BME Design-Fall 2024 - AVERY SCHUDA
Complete Notebook

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Team contact Information

AVERY SCHUDA - Sep 08, 2024, 4:21 PM CDT

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Project description

AVERY SCHUDA - Sep 11, 2024, 12:26 PM CDT

Course Number: BME 200/300

Project Name: Veterinary bone marrow aspirate models

Short Name:

Project description/problem statement:

Problem statement:

Veterinary professionals commonly collect bone marrow aspirates from three main sites in dogs and cats: the Iliac crest, the Trochanteric fossa, and Proximal humerus. This project aims to create a low-cost 3D anatomically correct model with relevant soft tissue structures and skin that mimics the consistency and structure of the bones and allows for insertion of "bone marrow" for collection, allowing veterinary students to practice the skill of bone marrow aspiration.

Project description:

"Veterinary professionals commonly collect bone marrow aspirates from three main sites in dogs and cats:
Iliac crest: The wing of the ilium, which is often used for medium to large dogs
Trochanteric fossa: The proximal femur, which is often used for small dogs and cats, or for neonates
Proximal humerus: The greater tubercle, which is often used for dogs and cats, especially young animals and small pets

I am interested in the creation of a 3D anatomically correct model of a cat or dog wing of ilium, trochanteric fossa and/or greater tubercle that mimics the consistency and structure of the bones and allows for insertion of "bone marrow" for collection. This model should come with relevant soft tissues structures and skin but does not need to represent a large region of the dog or cat. It should either be inexpensive and quick to replicate/manufacture (one and done) or come with replaceable components that are inexpensive and quick to replicate/manufacture (reusable base with exchangeable parts). In this manner veterinary students will be able to practice the clinical skill of collecting a bone marrow aspirate."

About the client:

Dr McLean Gunderson in an assistant teaching professor for the comparative biosciences department (CBS), course coordinator & instructor for anatomy of large domestic animals and an instructor for fundamental principles of anatomy and the clinical skills courses.

2024/09/13- First Client Meeting

ANYA BERGMAN - Sep 15, 2024, 11:58 AM CDT

Title: First Client Meeting

Date: 9/13/24

Content by: Anya Bergman

Present: Anya, Ellie, Ella, Avery, Helena

Goals: To meet the client and establish the goals and design specification for the project.

Content:

Cadaver procedure:

- the right proximal humorous has been chosen (this the shoulder site of the dog because it will have the least amount of fat)
    - it is flat and a little rough to try to help the needle find purchase
- Dr. Shaves the hair off the site to prep make the site sterile
- rotate elbow and shoulder outwards to find the flat ride of the bone- not much muscle or tissue coverage
- using a scalpel, they make a small incision through the skin and a thin layer of muscle and fascia in order not to dull the actual needle
- drill back and forth, move leg to ensure purchase
    - remove inner needle, replace with syringe and then pull back to get just enough marrow (we do not want a lot)
    - remove
- All of the structure is palpable
- would want most of the limb- from a few inches below the elbow, would like the joint spaces to give practice on avoiding it

teaching video one

- left hand is typically dirty hand and manipulates leg
- skin incision is 2-3 mm (very small)
- stabilize humorous and expose is by abducting the limb
- decrease in resistance when entering the marrow cavity4cc in large dog and 1 cc in cat
- should have little bone flecks and that's a good sign

Can find: canine bone marrow aspirate Cornell videos

Conclusions/action items:

After finding out more about this project we should start working on the PDS and should continue researching the procedure as well as begin coming up with some ideas for how we want to approach the project. It's also important that we create a model with movable joints, and is the average dog size, that is not too expensive to create. We also need to continue to set up meetings with the client in order to make sure that we are making the project to fit exactly with her needs.

AVERY SCHUDA - Sep 15, 2024, 12:45 AM CDT

- What is the budget for the project?
    - How do we access the budget?
        - Makerspace account- 5,000 between the 3 projects, if we need something not at makerspace, send Dr. G what we want, she waldo has many toys and model making supplies in house (lot soft silicone)
- "I am interested in the creation of a 3D anatomically correct model of a cat or dog wing of ilium, trochanteric fossa and/or greater tubercle." If you had to rank the different bones, which would be the highest priority? "Dog shoulders; proximal humerus
    - Can just be the shoulder, has to have a way to be stable, whole shoulder joint and humerus (should rotate too); good to have the elbow and down
    - Prefer a right-handed model with right front leg
    - How many models of each type are desired?
    - If Bone marrow changes as subjects mature, would you like models that vary on maturation within the same bone marrow site?
- Access to CT scans for creation of STL files?
    - Already done, can pick what size we want, must pick what's most appropriate for general use (bigger is more expensive- pick average size dog, and up to clinicians)
    - Cortical bone as life like as possible
- Access to anatomic specimens and models, including skeletons, cadavers, text books, etc.
    - Access to model making mat
- What types of biopsy needles do students typically use to practice these procedures?
    - What exactly is the difference between a biopsy and aspiration? The needles and procedures are different.
        - Biopsy- sample is solid and spongy bone marrow
        - Aspiration- liquid part of bone marrow
    - Will we need access to materials like needles?
- What is the desired shelf life and life in service for the models?
    - Replaceable parts (ie: skin,) to make the incision
    - Skin will be handles and added by clinicians
    - Want bone to be the most life-like aspect
    - Run out of real estate on bone (96 student x3)

- How often will the models be used?
  - 98 x 3 for how much but often not specified
- Are there any preferences and restrictions on materials?
  - Life-like, but not overly expensive
- What size of dog or cat? Model size restrictions-
  - Average sized dog, around 30 lbs (beagle)
- Info about what is desired for the relevant soft tissue structures and skin
  - Created by clinician, can be added, but most important aspect is the skin
    - Normal attached with rubber band or clips, also may be able to just lay above
- Are we also fabricating the "bone marrow" that is being collected?

Download

Questions_for_First_Client_Meeting_1_.pdf (49.2 kB)

AVERY SCHUDA - Sep 15, 2024, 1:03 AM CDT

Content by: Anya Bergman, Avery Schuda

Present: Avery, Helene, Anya, Ellie, Ella, Dr. McLean Gunderson, Dr. Calico Schmidt, Dr. McKenzie Pellin, Dr. Karen Hershberger

Goals: Learn more about the bone marrow aspiration procedure by seeing it performed on a cadaver dog, and define project goals by talking to industry professionals

Conclusions/action items: Dr. Gunderson will be in contact to share some of the materials we went over as well as the contact for the three doctors we met with. Going forward they will all be able to advise our project. Need to follow up with Dr Gunderson to confirm if they want just one model fabricated this semester, or multiple. The meeting was very informative, and each team member got to practice the procedure on the cadaver dog, which will be helpful in getting the right feel for the model in the future.

2024/09/27 - Meeting for Follow Questions/CT Scans

AVERY SCHUDA - Sep 27, 2024, 2:55 PM CDT

Title: Meeting with Client to Discuss Follow Questions

Date: 9/27/2024

Content by: Avery Schuda

Present: Avery, Ella, Anya, Dr. Gundeson, Dr. Schmidt

Goals: Discuss follow up questions and prepare to get .stl files

Content:

- Dr Schmidt was able to test the three samples that Anya printed (ABS, PLA, PETG)
- ABS 3mm, PLA 2 and 3 mm were all good tests
    - PLA 3 mm was the most realistic
- PETG had too slippery of a surface finish and was too flexible
- PLA had the most realistic feel of the three plastics
- Having the foam under the plastic actually gave a very realistic feel
- Collected samples of bones to 3D scan in the Makerspace
    - If scanning doesn't work then we can access CT scans, but this is a slightly more difficult process
    - We were given a right side and left side limb to scan
- The Makerspace can add one group member to Dr Gunderson's funding for the team to access
- The team should produce one right side model, and give the Vet team a blueprint for assembling more models
- Start with the solid model and worry about the liquid bone marrow later
- They have some connections with researchers that could potentially give us really accurate values for material properties and forces

Conclusions/action items:

Send the details of the presentation time and location to Dr Gunderson, cc the rest of the Vet team and send them the presentation .pdf after the fact. Look into the process for 3D scanning the bones asap.

2024/09/12 - First Advisor Meeting

AVERY SCHUDA - Sep 12, 2024, 4:55 PM CDT

Title: First Advisor Meeting

Date: 09/12/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie, Professor Bartels

Goals: Discuss progress so far and expectations going forward

Content:

- Reach out to Dr P about activities section in progress report
- Discussed project goals and expectations

Conclusions/action items:

Reach out to Dr P about progress report. Meet with client to see cadaver dog and answer questions about the project.

2024/09/20 - Second Advisor meeting

ELLIE KOTHBAUER - Sep 20, 2024, 1:42 PM CDT

Title: Second advisor meeting

Date: 9/20/24

Content by: Ellie Kothbauer

Present: groupmates, advisor

Goals: To update the advisor and go through our project

Content:

- Discussed what was worked on in the previous week
- Talked about our goals for next week
- Discussed when the group is meeting next week
- Went over project questions as well as timeline
- Research materials and work on testing

Conclusions/action items: Follow up on what is a good way to quantify the feel of the puncture of the bone, and see if there is a way to test the types of materials.

2024/10/11 - Third Advisor Meeting

AVERY SCHUDA - Oct 11, 2024, 1:40 PM CDT

Title: Third Advisor Meeting

Date: 10/11/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ellie

Goals: Discuss the preliminary presentation and progress thus far

Content:

- More feel based, try to get a larger number of (~10
- In reports and presentations address why quantitative values don't apply
- Try to have Dr Pellin test and see if she has colleagues
- MTS won't apply
- Quantify the range of motion
- Articulate the problem, be quantitative, and use scientific journals as references
-

Conclusions/action items:

2024/11/08 - Fourth Advisor Meeting

AVERY SCHUDA - Nov 08, 2024, 1:52 PM CST

Title: Fourth Advisor Meeting

Date: 11/8/2024

Content by: Avery Schuda

Present: Avery, Ellie, Anya, Helene, Dr Bartels

Goals: Talk about our progress

Content:

- Ordered silicone
- Working on CAD model
- Figure out how to quantify procedure
- Test Makerspace print vs Dr Gunderson's colleague's printer
  - Tolerancing based on that - multiple models for printing
- Complete all fabrication before Thanksgiving
- Potentially meet with Jesse from Team Lab
  - Only to convert .stl to CAD file not to redesign

Conclusions/action items:

Ellie, Ella, and Anya to meet with Jesse at Team Lab Tuesday @3pm. Anya to email Dr. G to ask for pseudo skin or materials.

2024/11/22 - Fifth Advisor Meeting

AVERY SCHUDA - Nov 22, 2024, 1:43 PM CST

Title: Fifth Advisor Meeting

Date: 11/22/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Wrap up finishing touches with advisor

Content:

- Testing with Dr G and team to get quantitative or at least confirmation that feel is correct
- Feedback on prelim report today
- Working through SolidWorks kinks
- Continue working on deliverables

Conclusions/action items:

Continue working on project deliverables.

2024/09/18 - Team Meeting to Work on PDS

AVERY SCHUDA - Sep 18, 2024, 2:40 PM CDT

Title: Team Meeting to Work on PDS

Date: 9/18/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Collaborate as a team to complete the PDS and weekly progress report

Content:

I divided the PDS into 5 sections, each team member will be responsible for one section, then the whole team will be responsible for proofreading the entire document before submitting.

Section 1 - Avery

Section 2 - Helene

Section 3 - Ellie

Section 4 - Ella

Section 5 - Anya

Conclusions/action items:

AVERY SCHUDA - Sep 19, 2024, 1:07 AM CDT

Conclusions/action items: Team finished the meeting with the PDS almost fully completed, with a plan to add additional citations and proofread the document. Team members will individually complete their weekly goals in the progress report. Agreed on a deadline of 12pm on Thursday 9/19 to have all materials complete so that the PDS and 9/19 progress report can be submitted to Canvas/ uploaded to the website by Ella, and both documents can be sent in one email by Anya. Next meeting with advisor is Friday at 1:30 in Discovery.

2024/09/25 - Team Meeting to Complete Design Matrices

AVERY SCHUDA - Sep 25, 2024, 2:24 PM CDT

Title: Team Meeting to Complete Design Matrices

Date: 9/25/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Work as a team to create 1-2 design matrices for the removable component design and bone 3D printing materials

Content:

Conclusions/action items:

2024/10/2 - Team Meeting to Work on Preliminary Presentatio

AVERY SCHUDA - Oct 06, 2024, 4:07 PM CDT

Title: Team Meeting to Work on Preliminary Presentation

Date: 10/2/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ellie, Ella (second half)

Goals: Complete and practice for the preliminary presentation

Content:

- The team started by going over what we had worked on independently the previous week
- Assigned sections to present and finish up slide content for
  - Ellie - Intro, Problem Statement, Background
  - Helene - Competing designs, PDS
  - Anya - Materials choices, design matrix, and testing
  - Avery - Three preliminary designs, design matrix
  - Ella - Final design, future work, acknowledgments
- Practiced the presentation
- Talked about progress report, due Thursday at 5pm
- Set deadline for finishing up slide content, Thursday at midnight
  - PDF is due by 10 am Friday

Conclusions/action items:

The team worked to evenly divide the sections and collaborate on slide content. We will be bringing an Illinois needle, plastic swatches used for testing, and real bones given to us by Dr G as props to the presentation.

2024/10/06 - Team Meeting to Work on Preliminary Report

AVERY SCHUDA - Oct 06, 2024, 4:13 PM CDT

Title: Team Meeting to Work on Preliminary Report

Date: 10/6/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ellie

Goals: Divide sections of the report to complete and collaborate with team to work on the preliminary report

Content:

- Talked about how the presentation went, overall felt positively
- Talked about lack of feedback/grading, will address at next advisor meeting
- Divided sections of the report that each person will be responsible for completing
    - Ella - Abstract, Introduction, and make sure Table of Contents is updated before submitting
    - Ellie - Background + help where needed
    - Avery - Preliminary Designs, and Design Evaluation
    - Anya - Fabrication, Materials and Testing
    - Helene - Discussion and Conclusion

Conclusions/action items:

2024/10/16: Team Meeting to 3D Scan at the Makerspace

HELENE SCHROEDER - Oct 16, 2024, 2:58 PM CDT

Title: 3D Scanning Meeting Notes

Date: 10/16/2024

Content by: Helene Schroeder

Present: Helene, Avery, Anya, Ellie, Ella

Goals: To 3D scan the scapula, humerus, radius/ulna at the Makerspace.

Content:

Software used: Creaform

- Employee at Makerspace helped set up machine and scan the bones
- Bone placed on turn table with reflective dots
- A few reflective dots were placed on the scapula
- Creaform machine is like a laser camera gun
- Basically just turn table while getting all angles of the bone with the gun
- Different types of scans, ones in a single line vs. ones in a grid
- Set something to 0.2 mm
- We did less precise since we don't need the model to have extreme texture and be extremely complicated
    - Scanning was still very precise
- To scan underside, had to balance it then redo the process
- Align 2 scans (top and bottom) and then merge to make 1 full scan of the bone
- Evaluate scan, see if there is anything missing in the scans
    - If there is, do another scan
    - We had to add some play dough to make it stand up/stay in a specific position
    - Cut off section with play dough in scan and then align and merge it to the other merged scan.
- Redid this with all bones (employee only helped with 1 bone)

Conclusions/action items:

2024/10/27 - Team Meeting to Work on CAD Model and Order Materials

AVERY SCHUDA - Oct 27, 2024, 7:32 PM CDT

Title: Team Meeting to Work on CAD Model and Order Materials

Date: 10/27/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Discuss progress on the CAD model and order materials

Content:

- Several weeks upcoming that we will not have an advisor meeting
  - Nov 1st - Show and Tell
  - Nov 15th - Tong Lecture
  - Nov 29th - Thanksgiving
  - Dec 6th - Poster Presentation
- Silicone in general is mechanically accurate
  - Pourable silicone requires a mold
  - Sheets would be easier for fabrication
  - TPR may be cheaper alternative
  - PVC is also alternative, but toxic so not good
- Difficulty finding ball and socket joint from McMaster or Grainger
  - There are some with limited range of motion
  - Anya is ordering a couple
  - Ellie to create spreadsheet to track who is owed what at the end of the semester and distribute funds
- Difficulties removing mesh from .stl scan files
  - Avery, Helene, and Anya troubleshooting
  - https://www.reddit.com/r/SolidWorks/comments/faypab/convert_stl_to_a_solid_body
  - https://hawkridgesys.com/blog/a-step-by-step-guide-for-creating-a-smooth-surface-from-tessellated-scan-data-in-solidworks
  - https://www.youtube.com/watch?app=desktop&v=dD-wLDRCX6E&t=139
  - meshmaker?
- Universal Joint for Shoulder options:
  - Grainger U joint
  - ball sockets | McMaster-Carr
  - Amazon: Ball and socket joint
- Neoprene sheet for skin
  - 8698K51 MacMaster Carr
- Silicone for Muscle
  - Home Depot Silicone Sheet - Red
  - Rubber-Cal Silicone 1/4 in. x 36 in. x 12 in. Red/Orange Commercial Grade 60A Rubber Sheet 20-116-0250-36-012 - The Home Depot
  - Cheaper
  - $ 13 . 44 /sq. ft. Silicone 1/4 in. x 36 in. x 72 in. Red/Orange Commercial Grade 60A Rubber Sheet
  - 1/8 in - 12x36
  - https://www.mcmaster.com/products/rubber/material~plastic-1/foam~/resilient-polyurethane-foam-sheets-and-strips/ - Resilient Polyurethane foam sheets and strips : similar to muscle

- TPR: good option

Conclusions/action items:

Meet on Wednesday at 2:25 to 3D print. Anya is taking charge of 3D printing, anyone else who is available to come will. Meet after 5:25 on Thursday to go over pitch.

2024/10/31 - Team Meeting to Prep for Show and Tell

AVERY SCHUDA - Nov 02, 2024, 9:01 PM CDT

Title: Team Meeting to Prep for Show and Tell

Date: 10/31/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Prepare for the Show and Tell

Content:

Group 1 (rotate, sit):
Avery
Ella

Group 2 (sit, rotate):
Helene
Ellie
Anya

60 sec pitch:
Hook: Every vet student has had to practice on a cadaver at least once. However, for the procedure of bone marrow aspiration, cadavers are not ideal for this purpose as bone marrow dies off and a bone can only handle so many piercings.

Hello, we are the veterinary bone marrow aspiration group and we are making a model of the proximal humerus of a dog to allow veterinary students to practice aspiration. Bone marrow aspiration is a procedure done on both humans and animals that takes a sample from the bone marrow. In dogs, the primary sites of aspiration are the trochanteric fossa, iliac crest, and proximal humerus. It is important for veterinary students to practice the procedure before they perform it on animals. Cadavers are usually used for this purpose; however, the bone marrow in cadavers typically dies off before a student performs bone marrow aspiration on it. This is why we are creating a model. Our model will use CAD scans of the bones of a forelimb of a dog, material that mimics muscle, pseudo-skin provided by the Vet School. There will be a cavity in the humerus for pseudo-bone marrow. There will also be a replaceable component on proximal humerus that can be replaced after 5 uses of the needle.

Video example (starts @ 4:34): https://youtu.be/-alOQRTbgPw?si=Y1D3kkSDwuCH8mZj

Questions:

- how to remove STL mesh from file, make it less messy (no triangles)
- can we make file smooth/be able to edit it (make 1 solid piece)
- Is there another software we should use?
- how to attach replaceable piece to model for it to be used
- how to make ball and socket joint
- how to attach humerus print to radius/ulna together
- how to attach muscle and skin to model; to frame??

Props:

- 3D printed humerus
- Illinois needle
- real bones
- SW file of humerus
- optional: video of BMA

Conclusions/action items:

The team will present the following pitch at the Show and Tell to get feedback and help on our project. The main issue that we want to emphasize is the .stl to workable CAD file to see if anyone has a solution.

2024/11/20: Team Meeting for Fabrication

HELENE SCHROEDER - Nov 21, 2024, 2:49 PM CST

Title: Team Meeting to Fabricate

Date: 11/20/2024

Content by: Helene Schroeder

Present: Helene, Avery, Ellie, Anya, Ella

Goals: To work on assembling and fabricating the model and be ready to make changes when necessary. We will also divide work for the poster and the final report to work on during Thanksgiving break.

Content:

gathered all materials

- silicone muscle
- silicone/neoprene skin
- 3D printed humerus WITH section cut out
- ball and socket joint
- magnets
- twist clasps
- L joint
- rubber feet
- glue
- wooden base

divide and conquer to work on different things

- avery anya: update SW files of humerus
  - make cutout piece hollow and longer
  - make cutout larger
  - make scapula flat
  - create way to attach ball and socket joint
- ella: work on base plate
- ellie and helene: work on deliverables and brainstorming (help where needed)

ideas for stuff to do in future:

- test out Dr. G's printer to see what changes need to be made to file for her to easily reprint it
  - requires us to meet with her
- test replaceable piece by printing out multiple (maybe 5) and bring them to Dr. G and ideally her team and have them stab the piece to see what it feels like
  - find way to add styrofoam into it?
    - make cutout hollow at bottom (makes it easier to print)
- scale up bones to make model slightly larger?
  - to hold more BM
  - to make it easier to work with when doing procedure

Conclusions/action items:

This meeting has been very productive. We were able to work out a lot of details that we think need refining, now we just have to put those ideas into motion and continue fabricating on Thursday (maybe Friday) so as to not overwhelm ourselves over Thanksgiving break. We also successfully divided up the poster presentation to work on over break. Ella successfully made the base plate with rubber feet to prevent sliding. Anya and Avery made a lot of progress on updating the SW files. Me and Ellie traveled around and helped where needed.

In our next meeting we need to continue fabrication, create testing protocols, schedule testing, and work on the poster if we have time.

2024/11/20 - Team Meeting to Work on Fabrication

AVERY SCHUDA - Nov 21, 2024, 12:29 PM CST

Title: Team Meeting to Work on Fabrication

Date: 11/20/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Work on fabricating the final model, divide up sections to work on final deliverables.

Content:

- Divided up sections to work on for final poster (these sections are flexible and are subject to change to make sure each group member is able to present for an approximately equal amount of time and teammates will collaborate to help with other sections so that the poster has a consistent flow/voice)
  - person 1: problem statement, part of background - Ella
  - person 2: part of motivation, design specs- Ellie
  - person 3: modeling and prototyping- Anya
  - person 4: testing - Helene
  - person 5: final model, future work - Avery
- Pseudo skin recieved from Dr G (Ellie)
  - Discussed attaching it in a sleeve that can be slid down
- Received silicone sheets (Ellie)
  - Concerns with material being too thick so that student cannot accurately palpate and feel the underlying bone structure
  - Potentially order similar silicone or similar material from McMaster (Avery/Anya)
- Received U-joint (Anya)
  - Will work, but potentially small if bones need to be scaled up
  - Potentially order alternative from McMaster (Avery/Anya)
- Received anti-slip rubber feet, fasteners, magnets, and L-brackets (Avery)
- Initial CAD complete (Avery)
- 3D printed iteration of final design (Anya)
  - Removable component is currently press fit and is small
    - Redesign slightly larger with tab to ensure correct orientation (Avery)
    - Additional discussion of scaling the whole model up because capsule only holds about 1.9 mL (enough for 1-3 aspirations) or finding an online humerus
  - Scapula only printed one layer
    - Need to extrude off the bottom to hold at angle on constructed base (Avery)
  - Scaling issues with forelimb, very big when downloaded scan
    - Looking into solutions (Avery/Anya) - also need to mate together for final model
  - Create spaces for joint to attach on scapula/forelimb (Avery/Anya)
- Fabricated base platform for model with anti-slip feet (Ella/Helene)

    - Purchased Masonite board as base (Ella)

- Send receipts to Ellie to keep track of purchases
- Want to have model complete by Tuesday 11/26 at the latest
- Reach out to Dr Gunderson and team to schedule testing on Monday December 2/Tuesday December 3rd
- Have poster completed and print by evening Wednesday December 4th

Conclusions/action items:

Meet again Thursday evening (5:25 pm) to continue working. Avery/Anya continue to work on CAD so model can be reprinted. Potentially order thin silicone and alternative joint from McMaster. Work on poster and final report.

2024/11/21 - Team Meeting to 3D Print and Brainstorm Final Fabrication Steps

AVERY SCHUDA - Nov 21, 2024, 8:16 PM CST

Title: Team Meeting to 3D Print and Brainstorm Final Fabrication Steps

Date: 11/21/2024

Content by: Avery Schuda

Present: Avery, Helene, and Ella

Goals: 3D print next iteration of humerus and brainstorm final fabrication steps

Content:

- Ordered Buna-N from McMaster in 1/32" and 1/16" for muscle
- Ordered ball and socket joint from McMaster
- Ordered ball and socket joints from Amazon
- Ordered faux fur from Amazon
- Printed Humerus and two capsules

Conclusions/action items:

Print next iteration of CAD tomorrow before meeting

2024/12/02: Team Meeting to Fabricate

HELENE SCHROEDER - Dec 02, 2024, 7:00 PM CST

Title: Team Meeting to Print and Finish Fabrication before testing

Date: 12/2/24

Content by: Helene Schroeder

Present: Helene, Avery, Ella, Anya

Goals: To make final adjustments on the CAD models and begin printing. Also to work on details in the testing protocol and final report.

Content:

- avery and anya worked on the CAD models
  - changing size of replacable piece (scale down so as to not get it stuck in the bone)
  - make back side of piece open
  - work on joint attachment for different (more rotateable) joint
- helene worked on testing protocol for tomorrow's testing at the vet school
  - what materials needed
  - what is being tested
  - how to make it quantitative
  - find statistical signifcance
  - GET NEW NEEDLE (with stylet)
- ella worked on the final report and a lot of other things
  - commenting on the report where things need to be fixed

to do:

- print final scapula
- print final humerus
- connect humerus with forelimb (either printed together or separately)
- attach scapula and humerus by ball and socket joint (screws and washers and glue)
- test with dr. g
- attach muscle to model
- create skin sleeve
- drill into base and attach L brackets for scapula attachment
- attach fur to base (velcro or glue?)
- attach picture frame tabs to humerus
- finish expense spreadsheet
  - calculate cost for the model (only final iteration-joint, fabric, masonite, brackets, 3D printed pieces)
    - FRACTIONS OF THESE
- poster done by WEDNESDAY at NOON
- report done by TUESDAY

Conclusions/action items:

This was a very productive meeting. We have made a to do list to help organize. We also have started some prints that will be useful for testing and the final design. We have also created a testing protocol to be used tomorrow during testing.

Testing will be done at 4 PM on Tuesday at the vet school with me, Anya, and Ella.

The poster will be completed by Wednesday at noon in which me and Avery will go print it. After that, we will meet up with Ellie to work on finishing fabrication.

On Thursday we will meet at 7:30 PM to practice the poster presentation. Everyone should come to the meeting with a general idea of what they will be saying.

2024/12/08 - Team Meeting to Work on Final Report

AVERY SCHUDA - Dec 10, 2024, 12:17 PM CST

Title: Team Meeting to Work on Final Report

Date: 12/8/24

Content by: Avery Schuda

Present: Avery, Helene, Ella, Ellie, Anya

Goals: Work to complete the final report

Content:

Google doc is filled with comments on what to fix. Team members are will not be assigned individual sections to work on but are expected to work on what they can from the report until it is complete. Ellie emailed Dr G to obtain payment and will disperse funds once received to Anya and Avery. Avery emailed client eval form to Dr P and Dr Bartels, we believe the project could be continued if Dr G wanted to because she has a lot of great ideas for add ons/updates to the current design. Avery and Helene would want to find a project that had more biomaterials involvement for BME 301, however.

Conclusions/action items:

Complete and report and notebook by Tuesday night. Feedback Fruits reflection from poster session due Wednesday @11:59 pm, as are individual and peer reflections. Need to schedule time for Dr G to pick up poster and deliverables, and send project files via Dropbox.

2024/09/19 - Product Design Specifications

AVERY SCHUDA - Oct 09, 2024, 11:50 PM CDT

Title: Product Design Specifications (PDS)

Date: 9/19/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Define the PDS based on client requirements and research

Content:

Veterinary Bone Marrow Aspirate Model

Product Design Specifications (PDS)

BME 200/300

19 September 2024

Client: Dr. McLean Gunderson

University of Wisconsin–Madison

School of Veterinary Medicine

Advisor: Dr. Randy Bartels

University of Wisconsin–Madison

Department of Biomedical Engineering

Section 313

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Function

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. Currently no veterinary bone aspiration models exist for students to practice on, requiring the use of cadaver dogs. Cadavers can only be used for about 5-10 insertions of the Illinois bone marrow biopsy needle per site, but does not contain live bone marrow that can be collected. This project aims to create a low-cost 3D anatomically correct model of the humerus with relevant soft tissue structures, mimics the consistency and structure of the bones, and allows for insertion of "bone marrow" for collection, allowing veterinary students to practice the skill of bone marrow aspiration.

Client requirements

- Functional model that allows the client to replace the simulated bone marrow and proximal humerus insertion site every 5 procedures performed.
- The model should include the right scapula, shoulder joint, humerus, elbow, proximal radius and ulna, and surrounding muscles and soft tissues. The shoulder joint should be fully articulable, while the elbow should be fixed in a flexed position.
- The client will assist with the fabrication of the skin and bone marrow materials. The model should include a way to attach the skin and insert the bone marrow into the humerus.
- The proximal humerus will include a removable section that is replaced every 5 procedures and filled with the bone marrow solution. Muscles will be replaced every 20 punctures.

Design requirements

1. **Physical and Operational Characteristics**
    1. **Performance Requirements**
        - The model will be an anatomically correct proximal scapula, humerus, shoulder joint, and elbow joint of a 13.6 kilogram (kg) dog. The shoulder joint will replicate a ball and socket joint, and the elbow joint will be fixed in a 120 degree angle.
        - A small, removable section of the humerus will be replaced every 5 uses. This section will be the flat surface on the humerus in which the bone marrow aspiration needle penetrates.
        - The muscle material covering the bone will be replaced every 20 uses.
        - The model will be held stably to the table to prevent movement during the procedure.
    2. **Safety**
        - The model will come equipped with safety instructions that detail steps of use, hazards, and proper sanitation.
        - There will be no live tissue components that can cause harmful exposures.
        - The procedure on the model should be done with proper technique so as to not cause injury by the Illinois needle.
        - The replaceable components of the model should not be used more than 20 times for the muscle and 5 times for the humerus piece.
    3. **Accuracy and Reliability**
        - The punctured humerus will only be used 5 times before it needs replacement so that students do not repeatedly enter the same puncture.
        - The muscle covering the bone will be used 20 times before it needs replacement for the same reason as the humerus, but since it is a softer material it will receive less damage.

- The model should be similar in size, shape, and feel of a 13.6 kg dog.
- The model should be able to aspirate 0.5-2 mL of bone marrow [1].

4. **Life in Service**
    - The model must withstand 5 years of in-class use with components that are replaced as needed.
    - The punctured section of the humerus will be replaced every 5 uses, and the muscle will be replaced every 20 uses.
    - The model will be used for multiple semesters of 96 students in which each student practices the procedure 3 times. Each practice procedure will take 3 minutes to complete.
    - The model will be able to withstand the moderate force used to puncture the humerus with the Illinois needle.
5. **Shelf Life**
    - The model should be kept in a cool environment, away from direct sunlight.
    - If stored in the proper conditions and without the “bone marrow” component, the model will last 10 to 12 years.
6. **Operating Environment**
    - The model will be used in a simulated clinical setting during practice procedures.
    - The device will be used in a standard indoor environment with temperature (20-25 ℃) and humidity (40-60 %) [2].
    - This model is designed for UW-Madison Veterinary students, and should be used for learning purposes only.
7. **Ergonomics**
    - The force used to puncture the bone should be a firm pressure similar to that on a real animal [3].
    - When not in use, the model should be handled delicately.
    - The Illinois needle should only be inserted within the replaceable region of the humerus.
8. **Size**
    - The model should be similar in size to a 13.6 kg dog, with a proximal humerus that is 14-15 cm [4].
    - With the added elbow and shoulder joint, the total length of the model will be 25 cm.
    - The section of humerus that is being replaced is a 3x3 cm section. The soft tissue encasing the bone can be removed to access the bone for replacement.
9. **Weight**
    - The weight of the model will accurately represent the weight of the anatomical structures used in the model. This will be no more than 2 kg.
10. **Materials**
    - The model can be split into four different categories of materials based on the anatomy of a dog:
        - The materials of the skin, as provided by the School of Veterinary Medicine, will be composed of mesh fabric fused to silicone. This material imitates the extent of the skin’s elasticity.

- The muscle of the model should mimic the feeling of penetrating the muscle on the proximal humerus. The muscle covering over the humerus has little thickness and thus should not be difficult to pierce. This is the quality that makes the proximal humerus favorable for bone marrow aspiration [5]
- The density of the model's proximal humerus should be roughly the same density as real dog bones. Thus, a material mimicking the density of a dog's humerus is preferred, which is roughly 27.1 µg/mg for a dry bone [6]. The material should respond to the clockwise and counterclockwise rotations of the Illinois needle used for veterinary bone marrow aspirations without cracking [7].
- The bone marrow will be fabricated by the School of Veterinary Medicine. The bone marrow material will be a thicker liquid with small bone particles mixed in.

11. **Aesthetics, Appearance, and Finish**
    - It is important for the model to be anatomically correct and feel like a real dog to the user.
    - The appearance of the model, while not as important as the materials, should at least be concise and neat in its presentation. The model should prioritize the feeling of performing bone marrow aspiration rather than the appearance of a real dog.

2. **Production Characteristics**
    1. Quantity:
        - There will be one main model with replaceable parts. Replaceable parts will be provided upon the full delivery of the product; subsequent replaceable parts may be able to be fabricated with 3-D printing files.
    2. Target Product Cost:
        - This model is intended to be a low cost solution and thus would preferably be under the $1,600 budget. A portion of the budget is intended for the replaceable components of the model.

3. **Miscellaneous**
    1. **Standards and Specifications**:
        - There are no standards that this model must meet in order to be used, as it is not coming into contact with patients, and is a model for practicing use only.
    2. Customer:
        - The customer would like a model that is made for right handed users, specifically a model of the right proximal humerus, extending from the scapula to just below the elbow.
            - The shoulder must move as a typical ball and socket joint, and the client would like the movement to expose the humerus from the muscle and skin that is around it when it is relaxed.
            - The client would like the elbow to be fixed at 120 degrees.
        - The client would like a model that can be refilled with a fluid that mimics bone marrow.
        - The cortical bone should be physiologically accurate.
        - It is important that the aspiration site on the humerus is flat and rough compared to the rest of the bone, so that the needle will have more traction.
    3. **Patient-related concerns:**

- As this model will not have any direct contact with patients, there is no concern of saving and protecting patient data.
- A concern that this model might raise is that it must be anatomically accurate. This is difficult because the procedure will vary depending on the animal, its maturation, and its weight.

4. Competition:

- There are no models that currently exist for a veterinary bone marrow aspiration procedure, however cadavers are regularly used despite their inaccuracies. The problem with cadaver models is that the bone marrow has dried up and cannot be extracted using a needle. Another issue with using cadavers, is they have a shorter shelf life, and they can really only take 4-5 punctures per site before the bone has degraded and is no longer an accurate representation of the procedure.
- There are models for human bone marrow aspirations such as Bonnie Bone marrow biopsy skills trainer, however this is not accurate to dogs, and a bone marrow biopsy is a different procedure targeting the solid aspects of bone marrow. This model is also extremely costly [8].
- Another model of bone marrow aspiration is . This is also an expensive model and despite having fluid within the model for practice the targeted area is a human hip, which is very different from the aspiration site on most animals (the right proximal humerus) [9].

References:

[1] E. Rudloff, “Bone Marrow Sampling,” VetMedux, Clinician’s Brief, May 2013. Accessed: Sep. 18, 2024. [Online]. Available: https://assets.ctfassets.net/4dmg3l1sxd6g/741fx8rc7yep3nVCUD7Cit/947077cff954178fe55849388aa85318/bone-marrow-sampling-14176-article.pdf

[2] Park HJ, Lee SG, Oh JS, Nam M, Barrett S, Lee S, Hwang W. The effects of indoor temperature and humidity on local transmission of COVID-19 and how it relates to global trends. PLoS One. 2022 Aug 10;17(8):e0271760. doi: 10.1371/journal.pone.0271760. PMID: 35947557; PMCID: PMC9365153.

[3] Rindy, Lucas J. “Bone Marrow Aspiration and Biopsy.” *StatPearls [Internet].*, U.S. National Library of Medicine, 29 May 2023, www.ncbi.nlm.nih.gov/books/NBK559232/. (Accessed Sept. 9 2024)

[4] E. J. Smith, D. J. Marcellin-Little, O. L. A. Harrysson, and E. H. Griffith, “Three-dimensional assessment of curvature, torsion, and canal flare index of the humerus of skeletally mature nonchondrodystrophic dogs,” *American Journal of Veterinary Research*, vol. 78, no. 10, pp. 1140–1149, Oct. 2017, doi: https://doi.org/10.2460/ajvr.78.10.1140.

[5] Cornell University College of Veterinary Medicine. "Indications/Methods." ECLINPATH. Accessed: Sept 10, 2024. [Online]. Available: https://eclinpath.com/cytology/bone-marrow/indications-methods/

[6] Aerssens et al. “Interspecies Differences in Bone Composition, Density, and Quality: Potential Implications for *in Vivo* Bone Research,” *academic.oup.com*. https://academic.oup.com/endo/article/139/2/663/2987138. (Accessed Sept. 9 2024)

[7] Grindem, Carol B. "Bone Marrow Biopsy and Evaluation." Veterinary Clinics of North America: Small Animal Practice. vol. 19, no. 4, pp. 669-696, 1989. Accessed: Sept 10, 2024. doi: 10.1016/S0195-5616(89)50078-0. [Online]. Available: https://www.sciencedirect.com/science/article/pii/S0195561689500780

[8]"Bonnie Bone Marrow Biopsy Skills Trainer," *Anatomy Warehouse*, 2024. https://anatomywarehouse.com/bonnie-bone-marrow-biopsy-skills-trainer-with-case-and-set-of-5-illiac-crest-inserts-a-106431 (accessed Sep. 19, 2024).

[9]"Anatomy Lab Adult Bone Marrow Aspiration Model," *Anatomy Warehouse*, 2024. https://anatomywarehouse.com/the-anatomy-lab-adult-bone-marrow-aspiration-model-a-106774 (accessed Sep. 19, 2024).

AVERY SCHUDA - Dec 11, 2024, 2:50 PM CST

Updated 12/11/2024

Product Design Specifications (PDS)

Function

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. Currently no veterinary bone aspiration models exist for students to practice on, requiring the use of cadaver dogs. Cadavers can only be used for about 5-10 insertions of the Illinois bone marrow biopsy needle per site, but does not contain live bone marrow that can be collected. This project aims to create a low-cost 3D anatomically correct model of the humerus with relevant soft tissue structures, mimics the consistency and structure of the bones, and allows for insertion of "bone marrow" for collection, allowing veterinary students to practice the skill of bone marrow aspiration.

Client requirements

- Functional model that allows the client to replace the simulated bone marrow and proximal humerus insertion site every 5 procedures performed.
- The model should include the right scapula, shoulder joint, humerus, elbow, proximal radius and ulna, and surrounding muscles and soft tissues. The shoulder joint should be fully articulable, while the elbow should be fixed in a flexed position.
- The client will assist with the fabrication of the skin and bone marrow materials. The model should include a way to attach the skin and insert the bone marrow into the humerus.
- The proximal humerus will include a removable section that is replaced every 5 procedures and may be filled with a bone marrow liquid. The muscle will be replaced every 5 punctures with the removable section.

Design requirements

1. **Physical and Operational Characteristics**
    a. **Performance Requirements**
        - The model will be an anatomically correct proximal scapula, humerus, shoulder joint, and elbow joint of a 13.6 kilogram (kg) dog. The shoulder joint will replicate a ball and socket joint, and the elbow joint will be fixed in a 120 degree angle.
        - A small, removable section of the humerus will be replaced every 5 uses. This section will be the flat surface on the humerus in which the bone marrow aspiration needle penetrates.
        - The silicone muscle covering the bone will be replaced as the client determines appropriate; about every 5 procedures.
        - The model will be mounted to a baseplate to prevent movement during the procedure.

    b. **Safety**

- The model will come equipped with safety instructions that detail steps of use, hazards, and proper sanitation.
- There will be no live tissue components that can cause harmful exposures.
- The procedure on the model should be done with proper technique so as to not cause injury by the Illinois needle.
- The replaceable components of the model should not be used more than 5 times so as to prevent injury.

c. **Accuracy and Reliability**
- The punctured humerus will only be used 5 times before it needs replacement so that students do not repeatedly enter the same puncture.
- The muscle covering the bone will be used about 5 times before it needs replacement for the same reason as the humerus.
- The model should be similar in size, shape, and feel of a 13.6 kg dog.
- The model should be able to aspirate 0.5-2 mL of bone marrow [1].

d. **Life in Service**
- The model must withstand 5 years of in-class use with components that are replaced as needed.
- The punctured section of the humerus, the piece and the muscle, will be replaced every 5 uses.
- The model will be used for multiple semesters of 96 students in which each student practices the procedure 3 times. Each practice procedure will take 3 minutes to complete.
- The model will be able to withstand the moderate force used to puncture the humerus with the Illinois needle.

e. **Shelf Life**
- The model should be kept in a cool environment, away from direct sunlight.
- If stored in the proper conditions and without the “bone marrow” component, the model will last 10 to 12 years.

f. **Operating Environmen**t
- The model will be used in a simulated clinical setting during practice procedures.
- The device will be used in a standard indoor environment with temperature (20-25 ℃) and humidity (40-60 %) [2].
- This model is designed for UW-Madison Veterinary students, and should be used for learning purposes only.

g. **Ergonomics**
- The force used to puncture the bone should be a firm pressure similar to that on a real animal [3].
- When not in use, the model should be handled delicately.
- The Illinois needle should only be inserted within the replaceable region of the humerus.

h. **Size**
- The model should be similar in size to a 13.6 kg dog, with a proximal humerus that is 14-15 cm [4].
- With the added elbow and shoulder joint, the total length of the model will be 25 cm.
- The section of humerus that is being replaced is a 3x3 cm section. The soft tissue encasing the bone can be removed to access the bone for replacement.

i. **Weight**
- The weight of the model will accurately represent the weight of the anatomical structures used in the model. This will be no more than 2 kg.

j. **Materials**
- The model can be split into four different categories of materials based on the anatomy of a dog:
  - The materials of the skin, as provided by the School of Veterinary Medicine, will be composed of mesh fabric fused to silicone. This material imitates the

extent of the skin's elasticity.
    - The muscle of the model should mimic the feeling of penetrating the muscle on the proximal humerus. The muscle covering over the humerus has little thickness and thus should not be difficult to pierce. This is the quality that makes the proximal humerus favorable for bone marrow aspiration [5]
    - The density of the model's proximal humerus should be roughly the same density as real dog bones. Thus, a material mimicking the density of a dog's humerus is preferred, which is roughly 27.1 µg/mg for a dry bone [6]. The material should respond to the clockwise and counterclockwise rotations of the Illinois needle used for veterinary bone marrow aspirations without cracking [7].
    - The bone marrow will be fabricated by the School of Veterinary Medicine. The bone marrow material will be a thicker liquid with small bone particles mixed in.

k. **Aesthetics, Appearance, and Finish**
  - It is important for the model to be anatomically correct and feel like a real dog to the user.
  - The appearance of the model, while not as important as the materials, should at least be concise and neat in its presentation. The model should prioritize the feeling of performing bone marrow aspiration rather than the appearance of a real dog.

2. **Production Characteristics**

a. Quantity:
  - There will be one main model with replaceable parts. Replaceable parts will be provided upon the full delivery of the product; subsequent replaceable parts may be able to be fabricated with 3D printing files.

b. Target Product Cost:
  - This model is intended to be a low cost solution and thus would preferably be under the $1,600 budget. A portion of the budget is intended for the replaceable components of the model.

3. **Miscellaneous**

a. **Standards and Specifications**:
  - There are no relevant codes or standards that this model must meet in order to be used, as it is not coming into contact with patients, and is a model for practicing use only.
  - No formal specifications exist for the bone marrow aspiration either on live or cadaver animals, or for the creation of a model mimicking the procedure.

b. Customer:
  - The customer would like a model that is made for right handed users, specifically a model of the right proximal humerus, extending from the scapula to just below the elbow.
    - The shoulder must move as a typical ball and socket joint, and the client would like the movement to expose the humerus from the muscle and skin that is around it when it is relaxed.
    - The client would like the elbow to be fixed at 120 degrees.
  - The client would like a model that can be refilled with a fluid that mimics bone marrow.
  - The cortical bone should be physiologically accurate.
  - It is important that the aspiration site on the humerus is flat and rough compared to the rest of the bone, so that the needle will have more traction.

c. **Patient-related concerns:**
  - As this model will not have any direct contact with patients, there is no concern of saving and protecting patient data.
  - A concern that this model might raise is that it must be anatomically accurate. This is difficult because the procedure will vary depending on the animal, its maturation, and its weight.

d. Competition:

- There are no models that currently exist for a veterinary bone marrow aspiration procedure, however cadavers are regularly used despite their inaccuracies. The problem with cadaver models is that the bone marrow has dried up and cannot be extracted using a needle. Another issue with using cadavers, is they have a shorter shelf life, and they can really only take 4-5 punctures per site before the bone has degraded and is no longer an accurate representation of the procedure.
- There are models for human bone marrow aspirations such as Bonnie Bone Marrow Biopsy Skills Trainer, however this is not accurate to dogs, and a bone marrow biopsy is a different procedure targeting the solid aspects of bone marrow. This model is also extremely costly [8].
- Another model of bone marrow aspiration is the Anatomy Lab Adult Bone Marrow Aspiration Model. This is also an expensive model and despite having fluid within the model for practice the targeted area is a human hip, which is very different from the aspiration site on most animals (the right proximal humerus) [9].

PDS References:

[1] E. Rudloff, “Bone Marrow Sampling,” VetMedux, Clinician’s Brief, May 2013. Accessed: Sep. 18, 2024. [Online]. Available: https://assets.ctfassets.net/4dmg3l1sxd6g/741fx8rc7yep3nVCUD7Cit/947077cff954178fe55849388aa85318/bone-marrow-sampling-14176-article.pdf

[2] Park HJ, Lee SG, Oh JS, Nam M, Barrett S, Lee S, Hwang W. The effects of indoor temperature and humidity on local transmission of COVID-19 and how it relates to global trends. PLoS One. 2022 Aug 10;17(8):e0271760. doi: 10.1371/journal.pone.0271760. PMID: 35947557; PMCID: PMC9365153.

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[9] “Anatomy Lab Adult Bone Marrow Aspiration Model,” *Anatomy Warehouse*, 2024. https://anatomywarehouse.com/the-anatomy-lab-adult-bone-marrow-aspiration-model-a-106774 (accessed Sep. 19, 2024).

2024/09/26 - Preliminary Design Matrices

AVERY SCHUDA - Oct 09, 2024, 11:50 PM CDT

Title: Preliminary Design Matrices

Date: 9/26/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie

Goals: Define the design criteria and score preliminary design to help determine next steps for testing and fabrication of the final design

Content:

Table 1: **Material of Replaceable Component Design Matrix:**

	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**	

Criteria Definitions:

Mechanical Accuracy: Mechanical accuracy refers to how similarly the printed plastic can mimic the mechanical properties of native bone tissue. A plastic with a tensile strength comparable to bone (67 MPa at the least) and similar density would score highest. Mechanical accuracy is weighted highest at a 25 because it is important that the bone model accurately represents native bone for practicing the procedure.

Strength: Strength refers to how well the material holds up against the needle. The bone model needs to be able to be punctured at least five times before the section of the proximal humerus is replaced, a material that is too brittle will not stand up to multiple punctures. A material that is not brittle would score highest. Strength is weighted at a 20 because it is important that the material can stand up to five punctures to increase the usability of the model.

Ease of Fabrication: Ease of fabrication refers to how easily and quickly the material can be printed. A material that prints at a high quality with minimal modification to print settings to make it accessible for Veterinary School staff to quickly print replacement components is desired. Ease of fabrication is weighted at a 20 because the material must be feasible for someone not previously familiar 3D printers to work with.

Texture: Texture refers to how similar the material is to the feeling of native bone, accounting for the adherence between layers of the print, flexibility, and interaction with the needle. A material with similar flexibility and surface finish to bone is desired without need for additional post print processing. Texture is weighted at a 15 because the surface finish should be similar to bone to best mimic the procedure.

Disposability: Disposability refers to how sustainable the material is and the ease of disposing of the replacement components. Since the proximal humerus is replaced every five punctures, a lot of plastic waste may be created. A material that is biodegradable and/or recyclable would score highest in this category. Disposability is weighted at a 10 because it is important that the waste material from the model can be disposed of in a sustainable manner.

Cost: Cost refers to how much the 3D printer filament typically costs per spool. Since the client will be printing a large volume of replacement components, it is important to keep the ongoing cost of material low. A filament that is low in cost per spool would score the highest. Cost is weighted at a 10 because the client desires a low cost prototype solution.

Materials Design Matrix Summary:

Polylactic acid (PLA) scored the highest in the categories of mechanical accuracy, ease of fabrication, texture, disposability, and cost. It scored the highest in mechanical accuracy compared to Acrylonitrile butadiene styrene (ABS) and Polyethylene terephthalate glycol (PETG) because of its ability to mimic the characteristics of native bone tissue in tensile strength. PLA is also cheaper than both ABS and PETG and takes the least amount of time to fabricate in a 3-D printer. Given the versatility of PLA structures and the qualities of the material itself, it scored the highest in the category of texture due to the range of patterns, textures, and layers it can be used to print.

ABS scored the highest in the category of strength due to its capacity to have a large tensile strength. However, it scored lower than PLA for mechanical accuracy because it may not accurately represent native bone tissue because its tensile strength value is higher than that of bone. This would also contribute to a model made of ABS to be more rigid than bone tissue, thus being less accurate than PLA in terms of tensile strength and elastic modulus. Compared to both PETG and PLA, ABS takes the longest to fabricate in a 3-D printer. Additionally, the disposability of ABS was rated very low out of all the material options because it is not biodegradable and can only be recycled a few times before it’s rendered unusable. Considering the frequency with which the replaceable component will need to be replaced, this is an important factor to consider. It also costs slightly more than PLA, but lower than PETG.

PETG was rated the lowest overall based on our grading criteria. It scored the lowest in mechanical accuracy because the highest tensile strength it can reach is lower than that of bone; it is also more elastic than PLA or ABS. PETG has the ability to be more brittle than PLA or ABS if printed incorrectly, and may be slightly deformed upon repeated use because of its low tensile strength. A lower tensile strength would not mimic the feeling of native bone; thus PETG scored the lowest in Texture. While PETG does not print as fast as PLA typically does, it prints faster than ABS and was thus scored higher in ease of fabrication. While not biodegradable like PLA, PETG can be recycled significantly more times than ABS, and scored higher than ABS for disposability. PETG was rated the lowest for cost because it is the most expensive material to buy out of the three options.

In conclusion, because PLA was given the highest overall score, it is the material that has been chosen to fabricate the replaceable component in our veterinary bone marrow aspiration model.

Table 2: **Replaceable Component Design Matrix:**

	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**	

**Drawings of the designs are being worked on and will be put into the matrix for the report/presentation*

Criteria Definitions:

Joint Interference: Joint interference refers to how easily replaceable the removable component is with respect to the shoulder joint, while still allowing the joint to be articulable. The section of the proximal humerus will need to be replaced frequently, so design that does not require any involvement of the shoulder joint to be replaced would score the highest. Joint interference is weighted at a 20 because the component must be easily replaceable without much interference with the shoulder joint.

Ease of Fabrication: Ease of fabrication refers to how easy the design is to model, 3-D print, and assemble. This includes the time it takes for the 3-D printer to fabricate the design, which is influenced by the size, density, and detail of the replaceable component. It is also important that the design can be replicated on different 3-D printers, and methods with a reduced need for exact accuracy with printing would score higher. Ease of fabrication is weighted at a 20 because it is important that the full design is feasible to fabricate within the semester and that the replaceable components are able to be easily fabricated by the client.

Ease of Use: Ease of use refers to how easily the components can be replaced and how easy it is for the Veterinary student to interact with the model in the same way they would a patient. A design that has easier access to replace bone marrow fluid and the section of the proximal humerus would score higher. Ease of use is weighted at a 15 because it is important that the user experience is simplified as much as possible.

Durability: Durability refers to the expected life of the model, taking into account chosen materials and how replaceable components interact with the rest of the model. A simple design for the replaceable parts that limits wear and tear on the surrounding surfaces is desired so that the non replaceable components will last for a period of 5 years. Durability is weighted at a 15 because it is important that the design maximizes the lifecycle of the product.

Bone Marrow Access: Bone marrow access refers to how easily the client is able to refill the model with bone marrow between each procedure. This includes difficulty in placing the bone marrow within, as well as if the replaceable part would cause any leakage of the bone marrow. Bone marrow access is weighted at a 15 because making sure the user can easily fill and can extract bone marrow is crucial to the functionality of the model.

Cost: Cost refers to how much the replaceable component will cost based on the size of the 3-D printed piece repeatedly replaced and if there are any additional costs for supplemental materials that are needed to secure the replaceable component to the model. A model that requires less material will cost less and be scored higher in this category. Cost is weighted at a 10 because it is important that the material cost of replacement components are minimized.

Safety: Safety refers to the security and stability of the replaceable component within the model. It is important that the component stay seated within the non-replaceable bone component so that it does not interfere with the aspiration process. A replaceable component that does not come out of the model with the needle or fracture upon pressure and break into potentially harmful pieces of plastic would be rated higher. Safety is weighted at a 5 because the safety risks of performing the procedure should be similar to that of performing the procedure on a live animal.

Component Design Matrix Summary:

The slide method scored highest in the categories of joint interference, ease of fabrication, ease of use, durability, and cost. It scored the highest in the joint inference category because the slide piece is only affecting the aspiration site, while the other two models would attach to the joint and would interfere with the joint when replacing the piece. As for ease of fabrication the slide method scored the highest because it is considerably much smaller, and could be replicated easily on any printer. The size factor of this method also makes it easier to replace, and reduces the cost significantly compared to the other methods.

The screw method scored the second highest because it has the best bone marrow access with a port just inside the screw on the “cap” of the bone. This is very crucial for the project as the bone marrow element is what makes this model such an effective teacher, however while the screw cavity is helpful in this way, it interferes heavily with the shoulder joint as the entire top of the bone would have to be replaceable. Additionally with such a large replacement piece it would be quite costly and time consuming to replace, and with the thread required it would require high levels of accuracy affecting its ease of fabrication as well. While this is a hindrance the large surface area of this piece really expands the target area and would prevent the model from getting regularly damaged, and would keep the needle from slipping into these damaged spots, giving it a higher score in safety than the others. It is also less durable than the slide method because the thread will get chewed up over time.

The Velcro method scored the lowest overall for many reasons. Primarily it was the least safe option, as there is worry that the velcro would not be strong enough when students use the model, and when the needle is pulled out of the aspiration site the velcro could give and the whole bone piece could potentially come off. Additionally it would interfere heavily with the joint because it stretches almost to the top of the bone. The velcro also makes it slightly more costly to replace, and makes the piece itself less durable as the velcro would get weaker and weaker over time. This could also impact the security of the bone marrow fluid within the bone and could lead to movement of the internal components.

2024/10/09 - Design Matrices V2

AVERY SCHUDA - Oct 09, 2024, 11:43 PM CDT

Title: Design Matrices Version 2

Date: 10/9/2024

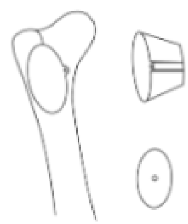
Content by: Avery Schuda

Present: Avery, Helene, Ella, Ellie, Anya

Goals: Update the design matrices to include design drawings and other charges

Content:

Table 1: **Replaceable Component Design Matrix:**

							
	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**	

Criteria Definitions:

Joint Interference: Joint interference refers to how easily replaceable the removable component is with respect to the shoulder joint, while still allowing the joint to be articulable. The section of the proximal humerus will need to be replaced frequently, so design that does not require any involvement of the shoulder joint to be replaced would score the highest. Joint interference is weighted at a 20 because the component must be easily replaceable without much interference with the shoulder joint.

Ease of Fabrication: Ease of fabrication refers to how easy the design is to model, 3D print, and assemble. This includes the time it takes for the 3D printer to fabricate the design, which is influenced by the size, density, and detail of the replaceable component. It is also important that the design can be replicated on different 3D printers, and methods with a reduced need for exact accuracy with printing would score higher. Ease of fabrication is weighted at a 20 because it is important that the full design is feasible to fabricate within the semester and that the replaceable components are able to be easily fabricated by the client.

Ease of Use: Ease of use refers to how easily the components can be replaced and how easy it is for the Veterinary student to interact with the model in the same way they would a patient. A design that has easier access to replace bone marrow fluid and the section of the proximal humerus would score higher. Ease of use is weighted at a 15 because it is important that the user experience is simplified as much as possible.

Durability: Durability refers to the expected life of the model, taking into account chosen materials and how replaceable components interact with the rest of the model. A simple design for the replaceable parts that limits wear and tear on the surrounding surfaces is desired so that the non replaceable components will last for a period of 5 years. Durability is weighted at a 15 because it is important that the design maximizes the lifecycle of the product.

Bone Marrow Access: Bone marrow access refers to how easily the client is able to refill the model with bone marrow between each procedure. This includes difficulty in placing the bone marrow within, as well as if the replaceable part would cause any leakage of the bone marrow. Bone marrow access is weighted at a 15 because making sure the user can easily fill and can extract bone marrow is crucial to the functionality of the model.

Cost: Cost refers to how much the replaceable component will cost based on the size of the 3D printed piece repeatedly replaced and if there are any additional costs for supplemental materials that are needed to secure the replaceable component to the model. A model that requires less material will cost less and be scored higher in this category. Cost is weighted at a 10 because it is important that the material cost of replacement components are minimized.

Safety: Safety refers to the security and stability of the replaceable component within the model. It is important that the component stay seated within the non-replaceable bone component so that it does not interfere with the aspiration process. A replaceable component that does not come out of the model with the needle or fracture upon pressure and break into potentially harmful pieces of plastic would be rated higher. Safety is weighted at a 5 because the safety risks of performing the procedure should be similar to that of performing the procedure on a live animal.

Component Design Matrix Summary:

The slide method scored highest in the categories of joint interference, ease of fabrication, ease of use, durability, and cost. It scored the highest in the joint inference category because the slide piece is only affecting the aspiration site, while the other two models would attach to the joint and would interfere with the joint when replacing the piece. As for ease of fabrication the slide method scored the highest because it is considerably much smaller, and could be replicated easily on any printer. The size factor of this method also makes it easier to replace, and reduces the cost significantly compared to the other methods.

The screw method scored the second highest because it has the best bone marrow access with a port just inside the screw on the “cap” of the bone. This is very crucial for the project as the bone marrow element is what makes this model such an effective teacher, however while the screw cavity is helpful in this way, it interferes heavily with the shoulder joint as the entire top of the bone would have to be replaceable. Additionally with such a large replacement piece it would be quite costly and time consuming to replace, and with the thread required it would require high levels of accuracy affecting its ease of fabrication as well. While this is a hindrance the large surface area of this piece really expands the target area and would prevent the model from getting regularly damaged, and would keep the needle from slipping into these damaged spots, giving it a higher score in safety than the others. It is also less durable than the slide method because the thread will get chewed up over time.

The Velcro method scored the lowest overall for many reasons. Primarily it was the least safe option, as there is worry that the velcro would not be strong enough when students use the model, and when the needle is pulled out of the aspiration site the velcro could give and the whole bone piece could potentially come off. Additionally it would interfere heavily with the joint because it stretches almost to the top of the bone. The velcro also makes it slightly more costly to replace, and makes the piece itself less durable as the velcro would get weaker and weaker over time. This could also impact the security of the bone marrow fluid within the bone and could lead to movement of the internal components.

Table 2: **Material of Replaceable Component Design Matrix:**

	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**	

Mechanical Accuracy: Mechanical accuracy refers to how similarly the printed plastic can mimic the mechanical properties of native bone tissue. A plastic with a tensile strength comparable to bone (67 MPa at the least) and similar density would score highest. Mechanical accuracy is weighted highest at a 25 because it is important that the bone model accurately represents native bone for practicing the procedure.

Strength: Strength refers to how well the material holds up against the needle. The bone model needs to be able to be punctured at least five times before the section of the proximal humerus is replaced, a material that is too brittle will not stand up to multiple punctures. A material that is not brittle would score highest. Strength is weighted at a 20 because it is important that the material can stand up to five punctures to increase the usability of the model.

Ease of Fabrication: Ease of fabrication refers to how easily and quickly the material can be printed. A material that prints at a high quality with minimal modification to print settings to make it accessible for Veterinary School staff to quickly print replacement components is desired. Ease of fabrication is weighted at a 20 because the material must be feasible for someone not previously familiar 3D printers to work with.

Texture: Texture refers to how similar the material is to the feeling of native bone, accounting for the adherence between layers of the print, flexibility, and interaction with the needle. A material with similar flexibility and surface finish to bone is desired without need for additional post print processing. Texture is weighted at a 15 because the surface finish should be similar to bone to best mimic the procedure.

Disposability: Disposability refers to how sustainable the material is and the ease of disposing of the replacement components. Since the proximal humerus is replaced every five punctures, a lot of plastic waste may be created. A material that is biodegradable and/or recyclable would score highest in this category. Disposability is weighted at a 10 because it is important that the waste material from the model can be disposed of in a sustainable manner.

Cost: Cost refers to how much the 3D printer filament typically costs per spool. Since the client will be printing a large volume of replacement components, it is important to keep the ongoing cost of material low. A filament that is low in cost per spool would score the highest. Cost is weighted at a 10 because the client desires a low cost prototype solution.

Materials Design Matrix Summary:

Polylactic acid (PLA) scored the highest in the categories of mechanical accuracy, ease of fabrication, texture, disposability, and cost. It scored the highest in mechanical accuracy compared to acrylonitrile butadiene styrene (ABS) and polyethylene terephthalate glycol (PETG) because of its ability to mimic the characteristics of native bone tissue in tensile strength. PLA is also cheaper than both ABS and PETG and takes the least amount of time to fabricate in a 3D printer. Given the versatility of PLA structures and the qualities of the material itself, it scored the highest in the category of texture due to the range of patterns, textures, and layers it can be used to print.

ABS scored the highest in the category of strength due to its capacity to have a large tensile strength. However, it scored lower than PLA for mechanical accuracy because it may not accurately represent native bone tissue because its tensile strength value is higher than that of bone. This would also contribute to a model made of ABS to be more rigid than bone tissue, thus being less accurate than PLA in terms of tensile strength and elastic modulus. Compared to both PETG and PLA, ABS takes the longest to fabricate in a 3D printer. Additionally, the disposability of ABS was rated very low out of all the material options because it is not biodegradable and can only be recycled a few times before it’s rendered unusable. Considering the frequency with which the replaceable component will need to be replaced, this is an important factor to consider. It also costs slightly more than PLA, but lower than PETG.

PETG was rated the lowest overall based on the grading criteria. It scored the lowest in mechanical accuracy because the highest tensile strength it can reach is lower than that of bone; it is also more elastic than PLA or ABS. PETG has the ability to be more brittle than PLA or ABS if printed incorrectly, and may be slightly deformed upon repeated use because of its low tensile strength. A lower tensile strength would not mimic the feeling of native bone; thus PETG scored the lowest in Texture. While PETG does not print as fast as PLA typically does, it prints faster than ABS and was thus scored higher in ease of fabrication. While not biodegradable like PLA, PETG can be recycled significantly more times than ABS, and scored higher than ABS for disposability. PETG was rated the lowest for cost because it is the most expensive material to buy out of the three options.

In conclusion, because PLA was given the highest overall score, it is the material that has been chosen to fabricate the replaceable component in the veterinary bone marrow aspiration model.

2024/11/12 - Design Lab Consultation Meeting

ELLA CAIN - Nov 13, 2024, 10:47 PM CST

Title: Design Lab Consultation Meeting

Date: 11/12/24

Content by: Ella

Present: Anya, Ella

Goals: To figure out a solution for our issues with editing our STL files of the bones in SolidWorks.

Content: We met with Jesse in the Design Lab and informed him that we were having issues with editing our STL files in SolidWorks. His advice was:

1. To use Onshape instead of Solidworks.

    -Anya imported the STL file of the humerus onto Onshape and the scan was considered a surface instead of a solid.

2. Use a software other than SolidWorks to simplify the geometry of the STL file, then import it onto Onshape. If the geometry is not too strange, Onshape would recognize it as a part instead of a surface, which makes editing easiest.

    -Bambu Labs is an option for this.

3. To separate the surface of the replaceable component using the 'Split' function in Onshape.

    -After spliting it, you can use 'Extrude' to begin working on the replaceable component.

4. If the three preceding steps didn't work, we could create the replaceable component retroactively.

    -Print the bone with solid infill and without support material. Then, use a machine at the Makerspace to cut out the replaceable component and 3D scan the component.

Extra Notes:

-To properly split the surface of the replaceable component in Onshape, the weird geometries of the bone need to be avoided. Otherwise, the function will not work properly. This makes simplifying or smoothing the STL necessary before working with it in Onshape.

-After using the 'Split' function properly, the hollowness of the inside of the bone can be viewed using 'Section View'.

-'Delete Face' is a function that can delete individual faces on an object in Onshape. However, this didn't work because the STL file as is has too complex of geometries to be workable in Onshape.

Conclusions/action items:

We will discuss with the team what our plan for fabricating the forelimb bones will be. A process that would simplify the geometry and detail of the bones is undesired. We may try to use Onshape for creating the replaceable component or search for a different program that will meet our needs. We will also continue reaching out to others for advice on our issue.

2024/11/19 - CAD Model of Humerus and Replaceable Component

AVERY SCHUDA - Nov 21, 2024, 12:37 PM CST

Title: CAD Models of Humerus and Replaceable Component

Date: 11/21/2024

Content by: Avery

Present: N/A

Goals: Complete initial iteration of Humerus with slot for replaceable component

Content:

- Imported scan of humerus as .stl into Fusion
- Manually removed any artifacts from scan
- Used repair mesh --> close holes, wrap, and stitch and remove
- Compressed model to ratio of 19 to avoid crashing with larger file
- Converted mesh to solid body (prismatic)
- Exported as .sat file
- Imported .sat file into SolidWorks
- Used internal repair tools to fill any remaining gaps
- Created sketch on surface in shape of replaceable component
- Extruded cut from shape to create the slot in the humerus
- Saved a separate copy of the same file
- Reversed the extruded cut to leave only the internal component
- Additional extruded cut to remove rest of humerus
- Saved both files and exported at .stl for 3D printing

Conclusions/action items:

Anya will 3D print at noon on Wednesday 11/20, so that print is ready for meeting at 2:30 that day. Review design with team and update as necessary.

AVERY SCHUDA - Nov 21, 2024, 12:39 PM CST

Download

right_humerus_slot.SLDPRT (49.6 MB)

AVERY SCHUDA - Nov 21, 2024, 12:40 PM CST

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right_humerus_inner.SLDPRT (33.4 MB)

AVERY SCHUDA - Nov 21, 2024, 12:41 PM CST

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right_humerus.sat (47.2 MB)

2024/12/02 - Final Humerus, Replaceable Components CAD + STL

AVERY SCHUDA - Dec 10, 2024, 1:10 PM CST

Title: Final Humerus, Replaceable Components CAD + STL

Date: 12/02/2024

Content by: Avery Schuda

Present: Anya Bergman

Goals: Finalize the humerus and replaceable components for 3D printing.

Content:

- Used previous version of humerus that was cleaned and compressed in Fusion then imported into SolidWorks.
- Decided to drill hole for ball and socket joint by hand.
- For humerus with slot:
    - Drew outline of shape on surface (fixed to several points on the surface).
        - Save point.
    - Extruded cut to desired depth of slot.
    - Used inside surface to create a step that was half the length of the slot.
    - Extruded boss/base the step to 1 mm.
    - Saved as SLDPT and STL
- For inner replaceable component:
    - Saved a copy of the humerus at the previously mentioned save point.
    - Extruded cut in the reverse direction of the humerus slot, so that the humerus except for the replaceable component was cut away.
    - A second plane was needed to cut away all of the remaining humerus outside of the inner component.
    - A step matching the one on the inside of the slot was created using extruded cut to ensure a one way fit into the humerus.
    - The inner component was then hollowed out using another extruded cut, leaving 1 mm wall thickness, and 3 mm thickness at the aspiration site.
    - The open back version of the replaceable component was saved as a SLDPT and SLT from here.
    - To create the enclosed version, a 1.25 mm base was extruded, and a 1 mm radius divot was created in the base with filleted edge to act as a port for injecting the bone marrow fluid into the replaceable component. Again, saved as SLDPT and STL.

Conclusions/action items:

This is the final iteration of the humerus and replaceable components. Replaceable components should be scaled down 5-6% based on printer so that they are not a press fit. Humerus should be drilled to accommodate ball and socket joint, which self-threads the hole as it is screwed in. The forelimb will be superglued to the distal end.

AVERY SCHUDA - Dec 10, 2024, 12:54 PM CST

Download

right_humerus_inner_v4_enclosed.STL (172 kB)

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right_humerus_inner_v4_enclosed.SLDPRT (27.5 MB)

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right_humerus_inner_v4.3mf (69.5 kB)

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right_humerus_slot_v4.STL (2.15 MB)

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right_humerus_inner_v4.STL (124 kB)

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right_humerus_inner_v4.SLDPRT (28.1 MB)

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right_humerus_slot_v4.SLDPRT (52.5 MB)

2024/12/02 - Final Scapula with Base, Joint Connection CAD + STL

AVERY SCHUDA - Dec 11, 2024, 2:34 PM CST

Title: Final Scapula with Base, Joint Connection CAD + STL

Date: 12/02/2024

Content by: Avery Schuda, Anya Bergman

Present: N/A

Goals: Final version of Scapula CAD, STL for 3D printing

Content:

- Features extruded baseplate and joint connection for ball and socket joint purchased from McMaster

Conclusions/action items:

3D printed with no scaling issues for final model. Joint connection is tight press fit as to not require any adhesive but may need to file a bit to make it easier to insert. Drilled holes and screwed in L-brackets, tapped joint in with rubber mallet.

AVERY SCHUDA - Dec 11, 2024, 2:28 PM CST

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right_scapula_bs.STL (3.96 MB)

AVERY SCHUDA - Dec 11, 2024, 2:29 PM CST

Download

right_scapula_bs.SLDPRT (110 MB)

2024/12/03 - Final Scaled Down Forelimb CAD + STL

AVERY SCHUDA - Dec 10, 2024, 12:41 PM CST

Title: Final Scaled Down Forelimb CAD + STL

Date: 12/03/2024

Content by: Avery Schuda

Present: N/A

Goals: Create an accurately sized right forelimb model for 3D printing

Content:

- For some reason the forelimb scaled incorrectly from the 3D scan, so it was much larger than life size. This was not an issue with the other scans.
- The .stl was imported into Fusion.
    - Mesh was cleaned up and artifacts from targets removed.
    - Closed several holes.
    - Fused the radius and ulna into one piece.
    - Compressed mesh into more manageable file size.
    - Exported as .sat for editing in SolidWorks.
- Imported into SolidWorks
    - Cleaned up any remaining gaps in the mesh.
    - Shrunk the size by 90%
    - Saved as SLDPT and STL files

Conclusions/action items:

This final version of the forelimb is ready for 3D printing, no scaling necessary. Since the file were too large to fuse the humerus and forelimb in SolidWorks directly, they were printed separately and superglued.

AVERY SCHUDA - Dec 10, 2024, 12:42 PM CST

Download

forelimb_scaled_down_20v1.sat (326 MB LA S3)

AVERY SCHUDA - Dec 10, 2024, 12:43 PM CST

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forelimb_scaled_down_v1.SLDPRT (177 MB)

AVERY SCHUDA - Dec 10, 2024, 12:43 PM CST

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forelimb_scaled_down_v1.STL (14.9 MB)

Full List of CAD Iterations

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

Download

right_humerus_slot.SLDPRT (52.5 MB)

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

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right_forelimb_v3.SLDPRT (12.3 MB)

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

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right_humerus_inner_v3_enclosed.STL (127 kB)

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

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right_humerus_inner_v3_enclosed.SLDPRT (32.7 MB)

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right_humerus_inner_v3_open.STL (94 kB)

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right_humerus_inner_v3_open.SLDPRT (32.7 MB)

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Download

right_humerus_slot_v2.STL (2.15 MB)

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right_humerus_inner_v2_hollow.STL (98.4 kB)

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

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right_humerus_inner_v2_enclosed_port.STL (139 kB)

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

Download

right_humerus_inner_v2_enclosed_port.SLDPRT (32.2 MB)

AVERY SCHUDA - Dec 11, 2024, 2:36 PM CST

Download

right_humerus_inner_v2_hollow.SLDPRT (32 MB)

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right_humerus_inner_v2.STL (90.4 kB)

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right_humerus_inner_v2.SLDPRT (33.5 MB)

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right_humerus_slot_v2.SLDPRT (48.7 MB)

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right_forelimb.3mf (4.74 MB)

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right_humerus_component.SLDPRT (21.4 MB)

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right_humerus_inner.STL (82.8 kB)

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right_scapula.SLDPRT (66.2 MB)

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right_scapula.sat (115 MB)

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right_scapula_compressed.sat (115 MB)

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right_forelimb_20v1.sat (317 MB LA S3)

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right_forelimb.f3d (69.7 MB)

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right_forelimb_v3.3mf (4.28 MB)

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right_humerus.3mf (5.27 MB)

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right_forelimb.stl (14.3 MB)

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right_scapula.3mf (9.78 MB)

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forelimb_scaled_down_20v1.sat (326 MB LA S3)

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forelimb_scaled_down_v1.SLDPRT (177 MB)

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forelimb_scaled_down_v1.STL (14.9 MB)

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right_forelimb_v1.SLDPRT (172 MB)

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right_humerus.SLDPRT (20.6 MB)

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right_humerus.STL (23.5 MB)

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right_humerus_test.SLDPRT (32.1 MB)

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right_scapula_v1.sat (116 MB)

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right_scapula_v1.SLDPRT (62.2 MB)

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Download

right_scapula_with_joint_.STL (3.96 MB)

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right_scapula.SLDPRT (27.3 MB)

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right_scapula.STL (31.7 MB)

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right_scapula_base.SLDPRT (64.4 MB)

AVERY SCHUDA - Dec 11, 2024, 2:42 PM CST

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right_scapula_base.STL (5.39 MB)

2024/09/27 - BPAG Meeting

ELLIE KOTHBAUER - Sep 27, 2024, 12:27 PM CDT

Title: BPAG information meeting

Date: 9/27/24

Content by: Ellie Kothbauer

Present: Other BPAGs

Goals: To understand the role of the BPAG

Content:

- Client is UW Affiliated but not in the BME department

- Next step find out how they are giving you funds, do they have UW funds?

- yes: follow UW purchasing guidelines, seek reimbursement within 90 days, client paying is the best option so you don't have to worry about client paying you back,

Shop UW works well: Clients are only able to buy from this system, so you have to ask the client to purchase it for you. Look through Shop UW preferred vender when purchasing.

-No: Anything is fair game: if you pay work with client for payment at end of semester

Lots of resources at UW: Design and Innovation Lab @ Wendt

- 3D printing
- Expertise
- Mini-mart
- Payment types: your client-fund number, you-Credit, debit or WISCard
- $50 budget per team from BME

Design Innovation Lab @ECB

- Machine, woodworking - subtractive manufacturing
- Expertise
- Stockroom: screws, nuts, bolts, ect
- Tool crip: screw divers, drills, force gauges, you have to use them down there and cannot take up to the design lab
- Free now

Reimbursement

- Only BPAG will be reimbursed
- E-Reimbursement from UW- Clients-start before the poster session
  - Must have original receipts
  - 90 day rule, no reimbursement beyond 90 days of purchase

NON-reimbursable expenses ~$13 per person

- Team notebook
- Poster Printing
- Do not ask client to pay for them

Accounting

- Use a table with all the vital information needed to purchase again
- ensure the table is legible, use the template
- Table belongs in
    - Progress report
    - notebook
    - final poster

Conclusions/action items:

General Notes

- Have your client make purchases
- Have all expenses approved
- Keep track of all expenses
- See Dr. P for any problems pertaining to transaction

2024/12/11 - Final BPAG Expense Sheet

AVERY SCHUDA - Dec 11, 2024, 1:14 PM CST

Title: Final BPAG Expense Sheet

Date: 12/11/2024

Content by: Avery Schuda, Ellie Kothbauer

Present: Avery, Ellie, Ella, Helene, Anya

Goals: Record final expenses for reimbursement by client, calculate final model cost.

Content:

Final model cost was $26.68, replaceable components cost $0.11 each to print. Total $200.96 was spent on materials.

Item	Description	Manufacturer	Mft Pt#	Vendor	Date	QTY	Cost Each	Total
Material test strips	We printed out strips of PLA, ABS, and PETG at different densities to see with materials work the as a bone replication	Makerspace 3d printers	.	UW Makerspace	9/26/2024	3	$0.17	$0.51
Right Humerus PLA print	We printed out a Right Humerus out of Bambu Labs		7747593925	UW Makerspace	10/31/2024	6	$1.38	$8.28
Scaled humerus pieces	We printed test replacable pieces at different sizes to test how they fit into the slot.		7911695812	UW Makerspace	11/22/2024	1	$0.70	$0.70
Right Leg Full Print	We printed out forelimb, humerous, and scapula	Makerspace 3d printers		UW Makerspace	11/14/2024	1	$4.18	$4.18
PLA replicible test strips	We Printed out replacable components to add in the humerous	Makerspace 3d printers		UW Makerspace	11/15/24-12	30	$0.11	$3.30
Right Scapula PLA print	We printed out a Right Scapula out of bambu labs PLA matte	Makerspace 3d printers		UW Makerspace	11/15/24 -1	2	$2.18	$4.36
Right partial forelimb	We printed out a partial forelimb at the UW Makerspace	Makerspace 3d printers		UW Makerspace	11/28-12/4/	2	$0.56	$1.12
4 Red silicone rubber sheets	4 1ft by 1ft sheets of Red silicone sheets were ordered for muscle replica	Tlence Stor		Amazon	11/7/2024	1	$23.99	$23.99
Universal Joint	1 3/4 in long, overall large chrome, used for the shoulder joint	Westward	54PR13	Granger	11/5/2024	1	$17.08	$17.08
Alecpea Special	Glue specficially for silicone for faux muscle	Alecpea		Amazon	11/18/2024	1	$9.99	$9.99
Oil- Resistant Buna- Rubber	1ft by 2ft 1/32 inch thick	McMaster-Carr		McMaster	11/26/2024	1	$6.06	$6.06
Oil- Resistant Buna- Rubber sheet	1ft by 2ft 1/16 inch thick	McMaster-Carr		McMaster	11/26/2024	1	$7.70	$7.70
Ball joint Linkage, Right hand ball stud	Ball joint	McMaster-Carr		McMaster	11/26/2024	1	$8.77	$8.77
Masonite	1 ft by 1 ft 1/4, inch thick	Makerspace 3d printers		UW Makerspace	11/20/2024	1	$3.25	$3.25
Humerus, Scapula, 2 Replaceable Components	PLA models	Makerspace 3d printers		UW Makerspace	11/25/2024		$3.96	$3.96
5 Scaled Replaceable Components	PLA models	Makerspace 3d printers		UW Makerspace	11/27/2024	5	$0.61	$5.00
Silicone scar sheets	Used to hold replacable piece, muscles in place	Slukhig		Amazon	12/3/2024	1	$13.58	$13.58
Medical grade silicone tape	Used to hold replacable piece, muscles in place	Tapechoice		Amazon	12/3/2024	1	$10.54	$10.54
3-piece impact universal joint	1/4", 3/8", 1/2" drive swivel socket	DURATECH		Amazon	11/21/2024	1	$16.87	$16.87
Brown plush fabric	Cover base plate to mimic dog fur	kullaloo		Amazon	11/21/2024	1	$18.88	$18.88
Non slip rubber feet	16 pcs with stainless steel wash screws, 2 sizes	Quadafy		Amazon	11/18/2024	1	$0.37	$5.89
Door Panel Clip	8 pack, clear acrylic	Prime-Line	T 8733	Amazon	11/18/2024		$1.25	$9.99
Magnets	50 6 x 2 mm magnets	Nuiknow		Amazon	11/18/2024	1	$0.08	$3.99
Picture frame turn button fasteners	Package of 100 to fasten replaceable component to humerus	Hoedia		Amazon	11/18/2024	1	$0.07	$6.98
Black Stainless Steel L-brackets	10 x 0.79", 10 x 1.57", 60 x screw	YAMASO		Amazon	11/18/2024	1	$0.30	$5.99
							TOTAL:	$200.96

Conclusions/action items:

Ellie will request final expenses needed to be reimbursed outside of things purchased directly with department funds and disperse funds to those who are owed.

AVERY SCHUDA - Dec 11, 2024, 1:15 PM CST

Download

_BPAG_Expense_Spreadsheet__Bone_aspiration_Model.xlsx (30.8 kB)

2024/10/30 - 3D Printed Humerus

AVERY SCHUDA - Oct 30, 2024, 6:41 PM CDT

Title: 3D Printed Humerus

Date: 10/30/2024

Content by: Avery Schuda

Present: Avery and Anya

Goals: 3D print humerus for Show and Tell

Content:

- Unmodified humerus from 3D scan as prop for Show and Tell
- Printed using Bumbu Labs software
    - Can download Bambu on our own devices to prep 3D prints ahead of time and experiment with settings
- Used tree supports
- Printed in white PLA
- See attached for file used and picture of final print

Conclusions/action items:

Meeting Thursday 10/31 to prep pitch for show and tell. Print quality will inform future prints.

AVERY SCHUDA - Oct 30, 2024, 6:41 PM CDT

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right_humerus.STL (23.5 MB)

2024/11/19 - Discussing Base for Model

ELLA CAIN - Dec 02, 2024, 5:37 PM CST

Title: Discussing Base for Model

Date: 11/19/2024

Content by: Ella

Present: Ella, Avery

Goals: To decide on the base design and begin fabrication.

Content: I met with Avery at the Makerspace to discuss the components of the base for the modeled forelimb. We decided the base should:

-Be made out of 1/4" masonite

-Have 4 rubber legs, one at each of the corners

-Be 1' x 1'

After I met with Avery, I went to the Makerspace the next day to fabricate the base. I cut a 24" x 36" board of 1/4" thick masonite into the 1' x 1' square.

Conclusions/action items:

To drill in the rubber legs and see if the 1' x 1' dimension is large enough for the forelimb to comfortably rest on.

2024/11/25 - Printing the Humerus, Scapula, and Replaceable Components

ELLA CAIN - Dec 10, 2024, 11:33 PM CST

Title: Printing the Humerus, Scapula, and Replaceable Components

Date: 11/25/24 edit(12/10/24)

Content by: Ella

Present: N/A

Goals: To print the latest versions of the replaceable component, humerus, and scapula.

Content: Went to the Makerspace and printed the STL files of the humerus with the attachment part, the scapula with the attachment part, and the 2nd versions of the replaceable components. One v2 of the open replaceable components and one v2 of the enclosed replaceable components were printed. The print was queued in at 12:00, but didn't start printing until the next day. After getting the prints back, it was found that the joints we ordered fit the attachment parts of both the humerus and scapula well. Only one of the replaceable components we had almost fit the hollow part of the humerus, but none of the other replaceable components fit. The replaceable component that almost fit was the encloded version 1 of the component.

Conclusions/action items:

To print more replaceable components and scale them down. We should also decide if using super glue for the joints would make them more stable.

ELLA CAIN - Dec 10, 2024, 11:38 PM CST

Photos of scapula, humerus, and joint:

Date archived: 12/10/24

Content: Scapula and humerus connected with joint; base of scapula.

2024/12/4-5: Fabricating Entire Model

HELENE SCHROEDER - Dec 10, 2024, 10:08 PM CST

Title: Fabricating the Entire Model/Putting it Together

Date: 12/4-5/24

Content by: Helene

Present: Helene, Avery, Ella, Anya, Ella

Goals: To finish putting the model together and add last touches!

Content:

The team went in groups/when available to different places around engineering to help finish the model. Some of these tasks included drilling the humerus for the joint (as pictured below) at ECB, mounting the scapula to the masonite board with L-brackets, attaching the fur to the board via velcro, and supergluing the forelimb to the humerus. The whole team worked really hard and had really good ideas for last minute adjustments that make the model so much nicer looking (for example, Ellie suggested a great way to cut the fabric to make the board look more realistic and neat).

Conclusions/action items:

With all the fabrication complete, the team only has to work on the poster presentation and completing the final deliverables (report and notebook). We were very successful in our final touches in fabrication and the model has turned out very professional looking compared to previous iterations of the model.

HELENE SCHROEDER - Dec 10, 2024, 10:02 PM CST

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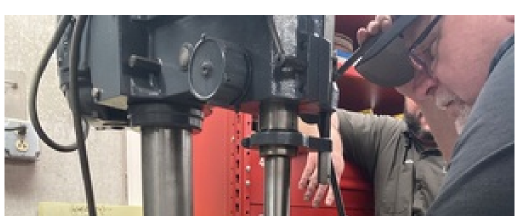
IMG_3027.jpeg (2.98 MB)

HELENE SCHROEDER - Dec 10, 2024, 10:03 PM CST



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IMG_3031.jpeg (3.26 MB)

2024/10/16 - 3D Scanning Protocol

ELLIE KOTHBAUER - Oct 16, 2024, 3:23 PM CDT

Title: 3D Scanning Protocol

Date: 10/16/2024

Content by: Helene Schroeder

Present: Helene, Avery, Anya, Ellie, Ella

Goals: To write the protocol for 3D scanning the scapula, humerus, radius, and ulna of the bones given to us by Dr. Gunderson.

Content:

1. Get Creaform 3D scanner and open correlating software on computer.
2. Place object (bone) on turn table.
3. Add (about 4-5) reflective stickers to various places around the object (especially if it is dark or colorful, we placed them onto the bone just to be safe).
4. Start scanning with the "handy scanner" until 3D scan is replicated on the computer software, and save the scan
5. Turn the bone model, and to scan it from multiple angles
6. Comprise all the scans together to get the full scan of the bone and save it to the

Conclusions/action items:

2024/12/02 - Model Testing Protocol

HELENE SCHROEDER - Dec 02, 2024, 7:01 PM CST

Title: Model Testing Protocol

Date: 12/2/2024

Content by: Helene Schroeder

Present: N/A

Goals: To create a protocol for testing of the model that will be conducted by vet school staff.

Content:

Materials:

- Model (mounted scapula attached to humerus with muscle covering replaceable piece)
- Replaceable pieces (around 10?)
- Foam to help mount humerus
- Foam to place in replaceable piece

Procedure to Assemble Model Before Testing:

1. Put foam into replaceable piece.
2. Put replacable piece into humerus.
3. Use rubber bands to attach muscle over humerus.

Procedure:

1. Gather staff and materials (listed above).
2. Each staff performs BMA on the model 3 times.
3. Staff will then describe the feeling of the procedure as:
    1. Not accurate
    2. Slightly accurate
    3. Moderately accurate
    4. Very accurate
4. The Chi-Squared Statistical Test will then be used to determine statistical significance.

Conclusions/action items:

This protocol will be helpful when performing testing tomorrow with vet staff at the vet school. After testing, I will determine the results to be put into the final poster and report.

HELENE SCHROEDER - Dec 08, 2024, 9:35 PM CST

2024/12/10 - 3D Printing Protocol

AVERY SCHUDA - Dec 11, 2024, 1:09 PM CST

Title: 3D Printing Protocol

Date: 12/10/2024

Content by: Avery Schuda

Present: N/A

Goals: Define a formal protocol for file preparation and 3D printing at the UW Makerspace.

Content:

3D Printing Instructions

1. Open the Bambu Studio software. In the upper left-hand corner, select File, Import, Import 3MF/STEP/STL/SVG/OBJ/AMF… (or Ctrl + I). Select the STL or STEP file ready for printing.
2. Use the controls to reorient the print on the plate. This is a preview of exactly how the printer will print your file. Oftentimes selecting Lay on Face (F) will set your print in correct orientation.
3. Add multiple files to print onto the same plate by selecting Add (Ctrl + I).
4. To scale an object, select the object(s), then select Scale (S). Replaceable components are scaled down to 95%-94%. Other components may not need to be scaled, depending on the printer and print quality.
5. If the print is at all unstable, consider adding supports to your print. You snap/cut these off after the print is complete. Under Support in the left panel, check the box Enable Support to auto generate supports for the print. Tree supports will be easiest to remove for a cleaner print finish.
6. Once everything is correctly oriented, select Slice Plate in the upper right corner. This previews the path that the 3D printer will take. If you are satisfied with this, save your print as a 3MF in the upper left corner.
7. If printing in the UW Makerspace, note the total print time (round up to the nearest hour) and total number of grams of filament required, as this is used to calculate the final cost.
8. At this point it is a good idea to call over a staff member to check the print and send it to one of the printers. Print the components in PLA, in the color desired.
9. After the print is complete, remove any supports by hand or with a small pair of wire cutters. Some light sanding or filing may be necessary to get the desired surface finish at the areas where supports were connected.
10. If any prints do not fit together correctly, try reprinting at a higher quality, or scaling the print slightly in the Bambu Studio software.

Conclusions/action items:

This protocol was used during the 3D printing of all iterations of bone and replaceable components, formalized here for the client to fabricated additional pieces/models.

2024/12/10 - Processing 3D Scans into Workable CAD Files Protocal

AVERY SCHUDA - Dec 11, 2024, 2:48 PM CST

Title: Processing 3D Scans into Workable CAD Files

Date: 12/10/2024

Content by: Avery Schuda

Present: N/A

Goals: Formalize the procedure for processing 3D Scans into Workable CAD Files

Content:

Processing 3D Scans into Workable CAD Files

1. Import the 3MF or STL into Fusion.
2. Under the Mesh tab, select Prepare, then Repair. Make sure preview is turned on before selecting whichever repair option works best to patch holes.
3. Remove any remaining artifacts from the 3D scan and targets using tools under the Prepare and Modify tabs as necessary.
4. Under the Mesh tab select Modify, then Convert Mesh. Turn on preview and select the desired mesh type. For bone, “organic” or “prismatic” may be most appropriate.
5. Then, under Modify, select Reduce. Reduce by proportion and adaptive re-mesh type. Reduce until the file size becomes more manageable to work with, but not too much as to lose the surface texture and anatomical markers.
6. Optionally, the body can now be scaled larger or smaller if desired. The model can also be scaled in SolidWorks, or before printing in the 3D printer software, so it may be wise to preserve the original size of the scan for now.
7. If printing the file without modification, export the file as a .stl.
8. To import the file into SolidWorks, export the file as a SAT. In SolidWorks open the file and run import diagnostics to clean up any remaining issues.
9. Finally, save the file as a SLDPRT (part) file in SolidWorks to begin modifying the body.

Conclusions/action items:

This procedure could be utilized to create additional models for the other aspiration sites (trochanteric fossa, iliac crest), or another humerus model from a different set of bones.

2024/12/3 - Vet School Testing Results

ELLA CAIN - Dec 10, 2024, 11:24 PM CST

Title: Vet School Testing Results

Date: 12/3/24

Content by: Ella (edit: 12/10/24)

Present: Ella, Anya (edit: 12/10/24)

Goals: To have the group of doctors at the school of Veterinary Medicine provide feedback on our design and rate the replaceable component on how realistic it feels to that of aspirating on a cadaver.

Content:

We allowed them to test aspirating the model. Each doctor pierced the component three times before it was replaced and handed to the next doctor.

>Trial 1: Dr.Pellin

>Overall Rating: 4.5

>Feedback:

- The replaceable component began to split after the first pierce

-Could be a "tiny bit firmer"

-Holding the bone felt natural

-Said it was very realistic

-Also split after first pierce;

-*(with silicone tape):* Not significantly different from aspirating without the tape

-*(with silicone tape):* Held the replaceable component in place without needing to use rubber bands

>Trial 2: (Dr. Calico)

>Overall Rating: 4-4.5

>Feedback:

-Said it was very realistic

-Liked the 'crack' sensation that having the supports in the replaceable component provided

-Suggested making the replaceable component slightly thicker

>Trial 3: (Dr. Gunderson)

>Overall Rating: 4

>Feedback:

-Suggested using silicone tape to hold the replaceable component in place

Advice for Skin and Muscle:

-Use silicone tape or use bulldog clips to secure it to the bone

-It may be better just to have the skin material instead of including the nitrile muscle

-Using cosplay foam may be a good replacement for muscle and would allow for a more realistic muscle look when the skin is placed over the forelimb.

General Advice

> All doctors thought the silicone tape would be a good idea; they tested different kinds of silicone tape and aspirated with them. The tape allows the piece to stick without needing something in place and may be even better to wrap around the bone than nitrile muslce.

> Dr. Calico suggested the idea of keeping the bone uncovered for beginning students then wrapping it with psuedo skin once they get more knowledgable, so it may not be necessary to secure the skin around the bone.

> For future work, Dr. Gunderson suggested a mechanism where there could be a port on the bottom of the humerus that had a tube that delivered psuedo-bone marrow fluid when negative pressure is applied by aspirating. This would avoid potential leaks or not aspirating enough bone marrow due to the cavity of the replaceable component lacking air flow.

Links for potenial materials to order:

Power Mesh

Silicone Scar Sheets

Silicone Tape

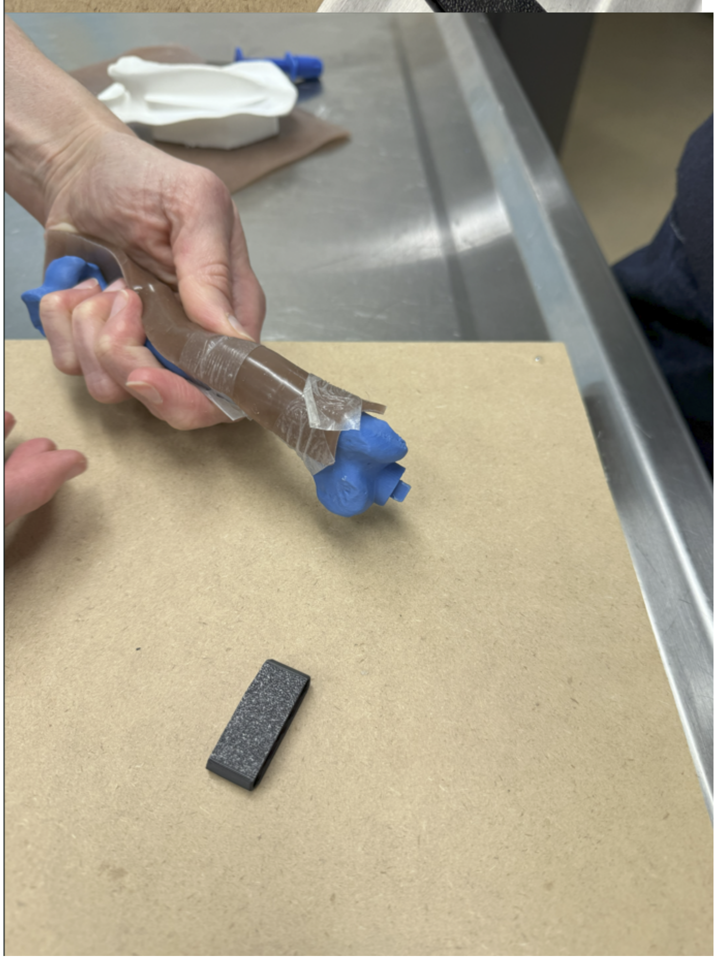
Conclusions/action items: We need to finish creating the CAD files for the new joint and print them. The replaceable component CAD files may need to have thicker tops as well. Then, we need to mount the scapula to the base board and attach the joint to the bones. We also need to print the poster for the poster presentation and make sure that we are fully prepared for it on Friday.

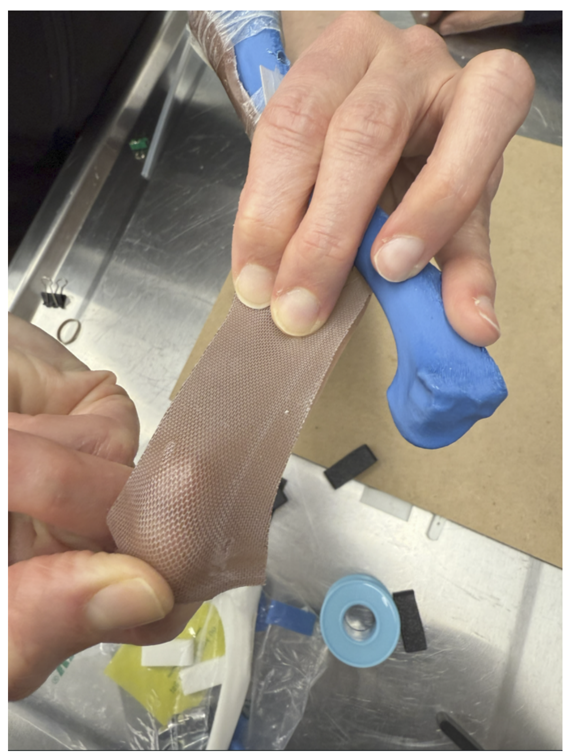
ELLA CAIN - Dec 10, 2024, 11:37 PM CST

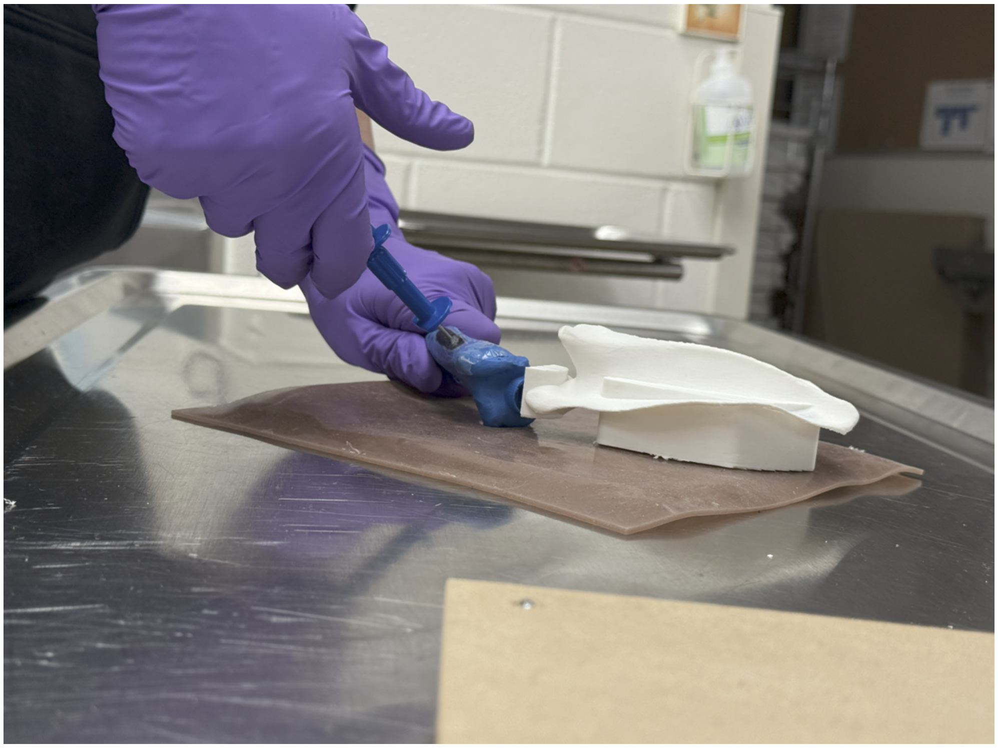
Photos from Testing:

Date archived: 12/10/24

Content: Silicone tape; replaceable component; test humerus; Dr. McLean Gunderson aspirating test component and humerus.







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2024/09/27 - Material Testing

AVERY SCHUDA - Dec 11, 2024, 1:17 PM CST

Title: Material Testing

Date: 9/27/2024

Content by: Avery Schuda

Present: Avery, Ella, Anya, Dr. Gundeson, Dr. Schmidt

Goals: Discuss follow up questions and prepare to get .stl files

Content:

- Dr Schmidt was able to test the three samples that Anya printed (ABS, PLA, PETG)
- ABS 3mm, PLA 2 and 3 mm were all good tests
  - PLA 3 mm was the most realistic
- PETG had too slippery of a surface finish and was too flexible
- PLA had the most realistic feel of the three plastics
- Having the foam under the plastic actually gave a very realistic feel
- Collected samples of bones to 3D scan in the Makerspace
  - If scanning doesn't work then we can access CT scans, but this is a slightly more difficult process
  - We were given a right side and left side limb to scan
- The Makerspace can add one group member to Dr Gunderson's funding for the team to access
- The team should produce one right side model, and give the Vet team a blueprint for assembling more models
- Start with the solid model and worry about the liquid bone marrow later
- They have some connections with researchers that could potentially give us really accurate values for material properties and forces

Conclusions/action items:

Send the details of the presentation time and location to Dr Gunderson, cc the rest of the Vet team and send them the presentation .pdf after the fact. Look into the process for 3D scanning the bones asap.

2024/10/04 - Preliminary Presentation

AVERY SCHUDA - Oct 09, 2024, 11:59 PM CDT

Title: Preliminary Presentation

Date: 10/4/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ellie, Ella

Goals: Communicate background, progress on the project thus far, and goals moving forward to our client, advisor, and peers.

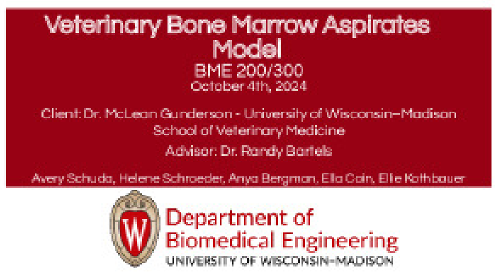
Content:

See attached presentation.

Conclusions/action items:

The next steps for the team are to work on the preliminary report, finalize all design aspects, 3D scan in the Makerspace, and begin fabrication.

AVERY SCHUDA - Oct 10, 2024, 12:00 AM CDT



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Preliminary_Design_Presentation_Veterinary_Bone_Marrow_Aspirate.pdf (1.21 MB)

2024/10/09 - Preliminary Report

AVERY SCHUDA - Oct 09, 2024, 11:55 PM CDT

Title: Preliminary Report

Date: 10/9/2024

Content by: Avery Schuda

Present: Avery, Helene, Ella, Ellie, Anya

Goals: Summarize the background of the project, progress thus far, and next steps moving forward

Content:

Veterinary Bone Marrow Aspirate Model

Preliminary Report

BME 200/300

9 October 2024

Client: Dr. McLean Gunderson

University of Wisconsin–Madison

School of Veterinary Medicine

Advisor: Dr. Randy Bartels

University of Wisconsin–Madison

Department of Biomedical Engineering

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Abstract

Many veterinary surgical procedures exist that can be practiced using cadaver animals. However, some procedures cannot accurately be performed on a cadaver due to the altered characteristics of atrophied cells as opposed to living cells. One such surgical procedure is bone marrow aspiration, the accuracy of which relies on bone marrow cells to be alive to gain the full experience of aspirating bone marrow. For this reason, the client Dr. McLean Gunderson has requested that a model be created in the place of a cadaver to simulate the process of aspirating bone marrow from an animal. There are currently no models on the market for veterinary bone marrow aspiration. The proposed final design is a veterinary bone marrow aspiration model that models the right scapula, proximal humerus, ulna and radius of a 30 pound beagle with an articulate shoulder joint. The model proximal humerus contains a replaceable component with an inner cavity that allows for pseudo-bone marrow to be injected and extracted from the model. The proposed final design is a cost effective model whose material mimics the feeling of a dog's skin, muscle, and bone when aspirating. Additionally, the material for the model bones has been qualitatively tested for its mechanical accuracy leading to a final choice of polylactic acid (PLA) for bone material choice and informing the ultimate thickness of the bone in the final design. Future quantitative testing of PLA, ABS, and PETG strengths compared to cortical bone is planned following fabrication.

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Introduction

1. **Impact and Motivation**

It is important for veterinary students to have experience in the process of conducting surgical procedures before performing them on living animals. Cadavers allow veterinary students to execute procedures without the potential consequences that accompany living animals; they also aid students in understanding the process of surgical techniques and an animal's anatomy [1]. Ideally, cadavers would provide an accurate experience of all veterinary surgical procedures. In the cases where cadavers cannot provide the similitude of a living animal, models may be used instead [2]. The procedure of veterinary bone marrow aspiration is one such operation that a model may be of better use than a cadaver. Veterinary bone marrow aspiration is a procedure that is intended to take bone marrow samples from bones and analyze them for abnormalities [3]. To accurately simulate the procedure of veterinary bone marrow aspiration, the bone marrow would ideally be alive. However, given the nature of cadavers, this is not always feasible, thus highlighting the need for a model to be used in its place.

As no current bone marrow aspirate models exist for use of veterinary students, this model may act as a guide for subsequent veterinary bone marrow aspiration models. This model is intended to educate veterinary students at the School of Veterinary Medicine and allow them to accurately simulate aspirating bone marrow from a dog.

2. **Existing Methods**

While no veterinary bone marrow aspiration models exist, there are human bone marrow aspiration models that are being sold for use. The Bonnie Bone Marrow Biopsy Trainer [4] and the Anatomy Lab's Adult Bone Marrow Aspiration model [5] are models for human bone marrow aspiration and do not provide the anatomical accuracy needed for veterinary procedures. Furthermore, these models can be expensive ($2,214) and are not cost effective or realistic for veterinary purposes [4]. However, the materials used for these models are similar to the materials used to fabricate the preliminary design. They also are models of specific parts of the body; the preliminary design will also model a specific part of a dog's body where bone marrow aspiration is typically performed.

3. **Problem Statement**

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 [6]. Currently no veterinary bone aspiration models exist for students to practice on, requiring the use of cadaver dogs. Cadavers can only be used for about 5-10 insertions of the Illinois bone marrow biopsy needle per site, but do not contain live bone marrow that can be collected. This project aims to create a low-cost 3D anatomically correct model of the humerus with relevant soft tissue structures, mimics the consistency and structure of the bones, and allows for insertion of "bone marrow" for collection, allowing veterinary students to practice the skill of bone marrow aspiration.

Background

1. **Biology and Physiology**

The purpose of bone marrow sampling is to examine both the fluid and the tissue of the marrow. There are two ways to obtain bone marrow: a core biopsy and a needle aspiration, in which aspiration is less invasive compared to biopsies [2]. For the bone marrow aspiration procedure, a small incision is made in the site where the sample is collected. The three main sites for bone marrow extraction in dogs and cats are, the iliac crest, the trochanteric fossa, and most commonly, the proximal humerus. The part of the bone where the needle is inserted is the cortical bone. The Illinois needle is then inserted at a perpendicular angle to the bone and pushed in a "clockwise-counterclockwise" rotation until it has fully advanced into the marrow cavity. After the needle has been fully inserted, the stylet is removed, and a syringe is used to aspirate roughly 0.5 mL to 2 mL of bone marrow [3]. The bone marrow is then tested for abnormalities.

Some of the abnormalities in bone marrow include non-regenerative anemia, myelofibrosis, leukemia [7]. This procedure is not common and is only prepared when they detect that there might be abnormalities in the blood. After the bone marrow is extracted the samples are placed on a slide and sent to the laboratory for analysis.

2. **Client Information**

Dr. McLean Gunderson is an Doctor of Veterinary Medicine and an Assistant Teaching Professor in the comparative biosciences department. She is a course director and instructor for Anatomy of Large Domestic Animals, Fundamental Principles of Veterinary Anatomy, and a Clinical Skills Elective.

Preliminary Designs

rall Design

All of the preliminary designs share some key aspects, as specified by the client. The bone structure will include a 3D printed scapula, fully articulable shoulder joint, humerus, and elbow joint fixed at a 120° position. The proximal humerus will include a replaceable 3D printed section containing a hollow cavity which will be filled with an artificial bone marrow, fabricated by the client. The skeletal structure will be covered with relevant muscles and soft tissue. Skin, fabricated out of neoprene and pourable silicone by the client, will be affixed over the top of the model to give an accurate look and feel to the limb. Finally, the whole model will be affixed to a base to create stability and position the limb accurately for performing the bone marrow aspiration simulation.

Design 1: Screw Method of Attachment

The Screw Method design features a 4 cm section at the proximal end of the humerus which attaches to the distal portion of the humerus through threaded ends that screw together. The removable piece of the proximal humerus has a 3 mm wall thickness to accurately mimic the feeling of real cortical bone. The removable end of the Screw Method design is hollow and features a port for filling bone marrow simulating fluid in the base of the threaded end. The design would require reattachment to the scapula every time it is replaced.

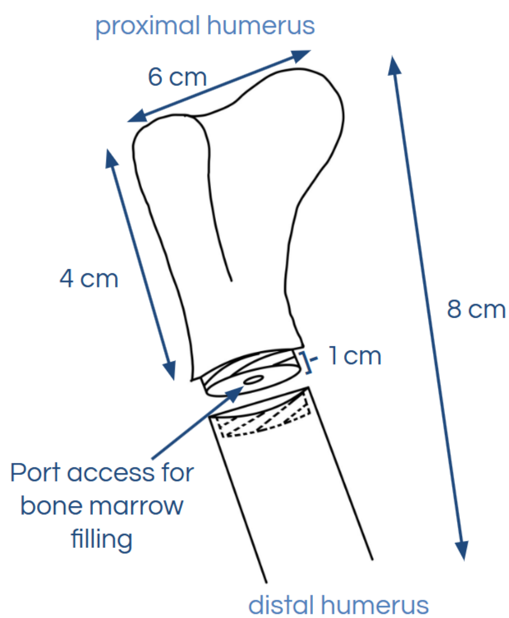


Figure 1: Drawing of the Screw Method of attachment

Design 2: Slide Method of Attachment

The Slide Method design features a 3 x 2.5 cm oval section of the proximal humerus that slides into place with the help of a tab. The tapered sides and 0.5 cm tab along the length of the removable section help to provide a one-way fit, ensuring the section is installed in the correct orientation. The replaceable section is hollow, and on the side facing inwards, there is a port for filling the simulated bone marrow solution. The surface of the section is rough and mimics the shape of the bone, with 3 mm walls to accurately simulate puncturing cortical bone while performing the bone marrow aspiration procedure.

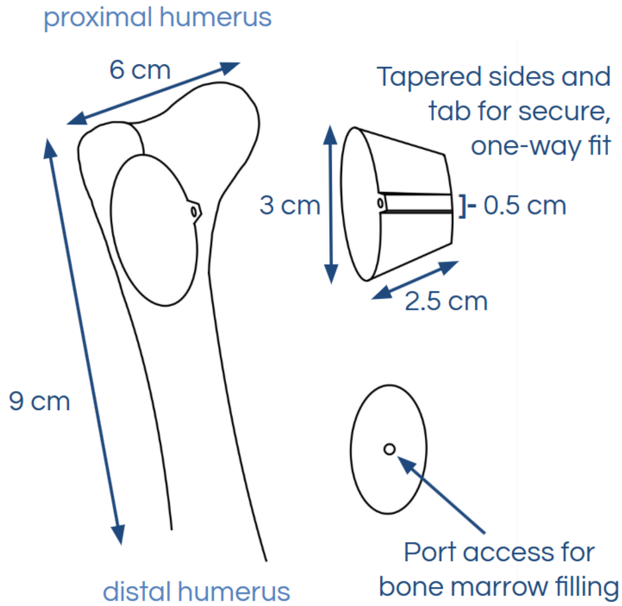


Figure 2: Drawing of Slide Method of attachment

Design 3: Velcro Method of Attachment

The Velcro Method design features a 5.5 x 1.5 cm removable section on the cranial lateral aspect of the proximal humerus. The replaceable section is fixed in place using self adhesive velcro on the inner facing side of the bone, while the base is left uncovered to allow access to the bone marrow port. The replaceable section of the Velcro Method design is hollow to allow the simulated bone marrow fluid to be filled via the port in the base, and features 3 mm walls with texture that mimics real cortical bone. There is some potential for interference with the shoulder joint when replacing the velcroed section.

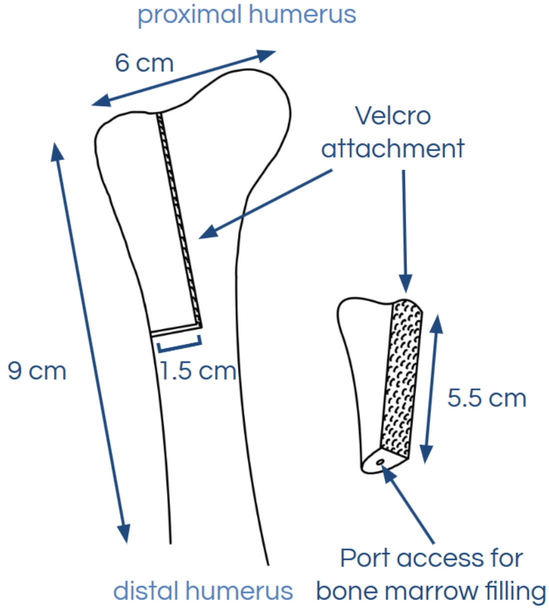
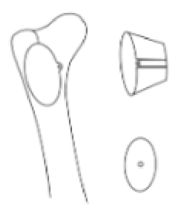
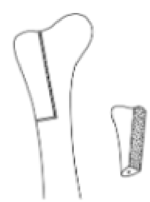


Figure 3: Drawing of the Velcro Method of attachment

Preliminary Design Evaluation

Table 1: **Replaceable Component Design Matrix:**

							
	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**	

Replaceable Component Design Matrix Summary

The slide method scored highest in the categories of joint interference, ease of fabrication, ease of use, durability, and cost. It scored the highest in the joint inference category because the slide piece is only affecting the aspiration site, while the other two models would attach to the joint and would interfere with the joint when replacing the piece. As for ease of fabrication the slide method scored the highest because it is considerably much smaller, and could be replicated easily on any printer. The size factor of this method also makes it easier to replace, and reduces the cost significantly compared to the other methods.

The screw method scored the second highest because it has the best bone marrow access with a port just inside the screw on the “cap” of the bone. This is very crucial for the project as the bone marrow element is what makes this model such an effective teacher, however while the screw cavity is helpful in this way, it interferes heavily with the shoulder joint as the entire top of the bone would have to be replaceable. Additionally with such a large replacement piece it would be quite costly and time consuming to replace, and with the thread required it would require high levels of accuracy affecting its ease of fabrication as well. While this is a hindrance the large surface area of this piece really expands the target area and would prevent the model from getting regularly damaged, and would keep the needle from slipping into these damaged spots, giving it a higher score in safety than the others. It is also less durable than the slide method because the thread will get chewed up over time.

The Velcro method scored the lowest overall for many reasons. Primarily it was the least safe option, as there is worry that the velcro would not be strong enough when students use the model, and when the needle is pulled out of the aspiration site the velcro could give and the whole bone piece could potentially come off. Additionally it would interfere heavily with the joint because it stretches almost to the top of the bone. The velcro also makes it slightly more costly to replace, and makes the piece itself less durable as the velcro would get weaker and weaker over time. This could also impact the security of the bone marrow fluid within the bone and could lead to movement of the internal components. Full criteria definitions are available in Appendix B.

Table 2: **Material of Replaceable Component Design Matrix:**

	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**	

Material Design Matrix Summary

Polylactic acid (PLA) scored the highest in the categories of mechanical accuracy, ease of fabrication, texture, disposability, and cost. It scored the highest in mechanical accuracy compared to acrylonitrile butadiene styrene (ABS) and polyethylene terephthalate glycol (PETG) because of its ability to mimic the characteristics of native bone tissue in tensile strength. PLA is also cheaper than both ABS and PETG and takes the least amount of time to fabricate in a 3D printer. Given the versatility of PLA structures and the qualities of the material itself, it scored the highest in the category of texture due to the range of patterns, textures, and layers it can be used to print.

ABS scored the highest in the category of strength due to its capacity to have a large tensile strength. However, it scored lower than PLA for mechanical accuracy because it may not accurately represent native bone tissue because its tensile strength value is higher than that of bone. This would also contribute to a model made of ABS to be more rigid than bone tissue, thus being less accurate than PLA in terms of tensile strength and elastic modulus. Compared to both PETG and PLA, ABS takes the longest to fabricate in a 3D printer. Additionally, the disposability of ABS was rated very low out of all the material options because it is not biodegradable and can only be recycled a few times before it’s rendered unusable. Considering the frequency with which the replaceable component will need to be replaced, this is an important factor to consider. It also costs slightly more than PLA, but lower than PETG.

PETG was rated the lowest overall based on the grading criteria. It scored the lowest in mechanical accuracy because the highest tensile strength it can reach is lower than that of bone; it is also more elastic than PLA or ABS. PETG has the ability to be more brittle than PLA or ABS if printed incorrectly, and may be slightly deformed upon repeated use because of its low tensile strength. A lower tensile strength would not mimic the feeling of native bone; thus PETG scored the lowest in Texture. While PETG does not print as fast as PLA typically does, it prints faster than ABS and was thus scored higher in ease of fabrication. While not biodegradable like PLA, PETG can be recycled significantly more times than ABS, and scored higher than ABS for disposability. PETG was rated the lowest for cost because it is the most expensive material to buy out of the three options. Full criteria definitions are available in Appendix B.

Proposed Final Design

The final design features the Slide Method of attachment for the design of the replaceable component. The oval section will be hollow to allow the client to fill the simulated bone marrow fluid into the port in the base of the design. The tab allows the user to easily orient the removable section correctly and slide it into place. Both the replaceable component and the rest of the bony structures (scapula, humerus, and fixed elbow) will be 3D printed using PLA. Surrounding the bones will be relevant musculature made from soft silicone which will further help the replaceable component remain in place when the needle enters and exits. The simulated skin, fabricated by the client out of neoprene and pourable silicone, will be affixed over top and will help to hold the musculature and bones in an anatomical position.

Fabrication

Materials

The main skeletal frame will be 3D printed using polylactic acid (PLA). The replaceable component will also be 3D printed in PLA, but will have a cavity meant to store bone mimicking fluid in the piece. For models where fluid is not involved, styrofoam will be used to fill the cavity. This foam will let the user know that the cortical bone piece has been successfully punctured. The top of the model will begin at the scapula of the dog, then down to the humerus and reach a fixed elbow joint. In order for the leg to realistically move, a ball and socket joint will be used to imitate the shoulder joint and at the same time fix the leg to a board in order to mimic a dog laying on its side. Pourable silicone will be used to model the muscle structure, and a thin layer of silicone over neoprene netting will be used to create a skin-like surface over the aspiration site. This will allow for an accurate representation of creating an incision during the procedure.

Methods

In order to fabricate the skeletal structure, bones of an approximately 30 pound (lb) beagle have been selected from the veterinary school. These bones will be 3D scanned at the Makerspace in order to create STL files from these. The STL will be modified in CAD software to include the replaceable component and create a system to attach a ball and socket joint to the scapula. The infill of the bone will also be edited to create a more realistic structure for the cortical bone. A sealable cavity will be created in the replaceable component to hold bone marrow mimicking fluid supplied by the client.

Final Prototype

Fabrication of the final design has not yet been completed, and thus the final prototype will be included in the final report.

Testing and Results

1. **Material Testing**

Table 3: **Material Testing**

Material	Thickness (mm)	Outcome (Pass or Fail)
PLA	1	Fail
PLA	2	Pass
PLA	3	Pass
ABS	1	Fail

ABS	2	Fail
ABS	3	Pass
PETG	1	Fail
PETG	2	Fail
PETG	3	Fail

Material testing was conducted to find which of the 3D printing filaments of the design matrix would mimic bone the best. In order to evaluate the different types of 3D printing, filament samples were made of polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), and polyethylene terephthalate glycol (PETG). Each sample was 38.1 mm x 25.4 mm, and had three different thicknesses of 1 mm, 2 mm and 3 mm. These were each placed on a foam block and one of the client's team members, Dr. Calico Schmidt, used an Illinois needle to puncture each material at each thickness. Tests were considered a pass if the puncture felt accurate to performing the procedure on live bone, and were considered a failure if they did not. After testing all of the samples and thicknesses, Dr. Schmidt determined that the most comparable material was the PLA at 2 mm and 3 mm. She found that ABS also felt accurate to the procedure but only at 3mm thickness, and PETG was overall too weak and too slippery for the needle. These results lined up very well with the design matrix and led PLA to be the final choice.

This was important to establish what material in its baseline form most closely resembles the texture and strength of bone. Literature values state that humerus bones have a tensile strength of at least 68 MPa. Compared to this, PLA has a baseline tensile strength of 40 MPa, and ABS and PETG have tensile strengths of 30 MPa [8]. As the project progresses, aspects of the 3D print can be manipulated to better replicate cortical bone, such as the infill pattern, thickness and outside texture, but this test was important to establish that PLA was strong enough to withstand the aspiration force of the Illinois needle without breaking or bending. This testing was qualitative and somewhat inaccurate, given that it was done before a specific dog breed was chosen for the model and each dog's bone structure is different. Now that a specific breed has been chosen, further testing and research can be conducted to ensure that the model more accurately represents the actual bone.

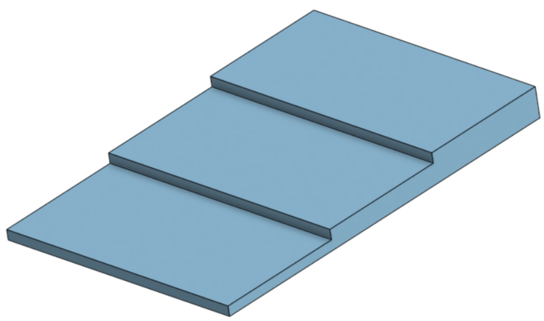


Figure 4: Material Test Swatch CAD Design

2. **Tolerance Testing**

In order to test that each printed copy of the replaceable component will fit in the model correctly, tolerance stack ups will be mocked up, and testing will be done to measure that the piece will fit in the model even when printed on different printers. More specifically, pieces will be printed from the 3D printer at the veterinary school to ensure the client is able to replace the component in house. This reveal variance in the printing and fit capabilities

3. **Pressure and Material Testing**

To test the exact force required to aspirate on the humerus, testing will be conducted on a cadaver bone using an MTS machine to test tensile and compressive properties of the bone. This will provide a more accurate value that would be precise to the specific dog that the model takes after, as there are so many factors that can affect the strength and thickness of the bone including age, gender, and size [9]. This pressure testing will also be conducted on the 3D printed PLA filament, as well as on the other materials (ABS and PETG) once they have been printed. This will be used to ensure that past testing was accurate.

Discussion

There has been no quantitative testing conducted so far, but there has been quantitative testing completed by Dr. Schmit to test various materials and thicknesses of the aspirate site. This quantitative testing has shown that the material and its thickness most similar to bone is 3D printed PLA at a thickness of 3 mm when punctured over styrofoam. While this testing has been helpful to determine which material to make the aspiration model out of, it has its limitations in the sense that the testing was not quantitative. Bone characteristics in dogs like density and strength vary with many characteristics like genetics and bone disorders [9, 10]. These variations make it difficult to pinpoint ideal target values to compare the aspiration model to.

In the future, testing will be done to quantify the strength of the PLA model. These values could then be compared to literature values of canine bone properties. ABS and PETG may also be tested to verify that PLA has the closest strength compared to bone. With this testing though, there are potential sources of error that could arise which include:

- Uneven surface of the material.
- Wide variety of target values.
- Operator error.
- Sensors being incorrectly calibrated.

Changes will then be made to the model based on the results of this testing. These changes could include alterations to the infill of the model, the thickness of the aspiration site, and the material chosen. Depending on the outcome of testing, it may be useful to choose an alternative material to PLA. This material could potentially be Tough PLA, which has a similar Young's Modulus to PLA, but its impact resistance is much larger [11]. It is important to conduct testing to ensure that the model is accurate since it will be learned as a learning tool for veterinary students.

Conclusions

Bone marrow aspiration is a procedure done to provide morphological details of cells and conduct tests on the bone marrow [12]. Veterinary professionals perform this procedure on dogs and cats in sites such as the proximal humerus, iliac crest, and trochanteric fossa. Students typically practice this procedure on cadaver dogs, which has many limitations. First, cadavers are not an accessible resource, especially considering the large number of students that need to practice bone marrow aspiration multiple times. Second, there is no live bone marrow in cadavers, so students cannot practice aspiration or know if they are properly aspirating. The goal of this project is to create a 3D printed model of an anatomically correct canine humerus and its surrounding soft tissues and bones.

Based on research and testing that was done, it was found that PLA at a 3 mm thickness placed over styrofoam is the most similar feeling to performing bone marrow aspiration on a dog's proximal humerus. PLA is the material that shares the most similar properties like tensile strength and texture to cortical bone as compared to ABS and PETG [13]. The 3 mm thickness was chosen because it closely mimicked the feeling of the amount of force required to puncture the bone.

While qualitative testing has been helpful to begin the fabrication process, it has not provided any definitive values to guide the project further. In the future, tests will find and compare the strength of PLA, ABS, and PETG to cortical bone. In addition, further research regarding specific values of bone will also need to be completed to compare the materials to bone. Also, 3D scans of the scapula, humerus, radius, and ulna will be done to obtain STL files and begin 3D printing the model. The preliminary design process has highlighted the importance of accuracy in order to allow veterinary students to receive the most useful training possible. This is why it is important to conduct further research and testing as well as begin fabrication.

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Appendices

1. **Product Design Specifications (PDS)**

Function

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. Currently no veterinary bone aspiration models exist for students to practice on, requiring the use of cadaver dogs. Cadavers can only be used for about 5-10 insertions of the Illinois bone marrow biopsy needle per site, but does not contain live bone marrow that can be collected. This project aims to create a low-cost 3D anatomically correct model of the humerus with relevant soft tissue structures, mimics the consistency and structure of the bones, and allows for insertion of "bone marrow" for collection, allowing veterinary students to practice the skill of bone marrow aspiration.

Client requirements

- Functional model that allows the client to replace the simulated bone marrow and proximal humerus insertion site every 5 procedures performed.
- The model should include the right scapula, shoulder joint, humerus, elbow, proximal radius and ulna, and surrounding muscles and soft tissues. The shoulder joint should be fully articulable, while the elbow should be fixed in a flexed position.
- The client will assist with the fabrication of the skin and bone marrow materials. The model should include a way to attach the skin and insert the bone marrow into the humerus.
- The proximal humerus will include a removable section that is replaced every 5 procedures and filled with the bone marrow solution. Muscles will be replaced every 20 punctures.

Design requirements

1. **Physical and Operational Characteristics**

    1. **Performance Requirements**

        - The model will be an anatomically correct proximal scapula, humerus, shoulder joint, and elbow joint of a 13.6 kilogram (kg) dog. The shoulder joint will replicate a ball and socket joint, and the elbow joint will be fixed in a 120 degree angle.
        - A small, removable section of the humerus will be replaced every 5 uses. This section will be the flat surface on the humerus in which the bone marrow aspiration needle penetrates.
        - The muscle material covering the bone will be replaced every 20 uses.
        - The model will be held stably to the table to prevent movement during the procedure.

    2. **Safety**

        - The model will come equipped with safety instructions that detail steps of use, hazards, and proper sanitation.
        - There will be no live tissue components that can cause harmful exposures.
        - The procedure on the model should be done with proper technique so as to not cause injury by the Illinois needle.
        - The replaceable components of the model should not be used more than 20 times for the muscle and 5 times for the humerus piece.

    3. **Accuracy and Reliability**

        - The punctured humerus will only be used 5 times before it needs replacement so that students do not repeatedly enter the same puncture.
        - The muscle covering the bone will be used 20 times before it needs replacement for the same reason as the humerus, but since it is a softer material it will receive less damage.
        - The model should be similar in size, shape, and feel of a 13.6 kg dog.
        - The model should be able to aspirate 0.5-2 mL of bone marrow [1].

    4. **Life in Service**

        - The model must withstand 5 years of in-class use with components that are replaced as needed.
        - The punctured section of the humerus will be replaced every 5 uses, and the muscle will be replaced every 20 uses.
        - The model will be used for multiple semesters of 96 students in which each student practices the procedure 3 times. Each practice procedure will take 3 minutes to complete.
        - The model will be able to withstand the moderate force used to puncture the humerus with the Illinois needle.

    5. **Shelf Life**

        - The model should be kept in a cool environment, away from direct sunlight.
        - If stored in the proper conditions and without the “bone marrow” component, the model will last 10 to 12 years.

    6. **Operating Environment**

        - The model will be used in a simulated clinical setting during practice procedures.
        - The device will be used in a standard indoor environment with temperature (20-25 ℃) and humidity (40-60 %) [2].
        - This model is designed for UW-Madison Veterinary students, and should be used for learning purposes only.

    7. **Ergonomics**

        - The force used to puncture the bone should be a firm pressure similar to that on a real animal [3].
        - When not in use, the model should be handled delicately.

- The Illinois needle should only be inserted within the replaceable region of the humerus.

8. **Size**
    - The model should be similar in size to a 13.6 kg dog, with a proximal humerus that is 14-15 cm [4].
    - With the added elbow and shoulder joint, the total length of the model will be 25 cm.
    - The section of humerus that is being replaced is a 3x3 cm section. The soft tissue encasing the bone can be removed to access the bone for replacement.
9. **Weight**
    - The weight of the model will accurately represent the weight of the anatomical structures used in the model. This will be no more than 2 kg.
10. **Materials**
    - The model can be split into four different categories of materials based on the anatomy of a dog:
        - The materials of the skin, as provided by the School of Veterinary Medicine, will be composed of mesh fabric fused to silicone. This material imitates the extent of the skin’s elasticity.
        - The muscle of the model should mimic the feeling of penetrating the muscle on the proximal humerus. The muscle covering over the humerus has little thickness and thus should not be difficult to pierce. This is the quality that makes the proximal humerus favorable for bone marrow aspiration [5]
        - The density of the model’s proximal humerus should be roughly the same density as real dog bones. Thus, a material mimicking the density of a dog’s humerus is preferred, which is roughly 27.1 μg/mg for a dry bone [6]. The material should respond to the clockwise and counterclockwise rotations of the Illinois needle used for veterinary bone marrow aspirations without cracking [7].
        - The bone marrow will be fabricated by the School of Veterinary Medicine. The bone marrow material will be a thicker liquid with small bone particles mixed in.
11. **Aesthetics, Appearance, and Finish**
    - It is important for the model to be anatomically correct and feel like a real dog to the user.
    - The appearance of the model, while not as important as the materials, should at least be concise and neat in its presentation. The model should prioritize the feeling of performing bone marrow aspiration rather than the appearance of a real dog.

2. **Production Characteristics**
    1. Quantity:
        - There will be one main model with replaceable parts. Replaceable parts will be provided upon the full delivery of the product; subsequent replaceable parts may be able to be fabricated with 3D printing files.
    2. Target Product Cost:
        - This model is intended to be a low cost solution and thus would preferably be under the $1,600 budget. A portion of the budget is intended for the replaceable components of the model.
3. **Miscellaneous**
    1. **Standards and Specifications**:
        - There are no standards that this model must meet in order to be used, as it is not coming into contact with patients, and is a model for practicing use only.
    2. Customer:
        - The customer would like a model that is made for right handed users, specifically a model of the right proximal humerus, extending from the scapula to just below the elbow.
            - The shoulder must move as a typical ball and socket joint, and the client would like the movement to expose the humerus from the muscle and skin that is around it when it is relaxed.

- The client would like the elbow to be fixed at 120 degrees.

- The client would like a model that can be refilled with a fluid that mimics bone marrow.
- The cortical bone should be physiologically accurate.
- It is important that the aspiration site on the humerus is flat and rough compared to the rest of the bone, so that the needle will have more traction.

3. **Patient-related concerns:**
   - As this model will not have any direct contact with patients, there is no concern of saving and protecting patient data.
   - A concern that this model might raise is that it must be anatomically accurate. This is difficult because the procedure will vary depending on the animal, its maturation, and its weight.
4. Competition:
   - There are no models that currently exist for a veterinary bone marrow aspiration procedure, however cadavers are regularly used despite their inaccuracies. The problem with cadaver models is that the bone marrow has dried up and cannot be extracted using a needle. Another issue with using cadavers, is they have a shorter shelf life, and they can really only take 4-5 punctures per site before the bone has degraded and is no longer an accurate representation of the procedure.
   - There are models for human bone marrow aspirations such as Bonnie Bone marrow biopsy skills trainer, however this is not accurate to dogs, and a bone marrow biopsy is a different procedure targeting the solid aspects of bone marrow. This model is also extremely costly [8].
   - Another model of bone marrow aspiration is . This is also an expensive model and despite having fluid within the model for practice the targeted area is a human hip, which is very different from the aspiration site on most animals (the right proximal humerus) [9].

References:

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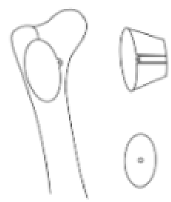
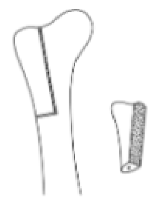
[9]“Anatomy Lab Adult Bone Marrow Aspiration Model,” *Anatomy Warehouse*, 2024. https://anatomywarehouse.com/the-anatomy-lab-adult-bone-marrow-aspiration-model-a-106774 (accessed Sep. 19, 2024).

2. Design Matrices

Table 1: **Replaceable Component Design Matrix:**

							
	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**	

Criteria Definitions:

Joint Interference: Joint interference refers to how easily replaceable the removable component is with respect to the shoulder joint, while still allowing the joint to be articulable. The section of the proximal humerus will need to be replaced frequently, so design that does not require any involvement of the shoulder joint to be replaced would score the highest. Joint interference is weighted at a 20 because the component must be easily replaceable without much interference with the shoulder joint.

Ease of Fabrication: Ease of fabrication refers to how easy the design is to model, 3D print, and assemble. This includes the time it takes for the 3D printer to fabricate the design, which is influenced by the size, density, and detail of the replaceable component. It is also important that the design can be replicated on different 3D printers, and methods with a reduced need for exact accuracy with printing would score higher. Ease of fabrication is weighted at a 20 because it is important that the full design is feasible to fabricate within the semester and that the replaceable components are able to be easily fabricated by the client.

Ease of Use: Ease of use refers to how easily the components can be replaced and how easy it is for the Veterinary student to interact with the model in the same way they would a patient. A design that has easier access to replace bone marrow fluid and the section of the proximal humerus would score higher. Ease of use is weighted at a 15 because it is important that the user experience is simplified as much as possible.

Durability: Durability refers to the expected life of the model, taking into account chosen materials and how replaceable components interact with the rest of the model. A simple design for the replaceable parts that limits wear and tear on the surrounding surfaces is desired so that the non replaceable components will last for a period of 5 years. Durability is weighted at a 15 because it is important that the design maximizes the lifecycle of the product.

Bone Marrow Access: Bone marrow access refers to how easily the client is able to refill the model with bone marrow between each procedure. This includes difficulty in placing the bone marrow within, as well as if the replaceable part would cause any leakage of the bone marrow. Bone marrow access is weighted at a 15 because making sure the user can easily fill and can extract bone marrow is crucial to the functionality of the model.

Cost: Cost refers to how much the replaceable component will cost based on the size of the 3D printed piece repeatedly replaced and if there are any additional costs for supplemental materials that are needed to secure the replaceable component to the model. A model that requires less material will cost less and be scored higher in this category. Cost is weighted at a 10 because it is important that the material cost of replacement components are minimized.

Safety: Safety refers to the security and stability of the replaceable component within the model. It is important that the component stay seated within the non-replaceable bone component so that it does not interfere with the aspiration process. A replaceable component that does not come out of the model with the needle or fracture upon pressure and break into potentially harmful pieces of plastic would be rated higher. Safety is weighted at a 5 because the safety risks of performing the procedure should be similar to that of performing the procedure on a live animal.

Component Design Matrix Summary:

The slide method scored highest in the categories of joint interference, ease of fabrication, ease of use, durability, and cost. It scored the highest in the joint inference category because the slide piece is only affecting the aspiration site, while the other two models would attach to the joint and would interfere with the joint when replacing the piece. As for ease of fabrication the slide method scored the highest because it is considerably much smaller, and could be replicated easily on any printer. The size factor of this method also makes it easier to replace, and reduces the cost significantly compared to the other methods.

The screw method scored the second highest because it has the best bone marrow access with a port just inside the screw on the “cap” of the bone. This is very crucial for the project as the bone marrow element is what makes this model such an effective teacher, however while the screw cavity is helpful in this way, it interferes heavily with the shoulder joint as the entire top of the bone would have to be replaceable. Additionally with such a large replacement piece it would be quite costly and time consuming to replace, and with the thread required it would require high levels of accuracy affecting its ease of fabrication as well. While this is a hindrance the large surface area of this piece really expands the target area and would prevent the model from getting regularly damaged, and would keep the needle from slipping into these damaged spots, giving it a higher score in safety than the others. It is also less durable than the slide method because the thread will get chewed up over time.

The Velcro method scored the lowest overall for many reasons. Primarily it was the least safe option, as there is worry that the velcro would not be strong enough when students use the model, and when the needle is pulled out of the aspiration site the velcro could give and the whole bone piece could potentially come off. Additionally it would interfere heavily with the joint because it stretches almost to the top of the bone. The velcro also makes it slightly more costly to replace, and makes the piece itself less durable as the velcro would get weaker and weaker over time. This could also impact the security of the bone marrow fluid within the bone and could lead to movement of the internal components.

Table 2: **Material of Replaceable Component Design Matrix:**

	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**	

Criteria Definitions:

Mechanical Accuracy: Mechanical accuracy refers to how similarly the printed plastic can mimic the mechanical properties of native bone tissue. A plastic with a tensile strength comparable to bone (67 MPa at the least) and similar density would score highest. Mechanical accuracy is weighted highest at a 25 because it is important that the bone model accurately represents native bone for practicing the procedure.

Strength: Strength refers to how well the material holds up against the needle. The bone model needs to be able to be punctured at least five times before the section of the proximal humerus is replaced, a material that is too brittle will not stand up to multiple punctures. A material that is not brittle would score highest. Strength is weighted at a 20 because it is important that the material can stand up to five punctures to increase the usability of the model.

Ease of Fabrication: Ease of fabrication refers to how easily and quickly the material can be printed. A material that prints at a high quality with minimal modification to print settings to make it accessible for Veterinary School staff to quickly print replacement components is desired. Ease of fabrication is weighted at a 20 because the material must be feasible for someone not previously familiar 3D printers to work with.

Texture: Texture refers to how similar the material is to the feeling of native bone, accounting for the adherence between layers of the print, flexibility, and interaction with the needle. A material with similar flexibility and surface finish to bone is desired without need for additional post print processing. Texture is weighted at a 15 because the surface finish should be similar to bone to best mimic the procedure.

Disposability: Disposability refers to how sustainable the material is and the ease of disposing of the replacement components. Since the proximal humerus is replaced every five punctures, a lot of plastic waste may be created. A material that is biodegradable and/or recyclable would score highest in this category. Disposability is weighted at a 10 because it is important that the waste material from the model can be disposed of in a sustainable manner.

Cost: Cost refers to how much the 3D printer filament typically costs per spool. Since the client will be printing a large volume of replacement components, it is important to keep the ongoing cost of material low. A filament that is low in cost per spool would score the highest. Cost is weighted at a 10 because the client desires a low cost prototype solution.

Materials Design Matrix Summary:

Polylactic acid (PLA) scored the highest in the categories of mechanical accuracy, ease of fabrication, texture, disposability, and cost. It scored the highest in mechanical accuracy compared to acrylonitrile butadiene styrene (ABS) and polyethylene terephthalate glycol (PETG) because of its ability to mimic the characteristics of native bone tissue in tensile strength. PLA is also cheaper than both ABS and PETG and takes the least amount of time to fabricate in a 3D printer. Given the versatility of PLA structures and the qualities of the material itself, it scored the highest in the category of texture due to the range of patterns, textures, and layers it can be used to print.

ABS scored the highest in the category of strength due to its capacity to have a large tensile strength. However, it scored lower than PLA for mechanical accuracy because it may not accurately represent native bone tissue because its tensile strength value is higher than that of bone. This would also contribute to a model made of ABS to be more rigid than bone tissue, thus being less accurate than PLA in terms of tensile strength and elastic modulus. Compared to both PETG and PLA, ABS takes the longest to fabricate in a 3D printer. Additionally, the disposability of ABS was rated very low out of all the material options because it is not biodegradable and can only be recycled a few times before it's rendered unusable. Considering the frequency with which the replaceable component will need to be replaced, this is an important factor to consider. It also costs slightly more than PLA, but lower than PETG.

PETG was rated the lowest overall based on the grading criteria. It scored the lowest in mechanical accuracy because the highest tensile strength it can reach is lower than that of bone; it is also more elastic than PLA or ABS. PETG has the ability to be more brittle than PLA or ABS if printed incorrectly, and may be slightly deformed upon repeated use because of its low tensile strength. A lower tensile strength would not mimic the feeling of native bone; thus PETG scored the lowest in Texture. While PETG does not print as fast as PLA typically does, it prints faster than ABS and was thus scored higher in ease of fabrication. While not biodegradable like PLA, PETG can be recycled significantly more times than ABS, and scored higher than ABS for disposability. PETG was rated the lowest for cost because it is the most expensive material to buy out of the three options.

In conclusion, because PLA was given the highest overall score, it is the material that has been chosen to fabricate the replaceable component in the veterinary bone marrow aspiration model.

3. **BPAG Expense Sheet**

Item	Description	Manufac-turer	Mft Pt#	Vendor	Vendor Cat#	Date	#	Cost Each	Total	Link
Category 1										
Material test swatches	PLA, ABS, and PETG test swatches	UW Makerspace		UW Makers pace		9/26/ 2024	3	0.17	$0.51	
									$0.00	
Category 2										
									$0.00	
									$0.00	
								TOTAL:	**$0.51**	

Conclusions/action items:

The preliminary report will serve as the outline for the final report, updated with progress and feedback.

2024/12/6 - Poster Presentation

HELENE SCHROEDER - Dec 10, 2024, 10:12 PM CST

Title: Poster Presentation

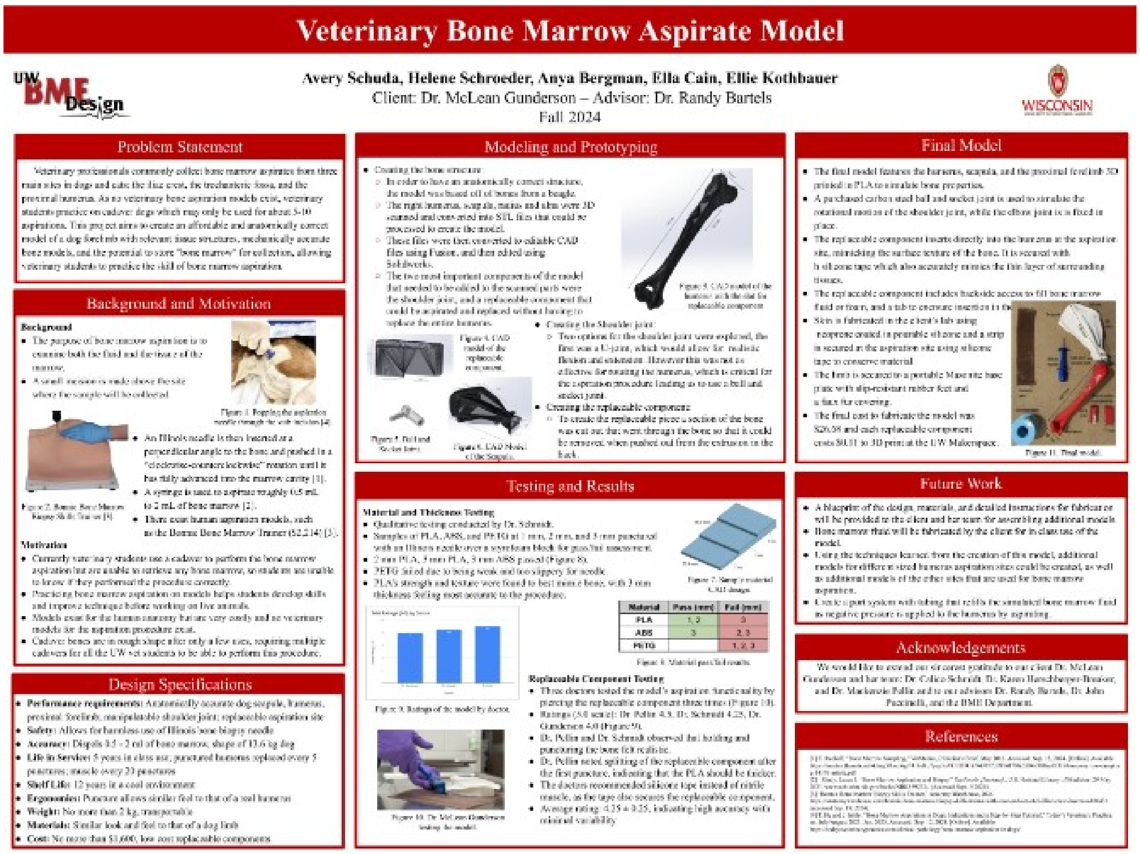
Date: 12/6/24

Content by: Helene

Present: Helene, Avery, Anya, Ella, Ellie

Goals: To upload the final poster presentation that was printed and presented during poster sessions.

Content:



Conclusions/action items:

This is our final poster that overviews and presents all the work that has been done this semester. This poster was printed and presented at the poster sessions.

2024/10/16 - Right Humerus 3D Scan

AVERY SCHUDA - Oct 22, 2024, 12:09 PM CDT

Title: Right Humerus 3D Scan

Date: 10/16/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie, Makerspace staff

Goals: 3D scan right limb bones from dog provided by Dr Gunderson

Content:

See attached files.

Conclusions/action items:

Any holes in the scans can be cleaned up in Blender and exported to 3D print or into CAD for modifications.

AVERY SCHUDA - Oct 22, 2024, 12:03 PM CDT

Download

right_humerus.3mf (7.11 MB)

AVERY SCHUDA - Oct 22, 2024, 12:05 PM CDT

Download

right_humerus.csf (35 MB)

2024/10/16 - Right Scapula 3D Scan

AVERY SCHUDA - Oct 22, 2024, 12:11 PM CDT

Title: Right Scapula 3D Scan

Date: 10/16/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie, Makerspace staff

Goals: 3D scan right limb bones from dog provided by Dr Gunderson

Content:

See attached files.

Conclusions/action items:

Any holes in the scans can be cleaned up in Blender and exported to 3D print or into CAD for modifications.

AVERY SCHUDA - Oct 22, 2024, 12:10 PM CDT

Download

right_scapula.3mf (9.78 MB)

AVERY SCHUDA - Oct 22, 2024, 12:11 PM CDT

Download

right_scapula.csf (72.8 MB)

2024/10/16 - Right Forelimb 3D Scan

AVERY SCHUDA - Oct 22, 2024, 12:12 PM CDT

Title: Right Forelimb 3D Scan

Date: 10/16/2024

Content by: Avery Schuda

Present: Avery, Helene, Anya, Ella, Ellie, Makerspace staff

Goals: 3D scan right limb bones from dog provided by Dr Gunderson

Content:

See attached files.

Conclusions/action items:

Any holes in the scans can be cleaned up in Blender and exported to 3D print or into CAD for modifications.

AVERY SCHUDA - Oct 22, 2024, 12:12 PM CDT

Download

right_forelimb.stl (14.3 MB)

AVERY SCHUDA - Oct 22, 2024, 12:13 PM CDT

Download

right_forelimb.csf (42.3 MB)

2024/09/11 - "Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs"

AVERY SCHUDA - Sep 11, 2024, 11:36 PM CDT

Title: "Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs"

Date: 9/11/2024

Content by: Avery Schuda

Present: N/A

Goals: Learn about different areas that bone marrow aspirate can be collected from in dogs and cats and determine if quality of the samples and procedure difficulty differs.

Search term: PubMed: veterinary bone marrow aspiration

Citation: A. Defarges, A. Abrams-Ogg, R. A. Foster, and D. Bienzle, "Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs," Veterinary Clinical Pathology, vol. 42, no. 2, pp. 170–176, Apr. 2013, doi: https://doi.org/10.1111/vcp.12036.

Link: Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs - PubMed (nih.gov)

Content:

- Samples were obtained from the sternum using one-inch 20- or 22-gauge hypodermic needles, from the right greater tubercle of the humerus, and the right iliac crest using 18-gauge Illinois needles.
    - Only the iliac crest and humerus are within the scope of this project.
- Two types of bone marrow smears were prepared and reviewed by a pathologist unaware of site of aspiration or dog. The number of particles per slide and overall slide quality were scored.
- Bone marrow (BM) aspiration is frequently performed in dogs and cats with unexplained hematologic abnormalities when a diagnosis cannot be established based on blood evaluation.
    - ex. anemia (low RBC count), leukopenia (low WBC count), thrombocytopenia (low platelet count), hyperglobulinemia (high globulin conc), unusual cell morphology, suspected cancer, or infection
- Generally performed with sedation combined with local or systemic analgesia, or general anesthesia.
- Aspirating bone marrow in small dogs or cats is considered technically challenging, and therefore is often time consuming.
- Bone marrow aspirates are most often obtained from the humerus or ilium in dogs through placement of a special 14–18 gauge needle with stylet in the bone marrow cavity, and aspiration of cells with negative pressure from a syringe attached to the needle.
- Needles for bone marrow aspiration are designed to penetrate cortical bone without becoming obstructed, and smears are prepared from aspirates for cytologic evaluation.
- Humeral and femoral BM aspirates may be of lesser diagnostic quality in older animals due to reduced hematopoietic activity in appendicular bones, but as the iliac crest is thin in small dogs and cats, long bone sites are nevertheless commonly chosen.
    - Aspiration from the pelvis or femur may be particularly challenging if the site is covered with abundant adipose tissue.
- Fifty percent (13/26) of sternal, 65% (17/26) of humeral, and 42% (11/26) of iliac aspirates were assessed as > 3 in overall quality.
    - Neither particle number nor particle density nor smear quality differed significantly among samples from the 3 sites.
    - Megakaryocyte number, lymphocyte/plasma cell number, G:E ratio, and iron stores varied slightly among the 3 sites, but all were considered within reference limits 3 for hematologically normal dogs

Conclusions/action items:

While the sternum is a viable option for collecting bone marrow aspirate, it is comparative to existing methods of collection from the iliac crest and proximal humerus. This article provided valuable information in the needle type, aspirate quality, and procedure techniques.

AVERY SCHUDA - Sep 11, 2024, 10:29 PM CDT


ORIGINAL RESEARCH

Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs

[illegible] trauma or pneumothorax.

Results: The number of attempts and time for bone marrow aspiration were greater for ilium than for sternum or humerus, but the sternum was the easiest to aspirate. Smear quality and particle number were similar for all sites. Neither trauma at the site of aspiration nor pneumothorax were identified.

Conclusions: Aspiration of sternal bone marrow with hypodermic needles is feasible and safe in Beagle dogs. Samples equivalent in quality to those from the humerus or ilium can be obtained from clinically normal dogs.

Introduction

Bone marrow (BM) aspiration is frequently performed in dogs and cats with unexplained hematologic abnormalities when a diagnosis cannot be established based on blood evaluation.[1,2] Examples of such abnormalities include anemia, leukopenia, and thrombocytopenia without evidence of adequate regeneration, hyperglobulinemia, blood cells with unusual morphology, and investigation of suspected occult neoplasia or infection. Bone marrow aspiration is painful and therefore generally performed with sedation combined with local or systemic analgesia, or general anesthesia. The former may be preferable in a compromised animal. In general, the more difficult, time-consuming or painful a procedure, the more likely general anesthesia will be required. Aspirating bone marrow in small dogs or cats is considered technically challenging, and therefore is often time consuming.[3] Ideally, bone marrow evaluation should include cytologic and histopathologic assessment, but sometimes a diagnosis can be established solely from cytologic evaluation of aspirated cells.

Bone marrow aspirates are most often obtained from the humerus or ilium in dogs through placement of a special 14–16 gauge needle with stylet in the BM

Dr. Bienzle is an editor of the journal and played no role in the peer review or the decision to accept this submission.

130 [illegible]

[Download](#)

Veterinary_Clinical_Pathol_-_2013_-_Defarges_-_Comparison_of_sternal_iliac_and_humeral_bone_marrow_aspiration_in_Beagle.pdf (433 kB)

2024/09/11 - "Overview of Bone Marrow Aspiration from 120 Cats in Different Hematological Conditions"

AVERY SCHUDA - Sep 12, 2024, 12:10 AM CDT

Title: Overview of Bone Marrow Aspiration from 120 Cats in Different Hematological Conditions

Date: 9/11/2024

Content by: Avery Schuda

Present: N/A

Goals: Learn about the purpose of bone marrow aspiration procedures and the technique required.

Search term: PubMed: Bone marrow aspiration in dogs and cats

Citation: Thierry et al., “Overview of Bone Marrow Aspiration from 120 Cats in Different Hematological Conditions,” Veterinary Medicine International, vol. 2023, pp. 1–13, Aug. 2023, doi: https://doi.org/10.1155/2023/2493618.

Link: Overview of Bone Marrow Aspiration from 120 Cats in Different Hematological Conditions - PMC (nih.gov)

Content:

- Bone marrow evaluation is highly important for the diagnosis of numerous hematological alterations in animals, especially cats, given their greater propensity for hematopoietic changes associated with retrovirus infections.
- Bone marrow evaluation is a valuable resource to identify diseases associated with the production, maturation, and release of erythrocytes, leukocytes, and megakaryocytes
  - In cats, bone marrow evaluation is recommended in cases of persistent regenerative anemia, neutropenia, and thrombocytopenia, as well as undefined leukocytosis, morphological abnormalities in circulating leukocytes, erythrocytes, and platelets
  - It is also of great diagnostic value in cases of suspicions of BM dysfunctions due to primary or metastatic neoplasms, or associated with feline leukemia virus (FeLV) and feline immunodeficiency virus (FIV) infections
- In veterinary medicine, despite being a diagnostic tool not often listed by the clinical community, bone marrow aspiration is more commonly used than biopsy due to its faster analytical speed and ease of sampling
- Seeks to characterize cells in terms of morphology, identifying cytoplasmic and nuclear alterations, and seeks a broad view of medullary composition, indicating numerical variation of precursor cells and their subsequent lineages
- Bone marrow samples were collected from the left deltoid tuberosity using standard Jamshidi trifaceted or Illinois beveled cannulas, with a Luer-Lock closure system and size of 16G (0BIL1617/080™ and BIL1617™, Biomedical Srl, Firenze, Italy)
- Aspiration was performed using 5–10 mL syringes coupled to the cannula, to obtain 0.3–0.8 mL of bone marrow
- All smears were stained using the May–Grunwald–Giemsa (MGG) technique diluted in Sorensen buffer.
- The smears were first evaluated according to the number of spicules per smear (×100), density and cellularity of spicules (number of precursors/adipocytes), degree of maturation of precursors, and quantity of lymphocytes and plasma cells in every five fields of higher magnification (×400)

Conclusions/action items:

This article was mainly focused on cellular results, rather than technique so further research is needed into the technique. The model only needs to mimic the consistency of bone marrow, not the exact cellular characteristics. It is more important that the bone, muscle, and surrounding tissues are mimicked accurately.

2024/09/12 - "Bone Marrow Aspiration in Dogs: Indications and a Step-by-Step Tutorial"

AVERY SCHUDA - Sep 12, 2024, 3:53 PM CDT

Title: Bone Marrow Aspiration in Dogs: Indications and a Step-by-Step Tutorial

Date: 9/12/2024

Content by: Avery Schuda

Present: N/A

Goals: Learn about the process of collecting bone marrow aspirate and the purpose of the procedure from an article provided by our client.

Search term: (link provided by client)

Citation: T. Hu and J. Intile, “Bone Marrow Aspiration in Dogs: Indications and a Step-by-Step Tutorial,” Today’s Veterinary Practice, no. July/August 2023, Jun. 2023, Accessed: Sep. 12, 2024. [Online]. Available: https://todaysveterinarypractice.com/clinical-pathology/bone-marrow-aspiration-in-dogs/

Link: Bone Marrow Aspiration in Dogs: A Step-by-Step Tutorial (todaysveterinarypractice.com)

Content:

- Bone marrow cytopathology and histopathology are vital tools for understanding diseases and conditions that affect or arise from the bone marrow.
- Bone marrow aspiration is a safe and beneficial procedure performed to help with the evaluation and diagnosis of various conditions affecting the bone marrow in dogs.
- The procedure is most often indicated when abnormalities are identified in peripheral blood.
    - Contraindicated for animals that have metabolic bone disease or are not stable enough to undergo general anesthesia.
- General anesthesia is recommended for dogs that can tolerate it.
    - Sedation combined with systemic or local analgesia or general anesthesia is required
    - General anesthesia is recommended for smaller dogs and cats.
- The procedure is associated with moderate pain, the most commonly reported complication.
    - Other complications are rare but can include pain, bleeding, bruising, and fracture if the bone is weak or compromised.
- The most commonly sampled sites are the proximal humerus and the ilium.
- Samples to submit to a clinical pathologist include a stained slide, unstained slides, and a peripheral blood smear.
- If the aspirate is nondiagnostic, a bone marrow core biopsy may be needed.
    - Recommended in cases of bicytopenia (reduction in any two of the cell lines of blood) or pancytopenia (all types of blood cells are low).
- Bone marrow, located within the center of bones, is the main hematopoietic organ at birth that produces blood cells (erythrocytes, leukocytes) and platelets.
- Active marrow is located throughout most flat and long bones of the body in young animals and will recede from long bones with maturity.
- In adults, active marrow persists in the flat bones of the vertebrae, sternum, ribs, and pelvis, along with the proximal ends of the humerus and femur.
- Bone marrow aspiration and evaluation are performed in conjunction with:
    - clinical findings and diagnostics
    - complete blood count
    - morphologic changes on peripheral blood smears
    - other laboratory data
    - imaging
- Evaluating aspirate and core bone marrow samples provides information about the status of the bone marrow and its ability to correct abnormalities in the peripheral blood and can indicate infection, myelofibrosis, necrosis, or neoplasia.
- Bone marrow aspiration is most commonly performed when abnormalities are detected in peripheral blood to determine the source of the disease, including:
    - persistent neutropenia
    - unexplained thrombocytopenia
    - nonregenerative or poorly regenerative anemia
    - bicytopenia or pancytopenia without adequate regeneration
    - blood cells showing abnormal morphology
    - or a combination thereof
- Bone marrow can also be examined to stage neoplastic diseases (e.g., lymphoma, mast cell tumors), estimate levels of body iron stores, evaluate lytic bone lesions, and search for suspected occult neoplasia or infection

- Can also indicate an underlying cause for hyperproteinemia secondary to multiple myeloma, leishmaniasis, and systemic fungal diseases.
- In dogs, bone marrow aspirates are often collected from the proximal humerus or ilium. A special 14- to 18-gauge needle with stylet is placed into the bone marrow cavity, and cells are subsequently aspirated.
    - These needles are designed to penetrate cortical bone without becoming obstructed.
    - Other sites in dogs include the sternum, ribs, and proximal femur.
    - Aspiration from the pelvis and femur is challenging if the region contains abundant adipose tissue.

Conclusions/action items:

The attached pdf goes through the bone marrow aspiration procedure step by step with helpful images. The team can use these images to help guide what our procedure model should look like. Several of the cited journals from this article will be helpful in determining next research steps and informing the product design specifications.

AVERY SCHUDA - Sep 12, 2024, 3:42 PM CDT

[Download](#)

TVP-2023-0708_Bone_Aspiration.pdf (344 kB)

2024/09/18 - "Bone Marrow Sampling"

AVERY SCHUDA - Sep 18, 2024, 12:55 AM CDT

Title: Bone Marrow Sampling

Date: 9/18/2024

Content by: Avery Schuda

Present: N/A

Goals: Review the process of bone marrow aspiration from a source provided by the client.

Search term: N/A (article provided by client)

Citation: E. Rudloff, “Bone Marrow Sampling,” VetMedux, Clinician’s Brief, May 2013. Accessed: Sep. 18, 2024. [Online]. Available: https://assets.ctfassets.net/4dmg3l1sxd6g/741fx8rc7yep3nVCUD7Cit/947077cff954178fe55849388aa85318/bone-marrow-sampling-14176-article.pdf

Link: How to Collect Bone Marrow Samples (cliniciansbrief.com)

Content:

Materials:

- Lidocaine, 2–4 mg/kg (may be diluted 50% with sterile isotonic saline)
- Sterile gloves
- Scalpel blade, #11
- Bone biopsy needle (eg, Illinois Sternal 15–18 g,1–2 inches)
- Syringe, 6–12 mL
- Glass slides and/or laboratory container
- 10% buffered formalin in small container

Indications:

- Persistent depression in RBCs, neutrophils, or platelets without evidence of regeneration (ie, reticulocytosis, bands)
- Unexplained, persistent elevation in peripheral WBCs
- Presence of abnormal cells (eg, megaloblastic cells, rubricytes, neutrophil hypersegmentation, giant platelets) in peripheral blood
- Suspicion of bone marrow dysfunction
- Staging for certain hemolymphatic cancers
- Unexplained persistent hypercalcemia (dogs)
- Unexplained monoclonal or polyclonal gammopathy
- Fever of unknown origin

Procedure:

1. Surgically prepare the area (in this case, the lateral proximal humerus) and inject local anesthetic into the dermis and periosteum. Drape as necessary
2. Use a #11 blade to make a facilitating incision in the skin over the proximal humerus
3. Seat the collection needle into the periosteum along the cranial and lateral aspect of the greater tubercle at the proximal humerus
    1. Use firm pressure and a twisting wrist motion to direct it ~1 cm along the axis of the bone, perpendicular to the flat surface.
    2. Penetrating the cortex requires persistence and effort.
    3. Once it is firmly embedded in the bone (B), the needle should be rotated 360° in both directions and rocked back and forth to disconnect the sample from remaining tissue
4. Remove the cap and stylet and attach a sterile syringe
5. Gently aspirate a small amount (<0.5–2 mL) of marrow with 1 or 2 pulls.
    1. If marrow is not aspirated, either disconnect the syringe, advance further, and retry or pull out the needle and reseat
6. Once marrow is aspirated, disconnect and immediately place drops on slides, tilting them along one end.
    1. Immediately smear the sample in the same manner as is done with a peripheral blood smear for obtaining a manual differential count.
    2. Using minimal pressure to avoid damaging cells, pull the slides apart; work quickly to prevent clotting
7. Evaluate a dry slide in-house with the same stain used for a peripheral blood smear.

1. Before recovering the patient and packaging the sample, ensure that there is a diagnostic sample (eg, spicules, cellular sample, megakaryocytes)

Conclusions/action items:

This article was a good review for the procedure we saw demonstrated and practiced at the UW vet school. An important data point was confirmed that <0.5- 2 mL of marrow is aspirated, which fits, but more accurately quantifies the estimated volume giving to us by the client and team. Going forward the team will have to figure out how often components need to be replaced based on the damage to the model that occurs during each procedure.

AVERY SCHUDA - Sep 18, 2024, 12:35 AM CDT


Bone Marrow Sampling

Bone Marrow Cytology (Aspiration) vs Histology (Core Biopsy)

Sampling Sites & Patient Preparation

In bone marrow cytology, the most important aspect is not collection of the sample but preparation of the slides; a perfect aspirate can be rendered nondiagnostic by suboptimal slide preparation.

MORE

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bone-marrow-sampling-14176-article.pdf (2.78 MB)

2024/09/25 - SimuBone 3D Printer Filament

AVERY SCHUDA - Sep 25, 2024, 12:20 PM CDT

Title: SimuBone 3D Printer Filament

Date: 9/25/2024

Content by: Avery Schuda

Present: N/A

Goals: Research 3D printer filaments to best mimic bone to get the right feel for needle insertion of the model

Search term: Google: best 3d printed filament for mimicking bone

Citation: “3DXTech SimuBone Bone Modeling Filament - 1.75mm (0.75kg),” MatterHackers, 2019. https://www.matterhackers.com/store/l/3dxtech-simubone-bone-modeling-filament-075kg/sk/MUML76V3 (accessed Sep. 25, 2024).

Link: 3DXTech SimuBone Bone Modeling Filament - 1.75mm (0.75kg) | MatterHackers

Content:

- 3DXech SimuBone Bone Modeling Filament
- 1.75 mm filament diameter
- 0.75 kg spool
- $98
- Ideal for use in both education and clinical settings as a replacement for cadaver bone and for patient-specific preoperative surgical planning
- ISO 22196:2011 certified antibacterial polymer
- Simulated the look and feel of bone
- Formulated for ideal sawing, drilling, and screw retention
- Nano-silver additive to eliminate 99.9% of bacteria for the life of the part
- PLA based formula
- Radio opaque additive allows for enhanced visibility on X-ray and CT scans

Conclusions/action items:

Our client does not require an antibacterial aspect to the model or have need for the visibility on X-ray and CT scans. Since the formula is PLA based, these additives are likely driving up the price of the filament to $98, which is not ideal since the client will be printing replacement components frequently and desires a low-cost solution. Next steps would be to look into basic PLA to see if it has properties similar enough to bone.

2024/09/25 - "Understanding compressive viscoelastic properties of additively manufactured PLA for bone-mimetic scaffold design"

AVERY SCHUDA - Sep 25, 2024, 12:52 PM CDT

Title: 'Understanding compressive viscoelastic properties of additively manufactured PLA for bone-mimetic scaffold design"

Date: 9/25/2024

Content by: Avery Schuda

Present: N/A

Goals: Research 3D printer filaments to best mimic bone to get the right feel for needle insertion of the model

Search term: Google: can you accurately mimic bone density with PLA

Citation: A. H. Foroughi, C. Valeri, D. Jiang, F. Ning, M. Razavi, and Mir Jalil Razavi, "Understanding compressive viscoelastic properties of additively manufactured PLA for bone-mimetic scaffold design," Medical Engineering & Physics, vol. 114, pp. 103972–103972, Apr. 2023, doi: https://doi.org/10.1016/j.medengphy.2023.103972.

Link: Understanding compressive viscoelastic properties of additively manufactured PLA for bone-mimetic scaffold design - ScienceDirect

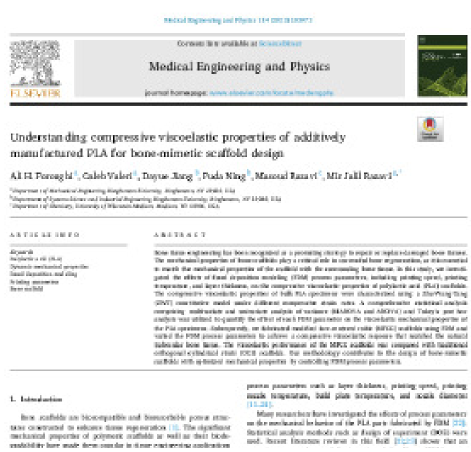
Content:

- MANOVA results showed that all of the investigated FDM parameters (V, T, and H) significantly influenced the compressive viscoelastic properties of PLA parts.
- ANOVA results showed that FDM printing speed (V) significantly influences the ZWT model coefficients (E0, α, E1, and η1). The effect of printing speed on the nonlinear elastic coefficient, β ($p = 0.463$), was found to be statistically nonsignificant in the range of parameters studied here.
- ANOVA results showed that FDM printing temperature (T) significantly influences the coefficients of the nonlinear elastic branch (E0, α, β) of the ZWT model. The effect of printing temperature on the parameters of the viscous branch of the ZWT model (E1 ($p = 0.253$) and η1 ($p = 0.626$)) was found to be statistically nonsignificant ($p = 0.241$) in the range of parameters studied here.
- ANOVA results showed that FDM printing layer thickness (H) significantly influences three of the parameters of the ZWT constitutive model (α, β, and E1). The effect of printing layer thickness on the linear coefficient of the elastic branch of the ZWT model, E0 ($p = 0.282$), and the viscosity of the viscous branch η1 ($p = 0.137$), was found to be statistically nonsignificant in the range of parameters studied here.
- MFCC scaffolds are superior to traditional OCS scaffolds from stiffness, yield strength, yield strain, and toughness perspectives.
- Viscoelastic properties of natural bone tissue can be achieved by the variation of FDM parameters of PLA bone scaffolds. This would reduce the mismatch between the scaffold and the natural bone tissue, which consequently reduces the adverse effects of stress shielding such as osteopenia.

Conclusions/action items:

PLA might be the most appropriate filament, given the correct infill density and pattern. It is low cost and widely available. I have printed with PLA many times and it is very easy to work with even for beginners, so the client should be able to continue printing replacement components after the conclusion of the project. Should continue to research other bioplastics that could also be viable options.

AVERY SCHUDA - Sep 25, 2024, 12:47 PM CDT


Medical Engineering and Physics

Understanding compressive viscoelastic properties of additively manufactured PLA for bone-mimetic scaffold design

ARTICLE INFO

ABSTRACT

1. Introduction

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1-s2.0-S1350453323000243-main.pdf (9.2 MB)

2024/10/01 - Screw Method of Attaching Replaceable Component Design

AVERY SCHUDA - Oct 02, 2024, 1:11 PM CDT

Title: Screw Method of Attaching Replaceable Component Design

Date: 10/1/2024

Content by: Avery Schuda

Present: N/A

Goals: Refine and sketch Screw Method of attachment design for the replaceable component of the model after team discussion and design matrix completion

Content:

Conclusions/action items:

AVERY SCHUDA - Oct 09, 2024, 1:28 PM CDT

Design summary:

The Screw Method design features a 4 cm section at the proximal end of the humerus model after a 30 lb sized dog which attaches to the distal portion of the humerus through threaded ends that screw together. The proximal end removable piece of the humerus has a 3 mm wall thickness to accurately mimic the feeling of real cortical bone. The removal end of the Screw Method design is hollow and features a port for filling bone marrow simulating fluid in the base of the threaded end. The design would require reattachment to the scapula every time it is replaced.

2024/10/02 - Slide Method of Attaching Replaceable Component Design

AVERY SCHUDA - Oct 02, 2024, 1:12 PM CDT

Title: Slide Method of Attaching Replaceable Component Design

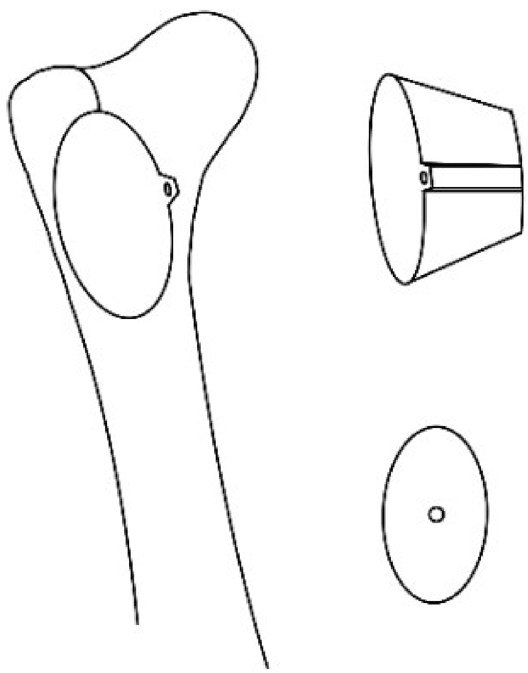
Date: 10/2/2024

Content by: Avery Schuda

Present: N/A

Goals: Refine and sketch Slide Method of attachment design for the replaceable component of the model after team discussion and design matrix completion

Content:



Conclusions/action items:

AVERY SCHUDA - Oct 09, 2024, 1:28 PM CDT

Design summary:

The Slide Method design features a 3 x 2.5 cm oval section of the proximal humerus that slides into place with the help of a tab. The tapered sides and 0.5 cm tab along the length of the removable section help to provide a one-way fit, ensuring the section is installed in the correct orientation. The replaceable section is hollow, and on the side facing inwards, there is a port for filling the simulated bone marrow solution. Surface is rough and mimics the shape of the bone, with 3 mm walls to accurately simulate puncturing cortical bone while performing the bone marrow aspiration procedure.

2024/10/02 - Velcro Method of Attaching Replaceable Component Design

AVERY SCHUDA - Oct 02, 2024, 1:13 PM CDT

Title: Velcro Method of Attaching Replaceable Component Design

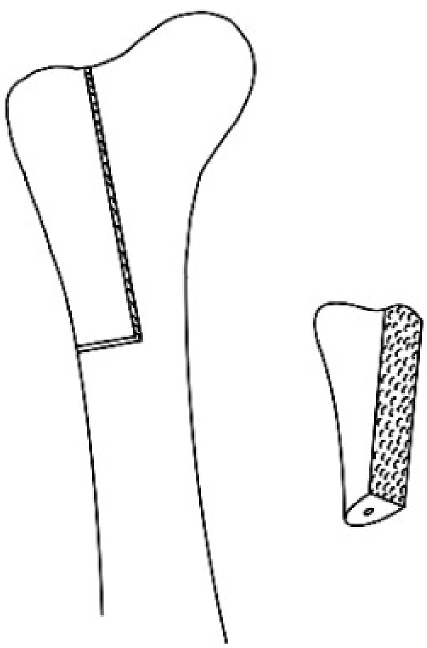
Date: 10/2/2024

Content by: Avery Schuda

Present: N/A

Goals: Refine and sketch Velcro Method of attachment design for the replaceable component of the model after team discussion and design matrix completion

Content:



Conclusions/action items:

AVERY SCHUDA - Oct 09, 2024, 1:29 PM CDT

Design summary:

The Velcro Method design features a 5.5 x 1.5 cm removable section on the cranial lateral aspect of the proximal humerus. The replaceable section is fixed in place using self adhesive velcro on the inner facing side of the bone, while the base is left uncovered to allow access to the port. The replaceable section of the Velcro Method design is hollow to allow the simulated bone marrow fluid to be filled via the port in the base, and features 3 mm walls with texture that mimics real cortical bone. There is some potential for interference with the shoulder joint when replacing the velcroed section.

2024/09/11 - Lecture 1 (BME Career Prep)

AVERY SCHUDA - Sep 11, 2024, 2:05 PM CDT

Title: Lecture 1 - BME Career Prep

Date: 9/11/2024

Content by: Avery Schuda

Goals: Prepare for the career fair and job searching

Content:

Job Searching

- BME 001 - Co-Op (spring/summer or summer/fall)
- Keep track of applications - ECS tracking sheet (ecs.wisc.edu/resources)
- Quality of source matters: Handshake/Employer website in the fall, LinkedIn/Employer website later in the year, over google search, never use Indeed
- Connect before you are a candidate, all connections are good connections
- Think beyond the title - focus on skills, industry, exposure

Resume Tips

- Tailor your resume to the position - quick changes
- Create balance - show a full picture of your experience
- ATS proofed resume is do-able
  - MS word
  - No columns, charts, colors
  - Design projects WITHOUT years or semester - what did you do?
  - Technical skills and coursework
  - Jobs - Organization + Location, Position title + Dates
  - ATS does not scan headers and footers, white text
  - Examples on ECS website

Cover Letters

- Not required for career fair
- Always based on specific job

Career Fair Advice for BME

- Identify your purpose - more than just an internship
- Looking beyond the obvious - overlap with other disciplines
- Research the employer - feedback from our partners
- Develop you "value added" statement - why you?
  - Four semesters of intensive design experience

Posting Logic

- Many majors or industries likely apply even though not explicitly listed
- Read about what companies actually do

Career fair: 9/16-9/19

11:00am-5:00pm

Different organizations

Conclusions/action items: Look into BME, ME, EE, and MatSE employment opportunities at the career fair. Update resume for ATS. Use the ECS tracking sheet to keep track of applications and when to follow up.

2024/09/18 - Lecture 2 (Exploring Your Leadership Style)

AVERY SCHUDA - Sep 18, 2024, 2:02 PM CDT

Title: Lecture 2 - Exploring your Leadership Style

Date: 9/18/2024

Content by: Avery Schuda

Goals: Define leadership and leadership styles to learn about improving leadership for BME 300 and future classes and jobs

Content:

Speaker: Angela Kita, Associate Director of Leadership

Leadership Qualities:

- Empathy
- Self-awareness
- Vision
- Transparent
- Communication
- Decision-Making

Power Model of Leadership

- Being in control is the most important thing
- Hierarchy, authority, command

Servant Leadership

- Being of service to others
- Sharing power
- Listening and understanding
- Empathetic, empowering, shared decision making

Authentic Leadership

- Building self-esteem and self-awareness
- Emotional intelligence
- Creating authentic relationships
- Transparency, genuineness, honesty

People Oriented

- Glue that holds the team together
- Get to know everyone as individuals
- Building trust and inclusive environment

Process-Oriented

- Sets the pace for the team
- Willing to work alongside everyone
- Systems for efficient work

Thought-Oriented

- Big picture
- Anticipate future
- New ideas

Impact-Oriented

- Set the bar high
- Push for excellence
- Inspire people to follow your lead

Define how you want to lead

- Self-assess
- Observe and reflect
- Seek out feedback

Goal Setting

- Start small, slow
- Focus on one element to practice
- Look for mentors
- Ask for feedback

Conclusions/action items:

My goal for myself and my team is I would like to improve communication and confidence in my team. I have noticed several group members seem hesitant to speak up and share their ideas. I want to create an environment that encourages the team to collaborate and have the confidence to speak freely about their ideas. I can focus on mentorship, relationship building, and empathy through my team leadership to help the team better function.

2024/09/25 - Lecture 3 (Fall Postgraduate Planning)

AVERY SCHUDA - Sep 25, 2024, 2:03 PM CDT

Title: Lecture 3 - Fall Post Graduate Planning

Date: 9/25/2024

Content by: Avery Schuda

Goals: Continue BME advising, learn about post graduate options and planning

Content:

General Tips

- Use undergrad experience to build a story
  - Gain experience while you can - easier while you are in school
  - Tie the, together - Big picture o who you are/want to go/want to be
  - Research = important for all post-degress and helpful for industry
- Do your homework
  - What does the ideal career look like?
  - What programs have the opportunities are you looking for?
  - Location, career development, people, disease, research, courses
- Think about letter writers or reference early - 3 strong ones
- School: think about preparing for MCAT/GRE

Writing your story

- Avoid I did this, then that, then the other thing
- Don't say you will do anything in your research/field interest
- General: Start with what you want to do - thesis statement
  - e.g. Cancer stem cells, roles , etc
  - Your narrow experiences(s) and how that applies to your broad interest
  - Specific to each position or place to which you apply
- Personal statement: show a reasonable idea of what
  - Mention researcher whose lab you want to be a part of, they may be the one reading your application
- CV

Grad School Options

- Masters, MS
  - Stepping stone, change directions, gain depth, expand credentials for future
  - Industry focused
  - Generally one year
  - Rewrite your story
  - Make yourself more desirable
    - Fill gaps in your resume
    - Higher level of skills - more lab time with less class time
    - More experience - teaching, mentoring, research thesis
    - Older more experience
  - Really powerful if you add in industry experience
  - Reasons
    - Opens doors (credentials and experience)
    - Higher starting salary
    - Another opportunity for summer internships
    - More time to find your dream job
  - Research (1.5-2 years)
    - For those continuing to a PhD
    - Thesis required (must have a lab PI identified)
    - Can be funded as RA/TA/PA (tuition remission and stipend)
  - Accelerated Program (accelerated 1 year)
    - Coursework only
    - Independent study/research allowed

        - Funding (TA only)
    - Biomedical Innovation, Design, and Entrepreneurship (accelerated1 year)
        - Project based - project required (BME design project continuity)
        - Partnership with business school
        - Funding (TA only)
    - Applying for accelerated programs
        - Applying online, pay fee and submit - Fall and Spring start available
            - Statement of purpose: why you want to pursue
            - Research MS only: list PI
        - Deadline 12/15
        - Special consideration to BME undergrads: needs at least 3.0 overall / 3.0 in the last 60 credits
- Masters elsewhere
    - Explore opportunities and interests
        - MEng
        - MS in Global Health
        - MS in other Engineering Dept. (generally takes longer)
        - MBA - generally industry pays for credits or evening options late
    - Similar to advice earlier and for PhD programs later
        - Find faculty/labs performing research/work in your passion area, area that aligns with your industry interests
        - Less competitive than PhD programs, generally not funded
- Doctoral, PhD
    - Desire to be an independent researcher
    - Write research grants
    - Work in academia
    - Lead projects in industry, startups, etc
    - Follow your passion, who is working in that area?
        - Network
        - Conferences
        - Utilize your lab PI here at Madison = Collaborators
    - Build Resume/Cv
        - REU - research experience for undergrads - summer
        - Research is a must - honors in research
    - External finding NSF - GRFP
        - Apply Fall senior year then once more 1st year of grad school
        - UW hosts workshops
    - Apply early and list names - most do rolling review
    - Generally >3.5 GPA and 75%ile Quantitative GRE
    - Review process
        - Faculty individually review applications that align with their research
        - Highly sought after candidates are invited for visit weekends
- Medical School (MD) or other pre-health field
    - Premed (pre-health) advising - check requirements early
    - Special requirements for most medical schools
- All can be satisfied within BMEs 128 credits - plan ahead

Conclusions/action items:

I am planning to do the BIDE masters, so I will need to plan for applying next fall. Dr P also said that the new biomechanics professor is looking for undergrads to work in her lab, so look out for his email.

2024/10/02 - Lecture 4 (Near Peer Mentoring)

AVERY SCHUDA - Oct 02, 2024, 2:07 PM CDT

Title: Lecture 4 - Near Peer Mentoring

Date: 10/2/2024

Content by: Avery Schuda

Goals: Learn about becoming a better peer mentor

Content:

Why are you mentoring 200 students?

- Getting 200s more comfortable with the design process and working with clients
- Teaching someone else helps you learn and grow
- Less intimidating because we are closer in experience level
- Giving on advice on classes and other experiences that you just took last year
- Learning how to work on a team and build good team dynamics
- Additional instructional and emotional support
- Peer mentors are mor approachable, mentees are more willing to ask questions
- Share experiences
- Increases belonging
- Mutual benefits (transferrable skills)

Transferrable skills

- Leadership
- Communications
- Active listening
- Study practices
- Self-awareness
- Interpersonal skills

General Benefits

- Increased self-esteem/confidence
- Increased patience
- Build positive habits
- Foster personal growth
- Help identify gaps in your own knowledge
- Sense of accomplishment

What does it mean to be a good mentor?

- Be proactive, anticipate issues
- Building trust
- Psychological safety (share w/o fear)
- Reliability
- Support/enthusiasm
- Being available
- Transparent (open and honest)
- Humanizing their challenges (be the coach)
- Good listening

Listening effectively

- Get rid of distractions
- Stop talking
- Act like you're interested
- Look at the other person
- Get the main idea
- Ask questions

- Check for understanding
- React to ideas, not to the person
- Avoid hasty judgements

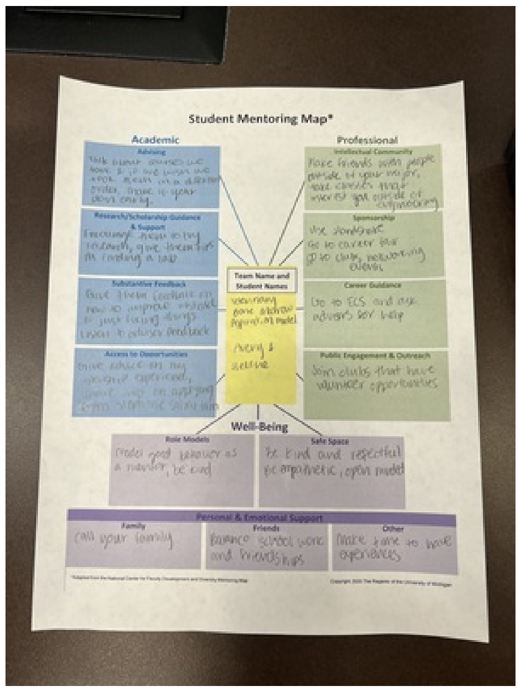
What do you wish you knew in BME 200?

- Getting information about internships, research, co-ops, resume writing, applications earlier
- Time management skills
- Failures are a learning opportunity
- Put everything in Lab Archives
- Be willing to ask for help/ask questions
- Create good group dynamics, you will be around the same people for four years

Conclusions/action items:

Work with Helene to be better mentors to the sophomores by following what we learned today to the best of our ability. Try to share the information that we wish we knew last year.

AVERY SCHUDA - Oct 02, 2024, 2:00 PM CDT



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IMG_9420.jpg (3.2 MB) Student Mentoring Map

2024/10/09 - Lecture 5 (Sustainable Engineering)

AVERY SCHUDA - Oct 09, 2024, 2:02 PM CDT

Title: Lecture 5 - Sustainable Engineering

Date: 10/9/2024

Content by: Avery Schuda

Goals: Explore the topic of sustainable engineering and think about how to apply the concepts to our project

Content:

Lecturer: Andrea Hicks

- 3 pillars: Environment, Social, Economic

Why should we care?

- Health care sector is responsible for ~5% of global emissions
- 388,000 disability adjusted life expectancy years lost
- Circular economy - keeping materials cycling through the economy
    - Keeping materials out of the waste stream so that we can reuse them
- Life cycle assessment
    - Fossil based plastic has higher carbon dioxide output
    - Bioplastics (ex. PLA) leads to utrification
    - Analyze material composition for reusable and disposable options, disinfection frequency

How does sustainability fit into your project?

- Minimize the size of the replaceable component as much as possible
- Use the less of the evils (PLA) since the replaceable component will be disposed of frequently
- Look into bioplastic recycling through the Makerspace or other to minimize environmental impact

Conclusions/action items:

Our team can fit sustainability into our project by minimizing material waste and using more recyclable plastics for 3D printing. Additionally using as many reusable components as possible and extending the lifespan of components wherever possible instead of replacing them. An action item for the future would be look into recycling options for PLA.

2024/10/16 - Lecture 6 (Intro to WARF, IP, Disclosing & Licensing)

AVERY SCHUDA - Oct 16, 2024, 2:07 PM CDT

Title: Lecture 6 - Introduction to WARF, IP, Disclosing & Licensing

Date: 10/16/2024

Content by: Avery Schuda

Goals: Learn about WARF and how they facilitate IP, disclosing, and licensing

Content:

Speakers Justin Anderson, JD and Jeanine Burmania

Who is WARF

- Enable UW Madison to research to solve the world's problems
- Support scientific research by providing financial support, actively managing assets, and moving innovations to the marketplace for a financial return and global impact
- nonprofit supporting organization
- Governed by a board of successful alumni with expertise in a variety fields

Technology Transfer

- Moving research results from campus out into the market
- WARF works at this interface to facilitate securing IP rights and commercial licenses
- IP licenses
- Industry sponsored research
- Consulting arrangements
- Fee for service

Intellectual Property Overview

- Four common types of IP
  - Patents
    - Only good for ~20 years
    - Property right, granted by a governmental agency
      - e.g. USPTO
      - No global patent
    - Patent holder has the right to exclude other from making, using, selling, or importing the claimed invention
    - Design - 15 years, form
    - Plant - 20 years
    - Utility - Provisional (1 year placeholder) and Non-provisional (20 year term, can claim property)
      - New and useful process, machine, manufacture, or composition of matter
      - ~ 2-5 years to issue after filing (patent examination)
      - `$30,000 in mostly attorney fees
  - Copyrights
    - Protection for creative works that are expressed in a tangible medium
    - A wide range of subject matter, including software code
    - Good for ~75 years
  - Trademarks
    - Protection for names, marks, logos, dress, etc.
    - Requires use in commerce
    - Source-identifying information
  - Trade secrets
    - Can be used to protect anything of value
    - Protection is good for so long as the concept is not generally known
- Other, WARF IP
  - Biomaterials
  - Techniques and know how (akin in some ways to Trade Secrets)
  - Data
- Requirements for Patenting
  - Eligible - cannot be a product of nature, abstract idea, or natural phenomenon

    - Novel - it must be new
    - Non-obvious - cannot be simple modification or combinations of existing concepts
    - Enabled and Described - must provide enough detail that the patent examiner can understand the inventions
- Disclosing to WARF
    - Disclosing
        - Describe the innovation
        - Identify its advantages and potential application
        - Name contributors
        - Provide funding and public disclosure details
    - Meeting with WARF
        - Discuss the innovation in more detail
        - Ask questions about WARF and patenting processes
        - Discuss next steps
- Assesing University Inventions
    - IP Cosiderations
        - Type of IP protection
        - Potential breadth and strength of IP protection
        - Public disclosure (past and planned)
        - Stage of development
    - Licensing Considerations
        - Application
        - Likelihood of identifying a commercial partner
        - Likely return for licensing
    - Marketing and Liscensing
    - Licensing the IP is the next step in transferring the technology
    - Market Analysis
        - Market status - established, emeging, new
        - Size and type - e.g., large and growing, medium, and contracting, etc.
        - Potential licensees - companies in the market
    - License Negotionation
        - Type and terms - e.g. exclusive and field limited, sublicensing, etc.
        - Consideration - e.g. upfront payment, royalties, reimbursement
        - Typically, exclusive license agreement for medical devices
    - Ongoing
        - Technology development, enforcement, amendment, termination

AI and IP

- Can AI invent?
    - No, inventor is a natural person, conception
- Limited to US only?
    - No, South Africa is the exception
- Can AI assist in inventing?
    - Evolving, but likely yes under Pannu Factors
- Copyright
    - Original works of human authorship
    - AI must be incidental to conception and creation
    - Original conception by human master mind - Are prompts sufficient? No
    - Combinations of derivatives works requires more than de minimis contribution from human
    - Traditional element of authorship generated by AI? No

Conclusions/action items:

There may not be a licensing or patent potential for this project, but for future projects this information will be very useful. We should make sure to cover the design process in great detail in case the veterinary team would be interested in patenting in the future.

2024/10/23 - Lecture 7 (IRB)

AVERY SCHUDA - Oct 23, 2024, 2:08 PM CDT

Title: Lecture 7 - IRB

Date: 10/23/2024

Content by: Avery Schuda

Goals: Learn about institutional review the basics of human participants research requirements, what they mean for you and how to learn more.

Content:

Speaker: Jennifer Fenne, PhD, Senior IRB Analyst, UW-Madison Institutional Review Board

- IRB = Institutional Review Board
- Committee that conducts ethical and regulatory review of research involving human participants
- Needed if you are conduction federally funded research or seeking FDA approval

Origin and Mission

- Unethical research --> ethical principles --> human research regulations
- Infamous studies
    - WWII nazi prisoner experiment --> 1947 Nuremburg Code
    - 1956-1971: Hepatitis studies at Willowbrook State School for Children
    - 1960s: Milgram shock experiments at Yale
    - 1932-1972: Tuskegee Syphilis Study --> 1974 National Research Act
- Belmont principles:
    - Respect for Persons - free choice, informed consent, special safeguards for those with reduced autonomy
    - Beneficence - maximize benefits while minimizing harm
    - Justice - access and benefits
- Regulations for protection of human "subjects"
    - Dept of Health and Human Services (DHHS) aka "Common Rule"
    - FDA

Institutional Review Boards

- Instituted by Common Rule and FDA regulations
- Review research studies to ensure they meet regulatory and ethical standards, follow institutional policies, and protect participants rights and welfare

IRBs at UW

- Minimal Risk Research (MRR IRB)
- Health Sciences IRB (HS IRB)
- Serve UW-Madison, UW Health affiliates, Madison VA Hospital
- May "cede" oversight to other institutions or independent IRBS

Do I need an IRB?

- Is it research under the Common Rule?
    - *Research* means a *systematic* investigation, including research development, testing, and evaluation, *designed* to develop or contribute to *generalizable* knowledge.
- Does it involve human subjects (Common Rule)?
    - *Human subject* means a *living individual about whom* an investigator conducting research
        - Obtains *information* or *biospecimens* through *intervention or interaction*, and uses, studies, or analyzes the information or biospecimens.
        - OR obtains, uses, studies, analyzes, or generates *identifiable private information* or *identifiable biospecimens*.
- Is it human research under FDA device regs?
    - Device - intended for use in diagnosis, treatment, or prevention of disease, or that affects structure or function of the body
    - Research/clinical investigation - involves one or more subjects to determine device safety or effectiveness
    - Subject - individual on whom or on whose specimen an investigation; device is used or as a control in the investigation

Preparing for IRB Review

- Researcher responsibilities
  - Complete required training for researchers through CITI
    - Human Subjects Protection Training
    - Conflict of Interest Training
    - Good Clinical Practice Training (if clinical trial or FDA-regulated)
    - HIPAA Privacy and Research Training (if any key personnel in HCC/ACE)
  - Complete annual Outside Activities Reports
- Develop your research plan
  - Identify appropriate principle investigator and study team
  - Collect preliminary (non-human) data& background info
  - Develop a research question and steps to answer it
  - If evaluating device effectiveness and/or safety, consult UW's FDA Regulated Research Oversight PRogram
  - Consider research participants
    - Who will you need and why? How many? Where will you find them?
    - What will they need to do? How will you minimize possible harms/burdens?
    - What will they need to know to make an informed choice to participate?
- What IRB application type will you need?
  - All use ARROW electronic submission systems
  - Basic types: protocol-based and non-protocol based
  - Studies limited to surveys, benign behavioral interventions, or secondary data
- PBA components
  - Protocol document
    - Detail study aims, rationale, procedures, device info, stc
  - Informed consent forms
  - Recruitments tool, screen scripts
  - Written assessments
- Resources: IRB Website
  - Toolkit Library
  - Education and Training
  - Link to ARROW
  - News, IRB Meeting dates
  - Contact US

IRB Review Process

- Review Steps
  - UROC review
  - SRC/PRMC review
  - Pre-review by IRB staff
  - Review at IRB meeting
  - Committee determination: approved, modifications requested, deferred
- Post-approval responsibilities
  - Obtain all required approvals before beginning research
  - Follow approved protocol precisely
  - Used on IRB-approved materials (protocol, recruitment materials, consent forms, assessment tools)
  - Submit change of protocol application for IRB approval
- More detail
  - IRB for Beginners Workshop

Conclusions/action items:

Our project does not fall under human subjects research, so no IRB would be needed. Further resources are available through the UW-Madison IRB for future projects.

2024/10/30 - Lecture 8 (Navigating FDA Device Requirements)

AVERY SCHUDA - Oct 30, 2024, 2:11 PM CDT

Title: Lecture 8 - Navigating FDA Device Requirements

Date: 10/30/2024

Content by: Avery Schuda

Goals: Define medical device and understand the different categories of medical devices, learn about how FDA requirements apply to research and development of drugs and devices

Content:

Speaker: Jake Rome, FDA Regulated Reasearch Oversight Program. ICTR IND/IDE Consoltation Service

UWClinicalTrials.org

What is a Medical Device?

- Anything that affects health that isn't a drug or biologic
- An instrument, apparatus, implement, machine, contrivance, implant, in vitro reagent, or other similar or related article
- Not certain types of software
- Examples of traditional medical devices
  - MRI
  - Bandages
  - Syringes
  - Monitoring equipment
- Examples of non-traditional medical devices
  - Laboratory developed tests
  - Software
  - Medical mobile apps (e.g. apple watch)
  - Mouthwash (physical not chemical mechanism)
- Software as a Medical Device (SaMD) examples
  - SaMD that uses the microphone of a smart device to detect interrupted breathing during sleep and sounds a tone to rouse the sleeper
  - SaMD that analyzes HR signals or patterns intended for monitoring asthma
- Applicable FDA regulations - 21 CFR
  - Part 50: Protection of Human Subjects
  - Part 56: Institutional Review Boards (IRB)
  - Part 801: Labeling
  - Part 803: Medical Device Reporting
  - Part 812: Investigational Device Exemption (IDE)
  - Part 814: Premarket Approval of Medical & the Humanitarian use Device
  - 840: Quality Systems Regulations (Devices)

Quality Management Systems

- QMS begins when decide to develop device
  - Frameworks to ensure products are safe and effective
- Many Components
  - Managment Responsibility, Document Controls, Production Controls, Labeling and Handling, Records
- Design Controls
  - Design/Development Planning - Risk assessment and verification
  - Design Reviews - Review to ensure meets specified requirements
- Risk assessments
  - Documentation needed to support submission to FDA or non-significant risk determination to IRB

Device Classification Overview

- Class I
  - Low risk - minimal potential for harms
  - Exempt from premarket approval
  - Mostly exempt from premarket notifications and Quality Systems (QS) requirements

    - Must follow certain general controls: labeling, record retention, and complaint files
- Class II
    - Risk moderate - higher than Class I
    - Submission of a 510(k) showing substantial equivalence, may be exempt
    - Must follow general and special controls, which can include performance standards, post-market surveillance, and specific labeling requirements
    - ex. noninvasive blood pressure measurement system, steerable catheter, integrated continuous glucose monitoring system
    - Also follow ISO standards
- Class III
    - Highest risk - sustain or support life, implanted, or potential for unreasonable risk
    - Must follow general controls and additional stringent requirements, such as clinical trials to demonstrate safety and efficacy
    - Bench testing, animal trials, and human subjects trials
    - Premarket approval (PMA) submission, which involves comprehensive FDA review of safety and effectiveness data before marketing
- This is for the US only, other countries have different requirements
- FDA continues to update these requirements

Market Submission Types

- 510(k) Exempt
    - Registration and listing only
- 510(k) Premarket Notification
    - Substantial equivalence
- PMA - Premarket Approval
    - Full safety and effectiveness submission
    - Manufacturing details
- De Novo Classification
    - Novel medical devices, no legally marketed predicate
    - FDA will tell you what class your device is and how you can market it
- 510(k) does NOT mean FDA approval or that the FDA has determined your device is safe and effective (safe enough and potentially effective)
    - Allows you to market your device

Classifying a Medical Device

- FDA lists most under part 800 of CFR
- Use Product Classification quick search on the FDA website to find devices that are somewhat related
- Look at Product Code
    - Device definition and Classification
    - Submission type
    - GMP requirements
    - Recognized Consensus Standards
- Look at Regulation Number
- Search Regulation Number of product you think is similar --> leads to other products with same regulation number
- 510(k) Device Lookup on FDA website --> 510(k) Premarket Notification
    - Can see nonclinical data, performance testing, etc.
- PMA Devices on FDA website --> Premarket Approval (PMA)
- Key Points
    - Depends on the intended use AND indication for use
    - Intended Use - General purpose of the device or its function
    - Indications for Use - Specify the specific conditions, population, or situation where device is intended to be used
    - Where indication for use may affect safety or effectiveness, then may be new intended use

Regulatory Controls Key Elements

- General Controls
    - Registration and Listing
    - Adverse Event Reporting
    - General Labeling
    - Good manufacturing Practice
        - Design Controls
        - Document Management
        - Production and Process Controls
        - Management Responsibility
- Special Controls

  - Performance Standards
  - Special Labeling Requirements
  - Post-Market Surveillance
  - Potential Data Requirements
- Premarket Approval
  - Data to show safety and efficacy

Conclusions/action items:

While our current project does not fall under FDA regulations, this information may be helpful in future projects that may seek FDA approval. The FDA's website has several very helpful lookup tools to see how regulations apply and compare similar devices.

2024/11/06 - Lecture 9 (Regulatory Strategy)

AVERY SCHUDA - Nov 06, 2024, 2:07 PM CST

Title: Lecture 9 - Regulatory Strategy

Date: 11/6/2024

Content by: Avery Schuda

Goals: Learn about regulatory strategy and the framework guiding advanced therapeutic product development, understand the overall structure of the FDA, how these regulations guide product development, what a "Quality" mindset is, and science/engineering career opportunity.

Content:

Speaker: Bill Murphy, director of the Ford Bio Institute, BME faculty

FDA Structure and Advanced Therapeutics

- Device (CDRH)
    - PMA - premarket approval
    - 510(k)
    - IDE -
- Drug (CDER)
    - NDA - new drug application
    - IND - investigational new drug
    - Synthetic
- Biologic (CBER)
    - BLA - biologics license agreement
    - IND - investigational new drug
    - Living thing or produced by a living thing
- Genome Editing - target a precise genome locus and delete, insert, or change existing sequences
- Gene Delivery - transfer molecular tools and assembled gene systems into the cell
- Cell Therapy - use expanded cells to transfer medicinal bioactivity to regenerate damaged tissue or restore health

Dramatic Implications: 351 vs 361

- Human cells, tissues, and cellular and tissue-based products (HCT/Ps)
- Markedly different in terms of the time, effort, and expense required to bring a product
- Basically, 351 products are regulated as drugs and/or biologic, while 361 products, comparatively, are largely unregulated
- 361 - Minimally manipulated products
    - ex. blood transfusion, transfer liposuction fat to another area, amniotic tissue, peripheral nerves, demineralized bone
    - Coming from a patient, going back into a patient
    - Generally safe
    - FDA approval not required
    - No clinical claims for homologous use
- 351 - Significant manipulation
    - ex. take bone marrow deliver a gene therapy and reimplant super cell, Carmell BHA, Humacyte HUMACYL
    - Regulated like a traditional biologic
    - Safety concerns
    - FDA approval required for marketing
    - Indicated for a specific therapeutic use
    - 12 years of marketing exclusivity

Product Development Life Cycle

- Each stage of the product development life cycle faces its own risks and challenges, and proper management of commercialization
- Distinguish between studies that are on the critical path vs. good research projects
- A Target Product Profile (TPP) is your product vision
    - When to use it?
        - Patient identification - Indication
    - Why to use it?
        - Patient benefits - Efficacy profile
    - How to use it?

        - Patient risks - Safety profile
    - Is it medically and commercially compelling?
    - Will patients and prescribers want it?
        - Validate TPP with key opinion leaders
    - Will regulators want it?
        - Discuss plans with regulatory agencies
    - Will payers reimburse for it?
        - Understand the evidence payers require
    - Why should I fund development?
        - Show that people will buy it,
        - Is the cost and timeline reasonable?
        - What are the risks?
    - Stakeholders: investors, physicians, contract manufacturers, etc.

Quality Management: System Implementation

- A system that documents policies, processes, internal rules, procedures, and other records to ensure product quality
- Components of a Quality System - risks with each
    - Materials/Input
    - Expansion Process/Output
    - System
    - Contamination
    - Hardware
    - Software
    - Machine
    - Up and Down Stream Processes
    - People

Career Options within a Regulated Environment

- Chemistry, Manufactuing, Controls (CMC)
    - Cell Characterization
    - Potency Assay Development
    - In-process Controls
    - Data Mining and Informatics
    - GMP Compliance
    - CMC
    - GMP Knowledge Base
    - Documentation
    - Design Space
    - CPPs for CQAs
    - Scale-up/Automation
    - Closed Processing
    - More in slides

Conclusions/action items:

The information presented focused on drug and therapeutics mostly, so the information does not really apply to our current project. However, this information may be helpful for a future project or job. There was a long list of potential careers provided in the slides.

2024/11/13 - Lecture 10 (Medical Device Innovation)

AVERY SCHUDA - Nov 13, 2024, 2:02 PM CST

Title: Lecture 10 - Medical Device Innovation

Date: 11/13/2024

Content by: Avery Schuda

Goals: Learn about medical device innovation from prototype to commercial use.

Content:

Speaker: Aimee Arnoldussen, PhD

- Start with IRB protocol
- Class I
    - 510(k) exempt
    - Premarket Notification 510(k)
    - 510(k) de novo
- Class II
    - Premarket Notification 510(k)
    - 510(k) de novo
    - Humanitarian Device Exemption (HDE)
- Class III
    - Premarket Notification 510(k)
    - Premarket Approval (PMA)
    - Humanitarian Device Exemption (HDE)
- Regulatory Timelines
    - Double the time you think it will take

Breakthrough Devices Program

- Formerly Expedited Access Program
- Timely access to medica devices for life threatening or irreversibly debilitating disease/conditions
- Program to expedite development, assessment, and review
- Enables early interaction with FDA experts in the review phase and prioritized review

Medical Device Process at a Glance

1. Innovation idea and development
2. Human testing data acquisition with IRB oversight
3. FDA regulatory process
4. Reimbursement or financial incentive
5. Sales

General Steps from Approval to Adoption

1. Clinical Studies
2. FDA Approval
3. CPT Codes
4. CMS National Insurance Decisions
5. Standards of Practices
6. National Regional Buying Groups
7. Regional/Local IDNS, Hospitals
8. Hospitals/IDN Value Analysucs Groups
9. Product Evaluations
10. Regional/Just in Time Distribution
11. Product Implementation

Stakeholders

- Administrative
    - Purchasing

  - Materials
  - IT
  - Billing
  - Value Analytics
- National Clinical Oversight
  - FDA
  - Clinical Advisory Groups
  - International Clinical Societies
- Patient Point of Care
  - MDs
  - RNs
  - RPh
  - Labs
  - OR
  - ER
  - OT
- National/Regional Groups
  - IDNs
  - Buying Groups
  - Distributions
  - GPOs
- Standards Organizations
  - AAMI
  - ISO
  - UL
  - IEC
  - Clinical Societies
- National and Regional Payment/Reimbursement
  - CMS
  - Insurers

Value Based HealthCare

- Find the sweet spot between clinical, economic, and patient
- If we define value more broadly as improving patient outcomes while making it more affordable to deliver those outcomes, there is a wider range of possibilities for product developers, providers, and payers to collaborate, and signs of progress are easier to find

Hospital New Product Adoption Process

- Clinical champion
  - Thought leaders
  - Department impact
  - Clinical, Economic, Patient
- Value analysis/Technology Assessment
  - Analysis of financials and clinical costs
  - Product costs
  - Cost to convert
- C-Suite Strategy - Final decision
  - Final metrics
  - Contracting
  - Time to implement
  - Costs to Implementation
  - Optics and marketing
- Trial, Evaluation, and Metrics
  - Time
  - Outcomes
  - Departments
  - Number of Suppliers
  - Costs to evaluate
  - Support product

Value Drivers to Discover

- Economic
  - Money

- Staff time
- Resources
- Waste
- Metrics
- Clinical
  - Improve outcomes
  - Reduce risk
  - Reduce complications
  - Shorten Length of stay
  - Solve "issues"
- Mission Impact
  - Patient satisfaction
  - Academic leadership
  - Innovation in care
- Evidence more compelling than "hand-waving" benefit assumptions

Key terms to uncover payment

- CMS - Centers for Medicare and Medicaid Services
- DRG - Diagnostic Related Groups
- CPT - Current Procedural Code
- ICD 10 - International Categorization of Diseases
- GPO - Group Purchasing Organization
- IDN - Integrated Delivery Networks
- Payer mix (% Private, Capitated (value-based), Medicare)
- Existence of codes does not necessarily equal financially favorable

Discover Through Research and Interviews

- Start with a detailed patient (or diagnosis) Flow/Care Pathway
- Explore pain points and gain creators
- Expand your knowledge of the procedure or diagnosis payment
- Examine about how products or therapies are adopted locally and nationally
- Understand the impact of outside organizations
- Include regulatory and standards groups
- Find out who really pays for it? And how...

Conclusions/action items:

While this lecture was not particularly useful for our particular project, it was very interesting and may be useful for future projects and/or jobs. The reimbursement pathway is not linear, but the most important thing is emphasizing your value creation to the various stakeholders through the medical device creation process.

2024/11/15 - Tong Lecture (Tasso)

AVERY SCHUDA - Nov 15, 2024, 12:51 PM CST

Title: Tong Lecture (Tasso)

Date: 11/15/2024

Content by: Avery Schuda

Goals: Learn about the design and entrepreneurship process that went into creating Tasso

Content:

Speakers: Dr. Ben Casavant, PhD and Dr. Erwin Berthier, PhD

- Core at the need for these technologies is the need for a blood draw
- 10 B blood tests happen in the US alone, over 1 B blood draws
- The future of healthcare is at home - what does it take for a blood draw to be done in the home?
- Used the Law & Entrepreneurship Clinic at UW-Madison
- Submitted as many grants as they could, were able to get awarded from DARPA and NIH
- Evolution of the technology - to make a better product, kill the product when needed
    - Open microfluidics
    - Physiology of capillaries in the skin
    - Think about the people using it, be thoughtful when you kill one iteration of a product
- Finding a key customer
    - You can trick someone to do a lancet once, you can't trick them to do it twice (fingerstick are painful and probably the worst way to collect blood)
    - Developed the technology for the customer, early adopter
    - Find your champion
    - USADA was looking to switch anti-doping to blood. but everyone hates needles and lancet even more
    - MLB, UFC, cycling converted to Tasso
    - Drowning in a sea of possibility - the everything problem
    - Grassroots effort - working directly with the people who have the problem and focus in
- Scaling up - lessons in quality, culture, and HR
    - Continual iteration of the product
    - Every contract for future development was cancelled due to the pandemic in 2020
    - But suddenly at home testing was more in demand
    - Problems start occurring when you scale up manufacturing - quality is key
    - Roll up your sleeves and get it done
    - Maintain good company culture when team scales up
- FDA and Regulatory Strategy
    - Lancet is Class I, but attached is Class II difficult clearance
    - Read the labels - easy to overanalyze what regulators say they want to do

Conclusions/action items:

If you have an idea, go for it, and if you put in the work, you can figure it out along the way. Look for people that are willing to help you.

2024/11/20 - Lecture 11 (NPD in the Medical Device Industry)

AVERY SCHUDA - Nov 20, 2024, 2:08 PM CST

Title: Lecture 11 - NPD in the Medical Device Industry

Date: 11/20/2024

Content by: Avery Schuda

Goals: Learn about how new product development works in the medical device industry.

Content:

Speaker: Russ Johnson, PhD

NPD in the medical device industry is:

- Highly regulated - FDA and other regulatory bodies have significant impact
- Expensive - Requirement for verification and validation is a cost multiplier
- Resource intense - Involves sizable teams
- Competitive

Selecting and prioritizing projects

- Corporate business strategy
- Product portfolio review
- Project review
- Budgeting and resource allocation

Types of NPD Products

- Line extensions - Addition of additional sizes and configurations
- Product improvements - Existing product change due to market feedback and/or new customer needs
- New to company - Product line that is not new to market, but is new to company
- New to world - Product line that is new to market

Managing NPD: Stage-Gate Process

- Stage 0 - Ideation
- Stage 1 - Exploration
- Stage 2 - Concept Development
  - Go/no-go descision
- Stage 3 - Design Development
- Stage 4 - Design Confirmation
  - Design freeze
- Stage 5 - Design Transfer and Commercialization
  - Launch
- Post-Market Surveillance
- Gate reviews between every stage!

Case study: ORwell

- Goal: Provide clinicians with an innovated solution for high fluid volume collection during surgical procedures
- Stage 0 - Ideation
  - Choose area of opportunity
  - Review market trends or competitive threats
  - Conduct primary research and secondary market research
  - Identify customer unmet needs
  - Create high-level "back of the napkin" ideas
  - Talked to clinicians
  - Went to customers who had the competitive product
  - Cleaning cycle was not working in competitive product
- Stage 1 - Exploration
  - Define problem to be solved and customer requirements

        - Defining the problem statement is arguably the most important step of the design process
    - Review, refine, and screen list of ideas from Stage 0 for exploration
    - Create concepts for 8-10 ideas
    - Develop high-level business cases (market size, value propositions)
    - Conduct preliminary technical scouting and IP landscaping
    - Volume and visibility of fluid were important factors
- Stage 2 - Concept Definition
    - Based on customer interviews and use-case assessments
        - Down select from 8-10 to 2-3 to 1 leading concept
    - Develop robust business case including market opportunity, initial forecast, and projected expenses
    - Conduct comprehensive examination
    - Next gate review is go/no-go business decision
    - Each device concept has a consumable sold for every procedure
    - Final design chosen differentiated from other competing products and fit well with company areas of expertise
- Stage 3 - Design Development
    - Move to functional prototype
    - Continue iterative design process including initial testing and reviews with customers
    - Confirm regulatory pathway
    - Begin formal Design Control documentation
- Stage 4 - Design Confirmation
    - Conduct extensive verfication and validation testing
    - Finalize product and component drawing/models
    - Accelerate manufacturing process development along with plans for quality control
    - "Freeze" design at the end of this stage
    - Submit regulatory documentation
        - e.g. FDA 510(k)
- Stage 5 - Design Transfer and Commercialization
    - Complete any remaining testing
    - Make final design changes
    - Build mold, assembly/test equipment
    - Create Instructions for Use (IFU) and user manuals
    - Develop service plan and resources
    - Finalize go-to-market strategy and start limited release (if applicable)
    - Packaging engineering
- Post Market Surveillance
    - Regulatory agencies expect that companies are monitoring and documenting customer complaints and field issues post launch
    - Companies continuously track customer and salesforce feedback via interviews and surveys
    - On a 4-6 month cadence, project teams report out to stakeholders
        - Account sales
        - Business and regulatory issues observed
        - Complaints
        - Product and process improvement opportunities

Design Control

- Mandatory for FDA Class 2&3 and almost all EMA devices
- Includes documentation of customer needs, design requirements, design inputs/outputs, testing and design reviews
- Tightly aligned with Risk Management

Conclusions/action items:

Medical device development is an expensive, complex, and highly collaborative effort. Having limited resources, most businesses have instituted processes like Stage Gate to reduce risk and increase probability of success. Good product design and development is necessary for commercial use, but not sufficient.

9/11/2024: Bone Marrow Biopsy and Evaluation

ELLA CAIN - Nov 13, 2024, 10:52 PM CST

Title: Bone Marrow Biopsy and Evaluation

Date: 9/11/24

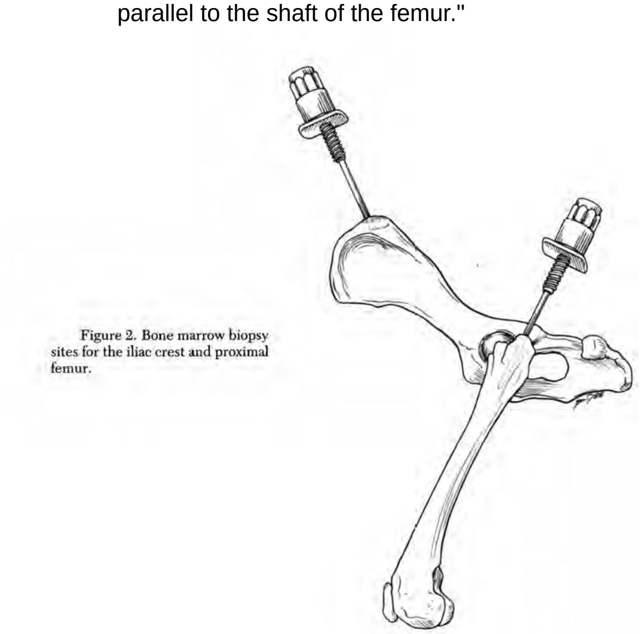
Content by: Ella Cain

Present: N/A

Goals: To gain more information about the purpose of bone marrow aspiration and the procedure that will inform our model.

Content:

- The purpose of bone marrow sampling is to examine both the fluid and tissue of the marrow.
- The article explains the requirements for bone marrow sampling which typically seeks out to discover more information about:
  - unexplained changes in the peripheral blood of the animal
  - suspected or confirmed cancerous cells
  - iron content within the body
  - and suspected disease of the marrow, whether cancerous or infectious.
- The needles used in aspiration biopsies are described as follows:
  - " [are] usually...15 to 18 gauge and 1 to 17/s inches long"
- Procedure for Aspiration:
  - An small incision to the skin is made near (not recommended above) the site where the sample will be collected
  - The needle is then inserted and follows a "clockwise-counterclockwise" rotation until it has fully advanced into the marrow cavity
  - When aspirating from the femur (as shown below), the animal should be in lateral recumbency (lying on their side)
    - The great trochanter is then palpated and the needle is inserted "medial to the trochanter and parallel to the shaft of the femur."



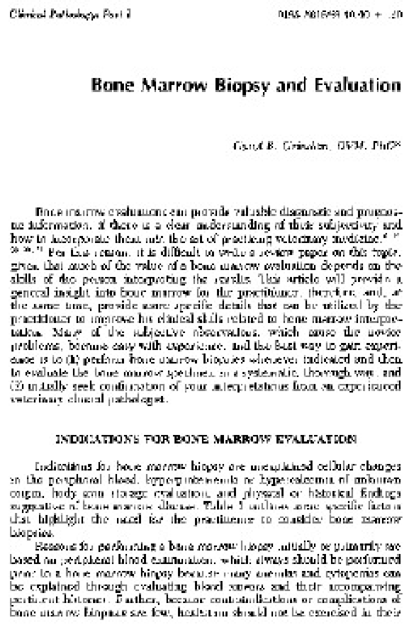
-
  - Figure 2: "Bone marrow biopsy sites for the iliac creast and proximal femur."
  - Source: [1]
- The article also includes diagrams of aspirations of the iliac crest and proximal humerus. [1]

References: [1] Grindem, Carol B. "Bone Marrow Biopsy and Evaluation." Veterinary Clinics of North America: Small Animal Practice. vol. 19, no. 4, pp. 669-696, 1989. Accessed: Sept 10, 2024. doi: 10.1016/S0195-5616(89)50078-0. [Online]. Available:

https://www.sciencedirect.com/science/article/pii/S0195561689500780

Conclusions/action items: The diagrams included in this article will be useful for visualizing the model of our preliminary design once we know from our client what bones---or if all---are considered important in our model. That is, do they have a specific bone in mind for the aspiration model. Identifying a bone would allow us to be more specific and accurate in our modeling of the animal's tissue, fat, and bone.

ELLA CAIN - Sep 11, 2024, 7:14 PM CDT



Clinical Pathology Part I

Bone Marrow Biopsy and Evaluation

*Carol B. Grindem, DVM, PhD**

Bone marrow evaluations can provide valuable diagnostic and prognostic information, if there is a clear understanding of their subjectivity and how to incorporate them into the art of practicing veterinary medicine. For this reason, it is difficult to write a review paper on this topic, given that much of the value of a bone marrow evaluation depends on the skills of the person interpreting the results. This article will provide a general insight into bone marrow for the practitioner, therefore, and, at the same time, provide more specific details that can be utilized by the practitioner to improve his clinical skills related to bone marrow interpretation. Many of the subjective observations, which cause the novice problems, become easy with experience, and the best way to gain experience is to (1) perform bone marrow biopsies whenever indicated and then to evaluate the bone marrow specimen in a systematic, thorough way, and (2) initially seek confirmation of your interpretations from an experienced veterinary clinical pathologist.

INDICATIONS FOR BONE MARROW EVALUATION

Indications for bone marrow biopsy are unexplained cellular changes in the peripheral blood, hyperproteinemia or hypercalcemia of unknown origin, body iron storage evaluation, and physical or historical findings suggestive of bone marrow disease. Table 1 outlines some specific factors that highlight the need for the practitioner to consider bone marrow biopsies.

Reasons for performing a bone marrow biopsy initially or primarily are based on peripheral blood examination, which always should be performed prior to a bone marrow biopsy because many anemias and cytopenias can be explained through evaluating blood smears and their accompanying pertinent histories. Further, because contraindications or complications of bone marrow biopsies are few, hesitation should not be exercised in their

[Download](#)

Bone_Marrow_Biopsy_and_Evaluation.pdf (961 kB)

9/11/2024: Indications/Methods of Bone Marrow Cytology

ELLA CAIN - Sep 11, 2024, 7:33 PM CDT

Title: Indications/Methods of Bone Marrow Cytology

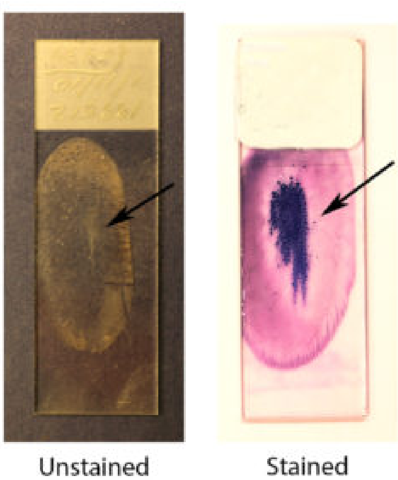
Date: 9/11/2024

Content by: Ella Cain

Present: N/A

Goals: To research the purpose of bone marrow aspiration and when it is deemed necessary.

Content:

- For an animal to be deemed as requiring a bone marrow sample, they may have one of the following:
  - Identification of abnormal characteristics in the peripheral blood of the animal, such as "unexplained anemia"
  - Abnormal cells in the blood
  - Various cancers that have either been confirmed or suspected
  - Uncontrolled growth of abnormal cells (neoplasia)
  - Suspected "infectious organisms" that can habitate the bone marrow
  - Unknown fever
  - To confirm anemia or to evaluate iron stores within the body
- The common sites for bone marrow collection range from the animal.
  - For dogs, the common sites are the "proximal humerus, proximal femur, iliac crest, sternum (manubrium in large dogs)"
- Bone marrow aspiration is accomplished with the introduction of a needle into the bone marrow of the animal
  - Slides are then collected with the bone marrow smears
  - This process is meant to be relatively short in time
  - The needle must be in the bone marrow cavity before the stylet of the needle inserted into the bone is removed. [1]
  - 

  - Figure 1: Example of a bone marrow aspiration slides
  - Source: [2]

References: [1] Cornell University College of Veterinary Medicine. "Indications/Methods." ECLINPATH. Accessed: Sept 10, 2024. [Online]. Available: https://eclinpath.com/cytology/bone-marrow/indications-methods/

[2] Stokol, Tracy. *Bone marrow slides*. (Jan 1, 2019). Accessed Sept 2024. [Online]. Available: https://eclinpath.com/cytology/bone-marrow/indications-methods/bone-marrow-slides/

Link: [Indications/Methods of Bone Marrow Cytology]

Conclusions/action items: To keep the requirements for a bone marrow aspiration in mind in creating our preliminary design for a model. This is a good general overview of why aspirations are collected and the general process of how samples are collected. This website's information is provides basic background information of the requirement and process of veterinary bone marrow aspiration.

9/18/24: Surgical Approach of the Anatomical Sites for Bone Marrow Aspiration in Dogs

ELLA CAIN - Sep 18, 2024, 9:19 PM CDT

Title: Surgical Approach of the Anatomical Sites for Bone Marrow Aspiration in Dogs

Date: 9/18/24

Content by: Ella Cain

Present: N/A

Goals: To further analyze the process of bone marrow aspiration with the addition of CT scans meant to show the insertion of the needle into the bone marrow cavity more clearly.

Content: This article describes a study done to compare the differences between the sites of bone marrow aspiration typically done on canines. It also provides images of three dimension computed tomography scans meant to identify the bones and the needle's placement within them.

we As the proximal humerus has been specified by our client as the desired site for our model, I will provide mainly information on the humerus from this article.

-Bone marrow aspiration is typically performed on dogs with unexplained hematological abnormalities as a means of gaining more information about the origin of the changes in the blood and body.

Abnormalities in the body that are tested for may include:

-infection

-myelofibrosis

-necrosis

-neoplasia

-The needle gauge typically used for aspiration in dogs ranges in size from 14-18 gauge

-The collection of bone marrow samples is achieved by negative pressure from the syringe that is attached to the needle.

-It is more difficult to collect good quality bone marrow aspirates in older dogs (and cadavers)

The process of aspiration in the study:

-Small dorsal stab incision made over the greater tubercle of the humerus.

-Needle was inserted and directed laterally into the bone

-Stopped when 6cm of the needle was inside the greater tubercle of the humerus bone.

-Rougly 3ml of aspirate could be collected

-The study then collected CT scans of the aspirations done on the humerus, iliac crest, sternum, and femur. Below is the scan of the humerus, our site of interest:

Figure (6): Showing computed tomographic imaging of humerus, 1-Aspiration needle (2.1 cm), 2-Humerus.

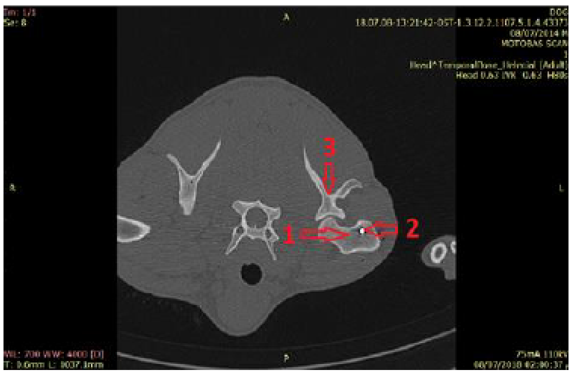


Figure (10): Showing transverse plane of humerus 1-humral medullary cavity . 2- insertd jamshidi needle in greater tubercle of left

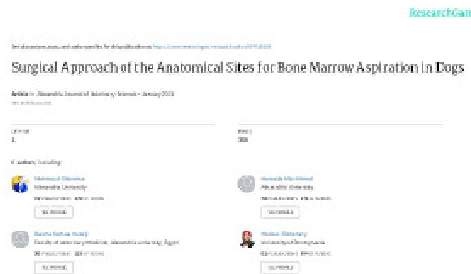
-The article cites the importance of accurately inserting the needle into the desired bone marrow cavity

-It is typical to have a more difficutl time aspirating bone marrow in dogs with tumors or other abnormalities of the flesh and bone. [1]

References: [1] S. Nouh, M. Elkammar, H. Hesham, and H. Abu-Ahmed, “Surgical Approach of the Anatomical Sites for Bone Marrow Aspiration in Dogs,” *Research Gate*, Jan. 2021. https://www.researchgate.net/publication/354518089_Surgical_Approach_of_the_Anatomical_Sites_for_Bone_Marrow_Aspiration_in_Dogs (accessed Sep. 17, 2024).

Conclusions/action items: To review the scans made of the bone marrow aspiration of the humerus as a guide for the anatomical design of our model. It is important that we understand where exactly the needle will be inserted, which is difficult to do once it is past the skin. This article also highlights the area of most importance on the humerus, which we would ensure the quality of in our model.

ELLA CAIN - Sep 18, 2024, 9:19 PM CDT



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BonemarrowaspirationManuscript_2021.pdf (479 kB)

9/18/24: "Canine Muscles and Movement" and "Anatomy: Dogs & Cats"

ELLA CAIN - Sep 18, 2024, 10:15 PM CDT

Title: Canine Muscles and Movement

Date: 9/18/24

Content by: Ella Cain

Present: N/A

Goals: To understand the placements of muscles, bones, and the movement of the shoulder and leg.

Content: This article describes how general movements of dogs are caused by the activations of certain muscle groups.

This will be useful in our model, as it is important that the shoulder and joints be moveable as to simulate a real shoulder and limb of a dog.

-This diagram of a dog's muscle is provided:

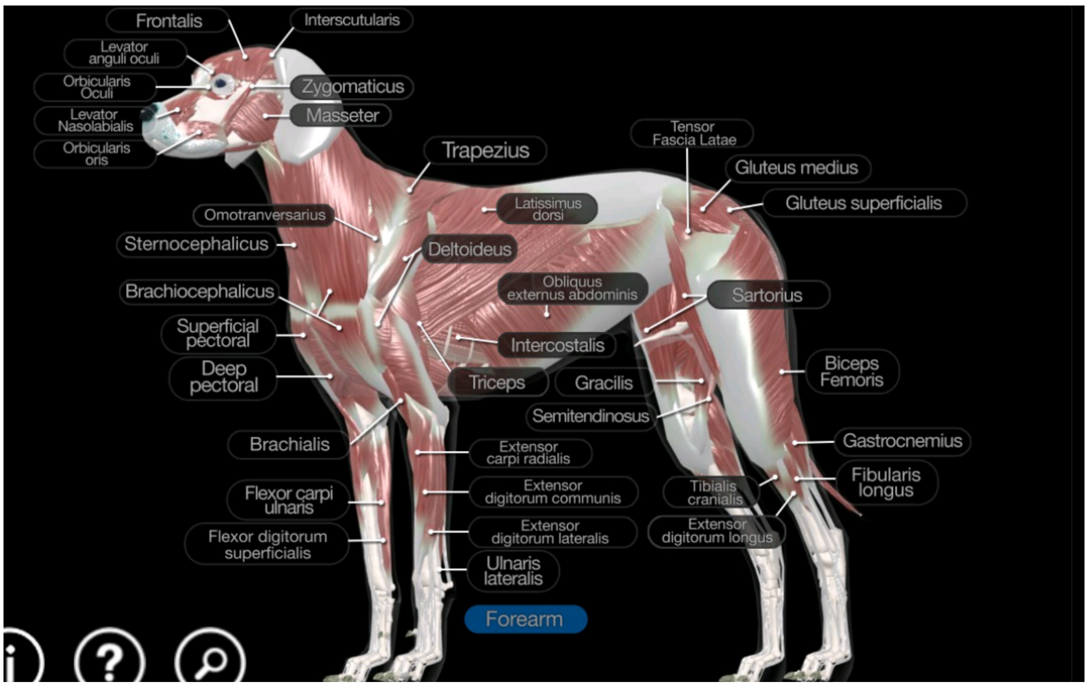

Figure 1. Canine superficial muscles (Canine Anatomy 3D App)

Source: [1]

-The muscles covering the proximal humerus include:

-The Deltoideus

-Biceps

-Triceps

-The scapula is a ball-and-socket joint that lifts when the forelimb is lifted for walking and running [1]

-The humerus, attached to the scapula, is also a ball-and-socket joint.

-The trapezius causes extension of the forelimb

-The biceps cause flexation at the elbow joint

Below is an image from a supplementary article on the anatomy of dogs; it shows the bones of the forelimb of a canine:

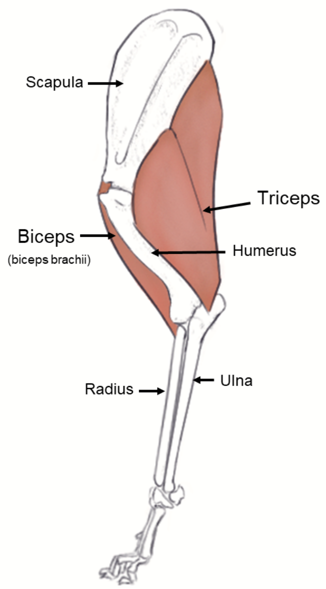

Figure 2: Canine (Sûga) Forelimb (Îthto)

-When the humerus lifts, the radius and ulna also lift [2].

Source: [2]

References:

[1] Four Amigos Veterinary Physiotherapy, "'Canine Muscles and Movement,'" *Fouramigosvetphysio.co.uk*, 2019. https://fouramigosvetphysio.co.uk/2023/01/canine-muscles-and-movement/#:~:text=In%20the%20forelimbs%2C%20movement%20rotate. (accessed Sep. 19, 2024).

[2] University of Calgary, "Dogs & Cats," *Animal Health and Veterinary Medicine* . https://vet.ucalgary.ca/community/learning-animal-health/anatomy/dogs-cats (accessed Sep. 18, 2024).

Conclusions/action items: These anatomical models will be useful in the conceptualization of our bone marrow aspiration model. One of our main focuses is to be as anatomically correct as possible, which will make the experience of practicing aspiration on our model as realistic as possible. The movement of the forelimb joint is also of importance; our client has told us that, in order to determine in the needle has been successfully inserted into the bone marrow cavity, the rotation of the entire syringe should cause the forelimb of the canine to rotate as well.

Tong Lecture Notes 11/15/24

ELLA CAIN - Nov 15, 2024, 12:55 PM CST

Title: Tong Lecture Notes

Date: 11/15/24

Content by: Ella

Present: N/A

Goals: To learn about developing a bio-technological product and a business.

Content: Berthier and Casavant came to the University of Wisconsin-Madison to help make the process of blood draws easier for patients.

Business Strategy:

-They had the idea of shipping do-it-yourself blood draws for people who are anxious to go in for blood draws.

-They created many prototypes for this "sample-and-send" idea.

-They created a patent for Tasso and got their paper published; they received funding and created grants (for DARPA and NIH) for their project as grad students do.

-They had to go to Washington D.C. to visit DARPA; they presented their technology to receive the grant

-3D map all of the capillaries in the skin that would make the technology more effective and allow for more blood to be collected (microfluids). This leveled up their prototype.

-They went through many iterations of the Tasso product; 10 years of development.

-Finding others to connect with; find a "champion," someone who is loud-spoken, passionate, and has a need. Connected with the Pharma Industry.

-"The USADA was looking to switch anti-doping to blood, but everyone hates needles and lancets even more"--a need. Tasso developed a tamper-prood security case to solve the chain-of-custody problem.

-You can't do all of the projects that people suggest; grassroots efforts are ultimately what got Tasso off the ground

-"They need this one thing, let's focus in;" bring people who benefit from the project and have them tell others. They got baseball players to agree to Tasso instead of anti-doping tests.

-Focus on the customer; figure out how to solve their problem; one foot in front of the other

-COVID presented a huge problem with cash-flow and future development. They changed their focus---people realized that they needed samples to be shipped because of quarantine. They found a warehouse to work in to keep up with the orders.

-Quality is the most important; quality is key when you scale up.

-Culture is also important; how to get that core mission into people; how to get communication going. Collaboration is very important

Regulatory Strategy:

-FDA regulations. Tasso is a diagnostic project that needs to undergo an expensive series of tests by the FDA.

-They separated the lancet and the tube to speed testing and getting FDA approval. Can you use the labels from before to give you a leg up? IDD label.

-They became the first lancet cleared this way by the FDA by being clever. You need a good regulatory person in your business.

-"This combination hasn't happened before, how can we get around that?"

Concluding Statements:

-Just try it; connect with other people

-You'll experience roadblocks, but that's why you need to be innovative and connect with others to solve the problem.

-Name your business. *Tasso* is italian for Badger.

-Find someone who is easy to work with; fun and hard-work without ego involved.

-Learn how to deal with conflicts; trust is important when making decisions with other people. Allow for compromises

Conclusions/action items:

It was really inspiring to hear about the process and success of their project. It was very informative to see how they combined business practices and development to create their business and project. It was also interesting to hear about how their partnership benefited their business.

9/25/24 - Structural composite based on 3D printing polylactic acid/carbon fiber laminates (PLA/CFRC) as an alternative material for femoral stem prosthesis

ELLA CAIN - Sep 25, 2024, 6:48 PM CDT

Title: Structural composite based on 3D printing polylactic acid/carbon fiber laminates (PLA/CFRC) as an alternative material for femoral stem prosthesis

Date: 9/25/24

Content by: Ella

Present: N/A

Goals: To analyze the materials others have used for bone models or devices meant to mimic the characteristics of bone.

Content: This article explores PLA and CFRC for femoral stem prothetics

-3-D printing allows for the easy customizability of and fabrication prosthetics and prosthetic components

>Makes it easier to match density to the bone the prosthetic is for

-Favorable results in the form of decreased implant/bone stress with the use of PLA and CFRC fibers with hydroxapatite

-Even distribution of stress in both PLA and CFRC; more tolerant of heavier loads

-PLA reinforced with PVDF showed increased mechanical resistance and a higher elastic limit; no change in strength

-PLA showed the lowest resistance to temperature as opposed to CFRC

-PLA sheets were tested under pressure in what this article calls the "tensile test"

>Brtille and ductile fractures were detected

>Orientation of 45 degress in direction of printed filament

>Prints with layers orientated at 45 degrees showed to have better mechanical characteristics than those oriented at 0 and 90 degrees

>Prints with a higher number of air bubbles had a decrease in mechanical properties

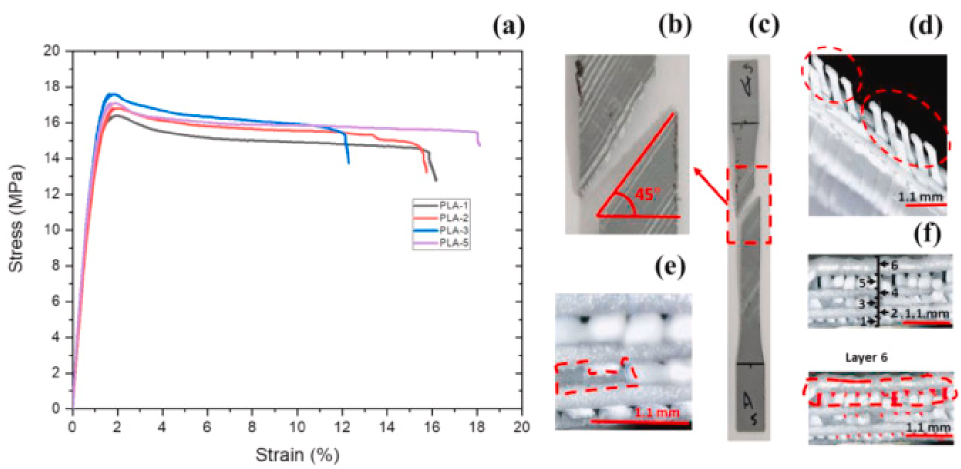

Figure 1:Tensile tests in 3D printing PLA, (a) stress-strain curves, (b) specimen's fracture, (c) test specimen, (d) filament strain, (e) brittle fracture, (f) number of layers and air gaps.

Source: [1]

-CFRC also had multiple fractures from the tensile test

>Fractures were observed to be orthogonal to the direction of the tensile load

>Displayed characteristic brittle behavior

-PLA mixed with CFRC performed better during these tensile tests

>An increase of a factor 11 to 14 in tensile strength and elastic modulus was shown in comparision to the PLA sheet

>Possessed lower rigidity than CFRC

>Presence of air gaps

-PLA is biocompatible and does not cause toxicity

-With respect to bone, the PLA/CFRC composite was shown to be a factor of 1.25 and 1.88 higher in elastic modulus and strength

References: [1] J. A. Paz-González *et al.*, “Structural composite based on 3D printing polylactic acid/carbon fiber laminates (PLA/CFRC) as an alternative material for femoral stem prosthesis,” *Journal of the Mechanical Behavior of Biomedical Materials*, vol. 138, no. 1751–6161, p. 105632, Feb. 2023, doi: https://doi.org/10.1016/j.jmbbm.2022.105632.

Conclusions/action items: It's important that we analyze other models that include modeling of bones or attempt to replace bones. PLA appears to be a popular choice in bone modeling due to its affordibility and versatility. It shows promise for the intended use of our bone model, as it is not meant to be a prosthetic but to mimic the texture and density of a bone.

ELLA CAIN - Sep 25, 2024, 6:50 PM CDT

ELSEVIER

Journal of the Mechanical Behavior of Biomedical Materials

Structural composite based on 3D printing polylactic acid/carbon fiber laminates (PLA/CFRC) as an alternative material for femoral stem prosthesis

ARTICLE INFO

ABSTRACT

1. Introduction

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Structural_composite_based_on_3D_printing_polylactic_acid_carbon_fiber.pdf (5.13 MB)

9/25/24 - Personalized endoprostheses for the proximal humerus and scapulohumeral joint in dogs: Biomechanical study of the muscles' contributions during locomotion

ELLA CAIN - Sep 25, 2024, 7:37 PM CDT

Title: Personalized endoprostheses for the proximal humerus and scapulohumeral joint in dogs: Biomechanical study of the muscles' contributions during locomotion

Date: 9/25/24

Content by: Ella

Present: N/A

Goals: To understand the role specific muscles play into the rotation of a dog's forelimbs.

Content: The most common bone tumor in dogs is osteosarcoma

>Endoprosthetics are created to spare the affected limb of the proximal humerus

>When the proximal humerus is removed it can significantly negatively impact the gait in dogs and cats

>This makes identifying the minimal number of the most important muscles in the movement of the forelimb a priority

>3-D printed prosthetics are one of the most convienent method of fabricating prosthetics

>It is important for the muscles to move the prosthetics

Three muscles that are attached to the humerus and that are impacted during the humerus removal and prosthetic addition surgery are:

1) *m. latissimus dorsi*

2) *m. pectoralis.superficialis*

3) *m. pectoralis.superficialis descendens*

-The muscles involved in the flexion of the forelimb are the *m. latissimus dorsi* and *m. pectoralis.superficialis descendens*

-The *m. pectoralis.superficialis descendens* is involved in adduction and extension of the front paw

-The muscles that are involved in the movement of the shoulder joint are:

> *m. latissimus dorsi*: involved in the generation of shoulder flexion motion

> *m. triceps brachii*: involved in the flexion of the shoulder and ensures the stability of the joint

> *m. biceps brachii*: involved in the extension of the shoulder and also ensures the joint's stability

-The article identifies specific angles that apply to the standing, flexion, and extension of the dog's forelimb

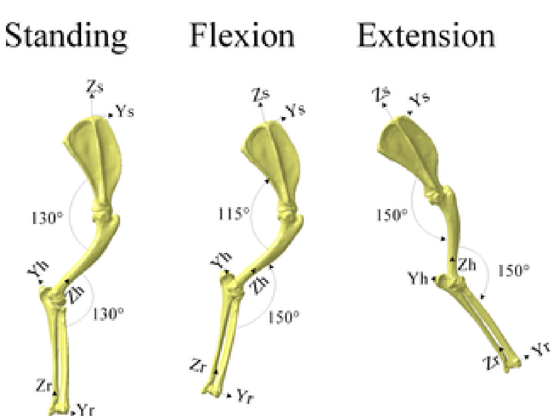

Figure: **Location of the forelimb bones and their axis systems defined by Shahar and Milgram in the thoracic limb.**

Source: [1]

The angles between the scapula and proximal humerus for each position are as follows:

-Standing: 130 degrees

-Flexion: 115 degrees

-Extension: 150 degrees

-Three prosthetics were tested for their effectiveness in mimicking the rotations of the proximal humerus:

1) Design A: Spherical Joint Prothesis: provides a spherical connection to the scapula and, combined with the muscles, was able to support the flexion and extension of the forelimb joint

2) Design B: Revolute Joint Prothesis: The muscles involved in stablizing the shoudler joint were more stressed in this model than in Design A

3) Design C: Monobloc Prothesis: This model does not allow for the rotation of the shoulder joint

- It is important to consider the connection of the prosthetic to the surrounding muscles and bones to allow for the most similar range of motion that keeping the proximal humerus within the dog

-The angles of flexion, extension, and standing are important to consider when choosing the attachment of the prosthetic to the scapula, radius, and ulna

References: [1] L.-A. Le Bras *et al.*, "Personalized endoprostheses for the proximal humerus and scapulohumeral joint in dogs: Biomechanical study of the muscles' contributions during locomotion," *PLoS ONE*, vol. 17, no. 1, p. e0262863, Jan. 2022, doi: https://doi.org/10.1371/journal.pone.0262863.

Conclusions/action items: The angles of rotation provided in this article will be important in considering our method of connecting the modeled bones together. Making sure the joints move in the model is an important component in ensuring the accuracy of performing aspiration. The muscles identified in moving the scapula and humerus will also be important to create the most realistic model.

ELLA CAIN - Sep 25, 2024, 7:38 PM CDT


PLOS ONE

RESEARCH ARTICLE

Personalized endoprostheses for the proximal humerus and scapulohumeral joint in dogs: Biomechanical study of the muscles' contributions during locomotion

OPEN ACCESS

Abstract

Introduction

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journal.pone.0262863.pdf (2.44 MB)

10/2/24 - An Investigation on Dimensional Accuracy of 3D Printed PLA

ELLA CAIN - Oct 02, 2024, 11:34 PM CDT

Title: An Investigation on Dimensional Accuracy of 3D Printed PLA, PET-G and ABS Samples with Different Layer Heights

Date: 10/2/24

Content by: Ella Cain

Present: N/A

Goals: To analyze the characteristics of PLA, ABS, and PETG.

Content: This article investigates the effect of layer height on the dimensional accuracy of 3D printed tensile test samples.

-The materials these samples are made out of are:

-PLA

-ABS

-PETG

-Samples with dimensions of 220x220x220mm and 200x200x200 were printed.

-The study found that ABS and PETG in particular showed a decrease in accuracy values with increased sample height.

-PLA showed the least amount of change in accuracy.

-PLA was found to have the best surface quality as a result of its better bonding capacity.

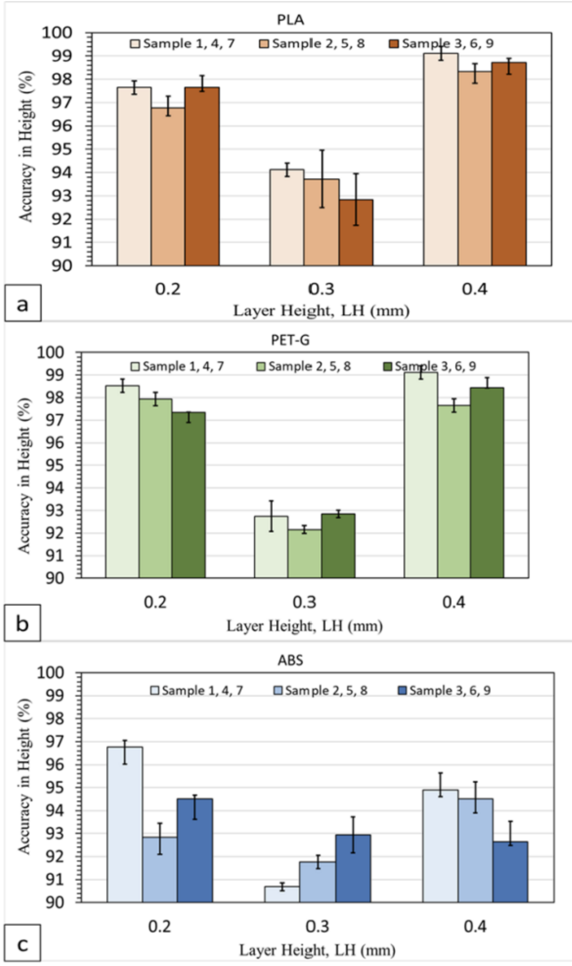

Figure 7. Accuracy values in height; PLA(a), PET- G(b) and ABS(c)

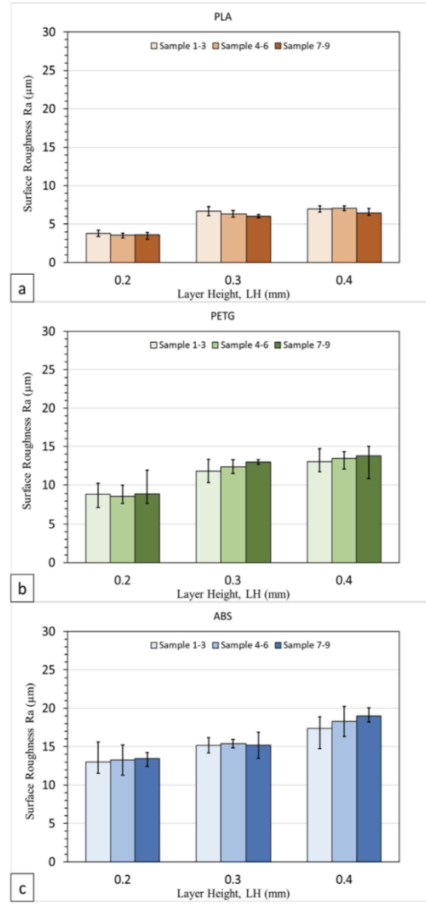

Figure 9. Surface roughness results of additively manufactured samples; PLA(a), PET-G(b) and ABS(c)

References: Çağın, Bolat., Berkat, Ergene. "Üç Boyutlu Baskı ile Farklı Katman Yüksekliklerinde Üretilmiş PLA, PET-G ve ABS Parçaların Boyutsal Doğruluğu Üzerine Bir Araştırma." Çukurova Üniversitesi Mühendislik Fakültesi Dergisi, 37 (2022).:449-458. doi: 10.21605/cukurovaumfd.1146401

Conclusions/action items: This article gives credence to the decision that we derived from the design matrix---that PLA is a good material for our model. It is important that the tensile and dimensional accuracy of our bone model does not change significantly to ensure the realism of the model and its longevity. Given the differences of thickness within our fabricated bones, the smallest change possible in accuracy is desired, making PLA a good candidate as opposed to ABS and PETG.

ELLA CAIN - Oct 02, 2024, 11:35 PM CDT

An Investigation on Dimensional Accuracy of 3D Printed PLA, PET-G and ABS Samples with Different Layer Heights

Çağın BOLAT[*1] ORCID
Berkay ERGENE[2] ORCID

Abstract

In this study, the effect of filament type and layer height on the dimensional accuracy of the 3D printed tensile test samples from PLA, PET-G, and ABS was investigated in depth. Based on the fused filament fabrication (FFF) technology, tensile test samples were produced with various layer heights (0.2 mm, 0.3 mm, and 0.4 mm) while the other printing parameters were kept constant, except for nozzle and building platform temperature. Length, width, and height values of the produced test samples were measured, and obtained results were compared with design dimensions to observe the dimensional accuracy of each sample. Also, surface roughness measurements were performed on the samples to examine their final surface quality. From dimensional measurements, it was seen that the most accurate results were recorded for PET-G (in length and height) and PLA (in width) samples. Furthermore, the best surface quality was attained in PLA samples compared to other filaments.

Keywords: Dimensional accuracy, Fused filament fabrication, PLA, PET-G, ABS

Üç Boyutlu Baskı ile Farklı Katman Yüksekliklerinde Üretilmiş PLA, PET-G ve ABS Parçaların Boyutsal Doğruluğu Üzerine Bir Araştırma

Öz

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An_Investigation_on_Dimensional_Accuracy_of_3D_Printed_PLA_PET-G.pdf (1.04 MB)

10/23/24 - Use of Silicone Materials to Simulate Tissue Biomechanics as Related to Deep Tissue Injury

ELLA CAIN - Oct 23, 2024, 7:18 PM CDT

Title: Use of Silicone Materials to Simulate Tissue Biomechanics as Related to Deep Tissue Injury

Date: 10/23/24

Content by: Ella

Present: N/A

Goals: To research what others have used as a model for muscle.

Content: This article's motivation is to assess the mechanical accuracy of selected silicon materials to the distribution of stress in human muscles to provide more accurate training tools for patients with Deep Tissue Injury (DTI).

-Silicon was chosen out of other materials because of it's known ability to maintain shape while allowing for deformity of its structure under stress.

-Silicon was overall found to adequately mimic the mechanical characteristics of certain muscles in similar stress distribution patters when subjected to loading.

-Here are some figures and tables that may apply to our model:

Table 1.

LITERATURE RANGES FOR SHEAR MODULI OF BIOLOGICAL TISSUES: ALL DATA REPORTED FROM COMPRESSION TESTING

Biological Tissue		*G* (kPa)
Muscle	Longitudinal	51–105[23–25]
	Transverse	11–54[23,25]
	Active	17.1–30.5[22,25]
	Relaxed	4.6–23.8[6,15,16,22]
Skin		2.8–31.9[6,20,26]
Fat		1.9–31.9[6,20,26]

Table 1: Literature Ranges for Shear Moduli of Biological Tissues: All Data Reported from Compression Testing

Source: [1]

Table 2.

BEST-FIT HYPERELASTIC MATERIAL CONSTANTS FOR SILICONE RUBBER FORMULATIONS

	Ogden Model Terms		
Silicone Type	Shear Modulus *G* (kPa)	Strain Hardening Exponent α	Poisson Ratio ν
Dragon Skin	75.449	5.836	0.4999
Ecoflex 0010	12.605	4.32	0.4999
Ecoflex 0030	22.081	0.825	0.4999

Table 2: Best-Fit Hyperealstic Material Constants for Silicone Rubber Formulations

Source: [1]

Figure 5.

RESULTS OF UNIAXIAL COMPRESSION TESTS ON SILICONE RUBBERS (DRAGON SKIN, ECOFLEX 0010, AND ECOFLEX 0030) COMPARED WITH FINITE ELEMENT SIMULATIONS

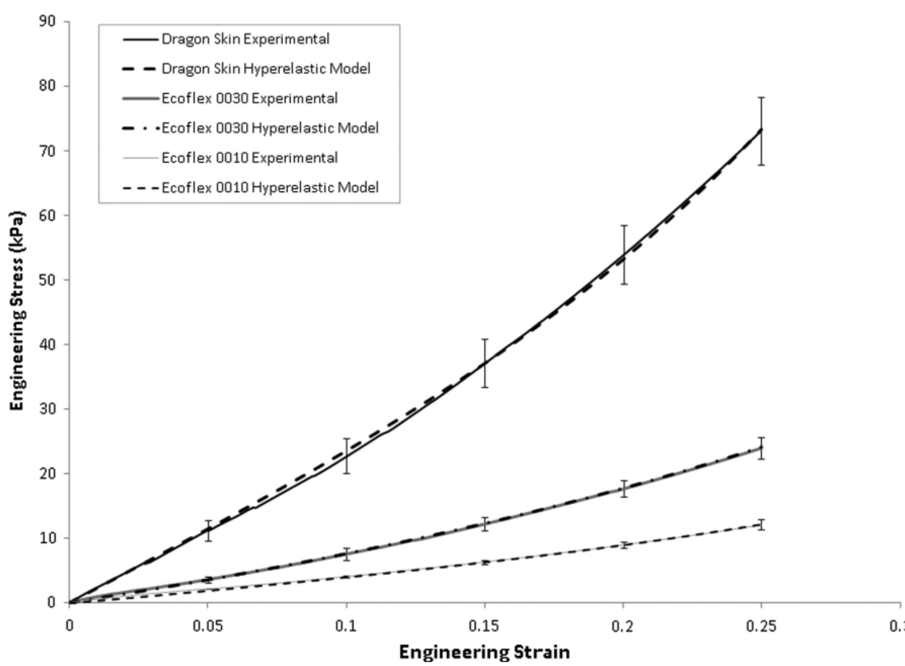
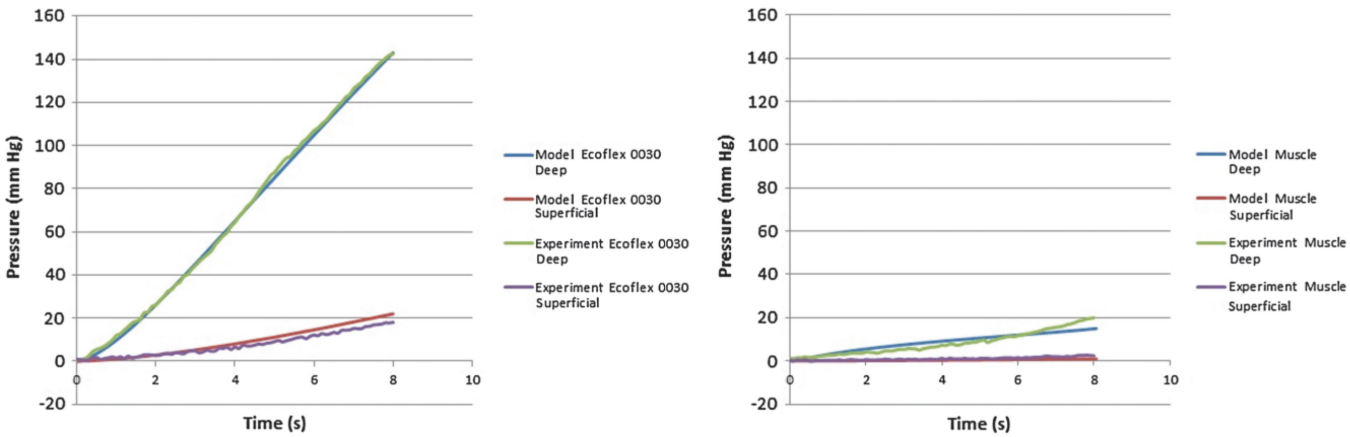


Figure 5: Results of Uniaxial Compression Tests on Silicone Rubbers (Dragon Skin, ECOFLEX 0010, and ECOFLEX 0030) Compared with Finite Element Simulations

Source: [1]

Figure 6.

PRESSURES MEASURED IN EXPERIMENTS COMPARED AGAINST FINITE ELEMENT MODEL-PREDICTED PRESSURES, FOR SILICONE AND MUSCLE INDENTATION TESTS



A, Ecoflex 0030 indentation test: deep and superficial pressures in relationship to time for both experimental and model data. B, Porcine muscle indentation test: deep and superficial pressures in relationship to time for both experimental and model data.

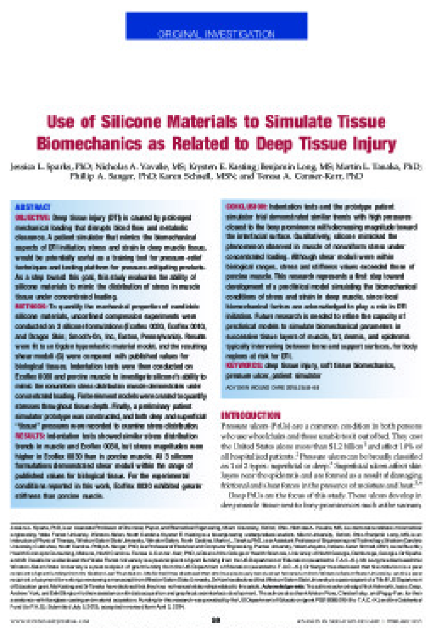
Figure 6: Pressures Measured in Experiments Compared Against Finite Element Model-Predicted Pressures, For Silicone and Muscle Indentation Tests

Source: [1]

References: [1] J. L. Sparks *et al.*, "Use of Silicone Materials to Simulate Tissue Biomechanics as Related to Deep Tissue Injury," *Advances in Skin & Wound Care*, vol. 28, no. 2, pp. 59–68, Feb. 2015, doi: https://doi.org/10.1097/01.asw.0000460127.47415.6e.

Conclusions/action items: It will be helpful to review these mechanical measurements of muscles and silicone materials with the team. This article not only provides data useful to us, but gives evidence to our choice of silicon as the pseudo-muscle for our model. We should research the silicon materials chosen for analysis in this article to determine if any of them may be implemented into our own model.

ELLA CAIN - Oct 23, 2024, 7:19 PM CDT


ORIGINAL INVESTIGATION

Use of Silicone Materials to Simulate Tissue Biomechanics as Related to Deep Tissue Injury

Jessica L. Sparks, PhD; Nicholas A. Vavalle, MS; Krysten E. Kasting; Benjamin Long, MS; Martin L. Tanaka, PhD; Phillip A. Sanger, PhD; Karen Schell, MSN; and Teresa A. Conner-Kerr, PhD

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Use_of_Silicone_Materials_to_Simulate_Tissue.pdf (6.19 MB)

10/9/24 - Design Idea for Complete Model #1

ELLA CAIN - Oct 10, 2024, 11:41 PM CDT

Title: Design Idea for Complete Model #1

Date: 10/9/24

Content by: Ella

Present: N/A

Goals: To brainstorm a design idea for the complete design with all of our model components accounted for.

Content:

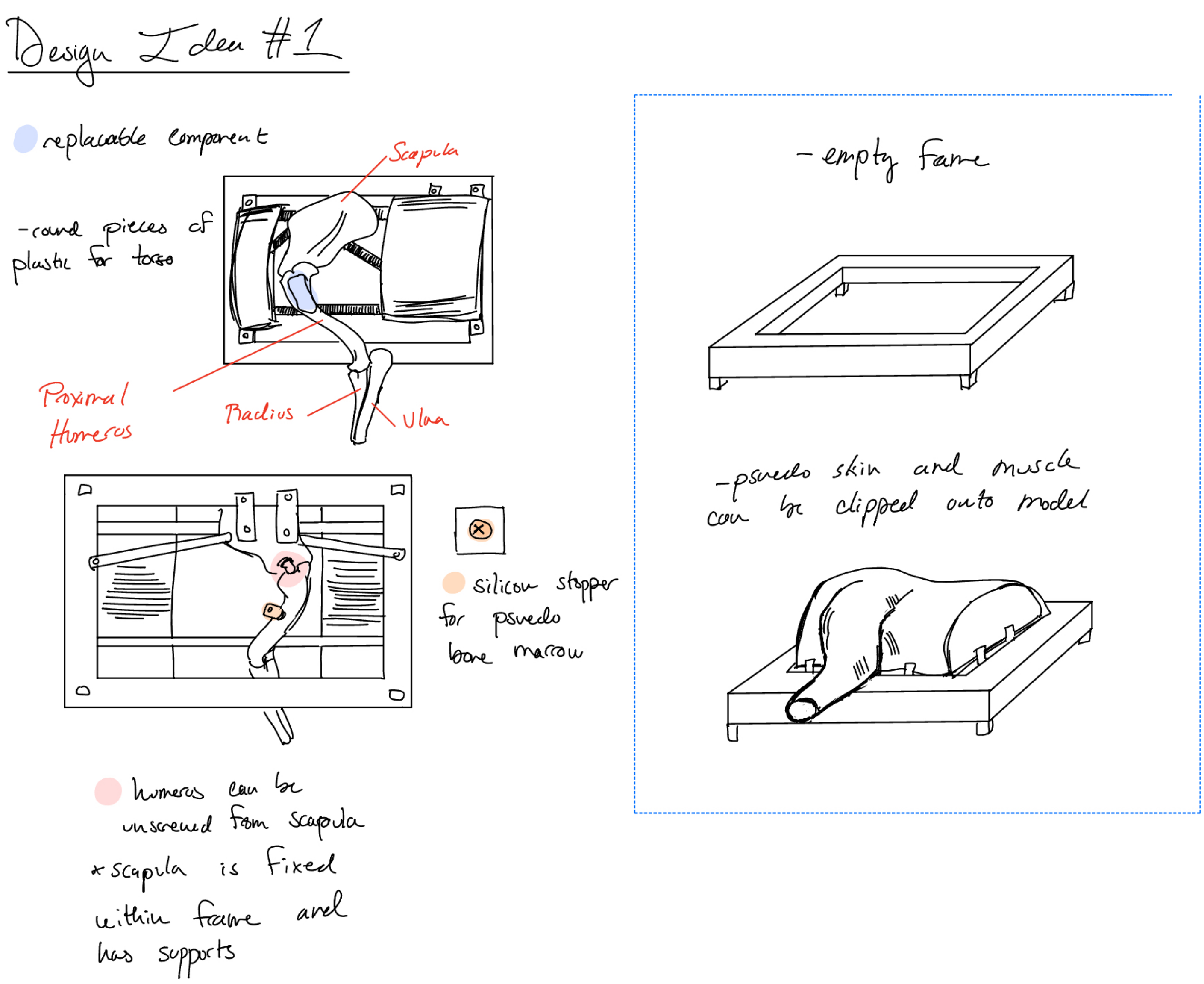


Figure 1: Design Idea #1.

The model is supported by a simple frame with rubber legs to keep in stable on a level surface. There are two rods going across the frame that will act as supports for the structure. Two curved half-cylinders of plastics are on either side of the frame, meant to model the torso of a dog, excluding the forelimb. The scapula is the only bone fixed within the structure, and it is supported by rods. The proximal humerus, radius, and ulna will be supported by the structure---either with rods or something else---but are not fixed within the frame. The proximal humerus has a small area where bone marrow can be injected into the cavity; it contains a rubber stopper that will keep marrow in once added to. The pseudo skin and muscle may be clipped onto both the frame and the model, using the fact that the frame has a hole in it. More supports will be needed for this model.

Conclusions/action items: We should continue to brainstorm ideas for the complete model that will incorporate all of the components. It needs to be secured and able to withstand the force that is applied to it. Further modification and testing will allow us to gain a better idea of the complete model that will suit the need best.

10/16/24 - Design #2 for Complete Model

ELLA CAIN - Oct 16, 2024, 5:04 PM CDT

Title: Design #2 for Complete Model

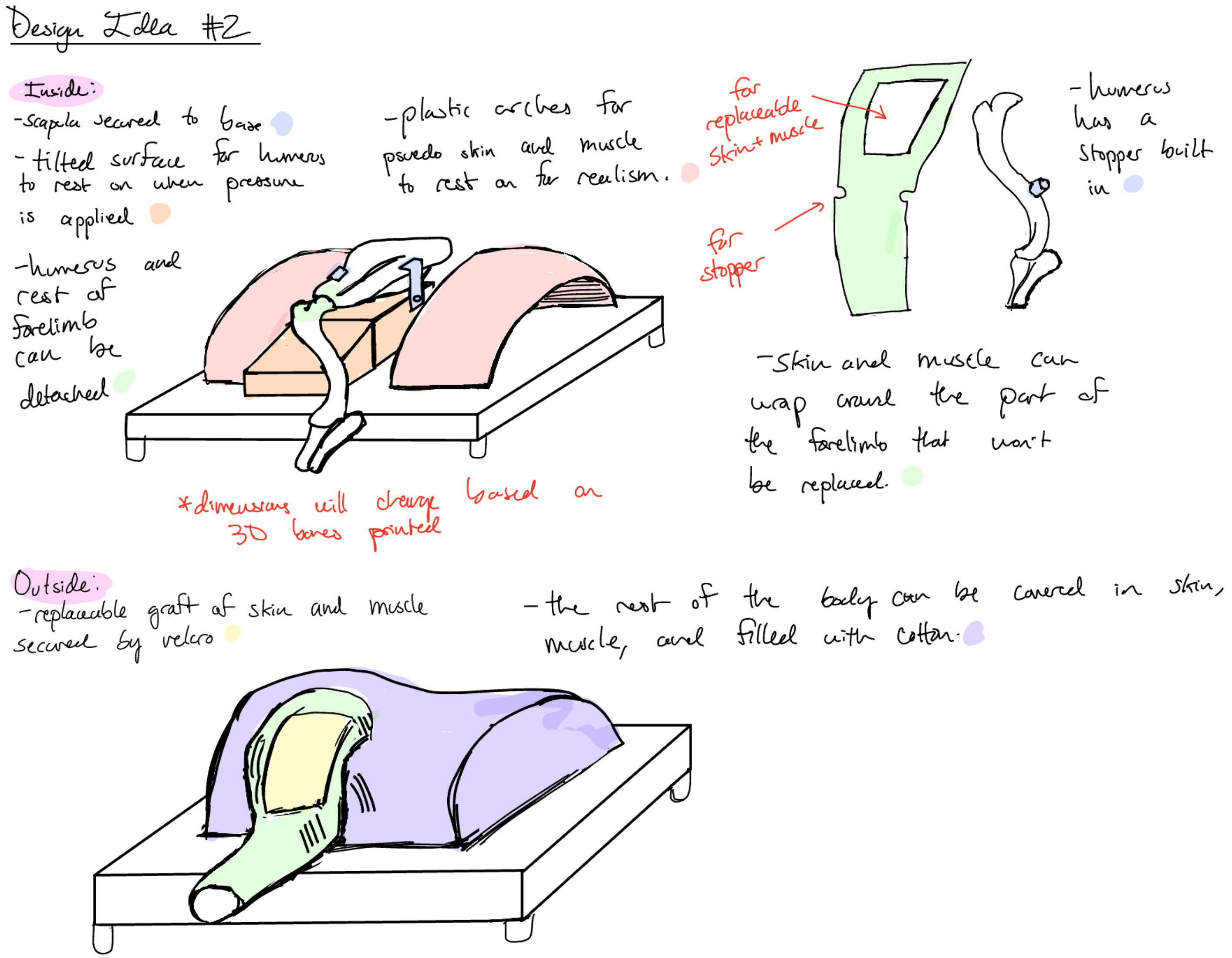
Date: 10/16/24

Content by: Ella Cain

Present: N/A

Goals: To come up with another potential design for the complete model.

Content:



This model is also supported by a simple framework with rubber legs to prevent the model from moving. The inside of the model will contain an elevated box, where the scapula will be secured. The other bones will be detachable from the scapula. The humerus will rest on a slanted surface that will provide the stabilizing force for when pressure is applied to the replaceable component during aspiration. The humerus in this design also contains a built-in port and stopper for pseudo bone-marrow to be injected. On each side of the forelimb, there are two plastic arches where the extra pseudo skin and muscle will rest on for added realism. The skin and muscle wrapped around the forelimb will be separate from the rest of the body and will be cut to allow room for the stopper and replaceable component. On the outside, in the space left by the skin and muscle wrapped around the forelimb, a graft of replaceable muscle and skin will be placed above the replaceable component. The graft will be secured by velcro connected to the other skin and muscle on the forelimb. The rest of the body may be covered with skin, muscle, and filled in cotton in some parts for realism.

Conclusions/action items: We should talk about our ideas of how the final model should be designed to incorporate all of our catergories in our design matrix and design specifications. It would also be helpful to test the stability of the humerus when it attached to the scapula in the air versus laying down on a flat surface. We should also chronological list of tasks that need to be completed in creating the model before we reach completion.

11/1/24 - Preliminary Design Show-and-Tell Notes

ELLA CAIN - Nov 13, 2024, 9:51 PM CST

Title: Preliminary Design Show-and-Tell Notes

Date: 11/13/24

Content by: Ella

Present: N/A

Goals: To review and assess the feedback recieved by our peers on our preliminary design.

Content: We recieved a lot of great and helpful feedback on our preliminary design. We had questions prepared to ask our peers, such as:

-How can we smooth out and edit our STL file of the humerus on SolidWorks?

-How can we attach the pseudo-skin and muscle onto our bones and frame?

-How can we create the replaceable component?

These were the questions we considered to be the most important.

We recieved a few ideas for how we can begin to edit our STL file of the humerus, such as splitting it into two parts using a plane. It was also suggested to import it into adobe to reconvert the file.

For the pseudo-skin and muscle, the most applicable feedback we received to attach them was to create a "sleeve" of the materials attached to one another and put it over the bone. Others also suggested using a glue or solvent that wouldn't dissolve anything else except for the skin and muscle, such as ethanol or alcohol soluble glue.

For the replaceable component, it was suggested that we create it retroactively by printing the humerus and carving out the replaceable component and 3-D scanning it. That way we could also hollow out the humerus for the pseudo-bone marrow.

Conclusions/action items:

We should attempt these suggestions for converting the STL file into something editable and without as complex geometry. It would be worth it to look into different glues or adhesives that would allow the silicon of the skin and muscle to attach to themselves. For the replaceable component, we should wait until we have tried multiple ways of editing the bone; if we cannot edit the bone, and thus cannot make the replaceable component using software, then we may create it retroactively instead.

11/6/24 - Design Idea #3

ELLA CAIN - Nov 13, 2024, 10:20 PM CST

Title: Adjusted Design: Idea #3

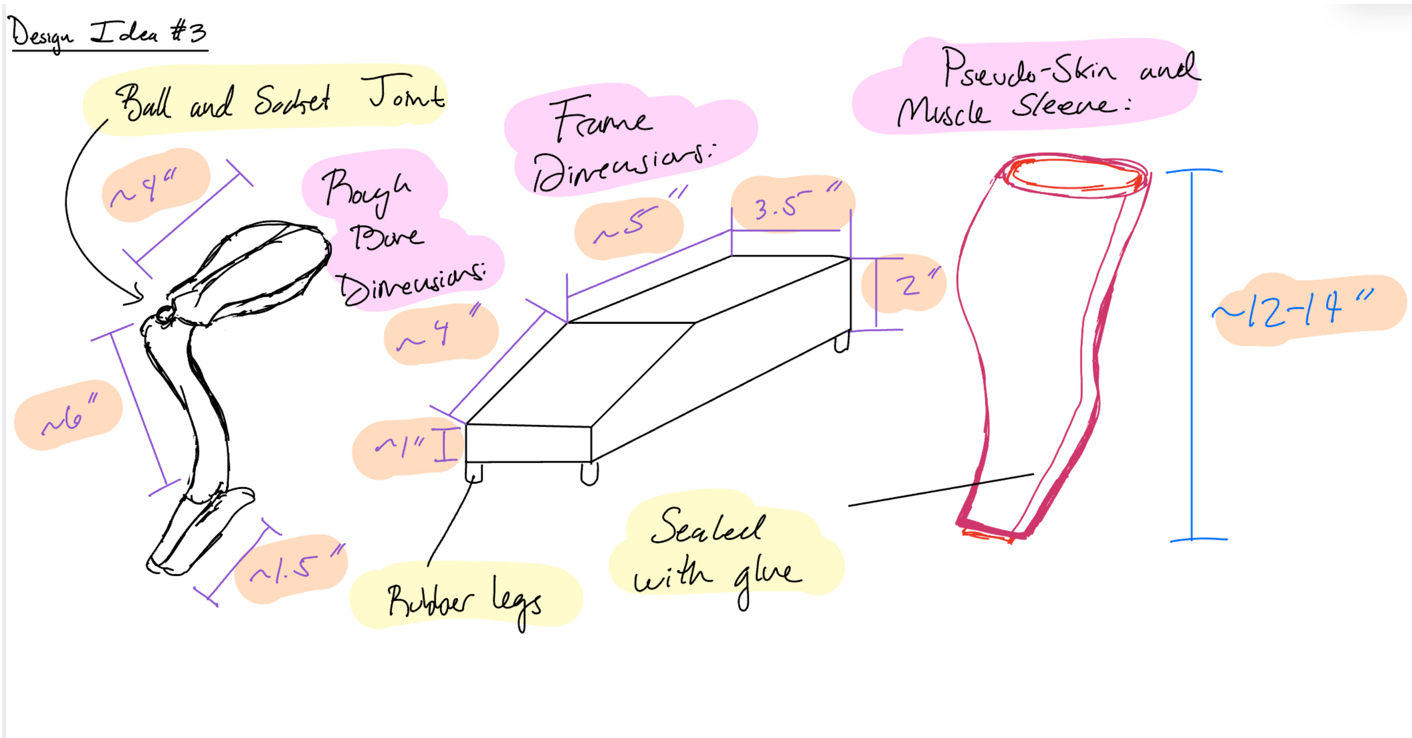
Date: 11/6/24

Content by: Ella

Present: N/A

Goals: To use the feedback from the preliminary design to adjust our design.

Content:



The main change in this design as opposed to the others is to the surrounding structures. The structures that would model the surrounding area of the dog torso have been omitted. I have also put down rough estimates for the dimensions of the bone, frame, and pseudo-skin and muscle sleeve. This is a design component that was suggested from the preliminary design show-and-tell presentation. The way the sleeve would be sealed is through a glue or adhesive that would allow silicon to stick to silicon without sticking to anything else. This design also includes the ball-and-socket joint that we will attempt to create through software; if we cannot do it using software, we have ordered a ball-and-socket joint that we will attach manually.

Conclusions/action items: This design is a very basic rendition of the client's requirements, the feedback we received from the preliminary show-and-tell presentation, and the limits of fabrication. It is very possible that the attachement methods for the bones, skin, and muscle will change as we begin assembly of the model. Right now, we need to print the entire bone model and go from there.

9/11/2024: Bone Marrow Aspiration and Biopsy

HELENE SCHROEDER - Sep 11, 2024, 7:05 PM CDT

Title: Bone Marrow Aspiration and Biopsy

Date: 9/11/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn more about what bone marrow aspiration is, not specifically in an animal. Also to learn the difference between aspirate and biopsy.

Citation:

Malempati, Suman, et al. “Bone Marrow Aspiration and Biopsy.” *New England Journal of Medicine*, vol. 361, no. 15, 8 Oct. 2009, p. e28, https://doi.org/10.1056/nejmvcm0804634.

Link:

https://www.researchgate.net/profile/Sarita-Joshi-2/publication/26879255_Bone_Marrow_Aspiration_and_Biopsy/links/57a08ff208aec29aed24bff3/Bone-Marrow-Aspiration-and-Biopsy.pdf

https://www.nejm.org/doi/full/10.1056/NEJMvcm0804634

Content:

Indications:

- "Bone marrow aspiration is performed to obtain specimens used to assess cellular morphology and conduct specialized tests on the bone marrow..."
- procedure used for evaluation of hematological conditions, cancers, metastatic disease, etc.
- BIOPSY is performed as part of the aspiration procedure
    - can provide more specifics about cellularity of the marrow
- invasive procedure, done by trained clinicians

Contraindications:

- none, besides issues with general anesthesia/deep sedation or an infection

Equipment:

- need sterile solution (chlorhexidine or povidone-iodine)
- sterile drapes
- sterile gloves
- local anesthesia
- 25-gauge needle with two 5-mL syringes for giving anesthesia
- 11-blade scalpel (stab incision)
- two large syringes
- bone marrow aspiration needle (disposable)
- one marrow biopsy needle
- slides

Bone Marrow Aspiration:

- make incision so you can put in BM aspiration needle
- some needles have a guard to keep the needle from going through the bone (if being used for intraosseous access)
- angle of insertion is very important, should be very perpendicular to the bone
- needle should stay in place without being held once it is in the marrow
- you will need to slightly move the needle to get it in the correct position
- remove stylet, aspirate approx. 1 mL of unadulterated bone marrow into a syringe
- someone (assistant) should check for presence of bony spicules (can be seen in syringe sometimes, easier to spread onto a slide)
    - if there are spicules, sample should be used to make smear slides
    - if no spicules, new sample is needed from a slightly different site
- more syringes (with preservatives) can be used to take more samples, but it has to be done timely

- remove needle

Bone Marrow Biopsy:

- you can use the same incision site, but you must adjust the needle for insertion at a different angle into the bone

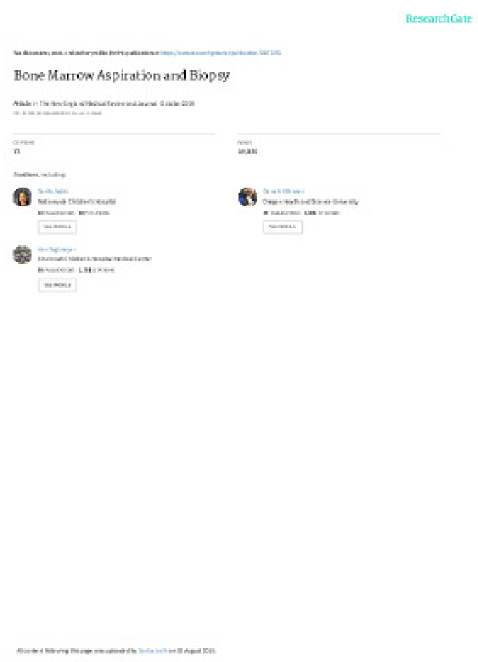
Complications:

- potentially hazardous procedure
- trauma to neighboring structures/soft tissues
- infection
- hemorrhage (most common complication)

Conclusions/action items:

This article has given me a lot of insight into what bone marrow aspiration is and what it is used for. I have also learned that aspiration and biopsies are often used in tandem, but they test for different things and the procedures are slightly different. Next I will find an article relating to bone marrow aspiration in veterinary medicine to see how it differs from the procedure for humans. I also would like to know in which specific bones this procedure is most commonly done in.

HELENE SCHROEDER - Sep 11, 2024, 6:59 PM CDT


ResearchGate

Bone Marrow Aspiration and Biopsy

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Bone_Marrow_Aspiration_and_Biopsy.pdf (223 kB)

9/11/2024: Practical bone marrow cytology in the dog and cat

HELENE SCHROEDER - Sep 11, 2024, 7:56 PM CDT

Title: Practical bone marrow cytology in the dog and cat

Date: 9/11/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn more about what makes up the bone marrow in dogs and cats. Also to learn about BM aspiration and its uses, specifically in dogs and cats.

Citation:

MYLONAKIS (Μ.Ε. ΜΥΛΩΝΑΚΗΣ) M. E. and HATZIS (Α. ΧΑΤΖΗΣ) A., "Practical bone marrow cytology in the dog and cat", *J Hellenic Vet Med Soc*, vol. 65, no. 3, pp. 181–196, Dec. 2017.

Link: https://ejournals.epublishing.ekt.gr/index.php/jhvms/article/view/15534/13982

Content:

Abstract:

- BM aspiration cytology is cost-effective
- provides morphological detail of cells and infectious agents
- major indications for BM aspiration:
  - unexplained clinical manifestations (fever, weight loss)
  - persistent hematological or biochemical abnormalities (anemia, leukocytosis)
  - diagnosis and/or staging of malignancies I lymphoma, mast-cell tumor)
  - diagnosis of infectious diseases (leishmaniosis and canina monocytic ehrlichiosis)
  - evaluation of canine iron stores
- complications associated are rare, supplies required are minimal
  - make this procedure more favorable compared to BM core biopsy

Indicators for BM Aspiration:

- hematopoiesis is normally confined to BM, occupies the medullary cavities of the trabecular bone
- BM comprises red marrow that contains hematopoietic cells (active marrow) and yellow marrow, predominated by adipose tissue
- proportion of red and yellow BM is age dependent
- at birth, only red marrow
  - with aging, red marrow replaced by yellow marrow so that red marrow is confined in vertebrae, skull, ribs, sternum, pelvis, proximal humeri/femora
- BM biopsy provides better reflections of the architectural pattern of tissue
- BM aspiration is more commonly used in dogs and cats
  - several considerations should be taken into account before though (whether or not the animal needs procedure done)
  - presence of blast cells or pancytopenia almost always require BM examination
  - little complications, but if aspiration is done from the sternum or ribs, risk of penetrating the thoracic cavity and lacerating intra-thoracic organs (especially in small dogs)

Sites, Equipment, Technique for BM Aspiration:

- sites for large dogs:
  - iliac crest
  - proximal (greater tubercle) humerus
- sites for small dogs, cats:
  - humerus
  - proximal (greater trochanter) femur
- recently proved that in Beagles, sternal BM aspiration with a hypodermic needle was safe
- historically, aspiration of proximal rib with special needle also works (technique more risky and labor-intensive)
- medium-large dogs: costochondral junction of the rib with a hypodermic needle
- recently in dog cadaver, aspiration precedes biopsy but is done with same needle and same site
  - no difference in cellularity, megakaryocyte count, myeloid/erythroid ratio, iron stores, or the overall diagnostic quality

    - marrow core length was shorter
    - hemorrhage artifact was more common
    - failure rate in obtaining diagnostic material was higher
- postmortem BM aspiration to be done within 30 mins of death due to cellular degeneration
    - if animal is planned to be euthanized, BM aspiration to be done before administration of euthanasia solution
    - cadaver can be placed in refrigeration, not frozen though
- equipment is minimal:
    - sedation (intramuscularly) for uncooperative animals
    - normally, local anesthesia is only needed
- patient position:
    - lateral for humerus and proximal femur
    - standing/sitting for iliac crest
- procedure:
    - area is clipped, surgically scrubbed, infiltrated with lidocaine (anesthesia)
    - stab incision with no. 11 scalpel blade
    - aspiration needle with stylet in place is passed through skin incision to the bone
    - needle is rotated and advanced in a CW-CCW motion until firmly embedded into the bone
    - stylet removed, syringe ringed with a few drops of ethylenediamine tetra-acetic acid (EDTA) solution is attached to the needle
    - steady negative pressure is applied to the plunger (5-7 mL vacuum pressure) to draw marrow into syringe
    - 0.5-1 mL of BM aspirate collected
    - pressure released, syringe removed along with needle
    - direct pressure to site to minimize bleeding
        - incision not normally sutured
    - if collection failed, stylet is reinserted and needle is advanced further into bone
        - repeated failures indicate that site needs to be changed or to perform core biopsy

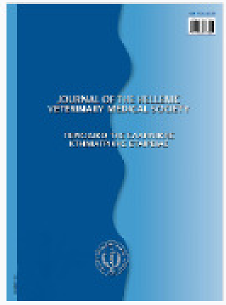
BM Aspiration Samples Processing:

- samples should be processed ASAP, within 2 hours
    - smear technique (most common: squash technique)
        - one drop of blood expelled onto glass slide, slide tilted to allow drainage of excess blood, slide-attached spicules are squashed by a perpendicularly-placed slide
    - also could be placed in Petri dish to get spicules to then transfer to glass slides and squashed
        - can be good for larger volumes

Conclusions/action items:

This article has provided a lot more specific information about BM aspiration in dogs than previous articles have. The remaining pages of this article describe what to look for in specific cells from the smears, but that part of the article does not apply to the project, so I chose to not write notes for it. Now I know what bones are used for the procedure based on the size of the animal. I also know more about how the procedure works and how the smears need to be analyzed quickly after the procedure is done.

HELENE SCHROEDER - Sep 11, 2024, 8:24 PM CDT



Journal of the Hellenic Veterinary Medical Society

Vol 65, No 3 (2014)

Practical bone marrow cytology in the dog and cat

M. E. MYLONAKIS (M.E. ΜΥΛΩΝΑΚΗΣ), A. HATZIS (A. XATZHΣ)

doi: 10.12681/jhvms.15534

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15534-505-37272-1-10-20171221.pdf (1.11 MB)

9/11/2024: Normal Structure, Function, and Histology of the Bone Marrow

HELENE SCHROEDER - Sep 11, 2024, 8:23 PM CDT

Title: Normal Structure, Function, and Histology of the BM

Date: 9/11/2024

Content by: Helene Schroeder

Present: N/A

Citation:

Travlos, Gregory S. "Normal Structure, Function, and Histology of the Bone Marrow." *Toxicologic Pathology*, vol. 34, no. 5, Aug. 2006, pp. 548–565, https://doi.org/10.1080/01926230600939856.

Link: https://journals.sagepub.com/doi/10.1080/01926230600939856?url_ver=Z39.88-2003&rfr_id=ori:rid:crossref.org&rfr_dat=cr_pub%20%200pubmed

Goals: To learn more about what exactly bone marrow is and what it is made up of.

Content:

Introduction:

- blood and BM is one of the largest organs in the body
  - important potential target organ of chemical exposure
- effects of a compound may be elicited in the circulating blood cell mass or productive of blood cells
  - because of this, evaluations of single or serial whole blood samples and smears, BM aspirates, and marrow tissue sections are needed to understand alterations

BM Structure and Function:

- found within central cavities of axial and long bones
- consists of hematopoietic tissue islands and adipose cells surrounded by vascular sinuses interspersed within a meshwork of trabecular bone
- accounts for 2% of body weight in dogs, 5% in humans
- major hematopoietic organ, a primary lymphoid tissue
- responsible for production of erythrocytes, granulocytes, monocytes, lymphocytes, and platelets
- inner surface of bone cavities and outer surfaces of cancellous bone spicules within cavities are covered by endosteal lining (consists of single later of flat "bone-lining cells" supported by thin layer of reticular connective tissue; also has osteoblasts and osteoclasts)
- long bones:
  - one or more nutrient canals pass through cortical bone entering marrow cavity obliquely
- flat bones:
  - marrow is served by numerous blood vessels of various sizes entering via large and small nutrient canals
- after entry into marrow cavity, artery splits into ascending/descending branches
- marrow has large blood supply
- circular pattern to blood flow within the marrow cavity (from center to periphery then back toward center)
- BM innervation in myelinated and non-myelinated nerves
- hematopoietic tissue contains variety of cell types:
  - blood cells
  - adventitial/barrier cells
  - adipocytes
  - macrophages
  - NOT randomly arranged
  - microenvironment for proliferation, differentiation, and maturation of stem cellsL
    - adventitial reticular cells (barrier cells), endothelial cells, macrophages, adipocytes, bone lining cells (osteoblasts)?, elements of ECM

Conclusions/action items:

From this research article, I have learned a lot about bone marrow, what types of cells are in it, what its general structure looks like, and its relevance to the body. This will help me understand the project more since I know why the aspiration procedure is so important to understanding the health of BM. I am curious about how bone marrow structure and composition differs by age, species, gender, and other factors.

HELENE SCHROEDER - Sep 11, 2024, 8:24 PM CDT

Normal Structure, Function, and Histology of the Bone Marrow

Gregory S. Travlos

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travlos-2006-normal-structure-function-and-histology-of-the-bone-marrow.pdf (9.92 MB)

10/2/2024: Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs

HELENE SCHROEDER - Oct 08, 2024, 3:09 PM CDT

Title: Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs

Date: 10/8/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about the differences between sites of BMA and if there are any quantitative values that can help further our project.

Link: https://onlinelibrary.wiley.com/doi/10.1111/vcp.12036

Citation:

[1] A. Defarges, A. Abrams-Ogg, R. A. Foster, and D. Bienzle, “Comparison of sternal, iliac, and humeral bone marrow aspiration in Beagle dogs,” *Veterinary Clinical Pathol*, vol. 42, no. 2, pp. 170–176, Jun. 2013, doi: 10.1111/vcp.12036.

Content:

Abstract:

- sternal BMA in dogs is not commonly performed as it is considered technically challenging in small dogs
- BUT sternum is readily accessible and associated with less pain
- goal: investigate feasability, ease, number of attempts, safety, and sample quality of sternal BMA in small dogs
- methods:
    - BMA obtained from 3 sites in 26 clinically healthy Beagles under general anesthesia
    - samples obtained from sternum using one-inch 20 or 22 gauge hypodermic needles
    - samples obtained from right greater tubercule of the humerus and the right iliac crest using 18-gauge Illinois needles
    - difficulty was scored
    - 2 types of smears were prepared and reviewed by pathologise unaware of site of aspiration or dog
    - number of particles per slide and overall slide quality were scored
    - site of aspiration and the cranial thoracic wall were evaluated at autopsy for evidence of trauma and pneumothorax
- results:
    - # of attempts and time for BMA greater for ilium than for sternum or humerus
    - sternum was easiest to aspirate
    - smear quality and particle # were similar for all sites
    - neither trauma at the site nor pneumothroax identified
- conclusion:
    - aspiration of sternal BM with hydodermic needles is feasible and safe in Beagles
    - samples are equivalent in quality to those from humerus or iliac

Intro:

- BMA performed in dogs and cats with unexplained hematologic abnormalities when a diagnosis cannot be established based on blood evaluation
    - anemia, leukopenia, thrombocytopenia
- BMA most often done from humerus or ilium in dogs through placement of a special 14-18 gauge needle with stylet in BM cavity
- aspirate with negative pressure from a syringe attached to needle
- needles for BMA are designed to penetrate cortical bone without becoming obstructed
- smears are prepared from aspirates for cytologic evaluation
- in humans, iliac crest and sternum are optimal sites for aspiration wrt accessibilty and sample quality
- in dogs, bones of axial skeleton, with gradual diminution along the appendicular skeleton are considered to contain the highest density of hematopoietic cells
- sternum bone is softer, soft tissue covering is minimal, hematopoiesis remains active thoughout adulthood
- sternum and iliac crest are standard sites for aspirating in large animals (not dogs and cats)
- in dogs and cats, iliac crest, proximal humerus, trochanteric fossa of the femur are commonly used
- humeral and femoral BM aspirates MAY be of lesser quality in older animals due to reduced hematopoietic activity in appendicular bones
- iliac crest is thing in small dogs and cats, so long bone sites are commonly chosen
- sternum not penetrated historically due to concerns about thoracic penetration
- sternum though has less soft tissue coverage than the ilium, femur, or humeral head

- aspiration from sternum in midly sedated dogs was associated with less pain than from the ilium, suggesting that general anesthesia may not be needed for sternum
- limitation: lack of practice and experience, so unknown whether samples are comaprable to those of other sites

Results:

- hard to retain dogs in sternal recumbency under general anesthesia
- sternal and iliac samples required siginificantly more attempts than acquiring from humerus
- almost all aspirates from the humerus were obtained on the first attempt
- samples from the sternum were obtained on the first attempt for 20/26 dogs
    - 2 attempts on 3 dogs
    - 3 attempts on 3 dogs
- ilium
    - 1st try, 15 dogs
    - 2nd try, 6 dogs
    - 3rd try, 5 dogs
- aspirating BM from humerus took significantly less time than from other sites
- aspirating from iliac crest required the most time
    - difficulty in deciding the depth of the cavity and appropriate placement for aspiration
- sternum was easiest site to aspirate, procedure became faster and simpler with more practice
- no more than 0.5 mL from sternum
- easily yield up to 1 mL of BM in humerus and iliac crest

Conclusions/action items:

This article has given me some good insight into why a different site of BMA would be chosen. I have learned that aspirating at the humerus (our site) is a lot more common than the iliac crest or sternum due to its smaller attempt number, ability to aspirate more BM, and other factors. I have also learned that in older dogs, the samples may be of lesser quality from the humerus due to reduced hematopoietic activity in appendicular bones. I want to apply this article to our project through the preliminary report, especially the discussion, conclusion, and introduction.

9/18/2024: A review on artificial bone modelling: Materials and manufacturing techniques

HELENE SCHROEDER - Sep 18, 2024, 8:26 PM CDT

Title: A review on artificial bone modelling: Materials and manufacturing techniques

Date: 9//18/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn more about artificial bone and the different materials that are used to fabricate it.

Link: https://www.sciencedirect.com/science/article/abs/pii/S2214785320347969

Citation:

[1] Neha Khasnis a et al., “A review on artificial bone modelling: Materials and Manufacturing Techniques,” Materials Today: Proceedings, https://www.sciencedirect.com/science/article/pii/S2214785320347969?via%3Dihub (accessed Sep. 18, 2024).

Content:

Abstract:

- artificial bone modeling to replicate the mechanical properties and microstructure of human cancellous and cortical bone
- applications: bone grafting, testing of orthopaedic instruments
- use of natual polymers and bio-compatible metals to manufacture porous structures replicating bone properties
- 3 manufacturing technqiues reviewed, SLM is a potential candidate for design flexibility and manufacturing accuracy

Material selection for artificial bone:

- need to prevent stress sheilding
- bio-ceramics
- carbon nanotubes
- metal scaffolds
- polymers and composites
- our material does not need to be biocompatible, but it does need to be mechanically similiar
- Herex C70.5 PVC Foam
    - similar cellular structures and modulus to strength ratio as cancellous bone
    - higher mechanical strength/improved bone tissue formation
- 13-93 bioactive glass
    - mechanical properties similar to human bone
    - glass seems expensive and inaccessible
- PLA/apatite- wollastonite
    - replicated properties of cancellous bone
    - similar properties to cortical bone
- hydroxyapatite
    - higher mechanical strength
    - improved bone tissue formation

mechanical properties regarding stress are listed in the article as well

Conclusions/action items:

This article has been helpful in determining common materials used for artificial bone. I think I want to search more for bone models rather than artificial bone so that the materials are more focused on mechanical strength/properties rather than biocompatibility and osteoconductivity. I think the group will work on 3D printing using PLA or a similiar material, but more research is needed about PLA and how comprobale it is to real bone.

9/24/2024: A simple and convenient 3D printed temporal bone model for drilling simulating surgery

HELENE SCHROEDER - Sep 24, 2024, 9:41 PM CDT

Title: A simple and convenient 3D printed temporal bone model for drilling simulating surgery

Date: 9/24/24

Content by: Helene Schroeder

Present: N/A

Search Terms: 3D printed bone model

Goals: To learn about methods to fabricate fake bone to be used in models.

Link: https://pubmed.ncbi.nlm.nih.gov/34928778/

Citation:

[1] Z. Yuan *et al.*, "A simple and convenient 3D printed temporal bone model for drilling simulating surgery," *Acta Oto-laryngologica*, vol. 142, no. 1, pp. 19–22, Dec. 2021, doi: https://doi.org/10.1080/00016489.2021.2015079.

Content:

Objective:

- to investigate a precise, simple, convenient way to 3D print temporal bone with a commercial desktop 3D printer
- method can be widely promoted and applied in the training of beginners in otology (ear studies)

Materials/Methods:

- CT data of temporal bone imported to Mimics (software) to construct a 3D digital model of the temporal bone
- after loaded to high-precision 3D printer, model printed at 1:1 scale
- model was evaluated by physicians for things like morphological accuracy, simulation about surgery, advantages and educational value

Results:

- life-like temporal bone successfully printed
- physicians all thought that the printed model was similar to natural temporal bone
- haptic sensation of drilling felt accurate, simple, convenient, and effective
- model considered to be of high application value in the teaching of temporal bone anatomy and surgery simulation
- cost $3

Conclusion:

- high-precision 3D printed temporal bone model is highly similar to natural temporal bone
- effectively used for training of simulating temporal bone surgery
- production is simple and economical

Conclusions/action items:

Although I did not have full access to this article, I still got some good information out of it. I was a little unsure about if it was possible to turn CT scans into something 3D printable, but it seems it is possible with a software called Mimics. I don't think that this software is easily accessible, but I will need to look into this software or other similar softwares that are capable of turning CT scans into stl files. I also need to look into how specifically they 3D printed this in terms of material and the density/composition of the printing.

9/24/2024: Creation of a 3D printed temporal bone model from clinical CT data

HELENE SCHROEDER - Sep 24, 2024, 9:41 PM CDT

Title: Creation of a 3D printed temporal bone model from clinical CT data

Date: 9/24/24

Content by: Helene Schroeder

Present: N/A

Search Terms: 3D printed bone model, CT scan

Goals: To learn how 3D printed bone models were made from CT scan data. This will help find materials and methods to print our model of bone.

Link: https://www.sciencedirect.com/science/article/pii/S0196070915000617?via%3Dihub

Citation:

[1] J. Cohen and S. A. Reyes, "Creation of a 3D printed temporal bone model from clinical CT data," *American Journal of Otolaryngology*, vol. 36, no. 5, pp. 619–624, Sep. 2015, doi: https://doi.org/10.1016/j.amjoto.2015.02.012.

Content:

Purpose:

- generate and describe the process of creating a 3D printed, rapid prototype temporal bone model from clinical quality CT images
- mastoidectomy: procedure used for cochlear implantation and otologic diseases

Materials/Methods:

- technique to create accurate, alterable, reproducible rapid prototype temporal bone model
- used freely available software to segment clinical CT data and generate three diff 3D models composed of ABS plastic
- models evaluated based on the appearance and size of anatomical structures and response to surgical drilling

Results:

- qualitative feel of ABS plastic was softer than bone
- pate produced by drilling was similar to bone dust when appropriate irrigation was used

Materials and Methods, in more detail:

- imaging data from CT scans performed for clinical pruposes were used for this study
- resolutions of scans: 0.227 mm x 0.227 mm x 0.5 mm or BETTER
- freely available software: ITK-SNAP
    - used to convert CT data into a 3D model
    - program has automated segmentation feature, CT scans were selectively segmented using intensity thresholds to isolate bone
    - selecting a starting voxel in a region corresponding to temporal bone and setting the intensity parameters with a lower and upper threshold
    - each threshold was made specific to the CT scan because bone density varied from patient to patient
    - reviewed automatic segmentations and an initial manual segmentation was performed to minimize artifacts and include any desired areas of bone not included by the automated segmentation
- post-processing of model consisted of 3D surface mesh formation and further manual segmentation
- surface mesh feature
    - automated segmented initial versions converted into a 3D surface mesh and smoothed using Gaussian filter with standard deviation of 0.8 mm and max approximation error of 0.03 mm (optical balance to produce a smooth surface)
- manual segmentation for: ossicles, mastoid air cells, drain hole insertion
    - most time consuming part of making prototype
- final virtual models were converted to STL files and printed by the Dimensions SST 1200es Printer
    - printer used Fused Deposition Modeling Technology
    - lays down consecutive layers of ABS thermoplastic with a layer thickness 0.254 mm
- for free hanging structures, the printer deposited a removabel support material made of resign to act as scaffolding

- once rapid prototype model was complete, it was placed in a heated detergent wash for 9-12 hours to remove the dissolvable resin scaffolding

Conclusions/action items:

Learning that there is a free software used to convert CT scans into 3D models is a very good step. I will have to look into this software (ITK-SNAP) and if it is actually accessible and free. I also have noticed that ABS plastic seems like a common material to make model bones out of and seems to be decently accurate. A limitation of this article is that it is about temporal bones for the ear instead of bones like the humerus or other long bones. I would like to learn more about this software as well as hopefully find more research about humerus bone models.

11/7/2024: Replacable Piece Testing Protocol DRAFT

HELENE SCHROEDER - Nov 07, 2024, 1:10 PM CST

Title: Replacable Piece Testing Protocol DRAFT

Date: 11/7/2024

Content by: Helene Schroeder

Present: N/A

Goals: To draft a protocol for how testing the replacable component will work.

Content:

Who will test it? Veterinarian clinicians (who can also refer other clinicians to test the model as well!)

What is needed to test?

- BMA model (including replacable component with styrofoam behind the piece, muscles, skin)
- Scalpel (to make incision in skin, but not muscle (how do we prevent incision in muscle like how procedure is actually done))
- Illinois needle (maybe with syringe, but probably not since no liquid bone marrow will be in the model yet)

Procedure:

1. For replicating real procedure, wear gloves and sterilize area, then make an incision into the skin with the scalpel
2. Feel around model for correct area to puncture with needle.
3. Use Illinois needle to puncture the "bone"
4. Assess qualitative feeling of the procedure.

Alternative procedure:

1. Only have the replacable component (at least 5 of them) and lay them on top of a piece of styrofoam.
2. Layer the muscle material over the piece (do not necessarily need skin, just don't practice incision).
3. Puncture replacable component with Illinois needle.
4. Assess.

How we will assess the model:

	Accurate Feeling?	Scale 1 (bad)-10 (great), accurate feeling	Notes
Trial 1	Yes/No	10	make notes on stuff like thickness, texture of bone and muscle, etc.
Trial 2			
Trial 3			
Trial ...			

Conclusions/action items:

This is only a draft of what the testing protocol could be like, but this is a good start to thinking about how we test. I would like to maybe alter the table I have created to ask different, more specific questions to the clinicians who are testing the model. The main point is that we need a way to quanittatively test the model, which I think would be easiest to do using "yes" or "no" statements, rather than ranking 1-10. Then we can determine if the results are statistically relevant easier.

The next step of this protocol is to go over it with the team and alter it based on their feedback. Once the model is ready to be tested, we will proceed with having clinicians test it. I also think the "alternative" method of testing would be easier and simpler to do at this stage in the project, but it would be less accurate/meaningful since it is not the full model, therefore not the full replication of the procedure.

9/11/2024: Lecture 1, BME Career Prep

HELENE SCHROEDER - Sep 11, 2024, 1:56 PM CDT

Title: BME Career Prep Lecture

Date: 9/11/2024

Content by: Helene Schroeder

Present: N/A

Goals: Learn information about the career fair and job searching to prepare for the career fair and applying to jobs.

Content:

Lecturer: Stephanie Salazar Kann

Job Search Tips:

- keeping track, ECS tracking sheet, ecs.wisc.edu/resources
- quality of source (handshake, linkedin)
- connect BEFORE you are a candidate (networking)
- applying is 1 step, follow-up is required (2-3 weeks)
- think beyond the title, focus on skills/industry/exposure
- it takes time
- don't let perfect be the enemy of good

Resume Tips:

- tailor your resume to the position (quick changes)
- create balance, show a full picture of your experience
- "flawless" product - ATS proofed resume is do-able
    - MS Word
    - no columns, charts, colors
    - design projects WITHOUT years or semesters, what did you do?
    - technical skills and coursework
    - jobs-organization + location, position title + dates
    - no link on resume!!

Career Fair Advice for BME:

- identify your purpose, more than just an internship
- overlap with other disciplines
- research the employer, feedback from our partners, come prepared for specific companies and roles!!
- develop your "value added" statement, why you?

Posting "Logic" in Handshake:

- read about companies, do not focus on job titles/industries listed in handshake, etc.

Career Fair

- Sept 16-Sept 19
- 11 AM-5PM
- EH, ME, ECB
- diff employers on each day
- BME, ME, EE, MS&E (for columns to look at on flyers)

Conclusions/action items:

This lecture has given me a lot of insight about what employers are looking for in terms of my resume and what I should do before the career fair. I realize I need to do a good amount of research about each company before I meet with them at the career fair. I also need to follow up with someone from the company who was at the career fair about my application. I also need to look more broadly for jobs, not only looking for labels like "Biomedical Engineer". I can apply to some jobs that would normally be listed as MS&E, ME, or EE.

9/18/2024: Lecture 2, Leadership

HELENE SCHROEDER - Sep 18, 2024, 2:01 PM CDT

Title: Leadership Lecture

Date: 9/18/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about different leadership styles

Content:

Lecturer: Angela Kita, Associate Director of Leadership Education

are u a leader??? depends :)

waht are important qualities of a leader?

- jerry
- confident
- communicative
- organized
- respectfuk
- smart
- aura

anatomy of a good leader

- self-awareness: understand strengths and weakness
- vision: provide direction and purpose (set goals)
- transparent
- communication
- decision making
- empathy

leadership styles

- power model
    - leadership = power
    - "someone has to take control and it should be me"
    - great man theory, trait theory: only certain people are born to lead
    - being in control is the most important thing
    - heirarchy, authority, command
- servant
    - leadership = serving each other
    - "its not about me and my needs, the needs of my followers is most important"
    - being of service to others
    - sharing power
    - listening and understanding
    - empathetic, empowering, shared decision making
- authentic
    - leadership = authenticity
    - "by being my genuine self, i will gain and build trust"
    - building self esteem and self-awareness
    - emotional intelligence
    - creating authentic relationships
    - transparency, genuineness, honesty
- people-oriented leader
    - glue that holds the team together; get to know everyone as individuals
- process-oriented leader
    - set the pace for the teaml willing to work alongside everyone

    - sees the big picture and anticipates the future
- impact-oriented leader
    - set the bar high and push for excellent performance

leadership does not require a particular job title

leading others starts with leading yourself

explore and define how you want to lead

- self assess (what do you enjoy, strengths)
- observe and reflect (what are tasks that give you a sense of accomplishment, how do you get in your own way)
- seek out feedback

goal setting

- start small
- focus on one element
- look for mentors
- ask questions, partner with others
- track your progress
- team goal:
    - communication, making sure my entire team communicates well
    - relationship building, make sure my team dynamic is friendly and not super strict and awkward
    - creativity, make sure people share their ideas
- self goal:
    - organization, i want to be organized with deadlines and work
    - responsibility, make sure i hold others and myself accountable for work
    - self-awareness, be self-aware

Conclusions/action items:

I have learned a lot about different leadership styles and have been able to do some reflecting about what kind of leader I am. I also have been able to understand what kinds of leaders I have had in the past. I think I am a people-oriented leader, and I work best with other people-oriented leaders. I love working in teams where I get to grow relationships with people because it makes working with each other so much more fun. I want to be able to be a better leader, and knowing what type of leader I am can help me be self aware.

9/25/2024: Lecture 3, Fall Post Grad Planning

HELENE SCHROEDER - Sep 25, 2024, 2:07 PM CDT

Title: BME Advising Session II: Fall Post Grad Planning

Date: 9/25/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about post graduate planning.

Content:

General pointers:

- PhD, Master's, med school, industry
- think about letter writers or references early (3 strong ones)
- prepare for MCAT or GRE (grad school, less required nowadays) summer before senior year
- do your homework: ideal career?
    - location, career development, people, disease, research, courses
    - opportunities
- research: helpful for all post-degrees and helpful for engineering

Writing your story:

- typical personal statements are done wrong
    - not narrow
    - no chronological regurgitation in statements (cover letters)
- what to do:
    - general: start with what you want to do, thesis statement
        - eg: cancer stem cells, role, etc.
        - your narrow experiences and how that applies to your broad interest
        - specific to each position or place to which you apply
    - personal statement: show a reasonable idea of what
        - you will achieve at university X
        - what you want to do afterwards
        - name the faculty there who are in your field of interest
    - defend your plan with your life experiences, most recent first
    - CV to some extent in paragraph form, BE SPECIFIC

Graduate school options:

- masters, MS
    - stepping stone/change directions/gain depth/expand credentials for future
        - med school
        - PhD programs
    - industry focused
    - generally ONE year
- doctoral, PhD
    - desire to be an indepdendent researcher
    - write research grants
    - work in academia
    - lead projects in industry, startups, and consulting
    - https://www.wisolve.org/

MS as a stepping stone

- reasons
    - rewrite your story
    - MD: need time to prep for MCAT or apply for med schools
    - PhD: cannot find a fundeding
- MS makes you more desirable

    - higher level of skills-more lab time with less class time
    - more experiences-teaching, mentoring, research thesis
    - older, more maturity
- reallly powerful if you add in industry experience
- industry:
    - expensive, but higher starting salary
    - opportunity for more co-ops or internships

BME grad program admin

- associate chairs
    - Prof. Megan McClean
    - Dr. Suarez
- grad student services
    - Janna Pollock

3 MS options withtin BME, 24 credits

- research (1.5-2 years)
    - for those continuing on for a PhD
    - can be funded as RA/TA/PA (tuition remission and stipend)
    - thesis required (MUST have a lab PI identified and willing to support before applying)
- accelerated program (1 year)
    - coursework only
    - independent study/research is allowed
    - funding (TA only) stipend only (no tuition remission $1200/credit)
- biomedical innovation, design, and entrepreneurship (1 year)
    - project based-project required (BME design project continuity)
    - partnership w business school
    - funding (TA only) stipend only (no tuition remission $1200/credit)

Applying for BME Accelerated MS Programs

- apply next fall
- apply online, pay fee, submit-fall and spring start available
    - statement of purpose: why you want to pursue further education in BME
    - research MS onlyL list PI who plans to support you
- 12/15 deadline (some flexibility)
- application is reviewed separately, and we will give special consideration to BME undergrad students
- need 3.0 overall, 3.0 in last 60 credits

Masters elsewhere

- MEng (no future for phd)
- MS in global health
- MS in other engineering dept (generally takes longer)
- MBA (generally industry pays for credits or evening options)
- MS -> PhD option

PhD advice

- "overqualified"
- do ur homework
    - network, who is working in that area>
    - conferences
    - utilize lab PI at madison = collaborators
- build your resume/CV
    - REU-research experience for undergraduates, summer
    - reserach is a must, honors in research
- external funding NSL-GRFP
    - due oct 15 (senior year)
    - definitely do it if you want to get PhD
    - you can apply 2 times

PhD application process

- apply early and list names, most do rolling review

- generally 3.5 of higher GPA, 75% quantitative GRE
- review process
    - faculty individually review applications that align with their research
    - highly sought after candidates are invited for "visit weekends"
        - NSP GRFP awardees are very highly sought after
        - visits are in spring sem (feb-march)
        - tour the dept, meet faculty, meet other prospective students
        - looking for the best fit, both ways

Med school advice

- premed advising-check requirements early
- special requirements for most med schools
    - 2 sems of gen chem
    - chem 344 and 345
    - 2 sem of physics, EMA 201/303, BME 315
    - 2 sem of english (use liberal studies)
    - I/A & S/H & Comm B (use liberal studies)
    - psych 202 and soc (liberal studies soc 134)
    - biochem 501 (science elective)
- all can be satisfied within BMEs 128 credits, plan ahead
- http://www.prehealth.wisc.edu/

Beyond the classroom

- research is required
- volunteer (clinical setting)
- shadow physicians
- patient contact time
- build relationships, letter writers
- use design experiences (clients)
- requirements vary by degree (dental, PT, PA, etc.)

BALANCE

Conclusions/action items:

This lecture has been really helpful for me. I am sort of undecided on what I want to do post graduation, but this has helped give me a lot of resources and information that can help me on whichever path I choose. I didn't know much about med school and its requirements, but I don't want to close off any doors so learning about it is really helpful. I may want to get my masters degree, so all of this information about the programs we have here is very useful to me.

10/2/2024: Lecture 4, Near Peer Mentoring

HELENE SCHROEDER - Oct 02, 2024, 2:04 PM CDT

Title: Near Peer Mentoring

Date: 10/2/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about ways to become a better peer mentor.

Content:

Why mentor 200 students?

- get students more used to the BME design process
- helping others help you learn more (mutual benefits, transferrable skills)
- share experiences, give advice (co-op, internship, research)
- additional instructional/emotional support
- peer mentors are more approachable
- increases belonging

Transferrable skills:

- leadership
- communication
- active listening
- study practices
- self awareness
- interpersonal skills (teamwork)

General benefits of mentoring

- increased self-esteem/confidence
- increased patience
- build positive habits
- foster personal growth
- identify gaps in your own knowledge
- sense of accomplishment

What does it mean to be a good mentor

- proactive
- building trust
- psychological safety
- reliability
- support/enthusiasim
- being available
- transparent (open and honest)
- humanizing their challenges (be a coach)
- good listening

listening effectively

- get rid of distractions
- stop talking
- act like you're interested
- get the main idea
- ask questions
- check for understanding
- react to ideas, not to the person
- avoid hasty judgements

What do you wish you knew in BME 200?

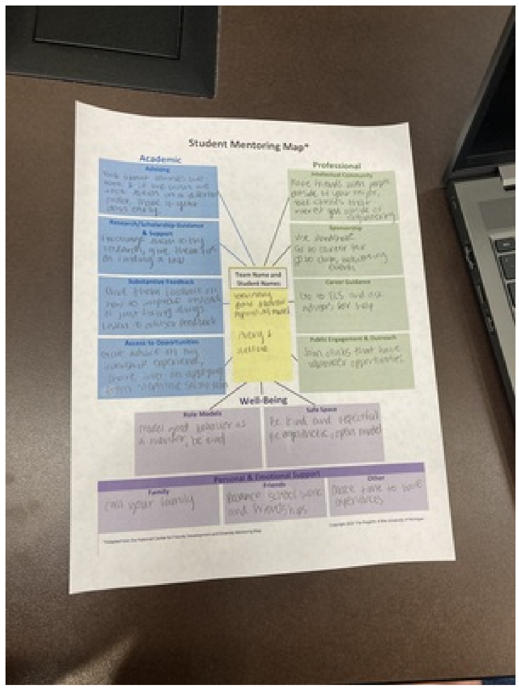
- getting information earlier (post grad plans, internship/co-op tips, etc.)
    - in bme 200 not 201 or 300
- ask for help more often
- failures are a learning opoortunity
- building group dynamic is important

Work on Mentor Map (see image in entry)

Conclusions/action items:

This lecture has provided a lot of insight about why we are peer mentors as well as how to be a better one. I have enjoyed hearing other people's opinions and ideas. I also have been able to reflect about why we are mentors and what its benefits are for not only the mentees, but also for us as mentors.

HELENE SCHROEDER - Oct 02, 2024, 2:00 PM CDT



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10/9/2024: Lecture 5, Sustainable Engineering

HELENE SCHROEDER - Oct 09, 2024, 2:02 PM CDT

Title: Sustainable Engineering

Date: 10/9/2024

Content by: Helene Schroeder

Goals: To learn about sustainable engineering.

Content:

Lecturer: Andrea Hicks

Why care?

- health care sector is responsible for 5% of global emissions and 8.5% of emissions at the national level in the US
- in 2018, greenhouse gases and toxic air emissions associated with health care sector led to an estimated loss of 388,000 disability-adjusted life-years
    - loss of life/loss of quality of life
- transforming the med device industry: road map to a circular economy
    - circular economy: keeping things out of the landfill
    - try to recover materials, don't throw in landfill
- lifecycle assessment
    - utrification
    - 1969, cocacola was first brand to do lifecycle assessment
- reusable BP cuffs in clinical setting
    - reusable: needs to be cleaned (takes resources)
    - disposable: doesn't need to be cleaned, goes straight to incinterator/landfill

Sustainability in your project:

- We are making a design with a replaceable component
- We have to make sure that the replaceable ocmponent is sustainable so as to not create a ton of landfill waste
- We are doing this by making the part out of PLA which is easily recyclable and biodegradable
- The replaceable part will be small to minimize material waste

Conclusions/action items:

Our project is aiming to be sustainable by making the replaceable piece small and easily recyclable/biodegradable. I have also learned that the healthcare field is the source of a lot of waste and greenhouse gases, which is surprising, but also not surprising. I have found it very interesting to learn about a lot of terms relating to environmental engineering and what impacts there are with our engineering projects. This lecture has showed me to be a lot more concious of what materials we use and how we use them/dispose of them.

10/16/2024: Lecture 6, Patents

HELENE SCHROEDER - Oct 16, 2024, 2:08 PM CDT

Title: Patents & Licensing w WARF

Date: 10/16/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about patents and licensing through WARF.

Content:

Who WARF is

- enable uw madison research to solve the world's problems
- support scientific research within UW madison community by providing financial support, manage assets, moving innovations to the marketplace for a financial return and global impact
- nonprofit

Technology Transfer

- moving research results from campus out into the market
- WARF works at this interface to facilitate securing IP rights and commercial licenses
- examples:
    - IP licenses
    - industry sponsored research
    - consulting arrangements
    - fee for service

IP overview

- four common types
    - patents
    - copyrights
    - trademarks
    - trade secrets
- other, WARF IP
    - biomaterials
    - technique and know how (akin in some ways to Trade Secrets)
    - data

Overview of Non-Patent IP

- copyrights
    - protection for creative works that are expressed in a tangible medium
    - a wide range of subject matter, including software code
    - protection for a LONG time
- trademarks
    - protection for names, marks, logos, dress, etc.
    - requires use in commerce
    - source-identifying function
- trade secrets
    - can be used to protect anything of value
    - protection is good so long as the concept is not generally known

Patents, generally

- a patent is a property right, granted by a governmental agency
    - US patents and trademark office (USPTO)
    - no global patent!
    - patent holder has right to exclude others from making, using, selling, or importing the claimed invention
- there are 3 types of US patents

- design (15 year term, limited to ornamental feature)
- plant (new variety, 20 year term, asexually reproducing, non-tuber)
- utility
    - provisional (effectively a 1-year placeholder)
    - non-provisional (20 year term, can claim priority to a provisional)

Utility (non provisional) patents

- issued for the invention of a new and useful process, machine, manufacture, or composition of matter
    - also includes new and useful improvements thereof
- a quid pro quo with the USPTO and the public
    - applicant gets a time limited monopoly on your invention
- often takes 2-5 years
- costs $30k on avg, mostly attorneys' fees
- 90% of patents issued by USPTO are non-provisional utility patents

Requirements for patenting

- 101- **eligible** - cannot be a product of nature, abstract idea, or natural phenomenon
- 102 - **novel** - must be new
- 103- **non-obvious** - it cannot be simple modification or combination of exisiting concepts
- 112 - **enabled and described** - must provide enough detail to teach others how to make or use the invention
- patent examiners are scientists hired and trained by the USPTO to review patent applications for these requirements

Disclosing an innvoation to WARF

- WARF received ~400 new innovation disclousures each year
- disclosing:
    - describe innovation
    - identify its advantages and potential applications
    - name contributors (inventors/authors)
    - provide funding and public disclosure details
- meeting with WARF
    - discuss the innovation in more detail
    - ask questions about WARF and patening processes
    - discuss next steps

Assessing university inventions

- WARF bases its decision on accepting an innovation into portfolio based on:
    - IP considerations
        - type of IP protection
        - potential breadth and strength
        - public disclosure
        - stage of development
    - licensing considerations
        - applications
        - likelihood of identifying a commercial partner
        - likely return from licensing

Marketing and licensing

- Licensing the IP is the next step in transferring the tech
- market analysis
    - market status
    - size and type
    - potential licensees
- license negotiation
    - types and terms
    - consideration
- ongoing
    - technology dev, enforcement, amendment, termination

Value of licensing

- benefits to the company
    - reduced R&D costs

  - improved time to market
  - opportunity to enter new markets and expand your company quickly
  - new features or products provide additional revenue opportunities
- determining value
  - tech application
  - key selling points/features/benefits
  - technology trends
  - market size, trend, competition
  - industry standards/historical deals

AI and IP

- patents
  - can AI invent? no
  - limited to US only? no, south africa is the exception
  - can AI assist in inventing
    - evolving, but likely yes under pannu factors
- copyright
  - original works of human authorship
  - AI must be incidental to conception and creation
  - original conception by human master mind, are prompts sufficient? no
  - combinations of derivative works requires more than de mimimis contribution from human
  - traditional elements of authorship generated by AI? no

Conclusions/action items:

With this lecture, I have learned a lot about patents and IPs that I hadn't known before. I have not ever worked on a project that has had to consider IP much, so I am very uneducated in the topic. This article has been helpful to learn the basics and how to go about contacting WARF when the day I need to comes. I also thought it was interesting to learn about the timelines of different types of patents and their purposes.

10/23/2024: Lecture 7, IRB

HELENE SCHROEDER - Oct 23, 2024, 2:04 PM CDT

Title: Do I need an IRB?

Date: 10/23/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about the basics of human participants research requirements, what they mean, and how to learn more about them.

Content:

IRB: institutional review board

- committee that conducts ethical and regulatory review of research involving human participants

origin and mission

- response to unethical reseaerch -_> ethical principles --> human research regulation
- infamous studies
    - WWII Nazi prisoner experiments --> 1947 Nuremberg Code
    - 1956-19971: hep studies at willowbrook state school for children
    - 1960s: milgram shock experiments at yale
    - 1932-1972: Tuskegee Syphilis Study --> 1974 National Research Act
- belmont principles: respect for prisoners, beneficence, justice
- regulations for protection of human "subjects"
    - dept of health and human services (DHHS) aka "common rule"
    - FDA

institutional review boards

- instituted by common rule and FDA regulations
- review research studies to ensure they meet regulatory and ethical standards, follow policies, and protect reserach participants rights and welfare
- include scientists, non-scientists, and members not affiliated with the project

UW MadisoN IRB

- minimal risk resrach IRB (MRR IRB)
    - biomedical, education, social/behavioral sciences reserach
    - secondary analysis of data, survey research, behavioral helath interventions, evaluations of educational practice
- health sciencies IRB (HS IRB)
    - biomedicla, interventional, any risk level
- serve UW madison, UW health affiliates, madison VA hospital

Does my project need IRB review

- is it reseearch under the common rule?
    - research means a systematic investigation, including research development, testing, and evaluation, designed to develop or contribute to generalizable knowledge
- human subject means a living individual about whim an investigator conducting reserach:
    - obtains info or biospecimens through intervention or interaction, and uses, studies, or analyzes the information or biospecifmens
    - obtains, uses, studies, analyzes, or generates indentifiable private info or indentifiable biospecimens
- is it human research under FDA device regulations?
    - device=intended for use in diagnosis, treatment, or prevention of disease, or that affects structure or function of the body
    - reserach/clinical investigation=involves one or more subjects to determine device safety or effectiveness
    - subject=individual on whom or on whose specimen an investigational device is used or as a control in an investigation

hypothetical project

- developming biodegradable adhesive bandage

- identified materials, tested them in lab, and refining prototype
- want to find out how well the bandage performs on human skin
- will this involve human research, need IRB?
  - yeah

preparing for IRB review

- researcher requirements
  - complete traiing from CITI
    - human subjects protection training
    - conflict of interest training
    - good clinical practice training (if clinical training or FDA regulated)
    - hipaa privacy and resrach training
  - complete annual outside activities report
- develop research plan
  - identify appropriate PI and study team
  - collect preliminary (non-human) data and info
  - develop a research question and steps to answer it
  - if evaluationg device effectiveness and/or safety, consult UW's FDA regulated research oversight program
  - consider resarch participants
    - who will you need, why
    - how many, where will you find them
    - what do they need to do
    - minimize harms and budgets
    - what will they need to know to make an informed choice to participate
- what irb application?
  - electronic submission system, ARROW
  - basic types: protocol base dand non-protocol based
    - PBA: research involving investigational devices, all FDA regulated studied
    - nPBA: studies with limited interventions/observations, exempt research
  - studies limited to surveys, benign behavioral interventions, etc.
- PBA components
  - protocol document
    - study aims, rationale, procedures, etc.
    - details eiligbility, recuritement, informed consent, protections
    - if evaluating device, use ICTR drug/device template
  - informed consent forms
  - recruitment tools, screening scripts
  - written assessments
- resources: IRB WEBSITE!!

IRB review process

- UROC review
- SRC/PRMC review
- pre-review by IRB staff
- review at IRB meeting
- committee determination: approved, modifications requested, deferred

Conclusions/action items:

This lecture has been helpful to learn more about what the IRB is, when it is needed, and how I can learn more about it if my project needs it. I previously had limited knowledge on IRBS from a previous lecture, but this lecture has been able to tell me more about what it is. I also know more about when they are needed and how it can actually be more complicated than you may think. If in the future I do a project that involves human research, I will be prepared on how to go about reaching out. I think it would be interesting to learn more about animal testing in the future.

10/30/2024: Lecture 8, Navigating FDA Device Requirements

HELENE SCHROEDER - Oct 30, 2024, 2:04 PM CDT

Title: Navigating FDA Device Requirements

Date: 10/30/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn abotu FDA requirements for devices.

Content:

Lecturer: Jake Rome

Objectives:

- define a medical device and how FDA regulates devices
- understand different categories of med devices
- apply FDA regulations to research with med devices

Defining a Med Device

- anything intended to improve health or structure of the body, but not through chemicals or biologicals (drugs)
- intended to be broad
- traditional med devices:
  - MRI, drug infusers, monitoring systems, bandage, syringe, etc.
- non-traditional devices:
  - lab tests (LDTs), software, mouthwash
- Software as Med Device (SaMD)
  - software intended for one or more medical uses that may run on diff operating systems or in virtual environments
  - SaMD (standalone) when not part of the intendended use of the hardware med device
  - not SaMD (in diff device) if it drives or controls the hardware medical device
- Traditional vs. non-traditional

Applicable FDA Regulations, 21 CFR

- some apply for entire lifetime of device (labeling, quality systems regulations)
- some apply for only certain amounts of times (protection of human subjects, IRBs, IDE) - research
- some apply for marketing (medical device reporting, premarket approval of med devices and the humanitarian use device)

Device Classification Overview

- classes of marketed medical devices
  - class I: low risk, exempt from premarket approval (band-aids, floss, tongue depressor)
  - II: moderate risk, 501(k) showing substantial equivalence (BP cuffs, sutures, catheters)
  - III: high risk, premarket approval (pacemakers, vascular stents)
- regulatory controls key elements
  - general controls
    - registration and listing
    - adverse event reporting
    - general labeling
    - good manufacturing practice
  - special controls
    - performance standards
    - special labeling requirements
    - post-market surveillance
    - potential data requirements
  - premarket approval
    - data to show safety and effectiveness
- Class I Devices
  - low risk (minimal potential for harm)
  - regulatory requirements

        - mostly exempt from premarket notification and Quality System (QS) requirements
        - must follow certain general controls: labeling, record retention, and compliant files
    - approval process:
        - self-registration and listing with the FDA
- Class II:
    - moderate risk
    - regulatory requirements
        - must follow general and special controls, which can include performance standards, post-market surveillance, and specific labeling requirements
    - approval process
        - submission of a 510(k) application to show substantial equivalence; may be exempt
- Class III:
    - high risk (sustain/support life, implanted, or potential for unreasonable risk)
    - regulatory requirements
        - must follow general controls and additional stringent requirements, such as clinical trials to demonstrate safety and efficacy
    - approval process
        - PMA submission, which involves a comprehensive FDA review of safety and effectiveness data before marketing
- Market submission types
    - 510(k) exempt
    - 510(k)-premarket notification
    - PMA-premarket approval
    - De Novo Classification
        - novel medical devices, no legally marketed predicate

How to Classify a Med Device

- databases to search for like items (FDA website)
- do a lot of searches
- product code (device definiton and classification, submission type, GMP requirements, recognized consensus standards)
- regulation number
- key points for classification
    - depends on the intended use and indications for use
    - intended use: general purpsose of the deivce or its function
    - indications for use: specify the specific conditions, populations, or sitations where device is inteded to be used
    - where indications for use may affect safety or effectiveness, then may be new intended use

Conclusions/action items:

From this lecture I have learned a lot about the different classes of medical devices, as well as what a medical device is. I have learned that the classifications of medical devices are typically left very vague intentionally. I also learned that at the same time, a lot of things have very specific definitons that you need to take into consideration when making a device. I have learned a little bit about this topic in the past, but I enjoyed learning more, specifically about the marketing side of the FDA medical devices. I also learned that the FDA website has a lot of resources about how to classify devices.

11/6/2024: Lecture 9, Regulatory Strategy

HELENE SCHROEDER - Nov 06, 2024, 2:06 PM CST

Title: Regulatory Strategy

Date: 11/6/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about the framework guiding advanced therapeutic product development.

Content:

Lecturer: Bill Murphy

FDA Structure and Advanced Therapeutics

- device (CDRH-center for devices radiological health)
  - PMA-premarket approval
  - 510(k)
  - IDE-investigational device exemption
- drug (CDER-center for drug evaluation)
  - NDA
  - IND
- biologic (CBER-biologic evaluation and research)
  - BLA-biologics license agreement
  - IND-investigational new drug
- genome editing
  - target a precise genome locus and delete, insert, or change existing sequences
- gene delivery
  - transfer molecular tools and assembled gene systems into the cell
- cell therapy
  - use expanded cells to transfer medicinal bio-activity to regenerate damaged tissue or restore health
- drug vs. biologic
  - drug: synthetic, produced in chemical reaction
  - biologic: living thing or produced by living thing

FDA Framework: Developing CGT Products for Hemophilia

- FD&C act
- PHS act
- CURES act (2016)
- CARES act (2020)

Dramatic Implications: 351 vs. 361

- human cells, tissues and cellular and tissue-based products (HCT/Ps)
- markedly different in terms of time, effort, and expense required to bring a product
- basically, 351 products are regulated as drugs and/or biologics, while 361 proucts are largely unregulated (compareatively)

Product Development Life Cycle

- extremely important to be able to distinguish between studies that are "on the critical path" vs. "good research projects"
  - academic researh are typically good research projects
  - in industry, easy to be "on the critical path", easily does not count for things for FDA to approve

A Target Product Profile (TPP) is your Product Vision

- when to use it? why to use it? how to use it?
- patient identification: indication
- patient benefits: efficacy profile
- patient risks: safety profile
- is it medically or commercially compelling?

Considerations when Developing a 351-Regulated CGT

- nonclinical
- quality
- clinical
- regulatory

Quality Management System Implementation

- a system that documents policies, processes, internal rules, procedures, and other records to ensure

Career Options within a Regulated Environment:

- characterizationa dn analytics:
  - cell characterization
  - potency assay development
  - in-process controls
  - data mining and informatics
- manufacturing development
- process development
  - design space
  - CPPs for CQAs
  - scale-up/automation
  - closed processing
  - in-process controls
  - process economics
  - device design
- gene delivery
  - vector design/optimization
  - large scale production

Conclusions/action items:

This lecture has given me a lot of information about the regulatory strategy that I had never heard before. I did realize how much goes into new product development in addition to the extreme amount of work I know already goes into product development. There are a lot of considerations to take into account when creating a new product that regard safety, who can use the product, what does it actually do, etc. I have also realized that everything needs to be extremely specific when defining these parameters. The quality of the research that goes into new product development or therapeutics is extremely important, and much more important than in projects you may do in school. There are also a lot of career paths that you can take that may not seem intuitive, and they are definetly things to consider when applying for internships and jobs.

11/13/2024: Lecture 10, Med Device Innovation from Prototype to Commercial Clinical Use

HELENE SCHROEDER - Nov 13, 2024, 2:02 PM CST

Title: Medical Device Innovation from Prototype to Commerical Clinical Use

Date: 11/13/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about medical device innovation from prototype to commercial use.

Content:

Lecturer: Aimee Arnoldussen, PhD

- use IRB for testing

medical device FDA pathways

- device classifications have different pathways (ex: 510(k) exempt, premarket notification 510(k), 510(k) de novo, premarket approval (PMA), humanitarian device expemption (HDE)

regulatory timelines

- takes longer than you think
- FDA can reset timeline
- significant part of commercialization process

breakthrough devices program

- formerly expedited access program
- FDA
- timely access to medical devices for life-threatening or irreversibly debilitating diseases/conditions
- program to expedite development

general steps from approval to adoption

- clinical studies
- fda approval
- CPT codes
- CMS national insurance decisions
- standards of practices
- national regional buying groups
- regional/local IDNs, hospitals
- hosptial/IDN value analytics groups
- product evalutations
- regional/just in time distribution
- product implementation

workflow: patient care pathway as a starting point

- think about who is involved
- think about pathway of patient, does the patient have any choice in something
- think about improving experiences
- lots of areas to think about

value based healthcare

- if we define value more broadly as improving patient outcomes while making it more affordable to deliver those outcomes, there is a wider range of possibilites for product developmers, providers and payers to collaborate, and signs of progress are easier to find
    - maria stewart, boston sci
- sweet spot between clinical, economic, patient incentives

trickle-down influence for new tech

- very important to consider

hospital new product adoption process

- clinical champion
- value analysis-technology assessment
- c-suite strat-final decision
- trial, evaluation and metrics

value drivers to discover

- economic
  - money
  - staff time
  - resources
  - waste
  - metrics
- clinical
  - improve outcomes
  - reduce risk
  - reduce complications
  - shorten length of stay
  - solve "issues"
- mission impact
  - patient satisfaction
  - academic leadership
  - innovation in care
- evidence more compelling than "hand-waving" benefit assumptions

who buys, pays and gets reimbursed (it depends)

- key terms to uncover payment
  - CMS centers for medicare and medicaid services
  - DRG diagnostic related groups
  - CPT current procedural code
  - ICD 10 international categorixation of diseases
  - GPO group purchasing organization
  - IDN integrated delivery networks
  - payer mix
- existence of codes does not equal financially favorable
- understand potential reimbursement path

discover through research and interviews

- start with detailed patient flow/care pathway
- explore pain points (OF COURSE) and gain creators
- expand ur knowledge of the procedure or diagnosis payment
- examine how products or therapies are adopted
- understand impact of outside orgs
- consider unqiue purchasing and distribution orgs
- include regulatory and standards groups
- find out who really pays for it.. and how

Conclusions/action items:

This article has showed me how many considerations need to be put into the making of device/product. There are a lot of resources to help with these considerations. Some of these considerations relate to testing, some relate to marketing, and a lot relate to the use of the product and how it affects the patient or the person using the product. These are things that may seem like are easy to consider, but when actually developing a product can take a lot of time and effort to consider. There are a lot of resources SPECIFICALLY in Madison/around campus that we should use and not forget about.

11/15/2024: Tong Lecture

HELENE SCHROEDER - Nov 15, 2024, 12:48 PM CST

Title: Tong Lecture

Date: 11/15/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about the speakers and how they started their company.

Content:

- Ben Casavant and Erwin Berthier
- founders of Tasso
- at home diagnostic access
- better blood draws
- starting from scratch
- QUALITY is KEY (one customer with bad experience can impact the company HEAVILY)
    - do not skimp on quality
- FDA strategy
    - very important
    - read labels, easy to over analyze what regulators say they "want" to do
    - not just medical device, also diagnostic, so more expensive and takes longer for clinical trials
- device is cute
- tasso = badger in italian
    - roll badge

Conclusions/action items:

The two speakers, Ben and Erwin, both had really interesting stories that were very individual but also mesh well together. Their story was also very inspring since they started with nothing/very little and made it into a really good product. I also liked how the mentioned how getting FDA clearance is very important.

11/20/2024: Lecture 11, New Product Dev in Med Device Industry

HELENE SCHROEDER - Nov 20, 2024, 2:08 PM CST

Title: How New Product Development Works in the Medical Device Industry

Date: 11/20/2024

Content by: Helene Schroeder

Present: N/A

Goals: To learn about how new product development works specifically in the med device industry.

Content:

Speaker: Russ Johnson, PhD

introduction

- NPD in the medical device industry is:
    - highly regulated: FDA and other regulatory bodies have significant impact
    - expensive: requirement for verification and validation is a cost multiplier
    - resource intense: involves sizeable teams to execute projects
    - competitive: speed to market is vital

selecting and prioritizing projects

- trickle down to next leadership
- corporate strategy --> product portfolio review --> project review --> budgeting and resource allocation

types of NPD projects

- line extensions
- product improvements
- new-to-company
- new-to-world
- increase in risk, cost, time to market with descending list

managing NPD: stage-gate process

- stage 0: ideation
- stage 1: exploration
- stage 2: concept dev
- stage 3: design development
- stage 4: design confirmation
- stage 5: design transfer and commercialization
- the cloud
- the funnel
- the tunnel
- post-market surveillance

case study: fluid management solutions for high vol (>8 L) cases exisitng in 2007

- manual: suction canister
- automaed: stryker neptune
- ORwell fluid management system
    - goal: make it easier to use, make it cleaner
- stage 0:
    - choose area of opportunity
    - review market trends and/or competitve threats
    - conduct primary and secondary market research
    - identify customer unmet needs
    - create high-level "back of the napkin" ideas
- stage 1: exploration
    - define problem to be solved and customer requirements

  - review, refine, and screen list of ideas from stage 0 for exploration
  - create concepts for 8-10 ideas
  - develop high-level business case (market size, value proposition, etc.)
  - conduct prelim technical scouting and IP landscaping
- define the problem: most important step in design process
- stage 2: concept definition
  - based on customer interviews and use-case assessments, down-select from 8-10 to 2-3 with 1 leading concept
  - develop robust business ase including market opportunity, initial forecast, and projected expenses
  - conduct comprehensive IP examination
  - next gate review is "go/no-go" business decision
  - always something to sell in this stage
- stage 3: design development
  - move to functional prototype
  - continue iterative design process including initial testing and reviews with customers
  - confirm regulatory pathway
  - begin formal DESIGN CONTROL documentation
- stage 4: design confirmation
  - conduct extensive verification and validation testing
  - finalize product and component drawings/modules
  - accelerate manufacturing process development along with plans for quality control
  - "freeze" design at the end of this stage
  - submit regulatory documentation (510(k))
- stage 5: design transfer and commercialization
  - complete remaining testing
  - make final design changes
  - build molds, assembly/test equipment
  - create instructions for use (IFU) and user manuals
  - develop service plan and resources
  - finalize go-to-market strategy and start limited release (if applicable)
- post market surveillance
  - regulatory agencies expect that companies are monitoring and documenting customer complaints and field issues post launch
  - companies continuously track customer and salesforce feedback via interviews and surveys
  - once 4-6 months pass, project teams report out to stakeholders
    - account sales
    - business and regulatroy issues observed
    - complaints
    - priduct and process improvement opportunities

design control

- mandatory for FDA class 2 and 3 and almost all EMA devices
- includes DOCUMENTATION of customer needs, design requirements, design inputs/outputs, testing, and design reviews
- tighly aligned with Risk Management
- need to meet all needs especially if product to be sold overseas

summary

- med device dev is expensive, complex, and highly-collaborative
- having limited resourcese, most businesses have instituted processes like Stage-Gate to reduce risk and increase probability of success
- good product design and development is necessary for commercial success but not sufficinet

Conclusions/action items:

This lecture has been one of my favorites of the semester. I felt like the lecturer was very interesting and the topic he presented was something I am very interested in. While I have also liked learning more in depth about the FDA regulations for a product, I think it was helpful to take a step back and learn more about how a product is developed from its VERY BEGINNING. I think that this topic is very applicable to us as students, and thus very important.

9/11/24 Bone Marrow Aspiration in Dogs and Cats

ELLIE KOTHBAUER - Sep 12, 2024, 3:57 PM CDT

Title: Bone Marrow Aspiration in Dogs and Cats

Date: 9/11/24

Content by: Ellie Kothbauer

Present: N/A

Goals: to understand Bone Marrow Aspiration

Content:

I. Procedure Summary & Goal

a. The collection and analysis of material from a patient's bone marrow provides a great deal of diagnostic and prognostic information.

- Diagnosing cause of cytopenia unresponsive to therapy, bicytopenia, pancytopenia, or markedly high blood cell counts.
- Visually detect histoplasma, leishmania, cytauxzoon, etc.
- Detect occult neoplasia iv. Fever of unknown origin
- Evaluate iron stores

In Veterinary Medicine, bone marrow aspirates are done more frequently then core biopsies.

Aspirates are easier, faster, and less expensive to preform than are core biopsies

Bone Marrow core Biopsies require special needles that cut a solid core of material, which is then plced in a fixative, decalcified, embedded, sectioned, stained, and examined microscopically by a pathologist.

Core biopsy sections provide a more accurate way of evaluating marrow cellularity and examining for metastatic neoplasia than do aspirate smears, but cell morphology is more difficult to assess.

Conclusions/action items:

In conclusion getting bone marrow aspirates are very important to veterinary medicine, and are a procedure that must be practiced and perfected before being used. So making a good model is very important to the students learning before they practice on real animals.

9/12/24 Bone Marrow Collection and Examination

ELLIE KOTHBAUER - Sep 12, 2024, 3:45 PM CDT

Title: Bone Marrow Collection and Examination

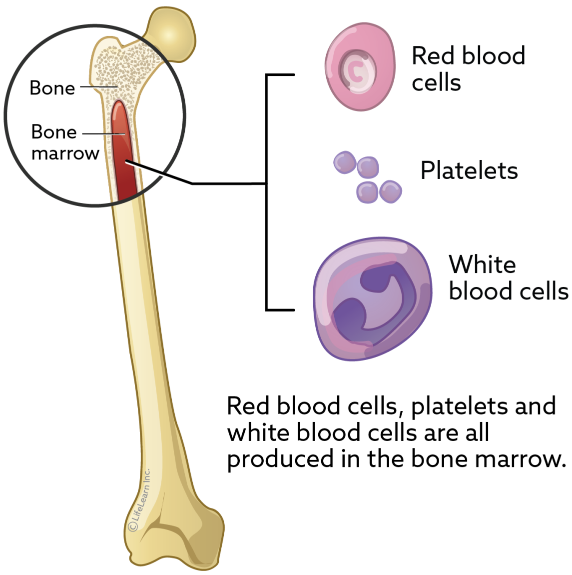
Date: 9/12/24

Content by: Ellie Kothbauer

Present: N/A

Goals: to understand the Anatomy of Bone Marrow Aspirate and how the Examination works

Content:



Bone marrow is the soft material found in the central core of many bones. Bone marrow is vitally important to producing blood cells, specifically red blood cells, white blood cells, and platelets.

- The main site for cats and dogs include: The hip bone, the top of the thigh bone, the forearm below the shoulder

Steps of Bone Marrow collection are as follows

1. The skin is shaved, cleaned, and disinfected.
2. A sterile scalpel blade is used to make a small opening in the skin.
3. A special bone marrow needle is passed through this opening, pushed firmly through the hard outer layer of the bone, and into the marrow.
4. A syringe is attached to the needle and a small amount of liquid marrow is sucked up into the syringe. This collected liquid is called a bone marrow aspirate.
5. The collected material is spread in a thin layer on a glass slide and allowed to dry completely.
6. The sample is stained with special dyes and studied under a microscope.

By knowing and understanding the steps of Bone Marrow Aspiration we can get a better understanding of the replica that we are trying to make.

9/19/24 Preparing for a Bone Marrow Aspirate

ELLIE KOTHBAUER - Nov 15, 2024, 3:24 PM CST

Title: Preparing a bone marrow aspirate

Date: 9/19/24

Content by: Ellie Kothbauer

Present: N/A

Goals: To understand how Vets Prepare the Bone Marrow Aspirate

Content:

1. Pre-operative Preparation

- **Fasting**: Fast the animal for 12-18 hours.
- **Pre-medication**: Follow Sedation and Anesthesia SOP.
- **IV Catheter Placement**: Insert an IV catheter and start isotonic fluids (LRS or 0.9% NaCl) at twice the maintenance rate.
- **General Anesthesia**: Induce general anesthesia as per SOP.

2. Site Preparation

- **Palpate Landmarks**: Identify aspiration sites (dorsal iliac crest, trochanteric fossa, lateral humeral head).
- **Skin Preparation**: Sterilize the aspiration site.
- **Local Analgesia**: Inject lidocaine at the insertion site (1 ml for dogs, 0.5 ml for cats).

3. Aseptic Technique

- **Final Scrub**: Complete a final scrub and don sterile gloves.
- **Prepare Equipment**: Draw up 1-2 ml of EDTA into a syringe, prepare the aspiration needle.

4. Aspiration

- **Incision**: Make a 3-mm stab incision.
- **Needle Insertion**: Advance the needle to the periosteum, then rotate to penetrate the cortex.
- **Sample Collection**: Remove the stylet, attach the syringe, and aspirate less than 1 ml of marrow. Transfer sample into a petri dish with EDTA.

5. Biopsy

- **Biopsy Needle Advancement**: Advance the needle 1-2 cm further, loosen the sample with rotation.
- **Redirection**: Partially withdraw, change angle, and advance again.
- **Sample Preservation**: Remove needle, place biopsy in formalin.

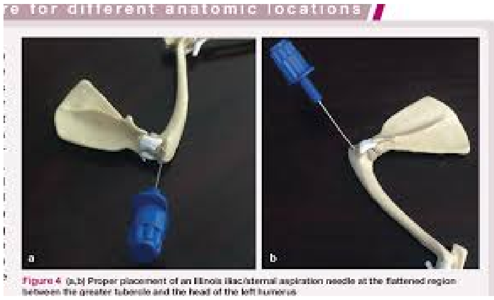
6. Post-Procedure Care

- Administer pain relief as needed (options vary for dogs and cats).

7. Adverse Effects and Mitigation

- **Potential Risks**: Infection, trauma, hemorrhage, and post-procedure pain.
- **Avoidance Measures**: Ensure sterile technique, supervise landmarks, apply direct pressure to control hemorrhage.

This structured breakdown captures the essential steps of the procedure while highlighting key precautions and actions



.

Conclusions/action items: In conclusion, bone marrow aspiration and biopsy are critical diagnostic procedures that require careful pre-operative preparation, precise site identification, and strict aseptic technique. Post-procedural care, including pain management, is essential for recovery. By following proper procedures and mitigating potential risks, complications can be minimized, ensuring the procedure's success and the animal's safety. Overall this research allowed me to understand how to take a bone marrow aspirate to help me understand how to make a good model.

https://www.research.vt.edu/content/dam/ouv_vt_edu/sops/small-animal/sop-dogs-cats-bone-marrow-aspiration-biopsy.pdf

9/28/24 Material similar to bone research

ELLIE KOTHBAUER - Nov 15, 2024, 3:44 PM CST

//Title: PLA similarities to bone

Date: 9/28/24

Content by: Ellie Kothbauer

Present: N/A

Goals: To see if PLA would work similar to bone density

Content:

Polylactic acid (PLA) is a synthetic polymer that is used to create scaffolds for bone tissue engineering because it is similar to natural bone in some ways:

- **Biocompatibility**: PLA is non-toxic, non-immunogenic, and non-inflammatory.
- **Processability**: PLA is easy to process and has design flexibility.
- **Cost-effective**: PLA is a low-cost material.

However, PLA has some drawbacks, including:

- **Low osteoconductivity**: PLA has low osteoconductivity and cellular adhesion.
- **Inflammatory reactions**: PLA can cause inflammatory reactions.
- **Mechanical properties**: PLA has inadequate mechanical properties.
- **Biomineralization**: PLA has very little mineralization in most environments.
- **Brittleness**: PLA is more brittle than ABS and can shatter into many pieces when it breaks.

To improve the performance of PLA, researchers have developed polymer composites that include bioceramics like hydroxyapatite, β-tricalcium phosphate, and akermanite. They have also added plasticizers like glycerin or triacetin to increase the flexibility of PLA.

https://pubmed.ncbi.nlm.nih.gov/37475653/

Conclusions/action items: PLA works well as it has design flexibility, low-cost, and biocompatibility but some drawbacks include inflammatory reactions, biomineralization, brittleness, ect.

10/3/24 - Three-dimensional assessment of curvature, torsion, and canal flare index of the humerus of skeletally mature nonchondrodystrophic dogs

ELLA CAIN - Oct 03, 2024, 9:37 PM CDT

Title: Three-dimensional assessment of curvature, torsion, and canal flare index of the humerus of skeletally mature nonchondrodystrophic dogs

Date: 10/3/24

Content by: Ella Cain

Present: N/A

Goals: To analyze the forelimb structure in canines.

Content: This article records and analyzes the humerus structures of different nonchondrodystrophic dog breeds with the intent of gathering information that will inform the creation of a prosthetic stem.

-Many figures and measurements are provided that are helpful to our project:

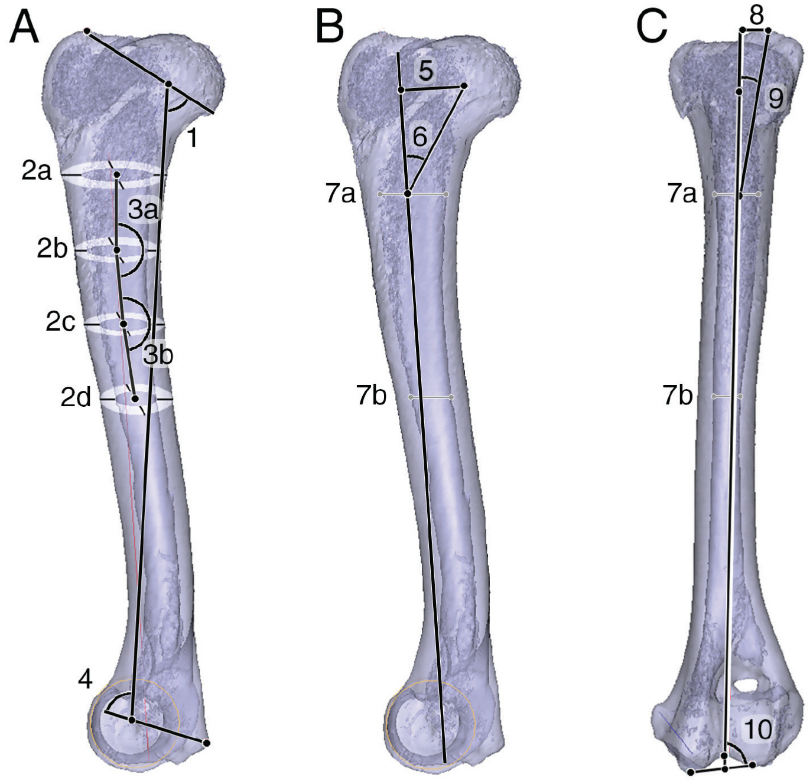


Figure 1: Canine humerus drawings depicting cortical thickness at different points of the bone.

Source: [1]

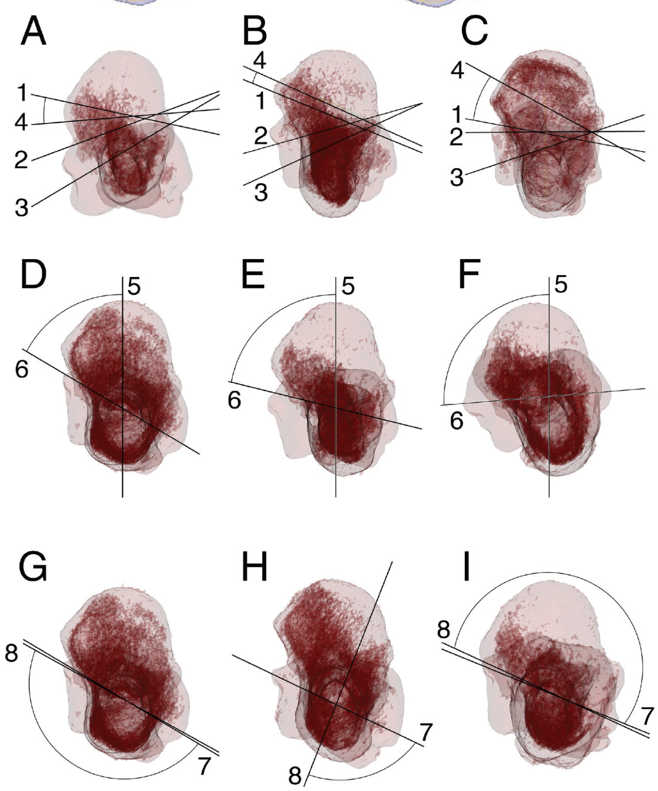


Figure 2: Drawings depicting the range of torsion of the distal aspect of the canine humerus.

Source: [1]

In addition to these diagrams, the article provides exact humeral measurements:

Table 1—
Mean ± SD values for age, body weight, and 3-D geometric humeral measurements for 40 skeletally mature nonchondrodystrophic dogs.

Variable	Low CFI (n = 13)	Medium CFI (n = 14)	High CFI (n = 13)	Overall (n = 40)	95% CI	Absolute CV (%)
Age (y)	4.5 ± 3.1	3.6 ± 2.5	3.5 ± 2.7	3.9 ± 2.7	NA	71
Body weight (kg)	40.4 ± 13.0	36.2 ± 10.4	31.2 ± 6.5	35.9 ± 10.7	NA	30
Humeral length (mm)	196.6 ± 21.5	190.6 ± 16.5	179.1 ± 15.6	188.8 ± 19.0	182.9 to 194.7	10
Torsion (°)*						
Proximal	36.6 ± 4.6	35.7 ± 5.5	31.2 ± 8.0	34.5 ± 6.5	32.5 to 36.5	19
Metaphyseal	6.4 ± 6.9	12.6 ± 6.9	6.8 ± 6.7	8.7 ± 7.3	6.4 to 11.0	84
Distal	−46.4 ± 7.4	−45.6 ± 12.4	−42.0 ± 4.3	−44.7 ± 8.8	−47.4 to −42.0	20
Overall	−3.4 ± 5.2	2.7 ± 9.2	−4.0 ± 7.2	−1.5 ± 7.9	−3.9 to 1.0	532
Craniocaudal canal width (mm)						
20% of humeral length	27.4 ± 4.9	26.2 ± 4.0	24.7 ± 5.6	26.1 ± 4.8	24.6 to 27.6	19
50% of humeral length	17.8 ± 3.3	15.1 ± 2.3	12.7 ± 2.8	15.2 ± 3.5	14.1 to 16.3	23
Craniocaudal CFI	1.54 ± 0.09	1.73 ± 0.06	1.94 ± 0.07	1.74 ± 0.18	1.68 to 1.79	10
Mediolateral canal width (mm)						
20% of humeral length	15.1 ± 2.6	14.3 ± 2.6	12.3 ± 1.8	13.9 ± 2.6	13.1 to 14.7	19
50% of humeral length	12.0 ± 2.3	10.5 ± 2.3	8.9 ± 1.9	10.5 ± 2.5	9.7 to 11.2	23
Mediolateral CFI	1.27 ± 0.12	1.37 ± 0.11	1.40 ± 0.15	1.35 ± 0.14	1.30 to 1.39	10
Humeral head						
Radius of curvature (mm)	14.4 ± 1.7	13.6 ± 1.9	13.1 ± 1.8	13.7 ± 1.8	13.12 to 14.26	13
Indexed radius of curvature ($mm/kg^{0.33}$)†	1.13 ± 0.23	1.17 ± 0.21	1.30 ± 0.24	1.20 ± 0.23	1.13 to 1.27	19
Inclination (°)	130.4 ± 5.2	127.7 ± 8.1	128.7 ± 11.1	128.9 ± 8.4	126.3 to 131.5	6
Version (°)	−76.5 ± 9.3	−77.6 ± 11.4	−73.4 ± 7.9	−75.9 ± 9.6	−78.9 to −72.9	13
Offset (mm)	20.4 ± 4.2	19.4 ± 3.1	18.4 ± 3.4	19.4 ± 3.6	18.3 to 20.5	18
Indexed offset ($mm/kg^{0.33}$)†	1.60 ± 0.39	1.69 ± 0.39	1.80 ± 0.30	1.70 ± 0.37	1.59 to 1.81	21
Greater tubercle						
Inclination (°)	170.6 ± 3.7	170.2 ± 6.0	170.3 ± 3.9	170.4 ± 4.6	169.0 to 171.8	3
Version (°)	−54.1 ± 147.0	−43.3 ± 153.2	−21.6 ± 154.7	−39.8 ± 148.4	−85.7 to 6.2	373
Offset (mm)	6.5 ± 2.8	5.9 ± 3.0	5.4 ± 2.3	5.9 ± 2.7	5.1 to 6.8	45
Indexed offset ($mm/kg^{0.33}$)†	0.49 ± 0.14	0.50 ± 0.20	0.55 ± 0.27	0.51 ± 0.20	0.45 to 0.57	40
Shaft curvature (°)						
20% to 40% of humeral length	12.8 ± 3.8	11.6 ± 2.1	12.2 ± 4.3	12.2 ± 3.5	11.1 to 13.2	28
30% to 50% of humeral length	8.0 ± 2.1	8.5 ± 2.0	8.2 ± 2.5	8.2 ± 2.2	7.6 to 8.9	26
20% to 50% of humeral length	20.8 ± 4.6	20.1 ± 2.3	20.4 ± 5.9	20.4 ± 4.4	19.0 to 21.8	21
mCaPHA (°)	49.0 ± 3.9	50.3 ± 3.5	51.2 ± 5.9	50.2 ± 4.5	48.8 to 51.6	9
mCrDHA (°)	73.9 ± 9.5	71.5 ± 5.5	73.2 ± 8.5	72.9 ± 7.8	70.4 to 75.3	11
mLDHA (°)	88.7 ± 3.8	88.7 ± 4.2	90.4 ± 3.5	90.0 ± 3.6	88.3 to 90.6	4
Glenoid cavity						
Radius of curvature (mm)	19.5 ± 2.2	18.0 ± 1.7	17.6 ± 2.8	18.4 ± 2.3	17.6 to 19.1	13
Indexed radius of curvature ($mm/kg^{0.33}$)†	1.55 ± 0.36	1.57 ± 0.31	1.73 ± 0.25	1.61 ± 0.31	1.52 to 1.71	19
Glenohumeral conformity index	0.73 ± 0.05	0.75 ± 0.07	0.75 ± 0.07	0.75 ± 0.06	0.73 to 0.76	8

The CFI was classified as follows: high (CFI > 1.83), medium (1.64 ≤ CFI ≤ 1.83), and low (CFI < 1.64).

*For torsion, proximal represents the proximal portion of the humerus (8% to 20% of humeral length), diaphyseal represents the diaphyseal portion of the humerus (20% to 75% of humeral length), distal represents the distal portion of the humerus (75% to 92% of humeral length), and overall represents 8% to 92% of humeral length.

†Values were indexed on the basis of body weight$^{0.33}$.

CI = Confidence interval. CV = Coefficient of variation. NA = Not applicable.

Table 1: "Mean ± SD values for age, body weight, and 3-D geometric humeral measurements for 40 skeletally mature nonchondrodystrophic dogs."

Source: [1]

References: [1] E. J. Smith, D. J. Marcellin-Little, O. L. A. Harrysson, and E. H. Griffith, “Three-dimensional assessment of curvature, torsion, and canal flare index of the humerus of skeletally mature nonchondrodystrophic dogs,” *American Journal of Veterinary Research*, vol. 78, no. 10, pp. 1140–1149, Oct. 2017, doi: https://doi.org/10.2460/ajvr.78.10.1140.

Conclusions/action items: These exact measurements will be very helpful when chosing the density of our 3D printed bones. It is also important to understand the range of motion between the scapula and humerus in the forelimb of a dog to accurately represent that in our model. We are aiming to be as exact as possible with our bone models and range of movement, and this article provides very useful information in the form of exact measurements.

ELLA CAIN - Oct 03, 2024, 9:38 PM CDT

Three-dimensional assessment of curvature, torsion, and canal flare index of the humerus of skeletally mature nonchondrodystrophic dogs

Emily J. Smith
Denis J. Marcellin-Little
Ola L. A. Harrysson
Emily H. Griffith

OBJECTIVE

SAMPLE

PROCEDURES

RESULTS

CONCLUSIONS AND CLINICAL RELEVANCE

ABBREVIATIONS

CFI

[Download](#)

ajvr-ajvr.78.10.1140.pdf (2.05 MB)

10/5/24 Design research: shoulder joint

ELLIE KOTHBAUER - Oct 24, 2024, 10:37 AM CDT

Title: Shoulder joint ideas

Date: 10/5/24

Content by: Ellie Kothbauer

Present: N/A

Goals: To find a working movable part what would work as a shoulder joint for our model

Content:

1. **Ball-and-Socket Joint**: This is an ideal design for allowing a wide range of motion. You could use a small ball attached to one end of the arm and a socket that allows for rotation in multiple directions.
2. **Hinge Joint**: For simpler motion, a hinge joint could allow for bending in one direction, mimicking the elbow or a basic shoulder motion.
3. **Rotational Mechanism**: Consider using a small gear system or a swivel joint that enables the arm to rotate, which can replicate the natural movement of a dog's shoulder.
4. **Flexible Materials**: Use materials like flexible plastic or rubber at the joint to allow for smooth movement while providing stability.
5. **Connectors and Rods**: Small rods or connectors can help maintain the structure while allowing movement. They should be sturdy enough to hold the model's weight but flexible enough to allow for articulation.
6. **3D Printing**: If you're crafting a model, using a 3D printer can help create precise parts for the joint that fit together well.
7. **Pivots or Axles**: Small metal or plastic pivots can be used to allow rotation at the joint, making it easier to pose the arm in different positions.

By combining these elements, you can create a functional movable shoulder joint that mimics natural movement.

Conclusions/action items:

Some ideas for a shoulder joint include a ball and socket joint, or a hinge joint. Some important aspects to think about when finding a joint in how it can be made or if it needs to be bought, or the flexibility or rigidity of the model.

10/15/24 Muscle research

ELLIE KOTHBAUER - Nov 15, 2024, 12:25 PM CST

To create fake muscle for costumes, performances, or special effects, there are several materials and methods you can use to simulate realistic muscle definition. Here are some of the best options:

1. Foam Rubber or EVA Foam

-
- Foam rubber (also known as upholstery foam) and EVA foam (Ethylene Vinyl Acetate foam) are popular choices. They are lightweight, flexible, and can be shaped into realistic muscle contours.
- You can use foam padding or foam sheets, cutting and shaping them to form bulging biceps, pectorals, or abs.
- Pros: Lightweight, customizable, relatively inexpensive.
- How to use: Cut foam into the desired muscle shape, then glue or attach it to your body or costume. You can cover it with fabric or paint it to match skin tone.

2. Latex or Silicone Prosthetics

-
- Latex and silicone prosthetics can create a highly realistic appearance of muscles, especially for professional or special effects uses.
- Silicone prosthetics can be molded to mimic muscles' contours and are often used for more detailed and professional looks.
- Pros: Very realistic, flexible, and durable.
- How to use: Mold the silicone or latex into the desired shapes, then apply them to your body using special adhesives for prosthetics.

3. Padding (Pillow or Upholstery Foam)

-
- Simple padding such as pillow stuffing or upholstery foam can be used to bulk up your body with an easy, budget-friendly option.
- Pros: Inexpensive, easy to find

4. Muscle Suits

-
- Pre-made muscle suits (like those worn in movies or Halloween costumes) are available in stores or online. These are often made from foam, latex, or silicone.
- Pros: Quick and easy to use, already pre-formed.
- How to use: Just wear the suit as you would any regular costume. It fits over your body and gives the illusion of muscles.

5. Special Effects Gel (For Smaller Muscles)

-
- Gel or fake skin products can be used for small details like veins, highlights, or bulging veins over fake muscles. Some makeup brands sell special effects gel that hardens into a rubbery texture to create realistic-looking veins or skin over the fake muscle.
- Pros: Can be used for detailing.
- How to use: Apply a thin layer over the foam or latex prosthetic, then use makeup to shade and detail the veins or muscle fibers.

.

11/25/24 CAD skills research

11/15/24 Tong lecture

ELLIE KOTHBAUER - Nov 15, 2024, 12:32 PM CST

Title: Tong Lecture

Date: 11/15/24

Content by: Ellie Kothbauer

Present: All BME

Goals: To learn from the Tasso co founders

Content:

- The CEO and CTO came to speak to use about their company tasso

- Tasso is a blood drawing technology, and turned over the pharma industry to use tasso

- Find a key customer: USADA was looking to switch anti-doping to blood, now all of the baseball teams uses tasso, and it was used during paris olympics

- Tasso developed a tamper-proof security case to solve the chain of custody problem

- Problem of possibilities: grass roots effort propel tasso, focus on problem and not too aggressive

10/15/24 Muscle research

ELLIE KOTHBAUER - Nov 14, 2024, 11:49 PM CST

To create fake muscle for costumes, performances, or special effects, there are several materials and methods you can use to simulate realistic muscle definition. Here are some of the best options:

1. Foam Rubber or EVA Foam

-
- Foam rubber (also known as upholstery foam) and EVA foam (Ethylene Vinyl Acetate foam) are popular choices. They are lightweight, flexible, and can be shaped into realistic muscle contours.
- You can use foam padding or foam sheets, cutting and shaping them to form bulging biceps, pectorals, or abs.
- Pros: Lightweight, customizable, relatively inexpensive.
- How to use: Cut foam into the desired muscle shape, then glue or attach it to your body or costume. You can cover it with fabric or paint it to match skin tone.

2. Latex or Silicone Prosthetics

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- Latex and silicone prosthetics can create a highly realistic appearance of muscles, especially for professional or special effects uses.
- Silicone prosthetics can be molded to mimic muscles' contours and are often used for more detailed and professional looks.
- Pros: Very realistic, flexible, and durable.
- How to use: Mold the silicone or latex into the desired shapes, then apply them to your body using special adhesives for prosthetics.

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- Pros: Inexpensive, easy to find

4. Muscle Suits

-
- Pre-made muscle suits (like those worn in movies or Halloween costumes) are available in stores or online. These are often made from foam, latex, or silicone.
- Pros: Quick and easy to use, already pre-formed.
- How to use: Just wear the suit as you would any regular costume. It fits over your body and gives the illusion of muscles.

5. Special Effects Gel (For Smaller Muscles)

-
- Gel or fake skin products can be used for small details like veins, highlights, or bulging veins over fake muscles. Some makeup brands sell special effects gel that hardens into a rubbery texture to create realistic-looking veins or skin over the fake muscle.
- Pros: Can be used for detailing.

- How to use: Apply a thin layer over the foam or latex prosthetic, then use makeup to shade and detail the veins or muscle fibers.

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10/21/24 shoulder joint

10/26/24 Muscle design

ELLIE KOTHBAUER - Nov 14, 2024, 11:47 PM CST

Title: Design ideas for fax muscle

Date: 10/9/24

Content by: Ellie Kothbauer

Present: N/A

Goals: to find a good use for muscle

Content:

1. Foam Rubber or EVA Foam

-
- **Foam rubber** (also known as upholstery foam) and **EVA foam** (Ethylene Vinyl Acetate foam) are popular choices. They are lightweight, flexible, and can be shaped into realistic muscle contours.
- You can use **foam padding** or **foam sheets**, cutting and shaping them to form bulging biceps, pectorals, or abs.
- **Pros**: Lightweight, customizable, relatively inexpensive.
- **How to use**: Cut foam into the desired muscle shape, then glue or attach it to your body or costume. You can cover it with fabric or paint it to match skin tone.

2. Latex or Silicone Prosthetics

-
- **Latex** and **silicone prosthetics** can create a highly realistic appearance of muscles, especially for professional or special effects uses.
- **Silicone prosthetics** can be molded to mimic muscles' contours and are often used for more detailed and professional looks.
- **Pros**: Very realistic, flexible, and durable.
- **How to use**: Mold the silicone or latex into the desired shapes, then apply them to your body using special adhesives for prosthetics.

3. Ways to apply the silicone

- Medical adhesive

- Velcro

- purchase silicone adhesive gel

-

Conclusions/action items: I think the Velcro and the silicone would work the best, as the muscle and adhesive because the silicone is easy to find, and the Velcro will allow it to attach and detach when the replaceable part is needed

10/9/24 Early bone design

ELLIE KOTHBAUER - Dec 09, 2024, 10:31 AM CST

Title: Early Bone design

Date: 10/9/24

Content by: Ellie Kothbauer

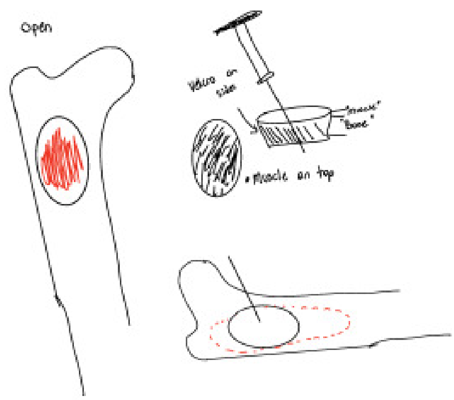
Present: N/A

Goals: To come up with a early bone design

Content: See below

Conclusions/action items:

ELLIE KOTHBAUER - Dec 09, 2024, 10:32 AM CST



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12/1/24 Testing the design

ELLIE KOTHBAUER - Dec 10, 2024, 7:59 PM CST

Title: Testing the final design

Date: 12/1/24

Content by: Ellie Kothbauer

Present: N/A

Goals: To show our design being tested by the clients

Content: See photo of testing below

Conclusions/action items:

- We had our client test our design, they practiced the procedure and made any final necessary remarks. From their input we changed the final joint used, and were able to add a forelimb. The client was then able to see the final product at the BME poster session.

Bone Marrow Aspiration in Dogs

ANYA BERGMAN - Sep 10, 2024, 4:27 PM CDT

Title: Bone Marrow Aspiration in Dogs

Date: 9/10/24

Content by: Anya Bergman

Present: Anya Bergman

Goals: To find background articles to establish what the procedure is used for

Content:

- Procedure purpose is to diagnose conditions that could be affecting bone marrow:
- Bone Marrow background:
    - hematopoietic organ- produces blood cells and platelets
    - it recedes from bones as the organism matures
    - this test can find:
        - infection,
        - myelofibrosis,
        - necrosis or
        - neoplasia- abnormal mass of cells, they are growing when they shouldn't and not dying when they should (cancer?)
- Common collection sites for dogs: proximal humorous or ilium, less common is sternum ribs or proximal femur
    - sternum is not historically aspirated but recent study shows it could be, this has softer bone covering it and covered by minimal soft tissue
    - pelvis and femur are tough with fat tissue (adipose tissue)
        - We can make several models of different bones that would be better practices
- table of Collection sites:

TABLE 1 Bone Marrow Collection Sites[15]

ASPIRATION LOCATION	IDEAL PATIENT SIZE	ASPIRATION OR CORE BIOPSY	SITE OF NEEDLE INTRODUCTION	PATIENT POSITION	CONSIDERATIONS
Proximal humerus	Large and small dogs, cats	Both	Greater tubercle	Lateral recumbency	▪ Avoid the articular cartilage ▪ Avoid sampling in young dogs due to the proximity of the growth plate
Proximal femur	Small dogs and cats	Both	Intertrochanteric fossa	Lateral recumbency	▪ Can be difficult in larger, well-muscled, or obese patients ▪ Cortical bone can be too dense in older patients ▪ Avoid the sciatic nerve (located medial and caudal to the greater trochanter) ▪ Use discretion in young animals due to proximity to growth plate
Ilium	Large and small dogs	Both	Dorsal iliac crest	Sternal recumbency preferred; lateral can be considered	▪ Can be difficult in obese patients ▪ Transilial approach useful in cats and small dogs with narrow dorsal iliac crests or in dogs that are obese
Sternum	Large dogs	Aspiration only	Manubrium or sternebrae (typically 2nd through 4th)	Dorsal recumbency preferred; lateral can be considered for 2nd through 4th sternebrae	▪ Carries risk of penetrating the thoracic cavity ▪ Can be performed with light sedation only
Rib	Large dogs	Aspiration only	10th rib above costochondral junction	Lateral recumbency	▪ Carries risk of penetrating the thoracic cavity ▪ Can be performed with light sedation ▪ Samples from older patients with less active hematopoiesis are frequently not representative

References: Bone Marrow Aspiration in Dogs: A Step-by-Step Tutorial (todaysveterinarypractice.com)

Conclusions/action items:

After reading this article I think it will be very important to explore each of these different bones and how the procedures are actually carried out, It is also important to find what these collection sites would be for other animals (if they also undergo this procedure)

Bone Marrow Background

ANYA BERGMAN - Sep 12, 2024, 2:12 PM CDT

Title: Bone Marrow Background

Date: 9/12/24

Content by: Anya Bergman

Present: Anya Bergman

Goals: To understand more about what bone marrow does in the body and what the aspiration procedure can test, and how these diseases effect the bone marrow.

Content:

- comprised of hematopoietic cells (these are cells that produce blood cells) and fat cells
    - Cells types:
        - hematopoietic precursors: Myeloid, erythroid, megakaryocytic, lymphoid
            - they have different levels of abundance based on maturation of the cells - part of what is evaluated in the procedure
        - Stromal cells- provide growth factors, support and mechanical cues- keys to blood cell production
- most hematopoiesis occurs in flat bones and at the end of long ones
    - initially occurs in mnay bones but with maturation it necomes restricited to flat bones and epphyseal regions
        - in periods of increased demand can happen in pother tissues such as spleebn and liver
- Erythropoiesis- process of making red blood cells, (medullary= happens in bone marrow)
- Granulopoiesis- type of white blood cell, with multiple lobed nuclei
- Monocytopoiesis

Reference:

"Bone Marrow." *eClinpath*, Cornell University, 9 Jan. 2019, eclinpath.com/cytology/bone-marrow/#:~:text=The%20bone%20marrow%20is%20composed%20of%20multiple%20cell,proportional%20maturation%20as%20part%20of%20bone%20marrow%20evaluation.

Conclusions/action items:

There are many different tyepes of cells that are being created in bone marrow, and they have various amounts depending on the maturity of the cells. These levels of abundance are part of what is tested in the bone marrow aspirations because it points out if there are issues when some of the blood producing cells arent as mature as they are meant to be. In the future I would like to do more research to understand these different cells, but also broaden the scope to understand mroe about the procedure itself.

Bone Mimicking material

ANYA BERGMAN - Sep 24, 2024, 9:36 PM CDT

Title: Bone Mimicking Material

Date: 9/22/24

Content by: Anya Bergman

Present: Anya Bergman

Goals: To find materials that best mimic bone for 3D printing

Content:

UW Makerspace Available Filaments:

- Ulti maker PLA
- Ulti maker tough PLA
- Bambu Lab:
    - PLA
    - PLA CF
    - PC
    - ASA
    - ABS
    - TPU
    - PETG
- Formlabs
    - standard resin
    - durable
    - tough 1500
    - Flexible 80A
    - Formlabs
        - Elastic
        - high temp
        - rigid
        - biomed Clear
        - Nylon 12 (powder)
    - Stratasys
        - ABS M300
        - PC-ABs
        - TPU 92A
        - QSR support
    - Markforged
        - Onyx
        - Fiber-Reinforcement

3D printing has a lot of dental applications:

- Formlabs uses BEGOTM VarseoSmile® TriniQ® Resin
    - it is ceramic filled biocompatible material (this is not necessary for our model)
    - also has good accuracy and transparent workflow

Physical Properties of bone (and chemical makeup)

- crystalline structure from natural minerals within bone
- rigid hard, great compressive strength (this will be very important for our model)
- general properties similar to fiber glass and bamboo
- tensile strength of 700-1400 kg/cm^2 (68-137mPa)
- compressive strength 1400-2100(137-205)
- similar to aluminum or mold steel but it is considerably lighter
- modulus of elasticity are 420-700 kg per square cm (much more elastic than steel)
-

-

References:

[1] “Bone morphology,” Encyclopædia Britannica, https://www.britannica.com/science/bone-anatomy/Bone-morphology (accessed Sep. 23, 2024).

[2] “3D printers,” Design Innovation Lab, https://making.engr.wisc.edu/equipment/3d-printers/ (accessed Sep. 24, 2024).

look into:

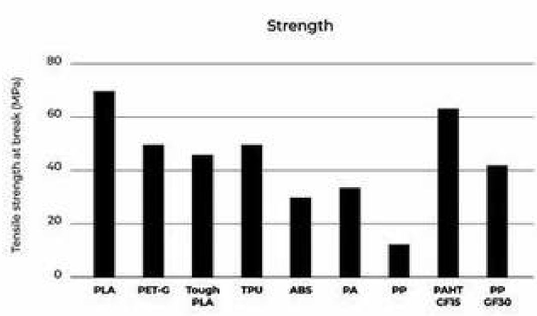
Thermal Insulation and Mechanical Properties of Polylactic Acid (PLA) at Different Processing Conditions (mdpi.com)

Definelty test rigid 4k (Formlabs)

Conclusions/action items:

I think after this research it's going to be very important to go through each resin type and decide what will be the closest fit. I am going to create a design matrix of this,and create a little test swatch for the best resins in order to have dr. Gunderson and her crew tst what feels closest to bone for them. Its also important to research what the aspiration cits exact thickness is so that the tests can be as close as possibel to our model. Next I think it will be important to find some kind of joint or hinge for the shoulder.

ANYA BERGMAN - Sep 24, 2024, 9:28 PM CDT



Download

OIP.jpg (11.5 kB)

Humerous Bone

ANYA BERGMAN - Nov 13, 2024, 3:04 PM CST

Title: Humorous Bone research

Date: 9/25

Content by: Anya Bergman

Present: Anya Bergman

Goals: To find more background knowledge on the anatomy of a dogs leg

Content:

References:

Dog Humerus Bone Anatomy » AnatomyLearner >> Veterinary Anatomy Study Guide For Vet's Students

Dog Leg Anatomy with Labeled Diagram - Bones, Joints, Muscles and Vessels » AnatomyLearner >> Veterinary Anatomy Study Guide For Vet's Students

Interspecies Differences in Bone Composition, Density, and Quality: Potential Implications for in Vivo Bone Research* | Endocrinology | Oxford Academic (oup.com)

Cortical thickness analysis of the proximal humerus - PMC (nih.gov)- using 3D scans to look at thickness

Conclusions/action items:

Tong lecture notes

ANYA BERGMAN - Nov 15, 2024, 12:53 PM CST

Title: Tong Lecture notes

Date: 11/15

Content by: Anya Bergman

Present:

Goals:

Content:

- Both cold emailed Dave and got jobs with him
- Idea for blood draw at home- that what the future of healthcare is- thik at home covid tests
- maxed out credit card! try everything
- got a grant in 2013- DARPA gave them a grant
- Helps people who don't have access to a car helps provide everyone with care
- Evolution of technology
    - make a better product
    - kill product when needed?
        - when it needs to be improved, it is hard to change up on people who have been using i
- The product was applicable in so many ways- might go into different paths, pick the one where you don't have many problems to solve
    - now they are doing the dope testing of sports
- Covid brought down the customer rate and everything had to be slowed down
    - but then everywhere needed at home testing! so they got so much buisness
- QUALITY IS KEY!!
- there is strategy in the FDA clearances
    - can we use labels that already exist to help a new product enter?

Conclusions/action items:

Human Bone Marrow Aspirate models

ANYA BERGMAN - Nov 13, 2024, 3:22 PM CST

Title: Human Bone Marrow Aspirate Models

Date: 9/19

Content by: Anya Bergman

Present: Anya

Goals: To look at competitive models for the competition section in the PDS

Content:

- Cadaver Models: (Info from client)
    - The bone marrow dies with the cadaver and can no longer be extracted, so vet students don't know if they have actually been succesful
    - Each cadaver only has up to 4-5 uses before the aspiration site has too many holes in it to be used
- Bonnie Bone marrow biopsy skills trainer, inaccurate to doges targets a bone marrow biopsy rather than aspiration, very expensive, biopsy site is on the hip.
- Anatomy Lab Adult Bone Marrow Aspiration:
    - Again, inaccurate to vet practices, very expensive, targets the hip again which is completely different

References:

"Bonnie Bone Marrow Biopsy Skills Trainer," *Anatomy Warehouse*, 2024. https://anatomywarehouse.com/bonnie-bone-marrow-biopsy-skills-trainer-with-case-and-set-of-5-illiac-crest-inserts-a-106431 (accessed Sep. 19, 2024).

"Anatomy Lab Adult Bone Marrow Aspiration Model," *Anatomy Warehouse*, 2024. https://anatomywarehouse.com/the-anatomy-lab-adult-bone-marrow-aspiration-model-a-106774 (accessed Sep. 19, 2024).

Conclusions/action items:

There are really no competing models for our bone marrow aspiration model, which is tough because it does limit the amount of inspiration we can take from preexisting models, however it also helps to differentiate our product and really stresses the importance of adding that bone marrow cavity and replaceable component because it will provide practice for this procedure that essentially does not exist right now.

Tong lecture notes

ANYA BERGMAN - Dec 11, 2024, 3:03 PM CST

Title: Tong Lecture Notes

Date: 11/15/2024

Content by: Anya Bergman

Present: Anya Bergman

Goals: To listen to a success story of Tasso.

Content:

- It started very small scale its more important to have a good idea, then to have the supplies, their prototype looked rough but the idea was there

-They allowed their idea to be changed for how it was going to be implemented, this is dependent on the markets at the time

-During COVID business they first struggled when the pandemic initially hit but then their idea became even more useful because people could use the product on their own rather than having to go into the hospital exposing them to COVID

-Then their device became important for drug testing in major sports, this was not their original plan for the device, but you have to allow the market and purpose to change, even specialize to fit the needs.

-in order to get FDA approved they wen the route of filing that they were similar enough with another device, this greatly expedites the process and made it easier for them to improve

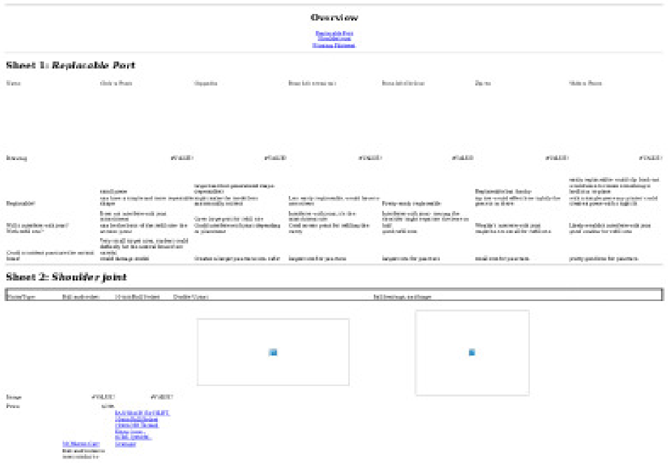
-

Conclusions/action items:

Their story was very impressive; despite not having amazing funding these two men were able to create a product, and their success was based entirely on how they applied themselves; they allowed their product to change in purpose, they had to spend their own money to make things happen and it was a little risky. They also applied for an FDA that would make getting their product cleared more easily and all of the steps in their business could not have happened successfully if it wasn't for the way these men applied themselves.

Pro con comparison of Designs 9/24

ANYA BERGMAN - Sep 24, 2024, 9:24 PM CDT



Overview

Sheet 1: Replacable Part

Sheet 2: Shoulder joint

Download

Design_Matrixes.xlsx (668 kB)

Materials

ANYA BERGMAN - Nov 13, 2024, 3:02 PM CST

Title: Materials

Date: 3/27

Content by: Anya Bergman

Present: Anya Bergman

Goals: To find materials that would mimic the muscles skin and joints

Content:

Amazon.com: Neoprene Rubber Sheet - 1/8 Inch Thick x 4 Inch Wide x 10 Feet Long Neoprene Rubber Strips Rolls for DIY Gaskets, Pads, Seals, Crafts, Flooring, Cushioning of Anti-Vibration, Anti-Slip : Industrial & Scientific

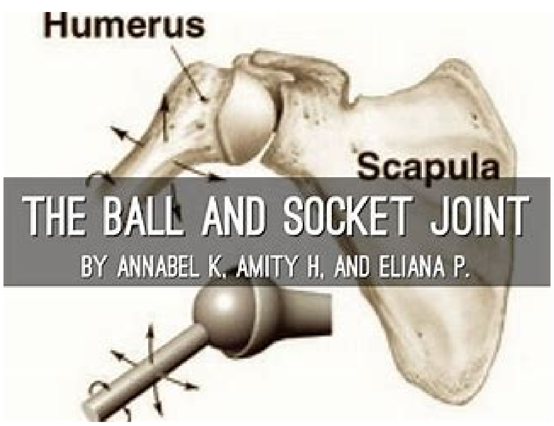
- these could be used to one practice having skin while we do not have any from dr g but could also be used to synthesize muscles because it is more pliable than pourable silicone so it could actually stretch, not sure if that required to mimic muscles
    - maybe use these for tendons
- for shoulder joint- way more cost effective to just modify the CAD, and easily repeatable, downside of this could be the movement wouldn't be as smooth and would not feel as realistic as the ball and socket join
    - hard to find ball and socket joints though

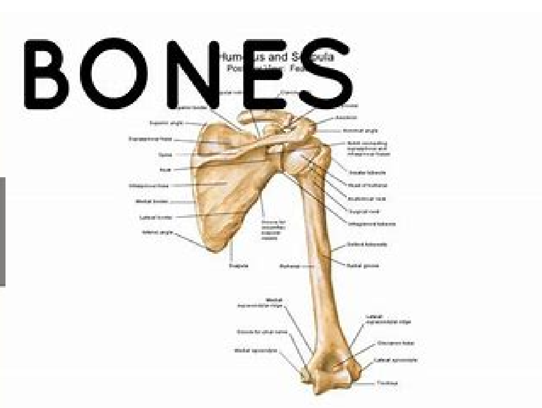
Smooth-Sil™ 945 Product Information | Smooth-On, Inc.

- can use for the muscles, we should create molds for the muscles so that we can produce multiple, and it will make assembly for dr g in the future a little easier
-

Conclusions/action items:

I ended up ordering a U-joint that is about 1 1/8" long so that it can fit between the humerus and the scapula without really adding a gap and I am going to cad a place to attach the joint on the humerus and scapula. Below are some drawings just to see how the joint should best be placed, in a way so that no part of the natural bone can restrict movement, while still getting the two bones to be as close to flush as possible.





11/12 3D printing ideas

ANYA BERGMAN - Nov 13, 2024, 3:39 PM CST

Title: CAD Model ideas for editing

Date: 11/12

Content by: Anya Bergman

Present: Anya, Ella

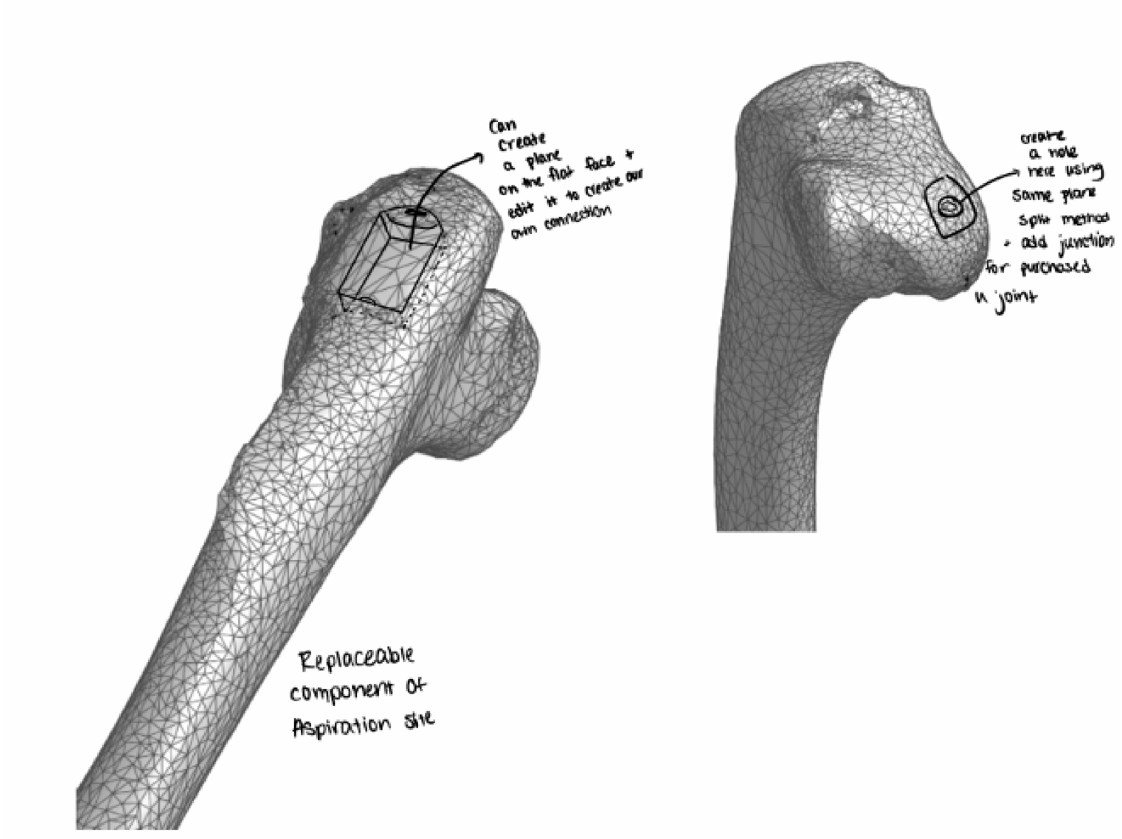
Goals: To edit the Cad model in a way that both keep the scan as anatomically correct as possible while also being able to create a replaceable piece.

Content:

Me and Ella went to the ECB and got help from a CAD specialist and I had some ideas for the CAD model:

- I think we should split the bone at the flat portion where the aspirating takes places which will make the site a little less accurate, but then we can create a compartment and maybe on the replaceable piece we can use the part we split to replace that structure. (I don't think this is super crucial because the part is very flat here.
- Then on the back of the top part of the bone we can again do a split and create a part inside that will fit with the U joint and then fasten it directly to the scapula using a drill rather than having to edit that part as well. This will be much quicker for this level of production and might be more secure than a 3D printed connection.
- One tricky thing about this is we will need to simplify the model anyway because of how many triangles there are on the surface it makes it nearly impossible to edit, so we have to simplify this in bambu labs which I have just downloaded and then we will probably need to edit this in On Shape rather than SolidWorks
    - Alternatively, we can go back and re do the 3D scanning of the bone and reduce the resolution of the initial scan so that we have less to simplify, so I may try to go back and attempt this
    - This does limit the accuracy of the piece but the current resolution we have goes beyond what we can actually get from 3D printing and because this will be covered in muscles and skin the texture of the bone is not nearly as important as the general structure and the ability for our client to remake these easily.
    - Also, despite being a little less accurate this whole model is based on one beagle, and that is already not very accurate to the range of dogs that will come in for this procedure.

Here are some of the sketches I have from my ideas:



Conclusions/action items:

I might have to revisit the help center in order to figure out how to properly scale the CAD design after decimating some of the triangles, but overall, I'm thinking we only need to actually edit this bone in these 2 sections, both of them to create a structure for our replaceable component to fit in and for our joint. I also think the limitations of this CAD will help us to narrow down what our replacabke componenet can be.

CAD model -humerus joint connection

ANYA BERGMAN - Dec 10, 2024, 7:31 PM CST

Title: CAD model -humerus Joint connection

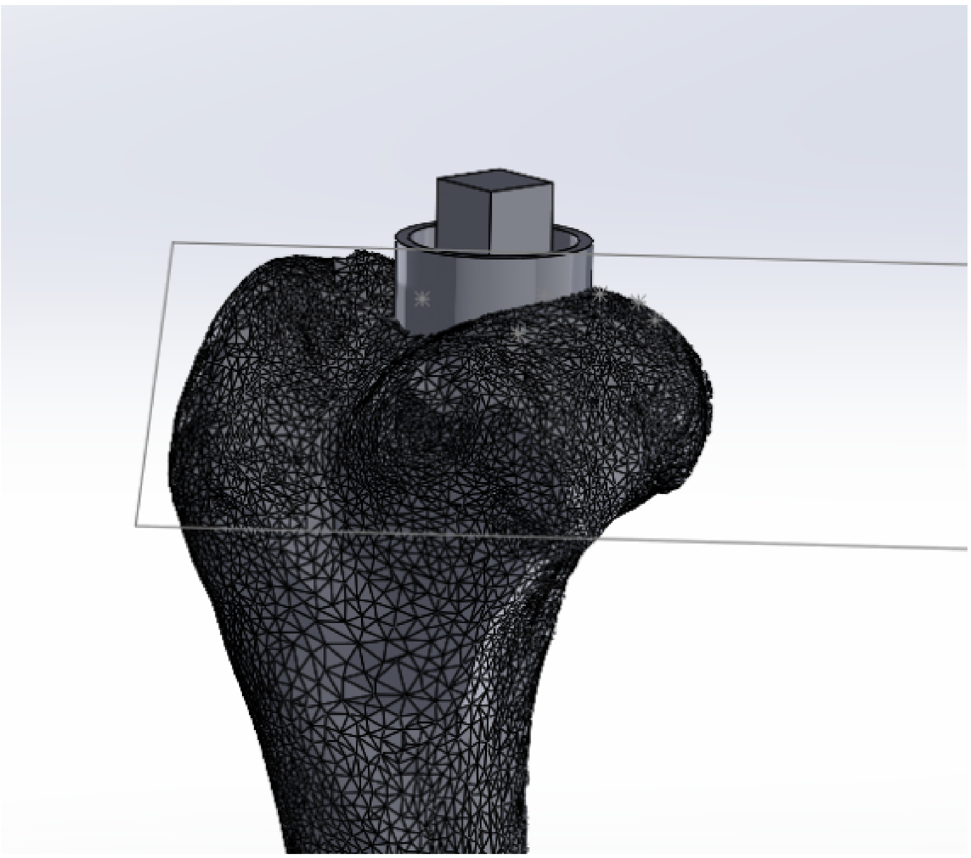
Date: 11/24/24

Content by: Anya Bergman

Present: Anya Bergman

Goals: Create joint attachment on the humerus bone

Content:



Conclusions/action items:

After trying to create and extruded cut through the graphic I found that it was very hard and could not figure out how to do it, in the end I don't think this will matter much because the two bones are not actually flushly connected to each other because they have Cartlidge and ligaments between them. So, I ended up creating an extrusion that could act as kind of a base and then I hollowed out part of this and then created another extrusion of a 1/4" square that would connect to the joint. I think this will hold up well and will have a better fit with the joint because it is a flat surface that the joint is now pushing into rather than the textured and curved surface of the bone.

CAD modeling for Scapula

ANYA BERGMAN - Dec 10, 2024, 7:18 PM CST

Title: CAD modeling for scapula

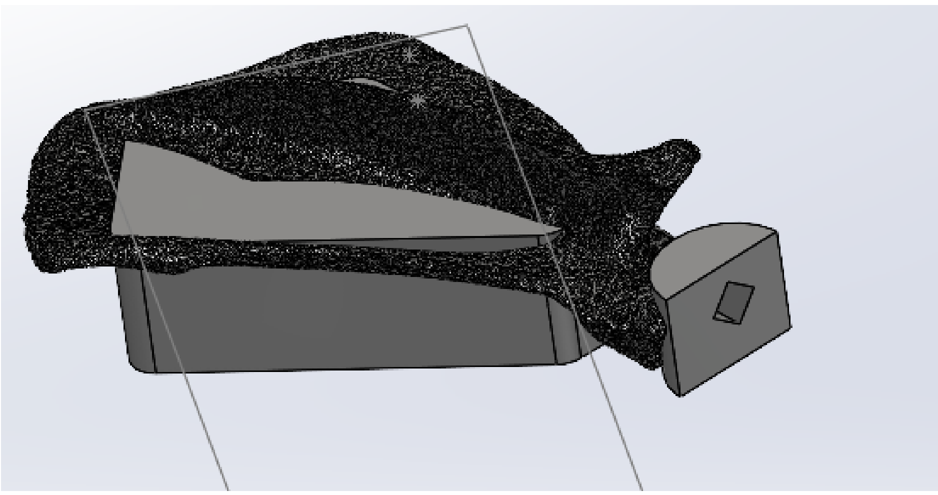
Date: 11/26/2024

Content by: Anya Bergman

Present: Anya Bergman

Goals: To finish the CAD models of the bone structure.

Content:



Conclusions/action items:

After redoing the scapula to fit the U-joint, and printed it the model was tested by my teammates and the joint did not seem to have the right range of movement that is needed by the client in order to rotate the shoulder to better access the aspiration site, so Avery ordered a new ball and socket joint which I will have to create a new connection to. It's also pretty interesting that I edited both the extruded hole for the joint connection and the extruded piece to have the exact measurements of the joint, and the hole was the perfect size, but the extruded piece was just a little too small and when scaled up by 2% it does fit but has to be forced in a little but more. So this is something I will have to take note of for the next joint connection.

Muscle attachment pieces

ANYA BERGMAN - Dec 10, 2024, 7:38 PM CST

Title: Muscle attachment pieces

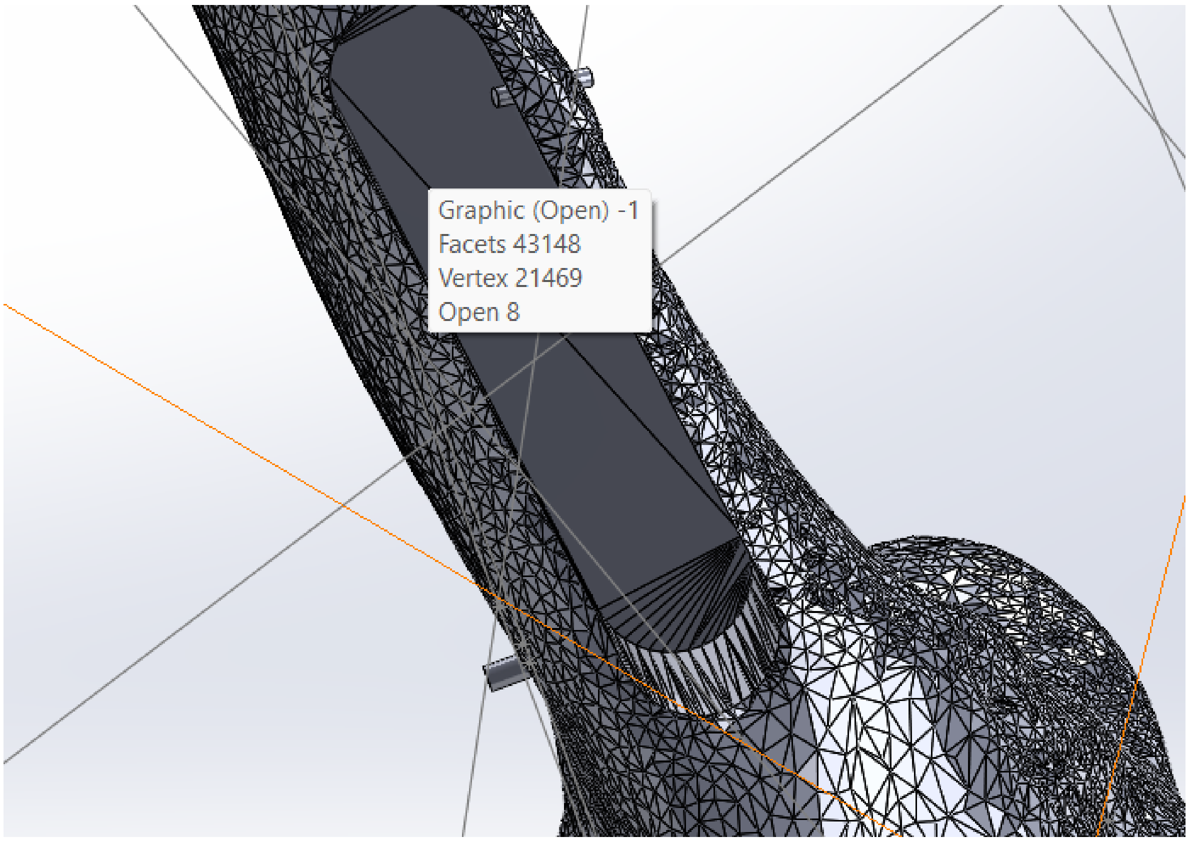
Date: 11/27/24-12/2/24

Content by: Anya Bergman

Present: Anya Bergman

Goals: To test small pegs that could hold the pseudo muscle to the bone

Content:



Conclusions/action items:

I tried to add small pegs onto the bones that the silicone could be stretched from if we made 2 small holes in the muscle and then pulled it taught over the bones, but after printing this piece I found that one the pegs were slightly too small to be structurally sound and the silicone was also a little too stiff to accurately simulate muscle as it could not be stretched very much. Also, when I tied to make two holes in the silicone trying to stretch them across the pegs actually ripped through the silicone so I don't think this method of attachment is actually going to work long term.

CAD model of Scapula with ball and socket joint connection

ANYA BERGMAN - Dec 10, 2024, 7:26 PM CST

Title: CAD model of Scapula with ball and socket joint connection

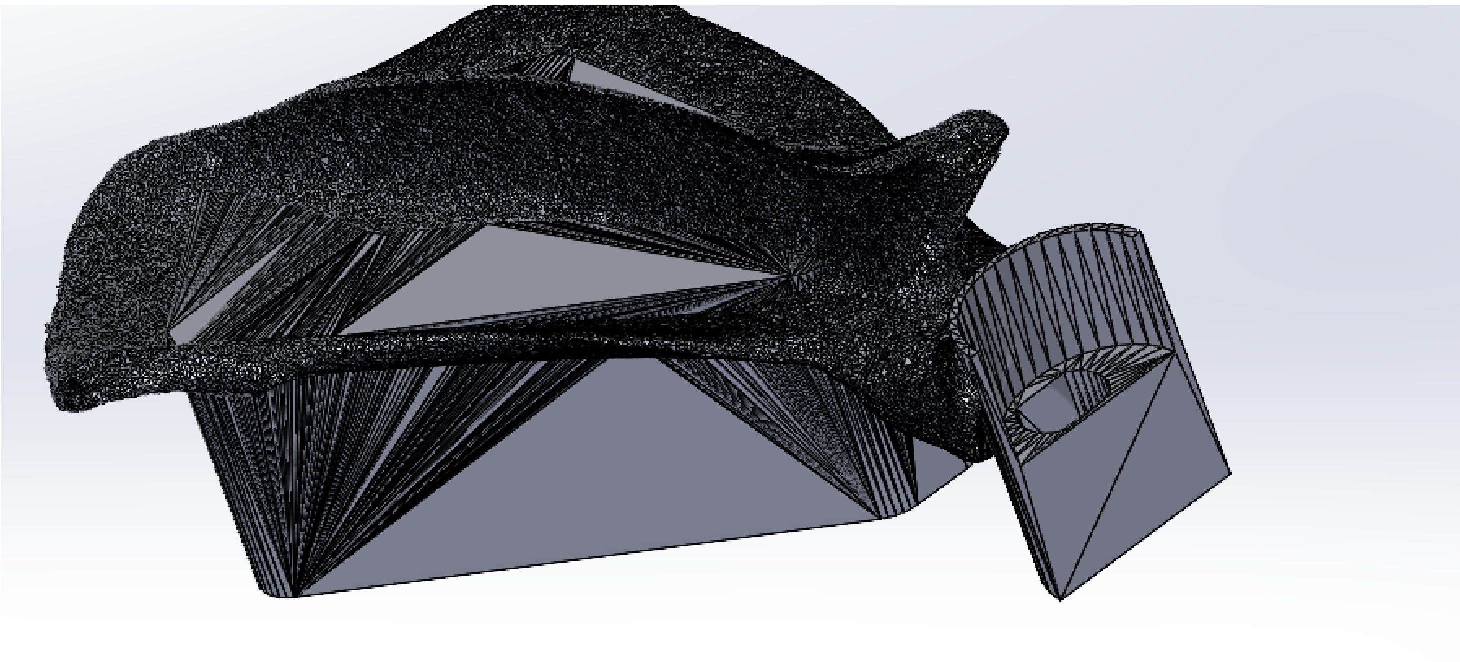
Date: 11/30

Content by: Anya Bergman

Present: Anya Bergman

Goals: To create new joint connection for ball and socket joint

Content:



Conclusions/action items:

After visiting the makerspace, I asked for advice on creating a tapped hole in SolidWorks for the humerus to connect it to the ball and socket joint we have but I was advised against creating a threaded hole because it would likely not hold up well overtime. I also looked into actually drilling and tapping but was also advised against tapping into the PLA filament because it is too weak to actually hold up to that. In the end it was recommended that I just drill a hole and forcefully thread in the screw for the joint, so I have selected where I feel that will be most accurate in regards to the anatomy of the shoulder. For the scapula I decided to actually hold the joint vertically in it, because that allows for 45-degree movement in either direction and then free rotation of the shoulder which isn't accurate to the actual shoulder but I think in future works would be easy to prevent the full movement just by adding some fake ligaments or a part that was attached to the board or something.

2014/11/03-Entry guidelines

John Puccinelli - Sep 05, 2016, 1:18 PM CDT

Use this as a guide for every entry

- Every text entry of your notebook should have the **bold titles** below.
- Every page/entry should be **named starting with the date** of the entry's first creation/activity, subsequent material from future dates can be added later.

You can create a copy of the blank template by first opening the desired folder, clicking on "New", selecting "Copy Existing Page...", and then select "2014/11/03-Template")

Title: Descriptive title (i.e. Client Meeting)

Date: 9/5/2016

Content by: The one person who wrote the content

Present: Names of those present if more than just you (not necessary for individual work)

Goals: Establish clear goals for all text entries (meetings, individual work, etc.).

Content:

Contains clear and organized notes (also includes any references used)

Conclusions/action items:

Recap only the most significant findings and/or action items resulting from the entry.

2014/11/03-Template

John Puccinelli - Nov 03, 2014, 3:20 PM CST

Title:

Date:

Content by:

Present:

Goals:

Content:

Conclusions/action items: