3D printing. The pouch will control the temperature of the cartridges to ensure the insulin remains at the recommended temperature. This piston design will improve the portability and size of the insulin pen and the pouch will keep the insulin from being spoiled.

5. Acknowledgments

We would like to thank our sponsor, Prof Anna Radziwillowicz for providing us with the resources to complete the project. Thanks to our project advisors, Dr. Patrick Kumavor and Dr. Krystyna Gielo-Perczak, for the feedback and advice. Special thanks to the Biomedical Engineering Department for providing us with the equipment for design formulation and testing.

6. References

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Microfluidic Organ-on-a-Chip device for testing the Blood Brain Barrier

Team 14

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Abstract **–** The blood-brain barrier (BBB) serves as a barricade between the blood and brain, allowing nutrient supply to brain tissues while filtering out harmful compounds. Transport across the BBB is restricted by tight junctions and metabolic barriers [1]. The stringent regulation of the BBB poses a limitation for the delivery of therapeutic agents into the Central Nervous System (CNS). This design project aims to construct an organ-on-a-chip device that will be 3D printed and can accurately model the BBB. This model will provide a convenient mechanism to easily study drug delivery of molecules at various concentrations. The device will feature transendothelial electrical resistance (TEER) sensors to monitor the integrity of the tight junctions and apply shear stress to cells to promote tight junction formation to create a more accurate barrier. Moreover, successful implementation of the TEER sensor and concentration gradient will offer valuable insights to researchers in understanding the transport of molecules into the BBB, thereby facilitating the development of more effective therapeutics for those suffering from neurological diseases.

Keywords: TEER, Blood-Brain-Barrier, Organ-on-a-chip, Concentration Gradient, 3D Printed

1. Introduction

Microfluidic organ-on-a-chip (OOC) devices that involve fluid flow can act as more accurate models for cell and tissue interactions when compared to other conventional methods like static transwell models and avoid many of the difficulties associated with animal testing. Many different cell types can be cultured on each OOC, providing unique insights into how cells behave. OOC devices are a cutting-edge technology in the field of biomedical engineering, with many potential designs tailored to specific purposes [2]. Current designs in OOC devices greatly increase testing capabilities compared to previous testing platforms, however there are still many limitations in these current designs. These limitations include chip material drug absorption, limited accuracy to in vivo conditions, and high technology barrier to entry.

One physiological construct of interest to researchers is the blood-brain barrier (BBB). The BBB provides unique challenges to drug delivery due to its structure and function [3]. The objective of this design project is to design and build an OOC device that can accurately model the BBB. This device will also be 3D printable and will be able to test multiple drugs or substances simultaneously. The cell cultures should involve both endothelial cells and astrocytes, and shear stress should be applied to the cells as they culture, in order to create the most accurate model possible. Transendothelial electrical resistance (TEER) should be measured as an indicator of barrier strength. A convenient concentration gradient generator will be included to allow users to quickly test multiple drug concentrations.

2. Methods

The full chip design, as seen in Figure 1 (right), consists of four channels above and below a porous membrane. To simulate the BBB, endothelial cells will be cultured on the top side of the membrane in the channels and astrocytes will be cultured on the underside. Fluid will be pumped through the channels during cell culture to apply shear stress and promote tight junction formation. Shear stress applied will be 5-25 dyne/cm^2 to mimic in vivo conditions [4]. After cell culture, drug testing can occur. One of the main features of the chip is the microfluidic concentration gradient generator, as seen isolated in Figure 1 (top). On the input side (the side with two holes), one input will be a solution with some concentration of drug dissolved in it and the other input will be just the solvent. When the fluids flow through the microfluidic system, the four outputs will contain a range of dilutions of the drug. As such, this chip will be able to automatically test different dilutions of a drug automatically, saving the time necessary to manually create dilutions of the drug solution. Initially, the group will test the SolidWorks model of the concentration gradient generator. It is 55 by 57 mm, the microfluidic tubes are 1 mm in diameter, and the inputs and outputs are 2 mm in diameter. After the model is 3D printed, its mixing capability will be tested by placing water in one input and water with food coloring in the other.

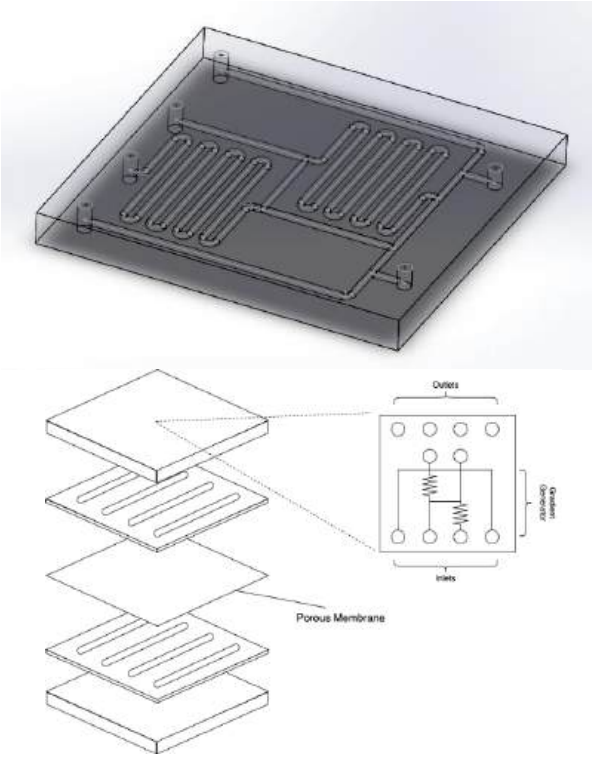

Figure 1 *– SolidWorks prototype of concentration gradient generator (left) and full chip design (right).*

3. Prototyping/Expected Outcomes

After completing our CAD file for our final design, we began the prototyping process for our concentration gradient. This process took place at the Werth Innovation Center and took approximately 30 minutes to complete. Ideally, we would want our prototype to mimic the design on our CAD file, but due to some errors our design was not accurately replicated. Moving forward, we will try to figure out what these errors were, and complete our initial prototype. After eliminating these errors, we will begin optimizing the size of the channels of our device to improve the capillary action of the concentration gradient and obtain accurate and replicable data. The expected result is a range of colors in the

Figure 2 *– Photograph of unsuccessful initial 3D printed prototype of concentration gradient.*

4. Future Work

By the beginning of the Spring Semester, the prototyping process for our device will be completed. We will then begin buying the materials, cells, sensors and pumps for our device. The device will be assembled at either the Bronwell Senior Design Workshop or at Dr. Kumbar's laboratory at UCONN Health, depending on availability. Once the sensors have been integrated into our device, we will begin culturing endothelial cells and astrocytes which will compose our Blood Brain Barrier. The culturing process will take around 1 week to complete and will be supervised by Dr. Kumbar in his laboratory at UCONN Health. Once the cell culture has been added to our device, the final process will be to test our models' sheer stress and drug permeability data and compare it to current in vivo models. This device will improve the speed at which new clinical therapeutics can be tested, aiding areas such as drug discovery and development.

5. Acknowledgments

We would like to thank our academic supervisors Dr. Kumbar and Aditya Ruikar for their sponsorship and support throughout the project. Testing, realistic constraints and device design were aided by Dr. Sangamesh Kumbar and Aditya Ruikar. Special thanks to the Werth Innovation Center for allowing us to use their 3 D printer.

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Mechanical Loading of Soft Hydrogels to Model Traumatic Brain Injury

Team 15

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***Abstract* - Annually, traumatic brain injuries (TBIs) are estimated to affect between 50 and 74 million people worldwide and were predicted to become the world's third main cause of death and disability in 2020 according to the World Health Organization (WHO) [1]. The purpose of this project is to investigate the various types of *in-vitro* hydrogel testing methods used to model TBI. Our goal was to design a method of dynamic testing that mimics TBI forces onto gelatin-alginate hydrogels and then measure the mechanical response. Our final design will utilize a universal testing machine to induce TBI forces, and we will insert fluorescent beads within the gel to measure the force propagation.**

Keywords - Hydrogel, *in-vitro*, TBI model, universal testing machine, fluorescent beads, force

1. Introduction

TBIs are caused by blunt forces to the head and typically have lasting effects both physically and mentally. Some disabilities include cognitive or motor deficiencies [1]. There are many current limitations to TBI treatments. Most treatments cannot undo the initial damage that occurs when the patient is afflicted with the injury. Current experimental treatments have a plethora of side effects and have yet to be fully tested in the public [2]. There is a lack of a proper testing system that can easily and accurately mimic brain matter and neuronal cells to be able to understand how TBIs can impact brain matter and cells and to create a possible testing mechanism for therapeutic drugs [3].

Current research involves studying TBI *in-vivo* in animal models. There are, however, very few studies available *in-vitro* that quantify the forces resulting in TBIs and the effects of such forces on brain matter and the cellular response following impact. Past research for this project has optimized a hydrogel system that mimics brain matter which provides a viable environment for neuronal cells.

The goal of our project is to induce forces that mimic TBI onto the hydrogel system and characterize the mechanical response under loading conditions. Our team plans to induce forces onto the hydrogels through nanoindentation utilizing the Instron 5869, which is a universal testing machine (UTM) on the UConn campus. To determine how the forces propagate, we will place fluorescent beads within gels and image them before and after impact.

2. Methods

Our team will first fabricate the gel-alg hydrogels according to the protocol developed by past senior design teams. The gels we plan to fabricate for force testing are 1% - 1% gelatin to alginate, and are crosslinked using calcium chloride and transglutaminase. During fabrication, we will place fluorescent beads within the hydrogels. The beads will act as a physical marker to track the displacement of the gel under loading conditions. Gels must be made 1-2 days before we subject them to TBI forces in order for crosslinking of the materials to be complete.

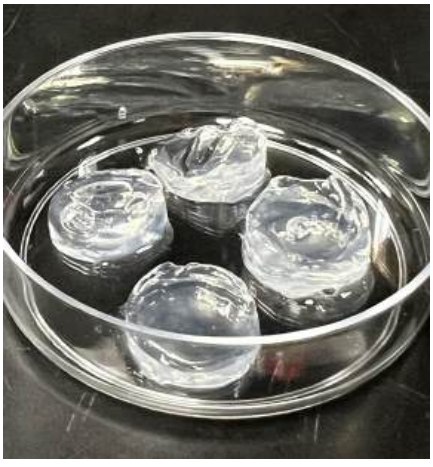

Figure 1. *Gel-alg hydrogels at 1% - 1% concentration*

Once hydrogels are fully fabricated, they will be placed in the UTM. The hydrogels will experience nanoindentation under a 5 to 10 Newton load cell to mimic the forces of TBI. During this process, the fluorescent beads will be imaged and then analyzed later using ImageJ software.

Figure 2. *UConn Instron 5869 Universal Testing Machine*

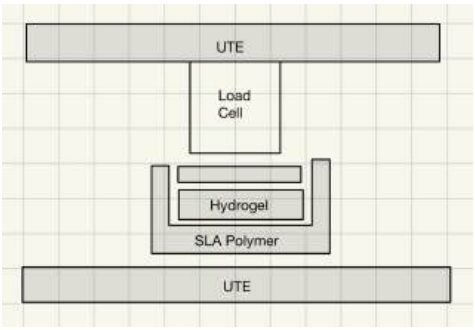

Figure 3. *Potential design of apparatus holding the hydrogel*

3. Expected Outcomes

We expect higher forces to result in greater deformation of the hydrogels, which would show that the testing apparatus is performing as designed. The force values following analysis are expected to match published values of similar testing apparatuses in current papers.

4. Future Work

We plan to visit the UTM on campus within the next few weeks. Once we know the dimensions and capabilities of this specific machine, we will be able to determine how the machine will house the hydrogel. We can then design a specific holding chamber for the hydrogel if needed. Additionally, our future work includes how we will specifically image the displacement of the fluorescent beads. Depending on the design of the UTM we may be able to image the bead movement with a camera in real time, or we may need to image the beads microscopically before and after force induction.

Starting in January 2024, we will use the Instron 5869 machine found at the UConn Innovation Partnership Building to conduct tests of the fabricated hydrogels. Analysis of the impact of TBI force induction on the hydrogels will be completed by members of the team using ImageJ software. The resulting data will be used to determine if the testing apparatus is appropriate in mimicking TBI. Data from the testing will also be used to assess the viability of the model for future trials that include cell seeding. The testing device and resulting data will be used to further understand the effect of TBI forces on brain matter *in-vitro*.

5. Acknowledgements

We would like to thank our Senior Design Advisor, Dr. Fayekah Assanah, Ph.D., for insight into traumatic brain injuries as well as access to her engineering lab. We would also like to thank Fei Wang, Ph.D. candidate, for her help in fabricating the hydrogels necessary for this project and the UConn Innovation Partnership Building for the use of their Universal Testing Machine.

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Minimally Invasive Surgical Device Burst Simulator

Team 16

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***Abstract*—The purpose of this design project is to design a testing device to test the resilience of Medtronic's trocar balloons. A sensor sleeve design is used to simulate the tugging motion used during surgery. This sensor sleeve surrounds the trocar balloon and interfaces the top of the inflated balloon in order to collect data once the simulated tugging force commences. This will be transferred via data collection to our system which will process the data with the utilization of LabView. Our finalized product will include the display of a pressure vs. time graph which will identify the certain testing characteristics of the target device.**

Keywords: Burst simulator, trocar, check valve

1. INTRODUCTION

Within the realm of medical device testing, burst simulators stand as pivotal tools for evaluating the resilience of components under varying pressure conditions. Used to determine pressure limits and failure points, these simulators play a crucial role in defining the expected performance of a wide range of medical devices. However, current simulators for trocars lack a way to assess their balloon's resilience to the vigorous movements they are subjected to in minimally invasive surgeries [1]. In response to this critical need, a Minimally Invasive Surgery Burst Simulator is being developed, utilizing pressure profiles to capture the performance of the trocar balloons [2]. This approach aims to ensure the safety and integrity of medical devices under realistic surgical conditions. The designing process will be done using SolidWORKS and LabVIEW for the coding.

Medtronic's trocar features a check valve connecting to the balloon, for the inflation of the balloon with CO2 to secure the trocar in place [1]. Given that the check valve represents a potential failure point, it is imperative for this project not to rely on the check valve for testing the balloon's susceptibility to potential bursts [2]. Instead, the testing approach requires evaluating the balloon's integrity from the external side, avoiding reliance on internal mechanisms like the check valve.

Upon completion, the simulator will not only contribute to manufacturing improvements and worst-case testing verification but also facilitate clinical scenario demonstrations, ensuring a more comprehensive understanding of medical device performance.

2. METHODS

Throughout our ideation and prototyping process, our team has determined that the initial design will include a fixation structure to hold the minimally invasive trocar while the balloon is inflated. This structure will include a sensor attached to the underside face which will interface directly with the inflated balloon [1]. This will allow for the accurate collection of pressure data when testing.

The team is still determining which method will be utilized to replicate the physiological motion of the trocar being inserted and/or extracted from an abdomen [2]. Initial methods that would be feasible include utilizing a controlled mechanical clamp that would pull on the trocar at a predetermined rate as well as using manual force of a human user to physically pull [2].

Moreover, the manufacturing of the device fixation structure was determined to be manufactured in two ways that are accessible on campus. First being via 3D printing which could be completed at various locations on campus. This would require the printing to be done in three separate parts and then assembled by hand. Another method will be to collaborate with the machine shop and weld the fixation structure with scrap metal.

Both decisions will be made after learning more about the product design and specifications in upcoming conversations with the team's sponsor Medtronic.

3. SIMULATIONS/EXPECTED OUTCOMES

A stress test will be conducted on the top plate as the balloon will primarily interact with that surface. That surface should not flex or bend when the trocar with the balloon is pulled against it. Doing a bend test would help determine the max stress and the manner in which that plate can fracture.

The expected outcome from the sensor is a pressure vs. time graph. How that graph changes throughout the experiment will indicate whether or not a leak has occurred. The compliance of the trocar balloon will be taken into account when determining the leak pressure threshold.

4. FUTURE WORK

The team plans to build a prototype and LabView code using various sensors in January 2024. This code will be used to output data received from different sensors attached to the balloon of a trocar that will be inflated in a minimally invasive procedure, mainly on the abdominal cavity. This project will provide a new testing method for minimally invasive surgical products [2]. The maximum pressure and leak parameters of the balloon will be the main sources of test measurements for this project. This device will speed up and more accurately improve the testing process that is currently being conducted on the various medical devices [2].

5. ACKNOWLEDGMENT

We would like to thank our sponsor Medtronic and Christopher Tokarz for providing us the resources and information to work on this project. Special thanks to Dr. Patrick Kumavor and Dr. Krystyna Gielo-Perczak for their continuous support and mentorship throughout this process.

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Mini Motion Lab

Team 17

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Krystyna Gielo-Perczak, Ph.D, Patrick Kumavor, Ph.D
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Abstract **– The goal of this project is to design a biomeasurement system that is able to operate in a small space, while also measuring parameters such as hop distance, jump height, and joint angles. Motion tracking technology allows healthcare professionals to assess an individual's movement patterns, risk for injury, and other progressive measures that can enhance their plan of treatment. Currently, most solutions available for analyzing and measuring gait parameters are high cost and complex, making them unfit for use in clinical settings. In order to collect objective measures for rehabilitation, a Microsoft Kinect will be used in tandem with a system of wearable motion sensors. The result of this project provides valuable information to clinicians, physical therapists, and patients to quantify**

Keywords – Physical therapy, motion capture, biomechanics, return to sport, injury rehabilitation

1. Introduction

Physical therapy, also called physiotherapy, is the treatment of an injury, deformity or disease with physical means. Physical therapy is extremely important not only to treat the immediate injury, but also to prevent future problems and establish regular routines for long-term rehabilitation [1]. These treatment plans vary by individual, with some patients benefiting from the implementation of motion-capture technology to track and evaluate their recovery.

Motion-capture technology is any technology that measures the movement of people or objects. In a clinical setting, movement analysis helps clinicians understand a patient's movement patterns, "assisting with prevention, identification and rehabilitation of a wide array of diseases, disabilities and injuries" [2]. Some examples of this technology may include multi-camera setups or inertial measurement units. Having access to specific, individualized, kinematic information can help to improve a patient's overall recovery, quality of life, and risk for future physical injury.

However, these types of technologies are not common in all medical practices, whether this be in a physician or surgeon's office, or a physical therapy clinic. In order to be replicated in various healthcare settings, these systems should be relatively inexpensive, less time intensive and not require any specialized personnel. Most importantly, this technology shouldn't be limited by size, as many healthcare facilities are already tight on space.

2. Methods

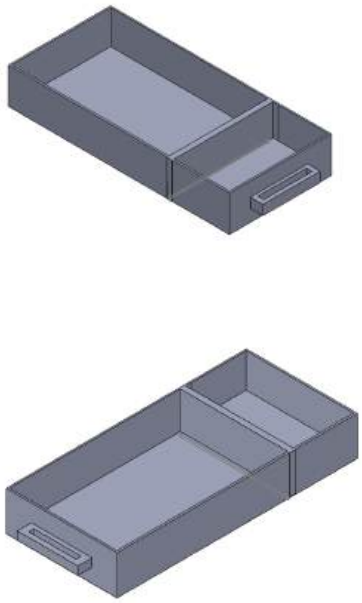

Figure 1 *– SolidWorks prototype of device casing for the accelerometer and*

To collect the data of jump height, hop distance, and the reactive strength index (RSI) a combination of an Arduino uno and accelerometer will be used. Custom C++ code written in Arduino ide is being used to calculate the magnitude of the acceleration data and

will calculate the height of the jump. Code will be written to determine the hop distance. This will be done by integrating acceleration twice with respect to time which will result in the displacement. The data will be exported into Excel to present the data in real time using Excel Data Streamer.

The Microsoft Kinect will be used with Brexel Body v3 to analyze the range of motion of different appendages. It will also be used to measure the joint angles.

3. Simulations/Expected Outcomes

The design and implementation of the biomeasurement system involve several critical simulations to ensure functionality and effectiveness in constrained spaces. Hop distance simulation using the biomeasurement system will be accomplished by utilizing varying hop distances mimicking that of real-world situations; these data will be input into the simulation to assess the system's capabilities and accuracy under distinctive conditions. In addition, the biomeasurement system's ability to accurately measure jump height will be tested. Different jump profiles, including disparity in jumping angles and forces, will be taken into account when evaluating the system's accuracy in capturing jump heights. Joint angle simulation involves real human models to precisely measure and capture joint angles during movement. The expected outcomes for these simulations include high accuracy and consistency in hop distance measurement with minimal error, high accuracy in jump height measurements for applications in physical therapy and athletic training, and precise real-time tracking of joint angles. The expectation is that the biomeasurement system will be capable of all this, while being optimized for constrained spaces. Thus, the system's design prioritizes effective data collection and analysis while being compact, without compromising data accuracy or performance.

4. Future Work

By April 2023, a prototype of the system will be built and a procedure will be created to accurately and repeatedly use the system to collect motion data for return to sport protocol. The device will be built and tested at the UConn BME Senior Design Lab and the GP MSM lab. Using the IMU sensor and Kinect setup in conjunction with various computer programs, the system will measure reactive strength index, acceleration, x and y position, and joint angles. This device will improve patient and clinician experience by providing valuable information to aid in an individual's treatment plan.

5. Acknowledgments

We would like to thank our advisors, Dr. Krystyna Gielo-Perczak and Dr. Patrick Kumavor for allowing us to utilize the equipment and software in their labs to complete our project. In addition, we would also like to thank our project sponsors, Dayle Stark and Brendan McGreevy of Hartford Healthcare Rehabilitation Network for providing support and informational videos to reference. Special thanks to Team 18 for allowing us to perform preliminary testing using their materials.

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Remote Gait Device for At-Home Rehabilitation

Team 18

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Abstract – **The purpose of this design project is to develop a gait monitoring device to allow physical therapists to remotely monitor gait parameters such as ground reaction force, step length, and stride length of patients with normal pressure hydrocephalus during rehabilitation after surgery, minimizing the need for in-person laboratory gait testing and analysis. A software will be developed to interface with the device, performing an analysis of the raw data gathered by the device and producing a practical, comprehensible dashboard that can be referenced by the physical therapist as a tool to monitor the patient's recovery progress.**

Keywords – Biomechanics, Gait Analysis, Hydrocephalus

1. Introduction

Gait analysis is a widespread technique used to understand healthy and pathological patterns of locomotion [1]. Gait analysis is typically performed in a laboratory environment; though the influence of controlled testing environments on normal walking patterns and inconvenience of patients having to be on site for the analysis may suggest a need for a device that remotely monitors a patient's gait in their everyday environment.

Normal pressure hydrocephalus is a chronic disease affecting predominantly elderly subjects, with its most prevalent symptom being a disruption to normal gait patterns [2]. Typical treatment for normal pressure hydrocephalus involves surgical implantation of a shunt to drain excess cerebrospinal fluid, in an attempt to mitigate symptoms such as gait difficulty, dementia, and urinary incontinence [3]. To analyze the efficacy of surgery, monitoring changes in gait during patient rehabilitation is critical.

2. Methods

The design began with a Solidworks model of the housing and its cap, that could contain the parts of the sensor system the design uses. The outer dimensions of the sensor housing box of the Solidworks models are 68.5 mm in length by 41.5 mm in width by 35 mm in height. The inner dimensions of the housing box of the Solidworks models are 25 mm in height by 35.5 mm in width by 62.5 mm length to provide space for our sensor system. There are two square holes in the side of the housing box, one is to provide an opening for the data cable used for collecting initial data and the other on the opposite side is for the insertion and extraction of a microSD card from the arduino board. There is a hole near the bottom of the model housing box that runs all the way through and has surrounding walls for the insertion of a velcro strip for ease to wear. The dimensions of the Solidworks model of the cap to the sensor housing box are 68.5 mm in length by 41.5 mm in width by 5 mm in height. The Solidworks models were made with rounded edges so as to prevent injuries from sharp edges when 3D printed.

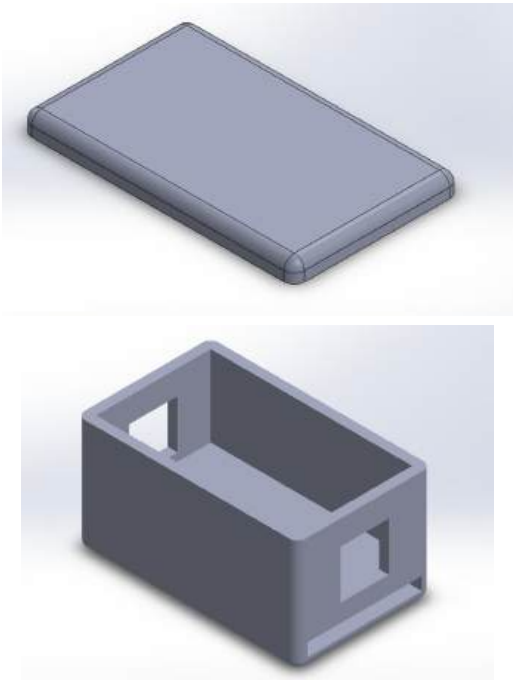

Figure 1 *– SolidWorks models of sensor housing and its cap that will contain the parts of our sensor design.*

The prototype of the design consists of an accelerometer and magnetometer sensor, an Arduino microcontroller board and a lithium ion battery to make up our sensor system that are situated into the custom housing that was modeled in Solidworks to fit the whole system in a closed box. The prototype contains the sensor system in its housing and a velcro strip to strap the device to the shin of the user.

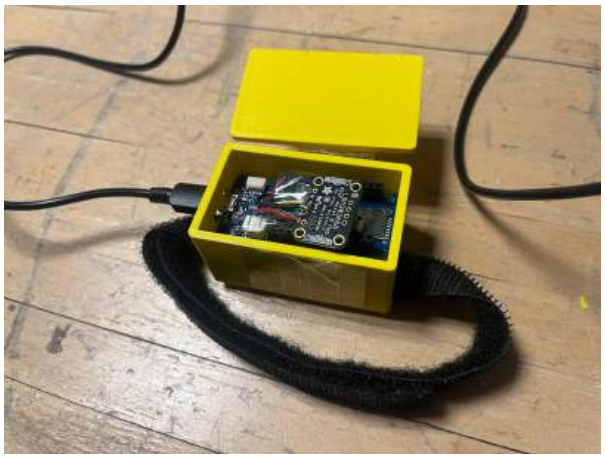

Figure 2 – *Sensor System situated inside of the 3D printed Sensor Housing.*

3. Simulations/Expected Outcomes

In order to gather the data output from the sensor system an arduino MCU, specifically the MKR Zero board is utilized due to its sensor reading capabilities and its SD card compatibility. Using the Arduino IDE and sample code provided for the sensor, 3 axes each for both the accelerometer and magnetometer were graphed in the serial plotter. From there, code was written to output just the magnitude of acceleration as opposed to all of the axes separately. Additionally the data output was now connected to Excel Data Streamer where the magnitude of acceleration over time was graphed.

Initial testing of the device has shown fairly consistent results, outputted in the form of acceleration over time while a subject is walking with the device attached to their ankle. It will be necessary to take this data and correlate the patterns seen in it to different parts of the gait cycle and to determine where one cycle starts and ends. It is expected that necessary parameters (such as impact peak, active peak, step length, and stride length) will be able to be isolated from this acceleration data. It is also expected that calibration of the device using a force platform will allow the development of a correlation between magnitude of acceleration and force to accurately determine the ground reaction forces.

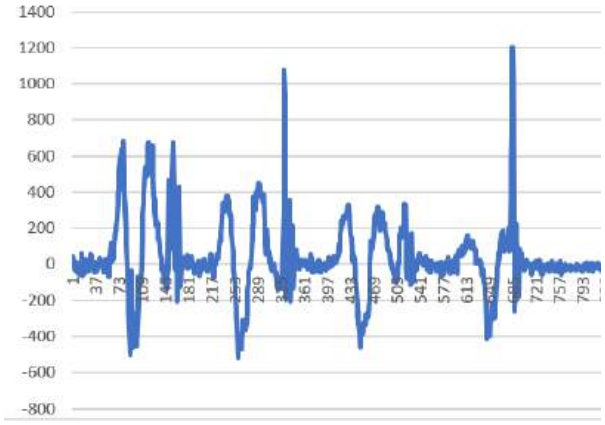

Figure 3 *– Magnitude of Acceleration over time while a test subject is walking, graph outputted in Excel Data Streamer.*

4. Future Work

By the beginning of next semester the current prototype of the device will be tested more thoroughly. This includes interpreting the output data to determine the desired parameters. Ground reaction force (GRF) parameters will be focused on first, such as impact peak and active peak. This will be accomplished through calibrating the device and determining a correlation between magnitude of acceleration and force. Step length and stride length will be focused on after we can gather GRF parameters reliably. The 3D printed housing prototype will also be revised in an effort to make it smaller and have it sit in a different orientation on the ankle. A dashboard will be created to easily view the data output from the device.

5. Acknowledgments

We would like to thank our sponsor, Dr. Kristin Morgan for providing us with the resources needed to figure out the parameters that are important to the gait analysis of patients recovering from treatment to hydrocephalus from home. As well as, providing us with access to her laboratory that contains equipment needed to calibrate our sensor design. Initial prototyping, testing and realistic advice on parts needed for the device were given by Dr. Patrick Kumavor.

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Multimodal Methodology to Evaluate Physiological and Psychological Stress of Patients under Compression of Hologic Paddle Designs for 3 Dimensions™ Mammography System

Team 19
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***Abstract*—The objective of this project is to analyze and synthesize different modalities of recorded stress of 25 patients under compression from the Hologic 3D SmartCurve Breast Stabilization System. Four platforms were utilized to measure signal responses from the various participants and data was collected from the Delsys and BioPac System. These being electromyography (EMG), electrocardiogram (ECG), balance control (FP), and Galvanic Skin Response (GSR). For this experiment, there will be a total of three different sets of controls- room scenarios (3), paddle type (2), and table/ C-arm positions (4). By analyzing and extracting missing data that will be used for extended research, we can determine the physiological and psychological stress data with parameters within the field of anthropometric data to determine which factors affect patient stress most during mammograms.**

***Keywords*—** Mammogram, Delsys, EMG, ECG, FP, GSR

I. Introduction

The Hologic 3-Dimensions mammography system is a machine that allows for higher resolution digital breast tomosynthesis. This 3D system helps detect small masses and cancers in patients that cannot easily be seen under their dense breast tissue. Breast cancer is the second most common cancer that leads to patient death [2]. According to the *American Cancer Society*, as of 2022 around 4.1 million women were reported to have a history of breast cancer. These rates have and are predicted to increase by 0.5% annually. Once reaching the age of 40 the probability of breast cancer being apparent in women gradually increases [2]. Mammograms are a breast examination, often recommended for women 40 and up, to detect breast cancer, early signs of breast cancer, or other breast diseases. Based on research, for every 1000 patients receiving repeated scanning, at the age of 50, nearly 1.8 lives are saved over a duration of 15 years [4]. Around 59% of women forgo their annual screening due to a multitude of factors. To increase the number of screenings women get to better combat cancer, there is a need to make it more practical of a procedure.

Currently, mammograms can cause pain and discomfort due to the high compressive forces against the breast tissue. Mammograms effectively compress the breast against two firm surfaces laterally, anteriorly, and posteriorly, to reduce the thickness of the breast and spread the tissue to examine for signs of breast cancer or breast diseases [3]. By reducing the thickness of the breast, it helps keep the exposure on the image receptors constant while minimizing radiation exposure, so the quality of the image can be improved [6]. Having the tissue compressed to one plane minimizes the risk of abnormalities going unnoticed from over layering of dense breast tissue [5].

This causes the participants to not be at ease and experience discomfort as the breast tissue is under high compressive forces. As reported in Influence of Discomfort Tolerance of Women who Undergo Mammography on the Perceived Pain Intensity Due to the Procedure, around 78.8% of women expressed pain during the procedure [1]. The pressure under the two firm surfaces and pulling of the breast tissue are some main causes of discomfort or pain. Along with the duration of testing, pitching near the chest, and breast positioning pre-mammography also cause patient discomfort. Hologic's goal is to make mammography more comfortable and decrease patient discomfort so women are more inclined to get annual exams, and increase early detection of breast cancer.

II. Methods

Twenty-five different participants were involved in an experiment to monitor their physiological and psychological stress during a mammogram. The participants' anthropometric data was recorded prior to the experiment along with a pre-appointment and screening questionnaire. Anthropometric data helps account for

individual variability because people may respond differently under compression based on their physical attributes. The subjective data provided an understanding of the current stress level of participants, their experience with mammogram screenings prior, and their pain tolerance. Comparing this verbal subjective data to physical pain and stress endured can call attention to patterns and reasons for certain stress responses.

For the physical setup for this experiment, there will be a total of three different sets of controls- room scenarios (Large Room, Small Room 1, Small Room 2), paddle type (Flat Paddle and SmartCurved paddle), and table/ C-arm positions (Right breast bilateral craniocaudal, Left breast bilateral craniocaudal, Left breast mediolateral oblique, Right breast mediolateral oblique). Large room was the initial room the participants entered with no mammogram machine, but were connected to all four sensors (EMG, ECG, FP, GSR) to measure their baseline stress signals before they saw the setup of the experiment. Small Room 1 was the next room the participants entered with the mammogram machine present, and their stress levels were measured before they underwent mammogram compressions with the Flat Paddle. The Small Room 2 setup was the same as Small Room 1, however their measurements were taken after the Flat Paddle mammogram compressions, and before they underwent SmartCurve Paddle compressions. The SmartCurve paddle is analogous to the standard flat paddle size, however, the chest wall edges of the new paddle are curved rather than being a straight 90º edge [6].

Figure 2- *Hologic 3 Dimension Mammography System [3]*

All four sensor platforms on the participants were connected to the same 14 muscles, creating a multimodal methodology to evaluate the physiological and psychological stress of the participants under compression of the two paddle designs for the 3 dimension mammography system. EMG Delsys Analysis was utilized to plot and analyze all EMG signals, along with MATLAB to normalize the data and determine significant parameters.

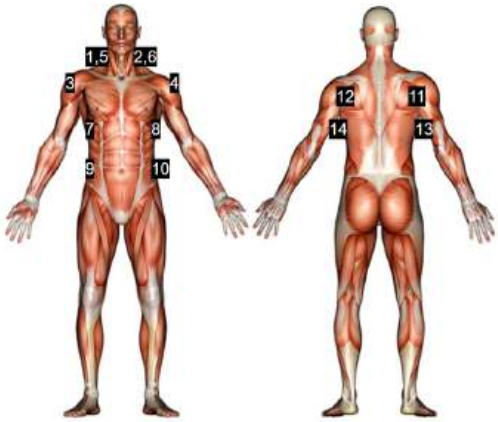

Figure 2- *Right Sternocleidomastoid (sensor 1,5), Left Sternocleidomastoid (sensor 2,6), Right Deltoid (sensor 3), Left Deltoid (sensor 4), Right Serratus Anterior (sensor 7), Left Serratus Anterior (sensor 8), Right External Oblique (sensor 9), Left External Oblique (sensor 10), Right Infraspinatus (sensor 11), Left Infraspinatus (sensor 12), Right Teres Major (sensor 13), and Left Teres Major (sensor 14) [7]*

III. Future Work

By the beginning of April all four platforms will be fully analyzed and we will be able to cross reference the results. This will allow us to draw an accurate conclusion using the entire dataset to back up our predictions that the participants underwent physiological and psychological stress, and determine how the body responded to increased stress. The accuracy of this data will be significant for future implementations to improve the mammography system so more women are inclined to receive annual screenings.

IV. Acknowledgments

We would like to thank our sponsor, Hologic, for providing us with the necessary resources to complete this project. Data analysis and organization, and MATLAB support were provided by Dr.Krystyna Gielo-Perczak and Riley McNaboe.

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A Novel Brace Design for Combined Drop Foot and Hyper-Extended Knee

Team 20

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***Abstract* – The purpose of this design project is to create a knee ankle foot orthosis (KAFO) for a client with drop foot and a hyperextended knee. The goal of the design is to correct gait alignment in the patient due to severe neuromuscular impairment in the foot and overcompensation causing injury in the knee joint [1]. The client's current brace solutions are uncomfortable, bulky, and intrusive. Without an orthotic, the client is limited in her gait speed, cadence, and efficiency. The result of this project provides a newly designed orthotic that is comfortable and effective for the client as well as providing valuable information to the biomechanics community on orthotic functionality with patients.**

Keywords: Biomechanics, Drop Foot, Knee Hyperextension, Orthosis

Introduction

Knee ankle foot orthoses (KAFOs) are used by individuals who have certain gait abnormalities. The client for this design has multiple sclerosis (MS). This degenerative condition caused drop foot and this challenge led to hyperextension of the knee, represented in Fig. 1 and Fig. 2, respectively. The patient now requires an orthotic to correct her gait in daily activities.

The clinical problems of drop foot and knee hyperextension require innovative solutions [1]. Existing orthotic solutions have design limitations and are usually mass manufactured, therefore not suiting every individual patient. The current state of research reveals a gap in comprehensive studies that evaluate the effectiveness of orthoses for MS patients, reinforcing the need for patient focused designs [2].

This design reconsiders the qualities of a KAFO that will prioritize comfort and patient experience without compromising functionality. Working closely with the client and addressing the current orthotic issues, the design will enhance the quality of life for the client.

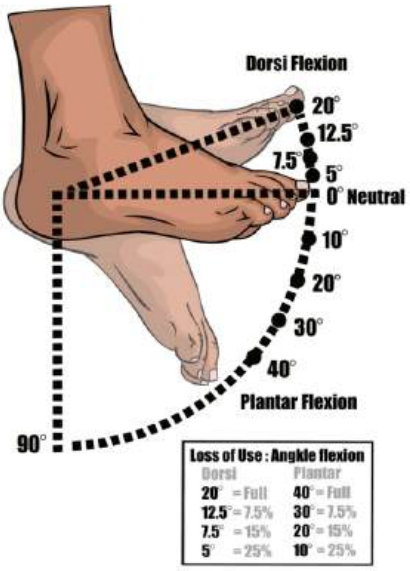

Figure 1. Angle measurements of drop foot.

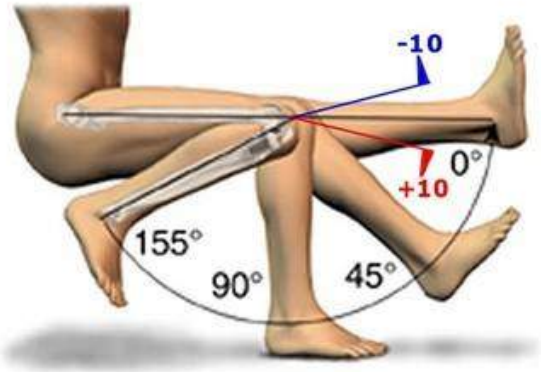

Figure 2. Angle measurements of knee hyperextension.

Methods

Numerous brands and styles of knee orthoses (KOs), ankle foot orthoses (AFOs), and KAFOs were studied prior to the generation of a novel design idea. The client was able to provide an extensive list of every brace she has tried, along with a detailed pros and cons list of each. In addition to the client's reviews of braces, customer

reviews from similar braces were also investigated in order to corroborate the client's likes and dislikes.

In general, it is apparent that the client, as well as the population of KO, AFO, and KAFO wearers, dislike orthotics that have hard plastic exteriors, due to the inflexibility and discomfort they cause; velcro straps, which have a limited lifetime of use and can cut the wearer if not aligned correctly; general bulkiness, which makes clothing and footwear options limited; incompatibility with other braces.

Options of methods to collect quantitative data specific to the client are limited, due to the client's current residence. However, studies using a force platform to collect data regarding plantar force and pressure distributions, as well as utilizing EMG sensors to measure muscle activity, will be performed. Data will be collected while wearing an orthotic and not, which will give relative data to refer to while constructing a novel orthotic.

In order to generate a preliminary design for the device, the client's preferences for device features and optimal activity levels were taken into consideration. The client prefers braces that are soft and comfortable to wear, and such that can be worn both during intensive activity and while relaxing. The goal of the preliminary design is to develop an AFO device that is akin to a sleeve or sock of compression or spandex material, equipped with laces along either side of the foot that can be tightened or loosened using a BOA dial device, as shown in Fig. 3. This device should provide the wearer with the comfort and flexibility of a sock, a non-intrusive option to wear with or without shoes, and ease to don and operate.

Figure 3. Solidworks Image of Preliminary AFO Design.

Simulations/Expected Outcomes

Anticipated simulations to test the functionality and comfort for the prototype of the device will involve testing a user's plantar force and pressure distributions while wearing the device versus not wearing the device. Ideally, the forces generated by the foot of an individual wearing an AFO will be lesser than that of a foot not wearing an AFO. Additionally, the pressure distribution should be more even for a foot wearing an AFO.

Another method for simulating use of the device and testing its efficacy is to have the wearer rate certain qualitative aspects of the device, such as comfort level, durability, ease to don, ease to clean, etc. Although this approach will not provide quantitative data, it will help establish advantages over traditional, pre-existing AFOs.

Future Work

By the middle of February 2024, a prototype of both the AFO and KO will be developed. After development of a working prototype, we will begin testing functionality and determine if the materials we use solve the issue of discomfort in existing braces. We will use the force platform and EMGs to better understand functionality of our prototyped design. After this we will revisit the drawing board and begin to improve upon our designs, hopefully by the end of the year coming up with a final product for our patient.

Acknowledgments

First and foremost, we would like to thank our patient for cooperating with us and providing us with the necessary information to help us help them. We would also like to thank the University of Connecticut School of Engineering as well as Dr. Krystyna Gielo-Perczak for providing us with funding and guiding us through the process.

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Evaluation of Shoulder Rehabilitation with the Application of Delsys Trigno Avanti and Galileo Electromyography Sensors and NeuroMap Software

Team 21

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***Abstract* – Shoulder injuries are extremely common and affect individuals across different age groups and activity levels [1]. However, existing shoulder rehabilitation methods, like rest, physical therapy, and surgery, are often insufficient in restoring the full range of motion. This is due to imprecise diagnostics and generic treatment plans, which highlight a need for a more advanced and comprehensive rehabilitation approach [2]. Thus, the goal of this project is to develop a versatile and extensive system for diagnosing muscle-related shoulder injuries through the use of the Delsys Trigno Avanti and Trigno Galileo electromyography (EMG) sensors. The sensors will be placed on various muscles of the shoulder/rotator cuff of a participant with a healthy shoulder and one with an injured shoulder [3]. The participants will then perform variations of a rowing motion with different shaped handles using a SLIDe apparatus, a shoulder-stabilizing device that allows for movement in the frontal plane developed by the Gielo-Perczak lab. These sensors will provide comprehensive insights into the muscular and neural activity of the injured tissues which will allow for customized rehabilitation plans that cater to individual needs [4][5].**

Keywords – Electromyography, Muscle Activation, SLIDe Apparatus, Comprehensive Shoulder Rehabilitation, Biomechanics

I. Introduction

Shoulder injuries are a prevalent challenge within the clinical realm of musculoskeletal pathology. The rotator cuff, composed of a complex network of muscles and tendons surrounding the shoulder joint such as the subscapularis, infraspinatus, teres minor, and supraspinatus muscles, plays a pivotal role in maintaining shoulder stability and facilitating its range of motion. When injured, everyday tasks that require the rotator cuff and other shoulder muscles, such as opening a door or raising one's arm, can often cause extreme pain and discomfort, and be debilitating [3].

The limitation of current shoulder rehabilitation methods is that the significant heterogeneity in the clinical presentation of shoulder injuries prevents these treatment plans from being specific enough to meet the needs of every patient, often failing to restore the full range of motion [6]. However, EMG sensors can be used to supply doctors and engineers with information regarding muscle activity to develop customized rehabilitation regimens catered to the patient's individual needs. Currently, Delsys, a wearable EMG sensor company, has two state-of-the-art surface EMG sensors capable of measuring the muscle activation of larger muscles like in the shoulder. The Trigno Avanti sensor allows the user to choose the EMG bandwidth setting and can measure the activity of one muscle fiber at a time [4]. The Trigno Galileo sensor is "the first-ever scientific instrument to measure neural firings and muscle activation for an integrated approach to human movement" [5]. To aid this project, the Gielo-Perczak lab has developed a shoulder-stabilizing device called the SLIDe apparatus equipped with a sliding platform and the ability to support handles or grips of varying sizes and shapes, shown in Fig. 1. The Delsys sensors in conjunction with shoulder exercises performed on the SLIDe apparatus are the basis of this project.

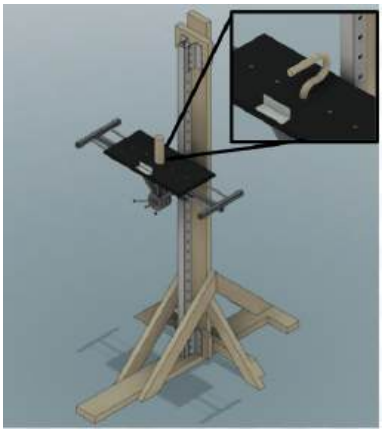

Fig. 1 *– CAD prototype of the SLIDe apparatus and the vertically- and horizontally-oriented grips.*

II. Methods

The design consists of investigating the shoulder muscle activity using both the Delsys Trigno Avanti and Galileo EMG sensors of two participants: one with a healthy shoulder and one with an injured shoulder. The exercise to be conducted is a rowing motion. Starting with the Trigno Avanti system, the four sensors will be placed on the deltoid, infraspinatus, trapezius, and teres minor muscles and the EMG data will be measured with the Delsys Acquisition software, shown in Fig. 2. The participant will start with their arm fully extended and holding the grip of the SLIDe apparatus. They will pull the grip towards their body and then return to the starting position for a total of three repetitions per trial. Three

Fig. 2 – *Delsys Acquisition EMG data collection while the participant performs the standing row exercise.*

variations of rowing exercises will be investigated including a standing row with the SLIDe platform parallel to the floor and two seated rows, one with the subject leaning forward and one with them leaning back, where the SLIDe platform is at a 45° angle to the floor. Each rowing variation will be performed first with a vertically oriented, 1-in. radius grip and then a horizontally oriented, 1-in. radius grip to mimic common-sized and oriented handles encountered in everyday life. All trials will also be conducted both unweighted and then with a 10-lb resistance to examine muscle recruitment and fatigue. The experiment will then be repeated using the Delsys Galileo sensors.

Once the muscle activity data is collected with the Avanti and Galileo sensors, the data will be processed and analyzed with the Delsys Analysis software and the NeuroMap software respectively. A root mean square calculation will be performed on the raw data and the maximum and average voltage achieved by the muscles during each trial will be calculated. Lastly, a custom-made Python regression analysis program will determine any relationships between the muscle activities of the two subjects.

III. Preliminary Results / Expected Outcomes

It is hypothesized that the muscle activity of the participant with no history of shoulder injuries will be greater than the participant with a hurt shoulder for all muscles. Yet, a preliminary trial of the subjects performing standing rows with the Trigno Avanti sensors placed on the deltoid and trapezius muscles showed higher voltages in the trapezius of the healthy shoulder but not the deltoid (see Table I).

This deviation from the expected results could be the result of a variety of factors including poor EMG contact with the skin, recruitment of other muscles to perform the task, and fatigue. More trials will need to be conducted to be able to draw any significant conclusions.

TABLE I: Absolute Maximum and Mean Voltage of Standing Row Trial

	Muscle	Maximum Voltage (mV)	Mean Voltage (mV)
Healthy Shoulder	Deltoid	0.136	0.085
	Trapezius	1.048	0.409
Injured Shoulder	Deltoid	0.32	0.125
	Trapezius	0.0412	0.0269

It is expected that adding resistance will increase the voltages measured for both subjects as more muscle fibers are recruited. However, it is predicted that the injured shoulder will exhibit signs of fatigue with added resistance. The two different grips should show variation in muscle activation both between the two subjects and among the same participant. Finally, the Delsys Trigno Galileo sensors should offer a more complete understanding of the neuromuscular effects of the patient's injury compared to the Delsys Trigno Avanti sensors as they can measure the muscle activity of multiple individual muscle fibers rather than just the whole muscle body. This will allow for the creation of patient-specific rehabilitation plans to increase the strength and mobility of their mending shoulder.

IV. Future Work

Data collection for both subjects is to be completed by the end of February 2024 for the Trigno Avanti sensors and by April 2024 for the Galileo sensors. The team then will perform a root mean square calculation on all of the raw data collected from the Avanti and Galileo sensors using the Delsys Analysis and NeuroMap software respectively and retrieve the absolute maximum and average voltage of each muscle. Regression analyses will be performed to determine if there are significant correlations between the muscle activity of the healthy and injured shoulders. This will improve shoulder rehabilitation by providing a detailed understanding of muscle activation patterns in rotator cuff injuries and paving the way for personalized and targeted rehabilitation strategies.

Acknowledgement

We would like to thank our project advisor, Dr. Krystyna Gielo-Perczak, for providing us with biomechanics guidance as well as the resources to complete the project including the Delsys Trigno EMG sensors, the SLIDe apparatus, and all the required software to process and analyze the collected data.

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Remote Gait Monitoring Device for Navy Personnel at Sea

Team 22

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Abstract – **Fatigue is a widespread problem for Navy personnel that significantly impacts both cognitive and physical performance [1]. Diminished cognitive and physical performance limits Naval personnel's ability to communicate and execute mission-related tasks in an effective and timely manner which can hamper mission goals. The result of this project will provide information to Navy personnel about their attention levels, and assist with shift changes and time management on submersible vehicles. The purpose of this design project is to design and build a sensor and algorithm that would monitor the ground reaction forces of Navy personnel, and alert them to their attention levels. Our design utilizes a thin insole with pressure sensors to store gait data from Navy personnel. That stored data would then be transferred to a computer and using MatLab, our code will be able to provide relevant data on their cognitive performance and attentiveness. By using the data, the Navy personnel will be able to analyze their fatigue throughout their shift and will be able to adjust factors such as their sleep schedules, sleeping environment, and working environment.**

Keywords – Sensor, Gait, Insole, Algorithm, Navy, Fatigue, Attentiveness, Cognitive Performance

1. Introduction

Current insole designs provide researchers with information regarding the gait, ground reaction forces, and stride length of an individual. These insoles are typically used to improve orthopedics and provide tailored insoles for everyday use for individuals. A current state-of-the-art gait sensor is the Orpyx design, which has embedded pressure sensors in an insole [2]. This information that can be collected from an individual walking includes the impact force (when the heel touches down), mid (flat foot), and active force (toe push off) from each foot, as well as stride and step length. Some research has been done on double-task simulations, where individuals will perform a cognitive task (either audible or visual) while walking with the sensor [3]. Despite such insoles existing on the market, there is currently little known correlation between these forces that are recorded and the attentiveness of that individual.

The current lack of research into correlating ground reaction forces with attentiveness makes it difficult to create an insole design and algorithm for that purpose. Due to this, it also makes it difficult to collect control data that can be used as reference material. Despite this, one objective of this project is to use data from the Orpyx and create an algorithm that correlates this data with attentiveness based on their GRFs and other data collected. The second objective of this project is to create an insole that can record GRFs and output the data directly to the algorithm.

2. Methods

The design consists of an Orpyx insole force sensor and MatLab code to quantify gait parameter data and draw correlations between cognitive ability and gait parameters. The three-part gait waveform can be collected using force sensors, such as the Orpyx or a moving treadmill force platform for lab-based settings. Data is collected from individuals who are performing cognitive tasks and those who are not. Future data will be collected from individuals who are cognitively fatigued and those who are not. The collected data will be uploaded into a MatLab code where the data is filtered, compiled, the gait parameters are extracted, and the correlations between the parameters and cognitive ability are made.

3. Simulations/Expected Outcomes

The data collected from the Orpyx includes values for the forces experienced by the heel, middle of foot, and toes, in a 3-part step function. Using an ideal one-step waveform to stimulate a traditional gait step length, gait parameter data was extracted. The preliminary MatLab program can be used to extract the maximum values for the heel forces (impact), the flat foot forces (middle), and toe forces (active). The program has the

ability to calculate step and stride length for both feet for multiple testing conditions as well as variability within individual gait habits over time. These testing conditions are Walking (Trial), Walking (Standard), Cognitive (Audible), Cognitive (Visual), and Cognitive (Both).

The program will use the collected gait parameters and correlate it with cognitive load. The preliminary program is able to find the maximum values of spikes on a step function, which will be used to find the peaks of the 3 part step function from the Orpyx data.

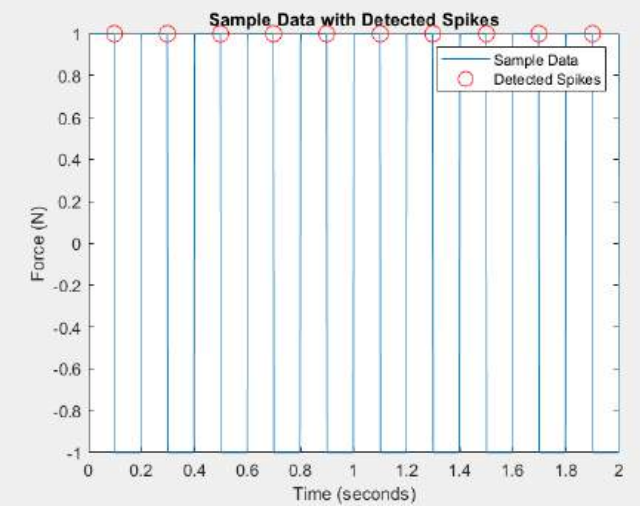

Figure 1*– An output to visualize how the MatLab code will function with sample gait data. The detected spikes represent when the toe lifts from the ground, the last phase of the repeating step function.*

4. Future Work

By the end of February 2024, we plan to have the necessary data from individuals who are cognitively fatigued and those who are not. Team members will then compare the two sets of data and using this, we will be able to fully finish our MatLab algorithm. Group member Madeline Stevens will also be creating an Android app to display data in a mobile format.

Additionally, the group would like to explore the idea of creating a gait sensor that does not require the use of a computer and instead utilizes an onboard solution. This sensor would have an LED attached to the device to quickly indicate the person's cognitive status. Additionally, the device would need to have a built-in solution that would process and analyze the data.

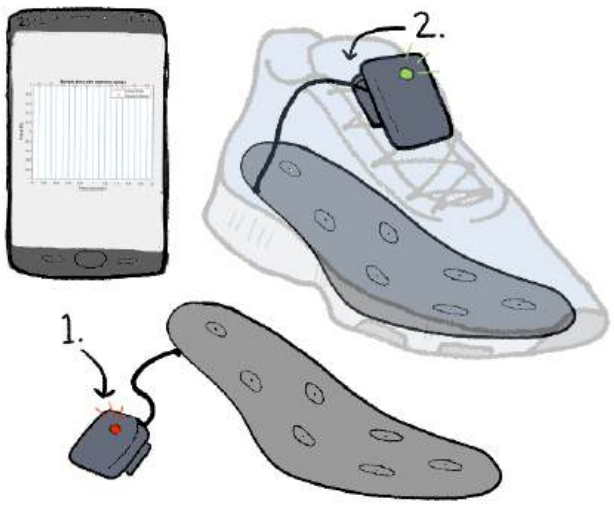

Figure 2 *– Illustration of our gait sensor with LED indicator (1) and conceptualized onboard solution (2), as well as a visualization of the planned app.*

5. Acknowledgments

We would like to thank our project advisor, Dr. Morgan, for providing us with sample code and previously collected gait data for reference. We would also like to thank our class advisor, Dr. Kumavor, for providing us with the prototype of the mechanical and electrical design for the reaction time testing device, timeline guidance, and realistic project constraints. Special thanks to Kevin Willy and David Swenson for providing us with first-hand insight into submariner life. Finally, we would like to extend our appreciation to Rebecca Labonte and Dr. Alexandra Hain for connecting us with the Navy personnel and assisting with budgeting for the project.

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Electrode Design for Continuous Blood Glucose Monitor

Team 23

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Abstract – **The purpose of this design project is to build reference, working, and counter electrodes for a continuous glucose monitor. Each electrode will have various coatings that will facilitate redox reactions generating current flow through the electrodes. Electrode designs will be altered to optimize the accuracy of the glucose monitor. Perforations will be added to the electrodes to increase the surface area and promote point diffusion rather than planar diffusion. Point diffusion results in a more accurate glucose reading because there is space for the reactants and products to enter and leave the reaction without interfering with one another. Titanium electrodes will be used due to their high corrosion resistance ability, and they will be coated in platinum. Titanium produces titanium oxide when exposed to oxygen, so the titanium oxide will be removed and then coated with platinum. The platinum coating is used due to its known catalytic property and because platinum is an inert metal that minimally passivates, and will not insulate the electrode [1]. The resulting device will accurately detect blood glucose levels for type 1 diabetes patients and transmit the data to a secondary device outside of the body.**

Keywords – Diabetes, Continuous Glucose Monitor, Electrode, Platinization, Titanium, Diffusion, Surface Area

1. Introduction

Diabetes is one of the most prominent diseases in the United States. About 1 in 10 people in the United States have diabetes resulting in approximately $413 billion lost per year from lost wages and medical costs [2]. Type 1 diabetes patients need to continuously monitor their blood glucose levels to ensure they are in range, and to take insulin when necessary. The current ways to check blood glucose levels is to prick your fingers or use devices such as Dexcom. The finger prick method involves pricking your finger and placing a drop of blood on the stick to test the blood glucose level. Dexcom is a small device on the outside of the arm that has small needles which are inserted under the skin. These devices need to be changed every 7-14 days depending on the brand and model.

The limitations of these methods include the cost of changing the device or test strips and the discrete information given through the finger prick method. The finger prick method only gives the glucose level at that specific instance. This method also does not tell the user whether or not the blood glucose rate is rising or falling. That information is critical for diabetes patients which makes this method inaccurate due to the discrete data. While the continuous monitoring devices do give continuous data with the rising and falling trends, they need to be replaced very often creating risk of infection due to the transcutaneous needles.

The proposed design is a fully implantable subcutaneous device that communicates externally using LEDs. This micron scale device will be approximately 0.5 mm x 0.5 mm x 5 mm and will be inserted by the user using a needle [3]. This device will have a lifetime of 3-6 months and will continuously monitor the blood glucose levels [3].

Each of the three electrodes will have 5 layers of coatings. The outermost layer of PVA provides mechanical support to the electrode and it provides the drug eluting capability. The next layer consists of glutaraldehyde-immobilized catalase enzymes that withdraws the H_2O_2 from the redox reaction while simultaneously preventing it from escaping to the surroundings. The third layer consists of a PU membrane which limits glucose flux to produce a linear current due to glucose concentration. The next layer consists of glucose oxidase (GO_X) enzymes that initiate a redox reaction from the breakdown of glucose which produces H_2O_2. The breakdown of H_2O_2 into oxygen produces 2 electrons which create the current that flows through the electrode. The innermost layer prevents active species such as ascorbic acid and uric acid from oxidizing the electrode.

2. Methods

The design for the electrodes will consist of three perforated electrodes linearly stacked on top of each other. Currently, the dimensions for each electrode are 0.75 mm x 0.025 mm x 9 mm; however, the goal for the final design is to decrease these dimensions. The hexagonal perforation design was ultimately chosen because it optimizes the surface area of the electrode greater than the circular design. Two of these electrodes,working and counter, will be titanium with a platinum coating while the reference electrode will be titanium with a silver coating.

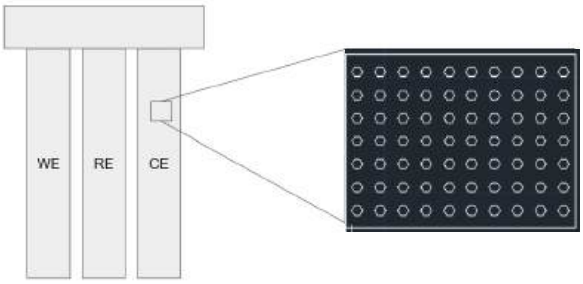

Figure 1 *– AutoCAD prototype of device with hexagonal perforations for surface area optimization.*

A custom made Jupyter Notebook Python code will compute and compare the changes in surface area depending on perforation spacing and design.

The titanium electrode etching will be executed by a femtosecond laser or a photolithography process. The femtosecond laser has a spot size limitation of 18 micrometers while the photolithography can execute etching as small as 5 micrometers with the correct materials. Photolithography etching involves the use of photoresist, furnaces, acid solutions, and design masks. The platinum coating will be administered to the surface of the titanium electrode using a method known as electroplating.

3. Simulations/Expected Outcomes

In order to assess the impact of electrode patterning on electrode sensitivity in a time effective manner, the design team has decided to proceed with glucose sensitivity testing using a 300 µm x 300 µm miniaturized electrode region. Photoresist is applied to insulate the surrounding surface areas of the electrodes, and only the area of interest is patterned. Net change in surface area simulations have been run assessing which patterning parameters optimize an increase in surface area, with the parameters in question being perforation shape, perforation radius, and interspacing between perforations. The automated code outputs the maximum number of perforations attainable with the provided inputs, and the design team has used this information to form preliminary AutoCAD designs that will be utilized in the femtosecond laser trimming. These simulations have shown that hexagonal patterning minimizing both perforation radius and spacing maximize the increase in surface area.

After further discussion of femtosecond laser resolution limitations, patterning designs will be finalized and glucose sensitivity testing will begin after electrode manufacturing. The expected outcome of these tests is that the designs with the largest increase in surface area will have the

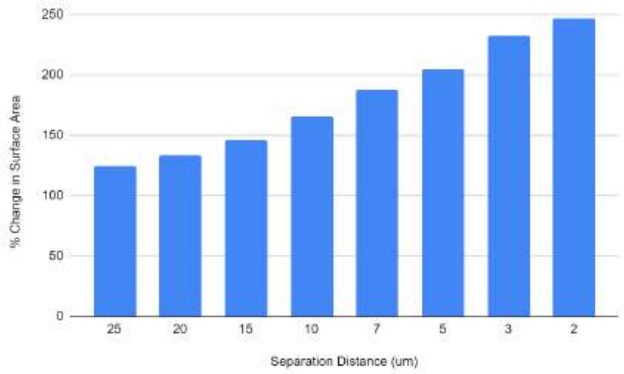

Figure 2 *–Percent change in surface area as a function of perforation separation distance for hexagonal patterning of 7 µm radius.*

greatest glucose sensitivity. This is due to these designs facilitating point diffusion mass transfer which was detailed previously.

4. Future Work

By April 2024, a prototype of the device will be built using platinum-coated titanium electrodes with perforations that maximize the surface areas while maintaining the mechanical properties and maximizing reproducibility. The perforations will be cut in the Innovation Partnership Building or the Information Technologies Engineering Building depending on the decided manufacturing method. The platinization of the electrodes will take place in Dr. Papadim's lab in the Science 1 Building. CTI testing will take place as well as surface area testing of the platinized electrodes with perforations. The reproducibility of the electrodes and the accuracy of the electrodes in testing the blood glucose level will be tested.

5. Acknowledgments

We would like to thank our sponsor, Biorasis Inc. (https://bio-orasis.com/) for providing us with the resources to complete the project. Testing, constraints and device design were aided by Dr. Faquir Jain, Raja Gudlavalleti, Dr. Fotios Papadimitrakopoulos, and Allen Legassey.

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Joint-on-a-chip Osteoarthritis Disease Modeling for Evaluating Anti-inflammatory Drug Performance

BME Team 24, MSE Team 7

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Abstract – **The purpose of the project is to establish a microfluidic chip system for mimicking the osteoarthritic knee joint for drug testing. The device is equipped with an alginate hydrogel-matrix chondrocyte cell culture to imitate the three-dimensional environment. Water compression channels will simulate the cyclical force from walking. Channels featuring a paper assay will detect inflammation biomarkers, with testing regulated by the user using valve-mediated fluid flow. The result of this project provides valuable insights to researchers and medical professionals by systematically assessing osteoarthritis components, facilitating advancement in understanding the disease and potential therapeutic interventions using an accessible and accurate system.**

Keywords – Lab on Chip, Organ on Chip, Osteoarthritis, Immune Response, Drug Testing

1. Introduction

Osteoarthritis (OA) is a pervasive degenerative musculoskeletal disease affecting hundreds of millions globally, and impacting quality of life for those afflicted [1, 2]. Traditional research methodologies rely on in vivo animal models, presenting limitations in terms of human accuracy, cost, and ethical considerations [3]. As there is a pressing need for better *in vitro* models, lab-on-chip devices have recently gained significant traction for their ability to replicate complex physiological conditions in a miniature, controlled environment.

The objective of this project is to create a model that accurately reflects the conditions of a joint afflicted by OA. Traditional in vitro models do account for one of three key aspects of a knee joint– immune response, mechanical stimulation, and multi-tissue interactions, and lack a holistic testing site [4]. By integrating fluid flow, a scaffold, and optical inflammation analysis, this comprehensive model will enable efficient testing of therapeutic interventions.

2. Methods

The microfluidic chip design is engineered to mimic the complex in vivo environment of the knee joint in the context of osteoarthritis. It consists of a single main channel of chondrocytes cultured on a 3D hydrogel scaffold. Directly adjacent to this main channel is a channel that will expand in response to water flowing through it. This will allow the chip to account for the cyclical mechanical stress experienced by chondrocytes in vivo, leading to a more physiologically relevant modeling of the knee joint.

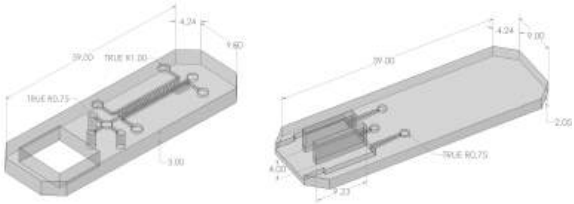

Figure 1 *– Top (left) and bottom layer (right) of SolidWorks prototype of device*

The media interacts with the chondrocytes through pillar wall architecture of another adjacent channel. This media then flows into a central output well, where it is then either released into one of three paper assay channels or manually removed for further testing. The three paper assay channels are used to help determine whether a drug molecule is successful in decreasing inflammation. They are pre-treated with essential reagents, including antibodies and enzymes, to enable the detection of biomarkers indicative of inflammation. The media will be released by an Arduino controlled key block before inflammation is induced via the proper cytokines, after inflammation is induced, and after the drug compound has been circulated. The colorimetric results obtained from these assays can be analyzed either qualitatively or quantitatively based on the specific experimental requirements.

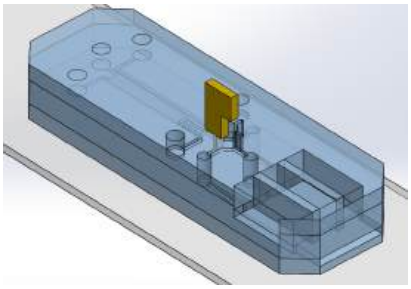

Figure 2 – *SolidWorks render showing key block.*

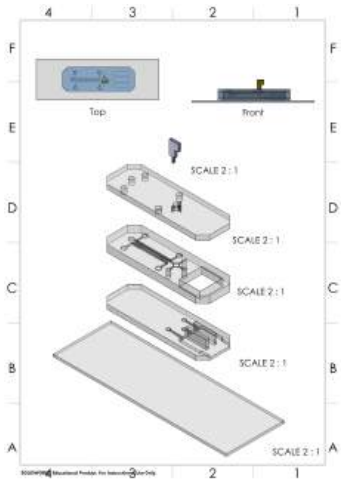

Figure 3 – *SolidWorks drawing showing layers.*

3. Simulations/Expected Outcomes

In order to confirm functionality of our device, simulation experiments will be performed outside of the chip. First, cell cultures of articular chondrocytes (C28/I2) will be established. Cells of a lower passage number (P < 4) will be used in order to ensure that the experiment is accurate. There will be three separate experimental groups, each with n=3: a control group that does not receive any proinflammatory molecules, a group of C28/12 in a monolayer, and a third group of C28/12 in an alginate hydrogel scaffold.

At t = 0, lipopolysaccharides (LPS) will be added. This, as well as the concentrations we use, are based on an inflammation induction model previously established in the Dr. Syam Nukavarapu lab. At t = 48 hours, ELISA and colorimetric sandwich paper assay will be done to detect inflammatory markers. Markers of particular interest are MMP13, AGG, and IL-8.

It is expected that at 48 hours, there will be a detectable upregulation of these inflammatory markers. This will confirm that the inflammation model used is effective and can be used to test anti-inflammatory drug molecules. In the event that this expected outcome is not met, alternative models using pro-inflammatory molecules such as IL-1beta. Additionally, by conducting both a conventional ELISA and paper assay developed, the efficacy of the latter will be validated. Once the inflammatory model efficacy is confirmed, tests will be run in the chip in similar formatwith the added component of mechanical strain.

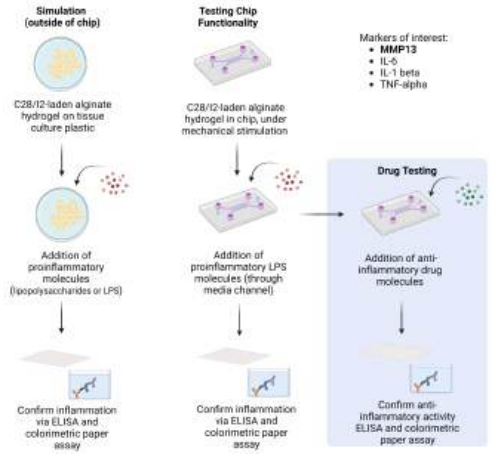

Figure 4 –*BioRender depiction of test methods.*

4. Future Work

By April 2023 a prototype of the device will be built and a procedure will be manufactured at Dr. Shor and Dr. Zhang's labs and tested to accurately and repeatedly use the device to test anti-inflammatory drugs. Healthy chondrocytes will be seeded into the device, osteoarthritis will be induced via cytokines, and anti-inflammatory drugs will be applied to the culture. Immune response will be assessed using colorimetric assay with MMP antibodies. The chip can be expanded to include bone cell types as well.

5. Acknowledgments

We would like to thank our sponsor, the UConn BME department for providing us with the resources to complete the project. Thank you to our advisor Dr. Syam Nukavarapu, as well as Dr. Sharareh Emadi, Dr. Yi Zhang, Vagif Abdulla, Dr. Leslie Shor and Christopher J. Hawxhurst for their help with manufacturing. Special thanks to Dr. Patrick Kumavor, Dr. Krystyna Gielo-Perczak, and Dr. Fiona Leek for project oversight.

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Parallel vs divergent screw placement for Femoral Neck Fracture Fixation: A Biomechanical Comparison

Team 25

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Abstract – **The purpose of this design project is to analyze two different cannulated screw patterns, parallel and divergent, to determine if one creates greater stability in femoral neck fractures. The goals of this design project are to create a device that attaches to the model femur bones to assist in cutting a simulated fracture as well as drilling screw guide wires, along with preforming finite element analysis on the 3D model to simulate results for the study. It is unknown if using parallel or divergent screw patterns is more effective in securing femoral neck fractures. There is currently no agreed upon method for securing femoral neck fractures with cannulated screws, and complication rates for these procedures are high [2]. This study looks to provide insight on which pattern is more effective. The result of this project provides a cutting and drilling guide to be used in the mechanical study on model bones, as well as simulated test results for the different screw patterns.**

Keywords – Femoral Neck Fracture, Cannulated Screw, Parallel, Divergent, Finite Element Analysis

Introduction

Some of the largest loads that the human body experiences are located at the hip. Forces at the hip are created from interaction of the foot with the ground during actions such as walking, running and jumping [2]. These forces can cause bone fracture, primarily resulting in the fracture of the femoral neck. Fractures can be classified by their angle of inclination from the vertical, deemed Pauwel's classification [3]. Different classifications call for different surgical treatments.

One treatment option available is the placement of cannulated screws through the femoral neck to secure the fracture. Placing such screws parallel to each other in an inverted triangle pattern (see Figure 1) is believed to be easiest for surgeons and leads to lower complication rates [1]. However, some surgeons choose to place these screws in a similar inverted triangle pattern, but in diverging directions. There is no specific research determining which pattern is more effective in resecuring the femoral head at the fracture site. A similar study was conducted, utilizing the two different screw patterns in patients, however no specific analysis was conducted, and results were based on patient follow-ups, rather than mechanical analysis [1].

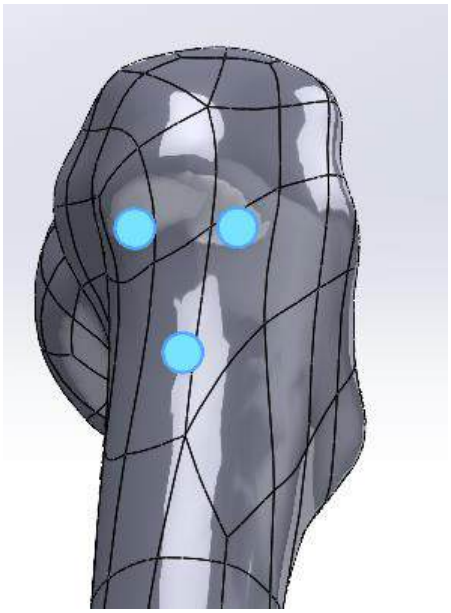

Figure 1 *– Representation of Inverted Triangle Screw Pattern Used in Cannulated Screw Placement for Femoral Neck Fracture Repair*

Methods

The design will consist of two different guides, one for creating the parallel screw pattern, and the other for creating the divergent screw pattern. Each guide will consist of two interconnected pieces which will be secured to model femur bones with two-millimeter guide wires. The guide is split into two pieces to allow for easy removal. The cutting part of the guide will provide a slot for the saw to pass through at an angle of 40 degrees from the horizontal. It will also hold the femoral head in place after the model bone is cut, as two two-millimeter guide wires will pass through the femoral head.

The drilling part of the guide will contain three pilot holes positioned to place six and a half millimeter cannulated screws in an inverted triangle pattern as close to the cortical bone as possible, without interfering with it. For the guide used to place parallel screws, the three pilot holes will be placed in parallel. For the guide used to place diverging screws, the bottom screw of the inverted triangle will remain in the same location as the parallel guide, but the top screws pilot holes will be positioned in a manner so that the ends of the screws will be as far apart as possible in the femoral head.

This guide is to be created with a 3D printer; thus, the design will be in a manner which allows for easy, replicable printing. The guide must be used multiple times; therefore, it needs to withstand being placed and removed from model bones many times.

Finite element analysis will be conducted on each of the femur 3D models containing modeled cannulated screws in their respective positions. A simulated force will be applied to the femoral head of each model, and reaction forces, stresses, and femoral head displacement will be recorded. The results for each model will be compared.

Simulations/Expected Outcomes

Anticipated simulations to test the stability of each pattern includes SolidWorks Simulation finite element analysis. Ideally, it is proven that a divergent screw pattern creates more stability within the femoral head, as the screws can contact the femoral head at a greater distance from each other. The outcome will be determined by analyzing the displacement of the femoral head at the fracture site. The screw pattern that produces the lesser displacement is the pattern that is deemed more stable. It is anticipated that multiple simulations will be run, computing displacement under maximum load and under repeated normal loading. Loading simulated will be modeled after loading experienced by the femoral neck under everyday use, including walking, running, and jumping.

The drilling guides created as part of this project will be used to place cannulated screws into model bones, which will be mechanically tested in the UConn Health Biomechanics Lab in Farmington, CT. It is anticipated that the results of simulated analysis will be comparable to those of the physical analysis done in the lab.

Future Work

By the middle of January 2023, the screw patterns and locations will be finalized. This will allow for the design of both the parallel and divergent guides to be completed by the end of January 2023. After creation of the designs, the guides can be printed, and an initial prototype created. After development of the prototype, the design will be tested on model femurs. If any changes are needed, they will be implemented.

After the screw patterns and locations are finalized by the middle of January 2023, work on the SolidWorks Simulation finite element analysis can begin. The cannulated screws will be modeled and placed into the femur models, and analysis performed. Results will be compared.

Acknowledgments

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