Revolutionizing Tympanoplasty: A Personalized Surgical Process Using Three-Dimensional High-Resolution Scanning and Modeling, Bio Printed Tympanic Grafts, and an Automated Autonomous Robotic Surgical Procedure With Reinforcement Learning

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Tympanic membrane perforations affect over 320 million people worldwide and are a large cause of preventable hearing loss. Current procedures rely on manual skill, limited visualization of the ear canal and tympanic membrane, and the use of cartilage grafts that dampen sound or fascia grafts that are susceptible to tears, resulting in undesirable outcomes and high failure rates. This project presents a personalized tympanoplasty procedure using three dimensional high resolution scanning and modeling, bio printed tympanic graphs, and an automated autonomous robotic surgical procedure with reinforcement learning. A high resolution 3D ear scanner captures the ear canal and tympanic membrane, overcoming obstructions that limit 2D imaging devices. Scans data are reconstructed into a precise 3D model for accurate perforation mapping and surgical planning. Using this model, a personalized tympanic membrane perforation patch is bio printed with matching thickness, curvature, and structure of the patient's tympanic membrane. Its cell composed structure allows for a painless placement, holds itself in place, and acts as a framework for a patient's cells to grow on during healing. Algorithmic analysis confirmed accurate anatomical reconstruction across diverse ear models. The model of the patient´s ear canal and a reinforcement training simulation is used to train an automated autonomous surgical robot that inserts the patch through the ear canal to patch the hole in the eardrum to reduce positional errors, minimize tissue contact, and for patch placement accuracy. Quantitative analysis of joint velocity variance and trajectory error and qualitative analysis of motion smoothness confirmed consistency and safety.

Awards Won:
Lehigh University: Four Scholarships ($20,000 per year for four years)
Westlake University: Westlake University is awarding Pre-college Summer Program Scholarships, covering the program fee, lodging, food, insurance, round-trip international airfare, and excursions in Hangzhou &amp
Shanghai this summer, to up to six finalists.