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ARTICLE #2

Life and Limb: Introduction to the World of Veterinary Orthotics and Prosthetics

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Veterinary orthotics and prosthetics (V-OP) is a relatively new industry that has been rapidly gaining popularity in veterinary medicine over the past 15 to 20 years, to aid in the treatment of limb dysfunction and limb loss.[1] Collaboration between professionals from the human orthotics and prosthetics field (H-OP) and veterinarians has led to the development of highly specialized devices which can assist animal patients in maintaining functional and mobile lives.[1] These devices can be applied to the extremities of companion animals to support a limb or replace a limb segment, and can provide customized options for animals where limited to no options previously existed.[1]

Figure 1 ■ Kota uses a rigid carpal orthosis to manage hyperextension of the carpus, which allows her to comfortably participate in her favourite activities. *(Image provided by the author, with consent from the owner)*

Although surgical intervention for the treatment of many orthopedic conditions is seen as the gold standard of care, V-OP can offer a non-invasive alternative for select patients.[1] In cases where surgical correction is not an option or has been unsuccessful; when there are concerns for post-op recovery; if the patient is at an advanced age or perceived increased anesthetic risk; or where financial costs involved in surgical correction are a concern, V-OP may be presented as a reasonable option for return to function.[1] This important service may allow pets the opportunity to maintain optimal mobility, reduce pain, improve quality of life, and, in certain cases, prevent premature euthanasia.[1]

Knowledge and awareness of the ways in which V-OP might benefit patients, as well as the limitations of such devices,[1] is crucial for every veterinary team member, to ensure caregivers are informed of all available options, and animals are given every opportunity possible to thrive. Most patients adapt quite readily to V-OP devices, but their day-to-day application and ongoing care relies heavily on a responsible caregiver.[1] Although a variety of small and large animals can be fit for a device, canines are the most common V-OP patients,[2] and are the focus of this article.

Orthotics vs Prosthetics

Often used interchangeably with the term brace, an orthosis is an orthopedic brace used to support a weak or injured limb, to enhance the function of that limb.[3] It provides external structure to a joint or series of joints, and may be designed to be rigid (completely immobilizing an affected joint), or built with hinges for an articulating device (allowing dynamic joint motion within a controlled range).[1] Orthoses may also be used to support correct alignment and positioning, and/or protection of a limb segment, such as in cases of peripheral nerve injury.[4] An orthosis can be used for long-term management of a condition, or to temporarily facilitate healing, such as in cases of pre- or post-operative support, in place of the traditional splint and bandage system.[3] Although, in theory, any part of the body can be braced, veterinary orthoses are most commonly fitted on the carpal, tarsal, and stifle joints.[4]

Figure 2 ■ This dog, who is also a hind limb amputee, wears a right forelimb prosthesis and a left carpal orthosis. *(Image provided courtesy of PawsAbility)*

A prosthesis replaces part of a limb, or augments a deficient limb or limb segment, in efforts to restore quadrupedal (or in some cases, tripedal) mobility.[1] Prosthetic devices can be fitted on the front or hind limbs, provided there is enough of the residual limb remaining to achieve adequate suspension, and allow for effective control of the device.[3] A prosthetic limb may be used in cases of congenital limb differences, as well as acquired amputations.[3] They are designed to provide a structure through which weight can be transferred, and offer protection for the residual limb.[3] A prosthesis will also provide additional height to match the length of the contralateral limb.[3]

Not All Devices are Created Equal

There is a wide range of assistive devices available on the market, but it is important to be aware of the variability in customization of these products, and the difference in materials used to make them.[4] There are many *off-the-shelf* supports available, which come in standard dimensions based on the average-sized patient (small, medium, large, etc.). Though these can be less costly and relatively convenient to access, they are often not suitable for animals with abnormal conformation; in cases of moderate to severe instability; or for long term use. Next, there are *semi-custom* products, which often involve some degree of modification of a prefabricated support, using patient measurements.[4] This method gives a relatively limited picture of the patient's anatomy, whereas a truly custom device, made using a cast of the affected limb, allows precise shape capture. This results in better suspension, reduced rotation of the device, and a generally superior fit.[4]

The materials used to create these products can also vary and must be taken into consideration when determining what the device needs to provide for the patient.[4] For example, a stifle brace made of flexible fabric, such as neoprene, is likely not going to provide sufficient support for a torn cruciate ligament.[4] Especially for situations where an external support is needed for long-term management of a condition, a product that is custom created for the individual and made of firm, durable material such as high-temperature thermoplastics or fibreglass laminates, is the preferred choice.[1,4] Furthermore, the design process itself - whether the patient is able to be evaluated directly or virtually - can also contribute to the level of customization that is achievable.

V-OP Fabricators

There are currently no formal certification programs specifically for V-OP;[1] however, certified H-OP professionals have extensive training in human anatomy, biomechanics, and material science, and can apply these concepts to animal patients.[5] Their advanced knowledge of the clinical and technical aspects of orthotic and prosthetic device design and fabrication is unmatched when compared to supplementary programs in other fields of study (veterinary, engineering). Of course, veterinary biomechanics and quadruped locomotion differ from their bipedal human counterparts, so the amount of animal experience a fabricator has is essential to consider.[1] There are now V-OP manufacturers who cater exclusively to animal patients,[2] and have a close working relationship with referring veterinarians and certified animal physical rehabilitation professionals.[1]

Custom V-OP Prescription

A patient must first be thoroughly assessed and the condition or injury diagnosed by their veterinarian before the process of device fabrication can begin.[4] After careful consideration of all other treatment possibilities, including any surgical options, a veterinarian may then refer the patient to a qualified V-OP fabricator to fill the device prescription.[4] Although V-OP is not currently regulated, this process ensures a valid vet-client-patient relationship and is considered best practice.[1]

Fabrication Process

Once the prescription for a custom device is established, the process from initial evaluation and casting to creation and fitting can begin. If there is a local fabricator available, an effort to have the entire process carried out on site is ideal.[4] In areas where a V-OP specialist is not locally available, several companies exist that work by mail; casting can often be done by the patient's veterinarian or certified animal physical rehabilitation professional, and the device is then fitted on the animal once the final product is sent back.[3]

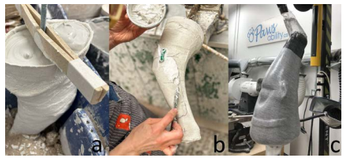

Figure 3 ■ a) A stifle cast that has been sealed and filled with liquid plaster. b) A certified prosthetist modifies the plaster positive of a stifle cast. They strategically apply plaster to create space where needed, and remove it over load-tolerant areas. c) The lamination of layers of fibreglass and resin to create a stifle brace. *(Images provided courtesy of PawsAbility)*

1. Casting

The first, and probably most crucial, step in creating a custom device is taking a cast of the affected limb segment, to create an accurate negative impression of the patient's anatomy.[5] This is usually done by placing one or two layers of stockinette over the desired area, and tethering it in place with the patient in an appropriate position. With gloved hands, a roll of fibreglass casting tape is then wrapped around the limb, and is massaged gently to capture the contours of bony landmarks as the tape hardens over several minutes. Once the casting tape is set, it is removed carefully from the patient using scissors or a cutting strip and blade.

2. Modification

Next, the cast is completely sealed and filled with liquid plaster. Once the plaster has hardened, the cast is stripped away to reveal a plaster positive model of the patient's anatomy. The fabricator then modifies the model limb, refining the shape by removing and/or adding plaster to the desired areas based on the individual's needs.[5] The completed plaster positive model of the limb segment is the template upon which the fabricator will create the device.[4]

3. Test Fitting

Some V-OP specialists will offer a test-fit appointment. A heated sheet of high-tem-

perature thermoplastic is draped over the positive plaster cast, sealed to itself, and then placed under vacuum to capture the contours of the model limb. Once cooled, the plastic is cut off of the plaster positive, and trimmed to create a plastic prototype of the device. The patient is then allowed to try it on and practice mobilizing with it. This provides the caregiver an opportunity to gauge how the animal might adapt to the device, and gives the fabricator a chance to evaluate the test device on the patient, assessing for any changes they may want to make, to ensure the highest quality fit possible before creating the final product.[4] A test-fit appointment, though highly recommended, is not always available.[4]

4. Lamination

First, a foam liner is vacuum molded over the plaster positive, which will form the padded inner layer. This is followed by lamination of layers of fiberglass and resin; once the resin cools it becomes a hard plastic, providing the durable outer shell of the device. Some companies will laminate a piece of fabric into the final layer, giving the device a colour or pattern chosen by the pet's caregiver. Trim lines are established and the device is then carefully cut off of the plaster positive. The fabricator further trims and grinds the foam liner and shell to the desired shape.[5] Instead of lamination, final devices can also be made of vacuum molded thermoplastics - a process which creates a highly structural device as well.

5. Final Fitting

Devices are generally held in place using foam pads, and hook-and-loop straps; some will require additional suspension material. Ideally, fitting of the device will happen with the patient present, to allow for any additional trimming or adjustments, and to ensure straps are riveted in appropriate locations with correct tension.[5] Orthoses with a paw section will also have a tread applied to the base,[5] and prostheses will have prosthetic componentry attached or rubber soling material applied to the base to reflect the desired height and alignment.[1] The caregiver will be educated on device donning and doffing, wear and care, and the recommended schedule of wear.

6. Follow-up

During the initial break-in period, follow-up with the fabricator may be necessary to adjust any final details that become apparent once the animal begins wearing the device for longer periods of time.[5] As animals cannot provide any verbal feedback throughout the fabrication process, a follow-up appointment should be expected within the first few weeks of device use, but is not always necessary.[1]

Should the caregiver observe any concerning physical or behavioural cues related to the device (excessive redness of the patient's skin, development of sores, chewing the device, sudden hesitancy to use the device, damage to the device structure or foam liner), either within the initial break-in period or at any point during device use, then follow-up with the fabricator is indicated. Further details on device wear and care are explained later in the article.

Common Applications for Orthopedic Bracing

Carpal Orthosis

A carpal orthosis may be used for a variety of reasons, such as in cases of carpal hyperextension, varus and/or valgus instability, or for support before/after an arthrodesis.[6] They can also be used in cases of carpal contracture, brachial plexus injuries, and digital or paw imbalances. A hinged carpal orthosis will allow the carpus controlled range of motion, or it can be made rigid, preventing any movement of the carpal joint. Depending on the diagnosis and goals of the device, it may or may not include a paw section, extending distally to provide structure under the paw.[6]

Figure 4 ■ Chance, who sustained a brachial plexus injury, before and after being fit for a brace. The rigid carpal-paw section protects his weak distal limb, and the hinged elbow section assists with elbow flexion to improve function of this limb. *(Image provided by author, with consent from the owner).*

Tarsal Orthosis

Tarsal orthoses are often considered for cases of tarsal hyperflexion, hyperextension, and varus and/or valgus instability.[2] They may or may not include a paw section, and may be created to be rigid or articulating. They are often used in cases of post-operative Achilles tendon repair, starting with a completely rigid tarsal-paw orthosis, and eventually incorporating hinges to allow for gradual increases in range of motion of the tarsus as the patient recovers.[3] This allows for progressive loading of the tendon, permitting it to be stressed under controlled circumstances before support is completely removed.[3] Tarsal orthoses can also be used for long term management, for a conservative approach to a deficient Achilles tendon to control tarsal hyperflexion.

Figure 5 ■ The device on the left demonstrates an articulating tarsal orthosis that leaves the paw free to contact the ground. On the right is an example of a rigid tarsal-paw orthosis, used in the conservative management of an Achilles tendon injury. *(Image provided courtesy of PawsAbility)*

Life and Limb: Introduction to the World of Veterinary Orthotics and Prosthetics ...continued

Stifle Orthosis

Stifle braces may be the most common type of veterinary orthosis,[2] due to the high prevalence of cranial cruciate ligament injuries, which lead to instability of the stifle. Although surgical intervention often provides superior stability, for those non-surgical candidates, a well-fabricated and properly-donned stifle brace can limit shifting of the tibia relative to the femur.[1] They may also be used in cases of medial/lateral stifle instability,[2] and occasionally in cases of patellar luxation.

Not all dogs are good candidates for stifle braces, as individual variation in conformation may affect access of essential anatomy and suspension points.[2] Some dogs may not have enough of the thigh accessible to be fit, for example, in obese and certain smaller breed dogs. Furthermore, since a dog's hind limb is fairly conical in shape, a harnessing system may need to be worn with the brace to ensure positive suspension. This may be necessary particularly in dogs with short legs and/or excess moveable tissue.

Figure 6 ■ Both of these patients are wearing custom stifle orthoses to aid in the conservative management of cranial cruciate ligament injuries. The short thigh and excess moveable tissue of the dog on the right necessitates an additional suspension strap to provide upward lift of the brace. (Image provided courtesy of PawsAbility)

Forelimb and Hindlimb Prosthetics

As previously mentioned, candidacy for a prosthesis relies on the assumption that there is sufficient anatomy remaining to attach a device to. The longer the residual limb, the more opportunities there are for the prosthesis to achieve good suspension and for the dog to have good control of the device. Though there are exceptions, generally, the highest available level for a forelimb prosthesis to fit is approximately mid radius/ulna, and for a hindlimb prosthesis the majority of the tibia/fibula needs to be present.[3] With higher amputations there is often not enough anatomy remaining for the device to hold on to, and the long section needed to provide adequate height to reach the ground can be a challenge for the patient to maneuvre.[3]

Figure 7 ■ A puppy with a congenital limb difference, wearing a forelimb prosthesis for the first time. This particular device is made out of the test-device thermoplastic to reduce the costs of multiple laminated devices as the dog grows. (Image provided courtesy of PawsAbility, with consent from the owner)

"But animals do fine on 3 legs..."

There is an old doctrine that suggests 'animals do fine on 3 legs;' however, recent studies show that the compensatory impacts on the spine and remaining limbs can lead to significant mobility challenges.[7] Consider the fact that dogs generally distribute 60% of their body weight between their front limbs, and 40% of their body weight between the hind limbs.[8] A well-fitting prosthetic limb allows the animal to resume more appropriate quadruped gait patterns and weight distribution, and reduces the chance of wear and tear injuries to the other limbs.[7] It can also decrease the severity of long term back pain as a result of chronic compensation.[7]

Figure 8 ■ Before and after application of a hind limb prosthesis. This dog has all of the tibia/fibula intact, as well as some tarsal bones. The structure crosses the stifle joint to provide additional support. (Image provided courtesy of PawsAbility)

"Contemplate before we amputate..."[1]

Of course, there are situations where amputation of the entire limb is necessary, and indeed animals have proved that they can adapt to life on three limbs. This is functional adaptation, however, and arguably not a reflection of the highest quality of life.[7] If the majority of the proximal limb is healthy, then subtotal limb amputation will need to be considered, when possible, if prosthetic limb fitting is to be successful.[1] This would also require a veterinary surgeon who is willing to perform an elective level amputation. In human medicine, amputating at the hip level would never be considered for a foot or ankle injury.[7] Communication between the pet's caregiver, veterinarian, and V-OP provider will determine if amputation for prosthesis fitting is possible, and the best plan to achieve the desired results.[1]

Often, for those patients who are unable to be fitted for a prosthetic limb, attention turns to the preservation of the remaining limbs. Some amputee patients may benefit from prophylactic bracing of the contralateral limb for support, or to reduce the effects of chronic wear and tear during the pet's most active times.[9]

Wear and Care

With all V-OP cases, the responsibility lies with the caregiver for proper wear and care, and close ongoing monitoring of the patient, their limb, and the device itself. Clear instructions from the manufacturer regarding proper donning and doffing technique is essential to overall success.[1] Moreover, positive reinforcement training techniques can go a long way in conditioning a patient to have a favourable response to their device.[9]

When the patient first receives their orthosis or prosthesis, the caregiver will be directed to follow an initial wear schedule, placing the device on the patient and allowing them to wear it for gradually longer periods of time.[10] This gradual break-in period allows the patient's tissues to adapt to having the device on. It also provides an opportunity for the caregiver to closely monitor the patient's skin, especially around bony prominences and load-bearing areas, for any early signs of irritation that could indicate a need to follow-up with the fabricator.[5] Many patients will wear a sock underneath to provide an additional interface between the device and the patient, and further improve comfort and fit. Ultimately, most V-OP devices are meant to be worn for all of the patient's active, supervised times (on walks, in the yard, or in the house when people are home, for example), and removed when they are unsupervised.[10] The main exception to this is when a brace is worn full-time in place of splinting for post-operative recovery.

The durable outer shell of a device can, in theory, last the lifetime of the pet, provided there are no significant anatomical changes. The softer components of the device, however, such as the foam liner, straps, and pads, are more susceptible to wear and will likely need to be replaced from time to time.[5] Similarly, depending on the size and activity level of the patient, and the terrain on which the patient ambulates, the device may require regular re-treading if it includes a section that contacts the ground.[4] The expectation should be set early that regular follow-up with the manufacturer for adjustments, repairs and refurbishments will likely be required as needed for maintenance.

Are There Any Complications?

A common misconception is that an animal will chew their brace and/or develop skin issues and most will reject V-OP devices. In actuality, however, this high level of customization during creation leads to an extremely accurate fit and increased acceptance of the device by the patient.[4] It also results in a much lower incidence of skin complications that may be seen more commonly with generic supports.[4]

If the patient does chew, or excessive skin irritation develops, it is most often due to an ill-fitting device or lack of caregiver compliance (improper placement, leaving the device on for extended periods of time, allowing the animal to wear the device when unsupervised), which can often be resolved with an adjustment by the fabricator or a review on proper placement technique.[5] As veterinary patients are non-verbal, much of the responsibility lies with the caregiver to ensure the proper placement and fit of the device, adherence to the advised wear schedule,[2] and follow-up with their V-OP fabricator and/or veterinarian as necessary. Both the patient's skin and the device itself should be carefully inspected daily to ensure any signs of wear or irritation are caught early.

Additionally, the device should be kept as dry as possible, both to maintain its longevity, and to limit skin complications, which may be more likely if the skin is wet and therefore more vulnerable to irritation. For these reasons it is advisable to wear an over-boot or similar type of water resistant cover in wet or snowy weather.

Although many patients actually adapt quite readily to a device, another common concern is the patient's willingness to wear the device and use it to mobilize. This can be influenced by many other factors such as the chronicity of the injury, the patient's general level of strength, condition of the affected limb, overall mobility, comorbidities, presence of pain, and individual variation.[6] Considering all of these variables, it is important to set realistic expectations about a reasonable adjustment period for the pet, and the degree of learning required to figure out how to use something completely novel to them. Physical rehabilitation can accelerate the initial adjustment period and is strongly recommended to help maximize limb use and overall mobility.[1]

Physical Rehabilitation

In human medicine, an H-OP patient would automatically be referred for physiotherapy to learn how to use a device properly.[7] Certified animal physical rehabilitation professionals will work with the animal patient and caregiver to help patients adapt to using a device, and improve the ease with which activities of daily living are performed, often using a combination of manual therapies, modalities, and exercises.

Through a targeted therapeutic exercise program, rehabilitation will begin by simply encouraging the patient to load into a device before moving on to basic tasks such as transitioning from sitting or lying to standing. Next would be working on more challenging skills such as maneuvering around obstacles or acclimating to stair use, if able.

Proprioceptive work is an essential part of any V-OP rehab program, especially in cases

Figure 9 ■ Victoria, a hind limb amputee, walks in an underwater treadmill at Toronto Veterinary Rehabilitation Centre to improve device use. This was her first device which she now wears solely for hydrotherapy. (Image provided courtesy of Toronto Veterinary Rehabilitation Centre, used with consent from the owner)

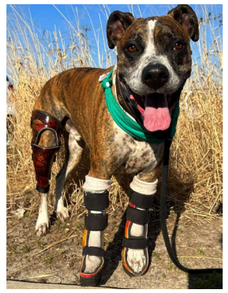

Figure 10 ■ Brindle, a young dog with multiple orthopedic issues, utilizes a carpal orthosis, forelimb prosthesis, and stifle orthosis. (Image provided courtesy of PawsAbility, used with consent from the owner)

of prosthetic limbs or orthoses with a paw section, where the patient is unable to directly sense the ground during movement. As the patient's confidence increases, more advanced gait training, strengthening, and endurance exercises are incorporated. Coupling V-OP with physical rehabilitation ensures the best chance at successful device use and overall improved patient mobility and functionality.[7]

Conclusion

The innovation of veterinary orthotic and prosthetic devices brings to light the advancement of alternative treatment options once thought to be reserved for human patients. V-OP interventions can now be added to the veterinary patient advocacy toolbox, and should be presented alongside any traditional forms of treatment where appropriate. Contrary to common assumption, the highly customized process of V-OP fabrication produces devices which are generally readily accepted by patients, and can have positive impacts on their day to day comfort, functional mobility, and overall quality of life. The possibilities for other custom supports extends beyond the scope of this article, but are plentiful and include boots, cervical collars, shoulder hobbles, and wheeled mobility, to name a few.

(This article was written using the author's experience as a veterinary orthotics and prosthetics assistant at PawsAbility. All devices shown in this article were made by Janice Olynich B.A., C.P(c), of PawsAbility.)

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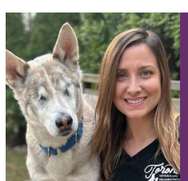

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