Negative Pressure Wound Therapy Device for Improved Microtia Surgery Recovery

Team: Bryan Heaton, Meghan Kaminski, Harshad Gunasekar, Serena Evers, Dhruv Nadkarni

Client: Dr. Daniel Cho & Ms. Nada Botros

Advisor: Dr. Russ Johnson

Overview

- Problem Statement
- Background
- Client Requirements
- Existing Products
- Preliminary Designs
- Final Design
- Future Work
- References

Clients

Dr. Daniel Cho:

Assistant Professor, Craniofacial and Pediatric Plastic Surgery
Director, Craniofacial Research and Innovation (CRANI) Lab

Ms. Nada Botros:

Research Fellow, Craniofacial Research and Innovation (CRANI) Lab
Division of Plastic Surgery

Problem Statement

Newly reconstructed auricles after microtia surgery are fragile, prone to destructive fluid build up, and difficult to dress securely. Clinicians need a conformal negative-pressure wound therapy device that holds a foam dressing over the ear, maintains consistent negative pressure over complex 3D geometry, and safely collects drainage from existing drains to reduce complications and support consistent healing.

Microtia Background

- Congenital condition where the external ear is malformed or absent
  - Most often unilateral rather than bilateral [1]
- 1 in 5,000-7,000 births worldwide [1]
  - Andean, Native American, or Asian descent
- Current treatments:
  - Surgical reconstruction - using rib cartilage [2]
  - Prosthetic ears - cosmetic replacement
- 91.3% of surgeons choose autologous cartilage staged reconstruction (National Survey of American Society of Plastic Surgeons) [3]

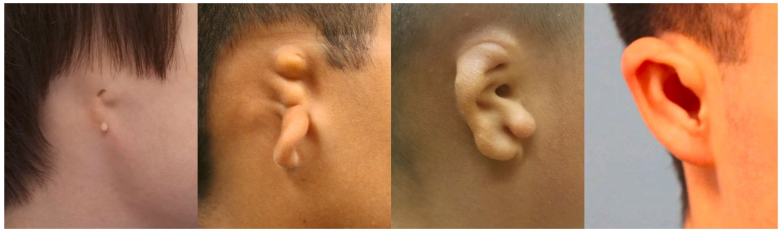


Figure 1: Microtia patients

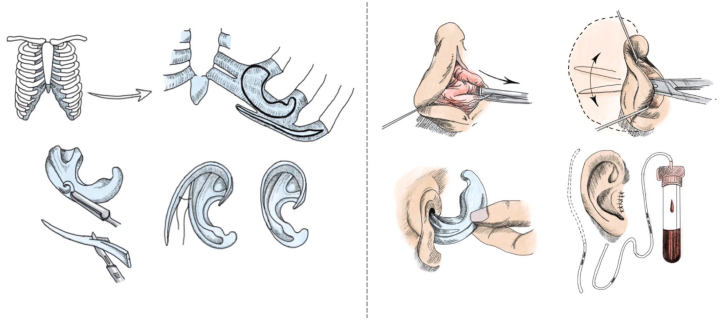


Figure 2: Reconstruction surgery

Motivation

- Clinical challenge:
  - Post-operative shaping and healing require both:[4]
    - Stable pressure
    - Controlled drainage
  - Complication rate:16.2% in average with a range of 0-72.9% [3]
  - During microtia reconstruction the exudate fluid is particularly apt to collect in the dead space of the concavo-convex shape of the frame [5]
    - Infection, skin necrosis, and cartilage exposure
    - NPWT therefore acts as a continuous external drainage system and promotes tissue adhesion

Product Design Specifications

- Device that maintains negative pressure for up to 7 days continuously
  - -125 mmHg (standard) to -50 mmHg (conservative) [6]
- Must allow for additional vacuum line for drainage / adherence
- Compatible with handheld vacuum units
- Must provide external protection of ear
- ISO 10993 [7], IEC 62366 [8]
- Must be comfortable for long periods of wear
  - ~250g - 350g weight [9]
  - Non-bulky, breathable
- Must mitigate fluid backflow / fluid buildup, tolerance 1µL
- Budget: $1000

Figure 3: NPWT Devices

Existing Products

- 3M Prevena Incisional Vac
  - Ideal operating conditions / dressing components
  - Does not fit ear
  - Is not compatible with additional vacuum line
- Other negative pressure wound therapy (NPWT) devices
  - Often used in open wounds
  - Not specialized for delicate over-ear fit

Figure 4: 3M Prevena

Figure 5: Traditional NPWT Dressing Components

Design 1: Hat

- 1 → Beanie holds inner components in place
- 2 → Drain tubes for fluid via incisional VAC
- 3 & 4→ Location and design of inner components
- 4 → Duoderm, foam, and adhesive seal around incision

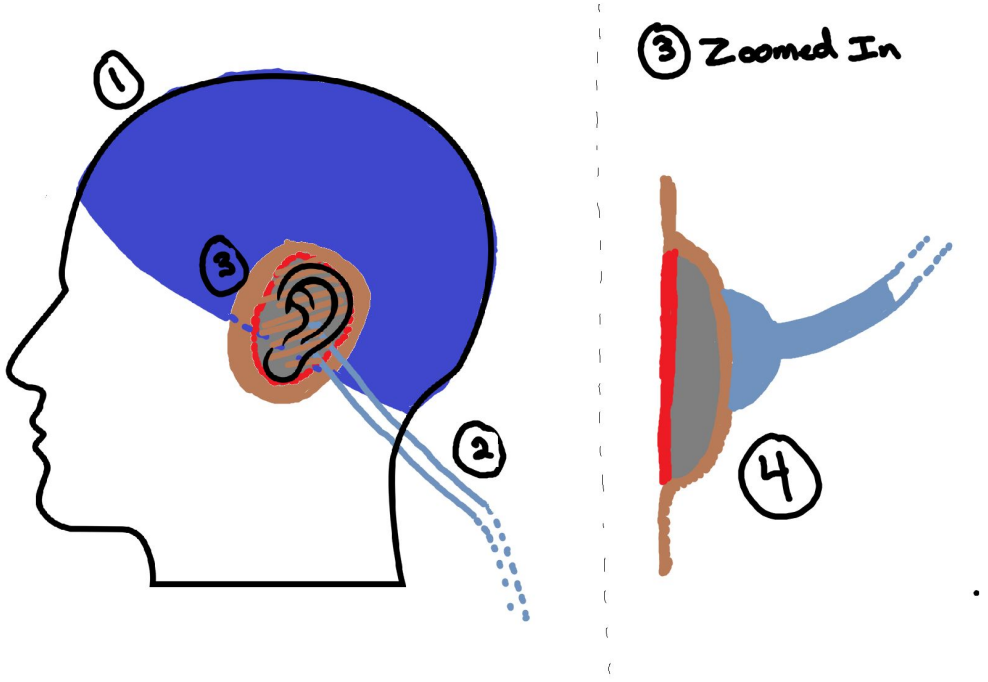


Figure 6: Preliminary Design of Hat

Design 2: Headphone

- 1 → Adjustable head strap
- 2 → Drain tube for fluid via incisional VAC
- 3 → Wound drain tube
- 4 → Headphone component
- 5 & 6 → Duoderm, foam, adhesive seal with hard covering

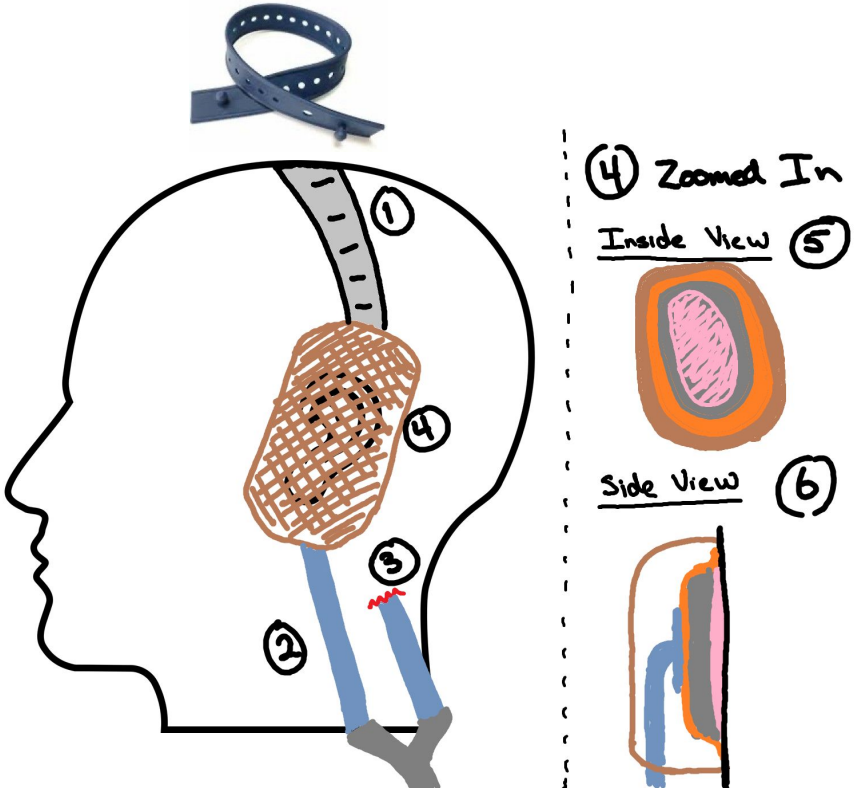


Figure 7: Preliminary Design of Headphone

Design 3: Headband

- 1 → Headband across forehead and back of head
- 2→ Inner components securely placed around incision site
- 3 → Duoderm, foam, adhesive, seal by ear
- 3 → Hard cover around the seal
- 3 → Drain tube for fluid via incisional VAC

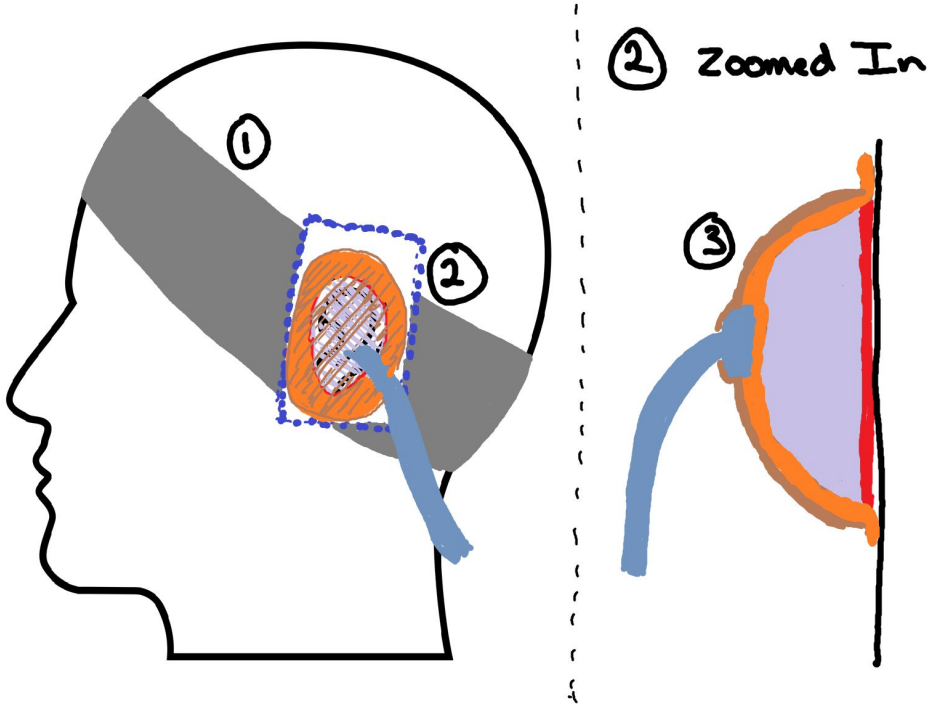
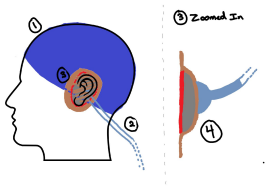
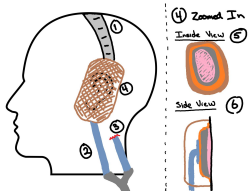
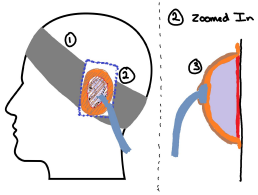


Figure 8: Preliminary Design of Headband

Design Matrix

	Design 1: Hat	Design 2: Headphones	Design 3: Headband
			
Safety (30)	18	27	20
Comfort (25)	25	25	15
Ease of Use (15)	15	15	15
Ease of Application (15)	9	12	9
Durability (10)	6	4	9
Cost (5)	5	4	5
Total (100)	80	87	73

Final Design

- Headphone inspired design
- Adjustable frame
- Flexible plastic material used as the base
- Tubing and dressings security ensured

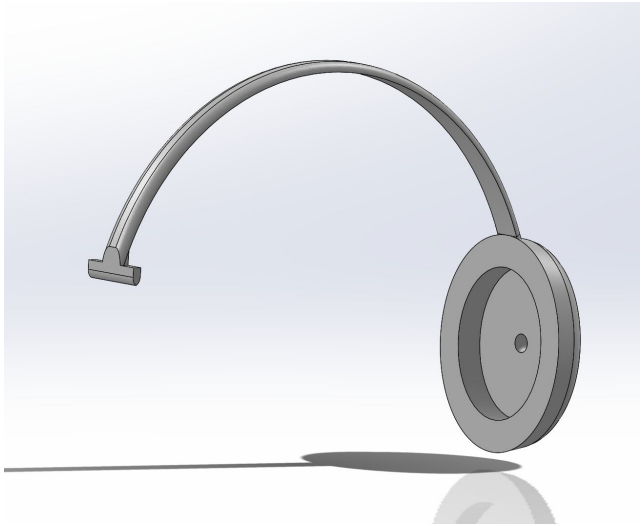


Figure 9. SolidWorks depiction of final design, interior included

Figure 10. SolidWorks depiction of final design, exterior included

Future Work

- Prototype Fabrication
  - Tailored for developing countries —> affordable materials
  - Headphone material and fabrication techniques
- Testing
  - Continuous negative pressure transmission
    - Both the wound vac and the drain
    - 25, 75, and 125 mmHg for 7 days
  - Consistent vacuum seal test
    - 7 days
  - Anatomy of ear test
- Potential Pitfalls
  - Even negative pressure → cushioning effect
  - No structural damage to the auricle of the reconstructed ear

Acknowledgements

- Dr. Daniel Cho & Ms. Nada Botros
- Jasmine Craig
- Muhaison Ibrahim
- Dr. Russ Johnson
- Dr. John Puccinelli

References

[1] Stanford Medicine, Otolaryngology—Head & Neck Surgery, "Microtia," Accessed: Oct. 2, 2025. Supports prevalence (~1 in 5,000), unilateral >90%. [Online]. Available: https://med.stanford.edu/ohns/OHNS-healthcare/earinstitute/conditions-we-treat/microtia.htm

[2] N. Baluch et al., "Auricular reconstruction for microtia: A review of available methods," Plastic Surgery (Oakville), vol. 22, no. 1, pp. 39–43, 2014. Summarizes autologous vs. prosthetic options. [Online]. Available: https://pmc.ncbi.nlm.nih.gov/articles/PMC412842/

[4]Plastic and Reconstructive Surgery, "Suction drainage system for microtia reconstruction (Brent technique note)," 2009. Classic description of using two suction catheters to coapt skin to cartilage. [Online]. Available: https://journals.lww.com/00006534-200912000-0007

[5]K. Sasaki, M. Sasaki, J. Oshima, A. Nishijima, Y. Aihara, and M. Sekido, "Salvaging exposed microtia cartilage framework with negative pressure wound therapy," *Journal of Plastic, Reconstructive & Aesthetic Surgery*, vol. 74, no. 6, pp. 1355-1401, Jun. 2021. doi: 10.1016/j.bjps.2020.11.010

[6] A. Panayi, "Evidence based review of negative pressure wound therapy," World Journal of Dermatology, vol. 6, no. 1, pp. 1–16, doi: https://doi.org/10.5314/wjd.v6.i1.1.

[7] O. for, "ISO 10993-1:2018," ISO, 2018. https://www.iso.org/standard/68936.html#lifecycle

[8] International Organization for Standardization, "IEC 62366-1:2015," ISO, 2015. https://www.iso.org/standard/63179.html

[9] B. Scarrott, "The best over-ear headphones for all budgets, tested by our experts," *TechRadar*, 5 August 2025. [Online]. Available: https://www.techradar.com/news/audio/portable-audio/best-over-ear-headphones-1280342

Questions?