Ergonomic Prosthetic Ear Attachment

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Abstract

Auricular prostheses are often used to correct deformities of the ear resulting from physical trauma, cancer, or birth defects such as microtia. When reconstructive surgery or slip-on prostheses are not an option, the remaining ear is often removed and a new prosthetic ear is made. To hold the prosthetic ear in place, magnetic abutments are implanted into the skull while matching magnets are set into a silicone prosthesis. Though the prosthesis is easy to attach with this method, it is easily displaced due to posterior or anterior forces. Our group developed an attachment method that allows the prosthesis to slide into a locked position. This design offers additional attachment strength while allowing the user to easily attach, remove, and clean the prosthesis. This semester the attachment method was further modified to be compatible with non-ideal abutment arrangements and to fail before the skull is damaged. Based on the results from testing this semester, it has been determined that the diameter of the breaking point for an acrylic abutment must be 0.153 mm. Since this diameter is so small, further material analysis is needed.

Need for a New Method

- Observable ear defects are a source of psychological trauma [1]
- The need for an ear prosthesis may result from physical trauma, cancer, or birth defects such as microtia [1]
- Prosthesis attachment and detachment is simple for the user with the magnetic attachments, but difficult with the bar and clip method [2]
- Security of attachment is at stake
  - Concern with anterior and posterior forces
  - Attachment is often too strong with bar and clip method and compromises the integrity of bone and surrounding tissue

Figure 1. Child with microtia where a silicone prosthesis has disguised the deformity [3].

Attachment Methods

Figure 2. Magnetic abutments [3].

Figure 3. Bar attachment method [4].

Figure 4. Spring and sheath design [5].

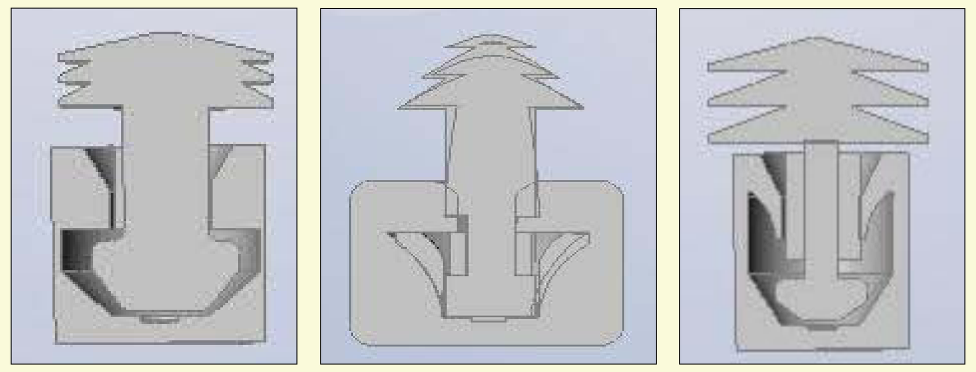


Figure 5. Prong and flange design [6].

Design and Fabrication

Design Criteria

- Resists unintentional dislodgement
- Withstands anterior and posterior forces
- Fails before bone is damaged
- Integrates with titanium implants
- Requires minimal effort to remove and attach
- Applies to a variety of abutment orientations and head topographies
- Costs less than current method ~ $110 per attachment

New Attachment System

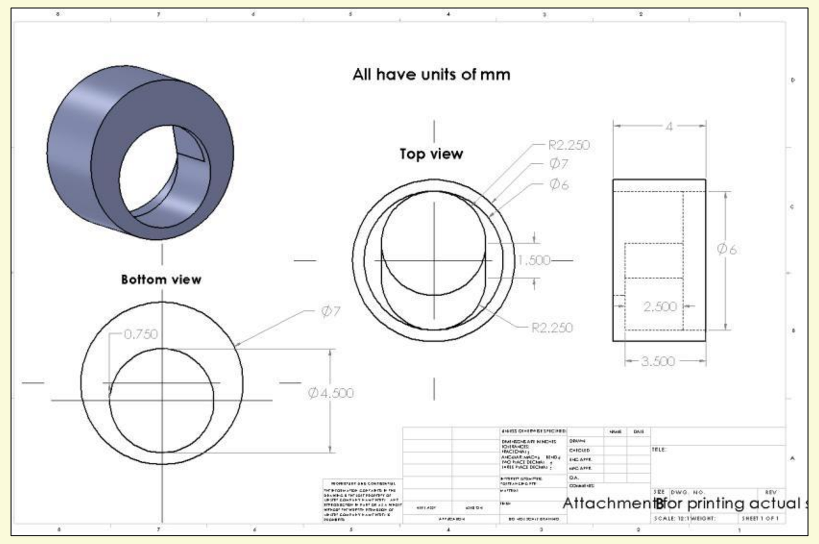
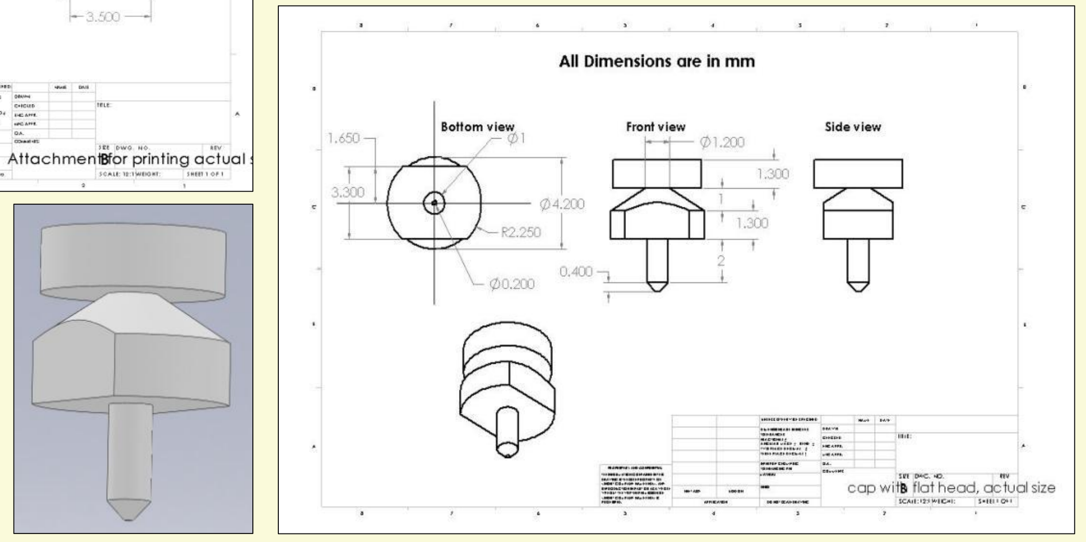


Figure 6 (left). SolidWorks drawing of attachment. The attachments are placed in the prosthetic ear and held with silicone. The attachments are manufactured from Ti-6Al-4V.

Figure 7 (right). SolidWorks model and drawing of cap. The cap is manufactured from acrylic based on the results from the testing data which is displayed in Figures 10 and 11 and screws into the titanium implants.



Final Prototype & Cost Analysis

Design Features

Attachment

- Embeds in ear as did o-ring attachments
- Sliding track allows for vertical sliding of prosthesis over the cap
- Prosthesis slides down 1.5 mm to locked position
- Lips on attachment prevent dislodgement from anterior/posterior forces
- Manufactured from Acrylic

Abutment Cap

- Conical lower half of abutment to accommodate angled implants
- Cylindrical upper half of abutment for secure fit in attachment
- Fit into implants with small screw glued to bottom of machined piece
- Fails directly below top cylindrical piece
- Manufactured from Acrylic

Figure 8. Photo of final prototype with three attachments.

Figure 9. Photo of final prototype with three abutment caps.

Cost Analysis

Product/Amount Used	Cost per Piece	Labor Cost ($40/hr)
0.5" x 0.5" x 0.06" Acrylic Sheet	$0.01	$13.32
0.5" x 0.5" x0.177"Acrylic Sheet	$0.02	
1 Cap Screw	$0.09	$30.00
0.5" x 0.5" Acrylic Rod	$0.12	

Cost for System – Acrylic Attachments	$130.86
Cost for System – Ti Attachments	$286.40

Testing Results

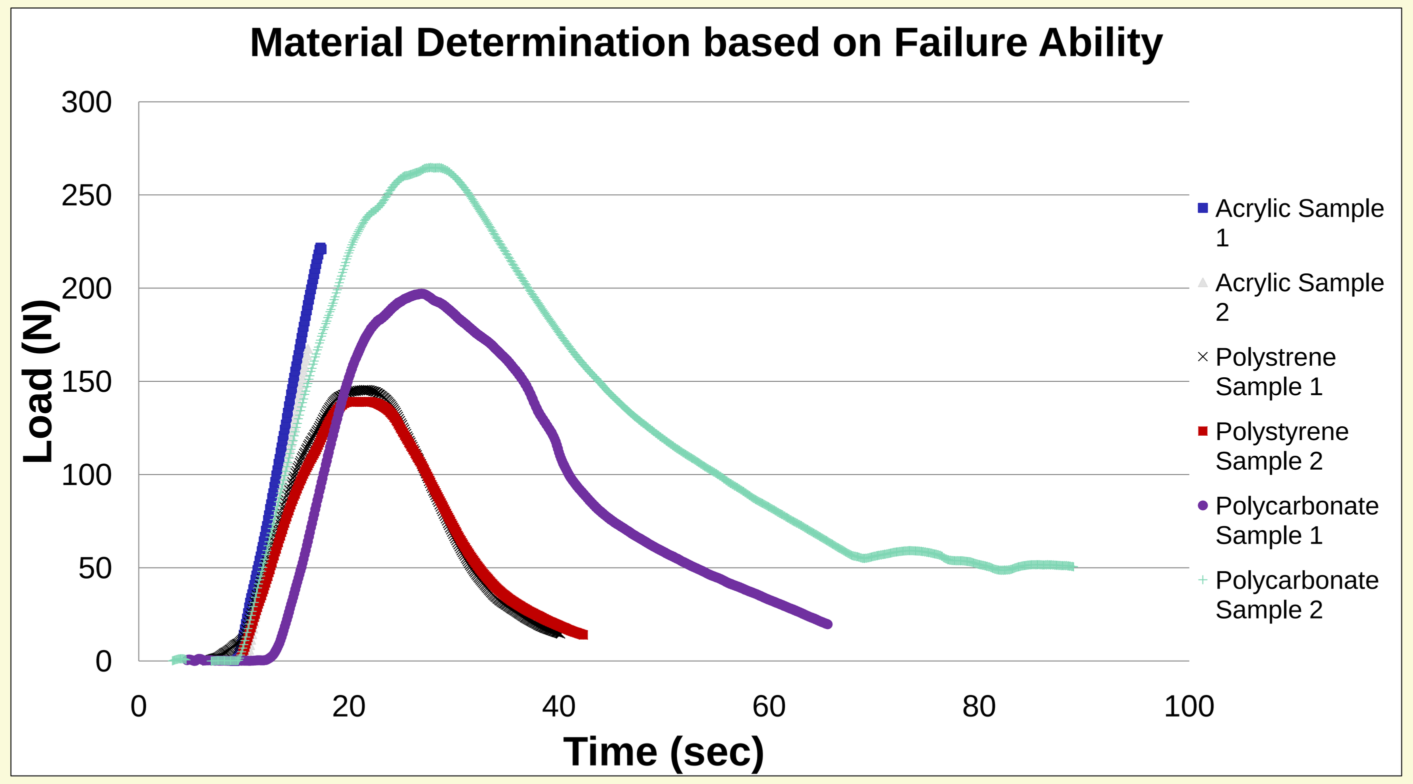
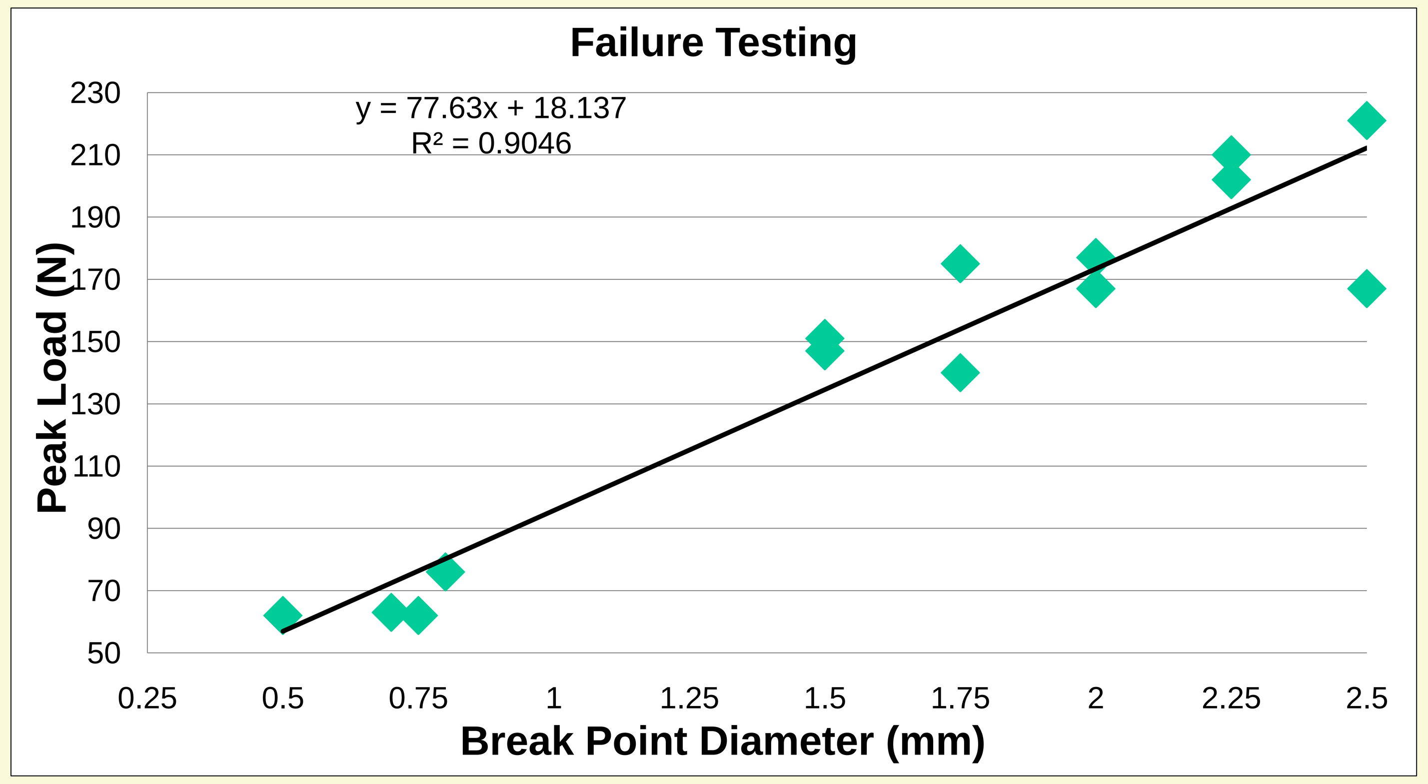


Figure 10 (left). Plot used to determine appropriate material for cap. Acrylic was chosen because Polystyrene and Polycarbonate did not fail cleanly or until they were significantly deformed.

Figure 11 (right). Plot of breaking force for different breaking diameters. Further work is needed since none of the caps failed at 30 N, which is the target breaking force to prevent skull damage. Based on the trend line, the cap would need a breaking diameter of 0.153 mm.



Future Considerations

- Complete material analysis to determine weaker material since Acrylic did not fail at the specified value of 30 N
- Perform a more accurate analysis of the failure point of bone
- Conduct failure testing in different directions and arrangements
- Metal attachments should be disguised with a flesh color coating
- Usability testing should be performed with actual patients
- Develop a system to allow the client to easily align the attachments when putting them in a prosthesis

Acknowledgements & References

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[1] Eavey, R. D., Monroy, A., Nicolau, Y., and Shabdiz, F. 2006. Microtia repair: the case for surgical reconstruction. *J. Oral Maxillofac. Surg.* **64**(11): 1655-1663.

[2] Gion, G. G. 2006. Surgical versus prosthetic reconstruction of microtia: the case for prosthetic reconstruction. *J. Oral Maxillofac. Surg.* **64**(11): 1639-1654.

[3] Figure from: <http://medicalartprosthetics.com/content.php?page=galleries&gallery=auricular>.

[4] Figure from: <http://medicalartprosthetics.com/content.php?page=prostheses&sec=auricular>.

[5] Figure from: http://homepages.cae.wisc.edu/~bme300/ear_attachment_f09/secure/reports/BME_300-Final_Report1.pdf

[6] Figure from: http://homepages.cae.wisc.edu/~bme300/ear_prosthesis_f08/secure/reports/Ear_Prosthesis_Final_Report.pdf