Title: Topic Search

Brainstorming

We investigated into multiple topics of interest, such as gene drug therapy, IgA Nephropathy treatments with bioartificial kidneys, and electrostimulation as a form of treatment for wounds. In the end, we confirmed our topic to be electrostimulation on chronic venous leg ulcers due to them being the most common type of lower body extremity.

picked up on routine urine analysis, is also a major presentation.

Pathophysiology

The basic defect in IgA nephropathy is not renal but systemic. In other words, the mesangial deposition of IgA-glycan complexes is related to a higher-than-normal level of abnormally glycosylated IgA1. This stimulates mesangial cell proliferation, expansion of the mesangial matrix, with the secretion of chemicals which finally result in glomerulosclerosis and interstitial fibrous tissue deposition. There are five gene markers of increased susceptibility to IgAN, such as on:

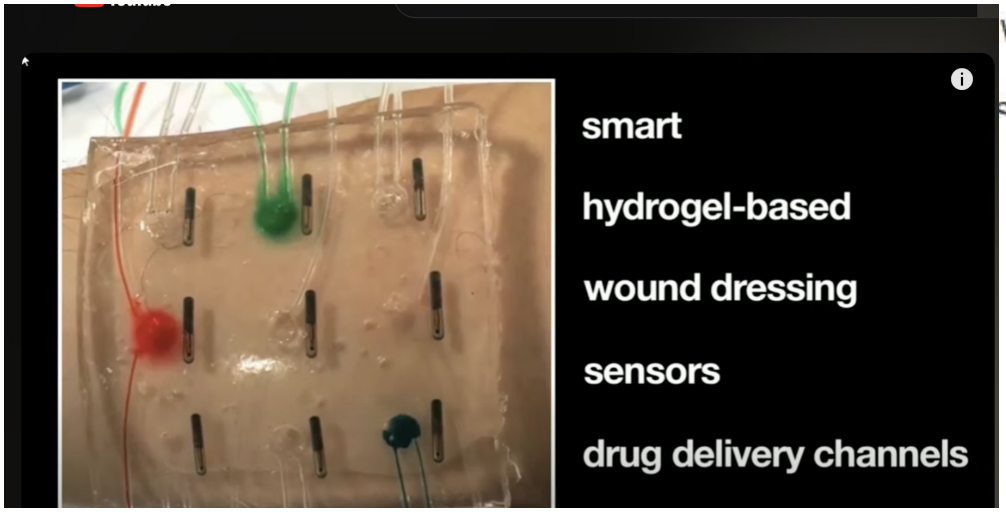
- chromosome 6p21
- chromosome 1q32 (H locus)
- chromosome 22q22 (gene cluster)

There are several risk factors for IgA nephropathy, include white or Asian origin, Family history of IgAN or of Henoch-Schonlein purpura and males between teenage to the late thirties.

The key molecular defect in people with IgAN is abnormal O-glycosylation of IgA antibodies. O-glycosylation -- in which a sugar molecule attaches to an oxygen atom in the amino acid residue of a protein -- plays a role in various physiologic processes. Studies of families have shown that problems in the O-glycosylation of IgA are common in people with IgAN and are largely genetic in origin,

were unknown.

sylation problems in



Title: Hydrogel addition to electrostimulation

Identify Problem

Further research identified a problem with traditional healing methods of CVLUs, including a high recurrence rate. This prompted us to innovate an entirely new treatment process for CVLUs, to make treatments more customizable and accessible. Hydrogels were selected for their adaptability and compatibility with various wounds.

win-win situation.

Table 2

The Commercially Available Hydrogels Used for Wound Dressings

Trade Name	Composition	Feature
Hydrosorb®	Polyurethane (PU)	Adsorption capacity, moisturizing, pain relief, reduce scar formation, breathable, waterproof, avoid adhesion
3M™ Tegaderm™	2% (w/w) Chlorhexidine Gluconate (CHG)	Effective under compression, safe on fragile tissue, protect the wound, maintains moisture balance
AQUACEL Ag®	Carboxymethylcellulose sodium (CMC)/Ag^+	Antibacteria, promoting wound healing
TenderWet®	Polyacrylate (PEA)/Ringer's solution	Continue active debr balance of seepage, h
Comfeel®	CMC/Calcium alginate/Purified water	Transparent, flexible

fibroblasts, and expedites new vessel formation [51]. Table 4 summarizes key findings of in vivo and in vitro studies that investigate the effect of ES on this phase of healing [43,44,45,46,47,48,49].

Table 4

In vitro and in vivo studies on the effects of exogenous ES on the proliferative and remodeling stages of wound healing.

Study Design	Type of ES	Exposure Duration	Experimented on	Key Outcome(s)	Reference
RCT	DW	14 days	20 healthy subjects, served as own control	Increase in VEGF, collagen, epidermal cells, and cell apoptotic markers	[43]
RCT	DW	14–20 days	40 healthy subjects, served as own control	Reduced wound volume, increased perfusion and vascularity	[44]
In vitro	Pulsed DC	At 4, 8, and 24 h	Human umbilical vein endothelial cell cultures	Increase in endothelial cell migration and VEGF production	[45]
		At 2, 4	Human fibroblast cells in a	Increase in EGF and differentiation of	[46]
				of fibroblast ibroblast gene	[47]
				to the growth ntinuous ES	[48]
				kness and ation	[49]

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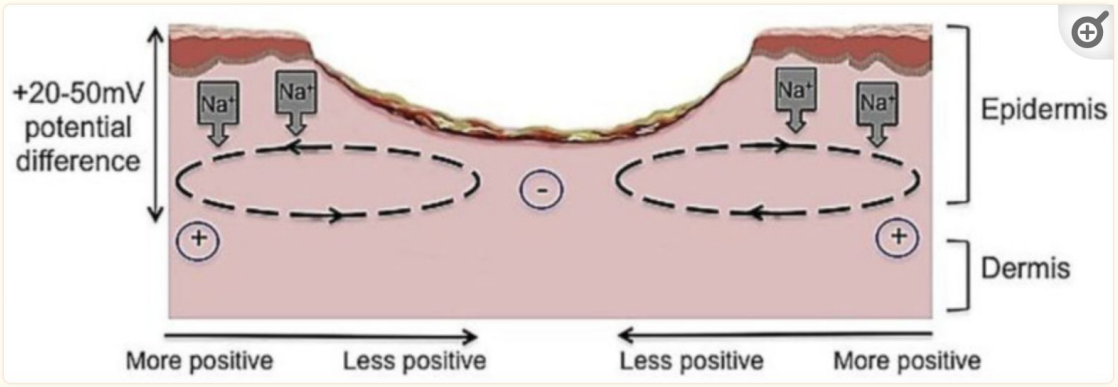
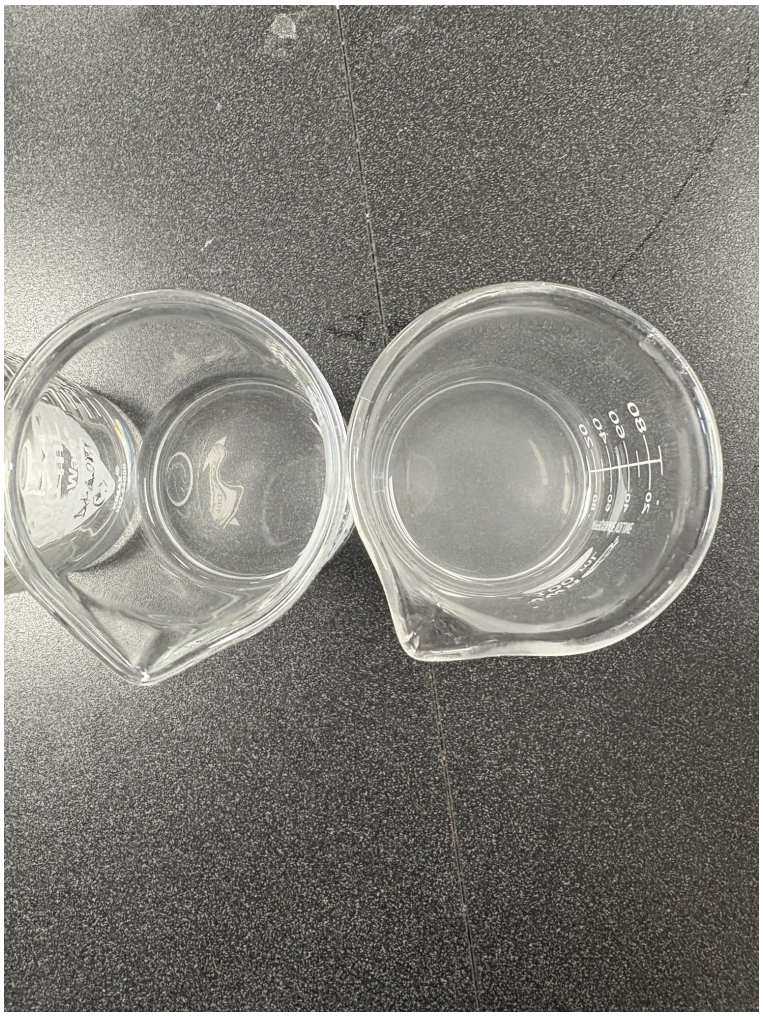


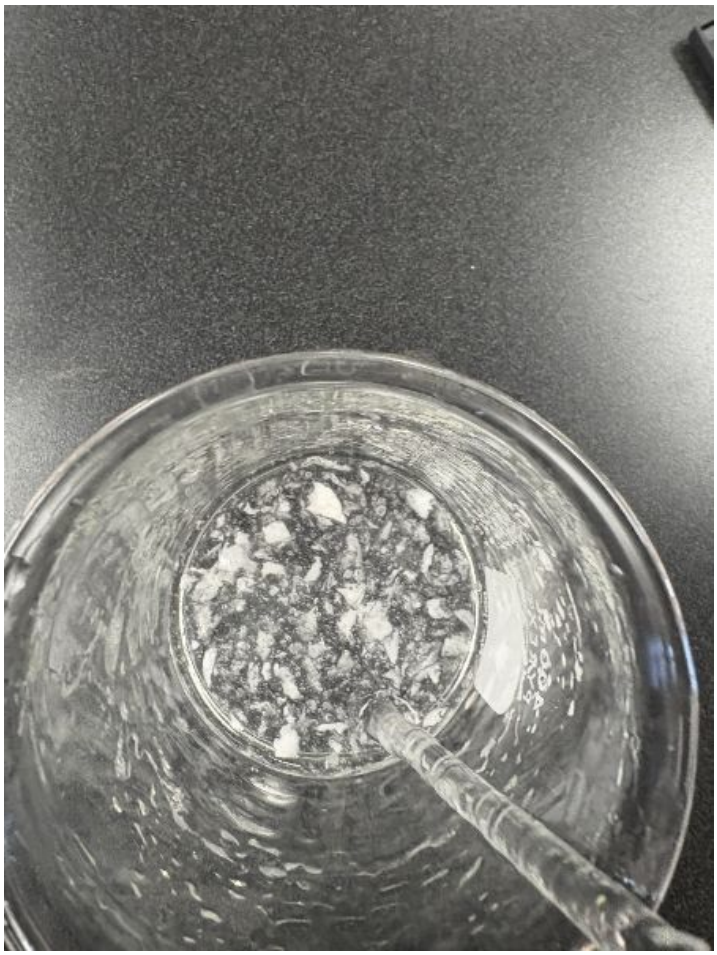
We have started fabricating two different types of hydrogels based on our research. They are:

1) Sodium alginate cross-linked with calcium chloride solution, and
2) Guar gum mixed with glycerin and sodium borate

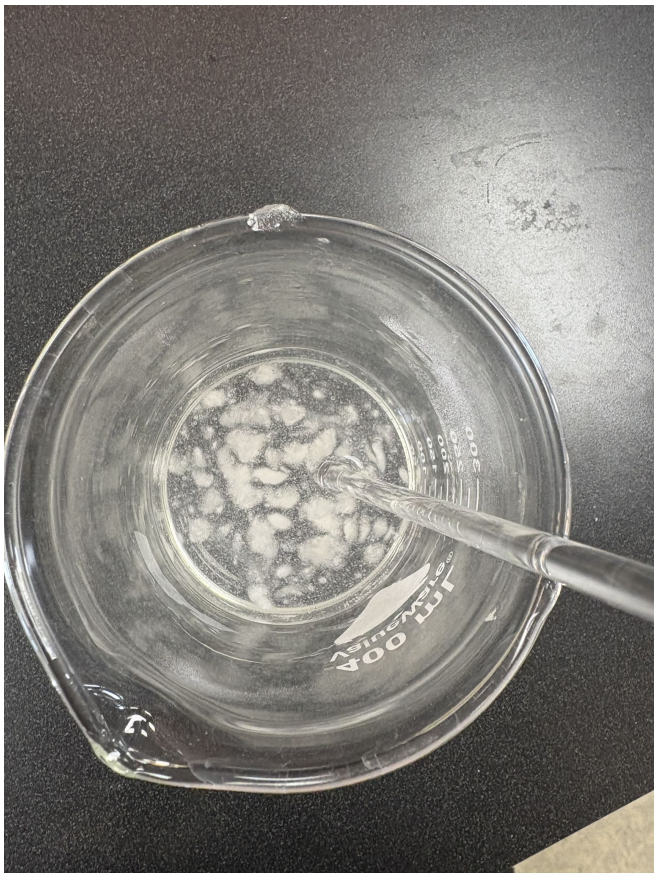
Immediately, we noticed that after a prolonged time > 1 day, the guar gum hydrogel started to mold and rot when exposed to open air, so we disregarded it as a potential hydrogel. The calcium alginate hydrogel was also exposed to open air but did not mold even after a week of exposure. This aligns with our research on the anti-bacterial nature of this hydrogel combination.



Varying concentrations of the calcium alginate hydrogel when the concentration of the added calcium chloride solution was manipulated (1% to 10%) as a preliminary experiment to determine optimal concentrations.

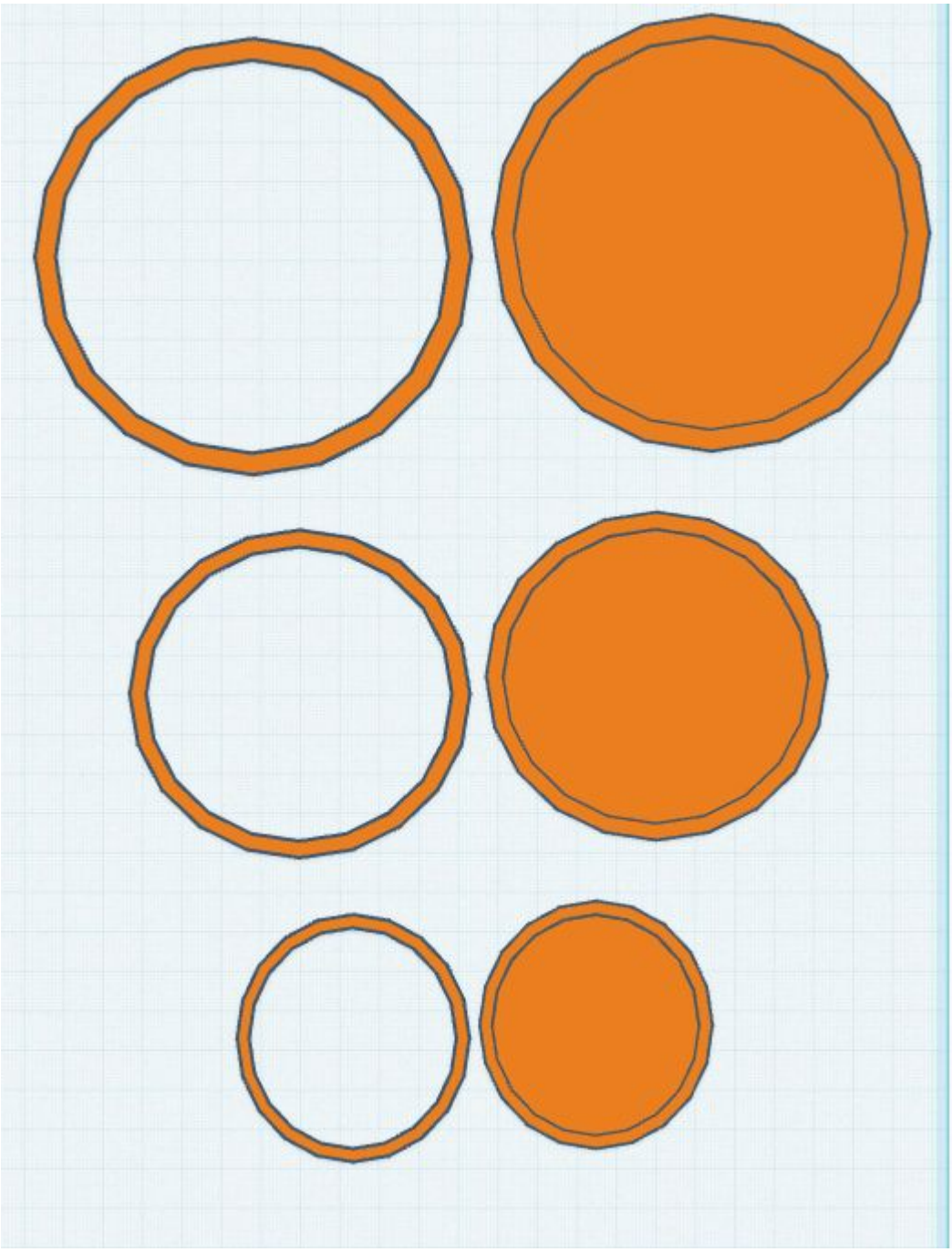


Various concentrations of sodium alginate solutions



Initial hydrogel synthesis to test different combinations of concentrations.

Eventually, our plan is to apply a thin hydrogel layer directly onto skin tissue. Thus, we need a mould to form the hydrogel shape. Below were a variety of 3d-printed moulds modelled in TinkerCAD with varying inner diameters (100mm, 80mm, 60mm). Each mould was made to be 2.5mm tall, and a ring attachment was printed alongside them so that we could extend its height to 5mm if we deemed the hydrogels to be too thin.



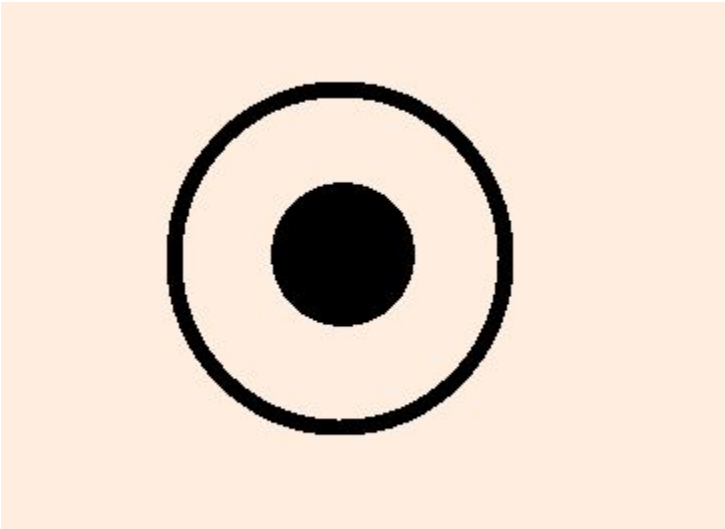
Title: Electrode Embedding

Plan

Because our wound dressing must be able to provide relief through the hydrogel while also delivering electric current to accelerate healing, we are planning on embedding electrodes within the hydrogel to compact our design. First, we started by researching commercial electrodes designed to contact skin earlier today. We came across TENS electrodes, which are designed to stimulate muscles. They were flexible and made out of carbon film, which was perfect for our use case as carbon film also happens to be anti-bacterial.

One issue we face is determining how to embed the electrodes in the hydrogel while still allowing both surfaces to contact the skin. If the electrode is positioned over the wound, then the hydrogel would not be contacting the skin and it would have no effect on healing.

We thought of embedding the electrodes as shown:



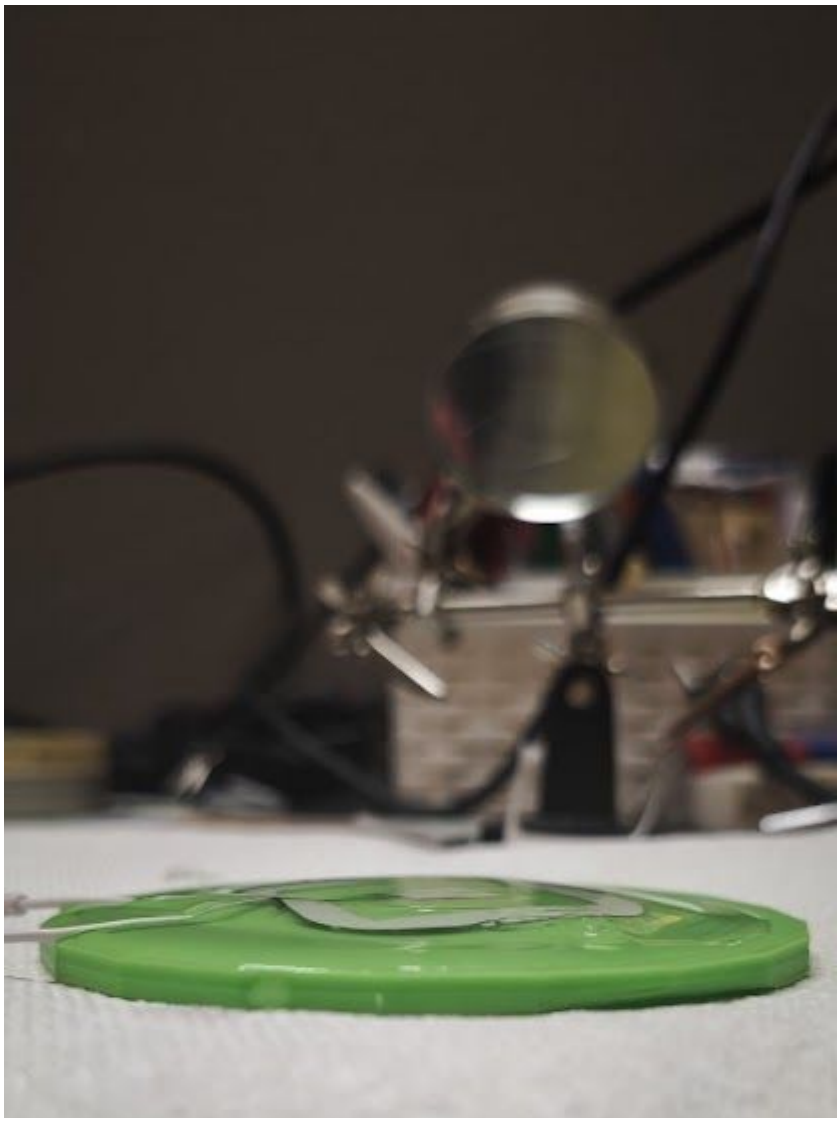
The small dot represents a piece of carbon film embedded at the centre of the hydrogel that contacts the skin, and there is a ring of film that surrounds it at a distance. This solves our issue by leaving a gap between the electrodes for the hydrogel to contact the wound site. We purchased a TENS electrode pack yesterday to experiment with.

Title: Electrode Embedding

Plan

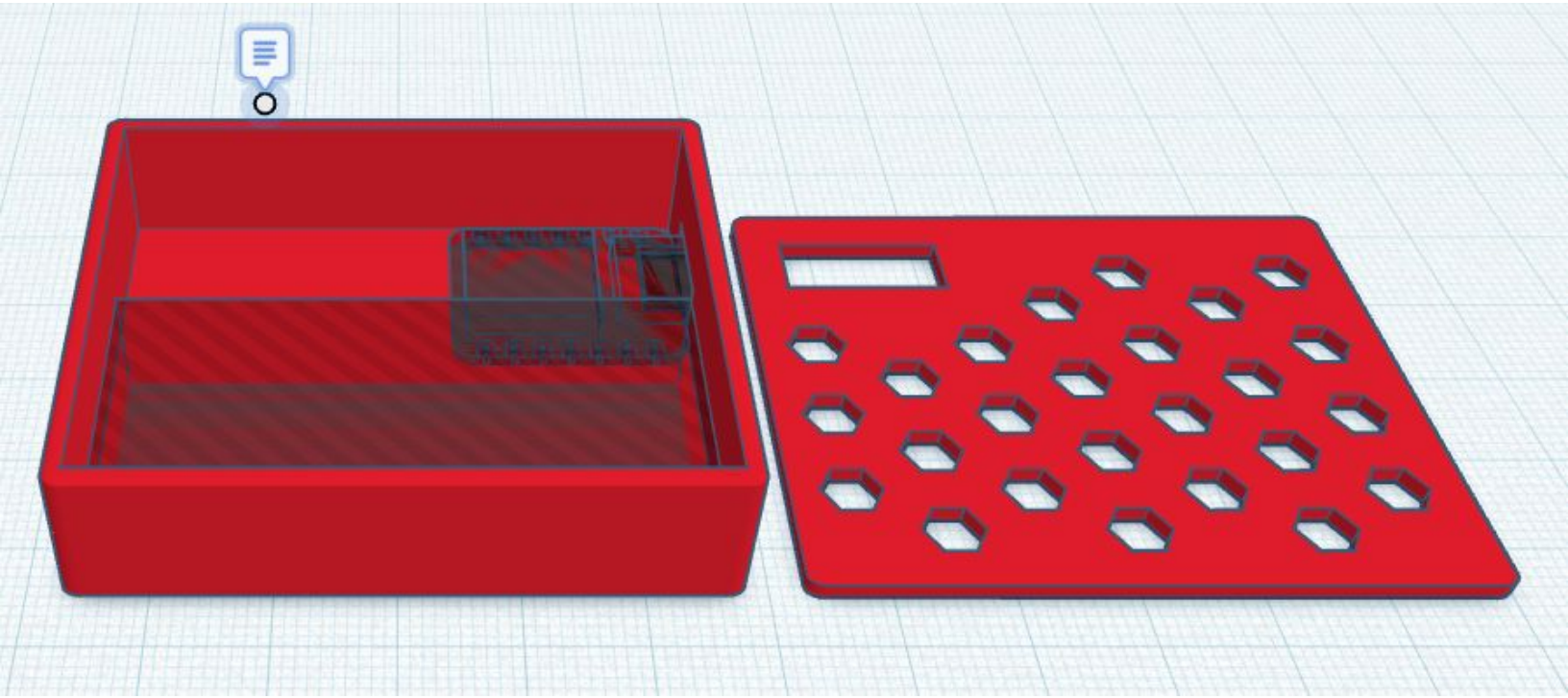
We soaked the TENS electrode in distilled water to remove the adhesive backing layer that comes pre-applied, exposing the black carbon film and a cotton protective layer on the other side (facing up in the image).

We cut the electrodes as per our diagram and poured sodium alginate solution around them along with calcium chloride solution to form our hydrogel.



Today, we started experimenting with our electronics. We chose a SEEED Xiao ESP32 microcontroller to drive our current delivery system as it is one of the smallest Arduino microcontrollers to exist (same size as a toonie) and perfectly fits our use case with many general purpose IO pins. The board has a built-in charge controller, which means we can directly solder our battery to it and charge using its USB-C port.

We also sought to design a 3D-printed housing for the electronics:



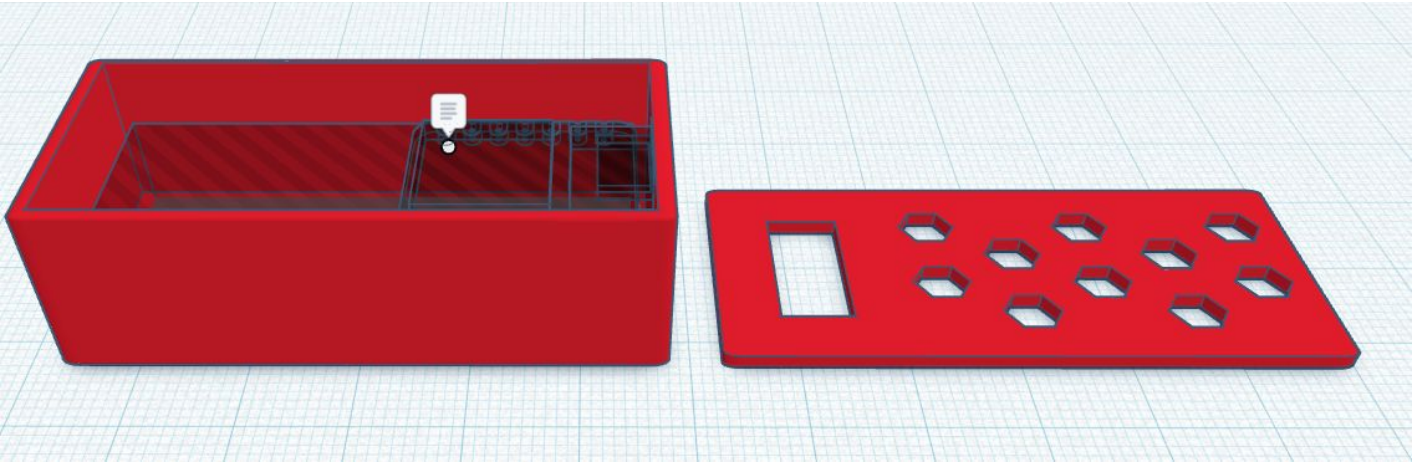
The translucent objects are reference models for the microcontroller and battery.

This case looks much larger in real-life than we thought it would be, so we are considering downsizing it by stacking the Xiao on top of the battery.

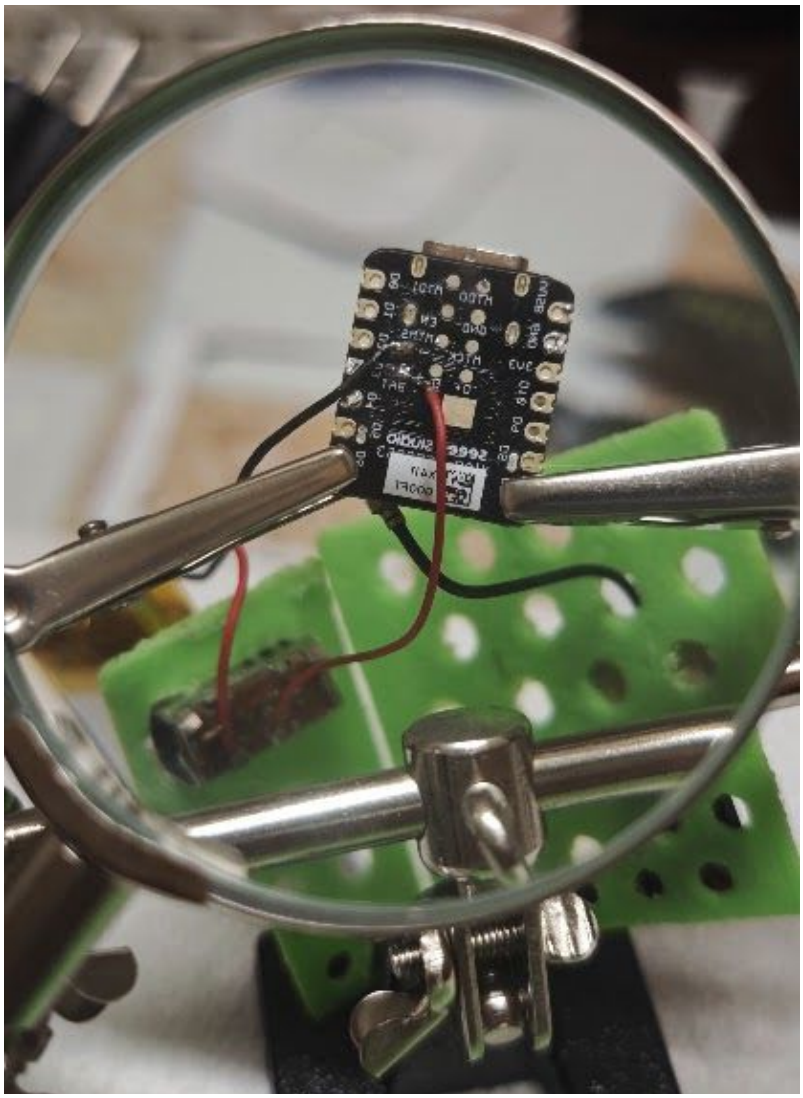
This is our MK.2 case design. It is the same length but much less wider and a few millimetres taller. There is enough space to attach a wireless antenna for the Xiao on its side or top.

This design takes up a much smaller footprint by stacking the Xiao vertically on top of the battery, which dramatically deduces its horizontal dimensions and only slightly increases height.

We plan on using a Dremel to cut along the sides after printing to accommodate for attaching velcro strips. This will help attach the device to the patient's limbs during practical use.



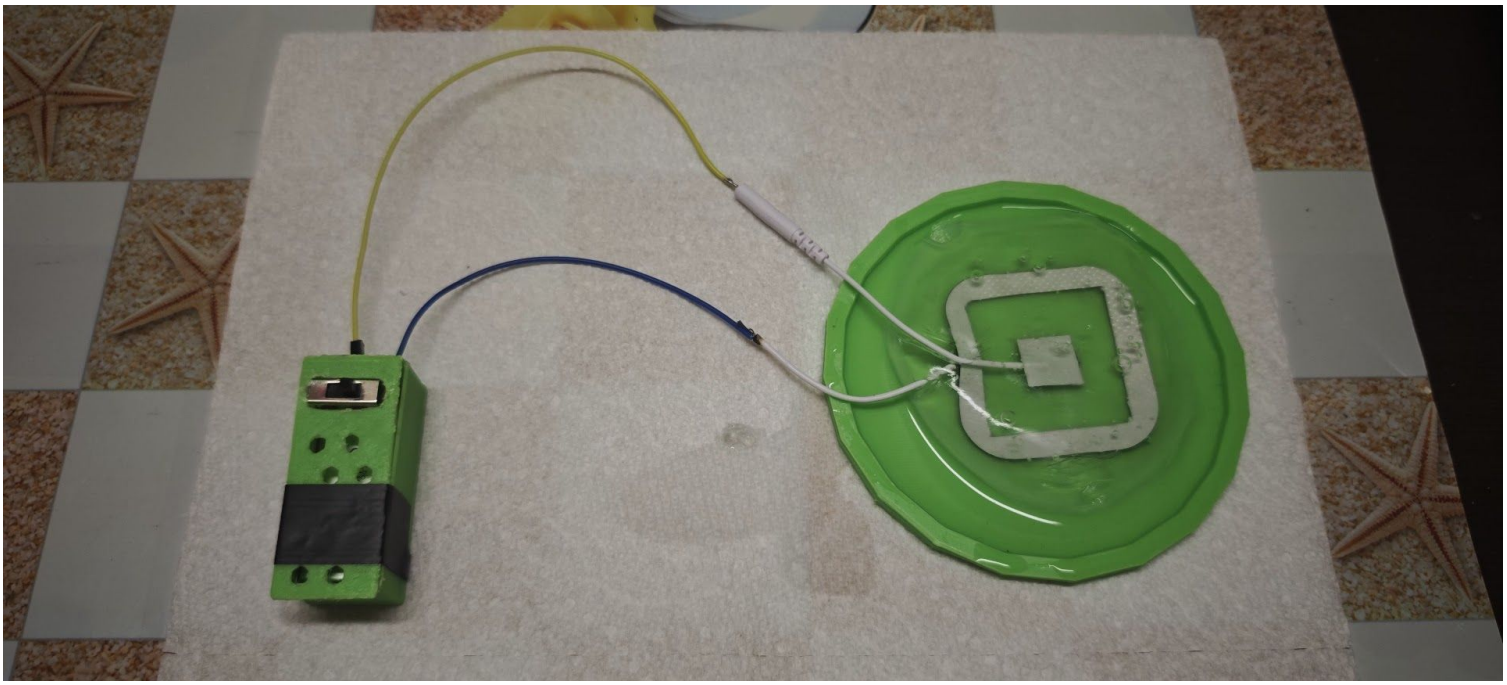
We ran into a minor roadblock while assembling the device. During assembly, we had to attach our LiPo battery to the Xiao MCU using hand-soldered joints:



Unfortunately, it seems like the joints were not soldered with enough solder and came lose. This constant power cycling may have caused faults to the board's power supply and broken the memory chip. The board does not respond to any commands sent to it. We've decided to buy two backup boards:

Part Numbers	Description	Qty	Price
Ordercode 55AK3427 Manufacturer No 102010388 Customer Reference No	SEEED STUDIO 102010388 SBC, XIAO SAMD21, ARM Cortex-M0+, 32KB RAM, 256KB Flash, I2C, UART, SPI, USB-C, With headers Manufacturer SEEED STUDIO	**Ordered Qty 1** In this Shipment 1	Unit Price $3.77 Line Price $3.77 Price for: 1 Each
Line Note			
Ordercode 61AK2694 Manufacturer No 113991054 Customer Reference No	SEEED STUDIO 113991054 Development Board, ESP32C3, RISC, Arduino Board Manufacturer SEEED STUDIO	**Ordered Qty 1** In this Shipment 1	Unit Price $9.19 Line Price $9.19 Price for: 1 Each
Line Note			

This was an assembled version of our electronics unit connected to our electrodes embedded in the hydrogel.



We identified that the electrode pads have a tendency to float up in the hydrogel solution while it sets, and we believe this could be resolved by affixing it to the mould using a small amount of gel adhesive.

One area of concern for us during the build phase was that carbon film, though conductive, still resists current. We wanted to make sure that our “impedance sensing” feature could still work with these carbon pads, so we conducted a resistance test. Using a multimeter, we measured the resistance of the pads to be roughly 220Ω. In our final iteration of the device, we think it would use software to tare its resistance on the user’s skin with a patch of non-wounded tissue.

Various frequencies of AC current were pulsed through the electrodes, and we used measured the voltage across the electrodes using the Xiao’s onboard ADC to derive resistance given V=IR and the initial voltage was 1.5V. We subtracted the raw resistance of the electrodes that was gathered before the test to determine the “experimental resistance” between the electrodes, which was surprisingly close to the true resistance (5kΩ). We noticed that the values were more accurate the lower frequency was.

Though the Xiao has both Bluetooth and WIFI capabilities, we think that Bluetooth is the best communication protocol to achieve our goal of external device communications. As we are primarily targeting mobile devices to interface with our electrostimulation device, we think that using Bluetooth is more convenient and aligns with how other personal health devices communicate with phones.

Using this guide (https://wiki.seeedstudio.com/XIAO_ESP32C3_Bluetooth_Usage/), we've been looking into achieving Bluetooth communication. As we don't have the resources to make a dedicated app, we will use the Lightblue app to directly communicate with the Xiao using text commands.

Our code uses device characteristics to communicate. The Lightblue app allows users to "write" text commands to the Xiao. The onboard code will pick up on these commands and parse their arguments.

From there, we can send a response message in the characteristic to verify that the command is being executed.

```
if (value.startsWith("calibrate ")) {
  String numberPart = value.substring(10);
  numberPart.trim();
  if (numberPart.length() > 0 && numberPart.toInt() != 0) {
    response += "Calibrating " + numberPart + "...";
    pCharacteristic->setValue(response.c_str());
    Serial.println(response);
  }
}

if (value.startsWith("pulse ")) {
  String numberPart = value.substring(6);
  numberPart.trim();
  if (numberPart.length() > 0 && numberPart.toInt() != 0) {
    response += "Sending AC at 3.75V, " + numberPart + "Hz frequency...";
    pCharacteristic->setValue(response.c_str());
    Serial.println(response);
  }
}
```