Veterinary Bone Marrow Aspirate Model

Product Design Specifications (PDS)

BME 200/300

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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**
    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 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.

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 20 times for the muscle and 5 times for the humerus piece.
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 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].
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 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.
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 3-D 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 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.
    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 Anatomy Lab's 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].

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