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On the transition to 3D-printed unibody cores for microdrive implants

Making a microdrive implant to record neuronal firings in the hippocampus of a rat is a labor-intensive process. Many parts must be made and the tolerances for each component are very small. Because of this, it can be difficult to manufacture a working microdrive implant where all of the parts work functionally together. Discussing this with my supervisor, Dr. Marcia Ratner, we decided that for my directed study I would capitalize on my interest in computer science and help our lab adopt a 3D-printing process used by Dr. Matthew Wilson at the Department of Brain and Cognitive Sciences at Massachusetts Institute of Technology to print part of the microdrive implant. The proposed process would combine the functionality of several parts using our current method into just one single part: a unibody core. Here I describe the current method we use, the benefits to switching to the new 3D-printed unibody core, and how this new method will improve the efficiency of the lab.

The core of the microdrive is what all of the recording electrodes mount to and serves as the foundation for the entire device. Currently, the core is made in stages and is formed from several independent parts (Figure 1A). The large white disk portion of the core, the most complicated portion, is made using a plastic mold that has to be prepped with screws and various wires to obtain the desired product. Plastic polymer is then poured into the mold and allowed to harden before removing all the screws and main pieces of the mold. This process is very time-consuming, usually requiring a day's work to finish one piece, and it is also not guaranteed to be a usable component due to a number of factors such as poor mixing of the polymer, incorrect preparation of the mold, or inadequate lubrication of the mold pieces. With the new 3D-printed unibody core, these problems no longer occur. The proposed unibody core is designed by Dr. Matthew Wilson's lab at MIT and accessible through jove.com. The unibody core combines all the parts from the current core into a single part (Figure 1B), improving structural integrity, much in the same way a unibody chassis on a car provides a strong complete structure for the entire car to be built around. Therefore, the proposed 3D-printed design will allow the lab to improve the reliability of its microdrive implants.

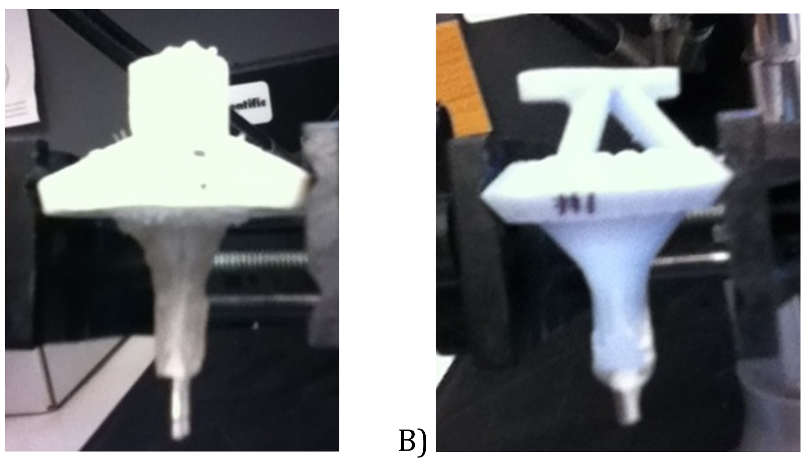
A) B)

Figure 1: Images of the finished cores from the two methods. A) Current method B) 3D-printed method

To manufacture the unibody cores, I took advantage of a new resource open to BU students. Using the BU Engineering Product Innovation Center (BU EPIC), I printed the unibody core using an Objet 30 Pro 3D printer. The Objet 30 Pro uses VeroBlue, a patented UV-cured liquid photopolymer that allows for reliable and extremely accurate products, even at the small scale we need such as the 23 gauge holes (~0.5 mm in diameter). The 3D printer lays down a fine layer of liquid photopolymer, as well as support material, and cures it with UV light. This process is then repeated several hundred times till the part is complete. The resulting part is then sprayed with high-pressure water to remove the waxy support material. Once cleaned, the part is ready for use.

There are numerous benefits to this 3D-printing method and I will highlight some of the major ones below:

1. **Structural Integrity:** Currently, the core is made from a combination of several parts which all have to fit together. By combining many parts into a single part, possible stress points introduced from two parts interacting are reduced, improving the structural integrity of the piece. Using a unified core piece will lead to a stronger foundation with which to build the rest of the implant.
2. **Weight:** By 3D-printing the foundation of the device, the weight of the final product can be precisely controlled. The weight of the current core in Figure 1A is ~9 grams (8.88 g), while the 3D-printed version weighs only ~3 grams (3.11 g), making the 3D-printed version almost one-third lighter than the current version (35%). This large reduction in weight will save on material and result in a lighter and more comfortable implant for the animal.
3. **Size:** The size of the 3D-printed unibody core takes up a significantly smaller volume (55.7%) compared to the current method. This will reduce the size of the implant and make it less likely for the rat to be hindered in any way by the implant.
    a. Current core: 3.4 cm diameter × 4.5 cm => 40.9 cm^3 of space
    b. 3D-printed unibody core: 2.8 cm diameter × 3.7 cm => 22.8 cm^3 of space

→ 22.8 cm^3 / 40.9 cm^3 => 55.7% of current volume

(Assumes volume of core can be approximated as a cylinder of space: [widest diameter of core] × [height of core])

4. **Finishing:** While the core is being made with the current method, there are all sorts of steps that need to be taken before it can be used for an implant. Some steps include reaming various holes, trimming/shaving off excess plastic, and forming the acrylic cone (the bottom portion of the core in Figure 1A). The 3D-printed unibody, however, takes minimal effort because it combines the functionality of several parts. All that is necessary is to remove the waxy support material with a high-pressure water jet, and it is ready to be used.
5. **Consistency:** By removing the human element from the equation, the main foundation of the implant can be made consistently and accurately every time, which means less time dealing with problems concerning compatibility or variability between components.
6. **Scalability:** One of the coolest things about 3D-printing technology is the ability to scale up the production of a part. The work required to make the current core means that only one of the main disk pieces can be made per day. In terms of work hours, the current core with all of its parts takes approximately 12 hours of work time to complete. A single unibody core on the Objet 30 Pro can be printed in less than 5 hours (4hrs 17min). The best part is because of the way the Objet 30 Pro prints, adding more objects will not substantially increase the time it takes to print. Instead, the time is dependent on the number of layers that need to be printed, which will not increase if multiple cores are printed at one time.

> For example, a job with 5 unibody cores only adds 37 minutes to the build time of a single unibody core (4hrs 54min). This means that more than ten unibody cores can be printed in the time it takes to make just one with the current method, greatly improving efficiency.

I think that using a 3D-printed unibody core will help streamline the electrophysiology work done in this lab. By creating a single part as the foundation for the microdrive implants, the structure of the drive will be more stable and lead to fewer damages to the device. The reduction in size and weight will provide a better experience for the implanted animal, leading to fewer cases of damage or discomfort because of the implant. The ability to reproduce large quantities of cores consistently and quickly will allow students to spend less time manufacturing drives and more time working with implanted animals and acquiring data. By adopting this approach pioneered by Dr. Matthew Wilson and his lab, we will improve efficiency of our own lab, leading to a bigger turnaround of implants and a shorter timeframe between a non-implanted rat and an implanted rat we can use to acquire data. Therefore, this method will improve the output of usable data this lab produces by improving efficiency during implant manufacture.