Veterinary Bone Marrow Aspirates Model

BME 200/300

October 4th, 2024

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Problem Statement

- Goal is to design a reusable model for UW-Madison veterinary students to allow for them to practice aspirating bone marrow.
- The current aspiration method uses a cadaver, but does not allow for any bone marrow (liquid) to be extracted.
- Students are unable to get the full experience without the bone marrow extraction.

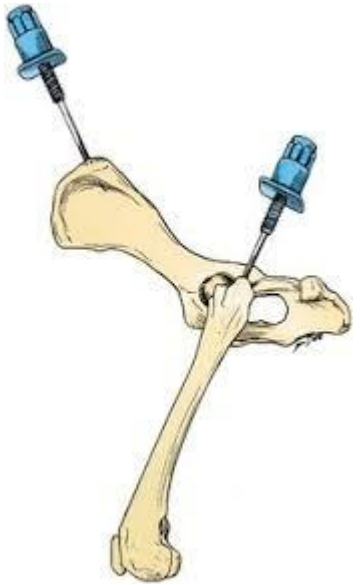


Figure 1: Depiction of bone marrow aspiration [1].

Background Material

- Our client, Dr. Gunderson, is a professor of veterinary anatomy and clinical skills for the UW-Madison School of Veterinary Medicine.
- Veterinary professionals commonly collect bone marrow aspirates from three main sites in dogs and cats: the iliac crest, the trochanteric fossa, and, mostly commonly, the proximal humerus [2].
- Bone marrow aspiration procedure

Figure 2: Bone marrow aspiration procedure being performed on a living dog [3].

Background Material

- Use of Illinois needle [4]
- Procedure is used to collect bone marrow and test for abnormalities of the blood [5].
    - For Instance: blood disorders, leukemia, FIV
- Students have to use cadaver dogs to practice these procedures, as no veterinary aspiration models exist.
- The cadaver can only be used for 10-15 insertions and does not contain live bone marrow to be collected.

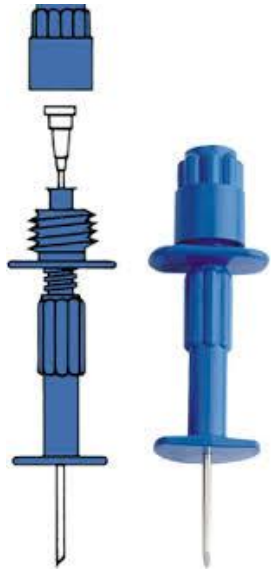


Figure 3: Illinois needle [6].

Competing Designs

Cadavers:

- Limited practice
- No bone marrow fluid
- Most anatomically accurate
- Multiple different practice sites [5]

Figure 4: Beagle [7].

Human Models:

- Bonnie Bone Marrow Biopsy Trainer [8]
- Anatomy Lab's Adult Bone marrow Aspiration Model [9]
- Not accurate to Veterinary procedures
- Expensive ($2,214) [8]

Figure 5: Bonnie Bone Marrow Biopsy Trainer [8]

PDS Summary

Anatomical Structure:

- Right scapula, shoulder, humerus, elbow, radius and ulna of 30 lb canine.
- Surrounding muscles and soft tissue.
- Articulate shoulder joint; fixed elbow joint at 120° [10].
- Humerus includes a ~3x3 cm removable section.
- Total length: 25 cm

Functional Features:

- Refillable bone marrow cavity.
- Aspirate 0.5-2 mL of bone marrow [11].
- Flat and rough aspiration site.

Figure 6: Model of canine right proximal leg. [12]

PDS Summary

Usage:

- 5 years in-class use, ~100 students, each student practices ~3 times.
- Humerus section replaced every 5 uses.
- Muscle replaced every 20 uses.
- Withstands aspiration force of Illinois needle.
- Used in simulated clinical settings.

Budget & Additional Specifications:

- Total budget: $1,600
- Designed for right handed users.
- Physiologically accurate model of canine right front arm.

Design Aspects

- 3D Printed material for bones with replaceable/refillable component
- Skin made from silicone and neoprene
- Bone marrow mimicking fluid in a small cavity inside the replaceable piece
- Muscles fabricated from pourable silicone

Figure 7: Image of bone marrow aspiration on beagle. [13]

Material Considerations

Polylactic Acid (PLA)

- Comparable tensile strength
- Accessible material
- Recyclable
- Low warp and Shrink properties

Acrylonitrile Butadiene Styrene (ABS)

- High elasticity
- Rigid
- Impact resistant

Figure 8: Depiction of different plastic materials [14]

Polyethylene terephthalate glycol (PETG)

- Comparable tensile strength
- Impact resistant
- Smooth finish
- Relatively flexible [14]

Design Matrix - Material

	Weight	PLA		ABS		PETG	
Mechanical Accuracy	25	5/5	25	2/5	10	1/5	5
Strength	20	3/5	12	5/5	20	2/5	8
Ease of Fabrication	20	5/5	20	2/5	8	4/5	16
Texture	15	4/5	12	3/5	9	2/5	6
Disposability	10	5/5	10	1/5	2	3/5	6
Cost	10	5/5	10	3/5	6	2/5	4
Total	**100**	**89**		**55**		**45**	

Table 1: Material Design Matrix.

Testing

- Created test swatches of the three materials under consideration
  - Thicknesses of 1 mm, 2 mm, 3 mm
- Placed on top of foam block
- Dr. Calico Schmidt conducted testing using an Illinois needle on each piece
- End result:
  - Texture and strength of PLA (3mm) was the most life-like

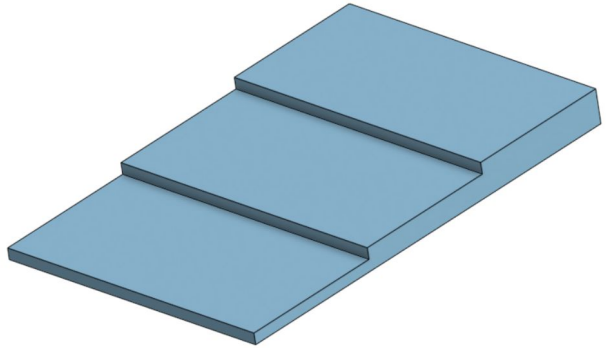


Figure 9: CAD model of Test Swatches.

Design #1 : Screw Method

- Allows the whole proximal end of the humerus to be screwed off for replacement

- Strengths: easy bone marrow access, secure
- Weaknesses: large joint interference, difficult fabrication, higher cost, alignment issues

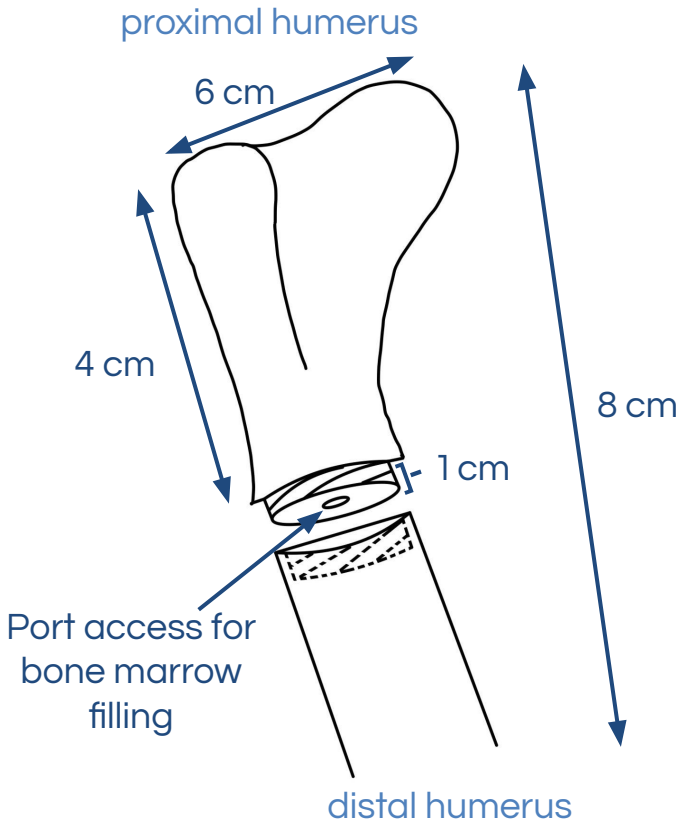


Figure 10: Drawing of Screw Method of attachment.

Design #2 : Slide Method

- Oval section slides into the humerus and clicks into place with tab

- Strengths: easy fabrication and replacing, low cost, easy filling, stability
- Weaknesses: tight tolerance for design in CAD

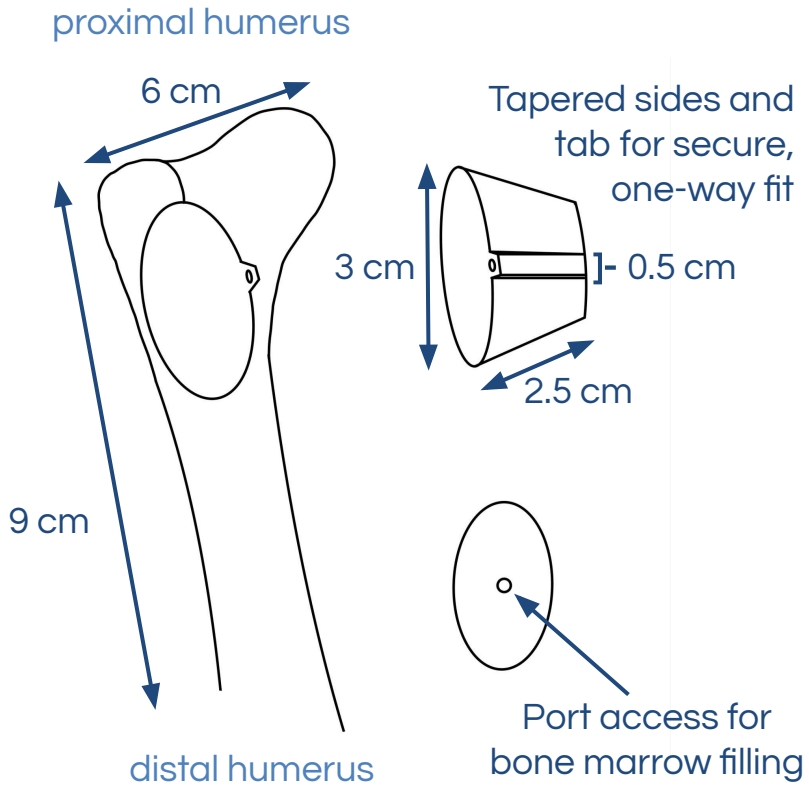


Figure 11: Drawing of the Slide Method of attachment.

Design #3 : Velcro Method

- Only the section that is punctured is replaced using velcro to attach the refillable component

- Strengths: easy fabrication
- Weaknesses: stability issues and added costs from velcro, port access, alignment issues

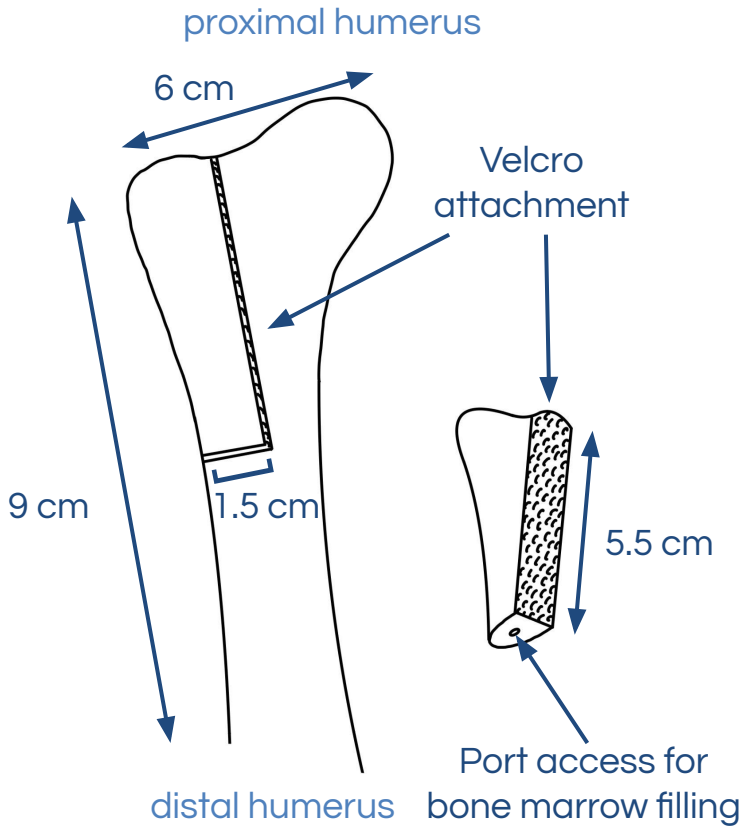
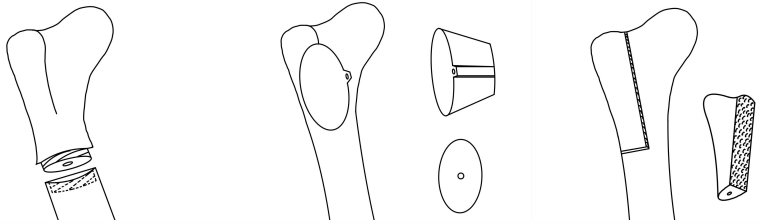


Figure 12: Drawing of the Velcro Method of attachment.

Design Matrix - Replaceable Component



	Weight	Screw Method		Slide Method		Velcro Method	
Joint Interference	20	2/5	8	5/5	20	1/5	4
Ease of Fabrication	20	2/5	8	4/5	16	3/5	12
Ease of Use	15	2/5	6	4/5	12	3/5	9
Durability	15	2/5	6	4/5	12	2/5	6
Bone Marrow Access	15	5/5	15	4/5	12	2/5	6
Cost	10	2/5	4	5/5	10	3/5	6
Safety	5	4/5	4	3/5	3	3/5	3
Total	**100**	**51**		**85**		**46**	

Table 2: Replaceable Component Design Matrix.

Final Design

- Slide Method chosen as final design
  - Small replaceable component, which will cost less overtime and be easy to replace
  - Minimal joint interference
- PLA chosen as final material
  - Most similar feeling to bone
  - Cost effective; easily accessible material and method of fabrication
  - Biodegradable and recyclable

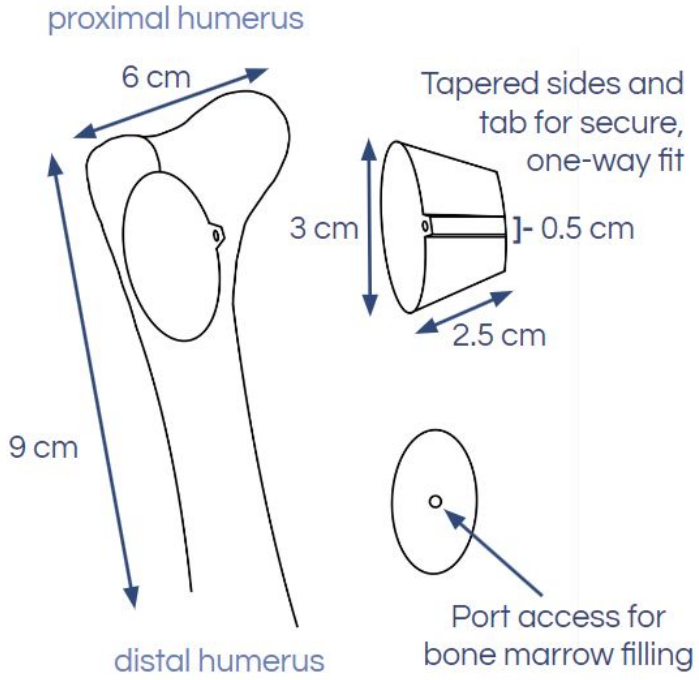


Figure 11: Drawing of the Slide Method of attachment.

Future Work

- 3D scans of selected bones
  - CAD Model
- Decide thickness of non-replaceable bone components
- Finalize fabrication plan for muscles
- Creating a shoulder joint
  - Modify CAD or purchase ball and socket joint
- Bone marrow fluid
- Skin attachment

Acknowledgements

We would like to thank our client, Dr. McLean Gunderson, her team: Dr. Calico Schmidt, Dr. Karen Herschberger-Braker, Dr. Mackenzie Pellin, and our advisor, Dr. Randy Bartels.

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Questions?