RESEARCH ARTICLE

Thermographic Study for Diagnosis and Assessment of Long Bone Fracture Healing in Dogs

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Abstract

Infrared thermography (IRT) has emerged as a valuable tool, enabling noninvasive assessment of heat dissipation during and after inflammatory processes or during recovery phases. However, its application in veterinary patients undergoing fracture healing remains an area requiring extensive investigation. This study aims to utilize IRT in diagnosis of fracture prior to surgery and monitoring fracture healing of long bone. In fractured cases, 1.5 to 4ºF higher temperature of the affected limb as compared to normal limb and intense thermal pattern at fracture site were noticed. On 15th post-operative day, the temperature of affected limb was 1.5 to 3ºF higher than normal limb. On 30th day it showed 1.0 to 2.5ºF difference, which might be due to reduction in inflammation related with soft tissue injury during surgery. Progressively, over a period of time, temperature difference was decreased and after 2 months of injury, temperature of operated limb was similar to normal or opposite limb. However, this technique requires further standardization and needs to explore more in terms of complementary tool along with other diagnostic modalities like radiography and CT scan.

Keywords: Bone healing, Dogs, Infrared thermography, Radiography, Temperature.

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Introduction

Infrared thermography (IRT) is a technique that uses a specialized camera to evaluate the infrared radiation related to the temperature of a body (Tattersall, 2016). It emerges as a diagnostic technology capable of capturing internal thermal changes and providing valuable insights into the healing process (Anders, 2013). Internal thermal alterations occurring during bone healing are mirrored in nearby tissues and are associated with variations in blood flow and/or infection within the traumatized region (Strasse *et al.*, 2021). IRT was used as a method to indirectly assess peripheral vascular integrity and its relation to the amount of radiated heat and as a diagnostic technique for tissue viability, degree of damage and wound care (Mota-Rojas *et al.*, 2023). Thermal imaging serves as a novel tool not only for diagnosing an established soft tissue injury, but also for detecting it in its early stages. Anders (2013) emphasized the technique exhibited high sensitivity to alterations in the muscular, vascular, skeletal and nervous systems, capable of detecting temperature variances of less than 0.5°C. Infrared thermography could be diagnostic tool for different stages of wound healing progress. The basic principle is that because of increased metabolism and blood flow around the fracture site the temperature of surrounding tissue is increasing. In fibrous formation phase in bone fractures and during migration to osteoblastic activity, blood flow around fracture site should increase during callus formation (Haluzan *et al.*, 2012). The lack of progression of the healing process, commonly diagnosed based on radiographic evidence is characterized by one of the following factors such as sclerosis at the end of the fracture, presence of hiatus, absent or hypertrophic callus and persistence or widening of the fracture line (Ulson *et al.*, 2021). This study focuses on thermographic diagnosis and assessment of long bone fracture healing in dogs.

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Materials and Methods

The thermographic examination in this study was carried out in 20 animals to explore the viability and utilization of thermography for the purpose of diagnosing before surgery. These evaluations were made in the cool, calm and indoor environment of hospital. The areas of focus were the affected limb and its comparison with normal limb. The data were captured using a infrared camera (FLIR T534) and analyzed using FLIR software. The cases which were presented for treatment and further follow up examinations with internal fixation underwent evaluations using thermal imaging, which were then compared with X-ray images. In this study, monitoring of bone healing was carried out in 10 cases, which were operated for fracture and stabilized with locking compression plate. Post-operative follow up examinations were carried out at different intervals up to 3 month of surgery and it was also compared with radiography to know the progress of healing.

Results and Discussion

Pre-operatively, the temperature at fracture site from affected limbs when compared with opposite normal limb varied from 1.5 to 4.0ºF. This variation depended upon injury, region of injury, severity of injury and involvement of soft tissue (Fig. 1 to 4). However, sometime temperature of normal limb was higher than affected limb due to soft tissue or crushing injury during automobile accidents, fall down or any traumatic injury of normal limb. Similarly, Strasse *et al.* (2022) assessed all patients with a bone fracture diagnosis, the average temperature of the injured limb displayed a noticeable positive deviation exceeding 33ºF in comparison to the opposite side. This signified a precise identification of the site of the bone injury. Conversely, regions identified with compromised blood circulation exhibited an average temperature with a discernible negative change.

15th day post-operatively, the temperature of affected limb was higher than normal limb and also showed intense thermal pattern due to injury to soft tissue, inflammation, increased blood supply towards bone healing, manipulation of soft tissue during surgery and application of bandage. Temperature difference varied from 1.5 to 3.5ºF when compared with normal or opposite site of same body parts (Fig. 5). Casas-Alvarado *et al.* (2024) opined thermography has become an assistance tool in veterinary and is used to noninvasively evaluate heat elimination during and after inflammatory processes or during the recovery period. On 30th day still there was increased temperature in affected limb as compared to normal limb, but intensity of thermal pattern was decreased as compared to 15th day observation. This might be due to reduction in inflammation related with injury of soft tissue, which was manipulated during surgery and skin wound also healed at this time. Increased temperature in affected limb could also be due to increase in the blood circulation towards fracture site for healing.

The temperature difference varied from 1.0 to 2.5ºF as compared to normal limb on day 30th (Fig. 6). Similar to this study Silvia *et al.* (2012) hypothesized that fractures would be associated with local hyperthermia, detectable with thermography which could then direct focused radiographs. Strasse *et al.* (2021) also obtained similar thermal images throughout the course of the 20 clinical assessments that enabled a connection to be established between the data derived from X-ray examinations and the opposite limb of the patient under evaluation. These images revealed thermal changes exceeding 0.3°C, which signify notable physiological irregularities. Progressively, over a period of time, temperature difference was decreased and after 2 months of injury, this difference was almost nil between opposite limb and the region of interest (ROI) (Fig. 7).

In this study, after 2 months of surgery, some time temperature in normal or ROI was higher than operated or affected limb, which might be due to increased weight bearing to support the affected limb or any soft tissue wound or injury over opposite limb. Similar findings were also reported by Reed *et al.* (2021), who stated the temperature distinction between the fractured and unaffected forearm reached its peak at 7th day post-injury. This discrepancy lessened by the time the injury progressed to 14th day and it became minimal by the 21st day after the injury. This variation could be attributed to the fact that the process of microvascular invasion and fracture healing tends to transpire more rapidly in children compared to adults, owing to their heightened vascularity. Sometime due to superficial wound or injury over skin resulted in increased thermal pattern. However, in such type of cases, bone healing or remodeling was good when compared it with radiograph. Similar findings were observed in this study, bone healing was good on 120th day radiograph but plate was seen outside. However, no infection and swelling was observed and the weight bearing was also similar to normal limb, although temperature of this limb was higher than opposite limb (Fig. 8 & 9). Conversely, regions identified with compromised blood circulation exhibited an average temperature with a discernible negative change. Haluzan *et al.* (2012) utilized this method during the fracture recovery process in canines. They conducted assessments on the 7th and 21st days post-fracture, following around 6 weeks of conservative treatment involving immobilization. They compared the temperature of the fractured limb with that of the unaffected limb and noted noteworthy temperature alterations throughout various stages of the healing journey.

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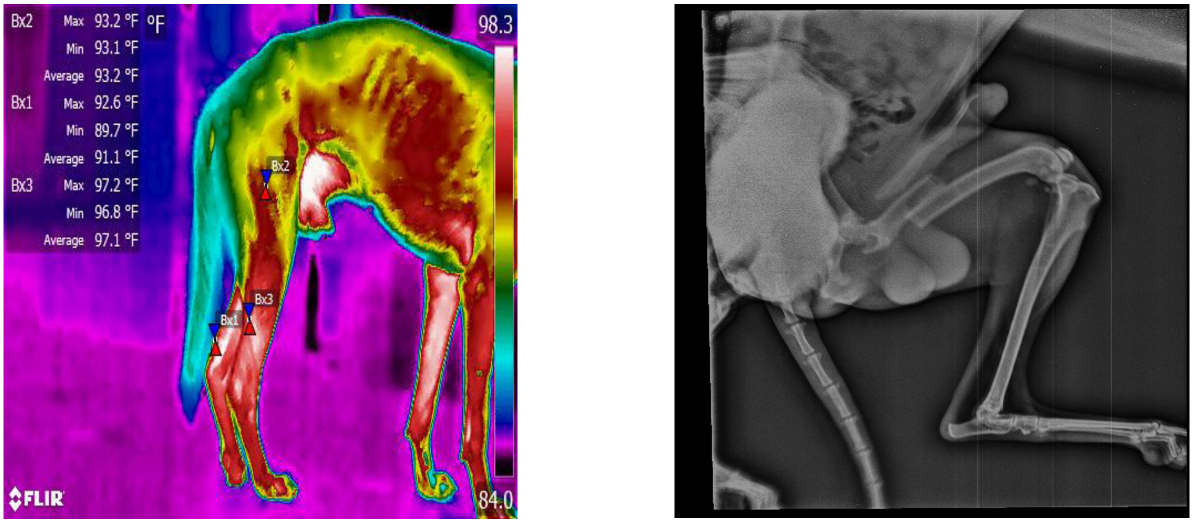

Fig. 1: Pre-operative comparison of thermogram and radiograph

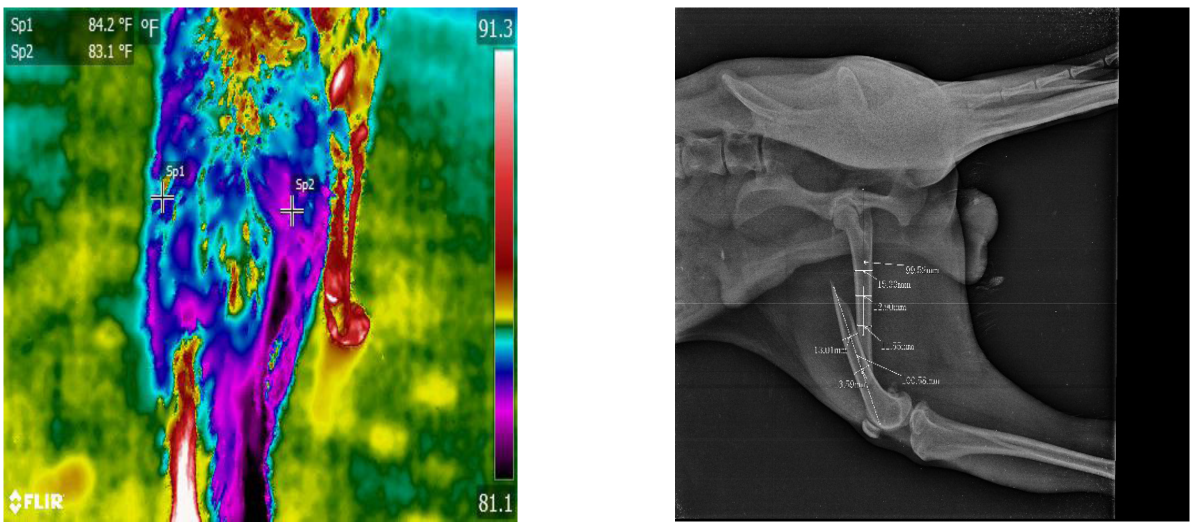

Fig. 2: Sp1: normal limb (84.2 ºF), Sp2: affected limb (83.1 ºF)

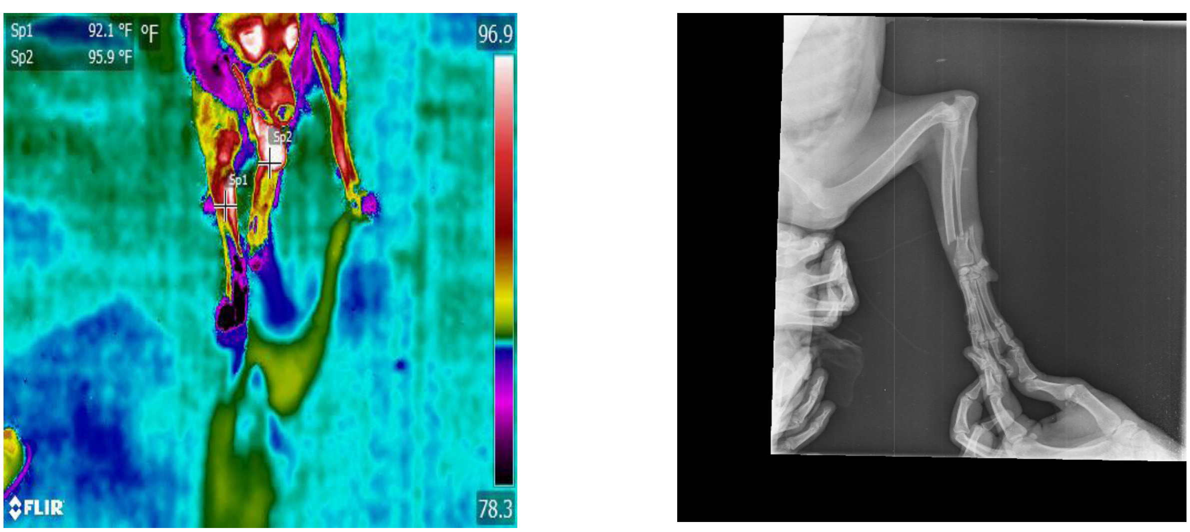

Fig. 3: Sp1: normal limb (92.1 ºF) , Sp2: affected limb (95.9 ºF)

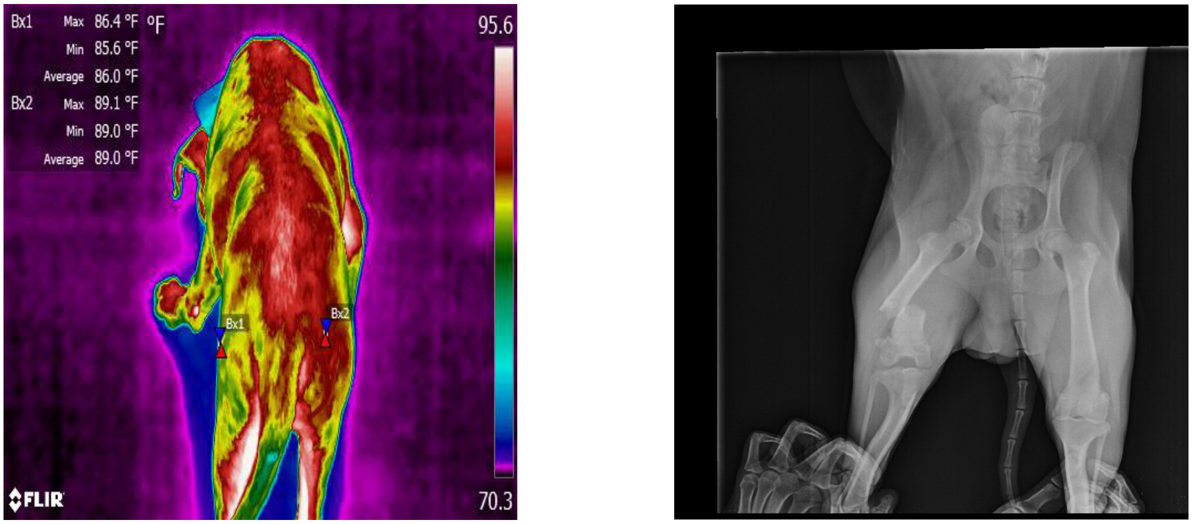

Fig. 4: Bx1: normal limb (86.4 ºF), Bx2: affected limb (89.1 ºF)

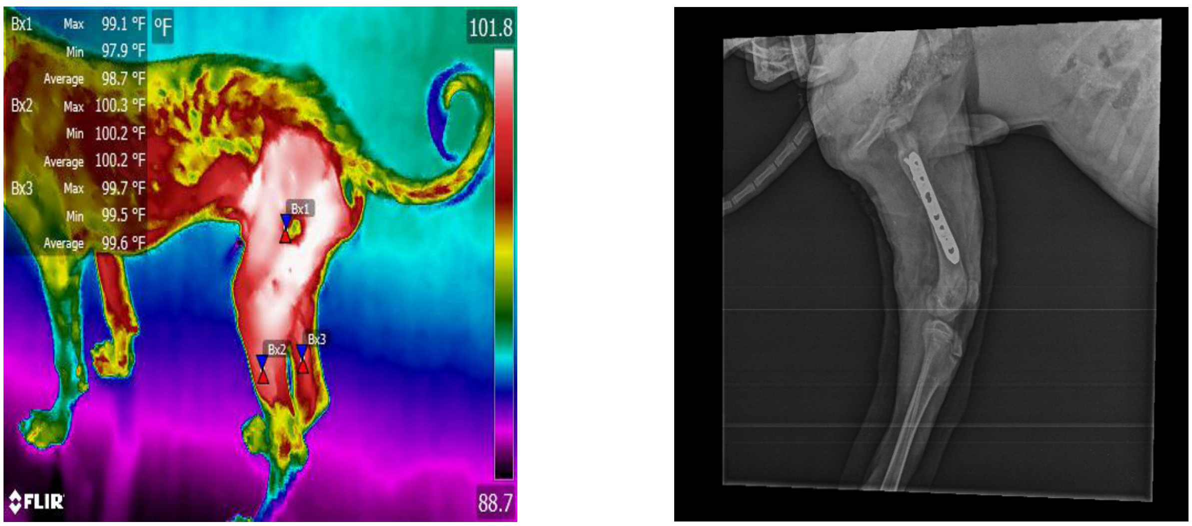

Fig. 5: Bx1 (99.1 ºF) is lesser than Bx2 (100.3 ºF). Bx3 is less than Bx2 (100.3 ºF). Bx1: operated site, Bx2: operated site, Bx3: normal limb (15th post-operative day)

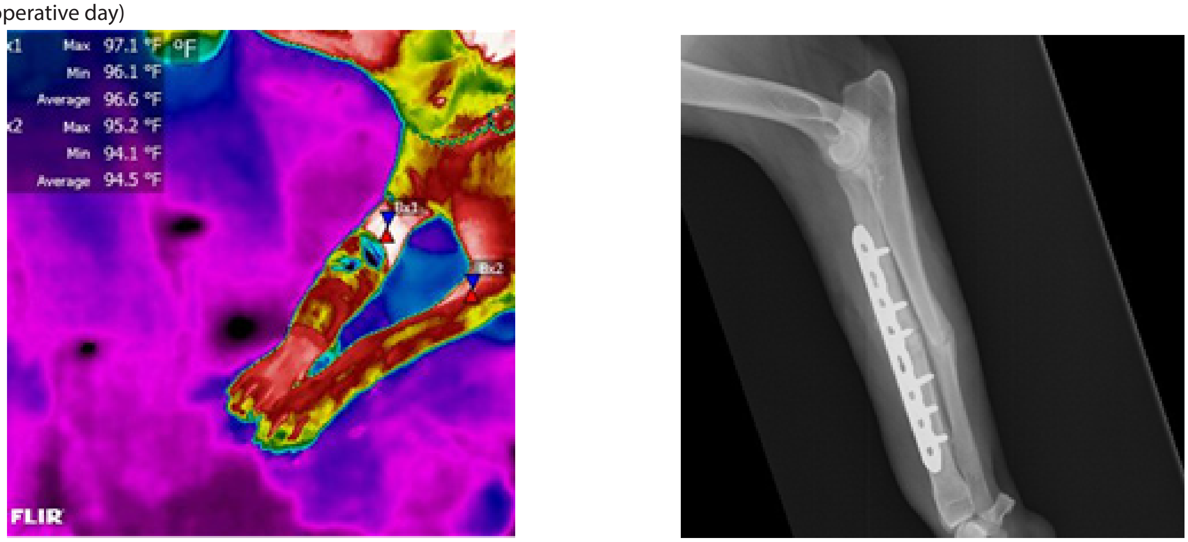

Fig. 6: Bx1 (97.1 ºF) is higher than Bx2 (95.2 ºF). Bx1: operated limb Bx2: normal limb (30th post-operative day)

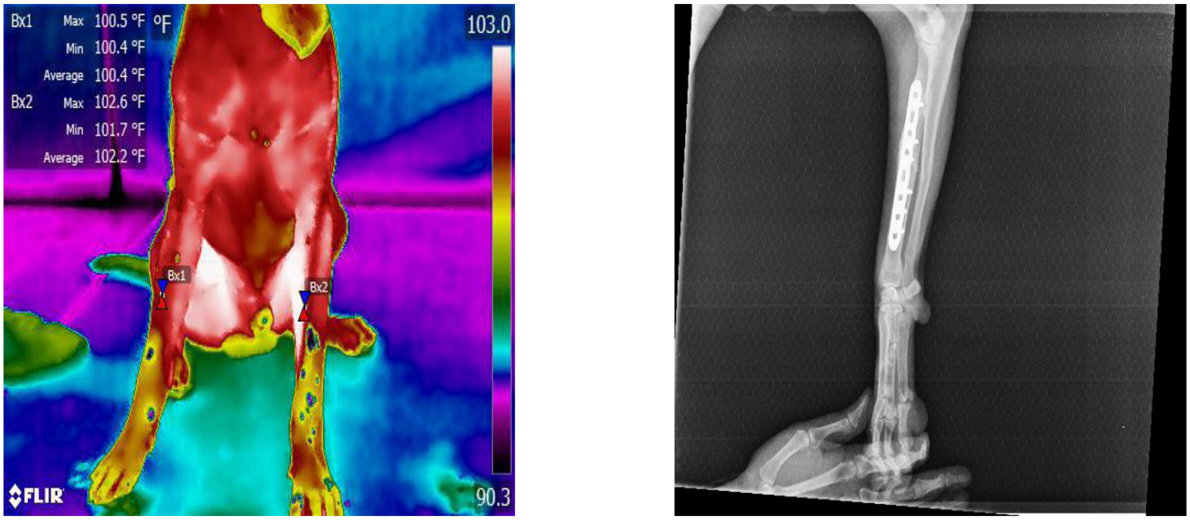

Fig. 7: Bx1 (100.5 ºF) is lesser than Bx2 (102.6 ºF). Bx1: operated limb, Bx2: normal limb (60th post-operative day)

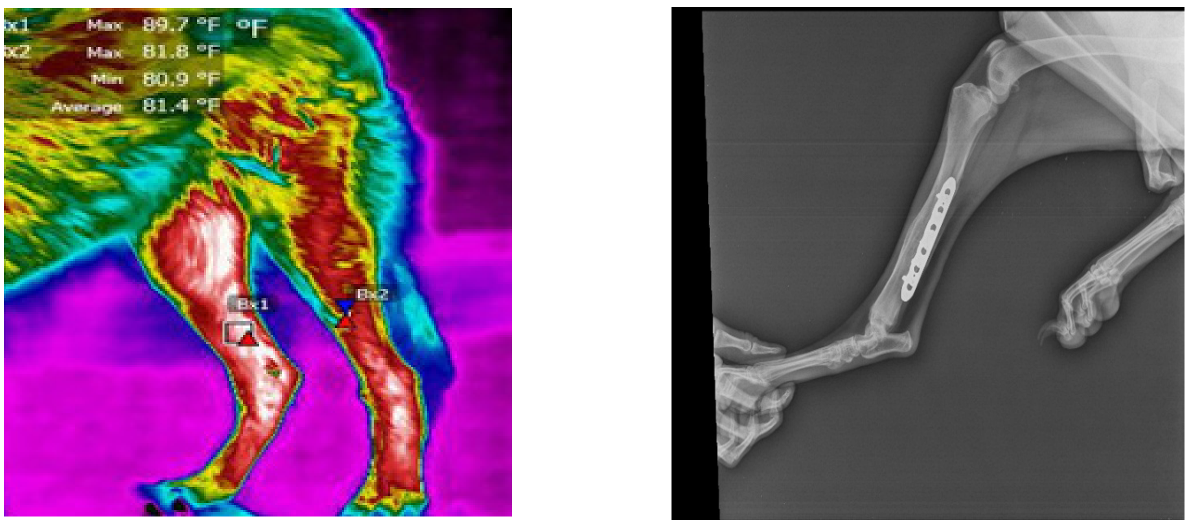

Fig. 8: Bx1 is increase as compared to Bx2 due to self mutilating wound exposing the plate outside. Bx1: operated limb, Bx2: normal limb (90th day after surgery)

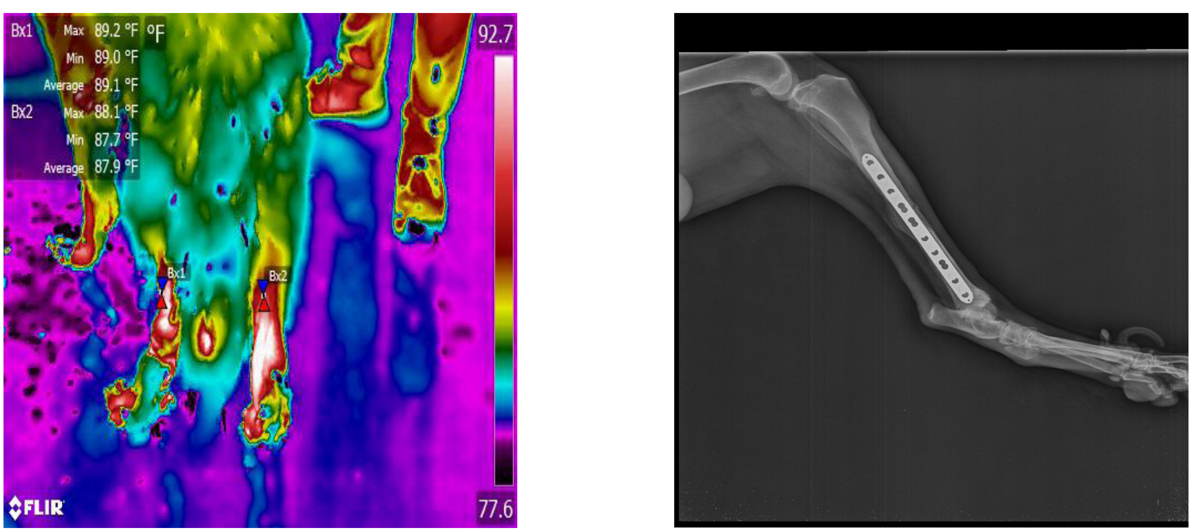

Fig. 9: Bx1 (89.2 ºF) is higher than Bx2 (88.1 ºF). Bx1: operated limb, Bx2: normal limb (120th post-operative day)

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