Models of the Muscles of Mastication

Jensen Weik (Leader), Kaiya Merritt (Communicator), An Hua (BPAG),
Leah Nelson (BWIG), Noah Kalthoff (BSAC)

BME 200/300
Section 305
October 4th, 2024
Advisor: Dr. Cameron Casey
Client: Dr. McLean Gunderson

Client Description and Problem Statement

Client

- Dr. McLean Gunderson, BS, DVM
- Department of Comparative Biosciences
- Teaching professor with primary interest in providing innovative and immersive techniques to demonstrate veterinary medicine

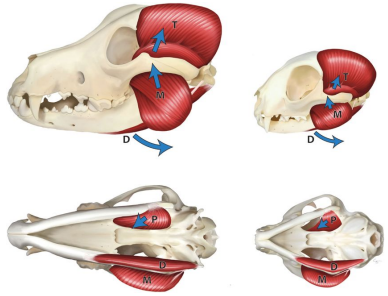


Figure 1: Canine Muscles of Mastication Diagram [1]

Problem Statement

- Muscles of mastication are vital in understanding the social and physiological behavior of herbivores and carnivores and for veterinary treatment [2]
- No existing models demonstrate the movement, function, and location of the muscles of mastication for herbivores and carnivores
- Dr. Gunderson has asked for two models depicting the muscles of mastication in which the user can contract the muscle to move the jaw

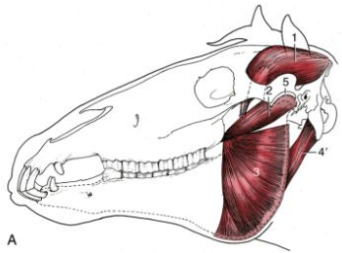


Figure 2: Horse Muscles of Mastication Diagram [3]

Background Information

- Skeletal muscles that are involved in opening and closing the jaw
- Important osseous structures include the mandibles, maxillae, and teeth [1]
- Contraction of each muscle pulls on the osseous structures
- Carnivores and herbivores differ due to varying methods of chewing, diet, and predation [2]
- Our client has had similar projects but was unable to find a method for sufficiently representing muscle movement

Figure 3: Dr. Gunderson's Painted Skeleton Model [4]

Product Design Specifications

GOAL

To develop a carnivore and herbivore model that accurately represents the anatomy of mastication muscles.

FUNCTION

- Exhibit the osseous structures relevant to mastication
  - Mandibles, maxillae, and teeth [1]
- Capable of manipulation and replaceability
- Include these primary muscles on the carnivore – Masseter, Temporalis, Digastricus [5]
- Include these primary muscles on the herbivore – Masseter, Temporalis, Digastricus, Pterygoid [6]

PHYSICAL REQUIREMENTS

- Under 10 lbs
- Portable and easy to transport
- Withstand structural integrity
- Budget: $1,500

Muscle Material Designs

Design 1: Thermoplastic Polyurethane (TPU)

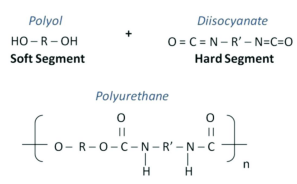


Figure 4: TPU Compound Formula [7]

- High elasticity
- 3D printable
- Durable, high tensile strength [8]

Design 2: Silicone

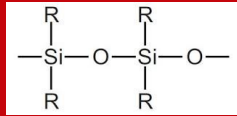


Figure 5: Silicone Compound Formula [9]

- Good flexibility [10]
- High aesthetics due to mold

Design 3: Stainless Steel Springs

Figure 6: Stainless Steel Springs [11]

- Cost effective
- Rigid nature

Design Matrix 1: Muscle Material

Chosen Design

Thermoplastic Polyurethane

- Durable
- Elastic
- Can be fabricated at Makerspace
- Compatible with future work

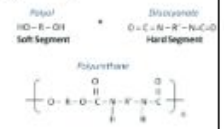
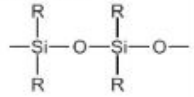
Criteria:	Design 1: Thermoplastic Polyurethane (TPU) 		Design 2: Silicone 		Design 3: Stainless Steel Spring 	
Elasticity (25)	*4/5*	20	*5/5*	25	*4/5*	20
Durability (20)	*5/5*	20	*2/5*	8	*5/5*	20
Ease of Fabrication (20)	*4/5*	16	*4/5*	16	*4/5*	16
Reproducibility (15)	*4/5*	12	*4/5*	12	*5/5*	15
Aesthetics (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**	

Table 1: Muscle Material Design Matrix

Muscle Attachment Designs

Design 1: Nut and Bolt

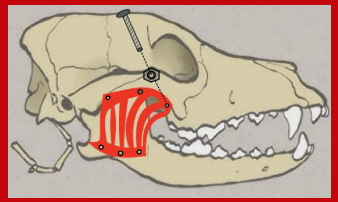


Figure 7: Nut and Bolt Attachment

- Secure and sturdy
- Safe to use, rests inside the model
- Low cost

Design 2: Epoxy Glue

Figure 8: Epoxy Glue

- Minimal fabrication
- Low cost

Design 3: Open Hook

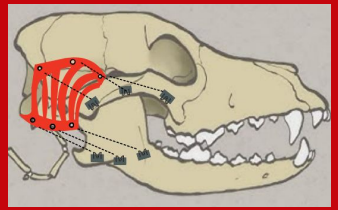


Figure 9: Open Hook Attachment

- Efficient reattachment
- Low cost

Design Matrix 2: Muscle Attachment

Chosen Design

Nut and Bolt

- Durable
- Safe
- Low in Cost
- Can be reattached

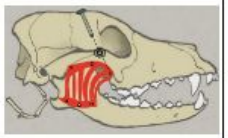
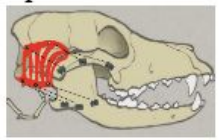
Criteria:	Design 1: Nut and Bolt 		Design 2: Epoxy Glue 		Design 3: Open Hook 	
Durability (30)	*5/5*	30	*3/5*	18	*4/5*	24
Ease of Fabrication (30)	*4/5*	24	*5/5*	30	*4/5*	24
Reattachment (20)	*4/5*	16	*2/5*	8	*5/5*	20
Safety (10)	*5/5*	10	*2/5*	4	*3/5*	6
Cost (10)	*5/5*	10	*5/5*	10	*5/5*	10
Total: 100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

Table 2: Muscle Attachment Design Matrix

Final Design

- TPU provides benefits of elasticity and durability
  - Striations in TPU for additional elasticity
- Nut and bolt optimal for durability and reattachment

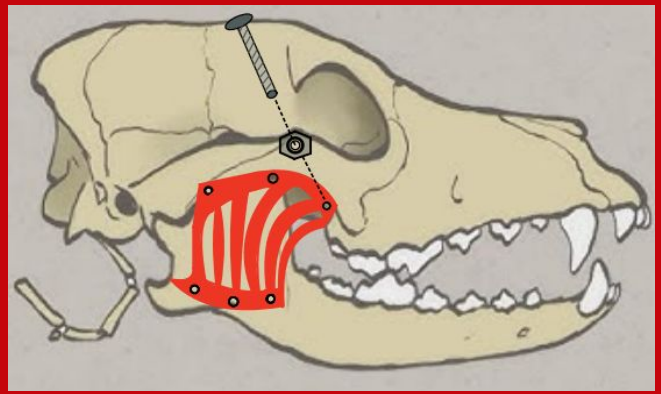


Figure 7: Nut and Bolt Attachment

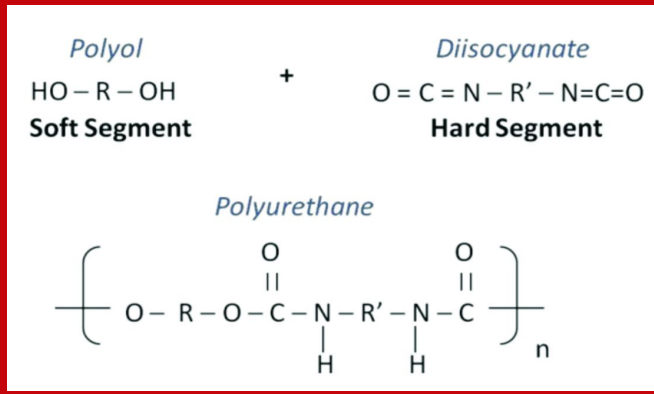


Figure 4: TPU Compound Formula [7]

Fabrication and Future Work

Fabrication Plans

- 3D print skulls from premade STL files
- Design in SolidWorks and 3D print TPU muscles
- Attach muscles to skull using nuts and bolts

Future Work

- Testing
- Improving realism
- Adding in more muscles within the skull
- Gain feedback from students and improve in ways to further educational use

Thank you!

Special thanks to Dr. McLean Gunderson and Dr. Cameron Casey for their guidance and input!

References

[1] S. E. Kim, B. Arzi, T. C. Garcia, and F. J. M. Verstraete, “Bite Forces and Their Measurement in Dogs and Cats,” *Front. Vet. Sci.*, vol. 5, Apr. 2018, doi: 10.3389/fvets.2018.00076.

[2] S. W. HERRING, “MASTICATORY MUSCLES AND THE SKULL: A COMPARATIVE PERSPECTIVE,” *Arch Oral Biol*, vol. 52, no. 4, pp. 296–299, Apr. 2007, doi: 10.1016/j.archoralbio.2006.09.010.

[3] T. Clark, “Head - CVM Large Animal Anatomy”, Accessed: Oct. 03, 2024. [Online]. Available: https://pressbooks.umn.edu/largeanimalanatomy/chapter/neck-head/

[4] “Painted Skeleton Model,” McLean Gunderson Model Laboratory. Accessed: Oct. 03, 2024. [Online]. Available: https://gundersonlab.vetmed.wisc.edu/?page_id=562

[5] S. Tomo, T. Hirakawa, K. Nakajima, I. Tomo, and S. Kobayashi, “Morphological classification of the masticatory muscles in dogs based on their innervation,” Annals of Anatomy - Anatomischer Anzeiger, vol. 175, no. 4, pp. 373–380, Aug. 1993, doi: 10.1016/S0940-9602(11)80047-6.

[6] P. M. Dixon, N. du Toit, and C. Staszyk, “A Fresh Look at the Anatomy and Physiology of Equine Mastication,” Veterinary Clinics of North America: Equine Practice, vol. 29, no. 2, pp. 257–272, Aug. 2013, doi: https://doi.org/10.1016/j.cveq.2013.04.006.

[7] “Polyurea Chemical Structure,” Mungfali, 2024. https://mungfali.com/explore/Polyurea-Chemical-Structure (accessed Sep. 30, 2024).

[8] 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.

[9] “Silicones - Preparation of Silicones, Properties, Structure, Uses, Types,” BYJUS. https://byjus.com/jee/silicones/

[10] 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

[11] “Stainless Steel Springs - Quality Spring, Affordable Prices,” www.acxesspring.com. https://www.acxesspring.com/stainless-steel-springs.html

Questions?