STRUCTURAL AND MECHANICAL FUNCTIONS OF BONES, MUSCLES, AND JOINTS BY USE OF 3D MODELS IN VETERINARY MEDICAL EDUCATION

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Problem Definition

Motivation:
- Create a model to improve veterinary medicine education so future veterinarians can provide more accurate and effective care to patients

Background:
- Hands on learning approaches are integral to anatomy studies
- 3D printed models have been on the rise in medical education, as they are cheaper, longer lasting, and do not encounter the ethical concerns of cadaver dissection [1]

Competing Designs:
- Axis Scientific: detailed, articulated skeleton models that cost $72+, but have no muscles [2]
- Anatomy Lab Domestic Canine Model: $333 model that include muscles, but are not detachable [3]
- Dr. McLean Gunderson: utilized a pre-existing dog skeleton and color-coded attachment points, but the attachment points corresponded to single points rather than anatomically correct attachment surface area and the muscles were represented by strings of elastic rather than 3 dimensional shapes

Figure 1. Axis Scientific Model [2]

Figure 2. Anatomy Lab Domestic Canine Model [3]

Figure 3. Dr. McLean Gunderson's Model

Design Criteria

Accuracy: Must represent canine hindlimb bones and muscles to 60% degree of accuracy according to survey of veterinary students.

Life in Service: Should withstand 45° flexion/extension (50 times) with no measurable decrease in attachment force.

Intuitiveness: At least 70% of vet students can use model without previous knowledge or instruction.

Durability: Model must withstand more force than competing designs (Axis Scientific).

Final Design

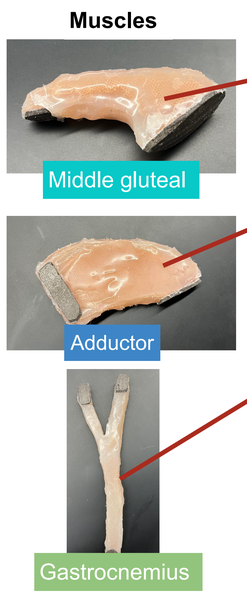

Figure 4. Silicone muscles with magnet attachment points.

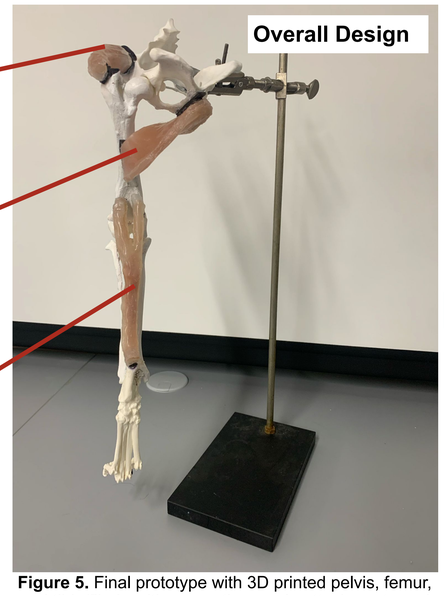

Figure 5. Final prototype with 3D printed pelvis, femur, and tibia/fibula with magnetic muscle attachments and silicone-fabric muscles.

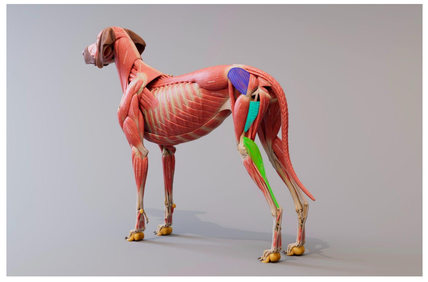

Figure 6. Modeled muscles on computer generated musculoskeletal dog diagram [4]

Materials:
- Bones
  - 3D printed with PLA
- Muscles
  - Silicone with Nylon/Spandex mesh
- Attachment Mechanism
  - Neodymium Magnetic Tape and Super Glue

Testing

a. Mechanical Testing System (MTS)

Figure 7. Image depicting the MTS performing a 3-point bend test on the 3D printed canine femur.

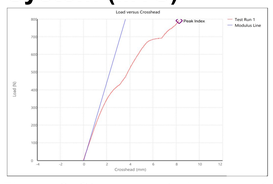

Figure 8. Stress vs. strain curve of an Axis Scientific canine femur.

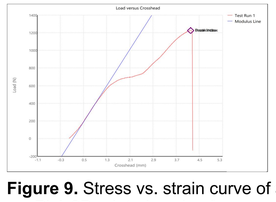

Figure 9. Stress vs. strain curve of a PLA 3D printed canine femur.

b. Life in Service Durability Testing

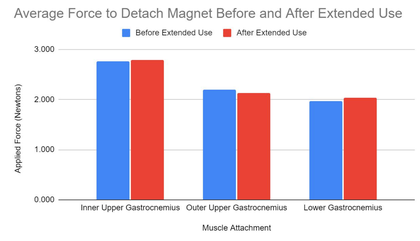

Figure 10. Bar graph depicting applied force (N). for each gastrocnemius muscle attachment point before and after 50 repetitions of flexion and extension. (SD =.05, p= .68) No significant difference was found between attachment force before and after extended use.

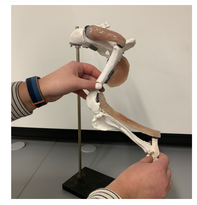

Figure 11. Image showing a period of extension during the life in service durability testing.

Figure 12. Image depicting a measurement of attachment force using a spring balance.

c. Qualitative Survey from UW Vet Med Students

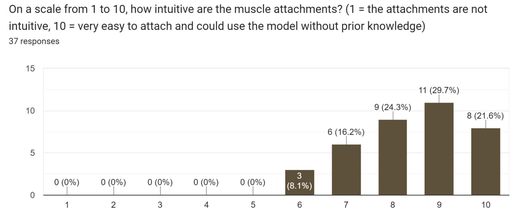

Figure 13. Vet student intuitiveness feedback measuring level in which model can be used without instruction.

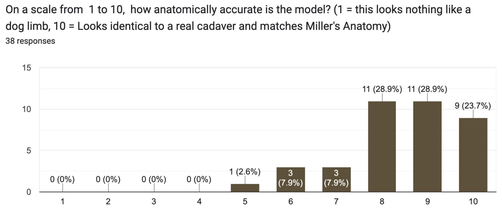

Figure 14. Vet student accuracy feedback evaluating anatomical correctness.

Results

MTS:
- Axis Scientific Peak Load: **791.425 N**
- PLA 3D Print Peak Load: **1225.161 N**
  - 3D printed model is more durable and **can withstand expected max load of 890 N**

Life in Service:
- **No measurable decrease** in attachment force before and after extended use
- Magnetic attachments are durable enough for long term use in the classroom

Survey:
- **84.3%** accuracy
  - Useful for veterinary anatomical education
- **83.8%** intuitiveness
  - Sufficiently easy for students to understand

Future Work

- Create additional muscles like the quadricep to further show counteraction mechanism between muscles and complex origins
- Follow up initial WARF disclosure
- Color code adductor, gastrocnemius and middle gluteal muscle prototypes
- Obtain long-term testing with veterinary students in a real-like classroom situation
- Fabricate a stronger muscle attachment mechanism for gastrocnemius
- Increase accuracy of muscle shapes/sizes

References

[1] Z. Ye, A. Dun, H. Jiang, C. Nie, S. Zhao, T. Wang, and J. Zhai, "The role of 3D printed models in the teaching of human anatomy: A systematic review and meta-analysis," BMC Medical Education, vol. 20, no. 1, 2020.
[2] "Axis Scientific Canine Hindlimb with Foot," Anatomy Warehouse. https://anatomywarehouse.com/axis-scientific-canine-hindlimb-with-foot-a-109194 (accessed Sep.20, 2022)
[3]"Dog skeleton (canis lupus familiaris), size L, specimen," 1020989 - T300091L - Predators (Carnivora) - 3B Scientific. [Online]. Available: https://www.3bscientific.com/us/dog-skeleton-canis-lupus-familiaris-size-l-specimen-1020989-t300091l-3b-scientific,p_228_29910.html?utm_source=google&utm_campaign=gmc_feed&gclid=Cj0KCQjwyt-ZBhCNARIsAKH11748lJa8A0OSaTU52_o9325GHCB02zrv_rRKA7azG4Uk-CEV_CU7zP8aAmwmEALw_wcB\. [Accessed: 04-Oct-2022].
[4] Frix, Jaime, khatri3d, Geert_Etcher_Melis, AlexDubnoff, Natashaa, Ravensilvermaine, Drdoug, MatthiasB, and aileen_K, "Canine ecorche - dog anatomy," *ZBrushCentral*, 22-Oct-2021. [Online]. Available: https://www.zbrushcentral.com/t/canine-ecorche-dog-anatomy/414409. [Accessed: 06-Dec-2022].

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