Acta Scientiae Veterinariae, 2025. 53(Suppl 1): 1051.

CASE REPORT
Pub. 1051

ISSN 1679-9216

Bilateral Femoral Intraosseous Transcutaneous Amputation Prosthesis (ITAP) in a Cat

Italo Barros de Freitas[1], Gilberto Serighelli Júnior[1], Adriana Marks[2], Milena Hauer Anfilo[2], Danielle Buch[2], Vanessa Wotkoski Benoni[2], Jéssica Gonçalves Clock[3] & Peterson Triches Dornbusch[1]

ABSTRACT

***Background*:** Intraosseous transcutaneous amputation prosthesis (ITAP) is a limb-salvage technique that involves anchoring an implant to the bone, enabling external prosthetic attachment via osseointegration. This approach offers an alternative to traditional amputation by preserving skeletal support and functional integration. Despite its increasing use in human medicine, ITAPs have been scarcely studied in veterinary practice, and no standardized guidelines exist for implant selection, considering the anatomical variability among species and breeds. This case report describes the successful application of ITAP in a cat following severe complications from bilateral femoral osteosynthesis, with a 27-month follow-up.

***Case*:** A 1-year-old male cat, missing for 54 days, returned home with bilateral Salter-Harris type I femoral fractures. The patient underwent multiple unsuccessful surgical attempts, leading to complications such as contamination, bacterial resistance, Rush pin migration, plate exposure, osteomyelitis, and the need for muscle and skin flap reconstruction. Given the failure of all limb-preserving options, ITAP placement in the bilateral femoral diaphysis was proposed as an alternative to total limb amputation, aiming to restore independence and mobility. Preoperative planning involved computed tomography (CT) imaging, with Radiant® software used for image segmentation, bone viability assessment, and osteotomy height determination. A custom-designed titanium intramedullary implant was developed using CAD software. The surgical procedure was uneventful, and the patient was hospitalized for 3 days for postoperative monitoring. Fifteen days postoperatively, skin dehiscence and implant exposure were observed in the left femur. A revision surgery was performed, including implant coverage, bacterial culture, copious Betadine® lavage, and wound closure with 2-0 nylon sutures for the musculature and 3-0 for the skin. *Enterococcus faecium* was identified, and a 3-week course of compounded marbofloxacin was prescribed, leading to complete wound healing without further complications.

***Discussion*:** The failure of prior fracture management necessitated the use of ITAP as an alternative to bilateral femoral amputation, ultimately resulting in excellent adaptation and quality of life. This case highlights the potential of osseointegrated implants in veterinary patients, demonstrating that ITAP can provide a durable and functional limb-salvage solution. The implant was designed with a fully intramedullary titanium structure to promote osseointegration, ensuring long-term biomechanical stability. A key feature was the inclusion of an anti-rotational locking pin to counteract rotational forces that could compromise implant integrity and prosthetic function. One of the major challenges in ITAP application is dermal integration, which is crucial to preventing ascending infection and soft tissue breakdown. Poor skin adherence to the implant can lead to complications such as infection, retraction, implant exposure, and mechanical failure, as reported in similar cases. The necessity for surgical revision in this patient underscores the importance of meticulous implant design and strict postoperative wound management. Long-term implant success also relies heavily on owner compliance, as proactive care and infection monitoring are essential to maintaining functionality and preventing complications. ITAP offers a functional alternative to total limb amputation by preserving biomechanics, restoring mobility, and improving quality of life. After 27 months, the patient showed no signs of implant failure or mobility impairment. Continued advancements in implant technology and surgical techniques will be essential to optimizing ITAP outcomes and expanding its application in veterinary medicine.

Keywords: Osseointegration, limb sparing, orthopedics, endo-exo prosthesis, surgery.

DOI: 10.22456/1679-9216.145883

Received: 21 March 2025 | Accepted: 3 August 2025 | Published: 30 August 2025

[1]Department of Veterinary Medicine, Agricultural Sciences Sector, Federal University of Paraná (UFPR), Curitiba, PR, Brazil. [2]Private Veterinary Practitioner, Curitiba. [3]Department of Health Sciences, Biological and Health Sciences Section, State University of Ponta Grossa (UEPG), Ponta Grossa, PR. CORRESPONDENCE: P.T. Dornbusch [petriches@ufpr.br]. Rua dos Funcionários n. 1540. CEP 80035-050 Curitiba, PR, Brazil.

INTRODUCTION

Limb amputation is indicated in cases of irreparable trauma, necrosis, ischemia, bone neoplasia, and iatrogenic neurological injury [27]. While most animals adapt well to limb loss, long-term consequences may include reduced quality of life and compensatory overload on the remaining limbs, leading to joint, ligamentous, tendinous, and osseous disorders [21]. Therefore, amputation should only be considered when limb preservation is not a viable option [6,7,14].

The intraosseous transcutaneous amputation prosthesis (ITAP) is a technique that utilizes a bone-anchored implant traversing the dermis, allowing direct prosthetic attachment through osseointegration [7]. This concept was inspired by the structure of deer antlers, where the skin integrates with a rigid bone structure without infection or marsupialization [4,7,22,23].

The 1st documented veterinary application of ITAP was reported in 2008 [4], involving bilateral intramedullary implantation in a canine tibia. Since then, this approach has been explored as an alternative to total limb amputation and limb-sparing procedures, with ongoing advancements aimed at expanding its applications and minimizing complications [7,9,25].

This study describes the successful use of ITAP to manage complications following bilateral femoral osteosynthesis in a 1-year-old cat, with a 27 months follow-up, demonstrating its feasibility as a limb-preserving strategy.

CASE

A 1-year-old mixed-breed domestic cat, weighing 3.6 kg, was missing for 54 days before being found and taken for veterinary evaluation due to severe hind limb dysfunction. Physical examination revealed significant ambulatory impairment, and radiographic assessment confirmed chronic bilateral Salter-Harris type I fractures of the distal femur.

Multiple prior surgical attempts for fracture stabilization resulted in complications, including contamination, bacterial resistance, Rush pin migration, implant exposure, osteomyelitis, and the need for soft tissue reconstruction with a cranial tibial muscle flap followed by a caudal mesenteric artery axial pattern skin flap. Given the failure of conventional limb-preserving approaches, bilateral femoral ITAP placement was proposed as an alternative to total limb amputation. The owner consented to the procedure, prioritizing the cat's mobility and quality of life.

Preoperative planning was conducted using computed tomography (CT), with image segmentation, bone viability assessment, and osteotomy level determination performed in Radiant® medical imaging software[1] [RadiAnt DICOM Viewer, Medixant®] (Figure 1). The internal and external prosthetic components were designed using CAD software[2] [CAD Computer-Aided Design; Autodesk®].

The selected implant was a threaded intramedullary titanium device featuring a proximal hole for locking with a 1.5 mm Steinmann pin (Figure 2). The external prosthesis was 3D-printed using polyethylene

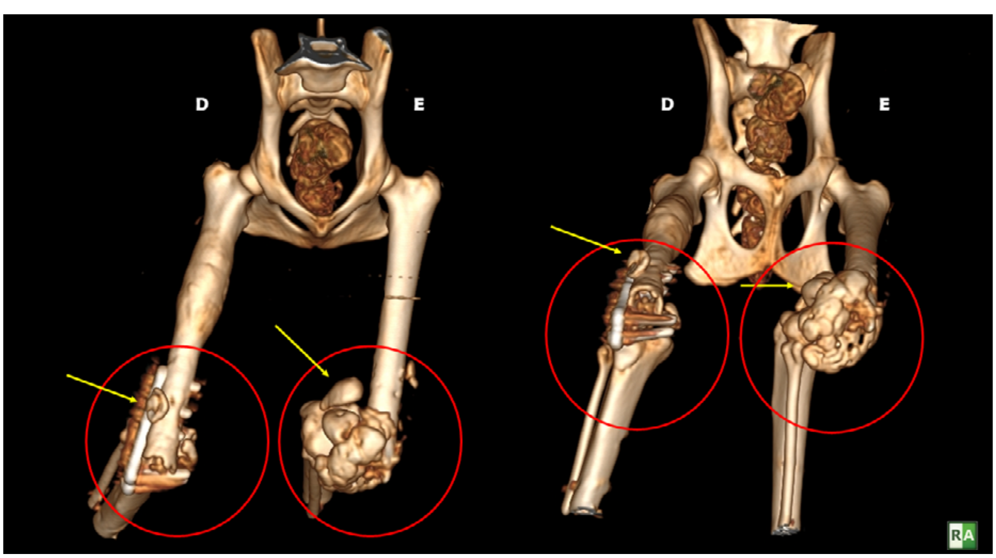

Figure 1. Three-dimensional (3D) reconstruction of the pelvic limbs for ITAP planning. The red circle highlights areas of articular damage in the stifle joints, while yellow arrows indicate luxated patellae and internal rotation of the left tibia.

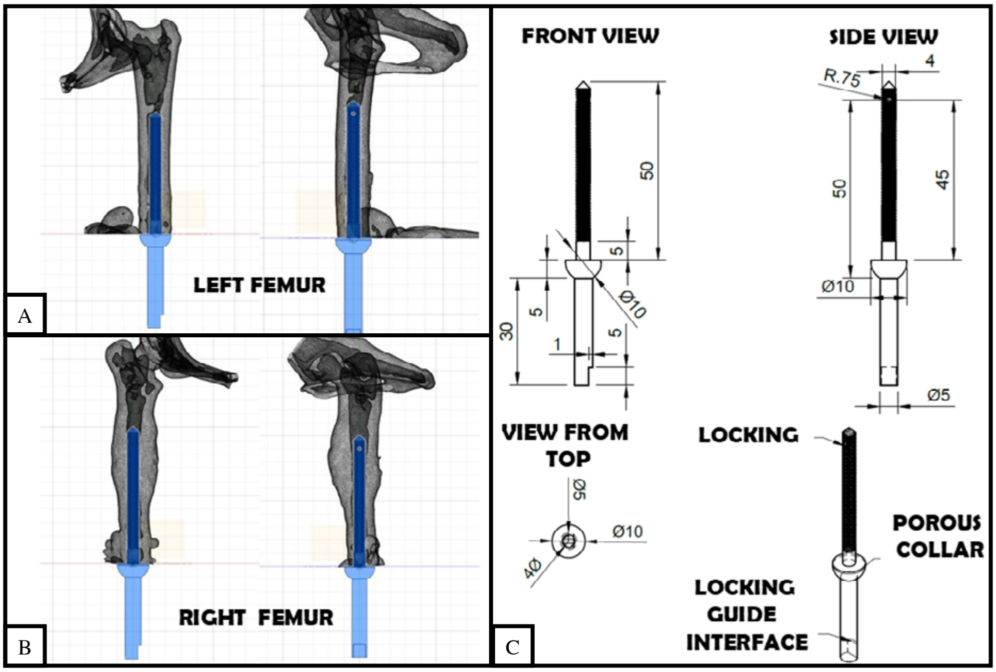

Figure 2. Technical and virtual planning of the femoral implant produced by BioFix 3D. A- Segmentation of computed tomography images in craniocaudal and mediolateral views, with implant overlay. B- Segmented right femur. C- Technical drawing of the implant.

terephthalate glycol[3] [PETG, Filament 1.75 mm, alfa-chemistry®]

The patient underwent an 8 h preoperative fasting period. Premedication included methadone[4] [Mytedom® - 0.3 mg/kg,] and acepromazine[5] [Acepran® - 0.03 mg/kg] intramuscularly (IM). Anesthesia was induced with esketamine[4] [Ketamin® - 0.5 mg/kg], midazolam[4] [Dormire® - 0.4 mg/kg], and propofol[4] [Propovan® - 4 mg/kg] intravenously (IV). Maintenance was achieved with isoflurane[4] [Isoforine® - 1 mL/mL] in 100% oxygen, combined with epidural bupivacaine[4] [Neocaína® 0,5%] and a continuous infusion of esketamine[4] [Ketamin® - 0.6 mg/kg/h] and fentanyl[4] [Fentanest® - 5 mcg/kg/h]. Intraoperative medications included ceftriaxone[6] [Ceftriaxona® - 30 mg/kg], dipyrone[5] [Analgex® - 25 mg/kg], and meloxicam[7] [Maxicam® - 0.05 mg/kg].

Following appropriate limb preparation, the patient was positioned in lateral recumbency, and the surgical site was aseptically prepared with 0.5% alcoholic chlorhexidine and draped with a sterile field.

A craniolateral approach to the femur was performed, with an elliptical skin incision followed by fascia lata dissection and retraction of the biceps femoris and vastus lateralis muscles. Osteotomy was conducted at the mid-diaphyseal region to prepare the implant bed.

After pre-drilling the femoral canal with a 3.5 mm drill bit, the implant was inserted retrogradely using a Jacobs Chuck until seated at the osteotomy site. A custom 3D-printed guide was used for precise Steinmann pin placement, and excess pin length was trimmed with side-cutting pliers. Muscular closure was performed using 2-0 polydioxanone (PDS) with interrupted and Sultan sutures, and dead space was minimized with 3-0 PDS. The skin was closed with 3-0 nylon sutures (Figure 3). The same procedure was repeated for the contralateral limb. Intraoperative and postoperative radiographs were obtained (Figure 4).

Postoperative treatment included cefovecin[8] [Convenia® - 8 mg/kg, SC every 15 days for 2 repetitions], meloxicam[7] [Maxicam® - 0.1 mg/kg, SID, 3 days], and tramadol hydrochloride[5] [Cronidor® - 2 mg/kg, BID, 5 days]. The patient remained hospitalized for 3 days for surgical site monitoring. Within 24 h, he showed good adaptation to the prostheses, and by 1 week, ambulated normally.

After 15 days, skin dehiscence, retraction, and partial implant exposure were observed in the left femur, requiring revision surgery. The implant was covered using copious Betadine lavage, bacterial culture, and layered wound closure with 2-0 nylon for muscle and 3-0 nylon for the skin. Culture identified *Enterococcus faecium*, and compounded marbofloxacin

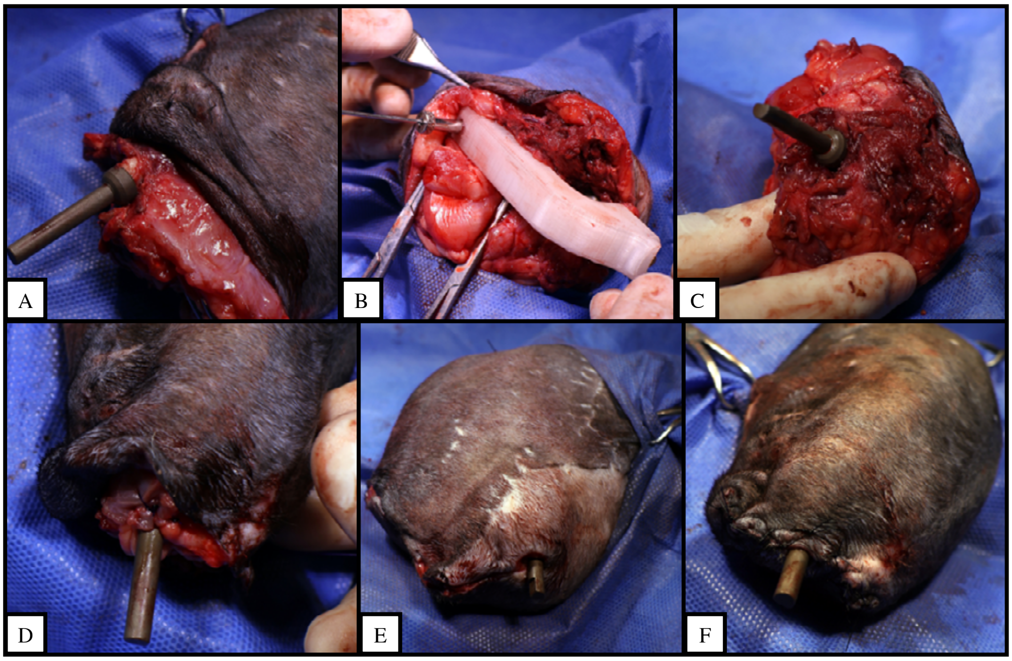

Figure 3. A- Intraoperative image showing implant placement at the osteotomy site. B- Application of a 3D-printed guide for implant stabilization using a 1.5 mm Steinmann pin. C- Muscular approximation. D- Myodesis with 2-0 PDS sutures. E- Subcutaneous closure. F- Skin closure with Sultan sutures using 3-0 nylon.

(following result of antibiogram) was administered for 3 weeks, resulting in complete wound healing with no further dehiscence or stump contamination.

At the time of this report, 27 months postoperatively, the patient exhibits no signs of pain, lameness, or orthopedic complications (Figure 5).

DISCUSSION

Partial limb amputation is a standard approach in human medicine to facilitate prosthetic use, whether external or osseointegrated. In veterinary medicine, limb amputation has historically been the primary treatment for various conditions [4,5,13,24,26]. However, advancements in surgical techniques and implant technology have enabled limb preservation in selected cases, mitigating the long-term biomechanical consequences of total amputation [4,7]. In this case, the failure of previous fracture management led to the use of ITAP as an alternative to total femoral

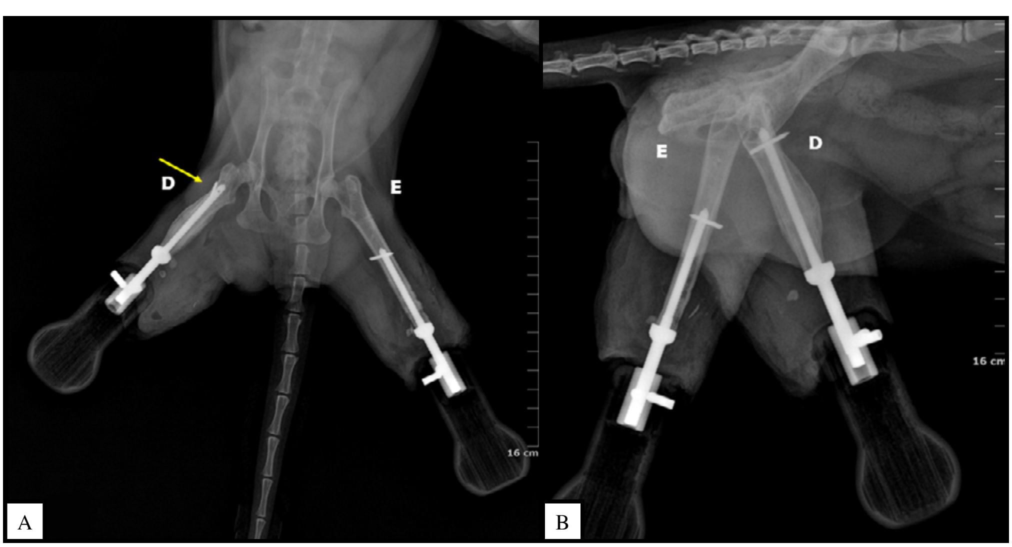

Figure 4. Immediate postoperative radiographs. A- Craniodorsal projection. B- Mediolateral projection. The correct positioning of the intramedullary implants and their intimate contact with the osteotomy site are observed. The yellow arrow indicates a failed 1.5 mm pin lock in the right femur.

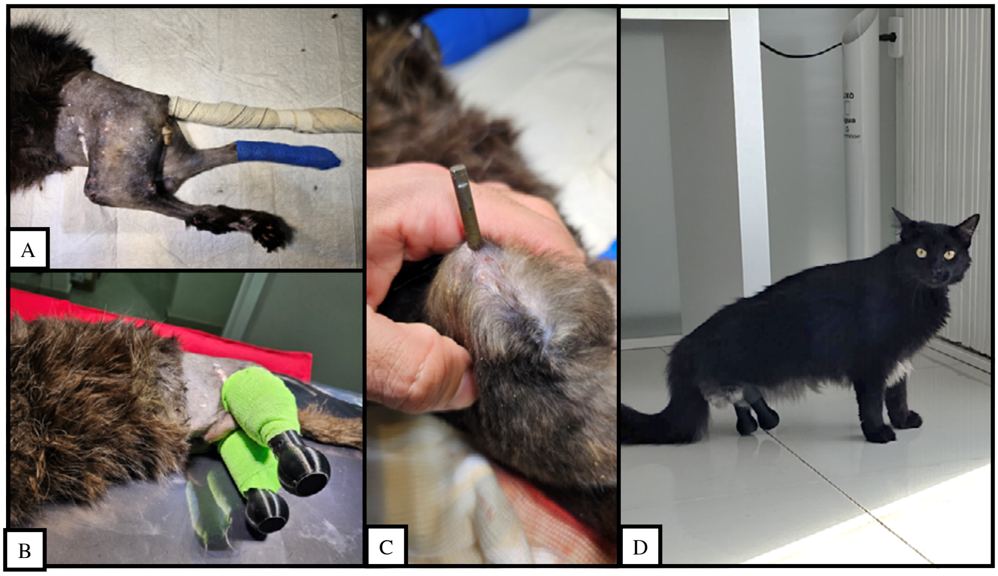

Figure 5. A- Preoperative image showing severe orthopedic deformity with internal rotation of the left tibia. B- Immediate postoperative image with prosthetic placement and bandaging. C- Thirty-day postoperative image, demonstrating dermal integration of the right femur. D- Image of the patient at 24 months postoperatively, fully adapted to the prostheses.

amputation, resulting in successful adaptation and restored mobility.

Veterinary applications of ITAP remain limited, and no standardized protocol exists for implant selection, considering anatomical variability across species, breeds, and patient adaptability [14]. Additionally, access to specialized surface treatment technologies and 3D-printed titanium implants remains a challenge for many veterinary surgeons [6,7]. Based on previous studies, the authors adapted a fully intramedullary titanium implant designed to promote osseointegration and ensure long-term functionality [9,10,18,20]. This approach incorporated CT imaging, CAD software, and 3D biomodel printing for surgical planning and implant optimization.

In human patients, a 6-week osseointegration period is recommended before fitting an external prosthesis to allow stable bone integration. Some veterinary studies suggest using external fixation devices to protect the endoprosthesis during the immediate postoperative period, transitioning later to exoprosthesis use [7,10,12,26]. However, this approach was not feasible in this case due to the high and bilateral level of amputation, which prevented effective external stabilization. Consequently, the prostheses were attached intraoperatively, and rehabilitation commenced immediately after recovery from anesthesia.

Implant rotational stability is a key factor in ITAP success, requiring a locking component, such as a screw or pin, to counteract rotational forces at the implant-limb interface. 3D-printed guides improve pin placement accuracy, enhancing surgical precision and biomechanical stability [17,18,20]. In this case, customized guides were used for Steinmann pin positioning. However, intraoperative difficulties arose due to excessive proximal muscle mass, limiting guide placement and leading to failed pin locking in the right femur (Figure 5). Despite this, the patient demonstrated good adaptation, and the guide design was modified for future applications, allowing 180° rotational positioning for improved compatibility.

Prosthetic development has evolved significantly since the 1960s, beginning with dental and auditory implants, later progressing to osseointegrated limb prostheses [2,11,16]. The 1st clinical report of ITAP in veterinary medicine was published in 2008, and since then, research has aimed to refine implant design and surgical techniques [4]. Current recommendations emphasize distal amputations whenever possible, as they facilitate ITAP placement and maximize limb function [1].

A major challenge in ITAP application is dermal integration, which ensures stable adhesion of soft tissue to the implant, preventing external contamination. Reported complications include infection, skin retraction, implant exposure, and mechanical failure [8,15,19]. Owner education is essential, as proactive management of these challenges facilitates long-term prosthetic function. In this case, skin retraction and implant exposure were observed in the left femur 15 days postoperatively, requiring revision surgery, bacterial culture, and targeted antibiotic therapy, resulting in complete wound closure with no further complications.

Limb prosthetic implantation is a viable option in veterinary practice, restoring natural biomechanics and functional mobility [7,10,18,19]. Only 1 prior case of bilateral distal femoral amputation was identified in the literature, reported by Mendonça [18]. In the present case, a more proximal (diaphyseal) amputation was successfully performed, demonstrating feasibility, good patient adaptation, and owner satisfaction after 27 months of follow-up.

The authors recognize ITAP's potential and encourage veterinarians to consider it as an alternative to high limb amputations. Further research will provide valuable insights to refine implant technology, improve surgical outcomes, and minimize complications for amputee patients.

MANUFACTURERS

[1]Medixant. Poznań, Poland.
[2]Autodesk. San Francisco, CA, USA.
[3]Alfa Chemistry. Holbrook, NY, USA.
[4]Cristália Produtos Químicos Farmacêuticos. São Paulo, SP, Brazil.
[5]Agener União. São Paulo, SP, Brazil.
[6]Asamed. São José, SC, Brazil.
[7]Ouro Fino. Cravinhos, SP, Brazil.
[8]Zoetis Brasil. Morumbi, SP, Brazil.

Declaration of interest. The authors report no conflicts of interest. The authors alone are responsible for the content and writing of paper.

REFERENCES

1 **Boylan M.T., Boston S.E., Townsend S. & Cavalcanti J.V.J. 2019.** Limb-shortening limb salvage (LSLS) in a cat with metatarsal osteosarcoma. *Canadian Veterinary Journal*. 60(7): 757-761.

2 **Brånemark P.I., Adell R., Breine U., Hansson B.O., Lindström J. & Ohlsson A. 1969.** Intra-osseous anchorage of dental prostheses. I. Experimental studies. *Scandinavian Journal of Plastic and Reconstructive Surgery*. 3(2): 81-100. DOI: 10.3109/02844316909036699. PMID: 4924041.

3 **Dickerson V.M., Coleman K.D., Ogawa M., Saba C.F., Cornell K.K., Radlinsky M.G. & Schmiedt C.W. 2015.** Outcomes of dogs undergoing limb amputation, owner satisfaction with limb amputation procedures, and owner perceptions regarding postsurgical adaptation: 64 cases (2005-2012). *Journal of the American Veterinary Medical Association*. 247(7): 786-792. DOI: 10.2460/javma.247.7.786.

4 **Drygas K.A., Taylor R., Sidebotham C.G., Hugate R.R. & McAlexander H. 2008.** Transcutaneous tibial implants: a surgical procedure for restoring ambulation after amputation of the distal aspect of the tibia in a dog. *Veterinary Surgery*. 37(4): 322-327. DOI: 10.1111/j.1532-950X.2008.00384.x. PMID: 18564255.

5 **Ephraim P.L., Dillingham T.R., Sector M., Pezzin L.E. & Mackenzie E.J. 2003.** Epidemiology of limb loss and congenital limb deficiency: a review of the literature. *Archives of Physical Medicine and Rehabilitation*. 84(5): 747-761. DOI: 10.1016/s0003-9993(02)04932-8.

6 **Faria L.G. & Rocha T.A.S.S. 2022.** Órteses e Próteses. In: Minto B.W. & Dias L.G.G.G. (Eds). *Tratado de Ortopedia de Cães e Gatos.* v.1. São Paulo: Medvet, pp.464-481.

7 **Fitzpatrick N., Smith T.J., Pendegrass C.J., Yeadon R., Ring M., Goodship A.E. & Blunn G.W. 2011.** Intraosseous transcutaneous amputation prosthesis (ITAP) for limb salvage in 4 dogs. *Veterinary Surgery*. 40(8): 909-925. DOI: 10.1111/j.1532-950X.2011.00891.x.

8 **Golachowski A., Al Ghabri M.R., Golachowska B., Al Abri H., Lubak M. & Sujeta M. 2019.** Implantation of an Intraosseous Transcutaneous Amputation Prosthesis Restoring Ambulation After Amputation of the Distal Aspect of the Left Tibia in an Arabian Tahr (*Arabitragus jayakari*). *Frontiers in Veterinary Science*. 11(6): 182. DOI: 10.3389/fvets.2019.00182.

9 **Gorshkov S.S., Ulanova N.V. & Manuilova V.V. 2017.** Percutaneous osseointegrated limb prosthetics in dogs and cats after partial amputation based on a series of clinical cases/Percutaneous osseointegrated limb prosthetics in dogs and cats after partial amputation based on a series of clinical cases. *Veterinary Pharma Magazine*. 4: 38.

10 **Gorshkov S.S. & Ulanova N.V. 2019.** *Interactive Traumatology and Orthopedics of Small Pets*. Moscow: Scientific Library, pp.438-508.

11 **Hagberg K. & Brånemark R. 2009.** One hundred patients treated with osseointegrated transfemoral amputation prostheses-rehabilitation perspective. *Journal of Rehabilitation Research and Development*. 46(3): 331-344.

12 **Kang N.V., Pendegrass C., Marks L. & Blunn G. 2010.** Osseocutaneous Integration of an Intraosseous Transcutaneous Amputation Prosthesis Implant Used for Reconstruction of a Transhumeral Amputee: Case Report. *The Journal of Hand Surgery*. 35(7): 1130-1134. DOI:10.1016/j.jhsa.2010.03.037

13 **Kirpensteijn J., van den Bos R. & Endenburg N. 1999.** Adaptation of dogs to the amputation of a limb and their owners' satisfaction with the procedure. *Veterinary Record*. 144(5): 115-118. DOI: 10.1136/vr.144.5.115. PMID: 10070700.

14 **Kneringer C. & Schnabl-Feichter E. 2024.** Intraosseous Transcutaneous Amputation Prosthesis (ITAP) compared to Exoprosthesis in veterinary medicine - a literature review. *Veterinary Practice*. 52(6): 359-366. DOI: 10.1055/a-2453-6622.

15 **Li Y. & Felländer-Tsai L. 2021.** The bone anchored prostheses for amputees - Historical development, current status, and future aspects. *Biomaterials*. 273: 120836. DOI: 10.1016/j.biomaterials.2021.120836.

16 **Lundborg G., Brånemark P.I. & Rosén B. 1996.** Osseointegrated thumb prostheses: a concept for fixation of digit prosthetic devices. *Journal of Hand Surgery American Volume*. 21(2): 216-221. DOI: 10.1016/s0363-5023(96)80103-1.

17 **Marcellin-Little D.J., Drum M.G., Levine D. & McDonald S.S. 2015.** Orthoses and exoprostheses for companion animals *Veterinary Clinics of North America: Small Animal Practice*. 45(1): 167-183. DOI: 10.1016/j.cvsm.2014.09.009.

18 **Mendonça A.G.C., Braga V.A.A., Fernandes T.H.T., Oliveira G.C.R. & Beraldo G.S. 2023.** Fixed bilateral endo-exo prostheses in feline femur - case report / Endo-exoprótese bilateral fixa em fêmur de felino - relato de caso. *Brazilian Archives of Veterinary Medicine and Animal Science*. 75(1): 107-112.

19 **Mendonça A.G. & Fernandes T.H.T. 2019.** Exoprótese fixa em rádio de cão: relato de caso. *Revista Nosso Clínico*. 22(127): 12-16.

20 **Meng M., Wang J., Sun T., Zhang W., Zhang J., Shu L. & Li Z. 2022.** Clinical applications and prospects of 3D printing guide templates in orthopaedics. *Journal of Orthopaedic Translation*. 13(34): 22-41. DOI: 10.1016/j.jot.2022.03.001.

21 **Mich P.M. 2014.** The emerging role of veterinary orthotics and prosthetics (V-OP) in small animal rehabilitation and pain management. *Topics in Companion Animal Medicine*. 29(1): 10-19. DOI: 10.1053/j.tcam.2014.04.002.

22 **Pendegrass C.J., Goodship A.E. & Blunn G.W. 2006.** Development of a soft tissue seal around bone-anchored transcutaneous amputation prostheses. *Biomaterials*. 27(23): 4183-4191. DOI: 10.1016/j.biomaterials.2006.03.041.

23 **Pendegrass C.J., Goodship A.E., Price J.S. & Blunn G.W. 2006.** Nature's answer to breaching the skin barrier: an innovative development for amputees. *Journal of Anatomy*. 209(1): 59-67. DOI: 10.1111/j.1469-7580.2006.00595.x.

24 **St Jean G. 1996.** Amputation and prosthesis. *Veterinary Clinics of North America: Food Animal Practice*. 12(1): 249-261. DOI: 10.1016/s0749-0720(15)30446-1.

25 **Timercan A., Brailovski V., Petit Y., Lussier B. & Séguin B. 2019.** Personalized 3D-printed endoprostheses for limb sparing in dogs: Modeling and *in vitro* testing. *Medical Engineering & Physics*. 71: 17-29. DOI: 10.1016/j.medengphy.2019.07.005.

26 **Wendland T.M., Seguin B. & Duerr F.M. 2023.** Prospective evaluation of canine partial limb amputation with socket prostheses. *Veterinary Medicine and Science*. 9: 1521-1533. DOI:10.1002/vms3.1146

27 **Ziegler-Graham K., MacKenzie E.J., Ephraim P.L., Travison T.G. & Brookmeyer R. 2008.** Estimating the prevalence of limb loss in the United States: 2005 to 2050. *Archives of Physical Medicine and Rehabilitation*. 89(3): 422-429. DOI: 10.1016/j.apmr.2007.11.005.