A Novel Pressure Regulating Brain Imaging Implant For Ultra-Large Field-of-View Microscopic Imaging in NHPs

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Problem Definition & Need

Problem Definition

Several problems challenge mesoscopic imaging in the brain: 1) Difficulty with positioning high-NA objectives near the brain; 2) Creating a flat imaging window against the surface of the brain; 3) Adjusting the imaging window to changes in swelling and pressure in the brain, such as those that may occur due to hydration changes and other physiological factors; 4) Preventing growth of dura and biofilms that cloud the imaging window; 5) Follow-on MRI imaging of the animal post-implantation.

Need Statement

Need a thin, strong, radiolucent, and pressure regulating implant for ultra-large field-of-view microscopic imaging in primates.

Design Inputs

Functional Requirement

Maintain a flat, clear, imaging window against the surface of the brain.

Constraints

- Radiolucent
- Thin enough to allow for an objective with a working distance of 2mm to image the brain.
- Allow for water immersion objective.
- Capable of holding attachments & bearing weight (at least 5 lbs).
- Imaging window must be at least 20 mm in diameter.
- Coverslip must move parallel to chamber to allow for manual control of the imaging window.
- Must be durable, last at least six months and be usable on awake monkeys.
- Must be hermetically sealed to prevent infection.

Hydrogel Design

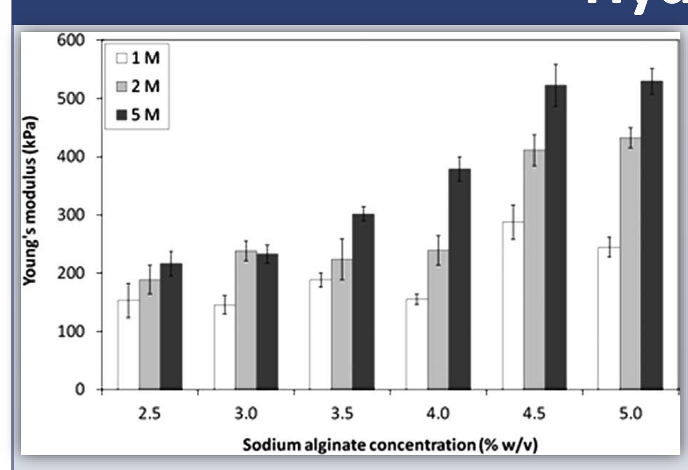
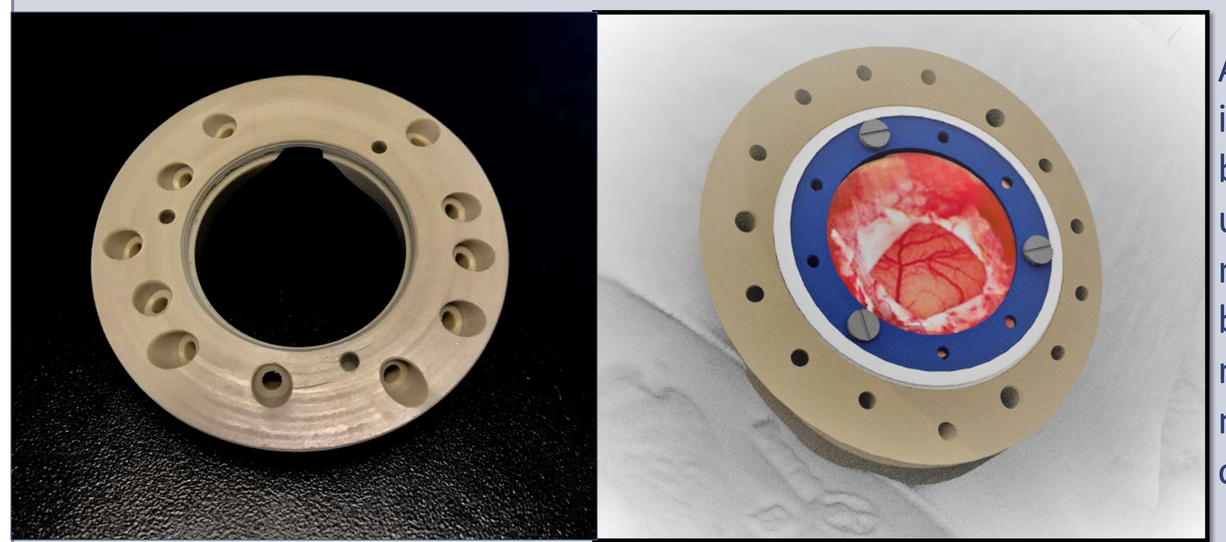


Figure 2: Various concentrations of sodium alginate gelled for 60 mins with 1, 2, and 5 M concentrations of Ca^{2+}.

The mechanical properties of alginate hydrogels can be modified based on the concentrations of cation and alginate concentrations. We chose a hydrogel with 2.5% (w/v) sodium alginate crosslinked with 1M Ca^{2+} solution because it had the smallest Young's modulus. The Young's modulus of mammalian brains is only .5 - 1.0 kPa. Therefore we need a very low young's modulus to match and apply appropriate pressure[3,4].

Alginate hydrogels can be sterilized with an ethanol wash without compromising its mechanical properties[5].

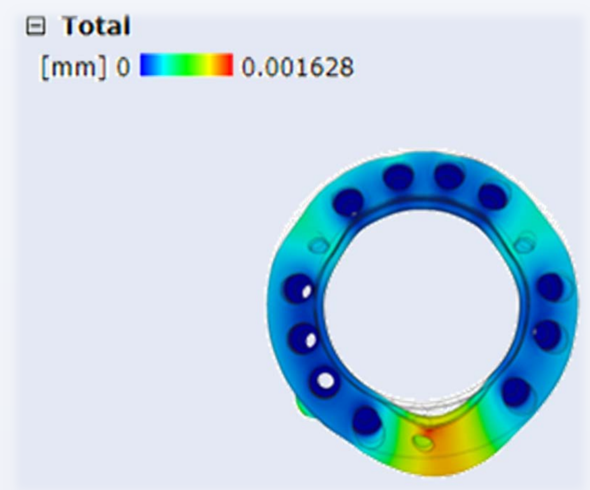
Prototype Development



A PEEK prototype implant was machined by Rogue Research using a 5-axis machine. A phantom brain made of a silicon mixture mimics the mechanical properties of the brain.

Figure 3: Comparison of early machined prototype with phantom brain (left) to advanced CAD model (right)

Static Stress Test



A simulation of five pounds of static stress placed on the implant was performed using Autodesk Fusion 360. Results indicate the maximum displacement caused by this amount of force would be .001628 mm.

Figure 4: Displacement results due to 22.21 N of Force (5 lbs).

Engineering Design Solution

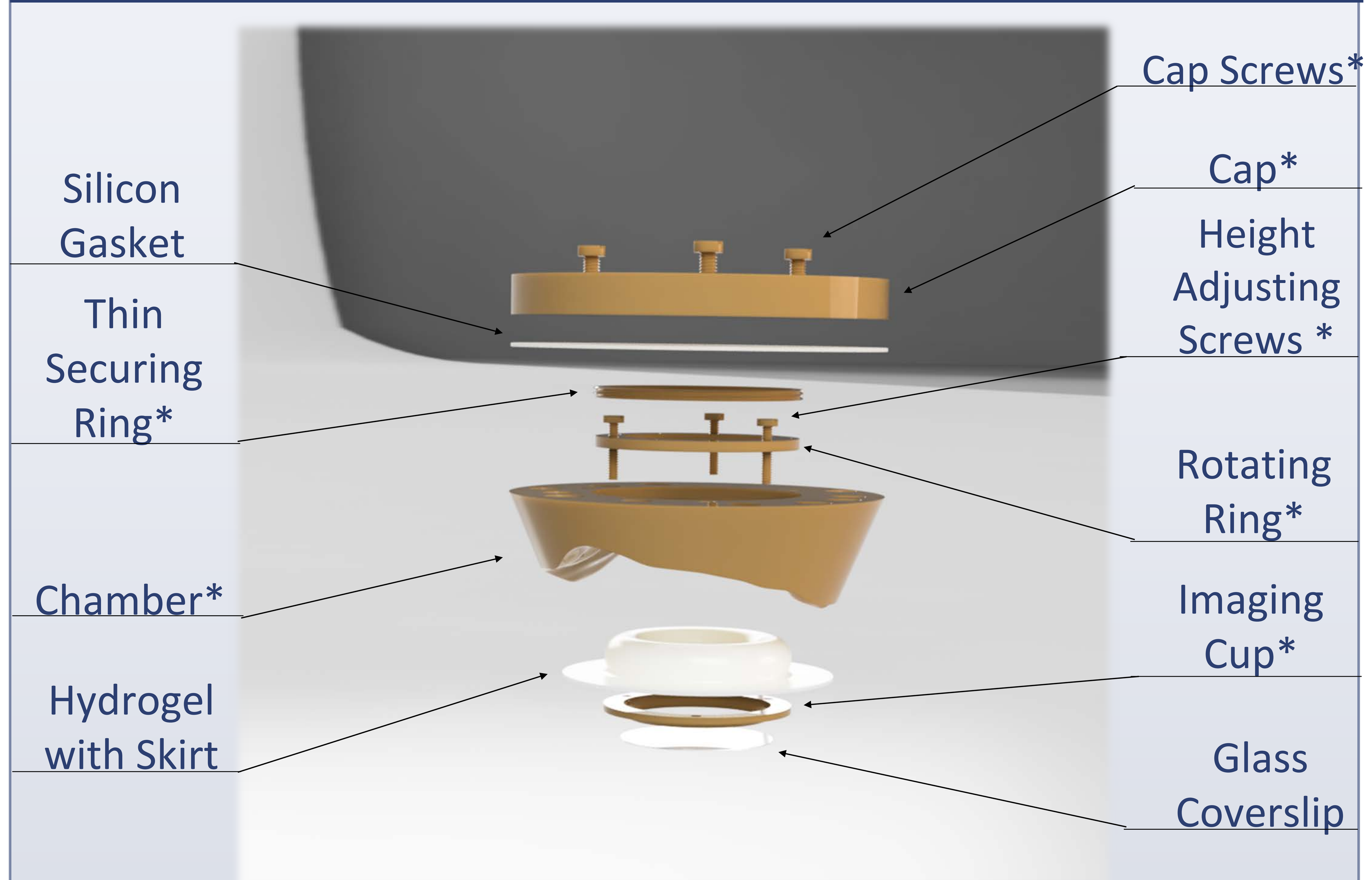


Figure 5: Exploded view of annotated imaging implant prototype. *Indicates part is made of PEEK plastic, chosen for its radiolucent properties, strength, and ability to be sterilized.

Component Listing with Description

Cap & Cap Screws- Removable cap for imaging and cleaning.
Silicon Gasket - Approximately .4 mm thick, prevents bacterial movement between chamber and cap.
Thin Securing Ring - Secures rotating ring against the bottom shelf of the chamber and prevents it from moving up.
Height Adjusting Screws – Pushes against cup and prevents the imaging cup from moving closer to the chamber. Threaded into the bottom securing ring and penetrates hydrogel.
Rotating ring – Multiple threaded holes for the height adjusting screws and can rotate to adjust the positions of the screws. Sits between shelf in chamber and thin securing ring.
Chamber - Has holes for bone screws that are perpendicular to the surface of the bone to increase the strength of the bond between the chamber and bone[1].
Hydrogel – Chosen for its ease in manufacturing, control of mechanical properties, and ability to be sterilized. Serves as a spring to adjust for pressure changes caused by the variations in swelling in the brain. Although not indicated in the drawing, the hydrogel connects to the lip of the imaging cup and rotating ring to create a sealed environment.
Imaging Cup & Glass Cover Slip – The glass is glued to the cup. Together they create a bowl that can hold liquid for a water immersion objective. A thin artificial dura coats the bottom of the cover slip to allow for penetration while maintaining a clear imaging window[2].

Future Work: OBServe Implant

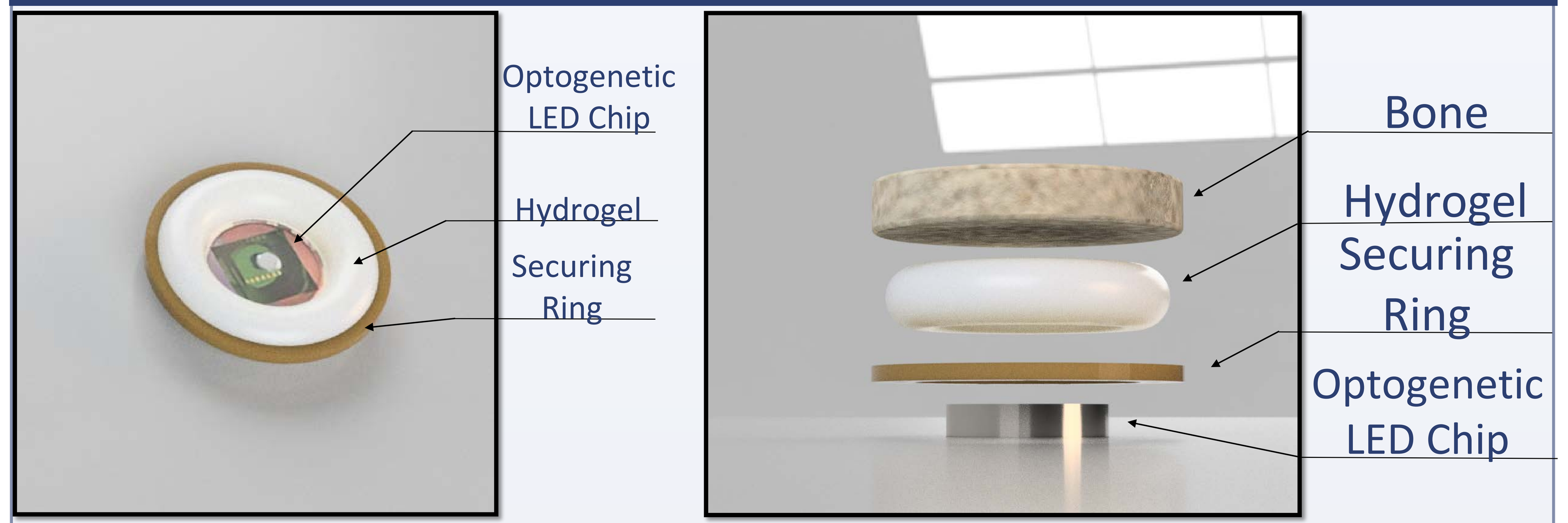


Figure 6: Left: Photorealistic rendering of the proposed OBServe implant with the hydrogel covering. The optogenetic LED chip meant to read and stimulate layer four of the primary visual cortex. Right: Exploded view of the OBServe implant and its subsequent parts.

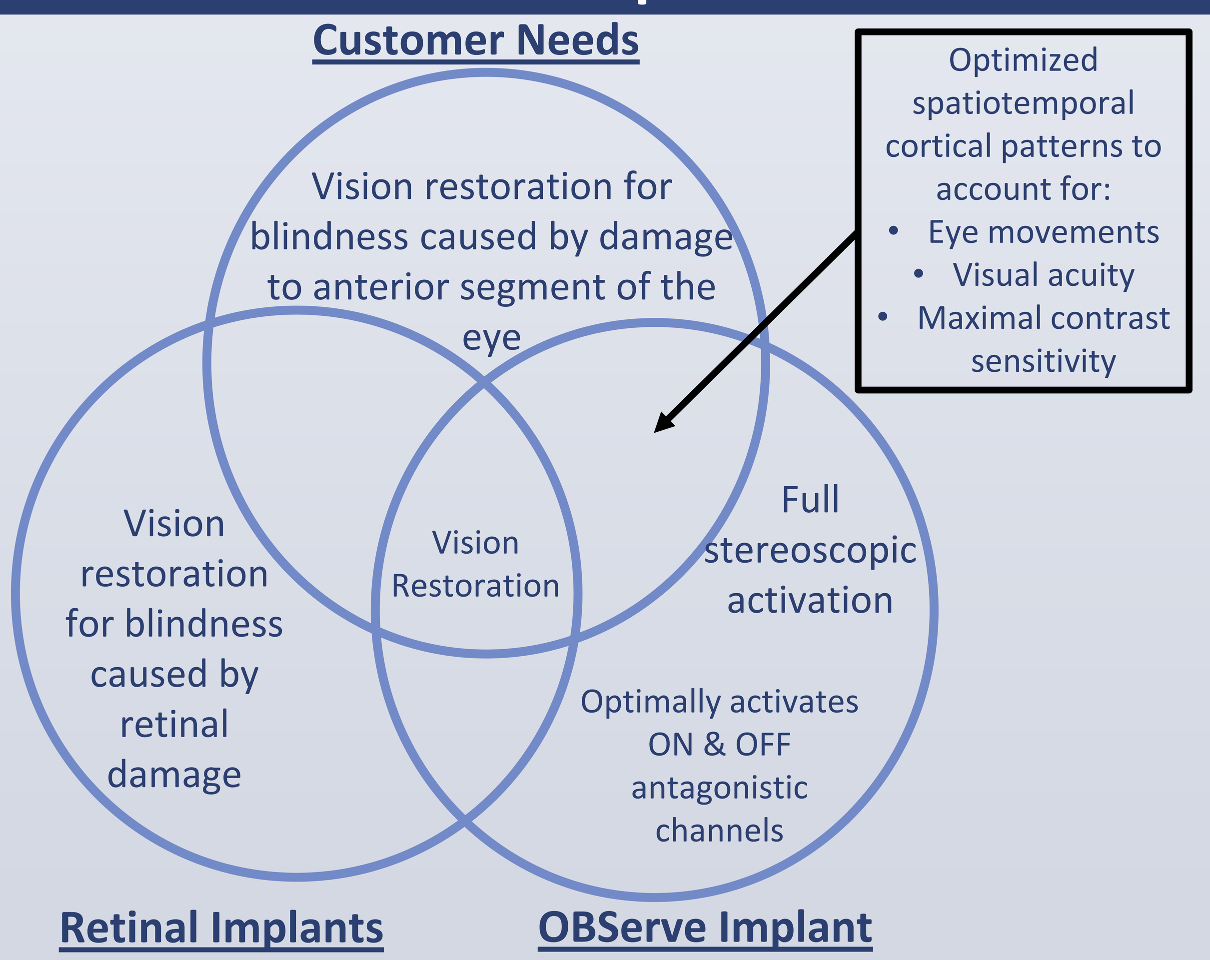
OBServe Implant Affected Population

175 Million

Number of people worldwide affected by blindness caused by traumatic ocular injury, macular degeneration, and glaucoma[6,7,8].

Target Available Market: Individuals with blindness caused by catastrophic damage to the anterior segment of the eye, the optic nerve, or the ganglion cells of the retina, cannot be treated with any known medical treatment, including existing neural prosthetics for the brain or retina.

OBServe Value Proposition



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