Onsite Pediatric Earmold Fabrication

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Problem Statement

The earmold manufacturing process is unnecessarily convoluted, lengthy, and expensive, causing inconvenience for pediatric patients that use hearing aids (Anderson & Madell, 2014).

Methodology

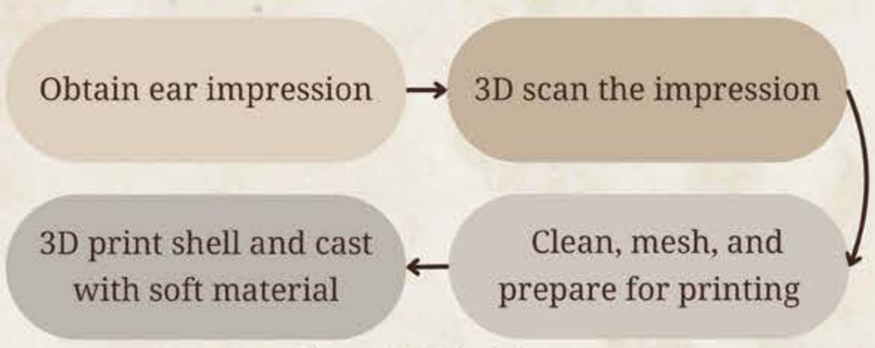

Figure 1: Methodology

Requirements

Onsite Earmold Fabrication	Predictive Model for Advance Fabrication
• Fabricated within the hospital site • Well-fitting and comfortable • Costs at most $100 each • Made of soft, long-term biocompatible material	• Produces earmold predictions that are accurate enough to be comfortable • Able to make earmold predictions at least three weeks in advance

Table 1: Level 1 requirements

Preliminary Designs

1. Ear Impressions

Figure 2: Ear impression

Pros
- Familiar process
- Safe and reliable for children

Cons
- Scanning requires extensive technology

2. 3D-Printed Earmold

Figure 3: 3D-printed earmolds

Pros
- Quick and reliable
- Requires minimal human intervention

Cons
- Soft materials are difficult to print - hard materials are unsuitable for children

3. Cast Earmold

Figure 4: Cast filled with rubber

Pros
- Enables use of soft materials

Cons
- Risk of human error
- Longer process

4. Predictive Model

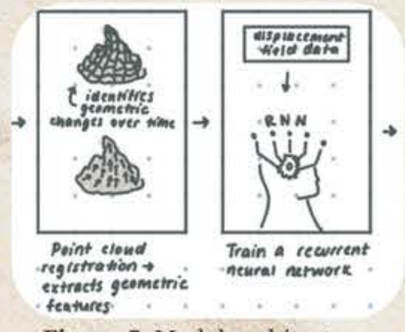

Figure 5: Model architecture

Pros
- Can be utilized remotely
- Enables advance instead of only quicker fabrication

Cons
- Can be inaccurate
- Currently waiting on IRB approval for better training data

Design Studies

Design #1: Ear Impressions
- Impression took **15 minutes** on average to obtain.
- Impression scanning and uploading takes **another 15-20 minutes**.
- The tools used for impression scanning were somewhat expensive.

Design #2: 3D-Printed Earmold
- It was created with less biocompatible and flexible materials than silicone.
- The first pair of 3D-printed earmolds did not fit comfortably for the user.
- The prints took **3 to 4 hours** to be created.

Design #3: Cast Earmold
- A rubber mixture was created and funneled into the cast (although silicon can also be used).
- The case was 3D-printed in **3 to 4 hours**.
- It took an **additional 25 minutes** to set up and cure.

Design #4: RNN Predictive Model
- A recurrent neural network was trained on longitudinal ear data for sequential prediction.
- The model obtained **61.8% accuracy** on validation set.

Final Design - 1 + 3 Combination

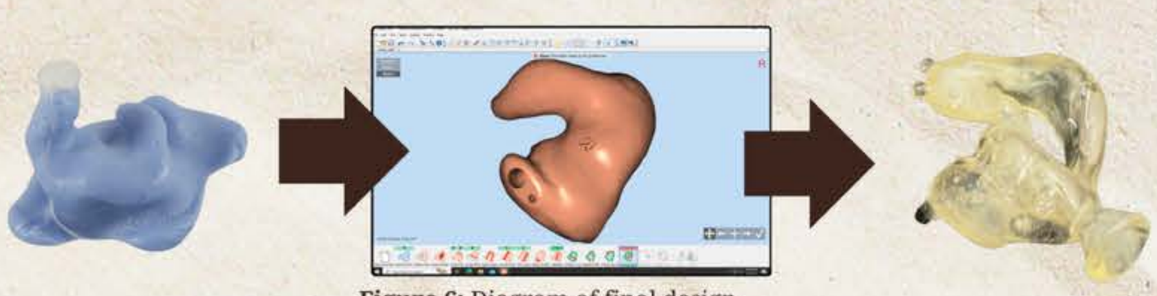

Figure 6: Diagram of final design

- Combines designs #1 and #3 - physical ear impressions and 3D scanning technology are used to generate an injection-ready earmold shell with the Cyfex Secret Ear Designer tool
- Decided to prioritize comfort of patient over speed

Features

- Custom earmolds are modelled based on ear impressions, a widely-known and simple process.
- Casts are 3D printed, which can be done in-hospital and relatively quickly.
- Fast-curing material with softness suitable for pediatric patients.

Conclusions

- Designed onsite pediatric earmold fabrication process
- Prioritized pediatric patient comfort over speed

Future Extensions

- Improve model by introducing convolutional architecture and training on more comprehensive data
- Compare and evaluate alternative onsite fabrication methods

References Anderson, K., & Madell, J. (2014). Improving hearing and hearing aid retention for infants and young children. *Hearing Review*, *21*(2), 16-20.

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