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Topical Review

The Emerging Role of Veterinary Orthotics and Prosthetics (V-OP) in Small Animal Rehabilitation and Pain Management

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In veterinary school, we learn much about how to repair bone fractures, ligament injuries, and neuropathies. The idea, of course, is to return some level of function to a damaged appendage and decrease pain. When a limb cannot be salvaged for medical or financial reasons, we are taught that dogs and cats do "great" on 3 legs. Three legs may mean a less functional limb or outright total amputation. We espouse this doctrine to our clients. Indeed, most of us have countless stories of triped patients acclimating to their disability with aplomb. Although it is true that many patients adapt, learning to ambulate and negotiate their environment, this is functional adaptation—not necessarily the highest quality of life. As a profession, we have come to expect—even accept—that limited mobility, limb breakdown, and chronic neck or back pain are unavoidable consequences. The short- and long-term consequences of limb loss or altered limb function are not benign as once thought. Furthermore, the quality of care demanded by clients is rising and the breadth of knowledge afforded by technology and global communication spawns innovative therapies readily accessible to the computer-savvy pet owner. Recent examples of therapeutic innovations include the following: dentistry, acupuncture, chiropractic, and rehabilitation. Often there is no precedent for these new therapies in animals, and the onus rests with the veterinary community to educate itself to provide best care for patients and clients and to establish evidence-informed best practice. The newest emerging therapeutic modality is veterinary orthotics and prosthetics. Like the previously mentioned modalities, the origin lies in human health care and subsequently leaps to veterinary health care.

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This article introduces the practitioner to veterinary orthotics and prosthetics (V-OP) as a therapeutic modality, its role in practice particularly as a pain management and rehabilitation tool, and to the important ethical issues surrounding its use.

Origins of V-OP

Human orthotic and prosthetic (H-OP) practice traces its origins to ancient Egypt and Greece. Earliest assistive devices were made of leather and wood. In the 18th and 19th centuries, these materials were replaced with metal. Not surprisingly, the profession of bracing predates surgery; bone setters and appliance makers were skilled artisans. Modern orthopedic surgery rapidly developed in the 20th century with the advent of implants and safer anesthesia; ultimately, surgery replaced bracing and splinting as the cornerstone of orthopedics. Consequently, bracing became ancillary to surgery. In recent years, improved technology has led to substantial improvements in bracing techniques and a more discriminate parsing of surgical vs. nonsurgical cases. A clear example is the decrease in Achilles tendon surgery in favor of dynamic bracing and rehabilitation for human patients.[1]

Today braces are more accurately termed orthoses. Orthoses are defined as any medical device attached to the body to support, align, position, prevent, or correct deformity; assist weak muscles; or improve function.[2] The term orthosis implies dynamic control, whereas brace more accurately refers to static control. Both are needed in modern therapy, and "orthosis" is preferred as a general term for both types of mechanical devices. They are not a replacement for necessary surgery, but complementary.

Prosthetists were originally black smiths and armor makers. Materials included wood and leather, calling to mind the classical image of the peg-legged pirate. Later, metal was incorporated albeit lending a great deal of weight to these devices. In modern times, a positive consequence of war, if this can be said, includes medical innovation by necessity. The American Civil War resulted in tens of thousands of catastrophic limb injuries. J.E. Hangar is reportedly the first amputee of that war.[3] He subsequently built his own prosthetic leg and ultimately the largest human prosthetic limb fabrication company in the United States, Hanger Inc, publicly traded on the New York Stock Exchange as HGR. In the late 1880s, his devices were available by mail order, typically selling for $75-$150, which is approximately $2000-$4000 in today's dollars. These early devices served an important purpose, but were utilitarian at best and truly uncomfortable at worst.

Once again driven by human conflict, today lightweight materials, microprocessors, and neural integration have resulted in spectacular improvements in function including sensation and lifelike grasping appendages. These devices have allowed amputees to return to and excel in nearly all human endeavors including sport; no longer are these individuals relegated to "getting by" and "making due" with their injury. The goal is to thrive with few or no boundaries. Amputees still face many challenges, and rehabilitation remains critical to successful return to function, but the list of limitations is shrinking.

Over the past decade, there has been a tremendous increase in our understanding of physical fitness for animals coincident with an increased demand for maximizing quality of life for our companion animals. We now know that optimal movement and mobility can significantly affect the physical and mental health of our veterinary patients. Rehabilitation has moved to the forefront of modern veterinary medicine with the debut of the American College of Veterinary Sports Medicine and Rehabilitation.[4] Not surprisingly, innovative human orthotists or prosthetists have

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been tapped to create one-off mechanical appliances to improve the mobility and functionality of the occasional veterinary patient. This seems to mirror the emergence of acupuncture, chiropractic, and rehabilitation therapy for animals in the preceding decades. During this time, human practitioners introduced and, not entirely legally, ministered to veterinary patients owing to a paucity of qualified veterinarians. We are in their debt in terms of introduction; subsequently, veterinary medicine has embraced and advanced these modalities with species-specific scientific vigor. Likewise, many veterinary practice acts have recognized these modalities and redefined the legal use by nonveterinary practitioners. As of this writing, these therapies are emerging as mainstream rather than so-called alternative therapies. Likewise, V-OP is emerging from beneath the wing of H-OP. Recent media productions such as Disney's *A Dolphin's Tale* and PBS's *My Bionic Dog* have recently brought V-OP as a therapeutic option to the public eye. Although these productions still leave the viewer with an impression that such cases are yet novelty, this is far from reality and the current state of the science.

V-OP and the Role of the Veterinarian

Veterinarians have a history of creating assistive devices from items at hand using everything from duct tape to superglue, plywood to low temperature thermoplastics, and aluminum rods to PVC pipe. We have a tradition of a "MacGuyver-like" fortitude driven primarily by economics and a lack of veterinary-specific products in the past. Public demand and the redefined modern role of the companion animal as a family member have provided an opportunity to excel beyond one-off and novelty in veterinary health care. Our clients have recognized there is a gap in veterinary services in terms of managing limb dysfunction and loss, a gap long filled in human medicine.

Scientific rigor and a culture of evidence-informed medicine drive new understanding and ultimately innovative therapies for animals. The structural consequences of a dysfunctional or missing limb or limb segment are now recognized.[5,6] As our understanding of the intricacies of quadruped mobility and biomechanics has grown, so have the variety and sophistication of mechanical assistive devices. Now they incorporate veterinary-specific hinges, composite plastics, titanium, carbon fiber, and specialty foam liners. Biomechanically sound designs improve fit and function. Surgical techniques such as subtotal amputation, intraosseous transcutaneous amputation prosthesis (ITAP), and rotational plasty are providing new opportunities and an expanding patient population. V-OP is evolving into a new subspecialty. Although it is true that techniques and materials used in H-OP can be translated to veterinary patients, specific modifications for quadruped ambulation and the significantly greater magnitude of force generated by these patients must be considered. A thorough understanding of the biomechanics and health issues of animals is essential to avoid injury to the animal, delayed healing, or delayed use of more appropriate therapies. The veterinarian is the key player in this process and must lead the way because of their knowledge of veterinary species and veterinary medicine. H-OP professionals will continue to serve a collaborative albeit secondary role. To do so, veterinarians must begin to educate themselves in this regard to best serve the demands and needs of their clients and patients.

Orthotics Basics

Orthoses provide protected motion within a controlled range, prevent or reduce severity of injury, prevent or relieve contracture, allow lax ligaments and joint capsules to shorten, and provide functional stability for an unstable limb segment.[2] These devices should not be seen as a replacement for surgery, but complementary or adjunctive. They can be designed to restrict, block, enable, or guide range of motion. They can absorb, store, and return energy. They may provide progressive, controlled dynamic return to motion. They can block one plane of motion while allowing another to persist. They may compensate for limb length discrepancy. Importantly, these devices do not create dependency or atrophy unless intended or is an unavoidable consequence of severe injury (Fig 1).

There are many conditions amenable to prescription orthoses (Table). Orthoses can be used as preoperative, postoperative, or "no-operative" solutions. In cases where surgery must be delayed, they can provide interim support, protect the limb, allow more comfortable and mechanically appropriate ambulation, and minimize disuse atrophy. In a postoperative situation, orthoses can provide a safe, effective, and dynamic alternative to traditional casting. Orthoses are also used when surgery is not possible. This might include patients who are poor anesthetic candidates, patients with comorbidities precluding surgery, the aged, injuries for which there is no surgical correction, and families with financial limitations, among others. These "no-operative" patients represent a large and heretofore underserved population.

Paw Orthoses

Injuries and pathology of the paw are often overlooked; yet, they can result in significant discomfort and dysfunction. Thoracic paw injuries are especially problematic because of the normal disproportionate weight distribution compared with the pelvic limbs (Fig 2). Pelvic paw injuries also markedly affect comfort and ambulation because forward drive in faster gaits originates in the pelvic limbs. Additionally, paw injuries ultimately affect the entire mechanical structure regardless of affected limb because compensatory or adaptive gaiting alters function up the kinetic chain (proximal joints, spine, muscles, etc.). Examples common to digital pathology include the following: osteoarthritis of the metacarpal or metatarsal-phalangeal joints; sesamoid bone fractures; flexor tendon laceration, degeneration, or contraction; pathologic supination or pronation; digital luxation; and neuropathy causing loss of dorsiflexion, among others. Orthotic devices can be used to improve comfort, assist in healing, or rehabilitate some injuries. The challenge is affixing such devices to the limb; commonly, the device must include the antebrachium or crus for proper suspension. Device design must take into account pathology, overall

Fig. 1. An example of stifle orthosis for lateral collateral ligament rupture. Orthoses are dynamic allowing joint range of motion.

Table

Thoracic limb pathology amenable to orthotic devices		
	Elbow	
		Subluxation
		Osteoarthritis
	Carpus	
		Osteoarthritis
		Hyperextension
		Varus and Valgus
		Failed arthrodesis
		Carpal support for contralateral thoracic limb amputation
		Flexor carpi ulnaris strain
	Paw	
		Congenital deformity
		Digital tendon laceration
		Digital amputation
		Digital supination or pronation
	Radial neuropathy (carpus distad)	
Pelvic limb pathology amenable to orthotic devices		
	Stifle	
		Cranial cruciate ligament rupture
		Patellar luxation (grades 1 and 2)
		Collateral ligament injury
		Patellar tendon injury
		Tibial crest avulsion
	Tarsus	
		Osteoarthritis
		Hyperextension
		Collateral ligament injury
		Achilles tendon strain, rupture or avulsion
		Failed Achilles tendon repair
	Paw injuries including tendon laceration and digit amputation	
		Congenital deformity
		Digital tendon laceration
		Digital amputation
		Digital supination or pronation
	Peripheral neuropathy	
		Degenerative myelopathy
		Sciatic nerve trauma
		IVDD, spinal canal stenosis, and cervical spinal instability
		Fibrocartilagenous embolus
Special conditions		
	Adaptive wheeled vest for bilateral forelimb amputee or amelia	
	Sciatic sling for peripheral neuropathy of hind limbs	

therapeutic plan and prognosis, limb topography, normal and pathologic limb function, and practicality and comfort. Examples of 2 devices are shown in Figs 3 and 4. The first is a typical orthosis for severe pronation including a custom insert for digital realignment and a hinged paw segment with flexor assist. Patients with this injury have reduced propulsion potential because flexor tendon failure prevents active engagement with the ground (push off). The second device assists in dorsiflexion and propulsion in pelvic limb neuropathy. Using an adjustable elastic cord, the digits within the bootie are dorsiflexed while flexion of the tarsus and cranial swing of the pes are assisted by elastic recoil for ground clearance.

Fig. 2. Severe manus pronation.

Carpal Joint Orthoses

Injury to the carpus is common and can be complex because the joint itself is complex. The carpus as a biomechanical structure must be thought of as 3 joints, 7 carpal bones, 2 antebrachial bones, and 4 or 5 metacarpal bones. There are multiple ligaments holding this structure together, collectively referred to as the collateral ligaments and the palmar fibrocartilage. Lastly, primary muscles of the carpus and digits including the flexor carpi ulnaris, flexor carpi radialis, and superficial and deep digital flexors play a significant role in distal limb function. Because of the role of the digital flexors, the digits themselves must be considered in carpal injuries. Primary carpal injuries can occur at any of the 3 joints (antebrachiocarpal, middle carpal, or carpometacarpal); additionally, any of these bones can be luxated or fractured. Compound or individual ligament injuries occur. Individual muscle strain (e.g., m. flexor carpi ulnaris) is not uncommon in canine athletes.

Clinical signs of carpal and digital joint dysfunction include lameness, collapse, swelling, and malalignment. Sagittal plane malalignment can include inability to fully extend the carpus or dorsiflex the digits, carpal or digital hyperextension, and radial neuropathy causing flexion collapse. Frontal plane instabilities typically owing to collateral ligament injury result in excessive varus or valgus while transverse plane issues present as rotational defects of the antebrachium or supination or pronation of the manus. The latter may be congenital, owing to ligament degeneration or repetitive strain, or digital amputation. Minor injuries may resolve with rest and a temporary splint. More severe injuries require surgery or an orthosis or both and rehabilitation. Common surgical approaches include repair of large ligament injuries when possible, implant fixation of fractures, and partial or complete arthrodesis. Orthoses may be chosen as a primary therapy or as adjunctive to surgery augmenting repair and assisting in controlled rehabilitation. Commonly, orthoses are used as an alternative to serial casting or splinting. The advantages include potential for dynamism, the ability to perform daily non–weight bearing rehabilitation because the orthosis is removable, the

Fig. 3. A custom orthosis with paw insert for digital alignment and dorsiflexion assist for the patient in Fig 2.

Fig. 4. Sciatic sling orthosis for sciatic neuropathy causing failure of digital dorsiflexion. Common applications include degenerative neuropathy, fibular nerve trauma, intervertebral disc disease, and lumbosacral stenosis.

ability to easily monitor for skin irritation or incisional infection, and no concerns regarding wet bandages and associated pododermatitis, among others. Orthosis options include devices with and without paw segments and devices that articulate and those that do not. The design of the device depends on the type and severity of injury. An orthosis may be an option when surgery is not appropriate, not necessary, or not possible.

Most carpal devices are designed based on a simple mechanical principle called 3-point correction (Fig 5). To support the joint in proper alignment, 2 counter forces and 1 corrective force are used. The further the counter forces are from the corrective force, the longer the lever arm and the greater the mechanical advantage. Consequently, less force is required; because force is transmitted to the mechanical structure (bone) through soft tissue, minimizing force and thus potential trauma to soft tissue is the goal. The 3-point correction can be used for articulating and nonarticulating devices so long as shearing is not a component of instability. Articulation is possible when instability is in one plane or is not severe.

An example is shown in Fig 6. This device is designed to limit carpal extension while allowing flexion; it is used for carpal hyperextension owing to palmar fibrocartilage damage or injury to the flexors of the carpus (muscles or tendon), or both. At full extension (10°), the device locks, resisting further carpal extension. This can be thought of as an arthrodesis on demand. The advantages over an arthrodesis are (1) functional range of motion of the digits, (2) range of motion of the carpus within safe limits, (3) removable for rehabilitation and skin management, and (4) dynamism allowing initial complete restriction of carpal flexion followed by sequential return of range of motion. This design can be used for frontal plane instability as well. In this case, the shell resists varus and valgus while full carpal range of motion in the sagittal plane is allowed by virtue of the polycentric hinge.

Importantly, with significant instability, soft wraps made of fabric, neoprene, bandage material, etc., do not have enough structural rigidity to resist joint collapse. Significant instability means more than 5°-10° difference in range of motion relative to the contralateral limb. As such, these products are reserved for

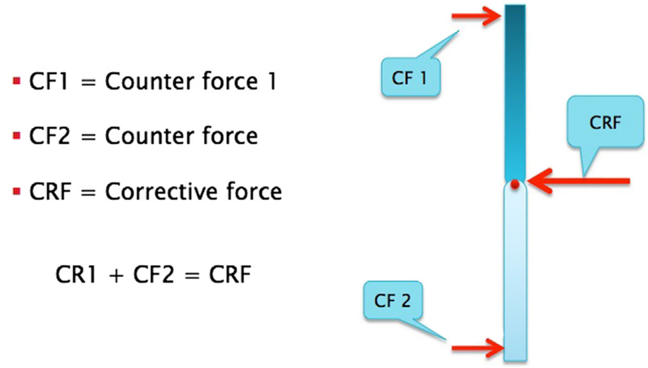

Fig. 5. The 3-point corrective system is composed of 1 corrective and 2 counter forces. The sum of counter forces equals the corrective force.

compression, proprioceptive cuing (so-called Kinesio Taping), and warmth.

Tarsal Joint Orthoses

From a biomechanical perspective, the tarsus is composed of 4 joints arranged in 4 levels: 7 tarsal bones, 2 crural bones (tibia and fibula), and 4 (rarely 5) metatarsal bones below. There are multiple ligaments for structural support and mechanical function. Muscles of importance to tarsal mechanics include the following: Achilles mechanism components (gastrocnemius, superficial digital flexor, semitendinosus, gracilis, and biceps femoris), deep digital flexor, cranial tibial, peroneus longus, and

Fig. 6. An example of canine carpal orthosis. This device is used for mild to moderate carpal hyperextension or collateral ligament injury (carpal varus or valgus).

long digital extensor. Injuries can occur at any of the joints (tarsocrural, talocalcaneal, talocalcaneocentral, calcaneoquartal, and tarsometatarsal); additionally, bones can be luxated or fractured. Injury to the Achilles complex and medial shearing injury causing failure of the medial collateral ligament are common soft tissue injuries.

Clinical signs of tarsal injury include lameness, swelling, and malalignment. Malalignment can include hyperextension of any of the tarsal joints, sinking or hyperflexion of the tarsocrural joint, hyperflexion of intertarsal or tarsometatarsal joints, and varus or valgus. Minor injuries will resolve with rest and a temporary splint. More severe injuries require surgery or an orthosis or both. Common surgical approaches include repair of large ligament or tendon injuries when possible or necessary, implants for fracture repair, and partial or complete tarsal arthrodesis. Orthosis options are similar to those for the carpus and include devices with and without paw segments and devices that articulate and those that do not. Although, most injuries are managed with the same 3-point corrective mechanism, orthosis design must take into account the difference in angulation of the pelvic limb compared with the thoracic limb and the subsequent mechanical implications. An orthosis is an option when surgery requires temporary support or is not appropriate, not necessary, or not possible.

Achilles mechanism injury is the second most common non-traumatic tendon injury in dogs.[7] It results in so-called dropped hock and clawed paw (Fig 7). Traditionally, it is managed with surgery, a period of immobilization with a cast, splint, or external fixator (6-8 weeks) followed by soft padded bandage and return to function. Unfortunately, this technique does not address the clawed paw, and sometimes does not result in complete resolution of tarsal hyperflexion. In human patients with Achilles tendon injury, general standards for therapy include surgery if indicated, controlled activity, partial immobilization with hinged orthoses limiting dorsiflexion at the ankle, early weight bearing (within 2-4 weeks), and early physical therapy, which result in faster return to function and decreased disuse atrophy.[8,9] McComis is credited with developing the concept of functional bracing (orthosis) as an alternative to conservative treatment for ruptured Achilles tendon in humans; bracing allows immediate weight bearing and active plantar flexion, but limits dorsiflexion at the ankle.[10] All of this allows for healing as well as return to normal function while limiting risk of recurrence.

Similar devices are now being used in veterinary patients. An example of the device is shown in Fig 8. This orthosis protects the tendon during healing phase, allows for return of digital dorsiflexion (resolution of claw paw), serially reloads the tendon, and finally limits reinjury during rehabilitation and return to normal activity.

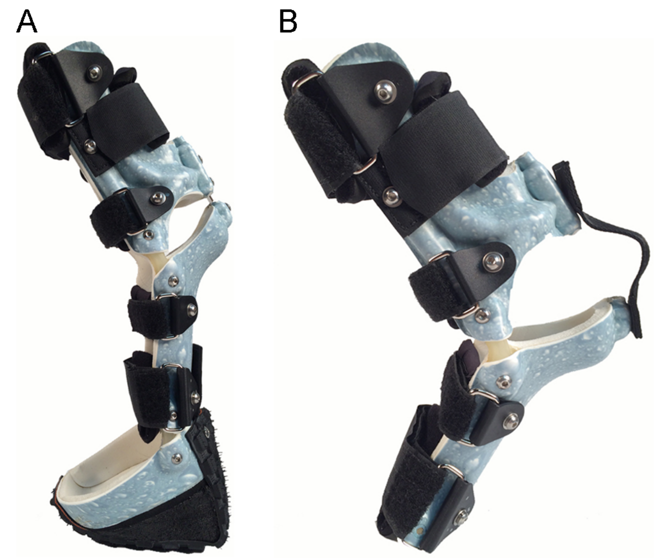

Fig. 8. In this example, dynamic (adjustable) Achilles tendon orthosis (A) can be progressed to a sports orthosis (B) once the tendon has healed and digital flexor tendon restriction (claw paw) is resolved.

Fig. 7. Achilles tendon injury results in tarsal hyperflexion (dropped hock) and digital plantar flexion (claw paw).

Stifle Joint Orthoses

The stifle joint is less complex in that there are fewer bones and ligaments than the tarsus and carpus and only 2 true joints (femoropatellar and femorotibial). However, it is more complex because it is intended to function in more than 1 plane of motion (femorotibial). The stifle is a polycentric joint rather than a monocentric (simple hinge) joint. In addition to sagittal motion, a certain amount of frontal and transverse plane motion provides livelier and more adaptive function. The tibia and femur shear across the articular surfaces as the joint goes through range of motion. Overall, 4 ligaments and 1 tendon (medial and lateral collateral, cranial and caudal cruciate, and the patellar tendon) limit and control motion. Important muscles include the quadriceps group, the hamstring group, the gastrocnemius, and the biceps femoris. Injury to any of these components may be managed surgically or with an orthosis. Rehabilitation is now considered a standard of care in stifle injury.

The classic example of transverse and sagittal stifle instability is injury to the cranial cruciate ligament (CCL). The etiology of this injury is beyond the scope of this article; however, knowledge of partial and complete tear is important. Traditionally, partial to complete, all CCL injuries are managed surgically. There are a number of techniques described each with merit, none perfect. Even so, there is a population of dogs for whom surgery is not possible or not appropriate. These include dogs with comorbidities, advanced age, and owners with limited financial means, among others. Until recently, treatment options for these patients were limited to weight management and nonsteroidal anti-inflammatory drugs.

Stifle support devices have been available for at least a decade. They include off-the-shelf and custom design devices. The intent of all is to support the limb. The degree to which they do is not yet known; however, studies are underway. From a mechanical perspective, a CCL orthosis must restrict tibial translation (cranial shear and internal rotation) or it must impel the muscular structures of the limb to do so. Importantly, the mechanical principle here is not the 3-point correction. This technique would fail during stifle articulation because the stifle undergoes rolling and gliding during normal range of motion. This means that the center of rotation changes, which cannot be accommodated by the 3-point corrective technique. The shearing mechanics of the CCL-deficient stifle are in contradistinction to the relatively simple mechanics of tarsal and carpal instability. Therefore a different technique is needed to stabilize. The proper mechanical principle is called force coupling (Fig 9). It uses the action of the major muscle groups to couple the femur and the crus while allowing a polycentric hinge to provide articulation and limit shear.

Prosthetics Basics and Subtotal Amputation

The current dogma goes something like this: "animals do great on 3 legs." This position advocates for total limb amputation when catastrophic injury (e.g., crushing and degloving) or pathology (e.g., neoplasia) arises. However, the short- and long-term structural consequences of a missing limb or limb segment are being recognized and defined in part through the efforts of pain management veterinarians (the American College of Veterinary Anesthesia and Analgesia[11] and the International Veterinary Academy of Pain Management[12]) sports medicine specialists (the American College of Veterinary Sports Medicine and Rehabilitation,[4] and rehabilitation therapists (the American Association of Rehabilitation Veterinarians[13]). As we begin to understand the biomechanics of normal quadruped locomotion, the implications when it is lost become clear. In terms of limb absence or total limb amputation, these include limited mobility and endurance, increased metabolic demand, weight gain, support limb breakdown, chronic neck and back pain, and premature euthanasia (Figs 10 and 11).[14] Because of these significant consequences, consideration must be made for the re-establishment of quadruped structure whenever possible.

In human medicine, amputation at the hip for a catastrophic ankle injury would be unthinkable. Yet, this is standard of care in veterinary medicine. Why is this? In the past, prosthetics were not available and therefore concern for injury to the remaining limb segment was valid. Fortunately, prosthetics coupled with subtotal amputation, standard of practice in human medicine, are recent and successful developments in veterinary medicine.[15,16] Given the consequences of limb loss in the short and long term, it seems appropriate to "contemplate before we amputate" an entire limb when only the distal segment is beyond salvage. Examples include neoplasia, trauma, and partial agenesis. Preservation of at least 50% of the radius or ulna or tibia or fibula allows ready application of a socket-based or ITAP prosthetic limb in species including dogs, cats, as well as others. Subtotal amputation is possible at nearly every level of distal joint as well as transtibial and transradial levels. The basic tenet is to preserve as much limb as possible

Fig. 9. An example of stifle orthosis for canine cranial cruciate insufficiency uses force coupling to limit tibial thrust and internal rotation. This device uses metatarsal suspension.

Fig. 10. Severe carpal varus and digital supination secondary to left thoracic limb total amputation.

Fig. 11. The spinal consequences of thoracic limb loss include chronic cervical, thoracic, and lumbar spine repetitive strain as well as carpal joint collapse.

while providing a tension-free closure. The ideal level of amputation for each injury, the best techniques, and the advantages or disadvantages of each level are still being defined. Regardless, the surgical techniques are simple, and complications are few.

The biomechanics of the quadruped make design of prosthetic limbs challenging, but not insurmountable. The end goal is to provide a limb that allows as close to normal ambulation as possible. Angulation of the thoracic limb vs. pelvic limb, breed differences, as well as level of subtotal amputation must all be considered. Furthermore, these considerations are distinctly different from the biped human amputee. Detailed quadruped prosthesis biomechanics are beyond the scope of this article.

Currently there are 2 types of prosthetic limbs available: socket based and ITAP. Socket-based prostheses have been used in humans for centuries and provide a socket within which the residual limb rests; an extension provides contact to the ground via some form of foot or paw. The key for socket-based prostheses is suspension and retention of the device on the residual limb. Improvements in materials, mechanical joints, and microprocessors have revolutionized these devices. ITAP provides an implanted endoprosthesis to which an exoprosthesis is attached.[17] Surgery is required and the endoprosthesis is integrated into the bone and skin similar to the way an antler is attached a deer's head; no socket is required.

Prosthetic limbs for animals are becoming available albeit with simpler models than those for humans. The advantage of socket-based prosthetic limbs is their relatively low cost, simplicity of application (no additional surgery required), and adaptability to many levels of limb loss from paw to midantebrachium or crus (Figs 12 and 13). The clear advantage of ITAP is direct skeletal integration of the exoprosthesis. This means there is no mechanical delay in gaiting because the exoprosthesis directly transmits forces to the skeleton via the endoprosthesis (implant). An additional advantage is less soft tissue trauma, an intermittent vexing although not intractable sequelae of socket prosthesis in humans and animals.

Rehabilitation is critical for the prosthesis patient human or animal. Control of the limb is reversed; top down rather than ground up control results in delayed feedback. Through rehabilitation, the prosthesis patient relearns proprioception, balance, gaiting at different speeds, and ambulation over varied terrain.

V-OP 101: Getting Started

Why V-OP is Important to Your Practice

1. Benefit to client and patient
   a. It provides diagnosis, treatment plan, medical support, and guidance for underserved population.
   b. It provides solutions where none existed before.
   c. It provides clients from obtaining inaccurate information, medical advice, and medical devices from nonveterinary sources.
   d. It provides ongoing professional care for the V-OP patient to ensure continued proper use of device.
2. Benefit to veterinarian
   a. These are extremely rewarding cases from a professional standpoint.
   b. It provides innovation and cutting edge therapies to your community.
3. Benefit to veterinary clinic
   a. V-OP clients are deeply grateful and bonded to the clinic providing a solution when there had been none before.
   b. These are unique patients who garner MUCH attention in the community as people wonder “what is that device?”
   c. There is much opportunity for traditional and social media exposure because these are interesting cases.
   d. A new revenue stream is created from a large population of animals who are not surgical candidates or whose surgery requires additional support.
   e. An entirely different population of animals that will benefit from prosthetic limbs is created when subtotal amputation is chosen over total amputation.
   f. In the case of long-term device use, twice-annual appointments bring the client into the clinic for continued support over years. These appointments are comprehensive and should be scheduled separately. They include evaluation of therapeutic plan, wearing schedule, activity, concerns, skin condition, device condition, and rehabilitation plan if appropriate.

Primary health care veterinarian responsibilities:

1. Diagnose presenting orthopedic issue
2. Create therapeutic plan
   a. Device prescription with the support of V-OP fabricator; such durable medical devices should never be provided without the prescription and care of a veterinarian with a valid doctor, client, patient relationship.
   b. Rehabilitation prescription, implementation, and supervision.
3. Management of device long-term therapeutic plan as needed.

Finding a V-OP Fabricating Partner

V-OP are custom-made from a fiberglass impression of the patient's limb after a diagnosis and complete biomechanical evaluation, and therapeutic plan are established. This is in contrast

Fig. 12. An example of a socket-based thoracic limb provided to the patient in Fig. 11.

Fig. 13. An example of a socket-based pelvic limb after subtotal amputation by tarsometatarsal disarticulation.

to off-the-shelf support wraps, splints or braces, or wheeled devices, which may or may not provide the proper therapeutic support and do not come with professional veterinary advice. Custom device design is unique based on the individual corrective needs, conformation, abilities, and environment of the patient. Manufacturing requires a firm understanding of quadruped biomechanics and skilled modification to accommodate limb topography, create appropriate corrective forces, and provide sufficient malleability to adjust as needed. V-OP is a hands-on therapy; each case should be managed carefully from diagnosis to device application to rehabilitation using a cohesive team approach. The ideal team includes the pet owner, the family veterinarian, a certified rehabilitation therapist, and a V-OP specialist skilled in custom design, fabrication, and fitting of devices for the intended species.

The advantages afforded by custom orthoses and prostheses include (1) reduction and immediate management of coaptation-related wounds; (2) management of primary pain generators associated with functional impairments; (3) improvement of biomechanics, allowing for greater activity and a significant decrease in compensatory pain; (4) return to active lifestyle, resulting in decreased obesity and associated comorbidities; (5) improvement in quality of life and functional independence, both of which can prevent premature decision to euthanize; and (6) the availability of treatment options where none existed before.

As of this writing, there are at least 12 companies offering veterinary-specific orthoses, prostheses, or assistive devices listed on the internet.[18] However, there are opportunities to learn about V-OP at local and national veterinary meetings, and a continuing education course is offered through the Canine Rehabilitation Institute.[19] There is as yet no certification for V-OP. Also, there are no regulating bodies and no requirements for V-OP fabricators at this time. H-OP has no practice act limiting scope of practice to which practitioners must adhere. Although human devices require prescription, the same cannot be said for any nonhuman patient. In addition, veterinary practice acts do not specify prescription or a valid doctor, patient, and client relationship for the use of V-OP devices. Keeping in mind veterinary practice acts have only recently addressed acupuncture, chiropractic, and rehabilitation, such clarification is likely forthcoming for V-OP. Until that time, clients can order and use such devices without the guidance of the veterinarian. Likewise, until regulations and limitations exist, the onus rests with the attending veterinarian to advocate for client and patient by ensuring proper, safe, appropriate prescription, and guidance in the use of these devices. Because clients will seek these devices with or without veterinary support, it behooves the veterinarian to participate in this process.

When choosing a fabricator, the following questions should be asked:

(1) What is the qualification of the fabricator? Many companies are founded by H-OP practitioners; this is a good start. The certifying organizations for this profession are the American Board of Certification-OP and the Board of Certification.[20,21] Currently, these are voluntary certifications and as such not all H-OP practitioners are adequately trained and certified. These certifications are considered a minimum.
(2) What is the fabricator's veterinary caseload? Do they work with animals exclusively or work with animals as a side business? Working with animal patients is not the same as working with human patients because of the vastly different biomechanics of the quadruped. Just as cats are not small dogs, chihuahuas are not small greyhounds, and quadrupeds are absolutely not small people on all fours. Veterinary species are tremendously diverse and challenging. Therefore, a fabricator should have a great deal of veterinary patient experience before providing a device for any companion animal.
(3) Does the fabricator require a prescription from a veterinarian with a valid doctor, patient, and client relationship?
(4) Does the fabricator have a close working relationship with a veterinarian who can provide consultation and guidance regarding animal health, locomotion, behavior, wound management, and rehabilitation?
(5) Does the collaborating veterinarian have advanced training in sports medicine, rehabilitation, and V-OP? There are several interest groups and specialty boards providing certification and continuing education for veterinarians. These include, but are not limited to, the Veterinary Orthopedic Society,[22] the American College of Veterinary Sports Medicine and Rehabilitation,[4] the American Association of Rehabilitation Veterinarian,[13] the Canine Rehabilitation Institute,[19] and the University of Tennessee.[23] Association with such organizations is ideal for any veterinarian providing consistent consultation to any V-OP fabricator.

The V-OP Evaluation, Fitting, and Assessment Processes

A V-OP patient evaluation must be thorough enough to provide a specific device prescription. It must take into account the entire patient from a mechanical and physiological perspective in addition to a clear understanding of the primary injury. The V-OP examination must fully define the presenting deficit, characterize biomechanical implications, identify complicators or comorbidities, and diagnose all primary and secondary pain generators. The examination should include a general wellness assessment in addition to orthopedic, myofascial, biomechanical, and neurologic examinations. Additionally, the case must be understood from the standpoint of lifestyle, environment, family dynamics, sport or activity, goals and intended outcome as defined by client and veterinarian, and alignment of goals with proposed orthotic or prosthetic device. The good news is that with the help of a qualified fabricator as noted previously, the general practitioner can succeed in providing V-OP devices.

Once a plan is developed and the device is designed, the next step in creating a custom orthosis or prosthesis is fiberglass impression molding of the limb. This step is critical for optimal fit and correct function of the device. Creating a precise replica of the limb in a thin layer of fiberglass tape requires a bit of artistic acumen and a clear sense of device purpose. This fiberglass impression is used to create a plaster model from which the custom device will be fabricated. Therefore, the limb must be molded in the properly aligned position. Just as a poorly positioned or exposed radiograph is less than adequate for accurate diagnosis, a poorly molded fiberglass impression is equally useless in fabricating the best device.

Manufacturing requires skilled modification of the model by hand or using computer-assisted design to build reliefs, which accommodate limb topography and create appropriate corrective forces when the completed device is applied to the limb. The modified model is the structure on which a thermoplastic shell is vacuum formed. The shell is then hand cut, trimmed, and ground to the final shape. Materials used to pad and line the shell vary. Hinges, straps, pads, and motion-limiting components complete fabrication. The typical custom V-OP device cost varies with components and materials and averages $600-$1000. This does not include the necessary appointments to ensure proper fit and function along with client education.

An important advantage to veterinarian-guided use of a V-OP device is fit and function assessment and adjustment. Adjustments are expected and are a normal part of the custom process. Reputable custom fabricators strive to accurately fit the device; however, variations in injury severity, gaiting pattern, and level and intensity of activity all affect the accuracy of initial fit and cannot be predicted in all cases. Couple this with a dynamic process such as Achilles tendon therapy and the necessity for adjustability is clear. Pressure and friction irritation are the most common reasons for adjustment followed by the natural progression of the case (Fig 8). Fortunately, with a removable device, such issues are quickly recognized and corrected; this is an advantage over casts and splints that are changed weekly at best.

Orthoses and prostheses are considered “durable medical devices.” This means that proper use is necessary to meet therapeutic goals and to ensure safe application over the lifetime of the patient or the duration of injury healing. Typically, several follow-up assessments are advised in the first few months. Thereafter, annual to twice-annual appointments, depending on injury, age, and activity of the patient, are needed. At these appointments, the orthopedic condition of the patient and the condition or fit of the device should be evaluated. Lastly, short- and long-term plans are adjusted.

Rehabilitation and V-OP: A Team Approach With a Precedent

Human patients receiving a prescription orthosis or prosthesis work with a physical therapist to learn how to use the device properly. There is a common misconception that orthoses are static, causing muscle atrophy, diminished joint range of motion, and dependence on the device. This is not true of modern dynamic orthoses. These devices are hinged and actually promote muscle development, normalize range of motion, and assist in balance and coordination by stabilizing an unstable limb segment (Fig 1). Rehabilitation provides the link between patient and device.

Most veterinary patients adapt quickly, and behavioral techniques can facilitate this. Device-specific rehabilitation focuses on specific skills. Skills include transitions (sitting, lying down, and getting up), stairs, getting into and out of vehicles safely, managing on different types of surfaces (ground, carpet, hardwood floor, etc.), and managing dog doors. Orthopedic injury leads to compensatory abnormal movement and associated muscle strain and weakness. Gait re-education focuses on resolving these issues. The best way to ensure the highest level of success with a V-OP device is to follow a rehabilitation plan established by a certified canine rehabilitation professional (CCRT or CCRP).[19,23] Each patient's condition and abilities are unique, and as such, an individualized rehabilitation program is needed. Furthermore, although V-OP devices can get wet, water therapy (swimming and underwater treadmill) comprises a small component of the overall rehabilitation plan. Land-based therapeutic exercise is essential. Balance, proprioception, muscle timing (neuromuscular retraining) and coordination lay the foundation for proper device use; these must be mastered on land so that the patient can learn response to normal ground reaction forces and shifts in their total body force vectors (Fig 14). The buoyancy of water complicates such mastery and does not represent the patient's home environment. Additionally, daily home exercises are an important part of the rehabilitation plan. Most clients do not have daily access to water therapies, thus practical land-based exercises make up the bulk of in home therapy.

As in the past for human physical therapists, OP is creating a new challenge for veterinary rehabilitation therapists: assistive device-specific rehabilitation. Animals are adaptive and will learn ways of ambulating in an orthosis or a prosthesis. This is not always the most efficient, safe, or functional method of ambulating. Therefore, using the human experience as a precedent, it is reasonable to suggest that veterinary patients are more likely to return to highest level function faster with professionally guided assistance. Veterinary patients present a seemingly endless variety of injury types and an exceptional drive to recover. For the creative rehabilitation therapist, this is an exciting area for professional growth.

Summary

There are many advantages afforded by orthoses and prostheses. Many injuries are amenable to these devices, and subtotal

Fig. 14. Rehabilitation for a stifle orthosis includes gait re-education using cavaletti poles.

amputation provides a substitute for quality of life, altering total amputation. Simply put, V-OP devices offer treatment options where none existed before. For chronic or catastrophic injuries, they play an important role in pain management, and can significantly improve, comfort, quality of life, and functional independence as well as limit premature decisions to euthanize. In the severe case, these devices serve as safe alternatives to traditional casting and splinting while providing the opportunity to initiate rehabilitation earlier. Many patients can return to an active lifestyle, which can reduce the risk of obesity and its associated comorbidities. Secondary or compensatory pain can be minimized by correcting or improving gait mechanics and re-establishing quadruped locomotion.

With increasing numbers of fabricators and internet suppliers, veterinarians must educate themselves to advocate for their patients and clients. V-OP devices are valuable therapeutic tools. However, paraprofessionals cannot and should not prescribe and treat. In the absence of knowledgeable and supportive veterinarians, this is the risk and reality. Providing these solutions within the primary care practice is possible and appropriate.

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