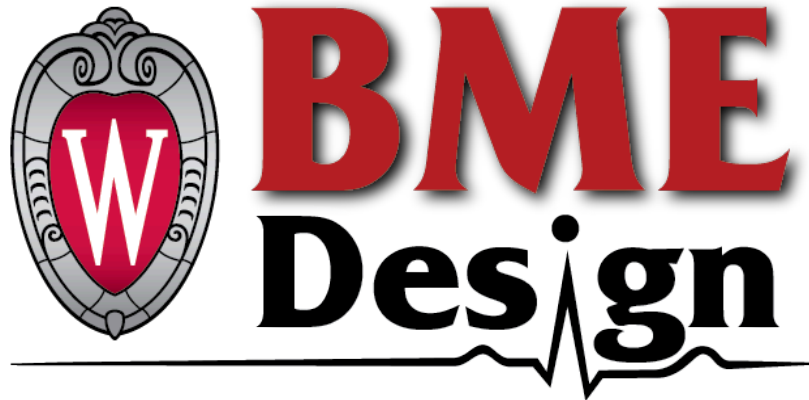




VET Stand

Preliminary Report

Team Members:

Norah Greer (njgreer2@wisc.edu) - Co-Leader
Cole Hwang (nahwang@wisc.edu) - Co-Leader
Zhien Luo (zluo@wisc.edu) - Communicator
Bridget Jensen (bcjensen2@wisc.edu) - BSAC
Ethan Abitz (eabitz@wisc.edu) - BWIG
Isabel Hillwalker (hillwalker@wisc.edu) - BPAG

Client:

Dr. James Sohn

Advisor:

Dr. Randy Bartels

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Abstract

Animals receiving radiation therapy must be set up in the same position from their first CT scan to their final treatment. This is achieved using a bite block; a device fitted to an animal's teeth or upper jaw, which securely holds the animal's head in place. No bite blocks are currently on the market, and those designed by individual veterinary clinics often include high-Z materials like metals and dental putty which can hinder CT scans. Additionally, these designs tend to be cumbersome, unreliable, and time-consuming to set up. This project aims to create a highly adjustable stand that can be reliably adjusted to the same height over multiple treatment sessions and support the weight of a large dog's head. The design will be tested for ease of use, where a successful result would include a technician's ability to adjust the stand with one hand in under 30 seconds. In addition, testing for weight capacity and function under radiation will be completed, where a successful result will show no failure or loss of function under defined maximum weight and radiation levels. To test reliability of adjustment, the stand will be reset to the same height over repeated trials and measured to ensure accuracy within the given tolerance.

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Introduction

Cancer affects both human and animal populations, radiation therapy being the most popular form of treatment. Animals cannot receive IV radiation therapy, so they must undergo external beam radiation through a medical linear accelerator machine (LINAC). LINAC systems deliver a highly precise dose of treatment to the affected area, minimizing the side effects when radiation hits healthy tissue [1]. To maintain this precise targeting, animals must be under anesthesia for treatment and are positioned with a bite block. Bite blocks maintain jaw and head orientation, while also ensuring the mouth stays open so the endotracheal tube can be inserted. However, the bite blocks used now are improvised and can cause inconsistencies throughout the patient's positioning. These improvised bite blocks extend setup time, decreasing the number of patients that can be seen in a day.

Although this tool is a vital part of animal radiation therapy, there are no standardized or regulated bite blocks. A bite block that follows American Animal Hospital Association (AAHA) veterinary guidelines is needed. These guidelines state that the head and neck should be stabilized when forces are applied in the mouth and that a mouth prop should not fully open the mouth or overextend the temporomandibular joint [2]. Current bite blocks use materials like dental putty or metal, interfering with CT scans and radiation therapy. A new device should be created without materials that interfere or that could harm the animals. Bite blocks are commonly used multiple times in a day, so easy sterilization must be a factor in fabrication.

There is a clear clinical need for a universal, adjustable, and sterilizable veterinary bite block. Standardizing this device will enhance targeting accuracy, safeguard patient anatomy, and increase daily clinical throughput.

Background

For pets undergoing radiation treatment for tumors, a CT scan is done first to determine the location of the tumor and the path of the radiation beam. The position of the pet during the CT scan is very important, as the same position must be replicated for the following treatments. This is done to minimize the amount of stray radiation hitting surrounding healthy tissue. Due to cats and dogs varying in size and shape across breeds, accurately replicating their initial position can be difficult.

The client for this project, Dr. James Sohn, recognized that the current method used by vet techs to position these pets for the treatments was very cumbersome and inefficient. Dr. Sohn requested a device that would allow vet techs to more efficiently and easily set up and position pets for treatment. Specifically, Dr. Sohn requested a device with an adjustable height mechanism, an adjustable bite block, and a height-indication system that allows positioning settings to be recorded and reproduced across multiple treatments.

Preliminary Designs

Design 1: Lever Clamp Stand

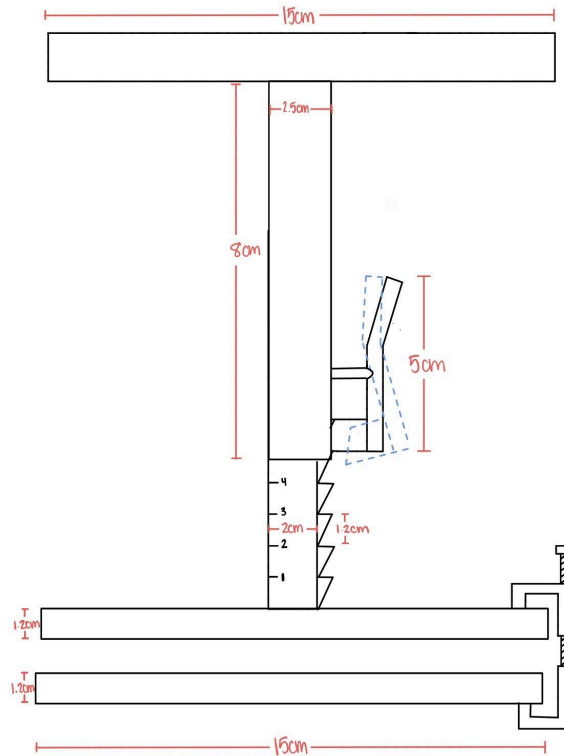


Figure 1. Lever Clamp Stand, all dimensions in cm

This design's adjustment is centered around a central post with teeth and a spring-loaded clamp. When the spring-loaded clamp is squeezed, the stopper is released, and the height can be adjusted. When the clamp is released, the stopper re-engages and secures the stand at its current position. This stand is secured to the table using a clamp.

Design 2: Dual Rack-and-Pinion Clamp

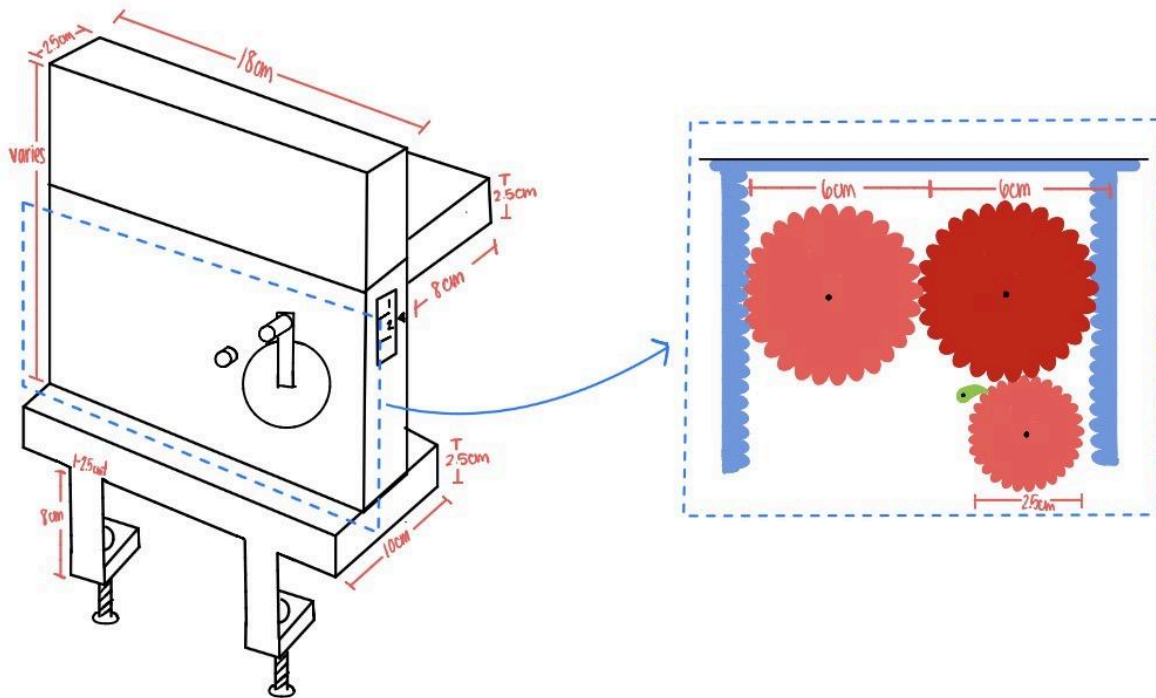


Figure 2. Dual Rack-and-Pinion Clamp, all dimensions in cm

This stand is adjusted via two sliding racks and two fixed pinions, which move simultaneously using a common central gear. The gear spins freely in the clockwise direction, but is prevented from spinning back by a spring-loaded pawl. To lower the stand, the pawl can be disengaged by pressing a button. The height markers in this design are located on the backside of one of the racks and can be seen through a cutout in the base. All mechanical elements are housed within a hollow rectangular base, and the stand is secured to the table using clamps.

Design 3: Rack-and-Pinion Stand

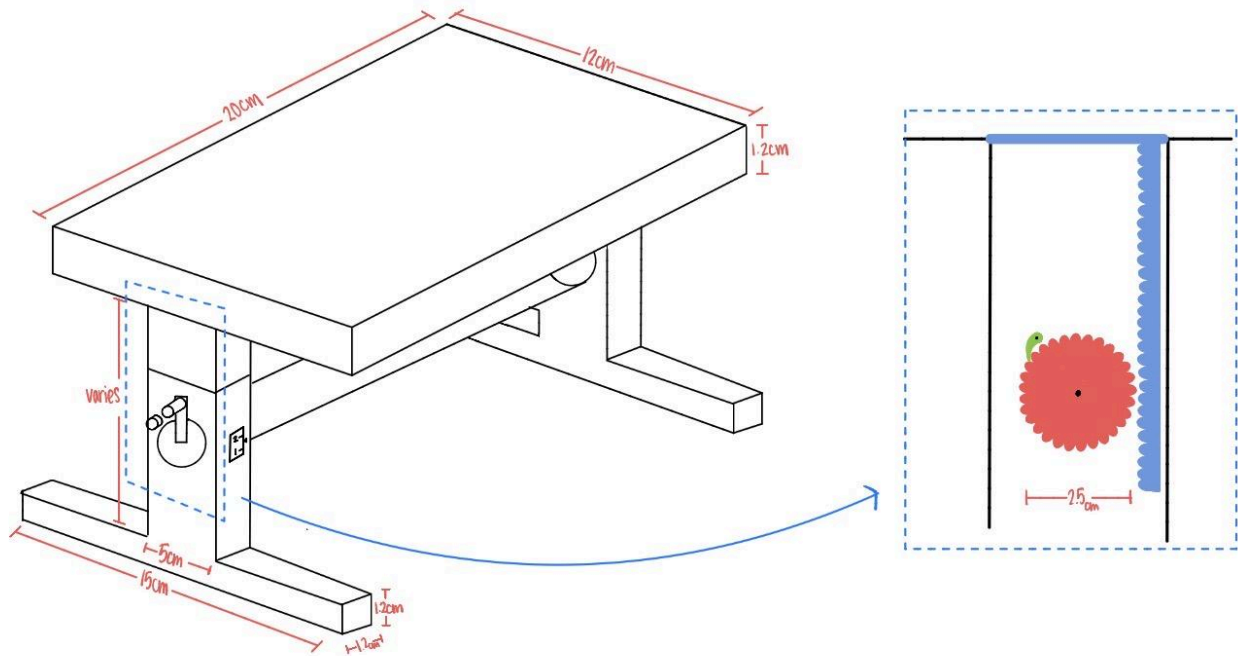


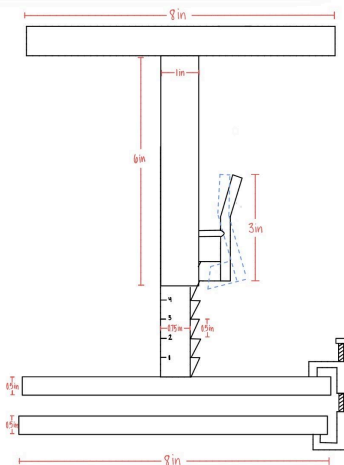
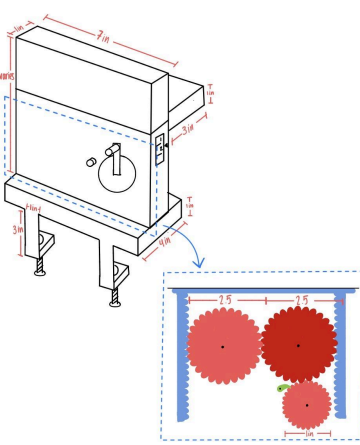
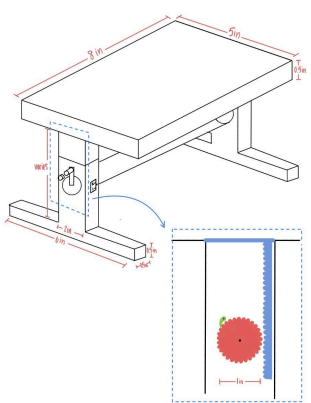
Figure 3. Rack-and-Pinion Stand, all dimensions in cm

This design adjusts using two sliding racks within the hollow legs, and corresponding fixed pinions attached via a central axle. To increase the height of this stand, the central axle is rotated, then locked in place using a spring-loaded pawl. To lower the height of the stand, a button is pushed to disengage the pawl. Height indicators are located on the back sides of the racks and can be seen through a cutout in the leg of the stand.

Preliminary Design Evaluation

Design Matrix

Table 1: Design Matrix

Design						
Criteria (weight)	<i>Figure 4. Lever Clamp Stand</i>		<i>Figure 5. Dual Rack-and-Pinion Clamp</i>		<i>Figure 6. Rack and Pinion</i>	
Efficiency of Adjustment (25)	4	20	5	25	5	25
Precision (25)	5	25	4	20	4	20
Stability (15)	4	12	4	12	5	15
Safety (15)	3	9	5	15	4	12
Cost (10)	5	10	3	6	4	8
Durability (10)	4	8	4	8	4	8
Total (100)	84		86		88	

Criteria Descriptions

Efficiency of Adjustment: Efficiency of adjustment is how quickly the design is able to be adjusted to fit an animal, and how much effort is needed to do so. To achieve this, designs must require minimal force to adjust, need a low number of rotations to reach peak height if a gear system is used, and be relatively low-weight. According to client specifications, the design should be able to be set up in under 5 minutes using only one hand.

Precision: Precision refers to the design's ability to consistently get the same measurements when adjusted to the same settings over multiple treatment sessions. To comply with this criterion, designs should have a stopper to hold the adjustment system at different heights, and a clear and reliable marking system, allowing technicians to note the adjustments and repeat them in the future.

Stability: Stability is the stand's ability to hold an animal's position under stress. Designs with high stability will have wide bases to prevent tipping, and clamps or other features that allow them to be attached to the table. Any sections of the stand will be secured tightly to one another to prevent wobbling or tilting.

Safety: Safety is the ability of the stand to minimize the risk of injury to the animal, technician, and other equipment during use. The stand should remain securely attached to the table and should not have sharp edges, exposed adjustment mechanisms, or components that could pinch the technician or animal. The stand's adjustment mechanism should also be secure to prevent unexpected dropping or movement of the bite block during treatment.

Cost: In the prototyping stage, the designs should be low cost. In the future, this project aims to distribute the device to veterinary clinics at a relatively low cost. Thus, if this product were to be mass-produced, it should maintain a low material cost and require a minimal amount of labor to manufacture.

Durability: Durability is the design's ability to maintain its original precision, ease of adjustment, and overall function over time. This means mechanical elements like gears and teeth should be resistant to wear or warping when under the forces of normal use, and the device as a whole should be able to withstand repeated use without cracking or breaking.

Design Scorings

Design 1: Lever Clamp Stand

The Lever Clamp Stand scored highly in precision, cost, and durability. The design scored highly in precision because its teeth only allow adjustment to discrete measurements, making adjustments easily repeatable over multiple treatments. This design also scored highly in cost due to its simple design, which resists wear and doesn't require parts to be replaced. Design 2 scored the same as the other two designs in durability because they will all be manufactured from the same material. This design scored lower in categories like stability and safety because its adjustment mechanism is less secure and more susceptible to sudden lowering.

Design 2: Dual Rack-and-Pinion Clamp

The Dual Rack-and-Pinion Clamp scored highly in efficiency and safety. This design was deemed highly efficient because of its quick and easy-to-use crank and auto-lock mechanism. Safety was also ranked highly because of its auto-locking and clamped base, which gives it a lower risk of tipping and injuring the animal. The durability of design 2 was ranked the same as the other two designs because they will all be manufactured from the same material. This design was ranked lower in precision and stability

because of its continuous measurement and its platform being on the side of the stand, rather than evenly across the top.

Design 3: Dual Rack-and-Pinion

The Dual Rack-and-Pinion design ranked highly in ease of adjustment and stability. This design was considered easy to adjust because of its simple crank and auto-locking mechanisms. It was ranked higher than the other designs in stability because of its wide-set design, which reduces the likelihood of tipping. This design was ranked lower in precision because of its continuous measurement, and equally to the other designs in durability because all designs will be made of the same material.

Proposed Final Design

Due to the above grading criteria, the Dual Rack-and-Pinion design was proposed as the final design. The design is easy to use, stable, as well as precise and safe to the standard set in our product design specifications.

Fabrication

Materials:

This product will consist mainly of two components: the adjustable height stand and clamp for the jaw, and the universal bite block for all sorts of animals. The primary function of the adjustable height stand is to lift the animal's head to a certain height so the rest of the body can avoid being affected by the CT scan. As a result, the height stand must be able to hold up the weight of the dog's head. As of now, PLA-CF is provided and can be used to create the stand.

The bite block element of this product has more specific requirements due to how materials are reflected in CT scans. High-density materials such as dental putties often show up on CT scans, leading to inaccurate results and scans that are hard to diagnose for cancer. Materials are flexible, but materials such as pure PLA have low density and may be a good choice of material.

Methods

Designs are first discussed with the team to determine which designs will fulfill most of the requirements given for the product: ease of adjustability and max weight load being the most important factors. After this process, the team will move on toward CAD design through SolidWorks/OnShape/Other CAD software.

Through CAD software, stress analysis will also be performed to determine the functionality of the prototype when a load equivalent to the weight of a dog's head is applied to the stand itself. After this stage is passed, physical testing of the prototype can begin.

In the physical testing stage of the prototype, ease of adjustment needs to be tested to ensure requirements are met: ease of adjustment with one hand that can set up the stand to a certain height within 5 minutes.

Final Prototype

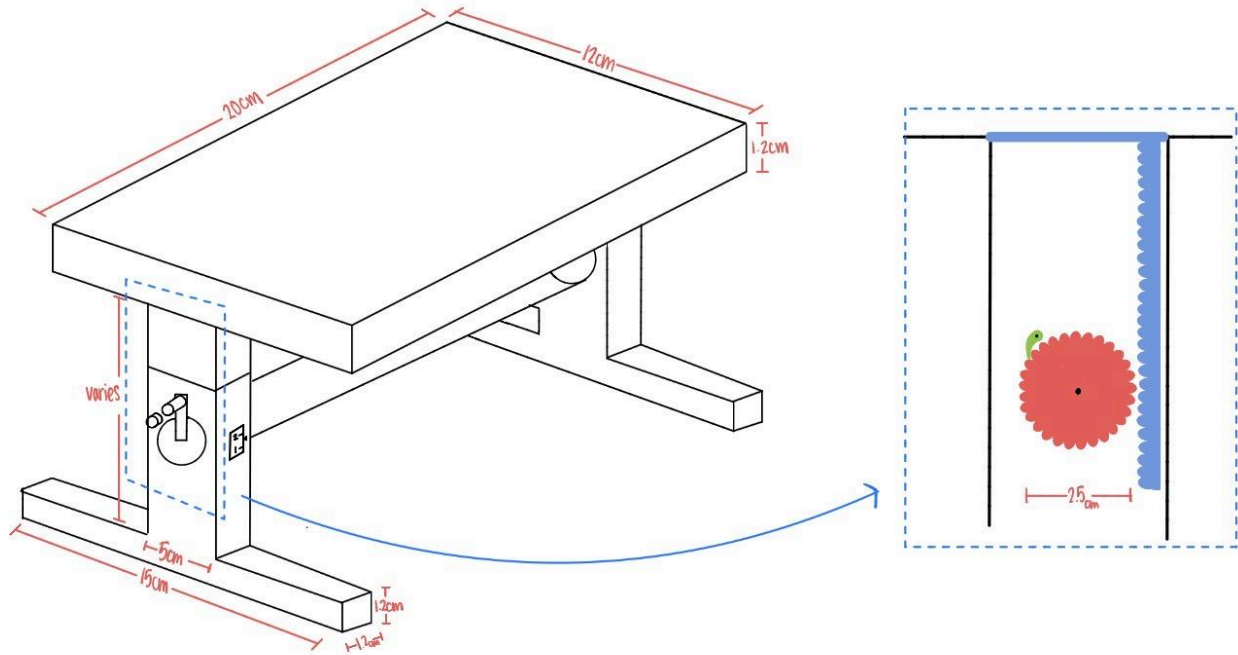


Figure 7. Dual Rack-and-Pinion Stand

Testing and Results

The next step of the fabrication process is to test the prototype to determine any changes that need to be made. As stated in the PDS, the stand should withstand a minimum of 66 N or roughly 7 kg [3]. In addition to the weight capacity, the stand needs to operate under 6 MV photon beams without yellowing or degradation and avoid being within +3000 – -600 Hounsfield Units to not impede the visibility of the radiation targets [4], [5]. Lastly, the adjustable parts should be able to withstand a minimum of 5000 cycles and precisely measure the height within ± 2.5 mm.

To test the weight capacity, SolidWorks load testing and in-person testing can be done. For the in-person testing, weights will be gradually added on top of the stand up to and past the target weight of 7 kg and the fracture weight will be recorded. Additionally, the deflection of the stand at different weights will be qualitatively described. For radiation exposure, the stand will be placed inside the linear accelerator radiation therapy machine and exposed to 6 MV photon beams. The conditions of the stand and the visibility of the stand on the x-ray will be qualitatively described. The adjustable parts will be tested for 5000 cycles of up and down motion. The height of each step will be measured to ensure that the recorded height is within the tolerance. The results of this testing will describe the total amount of force the stand can withstand, the effect of radiation exposure on the stand, the durability of the adjustable parts and the precision of the stepped parts of the stand.

Discussion

This device is designed to provide consistent and repeatable head positioning for animals undergoing CT imaging and radiation therapy. Compared with existing methods that use dental putty or animal-specific supports, the adjustable, reusable design aims to accommodate a wider range of animal sizes while maintaining stability and minimizing pressure on the teeth, jaw, and the endotracheal tube.

Ethical considerations include prioritizing animal welfare, minimizing discomfort, and ensuring veterinary oversight during testing. Materials should be durable, easy to disinfect, and compatible with imaging and radiation therapy. Evaluation results will guide design changes to improve stability, adjustability, and positioning accuracy. Potential sources of error include measurement inaccuracies, differences in animal anatomy, inconsistent technician adjustments, and movement of the device under load. Further testing and comparison with existing immobilization methods will help determine the device's safety, reliability, and clinical usefulness.

Conclusions

The goal of this project is to develop an adjustable, reusable bite block and stand that safely and consistently positions animals during CT imaging and radiation therapy. The final design, the Dual Rack-and-Pinion, ranked highly in ease of adjustment and stability due to its simple crank, auto-locking mechanisms, and wide-set structure that reduces the likelihood of tipping. However, its continuous measurement system ranked lower in precision. Moving forward, the prototype will be tested to evaluate its stability, positioning accuracy, and safety. The current design focuses on adjusting the stand's height, so future work will involve fabricating a universal bite block that attaches to the stand and accommodates a range of animal sizes. Testing will also determine whether the device can maintain the desired head position without placing excessive pressure on the teeth, jaw, or endotracheal tube. Future improvements will focus on increasing precision, refining the jaw supports, and incorporating feedback from veterinary professionals. Further testing will help determine whether the design provides a reliable and reusable alternative to existing animal head-immobilization methods.

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Appendix A: Product Design Specifications

Function

This device will allow radiation technicians to secure an animal's teeth and upper jaw into the correct position for radiation therapy. The device will be easily adjustable in both width and height to accommodate a large range of animal sizes, and these adjustments will be easily repeatable, allowing the animal's head to be put in the same position over multiple treatment sessions.

Client requirements

- Bite block stand adjustable to all breeds of dog and cat
- Components able to be adjusted with one hand
- Holds animal's head securely without use of dental putty
- Adjustments can be easily repeated

1. Physical and Operational Characteristics

a. Performance requirements

The bite block will have two round indents, adjustable to intercanine widths ranging from 12–65 mm and height from the table ranging from 0–15 cm [1], [2]. Technicians will be able to use one hand to make these adjustments, and setup for each animal should take under seconds. Each adjustment will have clear markings, allowing the technician to note and recreate the position of each animal over multiple treatment sessions. The device should withstand a downward force of 66 N distributed evenly onto both canine tooth indents [3]. All internal and external elements of the stand should be durable; this device is intended to be used multiple times a day for multiple days in a row, and should maintain its original adjustability and precision.

b. Safety

The FDA does not oversee or require approval for devices intended for animal use; however, care should still be taken to ensure the device does not pose any risk to the patient [4]. The device should be printed using non-toxic filament, and all mechanical elements should be contained or shielded from the area that will come into contact with the animal's mouth to prevent injury. The device must also have clear operation instructions to avoid misuse.

c. Accuracy and Reliability

This device's adjustable components will allow patient positions to be repeatable with a margin of ± 2.5 mm [5]. This device should retain this preciseness regardless of mechanical wear.

d. Life in Service

The stand should last 5 years. The track to control the intercanine distance and height should last 5000 uses.

e. Shelf Life

The stand should maintain structural and functional integrity during long-term storage. It should be stored at room temperature, in a dry area, away from large amounts of UV light.

f. Operating Environment

The stand will be used in both areas of diagnostic and treatment of cancerous tumors in cats and dogs. During use the stand will be exposed to X-rays, electron beams, disinfecting agents, and animal bodily fluids. The stand should be designed to withstand corrosion and degradation.

g. Ergonomics

The stand should be able to accommodate cats and dogs of various sizes by allowing adjustment to the height and size of the bite block. The adjusting mechanism should be accessible and easy to use allowing for a single person to adjust without the use of excessive force.

h. Size

The stand will need to be adjustable to heights within the range of 0 – 15 cm from the table to accommodate cats and dogs of various sizes. The bite block will need to adjust between a minimum size of 12 mm to a maximum size of 65 mm to fit various sizes of cat and dog canines [1], [2].

i. **Weight**

The stand should weigh no more than 3 kg to ensure that the operator can comfortably transport and operate the stand with one hand [6].

j. **Materials**

The bite block stand should be made out of carbon fiber PLA to reduce the amount of Z material used.

k. **Aesthetics, Appearance, and Finish**

The bite block and stand should be white to match other medical devices. The bite block and stand should have a smooth finish.

2. **Production Characteristics**

a. **Quantity**

This will depend on the mobility of the stand. If it's mobile on a cart, then a vet clinic would only need one. However, if they are stationary, then they may need one per CT or linear-accelerator.

b. **Target Product Cost**

There is no client-given budget, as the client will provide PLA and ABS if needed to print the prototype out on 3-D printers. The target product cost should be under \$100 because this product could be mass-produced.

3. **Miscellaneous**

a. **Standards and Specifications**

The device will be classified as a veterinary animal device because it is intended to physically position and immobilize dogs and cats during CT imaging and radiation therapy. The FDA regulates animal devices but does not require premarket approval, or establishment registration and device listing for devices intended exclusively for animal use [4]. The device will also follow relevant American Animal Hospital Association (AAHA) veterinary guidelines. The guidelines state that the head and neck should be stabilized when forces are applied in the mouth and that a mouth prop should not fully open the mouth or overextend the temporomandibular joint [6]. Because the device will be used in conjunction with CT imaging, the design should not interfere with the imaging process or introduce unnecessary artifacts into CT images. The FDA regulates CT systems as radiation-emitting products and medical devices, although these requirements primarily apply to CT equipment itself rather than external positioning devices [7]. Current AAHA oncology guidelines for dogs and cats emphasize that radiation therapy requires precise delivery of radiation to a defined target [8]. Therefore, the bite block should provide consistent and repeatable positioning of the animals head and jaw between CT imaging and radiation treatments while minimizing movement during treatment. The device should also be designed so that it does not obstruct the radiation field.

b. **Customer**

The client specified the need to set up the product quickly. Stands that are currently used require a long time to set up due to using screws to ensure lockage between each platform. The client wants to have an easy adjustable knob to set up the stand in a much quicker time alongside having an unique locking mechanism that prevents the platform from sliding or moving.

c. **Patient-related concerns**

The device will be designed to minimize discomfort and prevent injury to the animal's teeth, jaw, and surrounding tissues during anesthesia. The bite block should apply enough force to securely position the jaw without causing excessive pressure or jaw pain, and it should accommodate differences in jaw size between dogs and cats. The device should not interfere with the endotracheal tube or place pressure, tension, or displacement on the tube while the animal is positioned. Because the device will be used between multiple animals, it should be made from materials that can withstand sterilization or appropriate disinfection between uses without degrading. The device should also have smooth, non-irritating surfaces and minimize areas where saliva, blood, or other biological material could accumulate.

d. **Competition**

The client mentioned similar 3D designs online with a knob system that adjusts the height of a phone stand, and wants the design to have a similar mechanism. The knob must be pulled to be able to twist. Otherwise, the knob stays in place and can not be turned to ensure no random movement.

Citations

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