Puppy Prosthetics: A Method for Mobility Rehabilitation Implementing 3D Design

Literature Review

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Abstract

Many severe injuries can restrict blood circulation to specifics parts of a body. This causes the blood vessels to become damaged, which renders the limb to be functionless. The unworkable limb is then amputated since it serves no benefit to the body. Currently, a plethora of diverse prosthetic technologies exist and continue to be developed to help rehabilitate human amputees after their amputations. 3D printed technology is becoming a more common component of human prosthetics due to its versatility and cost efficiency.

Unfortunately, many small, domesticated animals also experience extreme injuries which require an amputation. The current scope for veterinary prosthetics is small, which leads to an increase in detrimental health problems for animal amputees. This literature review will present current research that has been conducted on both human and animal amputees, as well as emphasize the similarities in fundamental concepts of human and animal biomedical technology which can be utilized to design effective animal prosthetics.

Keywords: amputations; prosthetics; veterinary medicine; mobility; gait

Puppy Prosthetics: A Method for Mobility Rehabilitation Implementing 3D Design Literature Review

After a body sustains a major injury that cuts off blood flow to an area of the body, the blood vessels become damaged and unable to function properly. An amputation, the removal of a limb, is then required to keep the patient alive and healthy. Many amputees then go on to obtain a prosthetic in place of where their natural limb previously was. A prosthetic is an umbrella term for any assistive technology device that mimics and takes the place of a body part or limb. For humans, a plethora of diverse prosthetic devices are currently readily available .As time progresses, human prosthetics are becoming better at emulating real limbs due to advancing technology and integration of new biomedical engineering techniques (Cherelle et al., 2017). One example includes using bionics to optimize the actuators and power sources that are commonly utilized in various prosthetic body parts (Cherelle et al., 2017).

Contrastingly, prosthetics for domestic animals have not been developed as extensively. Many animals, mostly dogs, must receive amputations due to accidents, such as being hit by a car. Unfortunately, most are not able to get fitted for a prosthetic or brace due to the lack of accessible and affordable devices for dogs, leading to many detrimental health implications in the future.

Human Prosthetic Technology

Currently, there is a diverse selection of technologies and versions of human prosthetics available for various parts of the body. A large amount of research and development has already been done because research and development on human prosthetics have a wide scope since a variety of body parts can be safely amputated off a person. This led to the development of many

different prosthetics that cater to different patients that meet unique conditions. Additionally, while conducting research on prosthetic performance, running trials yields useful data since scientists can receive immediate feedback from their test subjects (Cutti et al., 2017). This is viable for scientists since one of the main goals for any prosthetic is to improve the comfort and quality of life of the amputee. It is simple to emulate scenarios where the prosthetic will have to work (Sekine et al., 2013). Human prosthetics still have room for improvement, specifically regarding cost and ability to emulate human touch, however, their overall functionality is strong and consistent (Resnick et al., 2014). A significant amount of time and resources are devoted to further advancing human prosthetics which allow for significant scientific breakthroughs in niche areas of movement.

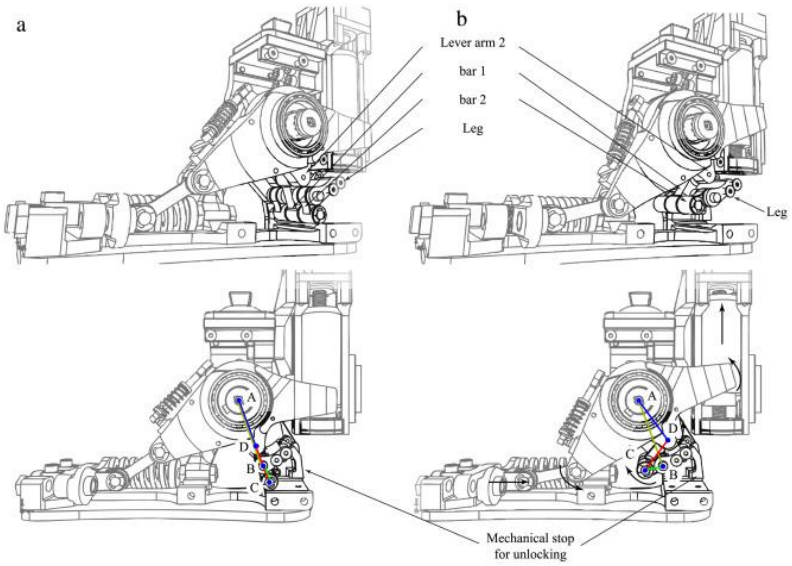

Figure 1: An orthographic sketch of a human foot prosthetic (Cherelle et al., 2017)

For example, Figure 1 shows how ankle prosthetics have been optimized to accurately imitate the motion of a foot pointing away from a leg, plantarflexion, and the movement of a foot pointing towards a leg, dorsiflexion.

Furthermore, human prosthetics are also accessible to the general population in North America (Cutti et al., 2017). This allows human amputees to receive their respective assistive devices quickly, allowing them to regain their mobility and independence in a timely manner after sustaining their injury and amputation.

Current Scope for Veterinary Prosthetics

Although not common, a few prosthetics for small, domesticated animals have been developed, particularly for common house pets such as cats and dogs.

Figure 2: Current available front limb brace for dogs (Animal Ortho Care)

The concept of these small animal prosthetics is very similar to human prosthetics. Furthermore, studies have proven that providing a cat with an artificial limb in place of where they originally had their natural limb improves their ability to walk at ease and increases their speed to be more like their pace to before they had to get an amputation (Jarrell et al., 2018). As shown in Figure 3, the gait, the pattern of cyclical limb movements, of the cat also returned to normal once implementing a prosthetic.

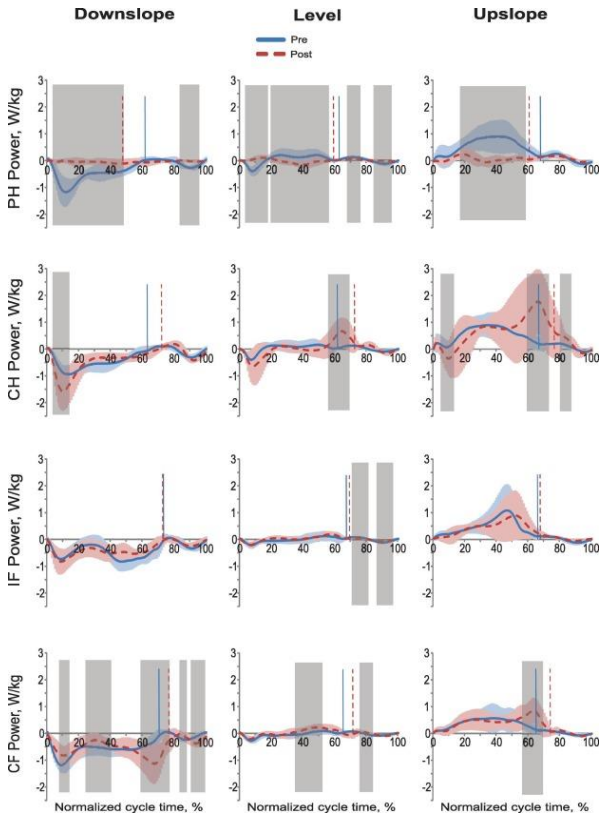

Figure 3: Analysis of a feline's walking cadence with and without a prosthetic (Jarrell et al., 2018)

Similarly to humans, dogs are also very adaptive and can adjust to physical changes and learn new skills. This means that they are completely capable of acclimating to the addition of new limbs after losing their original ones (Drygas et al., 2008). Therefore, there is no physical limitation for small animals regarding human prosthetics. A few companies design and sell prosthetics and braces that can be custom ordered for someone's pets. Since these assistive technology devices must be made individually for each client, it is a lengthy process to get the prosthetic, usually taking multiple weeks. Furthermore, the prosthetics are made custom for each client using expensive materials such as thermoplastics (Animal Ortho Care). This leads to increased expenses for animal owners. Custom animal prosthetics can cost upwards of hundreds

of dollars (Animal Ortho Care). Unfortunately, many animal owners simply cannot afford to provide these technologies for their pet.

Problems Resulting from Veterinary Amputations

Sadly, the lack of accessible and affordable prosthetics leads to many detrimental health complications for domestic animals. Some side effects include, but are not limited to weight gain, restricted mobility, and premature euthanasia (Jarrell et al., 2018). The main health problem for dogs is restricted mobility. Based on their anatomic structure, dogs rely on all four limbs to balance and move properly (Drygas et al., 2008). So, when a critical aspect of their movement is removed from their body, dogs are unable to walk, run, and move properly. Another common side effect is weight gain, which is a result of restricted mobility. The small animals, specifically dogs, are not able to be as active as they once were which causes their weight to increase. Since the dogs cannot exercise properly, it is difficult for them to return to a healthy weight. All these various health complications can lead to premature euthanasia, when a dog passes away due to the administration of drugs into their bloodstream via a shot (Jarrell et al., 2018).

Veterinarians chose to do this in only dire situations, when living is too painful for the dog. So, the lifespan and life quality of an amputated small animal is correlated with their access to a prosthetic. Like dentistry and acupuncture, many biomedical concepts can be translated from humans to animals. Similarly, principles of human orthotics and prosthetics can be implemented in animal versions. Dogs who have prosthetics have increased mobility and less pain in comparison to amputee dogs who do not (Mich et al., 2014).

Current 3D Printed Prosthetic Technology

Implementing 3D printing strategies is becoming increasingly popular in prosthetic sciences. 3D printed items are made of plastic and they are designed using a CAD (computer aided design) software. The design made in the CAD software is sent to the 3D printer, which then uses that input to print a three- dimensional model of the design layer by layer. 3D printing is cost friendly, since plastic filament is readily available and easy to purchase, as well as an efficient way to quickly create mechanical parts. 3D printed components are also a convenient way to customize prosthetics. Multiple designs can be modeled and manufactured relatively easily, which is useful to create separate prosthetics that are optimal for different and diverse activities, demonstrated in Figure 4 (Liacouras et al., 2017).

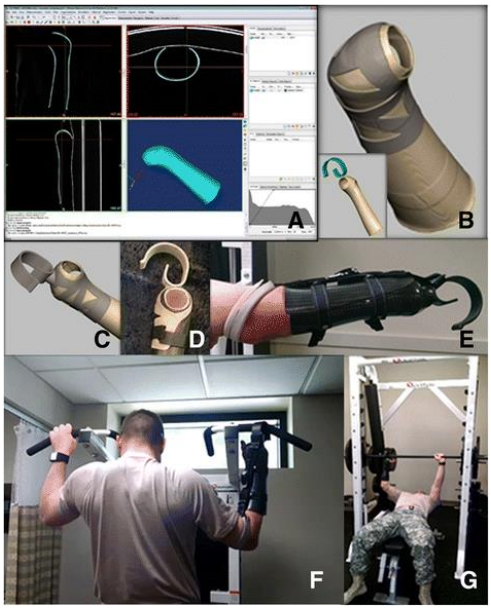

Figure 4: Process of 3D designing a weightlifting prosthetic for an amputee (Liacouras et al., 2017)

Most commonly, 3D printed components are used in addition to other expensive materials, such as metal alloys, which reduces the cost of prosthetics, but they are still expensive (Liacouras et

al., 2017). Since animal prosthetics do not require as much fine motor control capabilities, 3D printing is an excellent method to utilize to help disabled animals. 3D printed biomedical technology has already been implemented in other assistive devices as well, such as in artificial canine eyes (Park et al., 2020).

Conclusion

This literature review has explained the background of why amputations are a necessary medical procedure in both humans and animals. There is a need for prosthetics to be more commonly available for animals, specifically small animals such as dogs. Small animals sustain many major injuries that lead to the need of an amputation. The lack of prosthetics causes many medical complications for the animals, the most common one being restricted mobility, which ultimately leads to their untimely death. Prosthetics and other assistive technologies for humans has been developed deeply, yielding a wide variety of prosthetics that cater to a diverse range of amputees. Many human medical concepts and practices can be, and currently are applied and recreated during veterinary procedures. Which means that the bionics and technology from human prosthetics can be implemented in dog prosthetics as well. An emerging field of interest in orthotic engineering is 3D printing. 3D printing is an efficient and cost-effective way to design diverse and custom mechanical components. Currently, 3D components are implemented in human prosthetics, and they are starting to become more popular in the veterinary spectrum. By implementing these techniques and findings in the design for and small animal (dog) prosthetic, the mobility and quality of life will be improved for the animal.

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