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. To overcome this issue, our group developed an attachment method where three abutments will have a corresponding track implanted into the prosthesis which also incorporates a recessed magnet. Each track is 4.5 mm wide, 6 mm long and is made from Ti-6Al-4V titanium. Each attachment is 7 mm in diameter and 4 mm tall. This design offers additional attachment strength while allowing the user to easily attach, remove and clean the prosthesis. Testing proved our design has better attachment capabilities compared to the magnetic attachment method.

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].

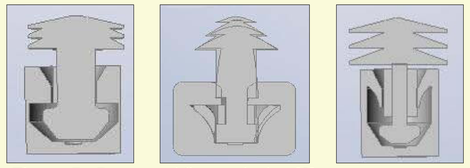

Figure 5. Prong and flange design [6].

Design Criteria

- Resist unintentional dislodgement
- Is low profile and completely contained within the prosthesis
- Withstands anterior and posterior forces
- Fits current abutment sizes which are 4.4 mm in diameter
- Requires minimal effort to remove and attach
- Is easy to clean
- Fabricated from medical grade titanium or stainless steel
- Costs less than current method ~ $110 per attachment

New Attachment System

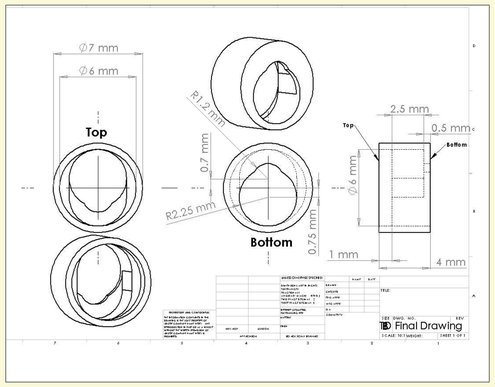

Figure 6. SolidWorks drawing of final design.

Design Features

- Attachment: 4 mm tall cylinder with 7 mm outer diameter
- 6 mm diameter hole to house magnet
- User places prosthesis on abutments and slides device downward to engage
  - Magnets guide prosthesis attachments onto abutments
  - Lip of attachment slides into groove under abutment cap when engaged
  - To remove, user disengages and pulls out

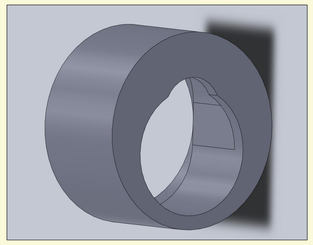

Figure 7. SolidWorks model of final design focused on abutment insert hole.

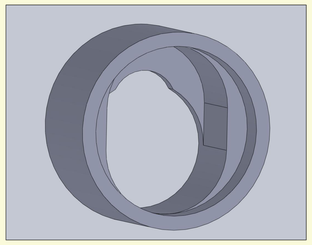

Figure 8. SolidWorks model of final design focused on magnet housing hole.

Figure 9. Sliding attachments embedded in silicone ear model.

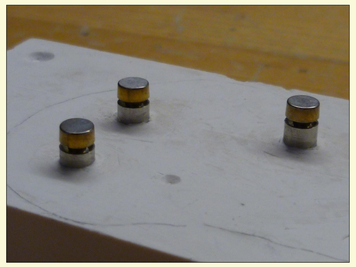

Figure 10. Abutment model showing groove under abutment caps.

Cost Analysis

- $185 for fabrication of 3 attachments
- $0.21 for 3 6 mm x 1 mm N38 Nickel Plated Neodymium Magnet Discs (Model D0601) from gaussboys.com
- $11.55 for 25 18-8 stainless steel general purpose flat washers, No. 00 screw size, 7/64” OD, 0.01”-0.02” thick (Part 92141A207) from mcmastercarr.com
- Total cost per prototype: $196.76
- Cost per attachment for our design: $63.26
- Cost per attachment for current method: $109.95

Testing Results

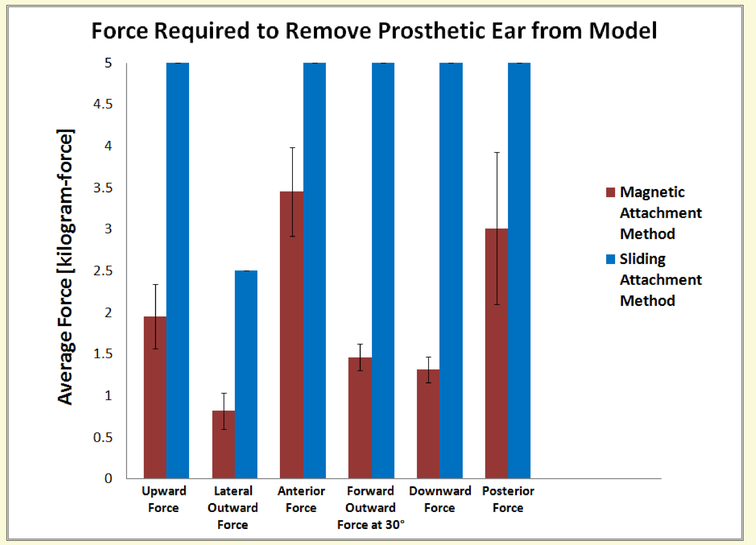

Figure 11. Average force required to remove the prosthetic ear with standard deviation bars. The sliding attachment model requires more force for removal. There is no standard deviation associated with the sliding method because testing ended at either 5 kgf or 2.5 kgf due to fear of damaging the silicone ear before detachment occurred.

Future Considerations

- Attachment should break before bone damage occurs
- Metal attachments should be disguised with a flesh color coating
- An easily replaceable attachment which could screw into the prosthesis if the device were to break should be developed
- 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
- Make abutment entry hole larger to make attachment and removal easier
- Test new device against bar and clip method

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References

[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
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