Executive Summary: BME Design Excellence Award, BME 402

Joint Arthroscopy Manikin for Viable Cartilage

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Client: Dr. Corinne Henak

Knee arthroscopies are the most common orthopedic procedure in the United States with over 1.7 million surgeries performed in North America each year according to the Arthroscopy Association of North America. Arthroscopic procedures are minimally invasive, typically involving three incisions of less than ¼ of an inch in length. A cannula to promote fluid flow through the joint, the surgical instruments, and an imaging device are each inserted into one of the incisions. In accordance with the current standard of care, surgeons typically use a light source and video camera which captures light within visible wavelengths to view the joint space during procedures. This method of imaging does not allow for the surgeon to assess the health of cartilage at the metabolic level. Our client, Henak Lab is developing a method of real-time dye-free metabolic imaging which leverages the autofluorescence of NAD(P)H and FAD to measure cartilage health during arthroscopic procedures. To develop and test this novel imaging modality, the lab requires an anatomically correct manikin of the knee which has the ability to house viable surgical discard tissue and maintain viability of the cartilage for up to two hours.

Currently the only products available for purchase are exclusively bioreactors for live cartilage or anatomically correct knee manikins. There are no designs which combine these two functionalities along with being compatible with the imaging scope to be tested by Henak Lab.

To create a functioning design, the team split into three sub teams of two members focusing on the attachment mechanism of the samples to the manikin, the enclosure of samples and compatibility with the scope, and the media pump system. CT scans of a tibia and femur were converted into a Solidworks part and modified to create flat surfaces for the cartilage to rest on. Sixteen attachment holes were added with a diameter of 2 mm to allow for wire to run through and hold samples in place. The bones were 3D-printed using PLA with 100% infill to ensure a high level of durability. The enclosure began as two "skeleton" frames opposite of each other with 8 rods around each bone. The frames were connected to each other by a hinge joint with physical limiters to prevent hyperextension of the knee which could damage samples due to mechanical stress. After testing, it was determined that the frame was too weak, so a solid PLA cylinder was 3D-printed with 100% infill to increase strength and prevent light from entering the joint which could affect fluorescent video capture. The media flow system consists of two peristaltic pumps and ¼ inch tubing connected to a media reservoir and the sample enclosure with barbed port fittings. The media reservoir contains a nitrogen bubbler to deplete the media of oxygen to a concentration between 2% and 10% to maintain tissue viability.

Due to the availability of Dr. Henak as our advisor, we have been able to leverage frequent feedback directly from her as our client to guide design decisions.