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Retrospective Study on External Canine Limb Prosthesis used in 24 patients

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ABSTRACT

Objective: The purpose of this retrospective study is to provide data regarding external prosthetic use in small animal patients, evaluate the common complications associated with external prosthetics, and evaluate the outcome of patients using an external prosthetic.

Background: The use of external canine limb prosthetics is relatively uncommon in veterinary medicine today. However, there is growing interest in prosthetics and their clinical application because these devices may offer an alternative to euthanasia in severe cases where full amputation or alternative methods of limb spare are not an option. The goal of the prosthesis is to provide a better quality of life, help prevent further deformation and degeneration of existing joints, decrease leg length discrepancies, increase exercise and activity levels, provide a means to participate in rehabilitation therapy and maintain the ability to perform daily acts of living. To the author's knowledge, there is no report of external prosthetic use in small animal veterinary medicine, providing the profession with baseline information for use in, not only general practice or referral practice, but also future research.

Evidentiary value: This retrospective study provides data regarding external prosthetic use in small animal patients, evaluates the procedures, manufacturing, rehabilitation and common complications associated with external prosthetics, and evaluates the factors that determine a patient's prosthetic candidacy.

Methods: Patients that had an external prosthesis custom manufactured for them at Animal Orthocare, LLC and had a complete medical record were identified for this study. A client survey was completed via e-mail or telephone to collect further data about the patients, including age, weight, breed, sex, affected limb(s), reason for prosthesis, level of amputation, activities patient could perform with prosthesis in place, prosthetic fit, prosthetic migration (e.g. rotating or slippage), quality of mobility comparing pre-prosthetic mobility to post-prosthetic mobility, prosthetic integrity, client's post-prosthetic mobility expectations, complications encountered post-prosthetic application, and client's perspective of patient's quality of life comparing pre-prosthetic and post-prosthetic placement.

Results: Of the 76 patients who were identified for this study and received a survey, survey information was obtained for 24 patients. There were 50% (n=12) forelimbs affected and 50% (n=12) hind limbs affected. Bilateral hind limb prosthesis was found in 8.33% (n=2) of the 24 cases included. Causes for the prosthesis were found to be due to trauma in 37.5% (n=9) of cases, congenital causes in 37.5% (n=9) of cases, neoplasia in 16.66% (n=4) of cases, infectious in 4.17% (n=1) of cases, and unknown in 4.17% (n=1) of cases. Of the 24 patients, 50% (n=12) of clients felt the prosthesis had an excellent fit; 20.83% (n=5) felt the prosthesis had a good fit; 16.67% (n=4) felt the prosthesis had an acceptable fit; 4.17% (n=1) felt the prosthesis had a less than satisfactory fit; lastly, 8.33% (n=2) felt the prosthetic had a poor fit. Of the 24 patients, 91.66% (n=22) were able to stand using the prosthesis; 87.5% (n=21) were able to walk using the prosthesis; 79.17% (n=19) were able to trot using the prosthesis; 70.83% (n=17) were able to climb stairs using the prosthesis; 54.17% (n=13) were able to jump on or off furniture using the prosthesis; 79.17% (n=19) were able to play fetch using the prosthesis. From these cases, 50% (n=12) of clients felt the patient's mobility improved post-prosthetic placement. Expectations were met in 70.83% (n=17) of cases; expectations were somewhat met in 4.17% (n=1) of cases; expectations were not met in 25% (n=6) of cases. Prosthetic migration affected 37.5% (n=9) of cases; residuum sore or infection affected 20.83% (n=5); refusal to use the prosthetic limb occurred in 20.83% (n=5) of cases; concurrent orthopedic disease occurred in 0% of patients; prosthetic failure (breaking) occurred in 20.83% (n=5) of cases. Finally, clients were asked to rate the quality of life of patients after prosthetic placement when compared to pre-prosthetic placement on a scale of 1 – 5 (1 = much worse than before, 5 = much better than before). Patients rated a quality of life of 5 were 20.83% (n=5); a rating of 4 was given to

20.83% (n=5); a rating of 3 was given to 45.83% (n=11); a rating of 2 was given to 4.17% (n=1); a rating of 1 was given to 8.33% (n=2).

Conclusion: External prosthetics may help improve quality of life and should be considered as an alternative to euthanasia where full amputation or alternative methods of limb spare are not an option.

Application: These results should be considered by veterinarians and prosthetists when searching for an alternative to full amputation or other limb spare surgical methods.

INTRODUCTION

The use of external canine limb prosthetics is relatively uncommon in veterinary medicine. There are a number of external prosthetics used in humans, utilising various methods of securing the artificial limb to the residual limb as well as various devices for different types of activity. In veterinary patients, we are limited in both areas, partially due to our patients' anatomies and the limited amount of evidence-based knowledge available (Canapp et al., 2012; Seymour R., 2002). However, there is more interest in prosthetics and their clinical application because these devices may offer an alternative to euthanasia in cases where full amputation or alternative surgical methods of limb spare are not an option. The goal of the prosthesis is to provide a better quality of life, help prevent further deformation and degeneration of existing joints, decrease leg length discrepancies, increase exercise and activity levels, provide a means to participate in rehabilitation therapy and maintain the ability to perform daily acts of living. There are specific requirements for a prosthetic to be successful, and complications may arise if appropriate surgical planning, accurate manufacturing of the prosthetic, or proper introduction to the prosthesis are not performed.

Patients should be assessed carefully when recommending an external prosthesis. One of the most critical characteristics for prosthetic eligibility is the amputation level (Canapp et al., 2012; Canapp et al., 2014). In human studies, the most successful candidates have amputations performed as distally as possible, salvaging vasculature and soft tissue coverage over the residuum, as this has been shown to achieve the optimal potential for post-operative ambulation (Bowker et al., 1992). When compared to non-amputees, patients with transtibial amputations were noted to have 9% higher oxygen consumption during ambulation, patients with transfemoral amputations were noted to have 49% higher oxygen consumption during ambulation and patients with bilateral transfemoral amputations were noted to have 280% higher oxygen consumption (Huang et al., 1979). It is also widely accepted that patients with distal amputations have fewer planes of movement versus patients with proximal amputations, which improves patient control over the prosthesis during ambulation (Bowker et al., 1992; Canapp et al., 2014). Due to the anatomy of our small animal patients, the hind limb offers an advantage for prosthetic success with distal amputations, while the forelimb's anatomy offers better success with proximal amputations (Canapp et al., 2012). The tarsus is an excellent suspension point to reduce prosthetic migration and has an anatomical advantage compared to other joints such as the carpus due to the acute angular nature of the joint, which reduces prosthesis axial rotation (Canapp et al., 2012; Canapp et al., 2014). In the forelimb, prosthetics may be utilised if the elbow joint is preserved (Canapp et al., 2012; Canapp et al., 2014). The humeral epicondyles provide a good prominence for self-suspension, and a circumferential strapping system used proximal to the elbow helps prevent migration and contributes to rotational stability (Canapp et al., 2012; Canapp et al., 2014). Procedures requiring amputation proximal to the elbow have limited ability for prosthetic success as there are no ideal prominences for suspension and there are more planes of movement, which will reduce control over the limb and could even lead to humeral fracture if the prosthesis shank is too long (Canapp et al., 2012). Proximal amputations in the hind limbs often have diminished success, unless a suspension system consisting of a harness is used. Further, the stifle joint provides minimal boney prominences to which an artificial limb may be suspended, making the prosthetic more prone to migration and excessive rubbing (Canapp et al., 2014).

Surgical planning for amputation should aim to maintain soft tissue coverage of the residuum while positioning nerve endings away from the distal residuum and preserving residual limb vasculature and smooth boney prominences to prevent residual limb sores (Canapp et al., 2012; Bowker et al., 1992; Burgess et al., 1981; Canapp et al., 2014). Maintaining adequate soft tissue coverage will help reduce shear forces on the residual limb involved with prosthetic ambulation. In humans undergoing transtibial amputations, there is often discomfort due to instability between the tibia and fibula (Bowker et al., 1992; Ertl Reconstruction Website, 2015; DeCoster et al., 2006). In the human literature it is also proposed that an open medullary cavity will increase discomfort with end-bearing prosthesis by altering normal conditions of pressure and circulation within the bone (DeCoster et al., 2006). Surgeons have developed a procedure to eliminate instability between the tibia and the fibula by using a tibiofibular bridge that creates a unified end-bearing limb and a callus over the medullary cavity to decrease disturbances in vascular supply to the end-bearing surface (DeCoster et al., 2006, Ertl Reconstruction Website, 2015). Currently, these techniques are infrequently utilised in veterinary surgery but could improve weight bearing and overall function in patients with a transtibial amputation (Canapp et al., 2014).

Prior to surgery, the level of the amputation for the soft tissues is marked distally, while the boney anatomy is marked proximally on the skin. The initial incision should be planned so that the closed incision does not lie over the distal or palmar/plantar surface of the residuum to ensure that the incisional scar does not adhere to the underlying bone (Canapp et al., 2012; Canapp et al., 2014; Bowker et al., 1992). It is vital that the soft tissues are handled carefully to prevent unnecessary trauma; good soft tissue coverage of the residuum will resist the shear forces involved in prosthetic ambulation and help maintain residual limb integrity (Canapp et al., 2012; Canapp et al., 2014; Bowker et al., 1992). A transverse osteotomy, at the most distal level possible, is made across the bone(s), proximal to the initial skin incision and soft tissue transection, and the distal limb is removed. The cortical bone edges should be smoothed to prevent sharp edges causing soft tissue trauma (Canapp et al., 2014; Bowker et al., 1992; Ert Reconstruction Technique, 2015; Decoster et al., 2006). The medullary cavity should be packed with bone wax to help provide hemostasis from the medullary canal. Hemostasis is especially important to obtain in amputations as hemorrhage will predispose the residuum to post-operative seromas (Canapp et al., 2012; Canapp et al., 2014; Bowker et al., 1992). To begin closure, muscles, tendons and fascia from the caudal limb are wrapped around the end of the bone and apposed to the muscles, tendons and fascia on the opposite side of the bone in a mattress pattern using a long-lasting monofilament suture (Canapp et al., 2012; Canapp et al., 2014). While it is not well defined for small animals, it is recognised that weight bearing occurs at the caudodistal aspect of the residuum. Thus, the surgeon should avoid creating possible weak points over the caudodistal surface as it could predispose the residuum to future soft tissue break down (Canapp et al., 2012; Canapp et al., 2014). Once all muscles, tendons and fascia are apposed, the skin incision should be closed over the cranial surface of the residuum with minimal to no tension to reduce the chances of ulcerations and to promote healing post-operatively (Canapp et al., 2012; Canapp et al., 2014). Skin sutures may be preferred to skin staples as they are considered more comfortable and are associated with a lessened risk for post-operative incisional infection (Smith et al., 2010).

Post-operatively, amputees are currently placed into a compression bandage to reduce swelling, protect the distal residuum from trauma and promote healing (Canapp et al., 2012). Prosthetic manufacturing should not begin until all swelling has resolved and muscle atrophy of the residual limb has occurred (Canapp et al., 2012; Canapp et al., 2014). Typically, the residuum is fitted for a prosthetic at about 2-3 weeks post-operatively when the swelling has fully resolved, as this will help reduce further prosthetic revisions (Canapp et al., 2012; Canapp et al., 2014).

It is important that prosthetic professionals work directly with both the veterinary orthopedic surgeon and a veterinary rehabilitation team to reach the most successful outcome. Starting with prosthetic introduction, a close relationship between the prosthetist and the client should be maintained to ensure proper wear and care of the prosthesis and to prevent complications or further injury to the patient. Firstly, the client should be instructed how to properly don and doff the prosthesis and a schedule for gradual introduction should be devised. Schedules for introduction will vary case by case, but a generic schedule is 1 hour on day one, increased by 1 hour each day until it can be worn at all times. Additionally, rehabilitation therapy is often recommended to help integrate the prosthesis into the everyday life of the patient and client. Rehabilitation commonly focuses on increasing circulation, enhancing forelimb and hind limb strength and increasing range of motion; for prosthetic patients it must also provide prevention of contractures or correction of existing contractures, improvement in coordination, reduction of edema to promote healing and, lastly, promote mobility using the device (Canapp et al., 2012; Canapp et al., 2014). Clients should also be made aware of signs of early complication (e.g. persisting erythema, etc.) so that earlier revisions may be made. However, there is little in the literature regarding the most common complications observed in patients wearing external prosthetics.

To the authors' knowledge, there is no report of external prosthetic use in small animal veterinary medicine. The purpose of this retrospective study is to provide data regarding external prosthetic use in small animal patients, evaluate the common complications associated with external prosthetics, and evaluate the outcome of patients using an external prosthetic.

METHODS & MATERIALS

Patient selection

Patients that had an external prosthesis custom manufactured for them at Animal Orthocare, LLC and complete records were selected from the database at Animal Orthocare, LLC. Seventy-six candidates fit the inclusion criteria. Information collected from the record included sex, age, weight, breed, and the affected limb.

Prosthetic fabrication

Each prosthesis was manufactured in a similar method for each patient.[a] Each patient's residuum had a cast made using several techniques – fiberglass cast, plaster of paris cast, 3D modeling, CT or MRI image reconstruction, algination or biofoam techniques were employed. Once a negative or positive cast was obtained, a positive mold was produced. Manual sculpting or 3D digital modeling techniques were used in order to take down areas of pressure tolerance and build upon areas of pressure resistance to produce the final positive mold on which the definitive socket is manufactured. Fabrication techniques used to form the socket include vacuum forming thermoplastics or carbon lamination. Several materials were employed to improve comfort of the prosthesis including a soft liner made from plastazote, aliplast or volara. Once the socket was created, methods of suspension were selected for each patient to help prevent migration of the device. Thereafter, a shank was selected to ensure limb length was maintained and a foot for the prosthesis was designed to provide appropriate breakover, depending on the patient's daily activity level. Pending the patient’s response to the prosthetic design, adjustments were made accordingly so that the device maintained proper fit and to prevent migration.

Client survey

For all patients identified for this study, a client survey was then completed via electronic email or telephone to provide further data about the patients, including age, weight, breed, sex, affected limb(s), reason for prosthesis, level of amputation, activities patient could perform with prosthesis in place, prosthetic fit, prosthetic migration (e.g. rotating or slippage), quality of mobility comparing pre-prosthetic mobility to post-prosthetic mobility, prosthetic integrity, client’s post-prosthetic mobility expectations, complications encountered post-prosthetic application, and client’s perspective of patient’s quality of life comparing pre-prosthetic and post-prosthetic placement.

RESULTS

Overall survey data

Seventy-six patients were identified for this study. The patient age ranged from 9 weeks to 15 years of age, with a mean of 4.7 years. The patient weight range was 4 to 155 pounds, with a mean of 61 pounds. Surveys were sent via electronic mail to all 76 cases and followed up via telephone. Of the 76 cases, survey information for 24 patients was obtained. From the 24 patients who responded to the survey, the patient age ranged from 5 months to 12 years, with a mean of 4 years. The patient weight ranged from 4 to 155 pounds, with a mean of 62.2 pounds. Breeds included were mixed breed (n=7), Golden Retriever (n=4), Pit Bull Terrier (n=2), Border Collie (n=1), South African Boerboel (n=1), English Mastiff (n=1), Shiloh Shepherd (n=1), German Shepherd Dog (n=1), Labrador Retriever (n=1), Boxer (n=1), Maltese (n=1), Giant Schnauzer (n=1), Bassett Hound (n=1) and Coonhound (n=1).

Gender survey data

From the 24 clients who responded to the survey, the patient sex ratio was 41.66% female (n=10), of which 70% (n=7) were altered. The male portion was a total of 58.33% male (n=14), of which 92.86% (n=13) were altered.

Affected limb survey data

From the 24 patients who responded to the survey, 5 different affected limb categories were recognised. There were 50% (n=12) forelimbs affected and 50% (n=12) hind limbs affected. The left forelimb was affected 16.66% (n=4) of the time; the right forelimb was affected 33.33% (n=8) of the time. The left hind limb was affected 25% (n=6) of the time; the right hind limb was affected 16.66% (n=4) of the time. Bilateral hind limb prosthesis was found in 8.33% (n=2) of the 24 cases included. Thus, there was a total of 26 affected limbs.

Reason for prosthesis survey data

From the 24 patients who responded to the survey, reason for prosthetic application was recorded (Figure 1). Prosthetic application was elected following trauma in 37.5% (n=9) of limbs, congenital malformations in 37.5% (n=9) of limbs, neoplasia in 16.66% (n=4) of limbs, and other causes in 8.33% (n=2) of limbs, which included partial limb loss due to parvovirus (n=1) and an unknown cause (n=1)

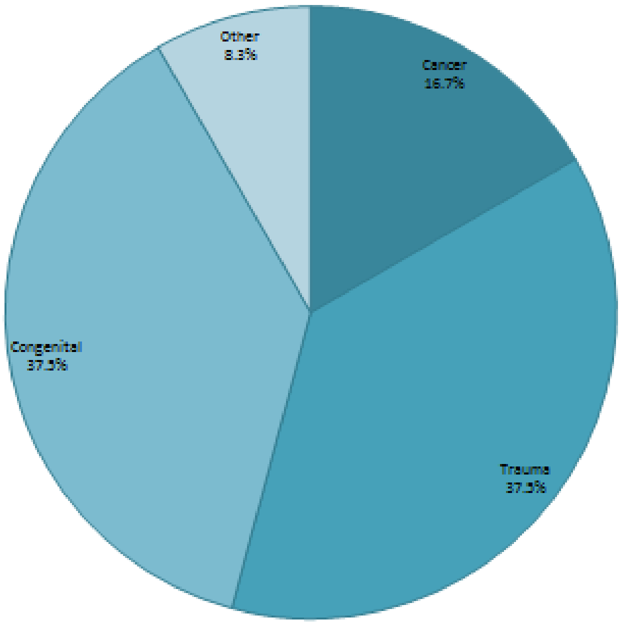

Figure 1: This chart shows the pre-existing conditions that led to the use of an external limb prosthetic to improve mobility, provide a method of limb spare or improve quality of life. This data was collected from client answered surveys retrospectively.

Level of amputation survey data

From the 24 patients who responded to the survey, the level of amputation was both obtained from the medical record and confirmed by having clients select the level of amputation from the Amputation Level Diagram provided (Figure 2). From the patients with a forelimb prosthesis, 75% (n=9) were amputees at the level of the metacarpus, while0% had amputation at the level of the carpus. Amputation at the level of mid-diaphyseal radialulnar occurred 25% (n=3) of the time. From patients with a hind limb prosthesis, 50% (n=6) were amputees at the level of the metatarsus, while 41.66% (n=5) had amputation at the level of the tarsus. Amputation at the level of mid tibial occurred 8.33% (n=1) of the time.

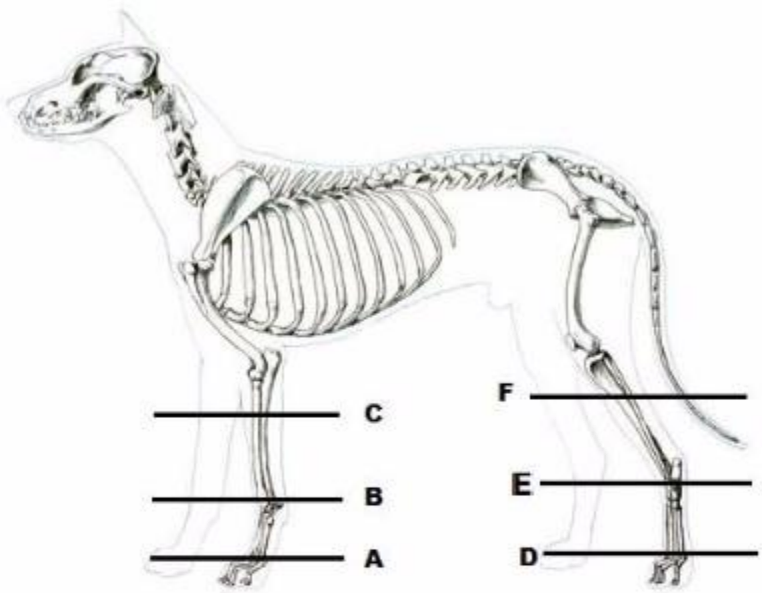

Figure 2: Amputation Level Diagram. Each letter denotes the level at which the limb was amputated. Levels A, B, & C relate to the forelimbs: Level A corresponds to amputation at the level of the metacarpus; Level B

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corresponds to amputation at the level of the carpus; Level C corresponds to amputation at the level of mid-diaphyseal radial-ulnar, or distal to the elbow. Levels D, E, & F relate to the hind limbs: Level D corresponds to amputation at the level of the metatarsus; Level E relates to amputation at the level of the tarsus; Level F relates to amputation at the level of mid-tibial or distal to the stifle.

Daily activities survey
From the 24 patients who responded to the survey, information about daily activities was evaluated (Figure 3). Of the 24 patients, 91.66% (n=22) were able to stand using the prosthesis; 87.5% (n=21) were able to walk using the prosthesis; 79.17% (n=19) were able to trot using the prosthesis; 70.83% (n=17) were able to climb stairs using the prosthesis; 54.17% (n=13) were able to jump on or off furniture using the prosthesis; 79.17% (n=19) were able to play fetch using the prosthesis.

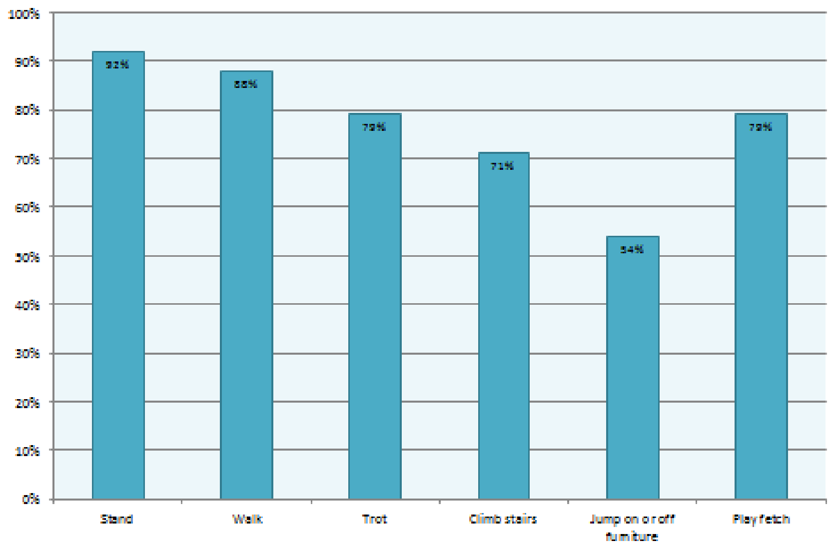

Figure 3: This graph shows data pertaining to daily acts of living for patients after prosthetic placement, obtained from client answered surveys.

Prosthesis fitting survey data
From the 24 patients who responded to the survey, information about prosthetic fit was recorded. Of the 24 patients, 50% (n=12) of clients felt the prosthesis had an excellent fit; 20.83% (n=5) felt the prosthesis had a good fit; 16.67% (n=4) felt the prosthesis had an acceptable fit; 4.17% (n=1) felt the prosthesis had a less than satisfactory fit; lastly, 8.33% (n=2) felt the prosthetic had a poor fit.

Prosthetic migration survey data
From the 24 patients who responded to the survey, information about prosthetic migration (e.g. slipping) was gathered. Of these patients, 45.83% (n=11) were reported to have no prosthetic slippage; 12.5% (n=3) were reported to have very occasional migration; 16.67% (n=4) were reported to have prosthetic slippage sometimes; lastly 25% (n=6) were reported to have prosthetic slippage often.

Prosthetic mobility survey data
From the 24 patients who responded to the survey, subjective comparative data about patient mobility pre-prosthetic placement versus post-prosthetic placement was collected (Figure 4). From these cases, 50% (n=12) felt the patient's mobility improved post-prosthetic placement. No difference in mobility between pre-prosthetic and post-prosthetic placement was found in 37.5% (n=9) of patients. In 12.5% (n=3) of patients, clients rated mobility to be worse after prosthetic placement.

Device integrity survey data

From the 24 patients who responded to the survey, 75% (n=18) of patient's prostheses did not break from the time of placement to the time of this study; 25% (n=6) of patient's prostheses did break from the time of placement to the time of this study.

Mobility expectations survey data

From the 24 patients who responded to the survey, clients rated how the prosthesis met their mobility expectations. The cases where expectations were met occurred in 70.83% (n=17) of cases; expectations were somewhat met in 4.17% (n=1) of cases; expectations were not met in 25% (n=6) of cases.

Complications survey data

From the 24 patients who responded to the survey, information about complications encountered was gathered (Figure 5). Prosthetic migration occurring often affected 37.5% (n=9) of cases; residuum sore or infection affected 20.83% (n=5); refusal to use the prosthetic limb occurred in 20.83% (n=5) of cases; concurrent orthopedic disease occurred in 0% of patients; prosthetic failure (breaking) occurred in 20.83% (n=5) of cases. Other complications encountered affected 8.33% (n=2) of patients. These complications included one patient never getting used to wearing the prosthesis and one patient who 'didn't like wearing' the prosthesis.

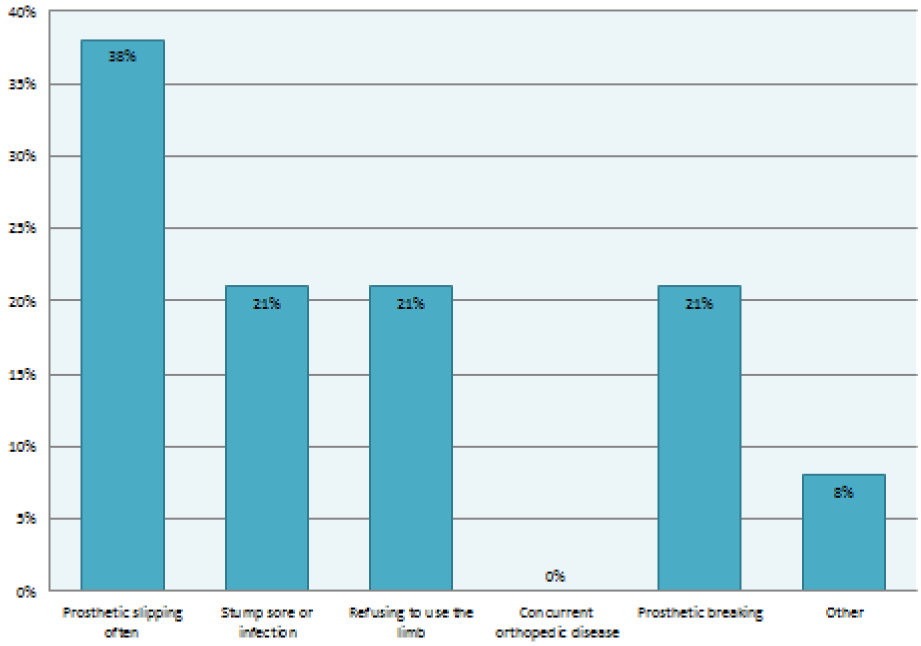

Figure 4: This graph details incidence and types of complications clients experienced when using prosthetics.

Quality of life survey data

From the 24 patients who responded to the survey, clients were asked to rate the quality of life of patients after prosthetic placement when compared to pre-prosthetic placement (Figure 6). A scale from 1 – 5 was provided (1 = much worse than before, 5 = much better than before). Patients rated a quality of life of 5 were 20.83% (n=5); a rating of 4 was given to 20.83% (n=5); a rating of 3 was given to 45.83% (n=11); a rating of 2 was given to 4.17% (n=1); a rating of 1 was given to 8.33% (n=2).

DISCUSSION

This study supports that external prosthetics may help improve quality of life and should be considered as an alternative to euthanasia where full amputation or alternative methods of limb spare are not an option.

To the authors' knowledge, this is the first report of external prosthetic use in small animal veterinary medicine, providing the profession with baseline information for use in, not only general practice or referral practice, but also future research. Furthermore, these results should be considered by veterinarians and orthotists when searching for an alternative to full amputation or other limb spare surgical methods.

Over 87% of clients reported that the prosthetic had both an acceptable fit or better and a quality of life that was equal to or better than the quality of life prior to prosthetic placement. It is important to note that the majority of patients with a forelimb amputation had an amputation at the level of the metacarpus (75%) and all but one hind limb amputation patients were at the level of the metatarsus or level of the tarsus. As previously mentioned, forelimb prosthetics are typically preferred for more proximal amputations as the elbow joint typically provides a better suspension point than the carpus, whereas distal hind limb amputations offer an advantage for prosthetic success as the tarsus is an excellent suspension point to reduce prosthetic migration (Canapp et al., 2012; Canapp et al., 2014). It is possible that the level of amputation contributed to the outcomes reported in this study; however, further study is necessary to determine if there is a correlation between amputation level and outcome measures.

Various complications were reported in this study, most notably prosthetic migration in 37.5% of cases and residuum sores or infection in approximately 20% of patients. This is consistent with previous reports in both humans and dogs that report prosthetic migration and residuum sores are commonly noted complications (Canapp et al., 2012; Armstrong et al., 2007; Bowker et al., 1992; Seversky et al., 2005; Canapp et al., 2014; Ertl Reconstruction Website et al., 2015; DeCoster et al., 2006). Previous reports have also stated the initial prosthesis often requires revisions as the residuum changes in shape due to the patient's altered ambulation (Canapp et al., 2012; Canapp et al., 2014). Indications for prosthesis revision are prosthetic migration and the development of residuum sores. Client vigilance is necessary for monitoring the health of the residual limb to ensure prosthetic revisions are addressed in a timely manner to avoid excessive soft tissue damage or infection. Otherwise, little daily maintenance is required if the prosthetic has an intimate fit and if it is used correctly (Canapp et al., 2014).

Many of the patients in this study were reported to be able to participate in a number of activities. Of the 24 patients, approximately 79% (n=19) were able to trot using the prosthesis, 70% (n=17) were able to climb stairs using the prosthesis, 54% (n=13) were able to jump on or off furniture using the prosthesis, and 79% (n=19) were able to play fetch using the prosthesis. As one can imagine with frequent use and wear over time, repairs to the prosthesis may be needed. Approximately 25% of patient prostheses were reported to have broken from the time of placement to the time of this study. It is important that owners are instructed on how to visually inspect the prosthesis for integrity and function as any damage to the prosthesis should be addressed promptly.

This study demonstrated that a large percentage of dogs in this study were still able to participate in normal daily activities. Furthermore, the clients' expectations for their patients' mobility was met in over 70% of cases. However, this study did not specifically inquire about or quantitatively analyze alterations in gait characteristic, which has been documented in dogs and humans who use external prosthetics (Canapp et al., 2014; Malchow et al., 2016; Kendell et al., 2016). Gait pattern changes often can occur due to a misaligned prosthesis or a leg length discrepancy. These problems should be addressed as soon as possible, and can often be remedied by simple alignment adjustments or by changing internal padding thickness in the prosthetic. Depending on the case, joint abnormalities in other limbs may develop if the gait pattern is not corrected in a timely manner. The most common psychological abnormality occurs immediately when the patient is fitted with the device, where the patient rejects the prosthetic or refuses to use the limb (Canapp et al., 2014). In this study, one patient would not use the prosthetic even after an appropriate acclimation period. In most patients, a gradual introduction schedule is the method of choice to get the patient used to the device and reduce the risk of outright rejection. Clients should be warned of all possible complications prior to electing limb spare involving external prosthesis. In the end, it is most important that the client is attentive to the possible complications and the veterinarian is adept at troubleshooting any situation which may occur. Limitations of this study are predominantly related to its retrospective nature and subjective outcome measures as reported by clients. Future studies should be prospective, randomised and blinded and include objective outcome measures, such as goniometric measurements, limb circumference muscle mass measurements, and objective gait analysis. Nonetheless, this study provides data regarding external prosthetic use in small animal patients, evaluates the common complications associated with external prosthetics, and evaluates the outcome of patients using an external prosthetic that should be taken into consideration by veterinarians and prosthetists when searching for an alternative to full amputation or other surgical limb spare procedures.

FOOTNOTES

a. Animal Orthocare Prosthesis, Animal Orthocare, LLC., Sterling, VA, USA.

CONFLICT OF INTEREST

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Competing interests: Derrick Campana, CPO, is the CEO and president of Animal Orthocare, LLC.

REFERENCES

1. Armstrong PD. (2007). Immediate postsurgical and early prosthetic management of lower extremity amputations, in Lecture. The Newington Certificate Program in Orthotics and Prosthetics, Newington, CT.
2. Bowker JH, Michael JW. (1992). Atlas of Limb Prosthetics: Surgical, Prosthetic and Rehabilitation Principles. 2nd ed. St. Louis, MO: Mosby-Year Book, Inc.
3. Burgess EM, Matsen FA. (1981). Determining amputation levels in peripheral vascular disease. The Journal of Bone & Joint Surgery 63, 1493. DOI: http://dx.doi.org/10.2106/00004623-198163090-00020
4. Canapp SO, Campana DM, Fair LM. (2012). Orthopedic Coaptation Devices and Small-Animal Prosthetics. In: Tobias KM, Johnston SA. Veterinary Surgery: Small Animal - Volume 1. St. Louis, MO: Elsevier Inc, 628–646.
5. Canapp SO, Petrovitch JL, Leasure CS, et al. (2014). Prosthesis: An alternative canine limb spare technique using partial amputation and external prosthetics, in Proceedings. European Society of Veterinary Orthopaedics and Traumatology.
6. DeCoster TA, Homedan S. (2006). Amputation Osteoplasty. *The Iowa Orthoaedic Journal*, 26, 54–59.
7. Ertl Reconstruction website. The Ertl Osteomyoplastic Transtibial Amputation Reconstruction Description of Technique and Long Term Results. Available at: http://www.ertlreconstruction.com/documents/transtibial-technique.pdf. Accessed July 4, 2015.
8. Gailey RS, Roach KE, Applegate EB, et al. (2002). The Amputee Mobility Predictor: An Instrument to Assess Determinants of the Lower-Limb Amputee's Ability to Ambulate. *Archives of Physical Medicine and Rehabilitation*, 83, 613–627. DOI: http://dx.doi.org/10.1053/ampr.2002.32309
9. Huang C, Jackson R, Moore N, et al. (1979). Amputation: Energy cost of ambulation. *Arch Phys Med Behahil*, 60, 18.
10. Kendell C, Lemaire ED, Kofman J, Dudek N. (2016). Gait adaptations of transfemoral prosthesis users across multiple walking tasks. *Prosthetics and Orthotics International*, 40(1), 89-95. DOI: http://dx.doi.org/10.1177/0309364614568410
11. Malchow C and Goeran F. (2016). Effect on observation on lower limb prosthesis gait biomechanics: preliminary results. *Prosthetics and Orthotics International*, 40(6), 739-

743. http://dx.doi.org/10.1177/0309364615605374

12. Seversky N. (2005). Theory and clinical applications of prosthetic gel liners, in Lecture. The Newington Certificate Program in Orthotics and Prosthetics, Newington, CT.
13. Seymour R. (2002). Prosthetics and Orthotics: Lower Limb and Spinal. Baltimore, MD: Lippincott Williams & Wilkins.
14. Smith TO, Sexton D, Mann C, et al. (2010). Sutures versus staples for skin closure in orthopaedic surgery: meta-analysis. *BMJ*, 340:c1199. DOI: http://dx.doi.org/10.1136/bmj.c1199

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