# Muscles of Mastication Group

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## Problem Statement

In veterinary anatomy education, there is a notable absence of interactive, hands-on models that illustrate the muscles of mastication for both carnivores and herbivores. This gap limits students' ability to engage in effective learning and understanding of the complex relationships between muscular and bony structures. Our goal is to develop two models that accurately replicate the anatomy of mastication muscles in two carnivores and herbivores allowing for the visualization of muscle function and clearly define individual muscles to enhance educational outcomes.

## Brief Status Update

The team is currently planning to meet with the MakerSpace to discuss 3D printing the skull along with getting material and design advice.

## Summary of Weekly Team Member Design Accomplishments

- Team:
  - Created and discussed our Design Matrices
- Jensen Weik:
  - Researched materials and attachment methods including silicone and knit elastic bands
  - Drew the designs for the attachment methods for the Design Matrix
- Kaiya Merritt:
  - Researched materials to use for the muscles and different attachment methods to secure the muscles to the skull.
  - Brainstormed a few design ideas to share with the team.
  - Met with the team and completed our Design Matrix.

- An Hua:
  - Brainstormed ideas for attachment methods and materials
  - Explained criteria ranking and results of the design matrix
- Noah Kalthoff:
  - Researched ideas for attachment and material ideas for our models
  - Look specifically at ways to 3D print our muscles and ways to attach that
  - Created/updated our design matrix
- Leah Nelson:
  - Brainstormed and researched different materials and attachments to replicate muscles for the model
  - Updated design matrix

## Weekly/Ongoing Difficulties

We have not had any difficulties yet.

## Upcoming Team and Individual Goals

- Team:
  - Meet with the Makerspace to discuss 3D printing and work on our preliminary presentation.
- Jensen Weik:
  - Meet with the Makerspace to discuss the difficulties of printing the STL files along with material choices for the skull and muscle
- Kaiya Merritt:
  - Meet with the Makerspace to discuss the capabilities of 3D printing our skull and using TPU to print the muscles
  - Start playing around with the STL files in SolidWorks
  - Start working on the preliminary presentation pdf
- An Hua:
  - Fix Product Design Specification document after feedback
  - Begin working on the preliminary presentation
- Noah Kalthoff:
  - Research more about how we can print a 3D muscle and have it stay intact when illustrating the motion of chewing
  - Start working on the preliminary presentation
- Leah Nelson:
  - Research more on the material that was chosen
  - Start working on preliminary presentation pdf

## Project Timeline

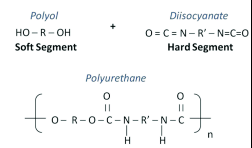
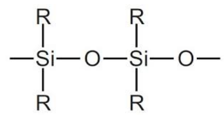
| Project Goal | Deadline | Team Assigned | Progress | Completed |
|---|---|---|---|---|
| Meet with client | 9/6 | All | 100% | 9/13 |
| Product Design Specification | 9/19 | All | 100% | 9/19 (ongoing with edits) |
| Preliminary Presentations | 10/4 | All | | |
| Preliminary Report | 10/9 | All | | |
| Show and Tell | 11/1 | All | | |
| Poster Presentations | 12/6 | All | | |
| Final Deliverables | 12/11 | All | | |

## Expenses

| Item | Description | Manufacturer | Part Number | Date | QTY | Cost Each | Total | Link |
|---|---|---|---|---|---|---|---|---|
| **Component 1** | | | | | | | | |
| | | | | | | | | |
| **Component 2** | | | | | | | | |
| | | | | | | | | |

| Component 3 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| TOTAL: | | | | | | | | $0.00 |

# Muscle Material Design Matrix

| **Criteria:** | **Design 1:** Thermoplastic Polyurethane (TPU)   | | **Design 2:** Silicone  | | **Design 3:** Stainless Steel Spring  | |
|---|---|---|---|---|---|---|
| **Elasticity (25)** | *4/5* | 20 | *5/5* | 25 | *4/5* | 20 |
| **Durability (20)** | *5/5* | 20 | *2/5* | 8 | *5/5* | 20 |
| **Ease of Fabrication (20)** | *4/5* | 16 | *4/5* | 16 | *4/5* | 16 |
| **Reproducibility (15)** | *4/5* | 12 | *4/5* | 12 | *5/5* | 15 |
| **Aesthetics (10)** | *4/5* | 8 | *5/5* | 10 | *1/5* | 2 |
| **Safety (5)** | *5/5* | 5 | *5/5* | 5 | *3/5* | 3 |
| **Cost (5)** | *2/5* | 2 | *4/5* | 4 | *5/5* | 5 |
| **Total: 100** | **83** | | **80** | | **81** | |

*<u>Criteria Descriptions and Justifications:</u>*

**Elasticity:** Elasticity is the highest weighted factor in the design matrix because the client's primary goal is being able to mimic movement of the mastication muscles. A design high in elasticity must be able to stretch and elongate without tearing during repeated manipulation while remaining in the elastic region. The silicone scored a 5/5 in this section due to its excellent flexibility, with a high elasticity score of 0.96 that closely mimics human skin [1]. The thermoplastic polyurethane (TPU) material scored a 4/5 due to its more rigid nature, as it is not as elastic as silicone, but it is the most elastic material that is capable of being 3D printed at the Makerspace. The stainless steel spring design also scored a 4/5 in this section, because of its ability to return to its neutral position. However, it is also more rigid than silicone, making it slightly difficult to stretch compared to the silicone.

**Durability:** Durability is ranked as the second highest factor in the design matrix due to the importance of the model being able to withstand classroom use. The client wishes to be able to adjust the model without the muscles snapping. TPU scored a 5/5, because of its balance of rigidity and elasticity [2]. The stainless steel spring also scored a 5/5, since it has high tensile strength and will not rust over time. Although silicone is highly elastic, it has an increased risk of snapping or breaking when overstretched, resulting in a score of 2/5.

**Ease of Fabrication:** Ease of fabrication was weighted the same as durability due to the project's time constraints. The client would ideally like us to complete more than one animal skull model, so designing something easy to fabricate will save time and allow for quick changes or fixes. The springs scored the highest at 5/5 due to easy purchasing, and the spring is already fabricated. TPU and silicone scored a 4/5 since TPU can be 3D-printed to create the muscles and silicone only requires molding. Overall, all the materials are acceptable for this section as fabrication will be achievable.

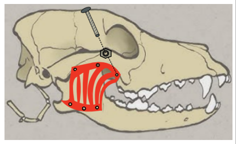
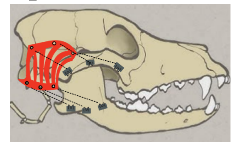
**Reproducibility:** Reproducibility had the third highest factor. Being able to reproduce the muscles on the skull efficiently in case something breaks is important for this project. The models we create will be used in classes with large amounts of students, so materials wearing down and potentially breaking is something that could happen. Because of this, reproducibility is important. The stainless steel springs scored the highest at 5/5. If a spring were to break, our client would simply need to purchase another one. The silicone scored a 4/5, as replacing this would require our client to pour silicone into a premade mold to produce another one. When put in a mold, silicone may need up to 24 hours to fully cure [3]. The TPU also scored a 4/5, as you would have to 3D print the muscle you were replacing again, but the STL files used to 3D print could be provided to the client.

**Aesthetics:** Due to our client emphasizing that aesthetics was not a topic of concern, we gave the category a low priority. However, our team decided that it still plays an important role in our design due to the model aiding with good educational outcomes. The TPU received a 5/5, as 3D printing the muscle enables us to add a good amount of detail. The silicone also received a 5/5, as we would be able to create an accurate looking muscle using a detailed mold. The spring received a 3/5, as there isn't much leeway to change how it looks.

**Safety:** Safety is vital, but our other categories have a higher importance in the scope of our project. TPU received a 5/5 due to it having a relatively strong tensile strength of about 30 MPa [4]. Silicone also received a 5/5, as the mold and silicone itself don't raise much of a concern in terms of safety. The spring, however, received a 3/5. This is because it is made of stainless steel and the hooks at the ends of the spring could potentially slip out, causing a potential hazard for anyone who is using the model.

**Cost:** Cost had a low rating due to the overall low material usage and high budget. The cost of TPU came out to be the highest at $3.84 per cubic inch [5] at the design innovation lab which led to the 2/5 rating. Silicone was comparatively more inexpensive at $32.69 for 2 lbs of powder, resulting in a score of 4/5. The springs are also broadly available at a low cost which we also rated as 4/5.

## Muscle Attachment Design Matrix

| **Criteria:** | **Design 1:**<br>Nut and Bolt<br> | | **Design 2:**<br>Epoxy Glue<br><br> | | **Design 3:**<br>Open Hook<br> | |
|---|---|---|---|---|---|---|
| **Durability (30)** | *5/5* | 30 | *3/5* | 18 | *4/5* | 24 |
| **Ease of Fabrication (30)** | *4/5* | 24 | *5/5* | 30 | *4/5* | 24 |
| **Reattachment (20)** | *4/5* | 16 | *2/5* | 8 | *5/5* | 20 |
| **Safety (10)** | *5/5* | 10 | *2/5* | 4 | *3/5* | 6 |
| **Cost (10)** | *5/5* | 10 | *5/5* | 10 | *5/5* | 10 |
| **Total: 100** | **90** | | **70** | | **84** | |

*Criteria Descriptions and Justifications:*

**Durability:** Durability was the highest weight on our muscle attachment design matrix, ensuring that the product can withstand repeated use without compromising performance. A design rated 5/5 in durability should exhibit resistance to wear and tear, maintain integrity under various conditions, and ensure reliability over time. This means the attachments used should be robust enough to endure rigorous handling and other environment factors that may wear down the attachment. Design 1 scored the highest due to this method being the most secure and sturdy for attaching the materials to the skull. Design 3 was the next highest due to the possibility of detachment from the hooks, and Design 2 scored the lowest due to the environmental factors making it more susceptible to failure with holding components together.

**Ease of Fabrication:** This criteria focuses on the simplicity and efficiency of the fabrication process for the design. A design that highly exhibits this should allow for straightforward assembly and minimal tooling requirements. Design 2 was rated the highest for this criteria since adhering the muscles to the skull with pre-made glue would require minimal fabrication. Design 2 and 3 were then rated the same at 4/5 because they both require minimal materials and can be easily assembled at the Makerspace or TEAM Lab.

**Reattachment:** Reattachment is crucial for the muscles as it guarantees the components can be easily restored in the event of a breakage. A design that presents this criteria would be straightforward in the reconnection process without compromising the structural integrity. Design 3 scored the highest for this as it would be simple to reattach a new muscle to the hook. Design 1 scored the next highest as the process would not be complicated, but it would take more effort in unscrewing the design and then re-fastening it. Finally, Design 2 scored the lowest due to reattaching involving new glue to be present to connect the parts together.

**Safety:** Safety was a low weight on the matrix due to the minimal safety risks associated with our model. Design 1 got the highest rating with regards to safety as the attachment would be inside of the skull and secure. Design 2 had the lowest safety rating as uncured epoxy glue causes irritation to the eyes and skin. Cured epoxy is safe for all human use with cytotoxicology results confirming this [6]. Lastly, with Design 3 the hook could be poking out of the skull and could lead to something getting snagged which gave it the 3/5 rating.

**Cost:** Cost had a low weight due to the overall inexpensive materials and high budget. All of these materials are at a reasonable price and fits well within our budget. We can also find all of the materials at the design innovation lab which allows us to not have to deal with outside sourcing. Due to this, we gave all of the designs a 5/5 rating.

## Appendix:

[1] Phadungsak Silakorn, M.Sc., Wangcha Chumthap, B.Sc., Somchai Chongpipatchaiporn, B.Sc., Arsada Khunvut, B.Sc., Supenya Varothai, M.D. Silicone Rubber Development for Medical Model Production. June.2015
https://www.semanticscholar.org/paper/Silicone-Adhesives-in-Medical-Applications-Schalau-Bobenrieth/02a461592d40c4c820d25903e6d507a9f38a3efe

[2] Nur Mohd, N. Mohd, Idris Mat Sahat, and Nur, "The CardioVASS Heart Model: Comparison of Biomaterials between TPU Flex and Soft Epoxy Resin for Biomedical Engineering Application," Mar. 2021, doi: https://doi.org/10.1109/iecbes48179.2021.9398731.

[3] "How Long Does Silicone Take To Dry?," Silicone Depot.
https://siliconedepot.com/blog/how-long-does-silicone-take-to-dry/

[4] H. J. Qi and M. C. Boyce, "Stress–strain behavior of thermoplastic polyurethanes," Mechanics of Materials, vol. 37, no. 8, pp. 817–839, Aug. 2005, doi: https://doi.org/10.1016/j.mechmat.2004.08.001.

[5] "3D Printer Cost Calculator," UW Makerspace.
https://making.engr.wisc.edu/3dprint-cost/

[6] Rudawska A, Sarna-Boś K, Rudawska A, Olewnik-Kruszkowska E, Frigione M. Biological Effects and Toxicity of Compounds Based on Cured Epoxy Resins. Polymers (Basel). 2022 Nov 14;14(22):4915. doi: 10.3390/polym14224915. PMID: 36433042; PMCID: PMC9698122.

Link to Purchase Ecoflex (silicone):
https://www.amazon.com/Ecoflex-00-20-Super-Soft-Silicone/dp/B01DUYKHGY/ref=sr_1_1_sspa?adgrpid=1332608658680210&dib=eyJ2IjoiMSJ9.TfBn6wPzQrOpsW2nuFyHGA-0swWfAnd1QzYj2tX0ZaFRtFS27KcXo73cohlByks8ChNBYUM2IjqcVv5lKa2_dCmnxfRglzoK_IWSvJ7pOPzqERE7WTonaqm_oxsgxAOK3NGHGmVlwlhQEb49Irc2Hg.fI7Ha8aSS258gKXJqsdHuuv5emgNCLVc1oKWZL0RA4E&dib_tag=se&hvadid=83288280111362&hvbmt=be&hvdev=c&hvlocphy=105633&hvnetw=o&hvqmt=e&hvtargid=kwd-83288388864602%3Aloc-190&hydadcr=5706_13190836&keywords=ecoflex%2B00%2B30&msclkid=e7e88335f7f815d4650fe5c163820392&qid=1727304849&sr=8-1-spons&sp_csd=d2lkZ2V0TmFtZT1zcF9hdGY&th=1