LEMELSON-MIT

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$15,000 "Cure it!" Lemelson-MIT Student Prize Graduate Winner
PhonoGraft: A 3D printed, biodegradable eardrum graft, and a new type of tympanostomy tube

The Challenge: Each year, millions of people across the world suffer perforated eardrum injuries.[1] Eardrum perforations frequently occur due to ear infections, direct trauma, and head injuries. Blast injuries from improvised explosive devices, like those prevalent in the wars in Iraq and Afghanistan, as well as at the Boston Marathon bombing in 2013, are a known cause of eardrum perforations.

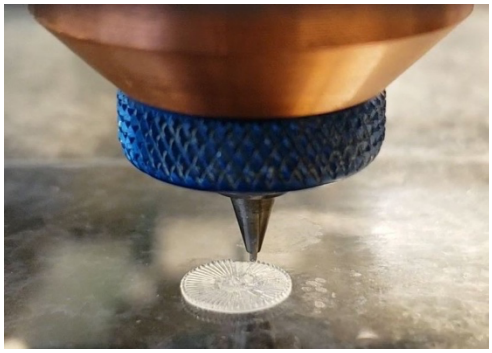
Eardrum perforations can lead to ear pain, drainage, and hearing loss. Although very small perforations (about the size of a grain of rice or smaller) can heal without intervention, approximately 1 million people worldwide, including 400,000 people across North America and Europe, undergo surgery to repair larger holes in the eardrum that cannot heal naturally.[2] A three-hour surgical procedure to correct eardrum perforation, known as tympanoplasty, is performed by an otolaryngologist (Ear, Nose, and Throat surgeon) under general anesthesia. The surgery involves grafting tissue from another area of the patient's body to recreate the eardrum.

The eardrum is made up of highly specialized tissue with a particular architecture, including radial and circular fibers. No other tissues in the body mimic this structure, so grafting native tissue from elsewhere in the patient's body is not ideal, as it does not integrate well with the eardrum. This can cause scar formation, poor healing, and persistent hearing loss after surgery. Although current grafts can be used to patch a perforation, their structural arrangement does not effectively conduct sound into the middle and inner ear. Patients may choose to avoid tympanoplasty due to need for general anesthesia and a prolonged recovery period.

The Solutions: Nicole's primary invention is PhonoGraft, a biodegradable, tunable, eardrum graft that mimics the eardrum, and can be easily implanted via a simple procedure in the clinic setting. PhonoGraft starts with a biodegradable polyurethane material that is 3D printed and developed specifically to match both the stiffness of the eardrum and its circular structure. No incisions are needed to harvest tissue

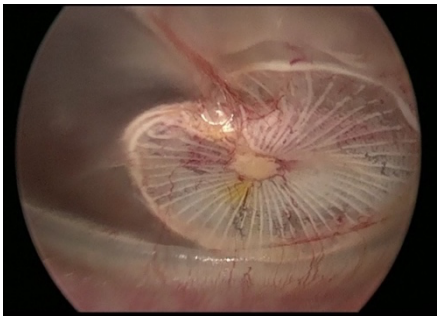
[1] Wani A, Rehman A, Lateef S, Malik R, Ahmed A, Ahmad W, Kirmani M. Traumatic tympanic membrane perforation: An overview. Indian J Otol 2016; 22:100-4. https://www.indianjotol.org/article.asp?issn=0971-7749;year=2016;volume=22;issue=2;spage=100;epage=104;aulast=Wani.
[2] ProMetic Life Sciences and Echelon Wealth Partners, 2019. https://www.dropbox.com/s/ndk8107310rhgvf/Prometic%20Life%20Sciences%20Inc%2020190416.pdf?dl=0.

from the patient for the procedure because PhonoGraft does not require human tissue for implantation. This dramatically reduces surgical complexity, duration, discomfort, healing time, and the possibility of infection. The PhonoGraft procedure takes only 30 minutes and can be performed in an outpatient setting without general anesthesia.



3D Printed PhonoGraft invention.
Photo Credit: Nicole Black

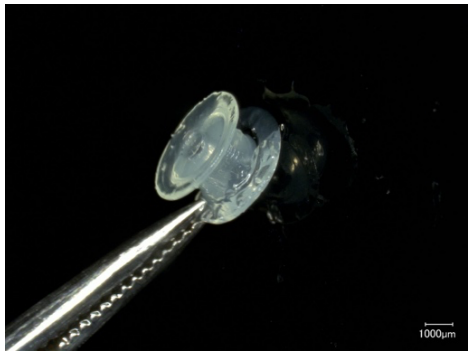
PhonoGraft is specially designed and printed to match the architecture of the eardrum, so it conducts sound into the middle and inner ear more naturally and effectively than traditional tympanoplasty. The body's natural cells in the eardrum then use PhonoGraft as scaffolding to grow, following the circular and radial architecture of the device. As the material within PhonoGraft degrades, the body's natural cells replace it, regenerating an architecturally natural eardrum. After 6-18 months, the PhonoGraft will completely disappear, and the eardrum will have fully regenerated, restoring its original specialized form and function, essentially healing itself.



PhonoGraft invention.
Photo Credit: Aaron Remenschneider

Results from animal studies demonstrate better outcomes for PhonoGraft compared to traditional tympanoplasty, including better adhesion, fewer repeat/corrective surgeries, and better hearing outcomes across a wide range of frequencies. The PhonoGraft procedure is a less obtrusive option than pursuing surgery, given the reduced time and discomfort, and fewer potential complications.

Nicole's secondary invention is a new type of tympanostomy tube ("ear tube") to treat chronic ear infections. The design and novel materials make the novel ear tubes easier to place, reduce cellular adhesion, and improve fluid transport through the eardrum. Other inventions in Nicole's portfolio include temporomandibular joint grafts, a biodegradable ink for bony implants, an antimicrobial stereolithography resin, and a method of fabricating bilayer eardrum grafts.



Secondary invention of a new kind of ear tube.
Photo Credit: Nicole Black

Commercialization: The commercial-grade 3D printers are used to create the detailed architecture of PhonoGraft and produce each device in just a few minutes. Because the material is synthetic, it is low-cost and comparable to other devices such as ear tubes. PhonoGraft is targeting multiple markets, including children suffering from chronic ear infections, adults with eardrum perforations from a variety of causes, and military populations both during service and after returning home.

Nicole has worked with doctors and industry experts since the beginning of her research to ensure that her inventions can be readily translated as practical solutions for medical professionals and patients. Her team has worked with the Office of Technology Development at Harvard and Mass General Brigham to identify opportunities for commercialization, and the patent for the PhonoGraft device is issued, with another pending patent for the novel material. They have also received funding from the Mass Eye and Ear Summit Fund, as well as Phase I and II Small Business Innovation Research grants (SBIR) from the Department of Defense alongside Triton Systems. Additional thought and strategic partners include Desktop Metal, Cook Medical, Stryker, and Baxter Healthcare. To assist in the technology development of PhonoGraft, Nicole was awarded a Gliklich Healthcare Innovation Fellowship through Mass Eye and Ear this year, and their team has been supported by an Institute Project grant from the Wyss Institute for Biologically Inspired Engineering at Harvard University, where Nicole conducted her graduate research.

In January 2020, Nicole formed a new venture, Beacon Bio, to carry out the development of PhonoGraft and other 3D printed tissue grafts. Currently, Beacon Bio, co-founded by Nicole, Elliott Kozin, MD, Jennifer Lewis, ScD, and Aaron Remenschneider, MD, MPH, is in the process of spinning out from Harvard University and Mass Eye and Ear. Beacon Bio was recently awarded the runner-up prize in the 2021 MassMEDIC IGNITE venture competition and is currently a finalist in the 2021 Health and Life Sciences track of the Harvard i-Lab President's Innovation Challenge.