Guidelines for surgical approaches for minimally invasive plate osteosynthesis in cats

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Keywords

Minimally invasive plate osteosynthesis, cat, approaches, MIPO surgery

Summary

Objectives: Minimally invasive plate osteosynthesis (MIPO) is one of the most recent fixation techniques that embody the concept of biological osteosynthesis. Several studies evaluating MIPO in dogs have been published in the recent years. However, there are few clinical reports of MIPO in cats and no description of the surgical approaches. The purpose of our study was to describe the safe corridors for plate insertion in cats using the MIPO technique.

Methods: The surgical approaches for the humerus, radius-ulna, femur and tibia were developed after reviewing the described techniques and surgical approaches for MIPO in dogs, while considering any relevant anatomical difference between dogs and cats. Following the MIPO approaches, the limbs were anatomically dissected and the relationship between proximal and distal positions of the implants and neurovascular structures was noted.

Results: The surgical approaches developed for the humerus and radius-ulna differed from what had been reported previously, because relevant anatomical differences were found between dogs and cats. Anatomical landmarks for safe plate application were described for all the major long bones in cats. No damage to vital structures following plate insertion was detected in the dissection.

Clinical significance: In this cadaveric study, we evaluated the safety of the surgical approaches for MIPO in cats. By respecting the anatomical landmarks described in this report, damage to the neurovascular structures can be avoided performing the MIPO technique in cats.

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Introduction

Minimally invasive plate osteosynthesis (MIPO) involves the application of a bone plate without making an open approach to the fracture site (1, 2). Following indirect reduction of the fracture segments, small skin incisions are made remote to the fracture site and an epiperiosteal tunnel is dissected bluntly to connect the incisions (3–5). The plate is applied as a bridging implant in most cases, and the most proximal and distal screws are inserted through the skin incisions. Additional screws can be introduced through small stab incisions using fluoroscopy to guide insertion (5). Several studies evaluating MIPO in dogs have been published in the recent years, describing the technique and reporting the outcome and complications (2, 4–7). However, there are few clinical reports of MIPO in cats and no description of the surgical approaches (8).

Thorough knowledge of the local anatomy is important for performing MIPO safely and effectively. The MIPO surgical approaches are limited and do not allow exposure of the typical anatomical landmarks used for open reduction and internal fixation. The surgical approaches for MIPO in dogs have been developed based on the open approaches to each bone segment (5, 9). Considering the anatomical differences between cats and dogs, a description of the safe corridors for plate and screw insertion in cats may offer valuable information for the performance of MIPO in this species. The purposes of this study were: 1) to describe the safe corridors for plate and screw insertion in cats using MIPO technique, with attention to the anatomical differences between cats and dogs; 2) to evaluate safety of these surgical approaches by evaluating the anatomical relationship between neuro-vascular structures and the implants after insertion.

Material and methods

Prior to the establishment of the MIPO approaches in cats, comparative dissections were performed in three cats (4-5 kg) and three dogs (20–25 kg) (euthanatized for reasons unrelated to the study) to evaluate the respective limbs for anatomical differences relevant to the MIPO approaches. Anatomical dissection was of great value for the review of the anatomical differences between cats and dogs, allowing the adaptation of the previously described canine MIPO approaches to cats. Subsequently 44 limbs of 11 cats euthanatized for reasons unrelated to the study, were used to develop the MIPO approaches in cats. Cadavers were used within 24 hours after euthanasia and were stored at 8° C until the approaches were performed. Each hindlimb of each cadaver was used for a MIPO approach of both the tibia and the femur. Similarly, each forelimb was used for a MIPO approach of the radius and the ulna. For each cadaver, either the left or the right humerus was randomly assigned to medial or lateral MIPO. The approaches described in this report were based on the techniques described in dogs, dissections conducted on cat cadavers, and our clinical experience using this technique (5). Briefly, after establishing the proximal and distal windows, an epiperiosteal tunnel was created with either small Metzenbaum scissors (humerus, femur) or a Freer periosteal elevator (radius, ulna, tibia) to connect the two incisions. Subsequently a 6.5 mm wide titanium locking bone plate[a] (radius, ulna, tibia) or a 8 mm wide titanium locking bone plate[b] (humerus, femur) was inserted in the tunnel with the aid of Crile haemostatic forceps placed at the end of the plate in order to assist in sliding the plate in the epiperiosteal tunnel. Following insertion of the plate, the corresponding open approach was performed. Signs of iatrogenic trauma to the muscles, the periosteum and neurovascular structures and their relationship with the plate *in situ* were noted.

After establishing the approaches in the initial 44 limbs, 14 additional fresh cadaveric limbs (euthanatized for reasons unrelated to the study) (6 hindlimbs, 8 forelimbs) were used to perform the complete MIPO techniques with insertion and fixation of the plates with two bicortical locking screws in the proximal and distal ends of the bone. Those limbs were also dissected after placement of the implants and any signs of iatrogenic trauma caused by plate or screw insertion were noted.

Results

Humerus

A cranio-lateral or a medial approach to the humerus can be used for MIPO in cats. Indications for the cranio-lateral approach include proximal and mid-diaphyseal fractures. Indications for the medial approach include mid-diaphyseal and distal fractures with limited distal bone stock and cases where double plating is indicated.

Craniolateral approach

The lateral approach combines modifications of the approach to the lateral aspect of the humerus, the humeral condyle, and epicondyle (9). The animal is positioned in lateral recumbency. The proximal anatomical landmarks for the cranio-lateral approach are the greater tubercle and the deltoid tuberosity of the humerus. A 1 to 2 cm long incision is created at the cranial border of the greater tubercle. Care should be taken to preserve the omobrachial artery and vein. The skin and subcutaneous tissue are retracted and an incision is made through the deep fascia cranial to the omobrachial vessels along the brachiocephalicus muscle. The acromial part of the deltoideus muscle is elevated, allowing exposure to the bone. The lateral epicondyle is used as a landmark for the distal insertion incision. The skin incision extends from the lateral epicondyle to approximately 1 to 2 cm proximally. The skin and subcutaneous tissue are retracted and the deep fascia is incised along the cranial border of the lateral head of the triceps muscle, which is larger compared to the dog (9). Access to the bone is achieved between the origin of the extensor carpi radialis muscle and the brachialis muscle. The origin of the extensor carpi radialis muscle is incised proximally and partially elevated. Damage to the deep and superficial branch of the radial nerve is avoided by 1) creating a tunnel between the two incisions from distal to proximal while visualizing the radial nerve, and 2) dissecting underneath the brachialis muscle (▶Figure 1).

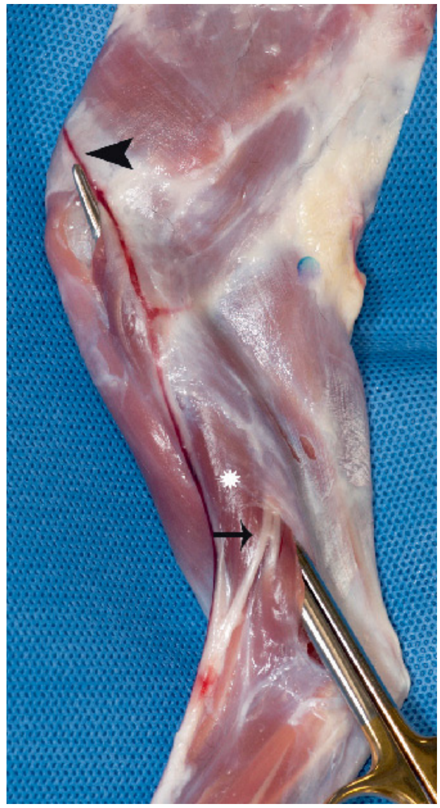

Figure 1 Minimally invasive plate osteosynthesis approach to the lateral aspect of the left humerus in a cat. Note the close proximity of the radial nerve (arrow) to the distal incision. Damage to the radial nerve with its deep and superficial branch is avoided by creating the tunnel deep to the brachialis muscle (asterisk). Care is taken to preserve the omobrachial artery and vein proximally (arrow head). Skin was removed for better presentation of neurovascular structures and anatomical landmarks.

The risk of penetrating the supracondylar foramen and injuring the median nerve and the brachial artery needs to be considered when placing bicortical screws in the distal humerus. Damage to the median nerve and brachial artery were observed in one of four limbs for which screws were inserted bicortically in the distal metaphyseal region.

Medial approach

For the medial approach, a modification of the medial approach to the humeral shaft and the supracondylar region of the humerus is used (9). The cat is placed in dorsal recumbency with the limb placed in abduction. A proximal 2–3 cm skin incision located approximately 1 cm caudal and 2 cm distal to the palpable cranial border of the greater tubercle is necessary for adequate exposure. Due to the larger amount of soft tissue overlying the bone in the proximal part of the medial humerus, careful retraction of the skin and soft tissue with blunt self-retaining Gelpi retractors was found to be beneficial. The brachiocephalic muscle is palpated cranially and

a ALPS 6.5 Plate: KYON, Zurich, Switzerland
b ALPS 8 Plate: KYON, Zurich, Switzerland

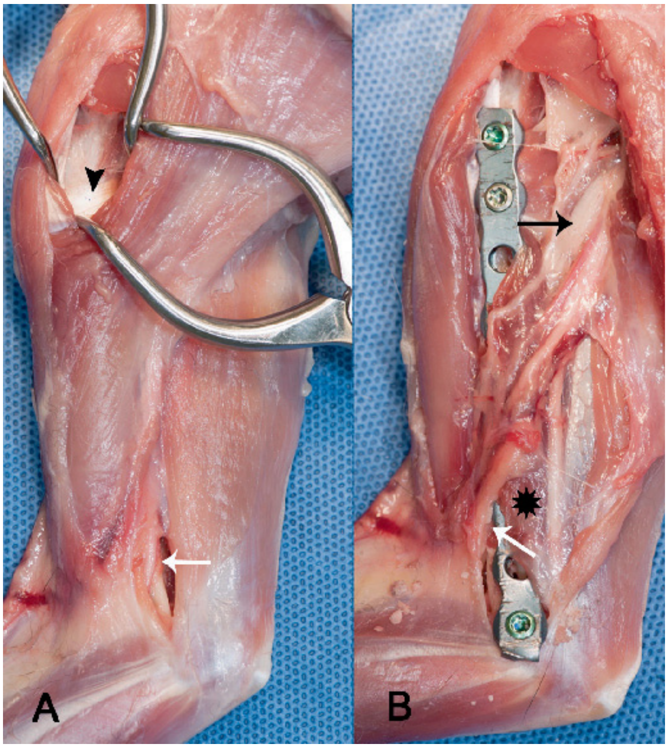

Figure 2 Minimally invasive plate osteosynthesis approach to the medial aspect of the right humerus in a cat after creation of the proximal and distal window **(A)** and after transection of overlying muscles following plate placement **(B)**. The tendon of the teres major muscle (arrow head) and the supracondylar foramen with the median nerve and brachial artery (white arrow) are shown as important landmarks. The plate is placed underneath the medial head of the triceps brachii muscle (asterisk) to avoid the overlying neurovascular structures (black arrow). Skin was removed for better presentation of neurovascular structures and anatomical landmarks.

Figure 3 Relevant anatomy of the medial aspect of the right humerus after caudal and cranial retraction of overlying musculature. The tendon of the teres major muscle must be identified as an important landmark (black asterisk). The musculocutaneous nerve (white arrow) is located immediately distally. Note the brachial artery and the median nerve (arrow head) as they pass through the supracondylar foramen (black arrow). The epiperiosteal tunnel is created underneath the medial head of the triceps brachii muscle (white asterisk). Note that the scissors are not representing the final plate position but have been dislocated with retraction.

the deep brachial fascia is incised between its caudal border and the superficial pectoral muscle. The brachiocephalicus muscle is retracted cranially. The superficial pectoral muscle is retracted caudodistally with careful attention to the underlying neurovascular structures. After incising the aponeurosis of the deep pectoral muscle along the shaft of the humerus, the proximal part of the biceps brachii muscle is visualized and retracted cranially (▶Figure 2). The underlying broad tendon of the inserting teres major muscle is an important landmark for the proximal approach (▶Figure 2, ▶Figure 3). Dissection should not be continued further distal to the insertion of the tendon of the teres major muscle to avoid damage to the brachial artery and the musculocutaneous nerve immediately distal to the aforementioned point.

The medial epicondyle and the supracondylar ridge are used as anatomical landmarks for the distal window. After performing a 2 cm skin incision along the supracondylar ridge, the deep fascia is incised along the cranial edge of the long head of the triceps muscle. Care is taken to visualize the brachial artery and the median and ulnar nerves before the medial head of the triceps is separated from its short part covering the supracondylar foramen. The short part of the medial head of the triceps brachii muscle is carefully elevated while visualizing the neurovascular structures (9, 10). If necessary for implant positioning, in order to avoid impingement of the neurovascular structures by the plate, cranial retraction of the brachial artery and the median nerve is possible after freeing these structures from the supracondylar foramen by removing its medial border with a rongeur (▶Figure 4).

A tunnel is created starting distally and connecting the two incisions. Care should be taken to stay underneath the medial head of the triceps brachii and along the caudal edge of the biceps brachii muscle as the neurovascular structures overlie these muscles. This position was found to be beneficial as the distal plate holes can be positioned caudal to the supracondylar for-

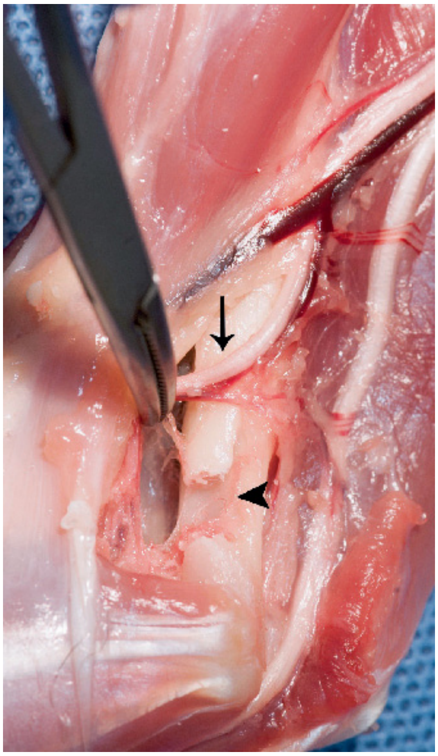

Figure 4 Cranial retraction of the brachial artery and the median nerve (arrow) after release from the supracondylar foramen (arrow head in the right limb. Skin was removed for better presentation of neurovascular structures and anatomical landmarks.

amen and the medial head of the triceps stays in between the plate and the overlying neurovascular structures (▶Figure 2). Alternatively, the plate can be positioned cranial to the medial head of the triceps in a true medial position. In the proximal window the tunnel is continued superficial to the tendon of the teres major muscle (▶Figure 2, ▶Figure 3).

The plate is inserted from distal to proximal in order to not damage the distal neurovascular structures. In addition, the large soft tissue coverage and the thorax can make proximal insertion of the plate more difficult. The plate is twisted to allow placing it caudal to the supracondylar foramen distally and on the medial aspect proximally (▶Figure 2.)

If the median nerve and brachial artery are not freed from the supracondylar foramen, the screw hole positioned over the supracondylar foramen is left empty and screws are placed in the adjacent holes (▶Figure 2.)

Radius

In contrast to the dog, a cranio-lateral approach is advocated in the cat due to the change of the orientation of the cranial surface of the radius directing cranio-laterally in the proximal part and cranio-medially in the distal part (▶Figure 5). The approach resembles a modification of the lateral approach to the shaft of the radius and a dorsal approach to the carpal joint (9). The indications for this approach include distal metaphyseal and diaphyseal fractures of the radius.

Dorsal recumbency of the cat is recommended. The surgical procedure is carried out with the limb extended caudally. The proximal approach is located in a more lateral position than described for the dog (5). A 1–2 cm skin incision is created in the palpable groove between the common digital extensor muscle and the lateral digital extensor muscle at the level where the two most proximal screw holes of the plate will be positioned. Small self-retaining Alm retractors may be used for retraction of the skin and soft tissues. The deep antebrachial fascia is incised between the common digital extensor muscle and the lateral digital extensor muscle. The supinator muscle may be elevated for increased exposure, taking care not to damage the deep branch of the radial nerve.

For the distal approach, the radio-carpal joint is identified by thorough palpation during flexion and extension. A hypodermic needle may be used for better orientation during the surgical procedure. A 1 to 2 cm cranio-lateral skin incision is created just proximal to the radio-carpal joint. The antebrachial fascia is incised between the tendon of the extensor carpi radialis muscle and the tendon of the common digital extensor muscle. If further exposure is desired, the tendon of the abductor pollicis longus muscle may be transected. Alternatively, the antebrachial fascia can be incised between the tendon of the common digital extensor muscle, and the tendon of the lateral digital extensor muscle (▶Figure 6). As described in dogs, it is preferable to create the epiperiosteal tunnel from distal to proximal. Care should be taken to preserve the tendon of the lateral digital extensor muscle to the first phalange as it

Figure 5 View to the cranial surface of the right limb radius of a dog **(A)** and a cat **(B)**. Note the obvious external torsion of the cranial surface of the radius of the cat, especially in the proximal part.

curves cranio-medially at the level of the radio-carpal joint. Insertion of the plate is generally performed from distal to proximal.

Ulna

A lateral approach is recommended for the ulna. The described approaches to the proximal and distal shaft of the ulna and the styloid process were combined and modified (9). Indications include diaphyseal and distal metaphyseal fractures of the ulna, when associated with comminuted fractures of the radius (11, 12). The animal is positioned as described for the radius. A 1 cm long incision is made on the lateral aspect of the proximal shaft. The deep antebrachial fascia is incised and retracted. The ulnaris lateralis muscle can be carefully elevated at its caudal border and retracted cranially to increase exposure.

The styloid process of the ulna is used as anatomical landmark for the distal

Figure 6 Minimally invasive plate osteosynthesis approach to the right limb radius in a cat, cranio-lateral view. Note the lateral position of the approach due to external torsion of the radius in the cat. Windows to the bone have been created between the common digital extensor muscle (asterisk) and the lateral digital extensor muscle (black arrow head). For orientation, the ulnaris lateralis muscle is shown with the white arrow head. Skin was removed for better presentation of neurovascular structures and anatomical landmarks.

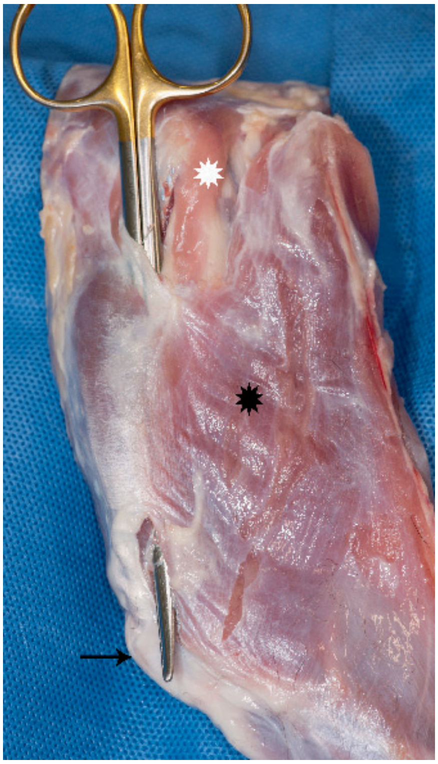

Figure 7 Minimally invasive plate osteosynthesis approach to the left femur in a cat. The proximal window is created along the cranial border of the caudofemoralis (white asterisk) and biceps femoris muscle (black asterisk) overlying the greater trochanter. For the distal window, the lateral trochlear ridge and the patella (arrow) are palpated. Skin was removed for better presentation of neurovascular structures and anatomical landmarks.

Figure 8 Minimally invasive plate osteosynthesis approach to the right tibia in a cat. The black lines indicate the incision lines for the windows. The tibial tuberosity (white arrow) is palpated for the proximal window. The medial malleolus (asterisk) helps identify the location for the distal window. Care is taken to preserve the medial saphenous artery and vein (arrow head). Skin was removed for better presentation of neurovascular structures and anatomical landmarks.

window. A 1 cm skin incision is made slightly proximal to this point. After incising the subcutaneous tissue, the antebrachial fascia is incised between the tendons of the ulnaris lateralis muscle and the lateral digital extensor muscle. The tendons are retracted and an epiperiosteal tunnel is created. The tunnel is created in a proximal to distal direction to avoid interference with the styloid process of the ulna during instrument insertion.

Femur

We advocate using a lateral approach to the femur, which combines the lateral approach to the greater trochanter and to the subtrochanteric region of the femur and an approach to the distal femur through a lateral incision (9). Indications for this approach include diaphyseal, proximal, and distal metaphyseal fractures. The cat is positioned in lateral recumbency. The greater trochanter is palpated and a 1 cm incision is made at its caudo-distal aspect. The caudofemoralis and biceps femoris muscle is identified and the superficial leaf of the fascia lata is incised along their cranial border. After retraction of the deep fascia lata the underlying vastus lateralis muscle is partially elevated off the proximal part of the femur. Subsequently the vastus lateralis muscle can be retracted cranially by placing a small Hohmann retractor cranial to the femur thereby exposing the lateral aspect of the femur. A distal 1–2 cm incision is made just proximal and caudal to the patella in case of proximal metaphyseal and diaphyseal fractures. For distal metaphyseal fractures, the skin incision is extended distally to the level of the tibial tuberosity. After incision of the subcutaneous fascia, the biceps femoris muscle is identified and the fascia lata is incised along its cranial border. The intermuscular septum between the vastus lateralis and biceps femoris muscle is incised. The distal femur is exposed by retracting the biceps femoris muscle caudally and the vastus lateralis muscle cranially. The two incisions are connected with an epiperiosteal tunnel (►Figure 7).

Tibia

A medial approach is recommended for tibial fractures. The described medial approach to the shaft of the tibia and proximal tibia were combined (9). Diaphyseal and metaphyseal fractures of the tibia are common indications for this approach. The cat is positioned in dorsal recumbency at the end of the operating table allowing adequate abduction of the limb in most cases. Alternatively, the cat can be rotated with the respective limb abducted down on the operating table. The tibial tuberosity is palpated and a 1 cm long incision is created midway between the tibial tuberosity and the caudal edge of the proximal tibia. The proximal tibia is exposed after incising the tendons of insertion of the semitendinosus, gracilis, and sartorius muscle. A 1 cm skin incision is created approximately 1 cm proximal to the medial malleolus for the distal approach. Care is taken to preserve the medial saphenous artery and vein (►Figure 8).

Discussion

Establishing specific guidelines for MIPO approaches in cats may be important because of the anatomical differences between dogs and cats. The only complication observed in this cadaveric study was a screw penetrating the supracondylar foramen in MIPO of the lateral humerus. The supracondylar foramen, unique to the feline humeral anatomy, should therefore be considered when selecting the approach for humeral fractures. Placing bi-cortical screws from the lateral to the medial aspect of the distal humerus is associated with the risk of iatrogenic damage to the brachial artery and median nerve, which pass through the foramen (10). Our study confirms this risk during MIPO, as we observed an iatrogenic injury in this location. To avoid this complication, we advocate a medial approach for managing distal diaphyseal or metaphyseal fractures that have limited distal bone stock. After freeing the brachial artery and median nerve out of the supracondylar foramen, retraction of these neurovascular structures is greatly facilitated and bi-cortical screws can be placed in this location from medial to lateral without the risk of iatrogenic damage. However, the potential influence of opening the supracondylar foramen and displacement of the associated neurovascular bundle on postoperative recovery has not yet been evaluated.

The medial approach to the antebrachium required modifications compared to the dog (5). The comparative dissection revealed that the feline radius has a more pronounced lateral torsion than the canine radius, requiring a lateral approach for a more direct exposure of the cranial surface of the radius.

For the ulna, we selected a lateral approach because lateral plating is preferred over caudal plating, as only limited soft tissue coverage is present on the caudal surface potentially leading to soft tissue complications with a caudal placed bone plate. We chose to report a MIPO approach to the ulna because dual bone fixation in cats is associated with less complications compared to fixation of the radius alone (11). Plate fixation of the ulna may be especially indicated in cases of highly comminuted fractures of the antebrachium when a robust repair of the ulna is desirable to avoid complications and potential revision surgery. A mechanical study reported higher failure loads of dual plate fixation compared to a single plate combined with an ulnar pin (12). The limited soft tissue coverage of the feline antebrachium should be considered when plating both the radius and ulna because of the risk of soft tissue tension at closure.

Neurovascular injuries are reported in people as a complication of MIPO but not yet in animals (2, 4, 7, 8). The only damage to neurovascular structures during dissection of the cadavers found in this study was a bicortical screw in the distal humerus penetrating the supracondylar foramen. However, our findings should be interpreted cautiously because of the inability to evaluate functional and histological nerve injuries such as neuropraxia, axonotmesis or neurotmesis. We found that the lateral and medial approaches to the humerus carry higher risk because of the specific anatomy and close relationship of the neurovascular structures. Especially when performing a medial MIPO of the humerus, it is crucial to respect the reported landmarks and individual anatomical differences. Another limitation is that the approaches were performed on intact bones. Future clinical studies should evaluate the efficacy and clinical safety of the described techniques in cats.

In our clinical experience, MIPO can be safely performed in cats for fixation of humeral, radial, ulnar, femoral, and tibial fractures. However, the approaches described in this manuscript are more challenging in clinical cases due to soft tissue swelling and interference with the fractured bones. In cases where MIPO is unsuccessful in restoring alignment or prevents adequate implant anchorage, conversion to an open approach is mandatory.

Author contributions

Both authors were involved in study conception and design, acquisition and analysis of data, and drafting and revising of the manuscript, and both have approved the final submitted version.

Conflicts of interest

There are no conflicts of interest to declare.

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