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Ergonomic Wheelchair for Paraplegic Dogs with Resting Mechanism

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ABSTRACT

After the development of specific wheelchairs for dogs, the quality of life of these animals with locomotor disabilities has improved considerably. However, even with the many benefits provided to dogs, canine wheelchairs can present some inconveniences to the animals that use them. An example of this is conventional wheelchairs, which do not have a resting mechanism, causing the animal to spend a long time without resting, which veterinarians consider to be very harmful to the health of the disabled animal. In light of the described problem, this project consists of the study of canine wheelchairs and the development of a wheelchair prototype with a resting mechanism so that the animal can rest without being removed from the chair, aiming to provide greater comfort to the animal and practicality to the owner. Additionally, the report presents the choice of ideal materials to be used in wheelchairs for dogs, in order to provide better ergonomics and experience for the animal during the use of the product. Finally, the use of rapid prototyping in the production of some parts made in 3D printers is also detailed in the report, along with presenting the assembly processes of the wheelchair prototype.

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Introduction

Since the development of wheelchairs for dogs, the product has become more commonly used, as this device has the ability to assist animals that have difficulty walking or those that have lost the ability to move their paws. Although canine wheelchairs are relatively recent innovations, these products have evolved over time, ranging from the diversification of materials used in the chairs to the various methods of production.

Nowadays, the materials most commonly used to make canine wheelchairs include PVC (polyvinyl chloride) and aluminum tubes and connections. These materials are chosen for their malleability, light weight, and low cost, which facilitate easy handling for the animal and provide comfort [1].

While wheelchairs assist animals with locomotor problems, certain precautions must be considered when using this product. These precautions include: never leaving the animal unattended while in the chair to prevent tipping over or getting stuck; introducing the use of the wheelchair gradually, as some animals may initially feel uncomfortable; monitoring the dog for any signs of pressure points or injuries; ensuring that dogs without motor activity do not allow their front or back limbs to make contact with the ground while using the wheelchair; and ensuring that the assistance mechanism does not hinder the animal's ability to fulfill its physiological needs, keeping the equipment clean of any impurities [2, 3].

Some dog breeds are prone to developing locomotor problems, such as the Dachshund breed. Animals of this breed represent 45% to 73% of all cases of dogs with acute disc extrusion. Dachshunds are 12.6 times more likely to develop a herniated intervertebral disc than other breeds, followed by the Pekingese, Beagle, and Cocker Spaniel, which are, respectively, 10.3, 6.4, and 2.6 times more likely to develop the disease [4].

Currently, several companies manufacture wheelchairs and prosthetics for dogs with disabilities. According to, some of the most popular wheelchair models and companies available on the market include Walkin' Pets wheelchairs from HandicappedPets, VetCar wheelchairs, models produced by the VidaSobreRodas atelier, devices developed by Dog Locomotion, and the 'Amigo' chair designed by engineer Nir Shalom in 2011 [5]. However, it's worth noting that the 'Amigo' model is still a prototype and is not available for sale. In addition to the aforementioned chairs, there are several other models produced using rapid prototyping.

Considering the enhanced quality of life for dogs utilizing wheelchairs, the requisite care, the prevalence of Dachshund dogs concerning locomotor disabilities, and the existing wheelchair models on the market, the project aims to introduce a wheelchair model tailored for Dachshund dogs. This model will incorporate a resting mechanism that can be activated by the animal itself, thereby enhancing its independence and comfort while using the device.

Theoretical Frameworks

In this chapter, the studies and research conducted on locomotor problems in dogs and their impact on the animals' lives will be presented, along with research on wheelchairs and their benefits for dogs utilizing this equipment.

Canine Mobility

Dog mobility refers to the process in which an animal moves from one geographic point to another, encompassing changes in direction, speed, inclination, as well as the initiation and cessation of movement. The term 'normal gait' describes the process of moving forward efficiently, with minimal energy expenditure. Therefore, any deviation from this pattern can be considered an abnormal gait pattern [6].

According to, the daily activities of animals, such as locomotion, depend on the condition of the neurological system, including the brain, spine, nerves, and muscles [2]. This system facilitates communication and interactions with the surrounding environment. This communication occurs through stimuli between the brain and the body, which are transmitted through nerves connected to the spine and ultimately reach the muscles, forming the central nervous system. Consequently, any trauma to the neurological system can disrupt nerve communication, leading to issues with body movements [2].

Locomotor Disabilities in Dogs

According to, there are specific terms that describe mild and severe loss of movement in dogs [5]. defines paresis and paralysis as the loss of movement resulting from voluntary motor dysfunction, typically originating from conditions rostral to the foramen magnum [7]. Loss of voluntary motor function in all four limbs is termed quadriparesis or quadriplegia. Partial or complete loss of movement in the pelvic limbs is referred to as paraparesis or paraplegia. When there is loss of movement in a single limb, it is classified as monopoiesis or monoplegia [7].

According to, there are various reasons that can lead to a dog becoming paraplegic, along with several methods to help the dog cope with the disability [3]. The spinal cord plays a crucial role in a dog's ability to move, containing a network of nerve tracts that are susceptible to injuries and pressure (Figure 1 illustrates the canine spinal cord).

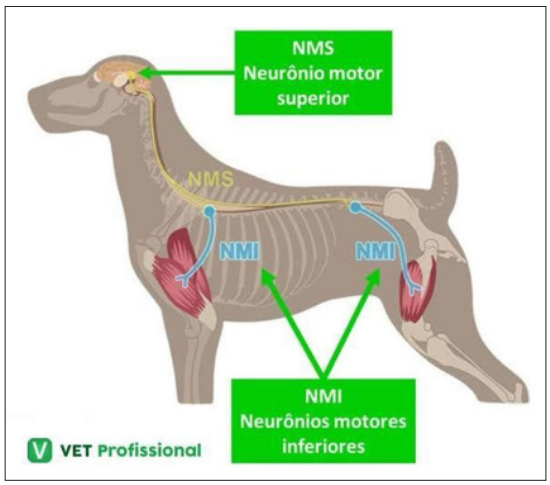

Figure 1: Dogs Spinal Cord

Source: https://cptstatic.s3.amazonaws.com/imagens/enviadas/materias/materia27296/neuro nios-motores-cao-vetprofissional.jpg.

Among the causes of paralysis in dogs, one of the most common is directly related to disorders of the spinal cord and spine, with IVDD (intervertebral disc disease) being the main culprit. Figure 2 shows the breeds that are most likely to develop this problem. Intervertebral disc disease (IVDD), as illustrated in Figure 3, is a neurological syndrome characterized by degeneration or injury to the intervertebral disc (IVD), which can lead to compression of the spinal cord. Certain dog breeds are more predisposed to developing IVDD, particularly small breeds with the chondrodystrophic condition [2, 8].

RAÇAS COM MAIORES CHANCES DE SOFREREM A DDIV
Dachshund
Pequinês
Beagle
Cocker Spaniel
Bulldog Francês
Bulldog Inglês
Lhasa Apso
Basset Hound
Shih Tzu
Wesl Corgi

Figure 2: Breeds with Greater Tendencies to Develop IVDD Source: [2].

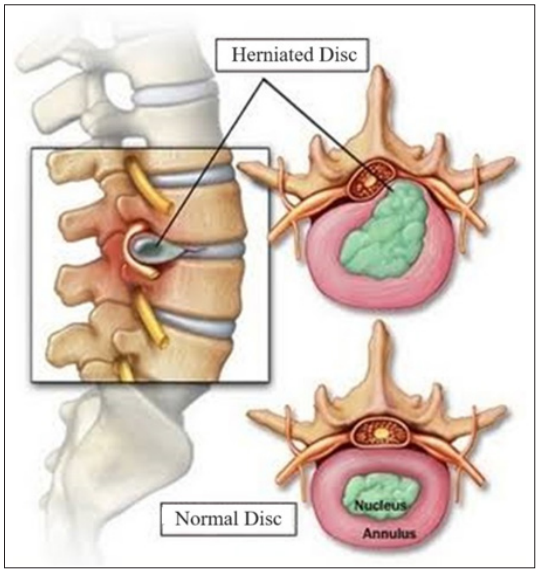

Figure 3: Intervertebral Disc Disease (IVDD)
Source: https://clinipet.com/admin/Uploads/herniadisco.jpg.

According to, Dachshund dogs are predisposed to certain back problems that can lead to paraplegia. Dogs of this breed have long bodies, and their bones tend to grow curved instead of straight (see figure 4) [3]. Additionally, the discs in their backs are fragile and susceptible to herniation, which can injure the spinal cord. When the spinal cord is impacted by the disc material, it can lead to swelling and even occlusion, resulting in paralysis.

Figure 4: Dachshund Skeleton
Source: https://i.pinimg.com/originals/38/5f/fe/385ffeef18cc59574917c90fdc874228.png.

Spinal cord injuries in dogs and cats can occur due to exogenous or endogenous causes. Endogenous injuries typically result from the protrusion or extrusion of intervertebral discs, pathological fractures, instability, and congenital abnormalities. Exogenous injuries, on the other hand, result from trauma such as automobile accidents, falls, injuries caused by objects or other animals, and firearm injuries [9].

In addition to IVDD and spinal cord injuries, another disease that can affect a dog's locomotor system is visceral leishmaniasis, an infectious disease with acute or chronic progression, leading to muscular atrophy [6]. Degenerative myelopathy, a slowly progressive disease, affects the long tracts of the thoracolumbar spinal cord. Figure 5 illustrates the breeds most likely to develop this condition. This disease primarily affects large dogs, typically German Shepherds (Figure 6), and crossbreeds [7].

RAÇAS COM MAIORES CHANCES DE SOFREREM MD
Pastor Alemão
Wesl Corgi
Husky Siberiano
Boxer
Poodle Miniatura
Chesapeake Bay Retriever
Leão-da-rodésia

Figure 5: Breeds with Greater Tendencies to Develop DM
Source: [2].

Figure 6: Dog Affected by Degenerative Myelopathy
Source: https://caes.silfrohn.pt/wp-content/uploads/2021/04/transferir-1.jpg.

Another disease that can affect the canine locomotor system is distemper, an infectious and highly contagious disease. This illness can manifest as clinical or subclinical infections, with symptoms involving the respiratory and gastrointestinal tracts, sometimes accompanied by neurological symptoms. Hip dysplasia (Figure 7), a common condition, is characterized by abnormal development beginning with a genetic predisposition and subluxation of immature hip joints, resulting in poor congruence between the acetabulum and the head of the femur. This condition interferes with normal development and places excessive stress on the articular cartilage [7].

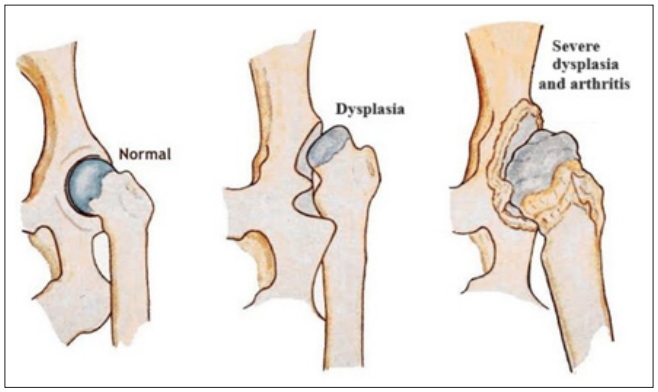

Figure 7: Hip Dysplasia in Dogs
Source: https://dranimal.com.br/wp-content/uploads/2022/07/displasia-coxofemoral.png.

In addition to the mentioned diseases, other traumas that can cause locomotor disorders in animals include ligament ruptures, dislocations, osteochondritis, disc herniations, neoplasms, arthritis, aseptic necrosis of the femoral head, meniscal injuries, and numerous other related pathologies. These conditions can vary depending on the breed, size, and age of the animal [5].

Use of Wheelchairs in Dogs and Its Benefits

When an animal's health problem becomes irreversible, resulting in the loss of sensitivity from deep pain caused by paralysis, it affects both the dog's and its owner's quality of life [2]. According to, in the past, euthanasia was often considered when a dog faced an injury or health issue that rendered it unable to walk [3]. However, with the development of wheelchairs specifically designed for dogs, instances of euthanasia have significantly decreased. A wheelchair can help a dog regain mobility and enjoy a relatively normal, pain-free life.

According to, there are various types of wheelchairs tailored to different needs [3]. states, 'There are wheelchairs for amputee dogs, dogs paralyzed due to stroke (FCE), older dogs with weak hind limbs due to arthritis and hip dysplasia, and dogs with more obscure neurological diseases such as cerebellar hypoplasia,' says Leslie Grinnell of Eddie's Wheels, a company specializing in designing and manufacturing wheelchairs for animals [2]. Wheelchairs for dogs can feature rear wheels, front wheels, or even quad wheels, depending on the animal's condition (see Figures 8, 9, and 10).

A dog unable to move or experiencing difficulty in movement may suffer pain and discomfort, leading to depression and dependence. Additionally, lack of exercise due to immobility can result in weight gain, increased weakness, and even muscle atrophy. 'A dog wheelchair gives your dog the ability to regain their independence and joy in life,' says Leslie. Furthermore, a wheelchair should be

made from lightweight and durable materials, such as aluminum, and should be easy to use, maintain, and clean [3].

Figure 8: Dog Wheelchair with Rear Wheels
Source: https://www.smartvet.com.br/wp-content/uploads/2018/11/small-walkin-wheels-1.jpg.

Figure 9: Dog Wheelchair with Front Wheels
Source: https://cdn-5f1347a4c1ac1811a414a189.closte.com/wp-content/uploads/2017/07/ca deira-de-rodas-frontal.jpg.

Figure 10: Dog Wheelchair with Four Wheels
Source: https://s35949.pcdn.co/wp-content/uploads/2017/02/cadeira-de-rodas-para-cachorro
-ideias.jpg.

Methodology

Search Classification

According to the 'Guidelines Manual for Research Projects', this project is classified as technological, qualitative, explanatory, experimental, and field research [10].

The classification of the project as technological research is determined by its involvement in the construction of a prototype wheelchair for dogs. Regarding the approach, the research is considered qualitative because it incorporates subjectivity rather than solely relying on statistical parameters. As the project aims to explain, analyze, and evaluate the functioning of a prototype, it is classified as explanatory in terms of objectives. Furthermore, the project involves modeling a wheelchair for dogs with a resting mechanism, which underwent testing; therefore, it also incorporates the technical procedure of experimental research. In conclusion, concerning the location, the project is classified as field research, also known as in situ research, as it is subject to local variables without changing the location.

Continuity Project

In 2022, the author conducted the project 'Virtual Model for an Ergonomic Wheelchair for Dogs', which serves as the foundation for this project. In the previous year's study, a wheelchair model was developed that allowed the owner of a dog with pelvic limb locomotor disability to adjust the chair's position, enabling the animal to either walk or lie down (see Figures 11 and 12). Additionally, a questionnaire comprising five questions regarding canine wheelchairs was administered in the previous year's project. Initially, the questionnaire was distributed to an agricultural and pet shop in Sapucaia do Sul. However, due to the specific nature of the questions, it was not feasible to collect responses. Subsequently, the questionnaire was forwarded to a veterinary hospital in Novo Hamburgo, where two veterinarians provided responses.

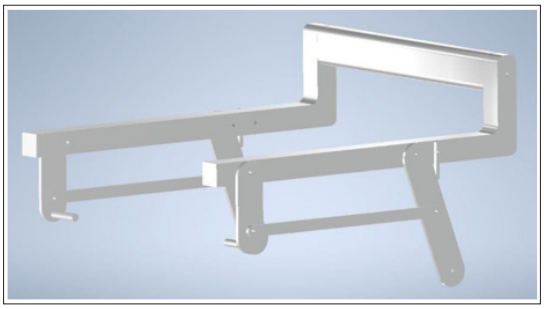

Figure 11: First Prototype Model Made at Autodesk Inventor
Source: The author (2022).

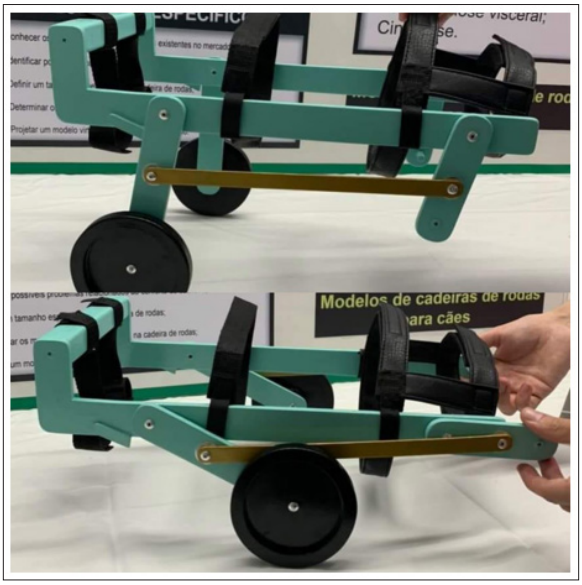

Figure 12: Wheelchair Model Manufactured with MDF
Source: The author (2022).

The material for the wheelchair structure will continue to be aluminum, as determined in the previous project, due to its lightweight and durable properties. With ergonomics in mind, the fabric components securing the animal to the chair will be made from neoprene fabric.

The dimensions of the wheelchair will also remain unchanged, as Dachshund dogs are more prone to developing locomotor problems (Figure 13 illustrates the general measurements of a Dachshund, which served as the basis for the prototype wheelchair dimensions).

Medidas (cm) / Categoria	*Dachshund Standard*	*Dachshund Kaninchen*
Altura	25	20
Comprimento	51	38
Largura	18	16
Circunferência peito	40	29
Circunferência pescoço	30	26
Circunferência coxa	25	22

Figure 13: Medidas Gerais De Um Dachshund
Source: [2].

Virtual Modeling
To determine the appearance of the prototype model for construction, drawings of the parts were created using Autodesk Inventor software, followed by assembly of the virtual project.

Lateral Structure
Initially, the design of the chair's side structure was created, consisting of two separate parts (see figures 14 and 15), each featuring a slot in the upper part to allow for the operation of a width extension system, which can be adjusted according to the size of the animal. Additionally, two holes were incorporated on the side of the mold to attach the support for the chair's wheels, along with a travel limiter.

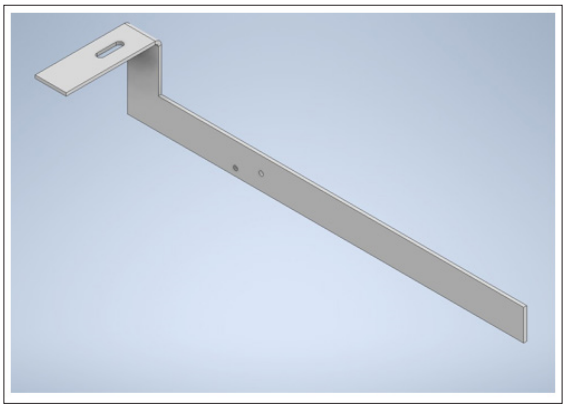

Figure 14: Prototype Side Structure (side 1)
Source: The author (2023).

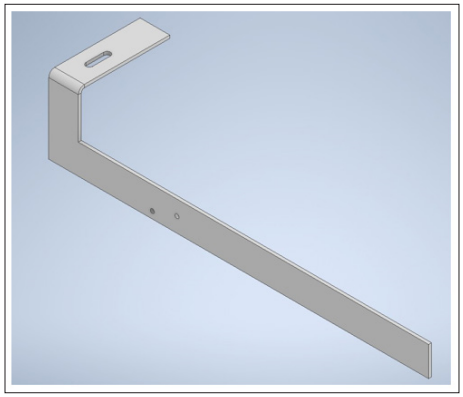

Figure 15: Prototype Side Structure (side 2)
Source: The author (2023).

Top Plate
The upper plate (see figure 16) serves to connect the two parts of the chair's side structure. The two holes above the plate serve both to join the pieces and to facilitate the operation of the width extension system.

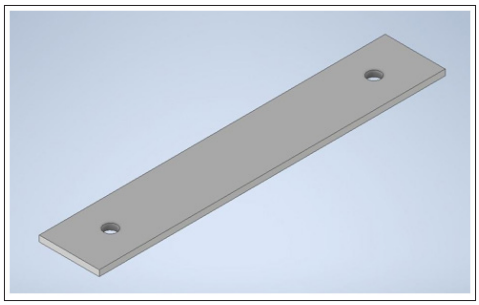

Figure 16: Prototype Top Plate
Source: The author (2023).

Wheel Support
This support (see figure 17) is attached to the sides of the wheelchair prototype. The upper hole is where it connects to the side structure of the chair. The middle hole houses the ratchet latch. The chair's wheels are fixed to the lower hole via an axle.

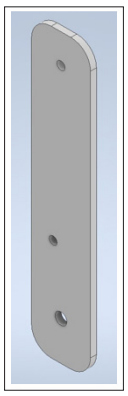

Figure 17: Wheel Support
Source: The author (2023).

Wheels
For improved functionality, the wheelchair wheels (see figure 18) were designed with a recess to accommodate a bearing. Additionally, the prototype wheels feature a notch at the top. This slot allows for the insertion of a rubber mat in the area where the wheel contacts the ground, enhancing traction and aiding the operation of the resting mechanism. Considering the uneven

terrain that a disabled dog may encounter, the size of the prototype wheels was determined to be 125 millimeters in diameter, without accounting for the thickness of the rubber mat to be used.

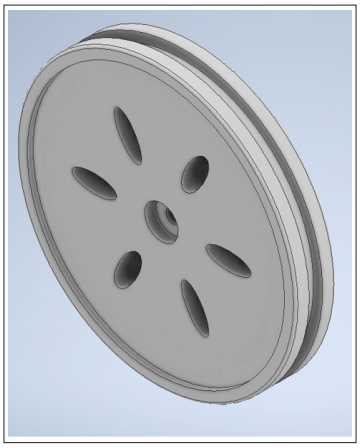

Figure 18: Prototype Wheel
Source: The author (2023).

Spacers

The function of the spacers (see figure 19) is to prevent friction between the wheels and the side structure of the chair.

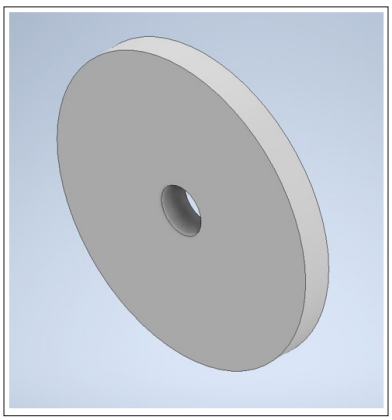

Figure 19: Spacer
Source: The author (2023).

Ratchet Mechanism

The ratchet mechanism of the wheelchair prototype (see figure 20) are positioned adjacent to the wheels, meaning they rotate in the same direction (clockwise or counterclockwise) and in accordance with the intensity of rotation of the wheels.

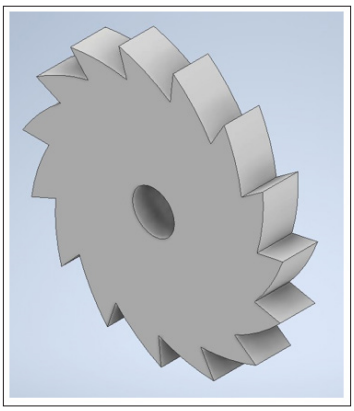

Figure 20: Ratchet Mechanism
Source: The author (2023).

The wheelchair's locks (see figure 21) serve to secure the ratchets and, consequently, the wheels, based on the direction of rotation, thereby enabling the chair to assume a resting position.

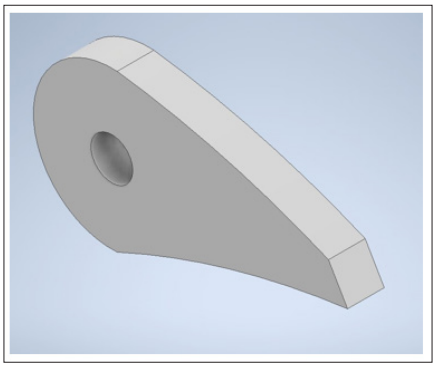

Figure 21: Pawl
Source: The author (2023).

The purpose of the stroke limiters (see figure 22) is to prevent the wheel supports from rotating backward. In other words, these components ensure that the wheelchair prototype is in the correct position for proper locomotion.

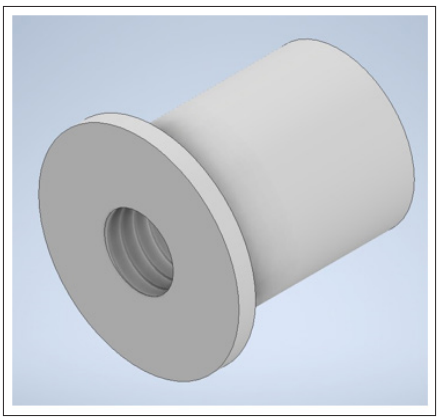

Figure 22: Stopper
Source: The author (2023).

Complete Structure

After modeling all the parts, the virtual prototype of the canine wheelchair was assembled (see figures 23, 24, and 25).

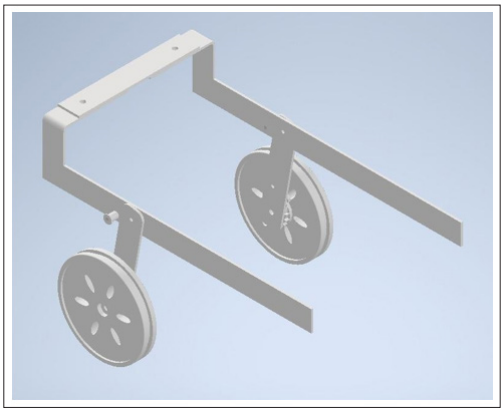

Figure 23: Complete Prototype Structure
Source: The author (2023).

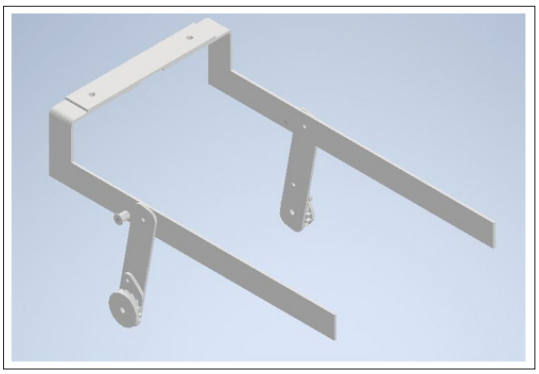

Figure 24: Prototype Structure without Wheels
Source: The author (2023).

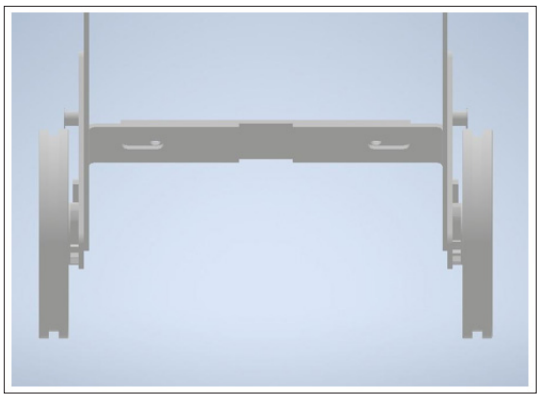

Figure 25: View from the Bottom of The Structure
Source: The author (2023).

Aluminum Parts

To manufacture the metal parts, a 3-millimeter-thick aluminum sheet was used. To achieve the desired shape and outcome, cutting and drilling processes were performed on the sheet metal. Additionally, files and sandpaper were used to enhance the finish (see figure 26).

Figure 26: Aluminum Wheelchair Parts
Source: The author (2023).

Rapid Prototyping

The rapid prototyping process became necessary for manufacturing some smaller and more complex parts due to the level of detail and functionality required. These parts include the wheels, ratchets, catches, and spacers that form part of the wheelchair. To carry out this process, the parts were modeled using Autodesk Inventor software, and then printed in 3D using Ultimaker Cura software (see figures 27 and 28).

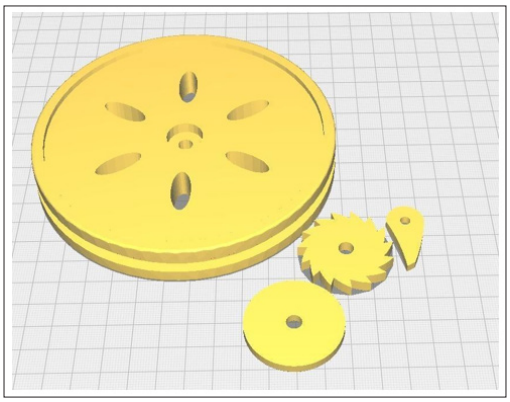

Figure 27: Prototype Parts in Ulti Maker Cura
Source: The author (2023).

Figure 28: Parts Made by Rapid Prototyping
Source: The author (2023).

Fastening Elements

For the wheelchair prototype and the resting mechanism to function correctly, it was necessary to use fastening elements. The elements utilized in the chair include screws, nuts, washers, bearings, and torsion springs (see figure 29).

Figure 29: Fastening Elements Used in The Prototype
Source: The author (2023).

Wheelchair Operation

The functioning of the wheelchair prototype is directly related to the animal's movement while using the equipment. Utilizing torsion springs, catches, and ratchets, the prototype mechanism operates as follows: when the animal moves forward, the chair functions normally, akin to any other chair (see figure 30). However, when the animal moves backward, the locks and ratchets secure the wheels, causing the wheel support to move forward, thereby assisting the animal in maintaining a resting position (see figure 31). Upon the animal's forward movement again, the torsion

springs prompt the wheel support and wheels to return to their standard position for locomotion. Additionally, the wheelchair features a width extension system, allowing for adjustments to ensure the chair's width is suitable for the animal's size (see figure 32) [11-20].

Figure 30: Wheelchair Prototype in Position for Mobility
Source: The author (2023).

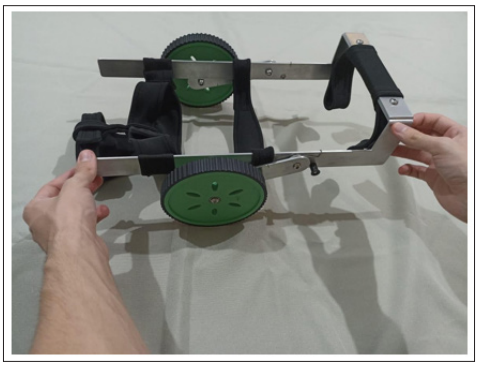

Figure 31: Wheelchair Prototype in Resting Position
Source: The author (2023).

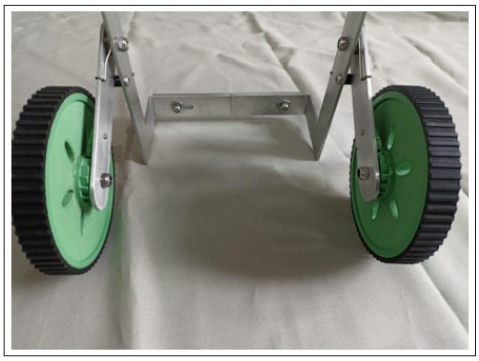

Figure 32: Width Extension System
Source: The author (2023).

Results and Discussions

After developing the project, it was possible to verify the functioning of the wheelchair's rest system. As it is a prototype, the mechanism has not yet been tested on any animals. Furthermore, since there is no load applied to the chair (the weight of the animal), the torsion springs are subject to relatively low loads, which are only necessary for measuring the device without any additional weight. Therefore, if the prototype is tested on a dog, there will be a need to increase the load on the torsion springs. Additionally, an analysis of the operation of the prototype's width extension system was conducted, and it worked correctly. To reduce the noise of the ratchet locks, a small rubber strip was added to the bottom of the lock, where there is friction with the ratchet.

Conclusion

During the course of the project, several modifications were made to the final modeling of the wheelchair prototype before arriving at the presented model. Considering the project conducted the previous year ("Virtual Model for Ergonomic Wheelchair for Dogs"), there has been significant evolution in how the rest mechanism is activated. Previously requiring assistance from the animal's owner or another person to activate, the system is now triggered solely by the animal using the wheelchair. Therefore, it can be concluded that the project objectives were duly achieved.

In conclusion, future plans for the project solely involve testing the prototype on Dachshund dogs with locomotor problems to analyze both the functionality of the rest mechanism and the comfort of the animal using the wheelchair.

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