Design And Development Of Prosthetic Leg For Dog

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Abstract- *Prosthetic limbs have been a source of hope and quality of life improvement for individuals with disabilities. Over the past few decades, there has been an increased interest in the development of prosthetic limbs for animals, particularly for dogs. This research paper focuses on the design and development of prosthetic legs for dogs, highlighting the various materials and technologies used, as well as the challenges and benefits associated with prosthetic leg adoption in dogs. Prosthetic leg with a provision to adjust the height has been manufactured using 3D printer and thoroughly tested on Greyhound dog and observed that many of the features introduced at the design stage, enhances the quality of locomotion in the dog.*

Keywords- Prosthetic leg, Shaper3D, 3D modeling, 3D printing

I. INTRODUCTION

In recent years, prosthetic legs for dogs have become popular, offering a solution to pet owners who want to improve their dog's quality of life. However, designing prosthetic legs for dogs requires a thorough understanding of their anatomy, gait, and behavior[1]. The some of these dogs experience mobility issues due to accidents, bacterial infections, cancer, clot formation, severe arthritis, and paralysis, which may require amputation of a limb[2]. The loss of a limb can significantly impact a dog's mobility and quality of life. While some dogs may adapt to the loss of a limb, others may experience difficulties in movement, leading to physical and psychological distress[3]. Prosthetic limbs offer a solution to help dogs regain their mobility and lead an active life. Prosthetic limbs for dogs are typically designed to mimic the natural movement and structure of the missing limb while providing the necessary support and stability[4].This research paper aims to explore the design and development of prosthetic legs for dogs, the materials and technologies used, the challenges and benefits of prosthetic leg adoption in dogs, and future research recommendations.

Dogs have unique anatomical structures and movement patterns compared to humans. Current prosthetic designs often rely on adaptations from human prosthetics, which may not adequately address the specific needs and biomechanics of dogs[5]. There is a need for research focused on developing prosthetic leg designs that account for the variations in size, shape, and limb dynamics across different dog breeds and sizes[6] Dogs comfort and acceptance of prosthetic legs are crucial factors for successful rehabilitation and long-term use[7]. However, there is limited research addressing the comfort aspects of prosthetic legs for dogs. Further studies are needed to investigate the impact of different materials, padding, and harnessing techniques on the dog's comfort, skin health, and overall acceptance of the prosthetic limb[8]. There is an area to explore innovative materials, designs, and manufacturing techniques that can reduce the weight of prosthetic legs without compromising their structural integrity and functionality. Dogs engage in a wide range of physical activities, including running, jumping, and playing. Prosthetic legs should be designed to adapt to various terrains and dynamic movements[9]. There is a research gap in developing prosthetic legs with adaptive features, such as adjustable to the shock absorption mechanisms, and terrain-specific functionalities. Such advancements would enable dogs to maintain balance, navigate challenging surfaces, and engage in their natural activities with greater ease[10].

The long-term durability and maintenance requirements of prosthetic legs for dogs have not been extensively studied[11]. It is essential to investigate the wear and tear of the materials, the need for periodic adjustments, and the ease of maintenance for prosthetic legs in real-world settings. Understanding these factors will contribute to the development of prosthetic legs that can withstand the demands of everyday use and minimize the need for frequent repairs or replacements[12]. Addressing these research gaps will lead to advancements in the design and development of prosthetic legs specifically tailored for dogs.

The prosthetic available till now are made up of the materials like magnesium, aluminum, also some part of this prosthetic is made up of the materials like steel, cast iron, aluminum alloys. The materials like steel and cast iron are heavy to lift and it causes major problem while it is attached to the amputated part[13]. While titanium and carbon fiber are costly to create the prosthetic leg for the dog. Selecting the suitable and cost effective material for manufacturing the prosthetic can reduce the weight and make it easy to manufacture[14].Looking into the available literature it is observed that their is a scope for a design and development of lightweight, flexible, and durable prosthetic leg. An attempt is made in this paper to propose a innovative, flexible and adoptable prosthetic leg through tailor made design, analysis, manufacturing and testing. Newly proposed methodology can significantly improve the mobility, quality of life, and overall well-being of dogs with limb disabilities.

A. Categories of amputation

Amputation of a dog's leg is a surgical procedure that involves the removal of a limb in part or entirely. This procedure is commonly performed in dogs as a result of a variety of conditions such as bone cancer, trauma, and congenital malformations[15]. The decision to amputate a dog's leg is usually made by a veterinarian after considering the severity of the condition, the dog's overall health status, and the prognosis of the disease[16]. Dogs that have undergone amputation of a limb can still lead healthy, active lives with the aid of prosthetic devices or adaptations to their environment[17]. The prosthetic devices are custom-made to fit the dog's unique anatomy and can help restore the dog's mobility and balance. In addition, physical therapy and rehabilitation can be utilized to help the dog adapt to its new mobility status[18].

Fig.1: Full Amputation of Leg

Fig.2: Partial Amputation of Leg

II. DESIGNING THE PROSTHETIC LEG FOR DOG

The weight of the prosthetic leg must be light enough to not to impede the dog's movement. Heavy prosthetic legs can cause discomfort and muscle fatigue, leading to further complications[19].The size of the prosthetic leg must be appropriate for the dog's breed, size, and shape. An ill-fitting prosthetic leg can cause skin irritation, sores, and even infection[16,19].The material used for the prosthetic leg must be sturdy, durable, and lightweight. Materials such as carbon fiber and titanium are commonly used for prosthetic legs due to their strength and lightweight properties[20]. The prosthetic leg must be flexible enough to allow for a range of movement, including walking, running, and jumping[21].

While designing and developing the prosthetic it is important to consider the dog’s weight and size[22]. The weight of the greyhound dog will be in the range of 25-50Kg. The dimension of selected Greyhound dog leg length is 340mm and the diameter of the leg is 63.7mm. The prosthetic is design is designed in such a way it can fit to these specifications. To cover the amputated part of the dog leg the design should be made in such a way that it will cover the amputated part. Presently Greyhound dog of 25Kg is taken as the reference and design calculations are performed.This particular dog was partially amputated the leg. The amputation is done in the front side left leg. The selected dog has a height of around 73cm. This particular dog was partially amputated the leg. The amputation is done in the front side left leg. For this particular research Greyhound dog selected. The prothetic leg should be designed in such a way that it can actually adjust its as per the amputated part. Also while designing the prosthetic a due care is taken to accommodate light impacts shocks via selecting appropriate material.

Considering the designing parameters and particular type of amputation of leg are the major factors while developing the design. To develop this design, shaper3d software is chosen. On the workbench of the shaper3d at the bottom part is selected and then as per the dimensions of the amputated part design is started with drawing the two circles with inner diameter equal to 72 mm and outer diameter is 77.8 mm. Then selecting circular portion it is extruded up to 240 mm. Then the front plane of the design is selected and making a rectangular shape that part is subtracted from the total part to obtain the Pylon as shown in figure 3. Similarly the other parts like shank, shock absorber and chest plate are modeled figure 4. The second body part of the design is called the shank. The dimension of the shank taken are like inner diameter is 78mm, outer diameter 84 mm and the length of the shank equal to 150 mm. Through slot of dimension 100 mm* 5mm is made on the shank and the purpose is to adjust to the length of prosthetic leg when it is connected to the pylon. The length can be adjusted up to the 100mm. Another rectangular slots with dimensions 8 mm*40 mm are made into the Pylon and shank so that it can be connected to shock absorber separately. The dimension of the shock absorber at the bottom are arc of 80mm and it has the thickness around 8mm. The design of the shock absorber is figure 4. Connection of the body 1 as shank and body 2 pylon with connecting to the shock absorber part is shown in the figure 4.

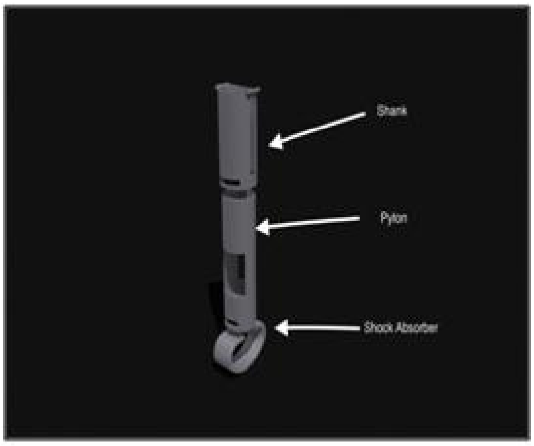

Fig.3: Partially amputated leg connection

For the connection between amputated leg and prosthetic is made through the chest plate which is actually covered with the bag for the connection between amputated leg and prosthetic. The final assembly constructed from pylon, shank, shock absorber and chest plate is shown in figure 4.

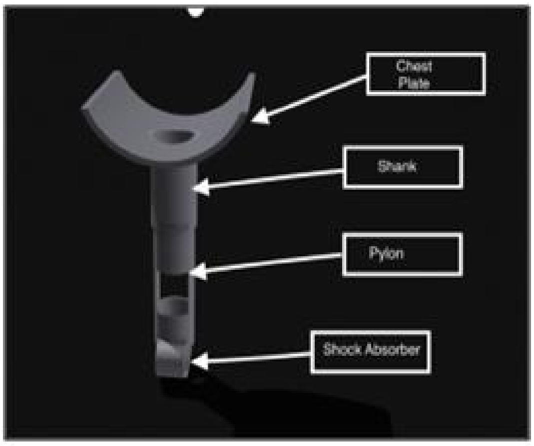

Fig.4: Assembly of prosthetic leg with fully amputated

III. MATERIAL SELECTION OF THE MODEL FOR THE ANALYSIS

The materials used in the fabrication of prosthetic legs for dogs include carbon fiber, titanium, and thermoplastics. Carbon fiber is a popular choice due to its strength, lightweight, and durability[11,12]. Titanium is also commonly used in prosthetic legs for dogs due to its high strength-to-weight ratio, biocompatibility, and corrosion resistance[13,15]. Thermoplastics are another material used in prosthetic legs for dogs due to their malleability, which allows for customization to the individual dog's needs. As per considering the price range for titanium and carbon fiber is high. Also to change shape of titanium is quite difficult due to which titanium is not suitable for the prosthetic development for dog.

Aluminum is the light weight material and can have the capacity to sustain the weight. Aluminum can be easily functioned to work in the environment. As dog behavior to bite the prosthetic can lead to the damage in the prosthetic if it is easily deformed. The first material. Is selected as aluminum for the stress analysis of the final design. Second material is selected as the PLA(Polylactic acid) because it is lightweight also when the developed prosthetic attached to the dog it create additional weight that body has to that’s why the prosthetic should be lightweight and the material does not create the major bruises on the attached area.PLA is a biodegradable material that is biocompatible, meaning it is not toxic to the human body and does not cause any adverse reactions.

IV. ANALYSIS OF THE PROSTHETIC LEG

To conduct the stress analysis, the model was imported from shaper3d software to Hypermesh software. Model was clean and properly format. To mesh the model automesh command is used and seven number of elements were selected. After meshing boundary condition were given as for static condition. Constraints are given at the bottom of shock absorber. The load is given for static condition is 490.5N. Then analysis is done for PLA and aluminum separately.

A. Results

The yield strength for the PLA is around 50-70MPa. The analysis of the prosthetic in the static condition is around 2MPa. From this result we can conclude that for the model to be failed in static require more loading.

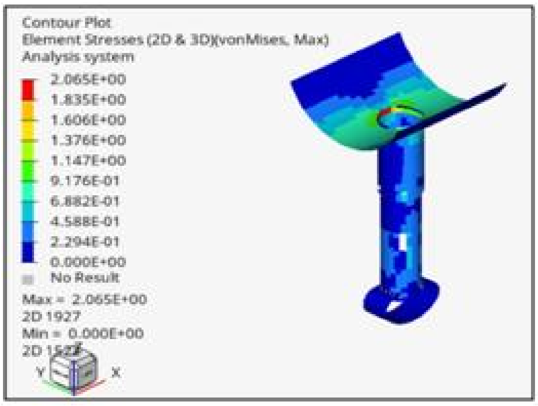

Fig.5: Analysis of PLA model

The yield strength for the aluminum is around 75MPa. The stress concentration for aluminum model is around 1.90MPa. From the analysis of the model came to the conclusion that model is within the stress limit as shown in figure 6.

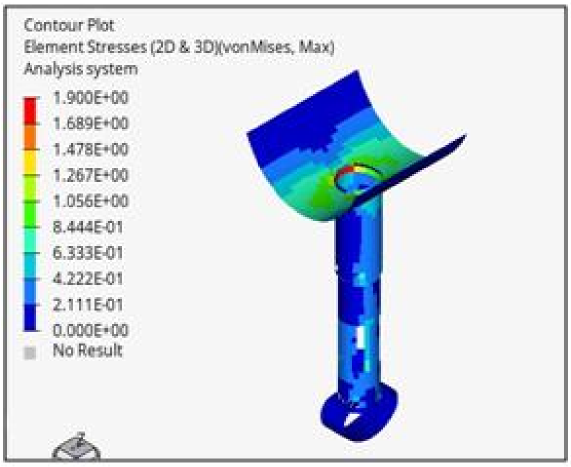

Fig.6: Analysis of Aluminum model

From the analysis came to the conclusion that both PLA and aluminum are within the elastic limit and both model will not fail under the static loading condition.

B. *Material selection between the Aluminum and PL*

The comparison between the PLA and aluminum about the yield strength aluminum has the maximum strength. The displacement for both materials is negligible. But aluminum is not bicompactible material while PLA is a biocompatible material. Also PLA can be easily 3D print. That’s why PLA is better material for manufacturing purpose.

V. 3D PRINTING OF THE FINAL DESIGN

As from the results PLA can sustain the loading. To manufacture the prosthetic Ender 3D printer is used. It has the build volume 220mm * 220mm *250mm. To manufacture the PLA prosthetic 0.4mm maximum layer height is used. The stp file of Shaper3d software is imported in to the simplify 3d software. Then each part of prosthetic is separately imported. Each part require different amount of PLA material for manufacturing pylon around 300gm of PLA is used. To manufacture all parts of prosthetic 1kg amount of PLA is required. Each part is separately manufactured. The amount of time required to manufacture the whole prosthetic part is around 144 hrs. The manufacture parts are shown in the figure 7 and figure 8.

Fig.7: 3D printed shank part

Fig.8: Pylon and shock absorber 3D printed

VI. TESTING

The PLA final model is attached to the Greyhound dog for the testing. The prosthetic attached to the leg shows the full support to the leg. While the testing the prosthetic on the dog it shows no bruises on the attached area.

Fig.9: Testing of the Prosthetic

Fig.10: Prosthetic supporting the dog

VII. RESULTS

The research conducted on designing and developing a 3D printed prosthetic leg for dogs demonstrated positive outcomes. The use of 3D printing technology allowed for customization, rapid prototyping, and cost-effectiveness in the creation of prosthetic legs. The results showed enhanced mobility and improved functionality for dogs with limb disabilities, thereby positively impacting their quality of life. This research contributes to the growing field of animal prosthetics and highlights the potential of 3D printing technology in improving the welfare of animals with limb disabilities.

VIII. CHALLENGES AND BENEFITS OF PROSTHETIC LEG ADOPTION IN DOGS

While prosthetic legs offer numerous benefits, they also present challenges in their adoption. One of the significant challenges is ensuring the prosthetic limb is compatible with the dog's anatomy and provides the necessary support and stability. Additionally, some dogs may experience discomfort, irritation, or pressure sores with the use of a prosthetic limb. Proper fitting and adjustment of the prosthetic limb are critical to avoiding these issues.

The benefits of prosthetic leg adoption in dogs include improved mobility, quality of life, and overall well-being. Prosthetic limbs can provide dogs with the ability to perform everyday activities such as walking, running, and playing. Furthermore, prosthetic limbs can reduce the risk of developing secondary health issues such as muscle atrophy and joint problems. Considering these challenges and benefits their is necessary amount of improvement can be done.

IX. FUTURE RESEARCH RECOMMENDATIONS

While significant progress has been made in the development of prosthetic legs for dogs, there is still room for improvement. Future research should focus on developing prosthetic legs that are more comfortable, lightweight, and affordable. Additionally, the development of advanced technologies such as sensors and microprocessors. Bionic legs have a significant impact on the replacement of the amputated part. But the cast of the particular leg exceed significantly while developing these type of leg. Soft robotics can help to comfort, natural movement, adaptability, sensory feedback, lightweight design, and customization, the development of prosthetic legs for dogs can be significantly improved. The integration of soft robotics into dog prosthetics holds great promise for enhancing the mobility, quality of life, and overall well-being of dogs with limb disabilities.

X. CONCLUSION

Designing and developing prosthetic legs for dogs that have undergone full or partial amputation of their front leg is an important area of research that requires consideration of the unique anatomy and biomechanics of the canine limb. Customized prosthetic devices using 3D printing technology, lightweight materials, and advanced sensors and control systems show promise in improving the mobility and quality of life of dogs following amputation. Additionally, physical therapy and rehabilitation are critical components of the overall treatment plan for these dogs.

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