*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

# Management and recovery of a fracture of the tibia and distal fibula in a juvenile Puma (*Puma Concolor*) in a natural reserve located in Tocancipá-Colombia. Case report

**Angela Natalia Agudelo Suárez[1*], Stevany Angelina Ruth Martha[2] , Maria Fernanda Triana Vergara[3] , Camilo Ernesto Galvis Moreno[4]**

[1*]Fundación Parque Jaime Duque, Colombia, Universidad de la Salle, Colombia, Email: nagudelo@parquejaimeduque.com
[2]Universidad de la Salle, Colombia.
[3]Universidad de la Salle, Colombia.
[4]Clínica Veterinaria Zooricatos, Colombia.

**ABSTRACT**
**Introduction.** This is a case report of a juvenile puma (*Puma concolor*) residing in a natural reserve located in Tocancipá, Colombia, that presented a complete oblique fracture of the tibia and fibula in its left hind limb (LHL), with the cause of the fracture unknown.
**Objective:** To describe the management of the clinical case and its evolution from a clinical perspective.
**Methods:** Different chemical restraint protocols were performed, along with paraclinical tests, to establish the definitive diagnosis. Medical treatment was established with analgesics, anti-inflammatories, and antibiotics, as well as bioregulatory medicine. Additionally, restricted space management was implemented with a constant environmental enrichment plan, prioritizing minimal physical activity for the patient and promoting well-being. The most appropriate surgical treatment was then implemented under the guidance of a specialist surgeon. Fracture reduction was achieved through the placement of two orthogonal plates with screws: one at the dorsal level and the other at the lateromedial border.
**Results:** The patient's evolution was successful; it began bearing weight on the affected limb on the same day of surgery, and after three months it was bearing weight completely. Bone callus formation began at 20 days, with adequate bone formation and consolidation occurring around 45 days. The first plate (medial) was removed one year and one month after surgery, and the second (mediolateral) was removed almost four months after the removal of the first.
**Conclusion:** The puma recovered successfully thanks to the multidisciplinary management and interventions carried out. This case will contribute to the knowledge base for similar cases in this and other wild species.

**Keywords:** Colombia; puma; tibia fracture; osteosynthesis; orthogonal plates; screws.

## Introduction

The puma is in the kingdom Animalia, within the phylum Chordata and the class Mammalia, in the order Carnivora. Its family is Felidae, in the genus Puma. The puma has many alternative names, some countries call them mountain lions, panthers, cougars and even catamount but the scientific name for this type of big cat is *Puma concolor* which is a name of Latin origin. The word puma itself in Latin translates to mountain lion and the species name concolor literally translated from Latin meaning 'together' and 'color' but translated to English it means 'of uniform color'. This is reference to their uniform coloration, which is considered a tawny color, but they can also be found in darker colors leaning more towards a brown and some even having a lighter tawny color (Murphy et al. 2019). Pumas have such a wide range of populations in different parts of the world where they vary in size and fur color depending on their location, leading to the classification of six subspecies of *Puma concolor* (LaBarge et al. 2020).
The puma's conservation status in the International Union for Conservation of Nature's (IUCN) red list currently shows as "least concern". This means that the species has been evaluated as not being a focus of wildlife conservation because the specific species is still plentiful in the wild, this is according to their last assessment of the species in 2014.
In Latin America, the puma is considered, in some areas, a nuisance because it will sometimes target livestock to hunt. However, in most regions it plays a crucial ecological role as an apex predator, contributing to the population control of various prey species (González & Góchez 2024). In other areas, the puma holds deep cultural and spiritual significance, such as in the Andes, where it is regarded as a soul-snatcher or a guardian figure among local communities.
Despite its ecological and cultural relevance, pumas are increasingly exposed to human-wildlife conflict, which represents one of the main reasons individuals end up under human care in zoological institutions. Among the most documented causes are illegal wildlife trafficking, possession as exotic pets, retaliatory capture, road accidents leaving individuals unable to survive in the wild, and confiscation by environmental authorities. Additionally, orphaned cubs whose mothers were killed due to livestock depredation conflicts are frequently admitted to zoological facilities, as they lack the survival skills necessary for life in the wild (Castaño-Uribe et al., 2016).

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

There are not many articles written about the medical management of fractures in pumas. One scientific article mentions the medical management of a female puma cub in Ecuador who presented a fracture of the calcaneal bone. The fracture was repaired by osteosynthesis with a 3 mm smooth Steinmann intramedullary pin. Surgical outcome was positive, and the patient presented full resolution of the fracture after about 4 months (Medina et al., 2022). Another report from a zoological institution in Cuba is about a puma cub with a femoral fracture that was also managed with osteosynthesis by intramedullary nailing in combination with an external skeletal fixation system using four threaded nails and a methyl methacrylate bar. By 75 days after the surgical repair, the patient had complete recovery of the limb (González-Chávez et al., 2019).
This case report describes the clinical and surgical management and outcomes of a tibia and distal fibula fracture in a juvenile puma.

**Methods**
**Clinical case**
This clinical case takes place at Bioparque Wakatá Natural Reserve, a zoological institution located in Tocancipá, Colombia. An 8-month-old male puma presented with a tibia and fibula fracture in its left hind limb (LHL), which was initially stabilized with a cast and subsequently underwent surgery to achieve adequate osteosynthesis.

**Clinical history**
The patient arrived at the reserve on December 28, 2022, at 5 months of age, having been rescued from a farm by the Regional Autonomous Corporation of Antioquia-Colombia “CORANTIOQUIA”. Due to the conditions in which the individual was found, he could not be rehabilitated or released, which is why he was transferred to the natural reserve located in Tocancipá-Colombia. The patient was admitted with a body condition score of 3/5, weighing 11 kg, alert and responsive to his surroundings, and presenting fear-induced tremors. Initial clinical examination revealed absence of the upper canine teeth and an erythematous lesion on the right upper eyelid, consistent with a transportation injury. No other abnormalities were noted.
On April 9, 2023, zookeepers at the reserve noticed that the puma was licking the back of his LHL more frequently than usual, where upon closer observation, the leg also appeared swollen. Preventive treatment was administered that day before physical restraint could be performed for a full clinical examination. He was administered enrofloxacin at a concentration of 150 mg/tablet, BD: 5 mg/kg, TD: ½ tablet PO SID (once a day), meloxicam 15 mg/tablet, BD: 0.3 mg/kg, TD: ½ tablet PO SID and Traumeel® ad us.vet. + Zeel® ad us.vet., TD 1 tablet each PO SID.
On the 11th of April the animal was restricted chemically darted with tiletamine and zolazepam at a concentration of 50 mg/mL, BD: 2 mg/kg, TD: 1.4 ml PO SD (single dose). Then supplementation with tiletamine and zolazepam with the same concentration was performed using BD: 1 mg/kg, TD: 0.7 ml IM. After that, dexmedetomidine hydrochloride was applied at 0.5 mg/ml, BD: 0.025 mg/kg, TD: 0.75 ml IM with an extension syringe. After sedation, the patient was taken to the reserve Veterinary Center where it was administered oxygen and vital sign rates were stabilized. The patient was weighed, recording a body weight of 15 kg. An intravenous catheter was placed in the left cephalic vein where blood samples were taken. Urine samples were taken via cystocentesis. In the clinical examination, it was observed that the axillary nodes were larger than usual, which was considered the body’s response to trauma through increased lymphatic activity. Palpation of the LHL was performed, finding a fracture in the distal part of the tibia. Radiographs were then taken, confirming the diagnosis of complete and oblique fracture of the left distal tibia and fibula (figure 1). It was determined that this type of fracture would need to be surgically repaired, which needed to be scheduled with the specialist orthopedic surgeon to be performed at a later date. Therefore, it was temporarily stabilized with a cast so that the fracture did not worsen during this waiting period (figure 2). The cause of the fracture could not be established. However, it was suspected that because the animal was young and very active, it was probably injured by one of the platforms while running through its habitat.

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026


Image source: RNBW; 2023

**Figure 1. Radiograph of the left hind limb (LHL) in mediolateral view of a juvenile puma (*Puma concolor*), showing a complete, oblique, distal fracture of the tibia and fibula.**

Image source: RNBW; 2023

**Figure 2. The patient's LHL in the temporary cast was kept on for 6 days while surgical preparations were made.**

On April 16, preoperative blood tests were done that showed everything was in normal ranges, so surgery to repair the patient's fracture was approved. Importantly, biochemistry profiling via blood and urine (cystocentesis) showed that calcium and phosphorus levels were also in normal ranges.

This confirms that the cause of the fracture was not due to a lack of nutrients that could cause the bones to not calcify properly.

**Surgical procedure**

Surgery to repair the fracture using osteosynthesis plates was performed on April 17, 2023. The animal was chemically restrained with dexmedetomidine hydrochloride at 0.5 mg/ml, BD: 0.025 mg/kg, TD: 0.75 ml IM and tiletamine and zolazepam at 50 mg/ml, BD: 1 mg/kg, TD: 0.3 ml IM. The patient was taken to the Veterinary Center where he was intubated with a No. 6 tube and maintained with isoflurane between 1-3% MAC (Minimum Alveolar Concentration). The patient was connected intravenously in the left cephalic vein and during the procedure two doses of ketamine hydrochloride with concentration 50 mg/ml were administered, BD: 0.5mg/kg, TD: 0.15ml IV, quercetin at 125mg/ml, BD: 12.5 mg/kg, TD: 1-5ml IV. Bioregulators Rinom-V LHA® + Zeel® ad us. Vet + Digest-V LHA® were also given at 1 ml per unit IV. Additionally, during the surgery it was administered a single dose of cefovecin sodium at 80 mg/ml, BD: 8 mg/kg, TD: 1.5 ml SC SID and ketoprofen at 100 mg/ml, BD: 1 mg/kg, TD: 0.15 ml IM SID. The patient received ketoprofen at the same dosage for a week following the surgery and since cefovecin has a duration of action of up to 15 days, it was not given a second dose of cefovecin. As there were no signs of infection, the patient was not given a further prescription of either cefovecin or ketoprofen. Rotation was performed with 0.9% NaCl fluids with another NaCl bag containing 0.5 ml of dopamine calculated for 4 hours of surgery to maintain blood pressure at appropriate levels.

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

During surgery, some episodes of apnea were observed, so to stimulate respiratory activity doxapram hydrochloride was applied at 20 mg/ml, BD: 0.5 mg/kg, TD: 0.37 ml IV, (only 1/3 of the dose was applied) final dose = 0.12 ml IV.
The LHL cast was removed, and the surgical area was clipped and cleaned with the appropriate antiseptic protocol (alternating 70% alcohol and 0.5% chlorhexidine). An incision was made until reaching the fracture point on the medial aspect of the LHL. The orthopedic surgeon chose to reduce the two fracture fragments using two plates with screws with the orthogonal technique, one at the dorsal level and the other at the lateromedial edge (Figure 3). This is since the orthogonal technique provides biomechanical advantages and good stability in long bone fractures. The use of orthogonal technique also allows for a greater number of screws to be used within small bone fragments (Craig et al., 2017) & (Ata et al., 2017). This, compared to single-plate techniques, gives fractures, such as multifragmentary tibial fractures, increased stiffness and resistance to bending, reducing plate strain. Because of this, there are also reports of lower complication rates using this technique compared to others (Craig et al., 2017).
These plates were slightly bent by the surgeon to sit flush against the bone and provide the maximum amount of stability. Specifically, a 2.7 mm T-compression plate with 9 holes and a 3.5 mm cortical compression plate with 10 holes (12 cm in length) were used (Figure 3). After approximating and fixing the edges, the incision was closed with a subcuticular suture and then cyanoacrylate skin adhesive was used. After surgery, the patient was moved to a temporary cubicle, where the environment was ideal for postoperative recovery. After being placed inside the enclosure, the patient was closely monitored to ensure he recovered properly from anesthesia.

Image source: RNBW; 2023

**Figure 3. Intraoperative photographs demonstrate osteosynthesis construct, consisting of a 2.7 mm T-compression plate with 9 holes and a 3.5 mm cortical compression plate with 10 holes (12 cm in length), applied at the dorsal and lateromedial aspects of the tibia, respectively. Note the plate contouring performed to ensure adequate cortical apposition.**

It should be noted that immediately after surgery, the patient was already presenting partial support to the limb, showing the success of the procedure. The animal was monitored closely for signs of infection, pain, and mobility during the first 72 hours of post-surgery.

**Post-op recovery**

On April 22, the reserve's zookeepers noticed a red hue on the lateral area of the affected limb, which was associated with contact dermatitis. When evaluated on April 24, the patient showed favorable signs of recovery; equal strength was evident in the digits of the affected limb, showing full support on the LHL. Adrisin ® ad us. Vet. 1 tablet PO was added to the patient's treatment plan for contact dermatitis.
On May 5, physical-chemical restraint was performed to do a control and evaluate the improvement in fracture fixation. It is important to note that this time physical restraint was difficult because the patient had climbed the roof of his habitat, which made it difficult to administer the medication necessary for chemical restraint. It was then decided to use an extension syringe with a protocol of tiletamine and zolazepam at 50 mg/ml, BD: 2 mg/kg, DT: 0.72 ml and xylazine at 2% concentration, BD: 0.5 mg/kg, DT: 0.45 ml IM.
The control x-rays showed that at this point in his evolution there was bone callus formation at the site of his fracture. With this, the Animal Health team of the reserve, together with the specialist orthopedic surgeon, recommended that the patient should remain in the management zone for three additional weeks to ensure that the fracture was properly fixed, which posed a challenge for patient management.
On June 2nd, the process described above was repeated to take a follow-up X-ray to assess the progress of the fracture. The images showed that there was only a slight displacement of one of the plate screws (Figure 4). Adequate bone callus formation was observed, indicating proper bone union. Due to the above, the specialist orthopedic surgeon, the animal health team, the behavioral health team and zookeepers of the reserve decided to transfer the patient to a larger secondary habitat, which offered mixed indoor-outdoor access according to the animal's preference. This enclosure featured structural environmental enrichment including platforms and shelters appropriate for a puma, predominantly

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

grass flooring with some concrete areas, and a dedicated management zone to facilitate safe handling by the professional technical team.
This opportunity was used to vaccinate the patient with Feligen C.R.P and Leucogen, recording a weight of 23.6 kg at this time. On June 5th, 2023, Adrisin® ad us. Vet was suspended from his treatment plan.


Image source: RNBW; 2023
**Figure 4. (A) Postoperative X-ray results. Radiograph in craniocaudal view of the LHL that shows slight displacement of one of the screws (arrow). (B) Shows the LHL in a mediolateral view where the slight displacement of the screw is more visible.**

**Removal of the plates and screws**
On May 27, 2024 (one year later), the patient underwent chemical restraint and was transported to the Veterinary Center for surgical plate removal. Radiographs were taken to assess the position of the plates and the number of screws to be removed (Figure 5). Since this was the largest plate, its removal would result in multiple bone defects, potentially compromising bone stability, and for safety reasons this was deemed inadvisable to avoid another fracture.
As mentioned above, there are very few articles with respect to pumas undergoing these kinds of surgical procedures and management. Therefore, information described in small animal reports has been used towards the benefit of the patient's recovery and well-being (figure 6). In this sense, it was decided to leave the other plate for an additional 3-4 months.


Image source: RNBW; 2024
**Figure 5A & 5B. Radiograph imaging taken before the surgical procedure to confirm the number of screws to be extracted.**

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026


Image source: RNBW; 2024

**Figure 6. Radiograph imaging which shows the craniocaudal plane, presenting the holes left behind inside the bone when the dorsal plate and screws were removed.**

After the removal of the first plate and screws, satisfactory bone healing was observed. On the 9th of September 2024, chemical restriction was carried out again with the same chemical protocol. Radiographs were taken before the first incision to ensure that the correct number of screws were removed (Figure 7), and the lateromedial plate was retrieved.


Image source: RNBW; 2024

**Figure 7. Radiograph imaging in the craniocaudal plane before the surgery to remove the second plate and screws. Bone callus formation is evident.**

The incision was sutured with the same pattern and materials as initially described. Another x-ray was taken after the surgery was completed to see the condition of the bone where the screw holes were evident.
But because the holes from the first screws removed were given adequate time to heal and form hard calluses, there was no concern for bone weakness (Figure 8 & 9).

Image source: RNBW; 2024

**Figure 8. Patient during the surgery to remove the last plate and screws from the LHL.**

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026


A

B

Image source: RNBW; 2024

**Figure 9. (A) Imaging of the mediolateral view of the LHL after all plates and screws were removed. (B) Dorsoplantar view of the LHL. Bone callus formation and bone union are visible.**

**Management of the clinical case**

The patient was kept in the management area with restricted movement, adequate to prevent him from jumping, for 2 months. This proved to be a constant challenge for the behavioral health team, in which different occupational, physical, sensory, and nutritional enrichments were implemented. Such as trunk with bark, frozen blood water, kong with blood and frozen meat inside, diet hidden in hay, new hay, etc.; to promote recovery from the injury and provide physical and mental well-being without putting the surgical intervention at risk.

It should be noted that the enrichment program was constant all the time even when the patient was moved to his original habitat. Dietary management consisted of meat and chicken, supplemented with oral medications, primarily crushed tablets. Overall, the patient maintained a good appetite, which facilitated adequate medication intake. The application of any topical medication to the affected limb was carried out with the support of the behavioral health team and zookeepers. All anesthetic procedures required a fasting period of more than 12 hours.

**Outcome and follow up**

In 2025, evaluation was conducted, including a complete blood count, serum biochemistry profile, viral screening and radiographic views of the previously affected limb, among other diagnostic assessments. All laboratory parameters, including calcium and phosphorus levels, were within the reference ranges reported in the literature for this species. However, radiographic evaluation of the affected limb revealed decreased bone density with increased radiolucency (Figure 10), a finding of particular interest given that serum mineral markers remained within normal limits.

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026


**Figure 10. Follow-up radiographic evaluation of the left tarsus (2025) (A) Lateral view demonstrating overall alignment of the tarsal region with evidence of decreased bone opacity. (B) Lateral view providing improved visualization of the tarsocrural and intertarsal joints, confirming maintained articular congruence with generalized increased radiolucency of the cortical and trabecular bone. (C) Dorsoplantar (DP) view of the left tarsus and distal tibia-fibula, revealing preserved bone alignment and joint spaces. Radiolucent tracts corresponding to previous screw placement sites are observed at the tibial cortex, consistent with post-implant removal remodeling (arrow).**

Additionally, it was observed that, in comparison with other pumas housed within the natural reserve, this individual had not reached a body size comparable to its conspecifics. This finding is noteworthy given that the animal had already reached adulthood, suggesting a possible association between its reduced body size and the previously described fracture process.

**Discussion**

Although the etiology of the fracture in this case could not be determined, tibial fractures in felids are primarily associated with traumatic events such as falls or conspecific fights (Fossum, 2019). The tibia is inherently subject to multiple mechanical forces, and fracture severity varies according to both the nature of the traumatic event and the resulting fracture pattern; in the present case, an oblique fracture configuration was identified.

As previously noted, published literature on surgical procedures and clinical management in pumas is limited. Therefore, findings from small animal case reports were extrapolated to guide the patient's recovery and welfare.

**Adverse effects associated with anesthetic management**

Given the limited availability of documented cases involving surgical management in this species, information from reports on other felid species was referenced. specifically, to document potential anesthetic complications associated with the procedure. Mainly to understand why the patient could have undergone the episodes of apnea that were present. During the collection of investigative materials for the article, some case reports about tigers (*Panthera tigris tigris*) had multiple mentions of that species of feline experiencing hypothermia, bradycardia and hypotension when under anesthesia (Boucher & Zeiler, 2015; Zeiler et al., 2013). The case reports that specifically mention the *Puma concolor* included in investigative material for this article do not mention any information regarding adverse effects to anesthesia.

However, as previously mentioned, the patient did present episodes of apnea during the surgical procedure. This shows that there are possibilities to the notion that this species could also have adverse effects to anesthesia similar to the tigers in the published case reports. Since there are no specific references to look to, reports of adverse effects in domestic felines in combination with reviewing the mechanisms of action of the medications used will help determine what caused the episodes of apnea in the patient and also discuss possible adverse effects that the patient could have undergone.

Before the surgical procedure the patient was administered dexmedetomidine combined with tiletamine and zolazepam as its chemical restraint. Dexmedetomidine, being an alpha -2 agonist, it has a high specificity and selection towards alpha-2 receptors which produce sedation and analgesia by activating the alpha-2 adrenergic receptors located in the brain, specifically the locus coeruleus which is the nucleus responsible for modulating awareness. This inhibits neuronal firing and by activating these receptors this medication also causes significant vasoconstriction which increases systemic vascular resistance and in turn, bradycardia (Castro et al., 2022). Effects on the respiratory system are beneficial as it increases oxygenation during mechanical ventilation by enhancing lung compliance and decreasing resistance. The combination of tiletamine and zolazepam means that it is a nonnarcotic, nonbarbiturate, injectable anesthetic agent and

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

it's usually used for induction of anesthesia followed by maintenance with an inhalant anesthetic. Respiratory depression is listed in its adverse reactions when given in high doses but can be combated by adequate pulmonary ventilation using oxygen (Jiwlawat, 2022). In combination these two medications enhance the individual potency of each drug, decreasing their required dosages and making them a good combination for sedation, analgesia and induction. Isoflurane was used for maintenance of the patient and in cats this inhalant anesthetic is known to produce respiratory depression by affecting the bulbar respiratory neurons in the brain leading to a reduced depth of breathing or tidal volume. This leads to reduced voluntary breathing causing bradypnea and sometimes even episodes of apnea and hypercapnia which is an increase in Co2 levels.
Ketamine hydrochloride will also produce respiratory depression if given in high doses and should also be combatted with adequate pulmonary ventilation using oxygen. Some authors, however, would even advise against the use of ketamine hydrochloride because of this and its profound effects on systemic vascular resistance (Borgeat, 2018).
From what little data could be gathered from literature, it is suspected that pumas are, in general, sensitive to the application of anesthetics independently from the protocol used, so close monitoring during anesthesia is highly recommended in order to catch adverse reactions on time and mediate them in the appropriate manner (Lescano et al. 2014).

**Types of plates for fixation**
There are a wide variety of plates that can be used for osteosynthesis. Fixation can be internal or external with each being used in their respective situations. Internal fixations include intramedullary pins and cerclage wire, interlocking nails and bone plates and screws. Considerations for internal fixation would be fracture classification and affected bone, or if a patient has concurrent injuries and the counteracting forces in the fixation method (Arthurs, 2015). External skeletal fixation can be used in many circumstances but especially when a patient has an open fracture that could be at risk for contamination (Corr, 2005). For long bone fractures such as the one in this clinical case, bone plates and screws or Steinmann pins are recommended (Farzad-Mohajeri et al., 2024).
The plating technique used in this clinical case was the orthogonal plating technique with screws (figure 12 ). The orthogonal plating technique is part of the dual plating types in which the plates are placed at 90 degrees to each other which will provide good stability to allow a fracture to fix and heal properly. The plates are made of stainless steel, considered twice as strong as titanium. This allows the plates to better maintain their position once placed and produce better fixation of the fracture. It is also beneficial because it is likely to produce minimal callus during healing and also does not compress blood vessels that may be near the fracture site (Ata et al., 2017).

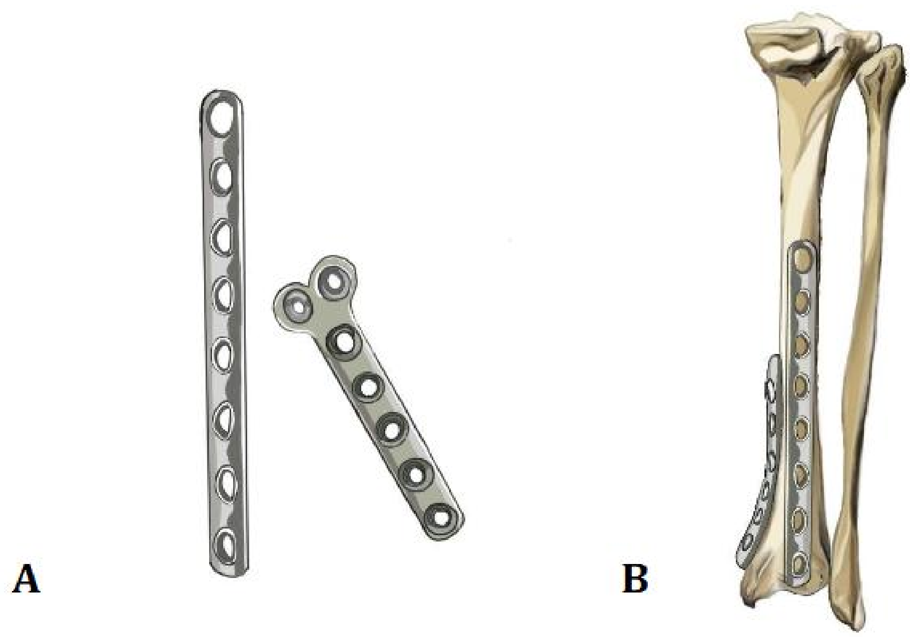


**Figure 12. (A) Illustration of the stainless-steel implants used in osteosynthesis construct, consisting of a broad dynamic compression plate (left) and a T-shaped plate (right), both featuring oval screw holes to allow axial compression and stable fixation. (B) Illustration of the orthogonal plating technique applied to the tibial shaft,**

REDVET - Revista electrónica de Veterinaria - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

**demonstrating the placement of two plates at a 90-degree angle to each other along the cortical surfaces of the tibia. Original illustrations by the authors.**

There are great benefits to providing fixation to a bone through both angles with this method. The two plates help provide a smoother healing process by ensuring fracture alignment and rotation are maintained. The plates also allow for a larger number of screws to be placed if necessary. Situations in which orthogonal plates are indicated over other types of fixation plates are long bone fractures, diaphyseal fractures, and coronal shear fractures (Craig et al., 2017).
Orthogonal plates were advantageous in this clinical case because, compared to other plates, they are better used for distal fractures (Roe, 2024).
One disadvantage that this type of plate can have, which we experienced in this clinical case, is that after removing one side of the orthogonal plates and the screws, the bone to which it was attached is also left with the holes where the screws were placed. These holes weaken the bone and therefore both plates cannot be removed at the same time. This is why there needs to be two separate surgery dates where the plates are removed one by one with enough time between each removal to allow the bone to create a hard callus where the bone had holes (Perry & Woods, 2018). Another disadvantage of this type of plates is that there is a greater risk of suffering iatrogenic injuries by the surgeon, which can mean anything from damage to the surrounding soft tissues and muscles to damage to the bone fragments that must be fixed. This is because with this technique more holes are drilled into the bone to ensure that the fracture has more stability (Au Yong et al., 2018).
However, it should be noted that the surgeon's expertise reduces the risk of iatrogenic complications as could be observed in the present case. An alternative to orthogonal plating is parallel plating, which is also part of dual plating techniques (Zalavras et al., 2011). The difference here is that the plates are placed at an angle of 180 degrees parallel to each other (Cheung et al., 2023).

**Advantages and disadvantages of locking plates**
Locking plates are functional in the way that their names suggest, they serve the purpose of locking fixation in a fixed angle where there is need for the bone to have compression contact with the plate. There are a locking mechanism of the screw heads and the plate where, when they are screwed and tightened all the way, they lock to the threaded screw holes of the plate, which stabilizes the segments without pulling the bone to the plate (Cronier et al., 2010). Advantages of this type of plate is that it will have very limited contact with the bone while still doing the job of providing good stability by the locking mechanism that the plate has with the screw heads. These types of plates function as fixators with multiple anchor points which will minimize gap length and strain of the fracture.
Disadvantage is that the screw placement and direction is predetermined by the existing holes on the plate, so there is little to no wiggle room to put screws in other areas that might be of interest (Kudo et al. 2016).
Non-locking plates and screws are considered the "conventional" screws because its goal is to obtain good stability with a rigid plate along with compression of fragments in the fracture. They are plates that help maintain fixation stability via the frictional force between the plate and the affected bone (Cronier et al., 2010). The screws used here are ones without the locking mechanism on their head.

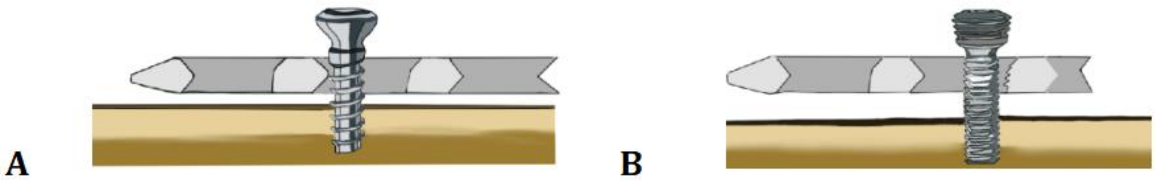


**Figure 13. Illustration of two screw fixation configurations used in osteosynthesis. (A) Conventional screw, characterized by a tapered tip and uniform thread pitch, which generates compression between the plate and the bone cortex through friction. (B) Locking screw, characterized by a threaded screw head that engages directly with the plate, creating a fixed-angle construct independent of bone-plate compression. Original illustrations by the authors.**

Beyond the technical considerations discussed above, the osteosynthesis construct utilized in this case consisted of conventional plates and screws, with distal screw placement in close proximity to the physeal region of the tibia, as evidenced by post-operative radiographic imaging. As described in the veterinary surgical literature, plate and screw fixation represents one of the implant configurations most likely to cause growth plate damage when applied near the open physes, potentially leading to growth disturbances (Aithal et al., 2023). Although fracture stabilization was the primary surgical objective, the risk of iatrogenic physeal involvement must be acknowledged as a potential contributing factor to any long-term alterations in limb development observed in this individual.

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

It is also worth noting that bone plates represent an excellent method for stabilizing tibial diaphyseal fractures, as they effectively neutralize axial, rotational, and bending forces acting on the fracture site. In this regard, physical rehabilitation plays a fundamental role in restoring the function of the affected limb following fracture repair. Although rigid stabilization of the fracture site is optimal during the initial phase of bone formation, subsequent bone remodeling is enhanced by progressively increasing the mechanical load on the healing bone (Fossum, 2019).

**Bone density and skeletal development associated with reduced mobility**

According to Chirchir et al. (2022), bone responds to high mechanical loading by increasing its mass and density. In this context, fracture management in young animals, particularly during developmental stages, directly influences longitudinal bone growth. Any injury sustained while the growth plates remain open, as observed in the present case report, may halt or alter normal growth, especially in long bones, leading to varying degrees of limb shortening. Nevertheless, it is worth noting that fracture healing in immature animals tends to be rapid, with abundant callus formation; however, these factors must be carefully considered when the patient is still in an active growth phase (Aithal et al., 2023).

The mobility restrictions implemented during the post-surgical period to prevent injury aggravation likely contributed to the observed reduction in bone density. This is consistent with the well-documented phenomenon of disuse osteopenia, in which immobilization leads to immediate bone loss in both the trabecular and cortical compartments, accompanied by relatively increased bone resorption and decreased bone formation (Rolvien & Amling, 2022). These findings underscore the critical importance of structured rehabilitation protocols following orthopedic injuries such as fractures, highlighting the compounded risk of disuse osteopenia in a juvenile individual undergoing post-surgical confinement during a critical phase of skeletal development.

Furthermore, locomotor and non-locomotor behavior varies in complex ways across felid taxa; mountain lions in particular are adapted for endurance travel, covering extensive distances under natural conditions (Chirchir et al., 2022). Ex-situ environments therefore inherently limit the mechanical stimulation required for optimal skeletal development, even in the absence of additional post-surgical confinement. At the molecular level, osteocytes detect mechanical loading through mechanosensors that translate extracellular mechanical signals into intracellular biochemical signals, regulating gene expression and bone remodeling activity (Rolvien & Amling, 2022). Consequently, physical inactivity emerges as one of the primary contributors to bone loss, as alterations in osteocytic signaling pathways directly mediate the skeletal response to mechanical unloading.

**Metabolic Considerations and Future Recommendations**

Future cases involving orthopedic injuries in juvenile felids under ex-situ management should incorporate the measurement of key metabolic bone markers as part of the diagnostic and monitoring protocol. Specifically, serum ALP, intact parathyroid hormone (iPTH), and 25-hydroxyvitamin D [25(OH)D] should be evaluated to determine whether the fracture may be associated with or aggravated by an underlying metabolic process, to monitor bone healing quality, and to guide a more specific therapeutic approach. In felids, 25(OH)D reflects dietary vitamin D intake, as cats are unable to synthesize enough vitamin D through sun exposure and use pro-vitamin D for cholesterol synthesis instead (Zafalon et al., 2020).

Regarding PTH interpretation, it is essential to measure it directly alongside ionized calcium from the same sample, as surrogate markers such as serum phosphorus do not accurately predict whether PTH is elevated (Parker et al., 2015). Elevated PTH concentrations are frequently observed in cats with nutritional secondary hyperparathyroidism, a condition well documented in captive wild felids fed diets deficient in calcium or vitamin D, which leads to chronic bone resorption, decreased bone density, and increased fracture susceptibility (Parker et al., 2015; Dutton et al., 2004).

Additionally, accurate assessment of vitamin D status in immature felids presents particular analytical challenges, as the quantification of 25(OH)D in cats has been complicated by the discovery of C-3 epimers of 25(OH)$D_3$, which may occur at concentrations ranging from 10% to 50% of the predominant β-epimeric form, potentially leading to an overestimation of true vitamin D status. Since reference intervals established for adult cats may not accurately reflect vitamin D status in juvenile individuals, results must be interpreted with caution (Backus et al., 2024). This consideration is especially relevant in the present case, given that the patient was a juvenile puma, and although direct species-specific data for large felids such as *Puma concolor* remain scarce, current knowledge is largely extrapolated from domestic felid studies, underscoring the need for species-specific research in this area.

**Conclusions**

This case report describes a successful clinical and surgical management of a tibial and fibular fracture of the left hindlimb in an eight-month-old juvenile puma, in which an orthogonal fixation technique with conventional screws at a 90-degree angle was implemented, providing adequate stability for fracture consolidation and callus formation. Postoperative radiographic follow-up was conducted throughout the recovery period, and two independent surgeries were subsequently performed for implant removal.

Regarding the anesthetic procedure, the species demonstrated notable sensitivity, as evidenced by the apneic episodes reported during surgery. These were attributed to the adverse effects of dexmedetomidine, which has been associated with bradycardia, in combination with tiletamine-zolazepam, which has been reported to cause respiratory depression. Additionally, isoflurane, also used in this case, has been described as a contributor to respiratory depression in felids. These findings underscore the importance of precise dose management and the implementation of assisted pulmonary ventilation when working with this species.
The most recent radiographic evaluation, conducted two years after surgery, revealed favorable alignment of the tibia and fibula; however, areas of increased radiolucency and decreased bone density were identified, particularly at the screw placement sites, findings consistent with disuse osteopenia. The mobility restrictions implemented during the post-surgical period may have influenced the definitive skeletal development of the individual, as supported by Wolff's Law, which states that bone adapts and remodels in response to mechanical loading, potentially explaining the fibrous union observed at the cortical channels. These findings are further supported by reports of reduced bone density in captive large felids, attributable to the diversity of locomotor activities that cannot be replicated in controlled environments.
It is essential to highlight the management of this case by the entire professional technical team at Bioparque Wakata Natural Reserve, who successfully executed a complex orthopedic procedure considering the species involved, while ensuring appropriate clinical, nutritional, and behavioral management with a constant commitment to animal welfare.
Finally, given the paucity of documented cases involving surgical management in *Puma concolor*, this case report contributes to the clinical knowledge of the species and underscores the need for greater documentation in wildlife veterinary medicine.

**Acknowledgement**
The authors would like to express their gratitude to Dr. Valentina Sánchez and the Animal Health Coordination team for their support and dedication to the care and follow-up of this clinical case. Special recognition is also extended to the Fundación Parque Jaime Duque for their commitment to the care of this patient, as well as to the entire Bioparque Wakatá team for their dedication throughout this process. The authors likewise wish to acknowledge the professionals from the Universidad de La Salle and the Fundación Parque Jaime Duque who contributed to the review of this manuscript.

**References**
1. Aithal, H.P., Pal, A., Kinjavdekar, P. & Pawde, A.M. (2023). Textbook of Veterinary Orthopaedic Surgery. Springer Singapore. DOI: https://doi.org/10.1007/978-981-99-2575-9
2. Arthurs, G. (2015). Advances in internal fixation: locking plates. In Practice, 37(1), 13–20. https://doi.org/10.1136/inp.g7695
3. Atalar, A. C., Tunalı, O., Erkoçak, A., Kapıcıoğlu, M., Sağlam, Y., & Demirkale, M. S. (2017). Biomechanical comparison of orthogonal versus parallel double plating systems in intraarticular distal humerus fractures. Acta Orthopaedica et Traumatologica Turcica, 51(1), 23–28. https://doi.org/10.1016/j.aott.2016.11.001
4. Au Yong, J. A., Lewis, D. D., Citino, S. B., Cunningham, M. W., Cross, A. R., Farese, J. P., & Pablo, L. S. (2018). Surgical management of appendicular long-bone fractures in free-ranging Florida Panthers (*Puma concolor* coryi): Six cases (2000–2014). Journal of Zoo and Wildlife Medicine, 49(1), 162–171. https://doi.org/10.1638/2017-0058r1.1
5. Backus, R. C., Colitz, C. M. H., & Schmitt, K. (2024). Age-dependent changes in plasma concentrations of 25-hydroxyvitamin D may complicate vitamin D status assessment of immature cats. Frontiers in Veterinary Science, 11, 1365204. https://doi.org/10.3389/fvets.2024.1365204
6. Borgeat, K. (2018). A practical approach to cats with respiratory distress [Conference proceedings]. World Small Animal Veterinary Association (WSAVA) Congress. https://www.vin.com/doc/?id=8896734
7. Boucher, C., & Zeiler, G. (2015). Femur fracture repair of a tiger cub (Panthera tigris tigris) suffering from nutritional secondary hyperparathyroidism and osteopenia. Veterinary Record Case Reports, 3(1), e000188. https://doi.org/10.1136/vetreccr-2015-000188
8. Castro, M. L., Cerqueira Câmara, B. M., Oliveira Barreto, M. S., Wenceslau, R. R., Karollini E Silva, A., Fagundes, N., Silva, R. A., Mariani Pimenta, E. L., & Beier, S. L. (2022). Effect of dexmedetomidine low doses with or without midazolam in cats: Clinical, hemodynamic, blood gas analysis, and echocardiographic effects. Anesthesiology Research and Practice, 2022, 9613721. https://doi.org/10.1155/2022/9613721
9. Castaño-Uribe, C., Lasso, C. A., Hoogesteijn, R., Diaz-Pulido, A., & Payán, E. (Eds.). (2016). II. Conflictos entre felinos y humanos en América Latina. Serie Editorial Fauna Silvestre Neotropical. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt (IAvH).

10. Cheung, Z. B., Nasser, P., Iatridis, J. C., & Forsh, D. A. (2023). Orthogonal plating of distal femur fractures: A biomechanical comparison with plate-nail and parallel plating constructs. Journal of Orthopaedics, 37, 34–40. https://doi.org/10.1016/j.jor.2023.02.003
11. Chirchir, H., Ruff, C., Helgen, K. M., & Potts, R. (2022). Effects of reduced mobility on trabecular bone density in captive big cats. Royal Society Open Science, 9(3), 211345. https://doi.org/10.1098/rsos.211345
12. Corr, S. A. (2005). Practical guide to linear external skeletal fixation in small animals. In Practice, 27(2), 76–87. https://doi.org/10.1136/inpract.27.2.76
13. Craig, A., Witte, P. G., Moody, T., Harris, K., & Scott, H. W. (2017). Management of feline tibial diaphyseal fractures using orthogonal plates performed via minimally invasive plate osteosynthesis. Journal of Feline Medicine and Surgery, 20(1), 6–14. https://doi.org/10.1177/1098612X17692470
14. Cronier, P., Pietu, G., Dujardin, C., Bigorre, N., Ducellier, F., & Gerard, R. (2010). The concept of locking plates. Orthopaedics & Traumatology: Surgery & Research, 96(4, Suppl.), S17–S36. https://doi.org/10.1016/j.otsr.2010.03.008
15. Dutton, C. J., Jaber, R., & Peirce, M. A. (2004). Nutritional secondary hyperparathyroidism in a white lion cub (Panthera leo) with concomitant radiographic double cortical line. Journal of Zoo and Wildlife Medicine, 35(2), 245–248. https://www.researchgate.net/publication/8492942_Nutritional_secondary_hyperparathyroidism_in_a_white_lion_cub_Panthera_leo_with_concomitant_radiographic_double_cortical_line_clinical_communication
16. Farzad-Mohajeri, S., Mollaei, Z., Sari, M. M., & Rostami, A. (2024). Surgical stabilization of a distal tibial fracture in a jungle cat (Felis chaus) using orthogonal double plating. Veterinary Medicine and Science, 10(2), e1382. https://doi.org/10.1002/vms3.1382
17. Fischer, C. P., & Romero, L. M. (2019). Chronic captivity stress in wild animals is highly species-specific. Conservation Physiology, 7(1), coz093. https://doi.org/10.1093/conphys/coz093
18. Fossum, T. W. (2019). Small Animal Surgery (5th ed.). Elsevier. https://shop.elsevier.com/books/small-animal-surgery/fossum/978-0-323-44344-9
19. González-Chávez, M. T., Rojas-Hoyos, N. A., Vega-Rodríguez, N., & Yrurzun-Estrada, C. (2019). Fijación esquelética externa y clavo intramedular en una fractura femoral de un *Puma concolor* del Zoológico Nacional de Cuba. Revista de Salud Animal, 41(1), e10. http://scielo.sld.cu/scielo.php?script=sci_arttext&pid=S0253-570X2019000100010
20. González, M. S., & Flores Góchez, M. M. (2024). Beneficios del puma (*Puma concolor*) como regulador de especies en Centroamérica. Revista Minerva, 7(2), 101–109. https://doi.org/10.5377/revminerva.v7i2.18527
21. Jiwlawat, N., Pacharinsak, C., & Durongphongtorn, S. (2022). Anesthetic effects of dexmedetomidine-tiletamine/zolazepam combination in cats undergoing ovariohysterectomy. The Thai Journal of Veterinary Medicine, 52(2), 267–274. https://he01.tci-thaijo.org/index.php/tjvm/article/view/256738
22. Kudo, T., Hara, A., Iwase, H., Ichihara, S., Nagao, M., Maruyama, Y., & Kaneko, K. (2016). Biomechanical properties of orthogonal plate configuration versus parallel plate configuration using the same locking plate system for intra-articular distal humeral fractures under radial or ulnar column axial load. Injury, 47(10), 2071–2076. https://doi.org/10.1016/j.injury.2016.08.012
23. LaBarge, L. R., Evans, M. J., Miller, J. R., Cannataro, G., Hunt, C., & Elbroch, L. M. (2022). Pumas *Puma concolor* as ecological brokers: A review of their biotic relationships. Mammal Review, 52(3), 360–376. https://doi.org/10.1111/mam.12281
24. Lescano, J., Quevedo, M., Baselly, L., Crespo, A., & Fernández, V. (2014). Chemical immobilization of captive cougars *Puma concolor* (Linnaeus, 1771) (Carnivora: Felidae) using a combination of tiletamine-zolazepam, ketamine and xylazine. Journal of Threatened Taxa, 6(14), 6659–6667.https://research.amanote.com/publication/85dV2nMBKQvf0Bhi6wRM/chemical-immobilization-of-captive-cougars-puma-concolor-linnaeus-1771-carnivora.
25. Medina, D., Armas Ariza, J. C., Ortega, O. A., Camacho, M., & Astudillo Vallejo, K. (2022). Corrección de fractura oblicua corta de calcáneo en una hembra juvenil de *Puma concolor*, utilizando una aguja de Steinmann y placa de compresión. CES Medicina Veterinaria y Zootecnia, 17(1), 78–95. https://doi.org/10.21615/cesmvz.6494
26. Murphy, S. M., Wilckens, D. T., & Augustine, B. C. (2019). Improving estimation of puma *(Puma concolor)* population density: Clustered camera-trapping, telemetry data, and generalized spatial mark-resight models. Scientific Reports, 9, 4590. https://doi.org/10.1038/s41598-019-40926-7
27. Parker, V. J., Gilor, C., & Chew, D. J. (2015). Feline hyperparathyroidism: Pathophysiology, diagnosis and treatment of primary and secondary disease. Journal of Feline Medicine and Surgery, 17(11), 1009–1021. https://doi.org/10.1177/1098612X15581134
28. Rolvien, T., Amling, M. (2022) Disuse Osteoporosis: Clinical and Mechanistic Insights. Calcif Tissue Int 110, 592–604. https://doi.org/10.1007/s00223-021-00836-1

*REDVET - Revista electrónica de Veterinaria* - ISSN 1695-7504
Vol 27, No.1 (2026)
http://www.veterinaria.org
Received: 20/06/2026 Revised: 22/08/2026 Accepted: 29/09/2026

29. Roe, S. C. (2024). Reducing plate strain with orthogonal plating. Veterinary and Comparative Orthopaedics and Traumatology, 37(04), v–vi. https://doi.org/10.1055/s-0044-1787966
30. Zafalon, R. V. A., Risolia, L. W., Vendramini, T. H. A., Ayres Rodrigues, R. B., Pedrinelli, V., Teixeira, F. A., & Brunetto, M. A. (2020). Vitamin D metabolism in dogs and cats and its relation to diseases not associated with bone metabolism. Journal of Animal Physiology and Animal Nutrition, 104(2), 322–342. https://doi.org/10.1111/jpn.13259
31. Zalavras, C. G., Vercillo, M. T., Jun, B. J., Otarodifard, K., Itamura, J. M., & Lee, T. Q. (2011). Biomechanical evaluation of parallel versus orthogonal plate fixation of intra-articular distal humerus fractures. Journal of Shoulder and Elbow Surgery, 20(1), 12–20. https://doi.org/10.1016/j.jse.2010.08.005
32. Zeiler, G., Rioja, E., Boucher, C., & Tordiffe, A. (2013). Anaesthetic management of two Bengal tiger (Panthera tigris tigris) cubs for fracture repair. Journal of the South African Veterinary Association, 84(1), e1–e5. https://doi.org/10.4102/jsava.v84i1.995